U.S. Fish & Wildlife Service

Effects of Oil Spills on Wildlife and Habitat

Alaska Region

Sediment plume and sheens of refloated oil, Prince William Sound, AK. NOAA

The U.S. Fish and Wildlife Service is the federal agency responsible for many of the nation's fish and wildlife resources. Having this responsibility has established the agency as one of the primary trustees for fish, wildlife and habitat at oil spills.

Oil spills affect wildlife and their habitats in many ways. The severity of the injury depends on the type and quantity of oil spilled, the season and weather, the type of shoreline, and the type of waves and tidal energy in the area of the spill.

Oil can be categorized into five groups, ranging from very light to very heavy oils. Most oil has a density less than water, so it floats. Oil tends to spread into a thin layer on the water surface as a sheen. Once in the water, oil undergoes weathering, a process that describes the physical, chemical, and biological changes that occur when oil interacts with the environment.

Weathering reduces the more toxic elements in oil products over time, as exposure to air, sunlight, wave and tidal action, and certain mircoscopic organisms degrades and/or disperses oil. Weathering rates depend on factors such as type of oil, weather, temperature, and the type of shoreline and bottom that occur in the spill area.

Types of Oil

Very light oils (jet fuel, gasoline) are highly volatile and evaporate quickly. Very light oils are one of the most acutely toxic oils and generally affect aquatic life (fish, invertebrates, and plants) that live in the upper water column.

Light oils (diesel, light crude, heating oils) are moderately volatile and can leave a residue of up to one third of the amount spilled after several days. Light oils leave a film on intertidal resources and have the potential to cause long-term contamination.

Pool of oil on a heavily impacted beach, Prince William Sound, AK. NOAA

Medium oils (most crude oils) are less likely to mix with water and can cause severe and long-term contamination to intertidal areas. Medium oils can also severely impact waterfowl and fur-bearing marine mammals.

Heavy oils (heavy crude, No. 6 fuel oil and Bunker C) do not readily mix with water and have far less evaporation and dilution potential. These oils tend to weather slowly. Heavy oil can cause severe long-term contamination of intertidal areas and sediments. Heavy oils have severe impacts on waterfowl and fur-bearing marine mammals. Cleanup of heavy oil is difficult and usually long-term.

Very heavy oils can float, mix, sink, or hang in the water. These oils can become oil drops and mix in the water, or accumulate on the bottom, or mix with sediment and then sink.

Wildlife and Habitat

Oil causes harm to wildlife through physical contact, ingestion, inhalation and absorption. Floating oil can contaminate plankton, which includes algae, fish eggs, and the larvae of various invertebrates. Fish that feed on these organisms can subsequently become contaminated. Larger animals in the food chain, including bigger fish, birds, terrestrial mammals, and even humans may then consume contaminated organisms.

Initially, oil has the greatest impacts on species that utilize the water surface, such as waterfowl and sea otters, and species that inhabit the nearshore environment. Although oil causes immediate effects throughout the entire spill site, it is the external effects of oil on larger wildlife species that are often immediately apparent.

Plants

Marine algae and seaweed responds variably to oil, and oil spills may result in die-offs for some species. Algae may die or become more abundant in response to oil spills. Although oil can prevent the germination and growth of marine plants, most vegetation, including kelp, appears to recover after cleanup.

Oily sheen in the intertidal habitat with aquatic plants following the Exxon Valdez spill.

Invertebrates
Oil can be directly toxic to marine invertebrates or impact them through physical smothering, altering metabolic and feeding rates, and altering shell formation. These toxic effects can be both acute (lethal) and chronic (sub-lethal). Intertidal benthic (bottom dwelling) invertebrates may be especially vulnerable when oil becomes highly concentrated along the shoreline. Additionally, sediments can become reservoirs for the spilled petroleum. Some benthic invertebrates can survive exposure, but may accumulate high levels of contaminants in their bodies that can be passed on to predators.

Fish
Fish can be impacted directly through uptake by the gills, ingestion of oil or oiled prey, effects on eggs and larval survival, or changes in the ecosystem that support the fish. Adult fish may experience reduced growth, enlarged livers, changes in heart and respiration rates, fin erosion, and reproductive impairment when exposed to oil. Oil has the potential to impact spawning success, as eggs and larvae of many fish species, including salmon, are highly sensitive to oil toxins.

Birds and Mammals
Physical contact with oil destroys the insulation value of fur and feathers, causing birds and fur-bearing mammals to die of hypothermia. In cold climates, an inch diameter oil drop can be enough to kill a bird. Heavily oiled birds can loose their ability to fly and their buoyancy, causing drowning.

In efforts to clean themselves, birds and sea otters ingest and inhale oil. Ingestion can kill animals immediately, but more often results in lung, liver, and kidney damage and subsequent death. Seals and sea lions may be exposed to oil while breathing or resting at the water's surface or through feeding on contaminated species.

Long-term or chronic effects on birds and marine mammals are less understood, but oil ingestion has been shown to cause suppression to the immune system, organ damage, skin irritation and ulceration, damage to the adrenal system, and behavioral changes. Damage to the immune system can lead to secondary infections that cause death and behavioral changes may affect an individual's ability to find food or avoid predators. Oil also affects animals in non-lethal ways such as impairing reproduction.

Oiled loon, Prince William Sound, AK.

Avian and mammalian scavengers such as ravens, bald eagles, and arctic foxes are also exposed to oil by feeding on carcasses of contaminated fish and wildlife. Direct mortality and reduced reproduction in bald eagles were attributed to the *Exxon Valdez* oil spill.

Habitat
Oil has the potential to persist in the environment long after a spill event and has been detected in sediment 30 years after a spill. Oil spills may cause shifts in population structure, species abundance and diversity, and distribution. Habitat loss and the loss of prey items also have the potential to affect fish and wildlife populations.

Oiled sea otter, Prince William sound, AK USFWS

Oil remains in the environment long after a spill event, especially in areas sheltered from weathering processes, such as the subsurface sediments under gravel shorelines, and in some soft substrates. However, pelagic and offshore communities are fairly resilient and rebound more quickly than inshore habitats. Although oil is still present in the sediment and coastal areas 15 years after the *Exxon Valdez* oil spill in Prince William Sound, Alaska, some wildlife populations have recovered. It is believed that continued effects will most likely be restricted to populations that reside or feed in isolated areas that contain oil.

The U.S. Fish and Wildlife Service responds to spills to minimize impacts to trust resources and continues its work long after a spill event. The Service continues assess and monitor the damage to habitat and wildlife and attempts to minimize the long-term effects on new generations of wildlife.

U.S. Fish & Wildlife Service
1 800/344 WILD
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December 2004

Dartmouth Undergraduate Journal of Science

Oil Spills: Severity and Consequences to Our Ecosystem

Posted by DUJS / In Winter 2012 / March 11, 2012

Oil spills are a byproduct of human activity in which oil is leaked "from ships, shore facilities, pipelines and offshore platforms" (1). Despite popular belief, the largest contributors to oil spills are not tankers, ships that carry large amounts of oil, but rather automobiles, boats, industrial plants, and machinery. This oil eventually reaches the ocean where it harms marine ecosystems. The severity of oil spills, however, is influenced by many factors, including the type of spillage, the quantity of oil, and the effects of tidal waves (2).

Categories of Oil and Associated Severities

According to the U.S. Fish and Wildlife Service, oil spills can be classified into five categories: very light oils, light oils, medium oils, heavy oils and very heavy oils.

Very light oils, such as gasoline and jet fuel, are extremely toxic to marine organisms, but evaporate rapidly in water so cleaning spills of this type is unnecessary.

Light oils, such as diesel, leave a residue in water and have long–term consequences on ocean life. Although light oils have fewer toxins than very light oils, they are still damaging. Nevertheless, light oil spills can be effectively cleaned.

Medium oils, including crude oils like petroleum, do not evaporate quickly. As such, these oils can devastate marine communities residing in intertidal areas, or areas between high and low waters. Medium oils are especially threatening to birds and mammals as they can adhere to their feathers, hair, or fur. Cleaning up medium oils is most successful if done immediately following the spill.

Heavy oils, on the other hand, are less likely to evaporate in water and can be exceptionally detrimental to aquatic life. Heavy oils are known to injure birds and mammals that come in contact with the contaminated site. Decontaminating areas in which heavy oils have been spilt is also very challenging.

Very heavy oils, also known as Group V oils, are capable of hovering and diffusing into water, affecting animals like lobster, which subsist on ocean floors. While Group V oils are not as toxic as the lighter oils, finding and pinpointing these oils is a difficult task (3).

Detrimental Outcomes of Oil Spills

Because oil does not dissolve in water, it undergoes a "biological, physical and chemical process called weathering" (1). Weathering degrades oil through natural mechanisms produced by sunlight, tidal waves, water temperature, and bacteria. As a result, some oil spills have short-term consequences, persisting for only weeks. If oil contaminates shallow water, however, the results can be much more dire. In these cases, the oil mixes with mud and other substances and accumulates on the bottom. As a result, the oil can last for decades causing a number of problems for marine life that comes in contact with the contaminated materials.

In the British Petroleum (BP) oil spill of 2010, 4.9 million barrels of crude oil were spilt in the Gulf of Mexico (4). According to *Time,* thousands of dead invertebrates like starfish and coral were found. Unfortunately, these species play an essential role in the ecosystems to which they belong, thereby impacting many other marine populations. Similarly, many dolphin offspring were found dead along the Gulf Coast. Oyster beds were also devastated by the oil spill; in fact, it could take ten years for the population to reach its former size (4).

The 1989 Exxon Valdez oil spill was equally catastrophic. According to BBC News, the oil killed over 250,000 seabirds, 2,800 sea otters, 250 bald eagles, 300 harbor seals, and 22 killer whales, as well as countless herring and salmon (5).

In addition to killing many sea dwellers, oil spills can also impact the health of those that survive. Oil can modify invertebrate feeding habitats, disrupt their shell development, and cause slow suffocation. Bottom-dwelling invertebrates are especially at risk when oil accumulates at the shoreline (2). Many bottom-dwellers can survive oil contamination; however, they transmit these toxins to their predators, leading to increased concentration of the toxins in higher species. From oil spills, fish can experience impeded growth, respiratory and cardiac malfunction, and stunted larval development. As a result, survival rates for offspring are low.

Oil spills can similarly thwart plant development. They can also spur growth of certain algae populations. When oil directly contacts birds, it can get in their feathers, which impedes their abilities to fly. As a result, many birds drown while others die of hypothermia. If oil is ingested, kidney, liver and lung damage often results, usually followed by death. Other side effects include an inability to reproduce, abnormal behaviors, a debilitated immune system, and skin irritability (2).

Humans can also be affected by oil spills. In Ogoniland, Nigeria, for example, the people have dealt with nearly 50 years of oil production and water contamination. Many communities are faced with dangerous levels of carcinogens, cancer causing agents. In one such community, families are drinking water polluted with benzene, a type of carcinogen, at a concentration 900 times that considered to be safe. In other areas of Ogoniland, nearly eight centimeters of oil were found on top of the water. This horrific spill has so far killed tens of thousands of people, as well as livestock, and is predicted to take up to 30 years to reach its former clean state (7, 8). Altogether, it will cost approximately $1 billion to rebuild the area. The Shell Oil Company, which was responsible for the spill, has neglected the impact this spill has had on the Nigerians. They have, however, taken responsibility for the recent 2008 and 2009 oil spills.

Cleaning Up

There are many natural processes that degrade oil, but human efforts are often required to prevent long-term damage to the environment from oil spills. There are four main methods by which an oil spill can be cleaned up: booms, skimmers, chemicals, or burning. Booms are floating devices used to trap, collect, and absorb the oil surrounding it. Skimmers are boats that can remove the oil from the surface of the water. Certain chemicals can be used to break down the oil into its less dangerous components. Lastly burning the oil is also possible, but this is often avoided because it can produce unwanted air pollutants. The effectiveness of the cleanup depends on a number of factors, including tidal waves and weather conditions.

Although it is debated whether humans could live without oil, we are heavily dependent on it in the modern world. Nevertheless, companies must follow safe protocols. Unlike the Shell Oil Company's failure to comply with this ordinance in Nigeria, companies must be prepared in advance to minimize the negative effects of oil spills on the environment. After the BP oil spill, BP proceeded to strengthen blowout preventers, install emergency systems, have pressure examinations, and increase personnel training. Although programs like these will not eliminate oil spills and leaks, they can at least help reduce the problem (10). The government also requires tankers to be double-hulled, which decreases the incidence of oil spills (11). Inspections and maintenance of the tanks can also be performed to reduce oil leaks.

Looking Forward

If we continue to use oil in our everyday lives, we must make sure to use it efficiently. Individuals can make a significant difference with relatively simple efforts. The California Coastal Commission suggests learning how to correctly change and remove motor oil from vehicles, getting a vehicle tuned, taking public transportation, biking, and becoming an oil spill volunteer as possible ways to help improve marine life (11). The challenge now is taking the steps to ensure this is what happens.

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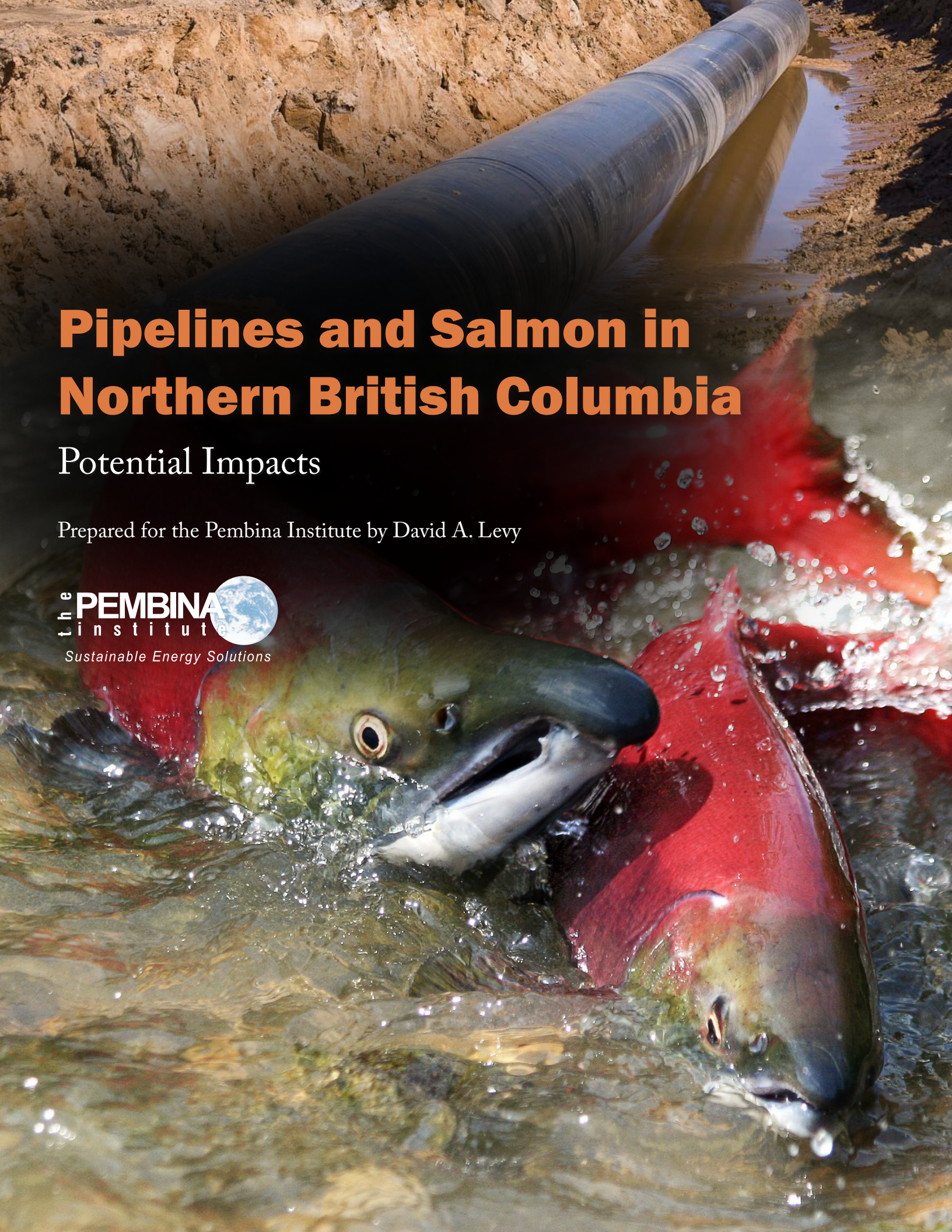

Pipelines and Salmon in Northern British Columbia

Potential Impacts

Prepared for the Pembina Institute by David A. Levy

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Pipelines and Salmon in Northern British Columbia

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Pipelines and Salmon in Northern British Columbia

The health and abundance of salmon is critical to the well being of Northern British Columbia. There are currently four pipeline projects proposed to traverse northern B.C. that could threaten the health of the Fraser, Skeena, and Kitimat watersheds and the salmon they are home to.

Of these four proposals, Enbridge's Northern Gateway pipeline project has generated the most interest and concern for a number of reasons. Communities and First Nations along the proposed route have expressed concern about the risks posed to northern watersheds by the more than 700,000 barrels per day of highly toxic petroleum products that would be transported in the proposed twin pipelines. Looking more broadly, additional concerns have been raised because of project's role in expanding Alberta's oil sands and bringing supertankers to B.C.'s coast. Questions about this project are also timely, because it will be subjected to environmental review in the near future.

All of these proposed pipelines would cross and at times run parallel to the critically productive salmon habitats of the Upper Fraser, Skeena and Kitimat Watersheds. If all five proposed pipelines were built, they would extend over 4,000 km stretched end to end. They would cross more than one thousand rivers and streams in some of Canada's most productive salmon habitat. If the Enbridge pipeline is built, the salmon and their ecosystems may be negatively impacted by its construction, operation, and potential failures.

Salmon habitats in the vicinity of the pipelines are vulnerable to numerous construction effects, particularly at stream crossings. The primary construction impacts of the proposed pipelines would be increased sedimentation and higher water temperatures from diminished riparian habitat; salmon and trout are highly sensitive to increases in each of these parameters.

The greatest concerns are the risks to salmon and freshwater habitat from pipeline failures that cannot be entirely prevented. Two types of pipeline failure exist: leaks and ruptures. Ruptures can result from third party damage, natural events (e.g. landslides) or general pipeline degradation. Failures that occur adjacent to stream crossings or where pipelines run parallel to streams are the greatest risk to salmon. As evidenced by industry performance, pipeline ruptures are an ongoing hazard of pipeline operations.

In Canada, there have been two recent major oil spills into freshwater habitats: the Pine River spill and the Lake Wabamun spill. The Pine River spill of 1 million litres of petroleum severely affected the freshwater habitat and caused a massive fish kill that extended for over 20 km downstream from the spill site. Spill responses were inadequate and eventually cost the operator $30 million in clean-up costs — though the affected area has not yet fully recovered. The Wabamum Lake event demonstrated that the behavior of diluted heavy oil in freshwater environments is poorly understood.

The terrain where the proposed Enbridge pipelines would cross, particularly the Coast Range, does nothing to ease these concerns. This project would be constructed and operated in areas of steep, unforgiving and dangerous terrain. Heavy precipitation events and significant avalanche and landslide dangers are the norm. Indeed, major landslides in northern B.C. have occurred along existing and proposed pipeline routes. These events have resulted in pipeline ruptures, knocked out roads and various infrastructure including major highways, and resulted in several deaths in the last few years alone.

The impacts from proposed pipelines would add to numerous stressors on salmon ecosystems — some existing and some expected in the future. These include forestry, hydro developments and climate change. Within northern B.C., current and historic land-use practices have detrimentally affected salmon habitats. There have been widespread environmental impacts that will likely persist into the future. These must be taken into consideration when evaluating the merits of pipeline proposals.

In summary, approving, constructing, and operating pipelines in Northern B.C. will expose salmon habitat in the Upper Fraser, Skeena, and Kitimat watersheds to increased impacts. Even the best pipeline construction and operating practices are insufficient to eliminate all risks. Approving a pipeline proposal such as Enbridge's Gateway project would expose salmon to those risks and the potential impacts. Any such decision should obviously not be taken lightly.

1. Introduction

The health and abundance of salmon is critical to the well-being of Northern British Columbia. First Nations have always depended on salmon for food, social and ceremonial purposes. Wild salmon support recreational tourism, sport, commercial fishing and value-added processing. Their health is also an indicator of the overall health of the ecosystems they support.

In Northern B.C., the Upper Fraser, Skeena and Kitimat provide some of Canada's best salmon habitat. There are currently four proposed pipeline projects that would traverse these watersheds and potentially threaten the salmon they are home to. Of these four proposals, Enbridge's Northern Gateway pipeline project has generated the most interest and concern for a number of reasons. Of note are the sheer volume of highly toxic petroleum products that would be transported in the proposal's twin pipelines (more than 700,000 barrels per day[1]), as well as the role of the project in expanding production in Alberta's oil sands and bringing supertankers to B.C.'s coast. Questions about the project are also timely, because the proponent is planning to submit the project to regulatory review in the near future.

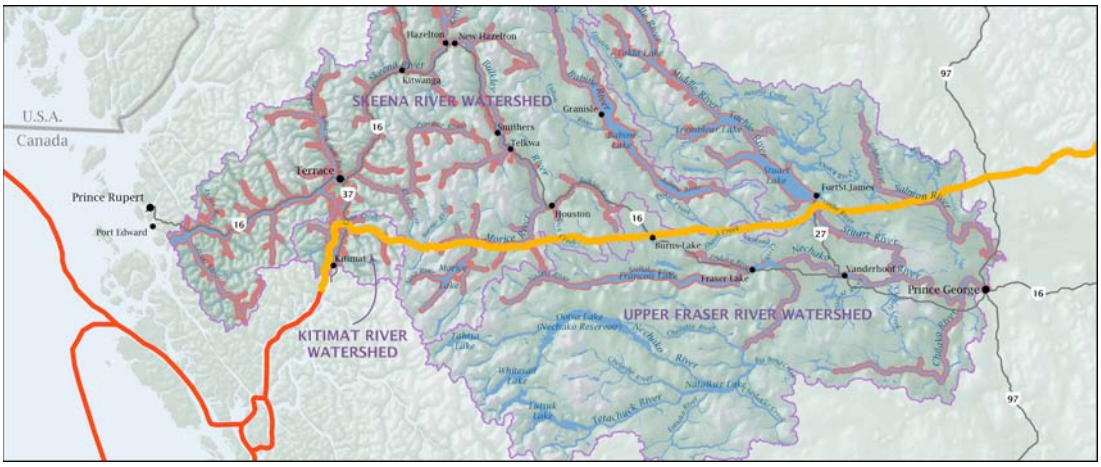

Figure 1. Proposed Enbridge Northern Gateway pipeline route in relation to the Upper Fraser, Skeena and Kitimat Watersheds.

Map: Eliana Macdonald

Some of the questions being asked include: How would construction of the project impact salmon and their habitat? What is the likelihood of minor or catastrophic spills? What would the impacts of an oil sands petroleum and condensate spill be for salmon and their habitat? Could the salmon and their habitat be protected when those pipeline failures happen?

These questions are especially relevant because the ecosystems in question have already been stressed, and will be further stressed by impacts such as mining, forestry, and climate change.

[1] The proposed 36-inch diameter westward line would export an average of 525,000 barrels a day of petroleum product. The proposed 20-inch diameter eastward line would import an average of 193,000 barrels a day of condensate.

This report was prepared to begin evaluating those questions. Having robust answers will help communities understand the potential impacts of Enbridge's proposed pipeline on the five species of salmon (sockeye, pink, chum, Chinook and coho) and steelhead. The report is structured as follows:

- Section 2 describes the salmon resources in the three affected watersheds, to identify the salmon populations that could be potentially affected by pipelines.
- Section 3 provides summary descriptions of the proposed Enbridge pipeline and other pipeline projects proposed for similar routes.
- Section 4 presents the impacts that pipeline construction and operation would have on salmon and other fish species using freshwater habitat.
- Section 5 discusses the impacts that pipeline failure would have on salmon and other fish species using the same freshwater habitat.
- Section 6 considers potential pipeline failure mechanisms and presents some examples of failures that affected aquatic resources in Northern B.C. and Alberta.
- Section 7 analyzes the combined risks to salmon from pipelines and other human activities in Northern B.C. and provides a preliminary cumulative impact evaluation.
- Section 8 summarizes the key conclusions.

2. Salmon Resources in Affected Watersheds

For thousands of years, the culture and well-being of the peoples of the Pacific Northwest have been inextricably linked to Pacific salmon. These fish return annually from the ocean bringing their gift of food, as well as enormous quantities of marine nutrients. Salmon define human and natural history in the northeast Pacific Ocean. B.C. salmon form part of the North Eastern Pacific salmon ecosystem, which is one of Earth's most productive biological communities, sustaining diverse terrestrial and aquatic life. The major salmon-bearing watersheds of the upper Fraser (including the Salmon, Takla-Stuart, and Nechako), the Skeena (including the Morice and Zymoetz), and the Kitimat are no exceptions. By any measure, salmon are a vital component of B.C.'s ecology, culture, economy and social fabric.

Figure 2 shows a map of the freshwater salmon habitats in B.C., while Figures 3, 4 and 5 show the Upper Fraser, Skeena, and Kitimat watersheds in relation to the proposed Enbridge pipeline. In total, the project would need to cross more than 780 waterways in these three watersheds.

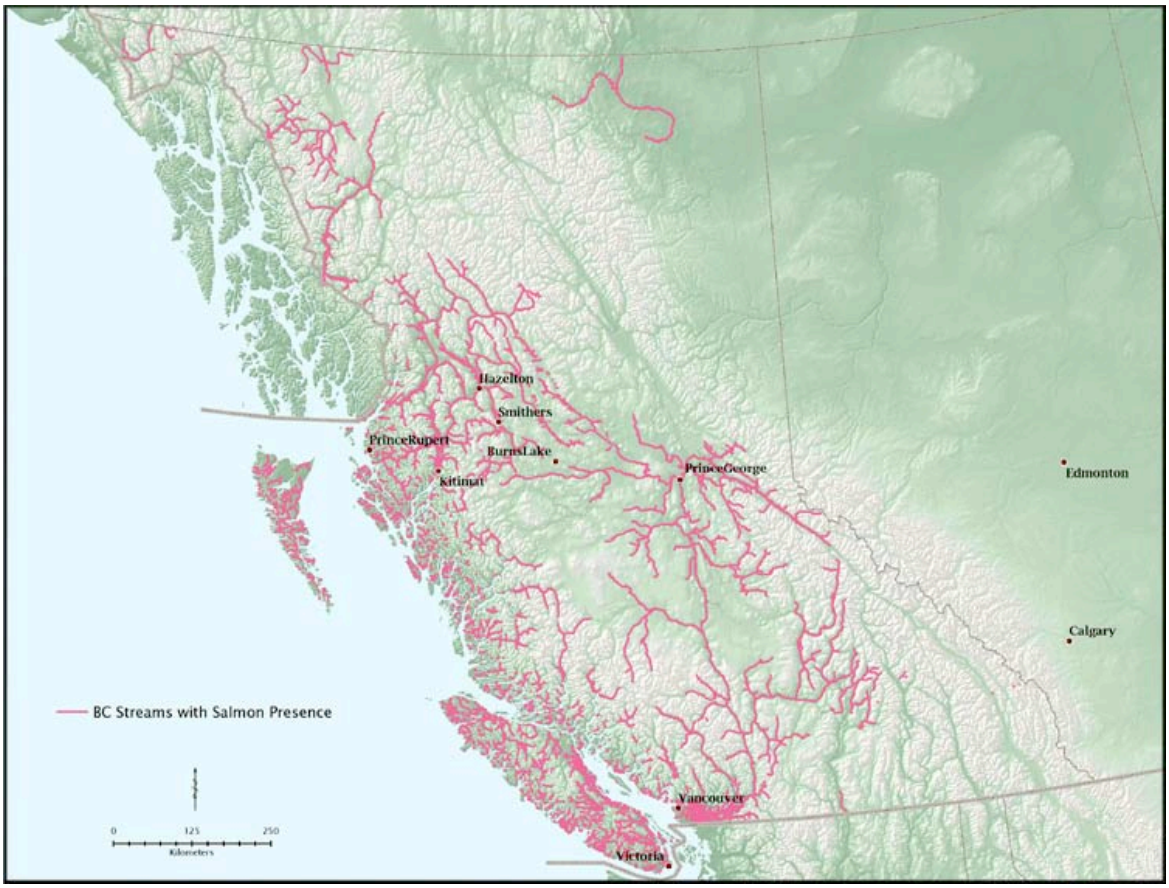

Figure 2. Salmon habitats in B.C.

Map: Eliana Macdonald

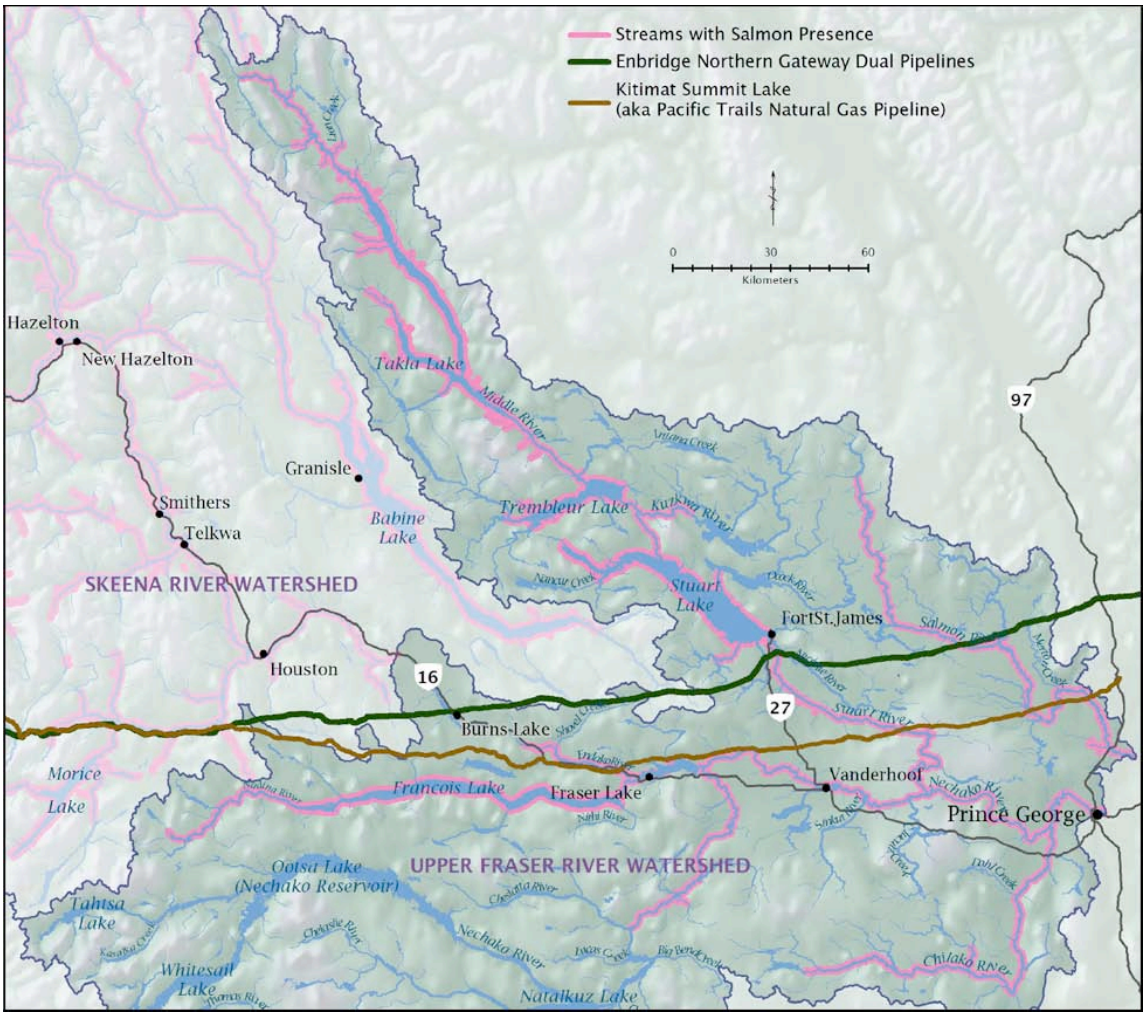

Figure 3. Upper Fraser River Watershed in relation to proposed pipelines.

Map: Eliana Macdonald

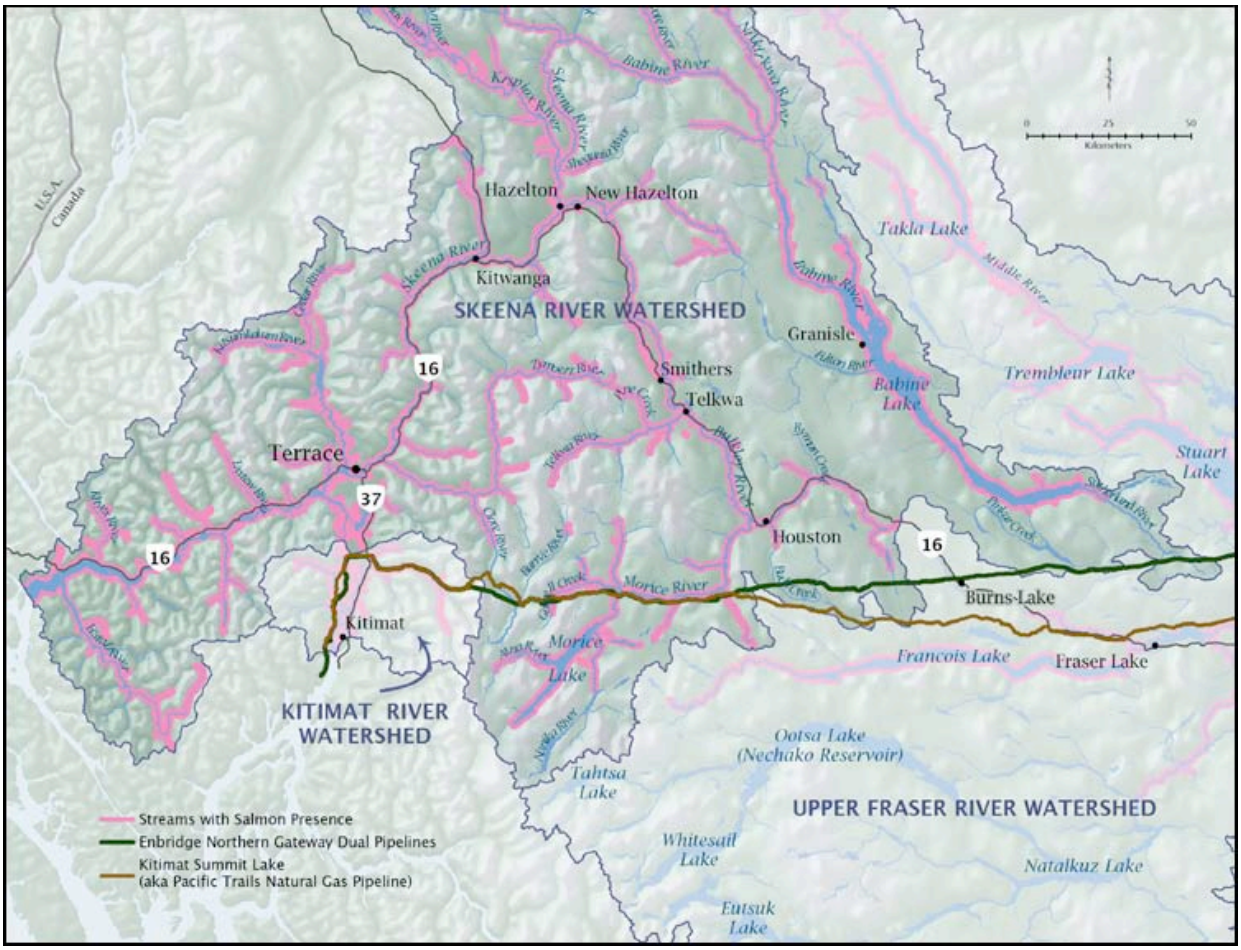

Figure 4. Skeena River Watershed in relation to proposed pipelines.

Map: Eliana Macdonald

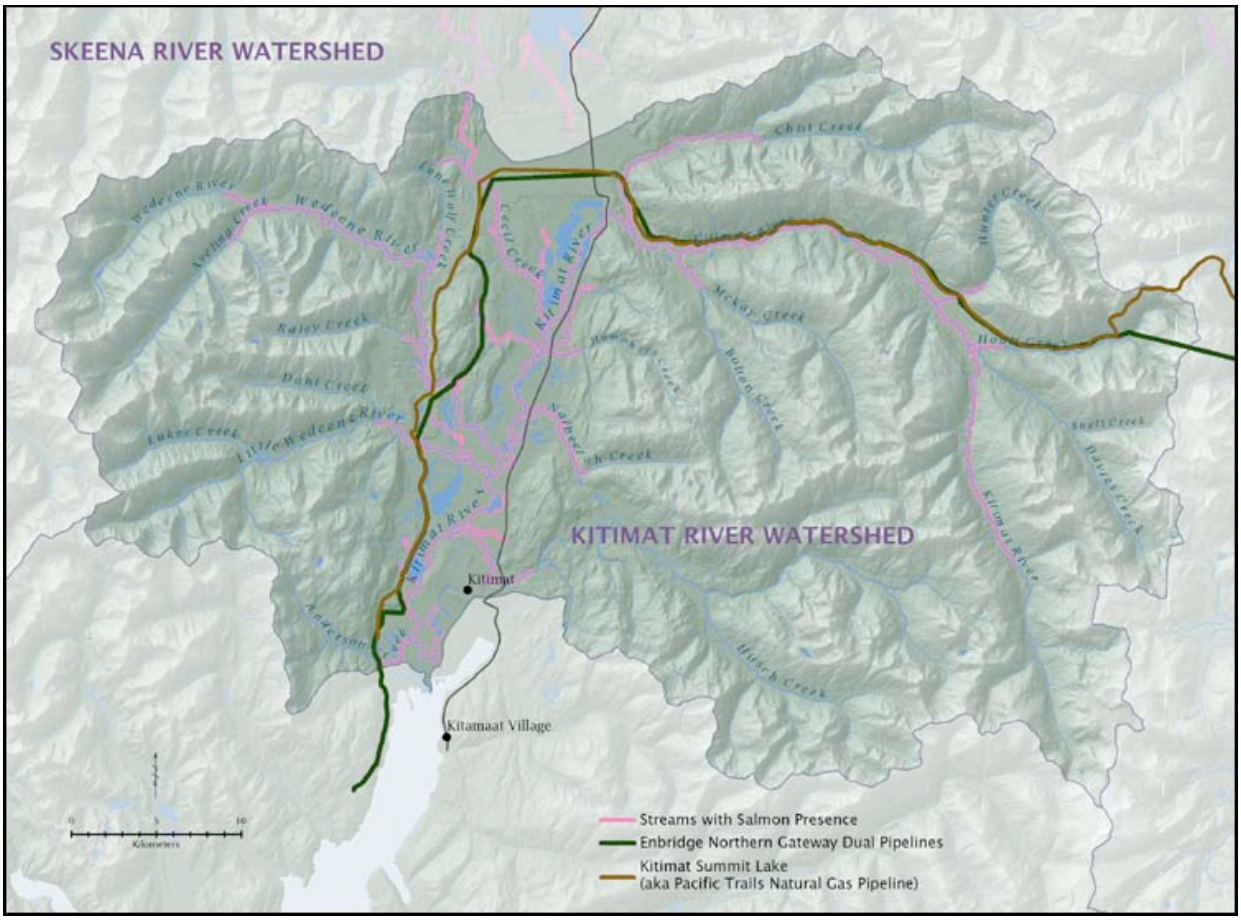

Figure 5. Kitimat River Watershed in relation to proposed pipelines.
Map: Eliana Macdonald

2.1 Salmon and First Nations

The remarkable salmon and steelhead which annually return from the sea serve as a cultural and economic foundation of many B.C. First Nations. In the Upper Fraser River, the Carrier fishery has taken place for millennia. Tl'az'ten, Nak'azdli and Takla Lake First Nations as well as other Carrier Sekani communities are highly dependent on the Stuart sockeye runs to meet their needs. The Kitamat river watershed has long been part of the ancestral homeland of the Haisla peoples. In the past, salmon, eulachon, and other species of fish were abundant and played a central and integral role in the Haisla's well-being.

In the Skeena River, the Gitxsan and Wet'suwet'en extensively relied upon the upper Zymoetz River watershed. The aboriginal fishery relied on a weir at the outlet of McDonell Lake, as well as spearing sites in the lower river. The Wet'suwet'en have also fished Morice-Nanika sockeye at Hagwilget and Moricetown Canyons for at least 6,000 years. The sockeye are critically important for food, social and ceremonial needs. Stock restoration is a high priority for the Wet'suwet'en, as Morice-Nanika sockeye are the last significant anadromous sockeye salmon population remaining on their traditional territory.

2.2 Salmon and B.C.'s Economy

In an average year, the commercial sector harvests around 28 million salmon, of which 75% are pink and sockeye.[2] The total landed value of the commercial catch is approximately $250 million. There are 350,000 recreational tidal water licenses issued in B.C. and a portion of the 300,000 non-tidal license holders also fish for salmon; collectively, fishers generate approximately $550 million in direct expenditures.[3] Nature tourism activities based on salmon are estimated to contribute hundreds of millions of dollars to the B.C. economy.[4]

The Zymoetz is considered one of the top ten steelhead rivers in B.C. for recreational fishing. The estimated annual steelhead catch, including guided angling, is 1,700 fish. The Morice is one of B.C.'s most significant streams for Chinook and is also considered to be a world-class summer steelhead stream. Coho are also fished in the Morice. Salmon and steelhead populations in both rivers are already stressed and various bans have been implemented to protect those populations.[5] A study of the Skeena Wild Salmon economy reported that it contributed $110 million to the regional economy[6].

The Kitimat River also provides some of B.C.'s finest recreational fishing for salmon, steelhead, and trout. The fishery is characterized by its ease of access for short-duration angling, as well as the large number of fish (augmented with hatchery releases).

2.3 Salmon Diversity and Abundance

Pacific salmon habitat extends from the freshwater rivers and streams in which they are born all the way to the Pacific Ocean, and back again where they spawn and die. The duration and timing of the migrations depend on the species and stock. Degradation in any part of that habitat will be detrimental to salmon health. In B.C., the five species of salmon are all present in the watersheds affected by the proposed Enbridge pipeline, as are steelhead (rainbow trout that migrate between freshwater and ocean habitats).

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[2] Fisheries and Oceans Canada, "Underwater World: Pacific Salmon," 2002, http://www.dfo-mpo.gc.ca/zone/underwater_sous-marin/salmon/salmon-saumon-eng.htm

[3] Fisheries and Oceans Canada, Fisheries Renewal, *A Vision for Recreational Fisheries in British Columbia 2008-2012: Draft Document for Discussion,* May 2008, http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/consultations/sfab/rec_fish_vision-documents/Recreational_Fisheries_Vision_Document_2008.pdf

[4] Wilderness Tourism Association of BC, *The Value of Wild Salmon to BC's Nature Based Tourism Industry and the Impacts of Open Net Cage Salmon Farming,* April 30, 2008, http://www.wilderness-tourism.bc.ca/docs/WTApositionpaper-salmon_farms-wild.pdf

[5] For the past several years, a kill ban has been instituted for the entire Skeena River watershed to protect steelhead runs from harvest. Throughout Morice River there is no angling from boats between August 15 and December 31 and a bait ban year-round.

[6] Northwest Institute for Bioregional Research *Valuation of the Wild Salmon Economy of the Skeena River Watershed*, prepared by IBM Business Consulting (2006), http://northwestinstitute.ca/downloads/IBM_skeena_report_06.pdf

Under the Wild Salmon Policy, the Department of Fisheries and Oceans (DFO) has grouped B.C. salmon into 423 "conservation units".[7] Conservation units are "groups of wild salmon sufficiently isolated from other groups that, if lost, would be unlikely to re-colonize naturally within an acceptable time frame." The areas of the Skeena, Kitimat, and upper Fraser that would be crossed by the Enbridge pipeline are home to at least 76 conservation units. This represents a huge range of unique and irreplaceable salmon biodiversity and some of Canada's most important salmon habitat (Table 1).

Table 1. Conservation units in contact with proposed B.C. pipelines

The Skeena Watershed shows the greatest biodiversity, providing habitat for 55 conservation units.

	Conservation Units						
Watershed	Pink	Chinook	Sockeye	Coho	Chum	Steelhead	Total
Upper Fraser	1	1	9	2	0	0	13
Skeena	5	8	32	4	4	2	55
Kitimat	2	1	1	1	1	2	8
Total	8	10	42	7	5	4	76

While the number of unique salmon populations within these watersheds is significant, their resiliency varies from population to population. In general, the combination of a 150-year legacy of high fishing rates, increased industrial activity and human settlement in the watersheds, and reduced marine survival has led to diminished salmon abundance and lower-productivity habitats.

Table 2 summarizes the average runs by species and watershed, including some historical information where available. Some of the runs have variable returns, some reporting highs in the hundreds of thousands of fish in some years (e.g. Kitimat River pink and chum salmon). Other runs have experienced significant declines from historical numbers, including the sockeye run of the Morice River and the sockeye runs of the Stuart River.

Appendix 1 provides more detailed information on the salmon population in each of these watersheds.

[7] Fisheries and Oceans Canada, *Canada's Policy for Conservation of Wild Pacific Salmon,* June 2005, http://www.pac.dfo-mpo.gc.ca/publications/pdfs/wsp-eng.pdf

Table 2. Average salmon runs by species and watershed

Watershed	Species					
	Pink	Chinook	Sockeye	Coho	Chum	Steelhead
Upper Fraser	Numbers of pink salmon are very low. They are expanding their ranges into Upper Fraser habitats.	The mean Chinook escapement in the Stuart River over the period 1995-2001 was 4200, with a range of 1900 to 7400. Over the period 1995–2008, mean Chinook escapement to the Salmon River was 920, with a range between 430 and 2400.	Populations are presently depressed due to adult migration difficulties and warm water temperatures encountered during migration.	Numbers of coho salmon are very low. They are expanding their ranges into Upper Fraser habitats.	None present.	None present.
Zymoetz (Skeena)	Over the past two decades there have been escapements of approximately 2000 pinks annually.	The annual Chinook escapement has ranged between 300 to 1000 spawners.	The average annual sockeye escapement has fluctuated between 1500 to 4000 spawners.	There are two distinct run components to the Upper and Lower river. There has been a long term decline in coho escapements.	The average annual chum escapement has ranged between 50 and 350 spawners.	Very high value recreational steelhead fishery. Predominantly summer run, with roughly 16% repeat spawners.
Morice (Skeena)	Insuffient information on Morice River pink salmon.	Morice River Chinook are the single most important Chinook population in the Skeena Watershed, constituting as much as 40% of the Skeena escapement in recent years. Escapements have ranged between 5,000 and 15,000 spawners.	Historically, Morice sockeye have comprised as much as 10% of the total Skeena River escapement. Levels in the 1940s and mid-1950s averaged around 40,000 spawners. Between the mid-1950s and the early 1990s the run collapsed to around 2,500 spawners. After 2000, the run has ranged from 3,000 to 10,000.	Morice River system coho comprise approximately 4% of the total Skeena coho escapement, however, absolute and relative abundance is declining. Escapements have fluctuated between 500 to 11,000 fish. Present escapement level is in the low thousands.	Very small run that historically had a few hundred spawners. Only a few are presently observed and these may be strays from the Kispiox system.	The Bulkley-Morice accounts for 30–40% of the Skeena steelhead escapement. These are summer run fish that enter the Morice system in mid-August and overwinter in the Morice mainstem, particularly downstream of Gosnell Creek.
Kitimat	Escapement has varied from 750 in 1971 to a high of 300,000 in 2003. Since 2003 there have been no annual stream inspections by DFO.	Escapement has fluctuated between 50,000 in the 1930s to a low of 1,000 in some years. The mean annual escapement for the 1990s was 13,400 spawners.	Escapement peaked at 15,000 in 1938. Since 1980, the mean annual escapement has been 3,000 spawners.	Escapement has varied from around 4,000 in the mid-1970s to a high of 75,000 in 1999. The mean annual escapement post-1980 has been 22,400 spawners.	The escapement is highly variable and has ranged from a high of 250,000 in 2003 to a low of 22,230 in 1990. A major component of the escapement is enhanced chum produced from the Kitimat Hatchery. Since 2003 there have been no annual stream inspections by DFO.	Kitimat winter-run steelhead are found throughout the watershed, migrating into the river between late March and early May. The peak spawning occurs in the first week of May. A small summer run is believed to spawn in the upper reaches of the mainstem and its tributaries.

3. Pipelines in Northern British Columbia

Northern British Columbia currently has one major natural gas pipeline (operated by Pacific Northern Gas between Summit Lake and Prince Rupert) and no major liquid petroleum pipelines. Proposals exist for a total of four liquid fuel pipelines and one additional natural gas pipeline.

3.1 Proposed Northern Gateway Pipeline

As discussed, Enbridge's Northern Gateway pipeline has recently attracted considerable attention because of the profound scope of its environmental impacts.

Enbridge's proposed project would transport petroleum products across Northern B.C. between Alberta's oil sands and the B.C. coast. To accomplish this, Enbridge proposes to build twin pipelines that would cross the Upper Fraser, Skeena, and Kitimat watersheds. The pipelines would connect an inland terminal near Edmonton and a marine terminal near Kitimat to transfer petroleum products and condensate into and out of large oil tankers.[8] The proposed route is shown in Figure 6.

Figure 6. Approximate route of the proposed Northern Gateway pipeline

Source: http://www.northerngateway.ca/project-info/route-map

The east-flowing pipeline would most likely carry condensate, which is used as a thinning agent that permits high density petroleum products, such as bitumen, to flow in a pipeline. Condensate is a relatively light hydrocarbon that is acutely toxic to aquatic and terrestrial environments and is highly flammable in high concentrations. Despite the fact that condensate volatizes quickly in comparison to bitumen, it can cause substantial damage in the immediate spill location and

[8] Details of the project come from Enbridge Northern Gateway Pipelines, "Project Info: Northern Gateway at a Glance," http://www.northerngateway.ca/project-info/northern-gateway-at-a-glance

adjacent areas. Approximately 193,000 barrels of condensate per day would be carried in a 20-inch pipeline.

The most probable contents of the west-flowing pipeline are oil products from the oil sands, including diluted bitumen. Bitumen is the raw product from tar sands extraction that has not been upgraded to synthetic crude oil or further refined into petroleum products. Bitumen is an extremely toxic mixture of organic liquids that is highly viscous, black, sticky and composed primarily of highly condensed polycyclic aromatic hydrocarbons. Bitumen needs to be diluted with a lighter petroleum product (condensate or naphtha) in order to reduce its viscosity so that it can flow in a pipeline. Approximately 525,000 barrels of oil sands oil per day would travel through a 36-inch pipe. In comparison, the Exxon Valdez spill leaked 240,000 barrels of crude into Prince William Sound.

The right-of-way for the dual pipelines would be about 1170 km long and 30 m wide. It would cross at least 785 watercourses in British Columbia of which around 80 have high fisheries sensitivities or constructability issues. Large stream and river crossings, from east to west, include Kinuseo Creek, Murray River, Parsnip River, Wicheedo River, Crooked River, Muskeg River, Salmon River, Stuart River, Endako River, Morice River and Thautil River.

The project has generated concerns from First Nations and communities in Northern B.C. and beyond.[9] There are concerns that pipeline ruptures would affect fish abundance and habitat, and that oil tanker spills on the north or central B.C. coast will adversely affect marine life including B.C. salmon production in coastal waters. As well, the pipeline's link to Alberta's oil sands will hasten the land, water, and climate impacts already being caused by that development.[10]

3.2 Other Proposed Pipelines

The one new natural gas pipeline being proposed is the Pacific Trails Pipeline, which would carry gas west from Summit Lake to Kitimat. The pipeline would share the same right-of-way as the Pacific Northern Gas (PNG) pipeline between Endako (west of Fraser Lake) and Summit Lake, and require a new right-of-way between Endako and Kitimat.

All four proposed liquid pipelines (the twin Enbridge pipelines, and individual pipelines under evaluation by Kinder Morgan and Pembina Pipelines) are connected to the expansion of Athabasca oil sands in northern Alberta. Two would export oil sands products (most likely diluted bitumen), and two would import condensate (Table 3). Appendix 2 provides more information on the specific pipelines.

[9] Some of these concerns have been documented at http://landkeepers.ca/pipelines.

[10] Additional information can be found at http://www.oilsandswatch.org.

Table 3. Existing and proposed pipelines in northern B.C.

Pipeline Project	Number of Pipelines	Product and Volume (per day)	Length of Right of Way	Linked to Oil Sands	Additional Tankers Required	Project Status
Enbridge Northern Gateway	2	525,000 barrels of oil products including diluted bitumen 193,000 barrels of condensate	1,170 km per pipeline	Yes	Yes	Proposed – Joint Review Panel process by the NEB and CEAA
Pembina Pipeline Corporation	1	100,000 barrels of condensate	465 km	Yes	Yes	Filed with the B.C. Environmental Assessment Office. Currently on hold.
Kinder Morgan Canada	1	400,000 barrels of oil products including diluted bitumen	760 km	Yes	Yes	Internal planning stages.
Pacific Trail Pipelines	1	885 million cubic feet of natural gas	470 km	No	Yes	Approved by CEAA and BCEAO.
Pacific Northern Gas	1	115 million cubic feet of natural gas	?	No	No	In operation

If all five proposed pipelines were built, they would extend over 4,000 km stretched end to end. They would cross more than one thousand rivers and streams in some of Canada's most productive salmon habitat. These watersheds are national assets that provide food and shelter for aquatic and terrestrial wildlife and water for human consumption and other uses. If built, the salmon and their ecosystems may be negatively impacted by the construction and operation of the pipelines and from their possible failures. The remainder of this report further analyzes these impacts.

4. Impacts on Fish from Pipeline Construction and Operations

The construction and operation of pipelines is well understood and based on a large body of experience. While the steep and mountainous terrain of Northern British Columbia is a complicating factor, best practices and anticipated impacts are relatively well known. This section maps out those anticipated impacts for the construction and operation of pipelines. The most significant impacts would occur during construction at stream crossings, where increased sedimentation can cause adverse impacts ranging from increased mortality to changes in salmon behavior.

4.1 Construction Effects

Pipeline construction effects occur primarily at stream crossings[11]. They are characterized by acute physical and water quality impacts of relatively short duration. The main physical impacts are related to sedimentation and increases in total suspended solids (TSS) due to trench excavation, disposal of fill, erosion and run-off from adjacent upland worksites. Additionally, water discharge from hydrostatic pipe testing and trench dewatering also contributes sediment. Salmon are highly sensitive to sedimentation increases.

Fish responses to sedimentation are related both to the duration of exposure and the suspended sediment concentration[12]. The higher the sediment concentration and the longer the exposure, the more detrimental the impacts will be to fish populations. Analysis of the severity of sediment-related effects on six groups of fish (including salmonids) were rated in order of increased sediment loading as shown in Table 4.

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[11] Lucie M. Lévesque and Monique G. Dubé, "Review of the Effects of In-Stream Pipeline Crossing Construction on Aquatic Ecosystems and Examination of Canadian Methodologies for Impacts Assessment," *Environmental Monitoring and Assessment* 132 (2007): 395-409, http://www.ncbi.nlm.nih.gov/pubmed/17674136

[12] C.P. Newcombe and J.O.T. Jensen, "Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact," *North American Journal of Fisheries Management* 16 (1996): 693-727.

Table 4. Analysis of the severity of sediment-related effects on fish[13]

Ranking of Sedimentation Effects	Fish Response
1. behavioral effects	alarm, abandonment of cover, avoidance
2. sublethal effects	short term reduction in feeding success, moderate physiological stress, cough and increased respiration rate, habitat degradation, impaired homing, long term reduction in feeding success, poor condition
3. lethal and paralethal effects	reduced growth, delayed hatching, reduced density, increased predation and moderate to severe habitat degradation, with mortality increasing incrementally from > 20 to 100%

The Canadian water quality guidelines define the safe level of TSS for the protection of aquatic life. The guidelines were developed using toxicity measurements from a suite of freshwater fish, including salmonids. The guideline is a maximum 25 mg/l increase over background levels during low flow over a period up to 24 hours, and a maximum 5 mg/l above background levels over a period between 24 hours and 30 days[14]. During pipeline construction, TSS can exceed 2500 mg/l[15].

The effects of high TSS from pipeline crossing construction on rainbow trout physiology were determined in cage experiments[16]. Measured effects of high TSS included increased respiration time and shorter times until loss of equilibrium. Differences in blood cell concentrations were attributed to sediment concentration and particle size.

Sedimentation effects on adult spawners may be very different than effects on fry. Behavioral impacts during migration or spawning may be more important for the former, and prey availability or physiological limitations may be more important for the latter.

Benthic invertebrates are also very susceptible to TSS increases. Drift invertebrate biomass was altered by winter pipeline crossing construction in Hodgson Creek, Northwest Territories in response to a pulse of sedimentation[17]. Elevated TSS caused an increase in invertebrate drift density from 2.6 to 37.6 per 100 m^3 downstream, and an increase in standing crop that lasted over 5 weeks. The increase was likely a reflection of sediment plume avoidance by the drift invertebrates.

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[13] Ibid.

[14] Canadian Council of Ministers of the Environment, *Canadian Environmental Quality Guidelines* (Winnipeg, MB: 1999).

[15] Scott M. Reid and Paul G. Anderson, "Suspended Sediment and Turbidity Restrictions Associated With Instream Construction Activities in The United States: An Assessment of Biological Relevance," *International Pipeline Conference 1998*: 1031–1035. http://aplwww.alliance-pipeline.com/contentfiles/30____TSS_Criteria.pdf

[16] Scott M. Reid, G. Isaac, S. Metikosh and J.I.M. Evans, "Physiological response of rainbow trout to sediment released during open-cut pipeline water crossing construction," *Water Quality Research Journal of Canada* 38 (2003): 473-481, http://cat.inist.fr/?aModele=afficheN&cpsidt=15025864

[17] Lucie M. Lévesque, *Method and Design for Assessment of Aquatic Impacts Associated with Pipeline Crossing Construction,* unpublished report prepared for Dr. Monique Dubé, National Water Research Institute, 2005.

One week after pipeline construction, the downstream benthic invertebrate community in Findlay Creek, Ontario was generally limited to only sediment-tolerant species of oligochaetes (aquatic earthworms)[18]. In contrast, at upstream control sites, the benthic invertebrate fauna was characterized as very diverse with over 26 species comprised of chironomids, caddisflies, stoneflies, mayflies, and dragonflies. Changes in observed benthic invertebrate communities tend to be transient. Full recovery of benthic invertebrate communities generally occurs within six months to a year after construction.

The amount of increased sedimentation and its duration depends largely on the method of stream crossing construction, and whether the crossing is below-ground or above-ground (i.e. a bridge)[19]. Construction impacts on salmon can also be partially mitigated by scheduling construction activities in specified timing windows. These windows are designed to avoid sensitive life history stages thereby minimizing salmon exposure to impacts. However, some stream-dwelling salmonids such as coho, Chinook and steelhead are present throughout the year, making these exposed fish vulnerable to short-term construction impacts all year round. Even following best practices, pipeline construction regularly results in TSS levels exceeding the Canadian water quality guidelines. While these guidelines provide a defensible biological basis for protecting salmon, they have no current legal status.

An Enbridge Case Study in Construction Impacts[20]

In early 2009, Enbridge Energy Limited Partnership was found liable for environmental damages incurred during the construction of two parallel pipelines in Wisconsin known as the Southern Access Expansion. The state lawsuit was settled after Enbridge paid $1.1 million in damages over violations of the conditions of their wetland and waterway protection permit. The Civil Complaint was filed by the Wisconsin Department of Justice and documented over 500 violations, including 282 wetland violations (soil mixing, rutting, unauthorized clearing, improper restoration), and 176 land disturbance and erosion control violations near navigable waters and wetlands. All of the violations were documented by independent environmental monitors hired by the Wisconsin Department of Natural Resources.

4.2 Operational Effects

After a pipeline has been installed and its associated road network has been developed, human access to streams is greatly enhanced at pipeline stream crossings in remote areas. This can promote activities, including fishing, that affect resident and migratory fish populations. In

[18] Scott M. Reid and Paul G. Anderson, "Effects of Sediment Released During Open-Cut Pipeline Water Crossings," *Canadian Water Resources Journal* 24 (1999): 235-251. http://aplwww.alliance-pipeline.com/contentfiles/45____EffectsofSediment.pdf

[19] Canadian Association of Petroleum Producers, Canadian Energy Pipeline Association and Canadian Gas Association, *Pipeline Associated Watercourse Crossings*, prepared by TERA Environmental Consultants and Salmo Consulting Inc. (Calgary, AB: 2005), http://www.neb.gc.ca/clf-nsi/rsftyndthnvrnmnt/nvrnmnt/rfrncmtrl/pplnwtrcrssngs2005-eng.pdf. This paper discusses watercourse crossing construction techniques and evaluates the environmental advantages and disadvantages of different pipeline crossings. A total of 43 pipeline construction methods were evaluated.

[20] Wisconsin Department of Justice, "Enbridge Energy Settles State Lawsuit Over Environmental Violations For $1,100,000," media release, January 2, 2009, http://www.doj.state.wi.us/absolutenm/anmviewer.asp?a=24&z=3

effect, the pipeline becomes a conduit for human contact at stream locations which were formerly difficult to access. Pipeline operations can thereby indirectly increase fish mortality via fishing or other human-induced secondary impacts.

In addition to concerns related to increased access, the clearing of trees around streams for pipelines and service roads can also affect salmon habitats. Deforestation frequently leads to decreased stream shading, which results in increased stream temperatures.

5. Impacts on Fish from Pipeline Failures

Pipeline failures and the resulting impact of spilled petroleum products are one of the main concerns associated with pipeline operations. A failure can be classified as a leak (where a pipeline may be losing product but continues to operate), or a rupture (where a pipeline has been compromised to the point where it cannot continue to operate). The Alberta Energy and Utilities Board (EUB) lists the following potential causes of pipeline failure: construction damage, damage by others, earth movement, external corrosion, internal corrosion, joint failure, excess pressure, pipe failures, valve failures, and weld failures[21].

The volume of a spill will depend on the volume of petroleum product being shipped in the pipeline, the size of the failure relative to the pipeline's capacity, and the time that passes until the pipeline is turned off. For example, in the Pine River spill near Chetwynd, B.C. (see Section 6), it took 55 minutes before a ruptured pipeline was shut down. The anticipated flow rate for the proposed Enbridge pipeline would be approximately 20,833 barrels per hour or roughly 350 barrels per minute.

Regardless of the cause, the end result of a pipeline failure is the same — petroleum products being spilled into the surrounding environment. The consequences to salmon are most severe if the pipeline failures occur in proximity to stream crossing locations and associated habitat. It is important to understand how spills will impact fresh water aquatic environments and salmon health. The remainder of this section assesses these consequences.

5.1 Behaviors of Different Petroleum Products in Fresh Water

The chemical properties of different petroleum products vary significantly in fresh water environments. Heavier oils may become associated with sediments and structures such as woody debris and boulders. After sticking to a substrate, the oil can become immobile, releasing contaminants slowly over a prolonged period.

Lighter materials (such as condensate) float along the surface and, depending on conditions such as wind speed and temperature, can persist for one to three days before breaking down or evaporating. However, during this period, the effects of condensate on salmon, aquatic biota, and other freshwater users can be acutely toxic.

[21] Alberta Energy and Utilities Board, *Pipeline Performance in Alberta, 1990-2005*, (Alberta EUB, 2007), http://www.ercb.ca/docs/documents/reports/r2007-a.pdf

If a spill of diluted bitumen occurs, its properties change rapidly as the light condensate evaporates[22]. If the diluted bitumen enters into water, it partitions and releases the condensate fraction. The physical behaviors of heavier materials, such as bitumen, are less well understood than crude oil under spill conditions. They tend to sink in fresh water, are slower to dissolve in the water column, and will not evaporate.

Failures in natural gas pipelines would result in only minor aquatic impacts because the gas itself is non-toxic and would likely dissipate quickly. Gas from a submerged rupture would quickly bubble to the surface.

5.2 Hydrocarbon Toxicity

There is a large literature on the chronic and acute toxicity of petroleum compounds on fish, including salmonids. Condensate and diluted bitumen are highly toxic to all species of salmon, and particularly for the egg and alevin stages. There can be little doubt that exposure to these contaminants would have a severely detrimental impact on salmon populations in northern B.C. In the three watersheds of concern, Kitimat, Skeena and Upper Fraser, stream rearing juvenile steelhead, coho and Chinook are present all year round and are therefore susceptible to spilled petroleum products and condensate.

A range of impacts has been measured in salmon and other fish species from exposure to oil and other petroleum products. These include lethal as well as sublethal effects on growth[23], gene expression[24] and defects in cardiac function, edema, spinal curvature and reduction in the size of the jaw and other craniofacial structures[25].

Polycyclic aromatic hydrocarbons (PAHs) that are dissolved in water from either floating or submerged petrochemicals are the most toxic components for fish and invertebrates. Chronic toxicity increases with higher concentrations of alkyl PAHs. These compounds are found in trace concentrations in condensates, about 0.1% to 2.0% in crude oils and light refined oils (eg. diesel), and up to 6–10% in heavier oils (i.e. heavy bunker oils). Typically, early life stages and developing embryos (Figure 7) are the most sensitive to the toxic effects of petroleum products.

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[22] H.M. Brown and P. Nicholson, "The Physical-Chemical Properties of Bitumen in Relation to Oil Spill Response," *Proceedings, Fourteenth Arctic and Marine Oilspill Program* (1991).

[23] R.A. Heintz, S.D. Rice, A.C. Wertheimer, R.F. Bradshaw, F.P. Thrower, J.E. Joyce and J.W. Short, "Delayed Effects on Growth and Marine Survival of Pink Salmon *Oncorhynchus gorbuscha* After Exposure to Crude Oil During Embryonic Development," *Marine Ecology Progress Series* 208 (2000): 205–216.

[24] R.M. Stagg, J. Rusin, M.E. McPhail, and A.D. McIntosh, "Effects of Polycyclic Aromatic Hydrocarbons on Expression of CYP1A on Salmon (*Salmo salar*) Following Experimental Exposure and After the Braer Oil Spill," *Environmental Toxicology and Chemistry*, 19 (2000): 2797–2805.

[25] J.P. Incardona, T.K. Collier and N.L. Scholz, "Defects in Cardiac Function Precede Morphological Abnormalities in Fish Embryos Exposed to Polycyclic Aromatic Hydrocarbons," *Toxicology and Applied Pharmacology* 196 (2004): 191–205.

Figure 7. Salmon embryos after oil exposure

Deformed pink salmon embryo (lower) exposed to oil compared to an unexposed fry (upper).

Source: Dr. Mark Carls, NOAA, Alaska Fisheries Science Center, http://www.afsc.noaa.gov/

Chronic toxicity is usually the result of prolonged exposure to contaminants and depends on the persistence of the spilled material. In streams and rivers, oil entrained in bottom sediments can destroy spawning habitat. If spilled material contaminates sediments of a spawning bed, salmon embryos in the spawning gravel would be highly vulnerable. Chronic toxicity to embryos will reduce the number of fish that survive to the adult population.

The chronic toxicity of petroleum contaminants for fish and aquatic life has been clearly demonstrated. In separate studies, exposure to toxic fractions of Alaska North Slope Crude[26] and contaminated wastewaters from the Athabaska oil sands area[27] had detrimental impacts on fish health. Compared to control fish populations, the contaminated fish showed higher mortality, malformations, growth reductions and enzyme induction that could cause deleterious reproductive effects.

Acute lethality effects are due primarily to the components that readily dissolve in water like benzene, toluene, ethylbenzene and xylene. Toxic effects vary with the degree of evaporation and dilution which in turn depend largely on temperature and wind velocity. Acute lethality usually occurs within 24 hours and can be manifested as a fish kill.

[26] P.V. Hodson et al., "Alkyl PAH in Crude Oil Cause Chronic Toxicity to Early Life Stages of Fish" in: *28th Arctic and Marine Oilspill Program (AMOP) Technical Seminar,* Environmental Science and Technology Division, Environment Canada, Proceedings of the 2007 AMOP Symposium, Edmonton, AB, June 4–7 (2007): 291–300.

[27] M.V. Colavecchia, P.V. Hodson and J.L. Parrott, "CYP1A Induction and Blue Sac Disease in Early Life Stages of White Suckers (*Catostomus commersoni*) Exposed to Oil Sands," *Journal of Toxicology and Environmental Health Part A*, 69 (2006): 267–994.

6. History of Pipeline Failures

The previous section demonstrated the significant adverse impacts on salmon health that can be precipitated by pipeline failures that occur near stream crossings. Two obvious questions stem from this conclusion. What is the likelihood of significant pipeline failures? What can be done to limit the damages if such a spill occurs?

An analysis of pipeline failures suggests there is a significant probability that proposed pipeline projects in Northern B.C. will ultimately fail. In Alberta, the oil and gas industry had 377,000 kilometres of pipeline in 2005, and averaged 762 pipeline failures per year between 1990 and 2005 for a total of 12,191 failures. Six percent of these (758) were ruptures and 94% (11,433) were leaks[28]. The 1990–2005 data for pipelines in Alberta indicate the following release volumes: 96.0% of the pipeline failures resulted in releases of less than 100 m^3 of liquid, 3.5% were between 100 m^3 and 1000 m^3, and 0.5% were greater than 1000 m^3.

Along the 43,000 km of pipelines regulated by the National Energy Board (NEB), there were 46 ruptures over a 20-year period, or 2.3 ruptures per year[29]. A 1,000 km section of liquid pipeline would be expected to experience a rupture every 16 years. No ruptures were recorded in pipelines that had operated for less than 12 years, which was attributed to a number of factors, including the quality of materials, construction methods and effective pressure testing. According to the same study, large diameter oil pipelines — such as the ones proposed by Enbridge — experience failures from corrosion and stress after 28 years on average.

Oil products from these types of failures persist in freshwater, contaminating aquatic ecosystems for an indefinite period of time. Planning for spill emergency responses can help limit the damages, however there is an inevitable time lag before responses can be mobilized and adequate responses in dynamic river ecosystems will be challenging. Based on the likelihood of failure, coupled with the highly toxic nature of pipeline contents and unresolved questions about spill responses, failures represent the most serious threat from pipelines on Northern B.C. salmon populations.

6.1 Sabotage and Natural Disasters

While steps can be taken to minimize the risk of pipeline failure, there is little that an operator can do to avoid damage from outside forces such as sabotage and natural disasters. Indeed, pipelines in northern B.C. may fail more frequently than the pipelines regulated by the National

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[28] Alberta EUB, *Pipeline Performance in Alberta*.

[29] Franci Jeglic, "Analysis of Ruptures and Trends on Major Canadian Pipeline Systems," *Global Pipeline Monthly* 1 (2005), http://www.neb-one.gc.ca/clf-nsi/rsftyndthnvrnmnt/sfty/pplnrptrs/nlssrptrtrndmjrcndnppln-eng.pdf

Energy Board[30] because of the mountainous terrain and frequency of heavy precipitation events, landslides and avalanches.

Figure 8 shows a small portion of landslides that have occurred in areas adjacent to the proposed pipeline routes[31]. Within northern B.C., at least 38 catastrophic landslides larger than 500,000 m^3 of rock or with runouts longer than 1 km have occurred since 1973[32]. Adding to these risks, climate change is predicted to induce hydrological changes and potential flooding (i.e. rain on snow events) that could increase the frequency and severity of landslides[33].

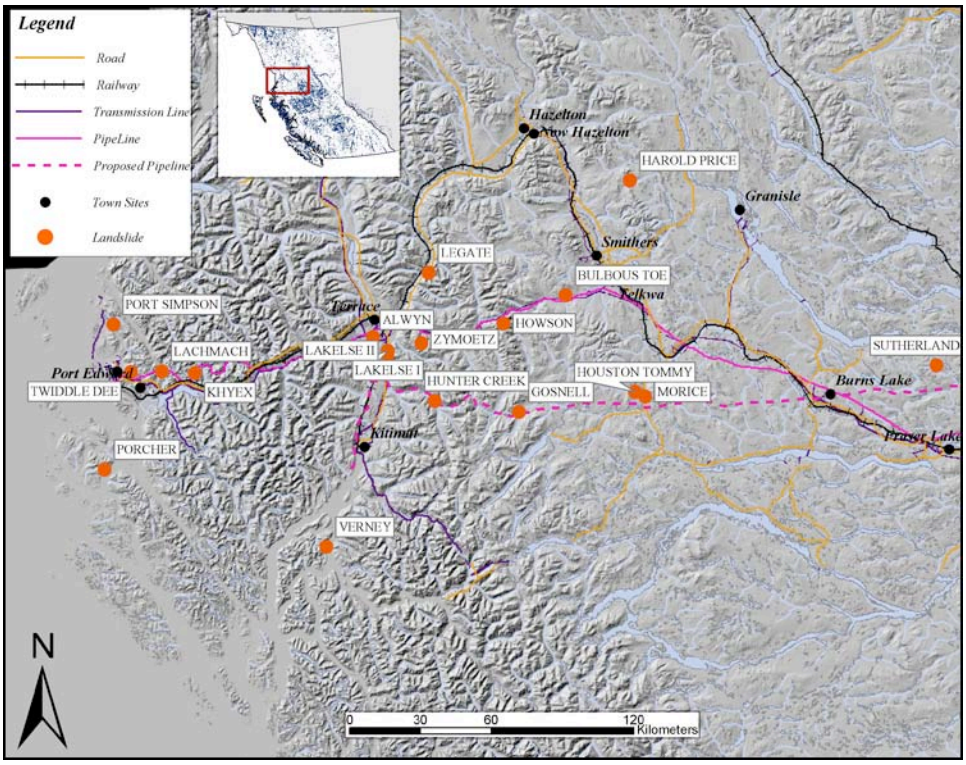

Figure 8. Landslides and linear infrastructure in northern B.C.

The landslides (shown in boxes on the map) represent a small proportion of actual landslides in the area. The solid purple line is the PNG pipeline and the dashed purple line is the proposed Enbridge Northern Gateway right-of-way.

Source: Geertsema et al., "Landslides and Linear Infrastructure."

Landslides ruptured natural gas pipelines in northern B.C. in 1978, 1999, 2002 and 2003. Two examples include the Howson rock avalanche and the Zymoetz landslide. The Howson rock

[30] Ibid.

[31] M. Geertsema, J.W. Schwab and A. Blais-Stevens, "Landslides and Linear Infrastructure in West-Central British Columbia," *Natural Hazards* 48 (2009): 59–72.

[32] M. Geertsema, J.J. Clague, J.W. Schwab and S.G. Evans, "An Overview of Recent Large Catastrophic Landslides in Northern British Columbia, Canada," *Engineering Geology* 83 (2006): 120–143.

[33] Ibid.

avalanche[34] (Figure 9) travelled a distance of 2.7 km and dropped 1,300 metres in elevation. The avalanche tore through mature forest covering an area 1,200 metres long and up to 400 metres wide. Trees were blown over by the air blast, and large boulders, some the size of a small house, were strewn along the landslide path. In total, the avalanche displaced up to 5 million cubic metres of rock.

Figure 9. Howson rock avalanche.

Left: The path of the avalanche showing cliffs (1), pipeline (2), powerline (3) and new lake (4).

Source: Geertsema et al., "Recent Large Catastrophic Landslides."

Upper right: View toward the ice valley showing rock avalanche width, forest removed, and gully on the left of photograph. Lower right: Helicopter next to a house-sized boulder carried down in the avalanche.

Source: B.C. Forest Service, "Catastrophic Rock Avalanche."

The Zymoetz landslide[35] (1.6 million m^3) travelled a distance of 4.3 km and dropped 1,255 m in elevation over this distance. This landslide ruptured a gas pipeline interrupting service to Kitimat, Terrace and Prince Rupert and also blocked access to a 3,000 km^2 basin for more than a year due to the flooding of the road adjacent to the river. Similar types of barriers to access could seriously hinder the ability to respond to a pipeline failure, especially if exacerbated by severe winter conditions.

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[34] British Columbia Forest Service, Forest Sciences Prince Rupert Forest Region, "Catastrophic Rock Avalanche: Howson Range, Telkwa Pass," *Extension Note #46,* March 2002, http://www.for.gov.bc.ca/rni/research/Extension_Notes/Enote46.pdf

[35] Geertsema et al., "Recent Large Catastrophic Landslides."

Intentional human-caused damage is a further potential cause of failure. Figure 10 provides a graphic example of a pipeline failure that created significant environmental impacts. This 2001 incident adjacent to the Copper River in Alaska occurred when a bullet fired from a high-powered rifle put a 1/3-inch hole through the half-inch steel, 48-inch diameter pipe. Over 1.1 million litres of oil discharged into the environment before the hole could be plugged.

Figure 10. An intentional breach of an Alaskan pipeline.

Source: Joint Pipeline Office[36]

6.2 Canadian Case Studies: Freshwater Oil Spills

The two largest oil spills in Canada this century have occurred in freshwater environments[37]: the Pine River spill and the Wabamun Lake spill. Both spills offer important lessons in terms of the potential damages that could be expected from similar spills and the difficulties that would be encountered in attempting to mitigate the damage.

6.2.1 The Pine River Spill

A pipeline owned by Pembina Pipeline Corporation that transports light crude oil from Taylor to Kamloops ruptured on August 1, 2000 near the Pine River, 120 km upstream of Chetwynd. Operators of the pipeline detected a loss of pressure at 1:20 a.m., but both valves weren't manually shut off until 2:15 a.m. In that time 1 million litres of oil spilled into the Pine River, producing the largest inland oil pipeline spill in Canadian history.

The environmental impact included mortality to fish, benthic invertebrates and some wildlife.[38] Fish populations in the first 20 km were heavily impacted. A rough estimate by the B.C. Ministry

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[36] Joint Pipeline Office, *2001/2002 Annual Report*, http://www.jpo.doi.gov/Publications/Annual/2001-2002%20Report.pdf

[37] Ron Goodman, "Wabamun: a Major Inland Spill" (paper presented at Freshwater Spills Symposium, Portland, OR, May 1–4, 2006), http://www.epa.gov/OEM/docs/oil/fss/fss06/goodman.pdf

[38] Carrier Sekani Tribal Council, *Aboriginal Interests and Use Study on the Enbridge Gateway Pipeline: an assessment of the impacts of the proposed Enbridge Gateway Pipeline on the Carrier Sekani First Nations* (Prince

of Environment indicated tens of thousands of mountain whitefish and sculpins killed in the spill affected zone. The river water supply to the District of Chetwynd was also shut off and the use of many groundwater wells near the river was discontinued.

Clean-up costs for the spill were over $30,000,000 making it the most expensive inland oil spill clean-up in Canadian history. Clean-up efforts recovered 450,000 litres from the river and 415,000 litres from contaminated soil[39], leaving about 80,000 litres that spread through the environment. In 2002 Environment Canada laid charges against the corporation for depositing a deleterious substance into the Pine River.

The impacts on the river sediment included increased hydrocarbon concentrations over the first 25 km downstream. Physical cleanup of the river bottom was not possible due to the impact it would create, so the residual oil was left to be physically broken down over time. A survey undertaken in 2005, five years after the spill event, showed that residual oil has persisted in some bottom substrates of the Pine River[40].

The Saulteau and West Moberly First Nations expressed major concerns about the spill and its biophysical impacts, the environmental monitoring and evaluation of environmental damage, the impacts on their Treaty and Aboriginal rights, and the lack of a meaningful consultation process in regards to the potential infringements on their Treaty and Aboriginal rights.

6.2.2 The Wabamun Lake Spill

On August 3, 2005, a Canadian National Railway freight train derailed on the shore of Lake Wabamun, west of Edmonton, spilling about 750 m^3 of Bunker C fuel oil and 75 m^3 of a pole-treating agent on the lakeshore. The spilled materials covered about 12 km of shoreline, and demonstrated complex behaviors over time such as submergence, neutral buoyancy, resurfacing and formation of several types of oil aggregates[41,42]. These varied and unpredicted spill behaviors (shown in Figure 11) were influenced by sediment uptake or loss, temperature change, photo-oxidation and weathering.

George, B.C., 2006) 59, http://www.cstc.bc.ca/downloads/Oil%20&%20Gas/AIUS%20COMPLETE%20FINAL%20inc.%20maps.pdf

[39] B.C. Ministry of the Environment, Environmental Emergency Management Program, "Pine River Oil Spill," http://www.env.gov.bc.ca/eemp/incidents/pembina_00.htm

[40] H. Goldberg, "Pine River: 2005 Assessment — Residual Oil Survey and Snorkel Survey," Arc Environmental Ltd. Kamloops, B.C., 2006.

[41] Merv Fingas, Bruce Hollebone and B. Fieldhouse, "The Density Behavior of Heavy Oils in Freshwater: the Example of the Lake Wabamun Spill" (paper presented at Freshwater Spills Symposium, Portland, OR, May 1–4, 2006) http://www.epa.gov/oem/docs/oil/fss/fss06/fingas_1.pdf

[42] Ron Goodman, "Wabamun: a Major Inland Spill."

Figure 11. Oil spill behavior in Lake Wabamun.

Left: Oil seeping along shoreline. Middle: Floating tar ball releasing sheen. Right: Tar log about 2 x 0.08 m.

Source: Fingas et al, "Density Behavior of Heavy Oils."

In general, the spill's behavior in a freshwater environment was more complex than anticipated. As a result, the spill response and contingency planning was largely inadequate, and governments were not prepared to provide response assistance. The spill demonstrated the low level of understanding of oil spill behavior in freshwater environments. In particular, little was known about the dynamics of neutral density oil, the spillage and flow of hot product, the interaction of oil and fine sediments, and appropriate clean-up procedures[43]. Heavy oils still persist at the bottom of the lake.

6.3 Enbridge Accidents

While Enbridge has indicated that it will follow best practices, the company is not immune to pipeline failures, having experienced a number of pipeline ruptures during their operations including:

- on January 24, 2003, a leak released at least 380,000 litres of oil into the Nemadji River, a tributary of Lake Superior.[44]
- in February 2007, when workers ruptured a Wisconsin pipeline, releasing 300,000 litres of oil.[45]
- on April 15, 2007, a pipeline rupture near Glenavon Saskatchewan released 990,000 litres of oil.[46]

A study undertaken by the Carrier Sekani Tribal Council relating to aboriginal interests on the Enbridge Gateway pipeline documented eight pipeline ruptures that have occurred on Enbridge

[43] Ibid.

[44] United States Environmental Protection Agency, "Oil Spill Program Update", July 2003, http://www.docstoc.com/docs/593974/EPA-Oil-Program-Update

[45] Enbridge, "2007 Corporate Responsibility Report," http://www.enbridge.com/csr2007/environmental-performance/spills-and-releases/

[46] National Energy Board, "Departmental Performance Report," March 31, 2008, http://www.tbs-sct.gc.ca/dpr-rmr/2007-2008/inst/ENR/ENR02-eng.asp

pipelines since 1992.[47] Data were obtained from records collected by the National Energy Board. The failures resulted in spills ranging from 50,000 to 4,000,000 litres of petroleum products, with an average of 1.8 million litres per rupture. An updated list of Enbridge failures to 2007 is documented in Table 5.

Table 5. Enbridge pipeline ruptures since 1992

Date	Nearest Centre	Year Installed	Product	Immediate Cause	Volume Released (Litres)	Note
Jan 2007	Clark County, WN	Not Specified	Crude Oil	Not Specified	200,000	Note 1
Feb 2007	Rusk County, WN	Not specified	Crude Oil	3rd Party Damage	475,000	Note 1
15 Apr 2007	Glenavon, SK	1968	Crude Oil	Corrosion	990,000	Note 2
22 Dec 2006	Sheridan County, MT	Not Specified	Crude Oil	Failure at Pump Station	300,000	Note 1
2006	Cromer, MB	Not specified	Crude Oil	Not Specified	126,000	Note 3
24 Jan 2003	Nemadji River, WN	Not specified	Crude Oil	Not Specified	375,000	Note 4
4 July 2002	Cohasset, MN	1967	Crude Oil	Cracking/Fatique	950,000	Note 5
29 Sep 2001	Binbrook, ON	1972	Crude Oil	Metal Loss/ External Metal Loss	50,000	Note 6
17 Jan 2001	Hardisty, AB	1968	Crude Oil	Cracking/Fatigue	3,800,000	Note 6
20 May 1999	Regina, SK	1968	Crude Oil	Cracking/Fatigue	3,123,000	Note 6
27 Feb 1996	Glenavon, SK	1968	Crude Oil	Metal Loss/ External Metal Loss	800,000	Note 6
13 Nov 1995	Langbank, SK	1965	Crude Oil	Cracking/Fatigue	768,000	Note 6
16 Jun 1995	Widthorst, SK	1968	Condensate	Metal Loss/ External Metal Loss	Not specified	Note 6
03 Oct 1994	St. Leon, MB	1963	Oil & products	Improper Operation	4,000,000	Note 6
02 Jan 1992	Cromer, MB	Not specified	Low Vapour Pressure Hydrocarbon	Metal Loss/ External Metal Loss	125,000	Note 6

[47] Carrier Sekani, *Aboriginal Interests and Use Study.*

Note 1: Source: Enbridge[48]

Note 2: Source: National Energy Board[49]

Note 3: Source: National Energy Board[50]

Note 4: Source: U.S. EPA[51]

Note 5: Source: U.S. National Transportation Safety Board[52]

Note 6: Carrier Sekani, *Aboriginal Interests and Use Study.*

[48] Enbridge, "2007 Corporate Responsibility Report".

[49] National Energy Board, "Departmental Performance Report," March 31, 2008.

[50] National Energy Board, "Departmental Performance Report," March 31, 2007, http://www.tbs-sct.gc.ca/dpr-rmr/2006-2007/inst/ENR/ENR02-eng.asp

[51] United States Environmental Protection Agency, "Oil Spill Program Update", July 2003.

[52] United States National Transportation Safety Board, *Rupture of Enbridge Pipeline and Release of Crude Oil Near Cohasset, Minnesota, July 4, 2002*, Pipeline Accident Report NTSB/PAR-04/01, http://www.ntsb.gov/publictn/2004/PAR0401.pdf.

7. Cumulative Environmental Impacts on Salmon

The health of Skeena, Kitimat, and Upper Fraser watersheds have already been compromised to varying degrees by past impacts, and the proposed pipelines pose an additional threat. Forestry, hydro-electricity, transportation, agriculture, mining, mountain pine beetle, climate change and coalbed methane illustrate the breadth of stresses that salmon are already experiencing or could be faced with in the future. Their combined (or cumulative) impact will dictate the long-term health and viability of salmon.

If allowed to proceed, the proposed Enbridge pipeline and the anticipated impacts from its construction, operation, and eventual failures would be incremental to these existing and proposed stressors. As a result, the anticipated impacts from the proposed Enbridge pipeline need to be understood and assessed on a cumulative basis. The combined effect of multiple impacts won't necessarily be additive. Interactions between environmental stressors can result in a total impact greater than the sum of the parts.

Providing a detailed cumulative impact assessment is beyond the scope of this report, but this needs to be a critical element of any process considering whether or not to approve future pipeline projects. The following sub-sections provide a high-level overview of the other important impacts in the Skeena, Kitimat, and Upper Fraser watersheds.

7.1 Forestry

Historically, past forest practices greatly impacted salmon populations and degraded habitat. Logging directly affects stream habitats in a number of ways. Stream volumes, flow rates and turbidity are altered because snow melt and rainfall runoff flow faster across logged areas. Stream channels can be changed because of road construction. Stream temperatures can also increase because of reduced riparian vegetation. Each of these factors influences salmon populations and habitats, and many have strong parallels to the construction practices needed for a pipeline project. Though practices have been improved, logging remains the predominant industrial activity in the Upper Fraser, Skeena and Kitimat watersheds.

7.2 Hydro Electricity

Large storage reservoirs and flow controls frequently create adverse impacts on salmon. In British Columbia and the Pacific Northwest, large scale hydro developments have left a lasting and profound legacy of decimated salmon populations e.g. Columbia River Watershed. Of note

in the Upper Fraser watershed is the Kemano Reservoir in the Nechako drainage. The project was developed by Alcan in the early 1950s to convey water into the Kemano watershed to generate electricity on the coast. Since 1987 there has been a Settlement Agreement between B.C., Alcan, and DFO that established the Nechako Fisheries Conservation Program to manage the impacts of the project on Chinook and sockeye salmon.

Within the Skeena and Kitimat watersheds there are also a number of proposals for smaller scale run-of-river hydro development. Run-of-river projects in B.C. have been controversial in part due to their potential impacts on salmon populations. Considerable scientific research is required to accurately assess the merits and impacts of these projects; such a detailed review is beyond the scope of this report. However, based on projects that have been approved elsewhere in B.C., it is reasonable to assume that some of these proposed run-of-the-river hydro projects could pose additional risks for Skeena and Kitimat salmon.

7.3 Transportation

Both rail and road alignments can block salmon access and alter fish habitats. These effects are prevalent in the lower Skeena watershed and the upper Bulkley floodplains because of poor design and construction of culverts and other drainage structures[53]. The most common problems are barriers to salmon migration, such as culverts with large outfall drops or culverts installed with excessive slope. These barriers create problems for returning adult spawners and also alienate the habitats for juvenile freshwater rearing. An example of alienated habitat is the 70% loss of the floodplain downstream of the Highway 16 Bridge crossing the Zymoetz River.[54]

7.4 Agriculture

The majority of agricultural impacts are associated with cattle grazing and the runoff of animal effluent as well as fertilizers and pesticides. Agricultural activity is significant in the Upper Fraser and there is also notable activity in the upper Bulkley of the Skeena. Agriculture is largely absent in the Kitimat watershed. Freshwater environmental impacts from grazing can be extensive. Unrestricted livestock access can negatively affect water quality, quantity, hydrology, riparian zone soils, instream and streambank vegetation, and aquatic and riparian wildlife.[55] In many cases, there can be reductions in fish production and biomass.

7.5 Mining

The reaches of the mid and upper Skeena plus the upper Fraser are dotted with various mineral deposits that have attracted mining exploration and development for the past century. Examples include three large open pit mines previously operated adjacent to Babine Lake in the Skeena watershed, the Duthie Mine in the Zymoetz drainage, the Silver Queen mining property east of

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[53] Allen Gottesfeld and Ken Rabnett, *Skeena River Fish and Their Habitat* (Skeena Fisheries Commission, 2008).

[54] Ibid.

[55] Belsky, A.J., A. Matzke and S. Uselman, "Survey of Livestock Influences on Stream and Riparian Ecosystems in the Western United States," *Journal of Soil and Water Conservation* 54 (1999): 419–431.

Owen Lake in the Skeena drainage, and the Equity Silver Mine in the Bulkley drainage. In some of these mines, inadequate controls on mining effluent have resulted in historical degradation of salmon habitat. While current mining operations do not present significant risks to salmon habitat, the development of large-scale mines in the future could change those risks depending on the nature of the project.

7.6 Climate Change and Warming Temperatures

Regardless of how successful efforts are to reduce greenhouse gas emissions, some degree of human-induced climate change is now inevitable. For these reasons, climate change is seen as a major threat to salmon survival. Small increases in water temperature can negatively affect salmon on their migratory spawning journey, as well as the viability of incubating eggs and juvenile salmon during the freshwater stages of their life cycle. Scientific studies have shown that prolonged exposure of several days in temperatures between 22–24°C can be fatal, and that at above 24°C death is almost certain within hours.[56] Of the five species of Pacific salmon, sockeye are the most sensitive and vulnerable to higher water temperatures.[57]

In recent years, temperatures in excess of 20°C have already being recorded on the Fraser River. Climate models predict temperature increases of 1.5–3.2°C by 2050. These higher temperatures will increase water temperatures to dangerously high levels for salmon.[58]

In addition to the direct impacts on salmon from increased water temperatures, changing weather patterns will impact salmon in several other ways:

- Higher temperatures can also increase the amount of organic materials present in freshwater ecosystems, raising the possibility for toxic algae blooms and leading to higher rates of bacterial infection.[59]
- Climate change will cause snow packs to melt earlier, resulting in stronger, more frequent spring flooding and reduced summer run-off. In the spring, increased volume, higher velocity and the mixed debris associated with heavy flooding and variable stream flows could scour existing redds and destroy incubating eggs.[60] Low summer flows could also isolate and destroy the rearing habitats of juvenile salmon.[61]

7.7 Mountain Pine Beetle

As shown on the distribution map of mountain pine beetle (Figure 12), Upper Fraser and Skeena areas along the proposed pipeline route have been subject to the beetle infestation. Infested

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[56] M. Ferrari, et al., "Modeling Changes in Summer Temperature of the Fraser River During the Next Century," *Journal of Hydrology* 342 (2007): 337.

[57] Ibid.

[58] James Battin et al., "Projected Impacts of Climate Change on Salmon Habitat Restoration," *Proceedings of the National Academy of Science* 104, no.16 (2007): 6722, www.pnas.org/cgi/doi/10.1073/pnas.0701685104

[59] Ibid., 6729

[60] Ibid., 6720

[61] Ibid., 6721

forests have higher water tables and faster snowmelt, resulting in higher spring floods and more flash flooding and erosion. Each of these changes in stream flow can stress salmon habitat.

The salvage logging associated with mountain pine beetle also introduces an additional layer of forestry impacts, with road building and stream crossing activities that can significantly impact salmon habitats.

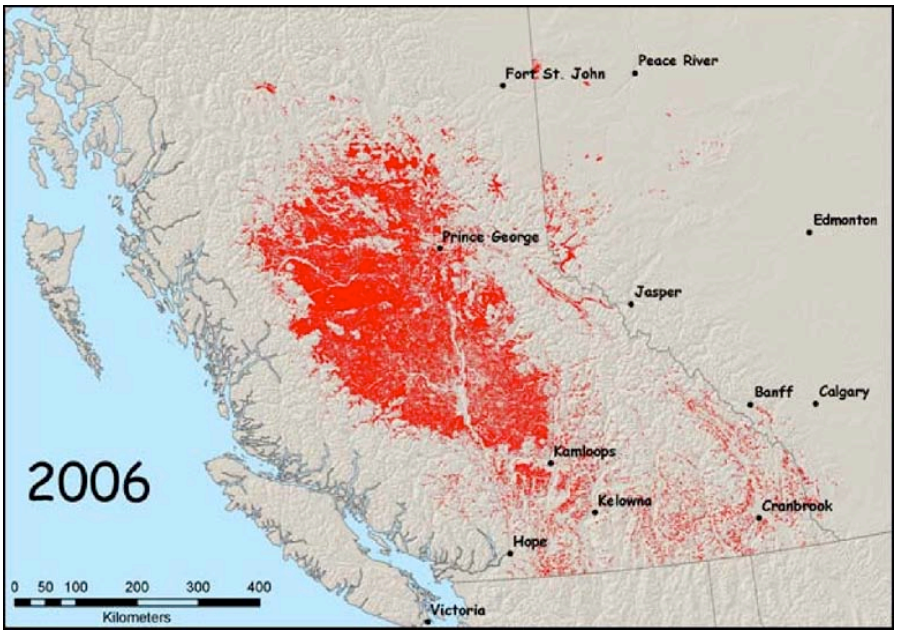

Figure 12. Distribution of mountain pine beetle
Source: Natural Resources Canada[62]

7.8 Coalbed Methane

Commercial coalbed methane has never been attempted in a salmon-bearing watershed and initial analysis suggests that it could have significant impacts on salmon habitat.[63] Coalbed methane requires a much higher density of wells, roads and pipelines than conventional gas. Each of these terrestrial impacts can influence stream volumes, flow rates and turbidity, which in turn can degrade salmon habitat. In addition, groundwater must often be removed before coalbed methane can be produced. Consequently, water tables could drop and ground water flow into streams could be reduced or stopped. The reduced groundwater inflow would alter overall stream flow and temperature, which could potentially reduce the stream's suitability for salmon. There are two areas in the Skeena that have been considered for coalbed methane development: one in the headwaters of the Skeena, Stikine and Nass rivers, and one area near Telkwa in the Bulkley watershed.

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[62] Natural Resources Canada, "Total Area Affected by Mountain Pine Beetle in Western Canada," http://mpb.cfs.nrcan.gc.ca/map_e.html

[63] The Pembina Institute, *Coalbed Methane and Salmon: Assessing the Risk*, prepared by GW Solutions, (Calgary, AB: The Pembina Institute, 2008), http://pubs.pembina.org/reports/cbmandsalmon-rpt.pdf

8. Conclusions

Each of the five proposed pipelines that could potentially traverse northern B.C. could threaten the health of the Fraser, Skeena, and Kitimat watersheds and the salmon they are home to. If all five proposed pipelines were built, they would extend over 4,000 km stretched end to end. They would cross more than one thousand rivers and streams in some of Canada's most productive salmon habitat. Any of the proposed pipeline projects in Northern B.C. will expose salmon to risks on a number of fronts.

During construction, pipeline stream crossings in particular are vulnerable to increased sedimentation, which can degrade salmon habitat. While many construction impacts can be minimized by adopting proven mitigation methods and environmental management plans, the best intentions do not always translate to the best practices as evidenced by Enbridge's 2009 pipeline construction violations in Wisconsin.

Of greater concern is the threat of pipeline failures in liquid pipelines and the resulting spills. The condensate and oil sands products that would be carried in the pipelines are highly toxic to salmon and if spilled into stream habitats, they have acute and chronic effects. Northern B.C. is mountainous and remote terrain, and whether failure is the result of normal pipeline decay over time or more sudden events like landslides or sabotage, the risk cannot be fully eliminated.

The experience of the Pine River and the Wabamun Lake spills also show that the complexity of oil spills in freshwater environments can be easily underestimated and emergency responses to those spills can be inadequate. Over the proposed life of these pipelines, the scenario of a failure that spills into the Upper Fraser, Skeena or Kitimat watersheds is real. Depending on the contaminant discharge volume and the spill location relative to stream crossings, serious and lasting adverse impacts on salmon habitats could occur. Any decision to approve such a pipeline should be made in recognition of these risks.

The risk of impacts from pipeline construction and failures should not be assessed and managed in isolation of other environmental impacts. If approved and constructed, the risks from pipelines would be in addition to existing and other new impacts such as forestry, mining, hydro-electric projects and climate change. The cumulative impacts of potential pipeline development must be evaluated to understand the contribution of numerous direct and indirect effects that over time combine to pose a serious and multi-tiered threat to salmon habitat and freshwater ecosystems.

Appendix 1 – Description of Salmon Resources

Upper Fraser River

The proposed pipeline routes would cross a number of important salmon-producing watersheds in the Upper Fraser (Figure 3) including the Salmon River and Stuart River systems. The Stuart River is a tributary that drains a network of large lakes (Stuart, Trembleur, and Takla) and flows into the Nechako River. The Salmon River joins the Fraser River northeast of Prince George. These two watersheds provide important salmon spawning, rearing and migratory habitats. The conservation units[64] in the Upper Fraser watersheds potentially affected by future pipelines include one pink, one Chinook, nine sockeye (eight lake-type and one river-type), and two coho.

Numbers of pink and coho salmon in the Upper Fraser are very low although both species are expanding their ranges into Upper Fraser habitats.

Chinook

Stuart River Chinook are summer-run. Spawning usually occurs in September. While some juveniles take up residency in the Stuart River for one year, others out-migrate for juvenile rearing into the Fraser mainstem and downstream tributaries for juvenile rearing. Age of returning adults is 3–6 years, with the majority returning at age five. The mean Chinook escapement in the Stuart River over the period 1995-2001 was 4200, with a range of 1900–7400.

Most of the Salmon River serves as rearing habitat for juvenile Chinook. Salmon River Chinook are spring-run: they enter the lower Fraser from February to early July, and show peak spawning activity around the third week of August. Over the period 1995–2008, mean Chinook escapement to the Salmon River was 920, with a range of 430–2400.

Sockeye

Two major Upper Fraser sockeye stocks are supported in the Stuart River watershed. These include the Early Stuart and Late Stuart populations. Adults migrate to spawning grounds in the summer (Early Stuart) and fall (Late Stuart) and spawn in tributaries adjacent to Stuart, Trembleur and Takla Lakes. Both of these populations are presently depressed due to adult migration difficulties and warm water temperatures encountered during migration.

[64] Salmon Conservation Units in this Appendix were identified from maps developed by DFO. http://www.pac.dfo-mpo.gc.ca/consultation/wsp-pss/2008/docs-eng/CUsummlist.pdf

Fisheries

The Carrier fishery has taken place for millennia. Salmon has long been the most important food staple. Tl'az'ten, Nak'azdli and Takla Lake First Nations are highly dependent on the Stuart sockeye runs to meet their needs.

Skeena River

The Skeena watershed (Figure 4) provides extensive spawning and rearing habitat for all five salmon species, steelhead, and at least 22 other fish species[65,66] . The list of conservation units for Skeena salmon includes 32 sockeye CUs (30 lake-type and two river-type), eight CUs for Chinook, four for coho, four for chum, and five for pink salmon. There are two steelhead CUs for the Skeena watershed that are distinguished based on adult run-timing (summer-run and winter-run). There are important enhancement facilities in the Skeena Watershed including two major sockeye spawning channels adjacent to Babine Lake. The Zymoetz (Copper) and Morice Rivers, major Skeena tributaries with high fisheries values that would be crossed by future pipelines, are described below. [67]

Zymoetz River

Chinook

The annual Chinook escapement to the Zymoetz River has ranged between 300–1000 spawners. Chinook enter the Zymoetz River in late June, and spawning occurs from the end of August to the end of September. Critical spawning habitat occurs in patches throughout the mainstem and in the lower reaches of two tributaries: Limonite Creek and the Clore River.

Chum

The average annual chum escapement to the Zymoetz River has ranged between 50 and 350 spawners. Chum enter the river in August and spawn in September and October in an unconfined reach in the lower river. Habitat loss in the Zymoetz due to repositioning of the Highway 16 bridge and channelization efforts below the bridge may have contributed to recent low chum returns.

Sockeye

The average annual sockeye escapement to the Zymoetz River has fluctuated between 1500 to 4000 spawners. Sockeye enter the river in July and spawn in the upper watershed during August and September. McDonnell, Dennis and Aldrich Lakes serve as rearing areas for sockeye fry.

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[65] Gottesfeld and Rabnett, *Skeena River Fish.*

[66] C.J. Walters, J.A. Lichatowich, R.M. Peterman, and J.D. Reynolds, *Report of the Skeena Independent Science Review Panel*, report to the Canadian Department of Fisheries and Oceans and the British Columbia Ministry of the Environment, 2008, http://www.psf.ca/sisrp.pdf

[67] Fisheries information for these two watersheds was summarized from Gottesfeld and Rabnett, *Skeena River Fish.*

Pink

Over the past two decades there have been escapements of approximately 2000 pinks annually. Adults enter the river in August and spawn in September/October within the largely unconfined lower reaches. Pink fry migrate to the ocean directly following emergence.

Steelhead

Adult steelhead enter the Zymoetz River between July and November and spawn the following May to June. Zymoetz River steelhead are believed to include both summer-run and winter-run fish, though summer-run predominates. Repeat spawners comprise 16% of the steelhead population. Steelhead spawn primarily in the upper watershed particularly at the outlet of McDonell Lake. Steelhead overwinter in McDonell Lake and in mainstem areas upstream of the Clore River confluence.

Fisheries

Traditional use of the upper Zymoetz River watershed by Gitxsan and Wet'suwet'en was extensive and there is a network of trails, village sites and fish houses in the watershed. The aboriginal fishery relied on a weir at the outlet of McDonell Lake, as well as spearing sites in the lower river.

The Zymoetz is considered one of the top-ten steelhead rivers in B.C. for recreational fishing. Estimated annual steelhead catch is 1,700 fish which includes guided angling effort. For the past several years, a kill ban has been instituted for the entire Skeena River watershed to protect steelhead runs from harvest.

Morice River

Chinook

Morice River Chinook are the single most important Chinook population in the Skeena watershed, constituting as much as 40% of the Skeena escapement in recent years. Escapements have ranged between 5,000 and 15,000 spawners. Peak spawning takes place in mid-September. Spawning occurs primarily in the 2 km downstream of the Morice Lake outlet in large gravel dunes that are constructed during redd excavation. Chinook fry are displaced downstream upon emergence and then rear throughout the Morice river mainstem and its side channels. Downstream migration of one-year-old smolts peaks in early June.

Sockeye

The Morice-Nanika sockeye population is the largest in the Bulkley basin. Historically, Morice sockeye have comprised as much as 10% of the total Skeena River escapement. There are two run components: Nanika River spawners and Morice Lake and Atna Lake beach spawners. Historic levels in the 1940s and mid-1950s averaged around 40,000 spawners. Between the mid-1950s and the early-1990s the run collapsed to around 2,500 spawners. After 2000, the run has averaged around 5,000 fish (range: 3,000–10,000). Morice Lake serves as the juvenile rearing lake. Due to the very low productivity of Morice Lake, over 85% of the sockeye spend two years in the lake.

Coho

Morice River system coho comprise approximately 4% of the total Skeena coho escapement; however, absolute and relative abundance is declining. Escapements have fluctuated between 500–11,000 fish. Present escapement level is in the low thousands. Coho enter the Morice system in mid-August through mid-September and then hold in the mainstem or in Morice Lake. They spawn in the tributaries in late October and November during fall freshet periods. Juvenile coho are widely distributed throughout the Morice River mainstem as well as in its tributaries and lakes. Pipeline proposals in the Gosnell are in the heart of the coho spawning and rearing habitats.

Pink

There is not much information available for pink salmon. Colonization of the Morice system by pink salmon was facilitated by rock blasting in the Hagwilget Canyon in 1959.

These fish occur in the mainstem Morice and Gosnell in the vicinity of proposed pipeline activity and in some years the escapements can be large. Pink salmon are particularly vulnerable in the mid-reaches of the Morice, since much of their spawning is in extensive sidechannels of the main river downstream from the Thautil. This is below potential pipeline stream crossings of Morice tributaries which could be impacted by a rupture of a petroleum or condensate pipeline.

Steelhead

The Bulkley-Morice accounts for 30–40% of the total Skeena escapement, making it the single largest component of the population. Morice are summer-run steelhead that begin to move into the river in mid-August. Overwintering occurs throughout the mainstem, Morice Lake and in Gosnell Creek. Spawning occurs in May to June throughout the mainstem and its tributaries. Steelhead fry emergence occurs between August and September. Most steelhead remain in the river for three or four winters prior to downstream migration.

Fisheries

The Wet'suwet'en have fished Morice-Nanika sockeye at Hagwilget and Moricetown Canyons for at least 6,000 years. The sockeye are critically important for food, social and ceremonial needs. Stock restoration is a high priority for the Wet'suwet'en as Morice-Nanika sockeye are the last significant anadromous sockeye salmon population remaining on their traditional territory.

The Morice is one of the most significant streams, provincially, for Chinook and steelhead angling. The river is considered to be a world class summer steelhead stream. Coho are also fished. Throughout Morice River there is no angling from boats between August 15 and December 31 and a bait ban year-round.

Kitimat River

The Kitimat watershed (Figure 5) supports a relatively low-diversity complement of CUs including one (each) CU of river sockeye, Chinook, chum, coho, odd-year pink and even-year pink. There are two steelhead CUs: summer-run and winter-run.

Chinook

Chinook salmon concentrate in the Kitimat River mainstem, as well as in most of the larger tributaries including Wedeene River, Little Wedeene River, Chist Creek, and Hirsch Creek. Escapement has fluctuated between 50,000 in the 1930s to a low of 1,000 Chinook in some years. The mean annual escapement for the 1990s was 13,400 spawners. Upstream migration occurs from May to September with the heaviest spawning in July and August.

Chum

Most chum spawn in the Kitimat River with lesser numbers in the tributaries. The escapement is highly variable and has ranged from a high of 250,000 in 2003 to a low of 22,230 in 1990. A major component of the escapement is enhanced chum produced from the Kitimat Hatchery. Spawning begins in July, peaks in August, and is usually over by the end of September.

Sockeye

Sockeye in the Kitimat system are a river-type population. Sockeye spawn mainly in mainstem groundwater channels downstream of Hunter Creek. Sockeye escapement peaked at 15,000 in 1938. Since 1980, the mean annual escapement has been 3,000 spawners. After emerging from the gravel, sockeye fry migrate to the estuary where they rear for the summer.

Pink

The Kitimat River pink run is predominantly an even-year run. Most adult pink distribute in the Kitimat mainstem with additional spawning in the tributaries. By the first week of September most spawning is completed. Escapement has varied from 750 in 1971 to a high of 300,000 in 2003. Juveniles emerge from the gravel in late March and early April and spend their first summer in the Kitimat Estuary.

Coho

Coho salmon are distributed throughout the watershed. Tributaries are also important producers. A major portion of the escapement spawns in or adjacent to the Kitimat River. Cecil Creek provides the largest amount of high quality spawning habitat. The Kitimat River is especially important for rearing due to the relatively large amount of high-quality coho habitat. Coho escapement has varied from around 4,000 in the mid-1970s to a high of 75,000 in 1999. The mean annual escapement post-1980 has been 22,400 spawners. Most coho fry enter the estuary during spring of their second year and remain there until the end of August.

Steelhead

Kitimat winter-run steelhead are found throughout the watershed, migrating into the river between late March and early May. The peak spawning occurs in the first week of May. A small summer-run is believed to spawn in the upper reaches of the mainstem and its tributaries. The mainstem absorbs the majority of spawners and a number of tributaries are also important. Steelhead juvenile age at outmigration is variable, ranging from age two to age four.

Fisheries

The Kitimat river watershed has long been part of the ancestral homeland of the Haisla peoples. In the past, salmon, eulachon, and other species of fish were abundant and played a central and integral role in the Haisla's well-being.

Kitimat River provides some of B.C.'s finest recreational fishing for salmon, steelhead, and trout. The fishery is characterized by the ease of access for short-duration angling, as well as the large number of fish, which are augmented with hatchery releases. Angler effort is primarily by shoreline fishing and drift boats. The majority of anglers fish the lower mainstem in April through October. Principal species fished are Chinook, steelhead, coho, chum, and sea run cutthroat trout.

Appendix 2 – Detailed Pipeline Routes

Liquid Petroleum Pipelines

Enbridge Northern Gateway[68]

Enbridge proposes to build an export petroleum pipeline and an import condensate pipeline between an inland terminal near Edmonton and a marine terminal near Kitimat (Figure 6). Enbridge also proposes to construct and operate marine infrastructure at Kitimat to transfer petroleum products and condensate into and out of large oil tankers. The marine infrastructure would be an integral component of the pipeline terminal near Kitimat, all of which, together with the pipelines, are collectively referred to as the Enbridge Northern Gateway Project.

Bitumen (diluted, most likely with condensate) is the most probable petroleum product to be transferred via the pipeline to Kitimat. A right-of-way, about 1170 km in length and 30 m wide, would be constructed between the Edmonton area and the Gateway marine terminal near Kitimat. Both the petroleum (525,000 barrels per day, 36-inch pipe) and condensate (193,000 barrels per day, 20-inch pipe) pipelines will be located in this right-of-way.

The project will cross at least 785 watercourses in British Columbia of which around 80 have high fisheries sensitivities or constructability issues. Large stream and river crossings include, from east to west, Kinuseo Creek, Murray River, Parsnip River, Wicheedo River, Crooked River, Muskeg River, Salmon River, Stuart River, Endako River, Morice River and Thautil River. The latter five systems are salmon bearing, as are many hundred smaller streams that would need to be traversed by the pipeline.

The Enbridge Gateway project has initiated a Joint Review Panel process through the National Energy Board and the Canadian Environmental Assessment Agency. CEAA is currently reviewing the terms of reference for the review, after the 60 day public comment period. It is anticipated that Enbridge will file their application some time in 2009.

Additional pipeline capacity is due to planned expansion of the Alberta tar sands. If allowed to proceed, the pipeline will further facilitate the destruction of the Boreal forest and pollution of

[68] The description of the Enbridge Northern Gateway Project comes from the Preliminary Information Package (PIP) that was filed with the National Energy Board in November, 2005, and from Enbridge Northern Gateway Pipelines, "Project Info: Northern Gateway at a Glance," http://www.northerngateway.ca/project-info/northern-gateway-at-a-glance

the Athabasca River and will lead to greater expansion of highly toxic tailing ponds and increased GHG emissions.[69]

Kinder Morgan Canada

Kinder Morgan Canada has initiated internal planning on the northern leg of their Trans Mountain Pipeline.[70] The company is examining the viability of connecting Canadian producers and refining customers in Asia. In B.C., the proposed northern leg would connect to the existing Trans Mountain Pipeline at Valemont and extend 760 km to a deep-water port at Kitimat, passing north of Prince George. The pipeline would carry 400,000 barrels per day, transporting petroleum products including diluted bitumen. Although there is limited information available on the routing, it is assumed that the routing would follow the Pacific Trails Pipeline right-of-way. The existing Trans Mountain Pipeline connects Edmonton to Burnaby and Washington State and has a capacity of 300,000 barrels per day.

Pembina Pipeline Corporation

Pembina Pipeline Corporation has proposed to transport about 100,000 barrels per day of condensate from Kitimat to Pembina's existing Western System at Summit Lake via a 16-inch pipeline[71]. The condensate would be used in the development of the Alberta oil sands as a thinner for heavy oil, such as bitumen. The Canadian Environmental Assessment Act requires a federal screening environmental assessment. Preliminary routing information (Figure 13) indicates that the routing would follow the Pacific Trails Pipeline right-of-way.

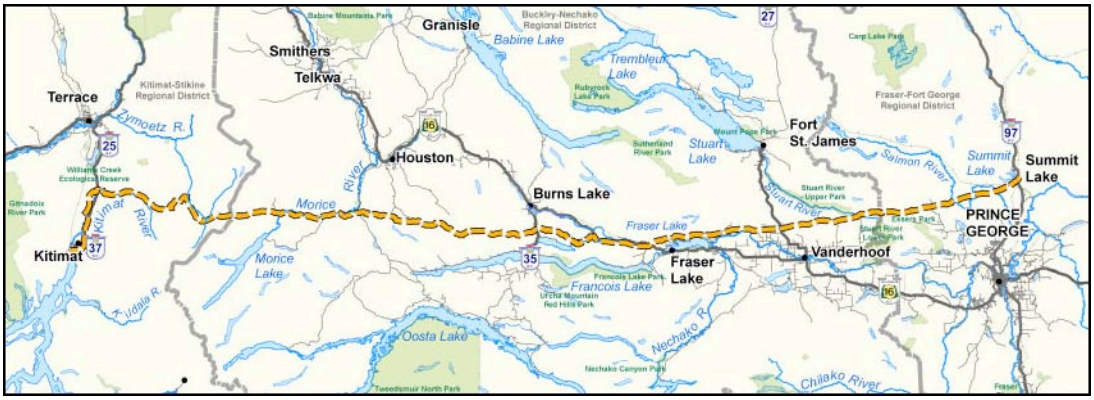

Figure 13. Kitimat to Summit Lake corridor proposed by Pembina Pipeline Corporation.

Source: Pembina Pipeline Corporation, *Project Description*

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[69] Dan Woynillowicz, Chris Severson-Baker, Marlo Reynolds, *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush* (Drayton Valley, AB: The Pembina Institute, 2005).

[70] Kinder Morgan Canada, *Trans Mountain Expansion (TMX) Proposal*, 2008, www.kindermorgan.com/business/canada/TMX_Documentation/brochure_single_page.pdf

[71] Pembina Pipeline Corporation, *Proposed Kitimat to Summit Lake Condensate Pipeline Project: Project Description*, filed June 14, 2006, at the B.C. Environmental Assessment Office: http://a100.gov.bc.ca/appsdata/epic/html/deploy/epic_project_home_280.html

Natural Gas Pipelines

Pacific Northern Gas

Pacific Northern Gas Ltd. (PNG) currently owns and operates a gas transmission and distribution system that delivers natural gas in a westerly direction from the Spectra Energy Transmission (formerly Duke Energy) gas pipeline system near Summit Lake to Kitimat and Prince Rupert on the west coast of British Columbia (Figure 14). The gas transmission line was constructed in 1968, with service commencing in 1969 for large industrial customers. Service was later provided to communities adjacent to the transmission line.

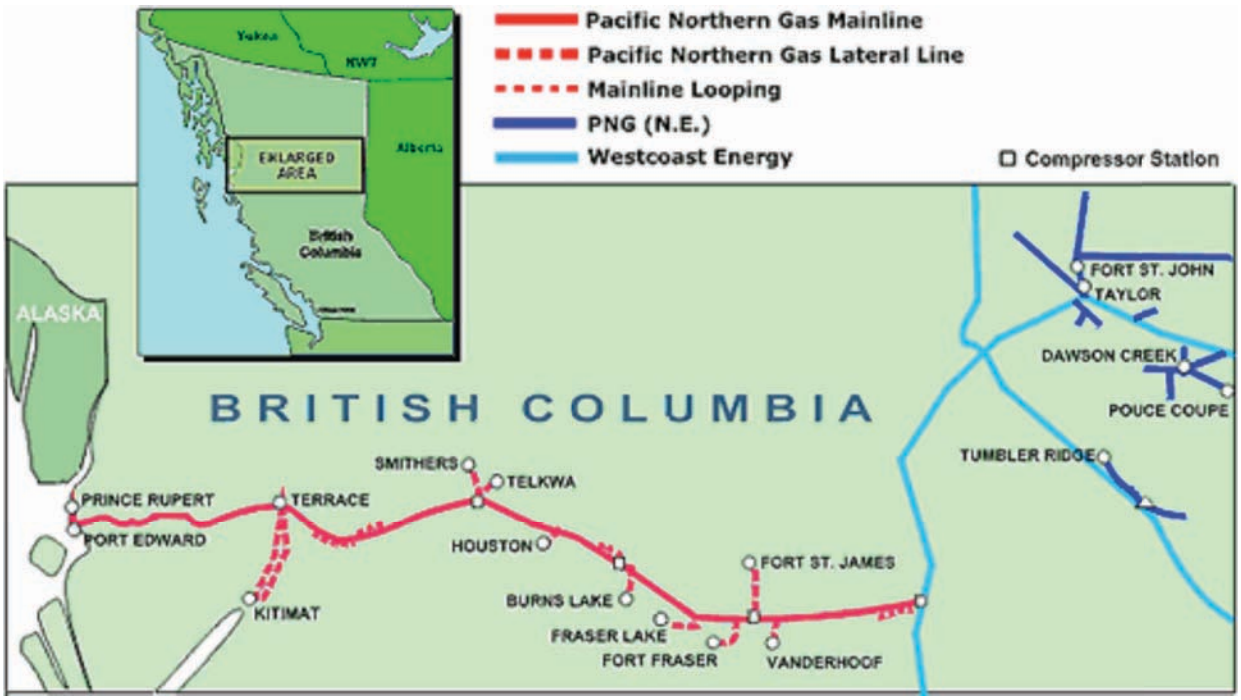

Figure 14. Location of Pacific Northern Gas pipeline system in Northern B.C.

Source: Pacific Northern Gas[72]

Pacific Trail Pipelines

Pacific Trail Pipelines, a 50/50 partnership between Galveston LNG Inc. and Pacific Northern Gas Ltd. (PNG) plans to construct the Kitimat to Summit Lake Pipeline Looping Project (KSL Project) a new 470 km, 30-inch natural gas pipeline between Summit Lake and Kitimat B.C. along current and new rights-of-way[73] (Figure 15). The eastern portion of the pipeline is proposed for construction primarily within, or adjacent to, the right-of-way of the existing PNG

[72] Pacific Northern Gas, "Company: Systems Map," http://www.png.ca/company_map.cfm

[73] Pacific Trail Pipelines, *Kitimat-Summit Lake (KSL) Pipeline Looping Project: Project Description (Revised February 2006)*, filed February 24, 2006, at the B.C. Environmental Assessment Office: http://a100.gov.bc.ca/appsdata/epic/html/deploy/epic_project_home_270.html

pipeline system between Summit Lake and Endako (west of Fraser Lake). The western half of the project would be constructed primarily within a new right-of-way between Endako and Kitimat. The divergence, in the western section, from the existing PNG right-of-way has been proposed to avoid difficult terrain through the Telkwa Pass, as well as environmentally sensitive areas in the Zymoetz (Copper) River valley. The project may also include one or more new compressor stations along the pipeline. Recently, the company announced that they would use Kitimat LNG Inc.'s liquified natural gas terminal near Kitimat as a component of an export operation.

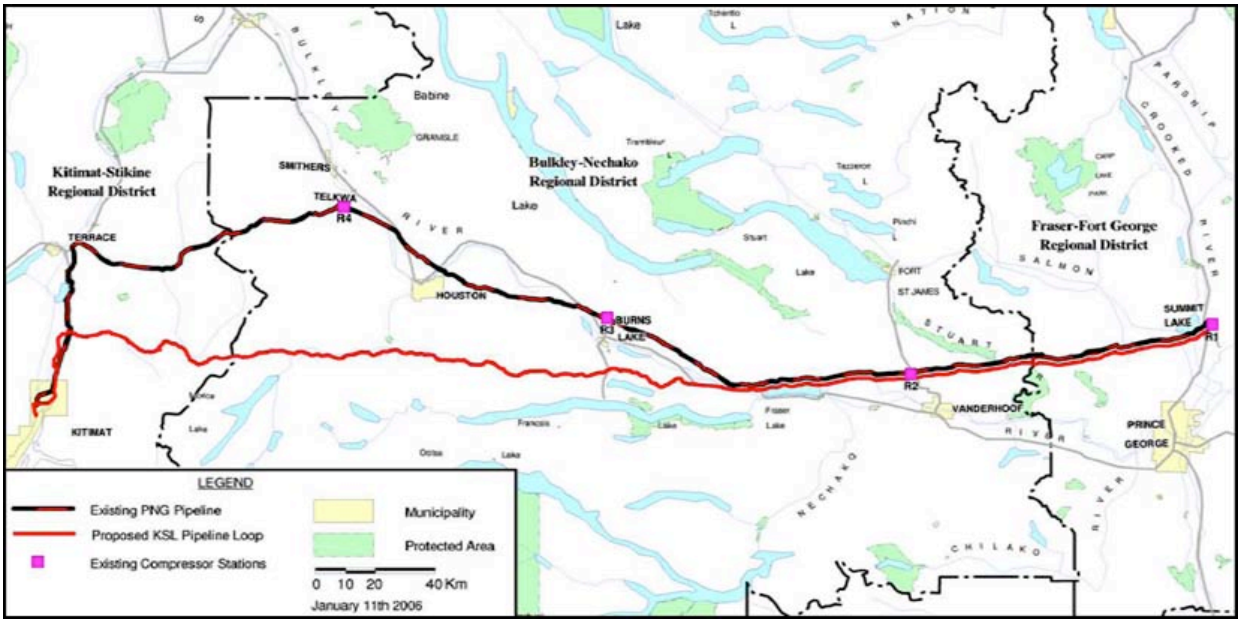

Figure 15. Kitimat to Summit Lake Pipeline Looping Project (KSL Project) under development by Pacific Trail Pipelines.

Source: Pacific Trail Pipelines, *Project Description*

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

APR 2 2 2013

ASSISTANT ADMINISTRATOR
FOR ENFORCEMENT AND
COMPLIANCE ASSURANCE

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U.S. Department of State
Washington, DC 20520

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Dear Mr. Fernandez and Dr. Jones:

In accordance with our authorities under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act, EPA has reviewed the Department of State's draft Supplemental Environmental Impact Statement (DSEIS) for a Presidential Permit application by TransCanada Keystone Pipeline, LP (TransCanada) to construct and operate the Keystone XL Project (Project). This DSEIS builds on the Department of State's August 2011 Final EIS, and includes information regarding a new proposed route in Nebraska.

NEPA serves an important role in the decision making process for federal actions that may have environmental effects. Through the NEPA process, federal agencies disclose and analyze the potential impacts of a proposed action and reasonable alternatives, as well as measures that could mitigate any potential harmful effects. NEPA brings transparency to the federal decision making process, requiring that other federal, state, tribal and local agencies, as well as citizens, are given a meaningful opportunity to provide comments, helping to ensure federal decisions are better informed.

EPA believes this DSEIS strengthens the analysis presented to date in the NEPA process. While we appreciate this effort, we also have several recommendations for improving the analysis and considering additional mitigation as you move forward to complete the NEPA process.

Greenhouse Gas Emissions

We commend the Department of State's efforts to estimate the lifecycle greenhouse gas (GHG) emissions associated with oil sands development and the proposed Project, to analyze the effect of the Project on Canadian oil sands production and to consider measures to reduce GHG emissions. As recognized by the DSEIS, oil sands crude is significantly more GHG intensive than other crudes, and therefore has potentially large climate impacts. The DSEIS reports that lifecycle GHG emissions from oil sands crude could be 81% greater than emissions from the average crude refined in the U.S. in 2005 on a well-to-tank basis, and 17% greater on a well-to-wheels basis.[1] This difference may be even greater depending on the assumptions made.[2] The incremental emissions from oil sands crude transported by the Project would therefore be 18.7 million metric tons CO_2-e (carbon dioxide equivalent) per year when compared to an equal amount of U.S. average crudes, based on the Project's full capacity of 830,000 barrels of oil sands crude per day.[3] To place this difference in context, we recommend using monetized estimates of the social cost of the GHG emissions from a barrel of oil sands crude compared to average U.S. crude. If GHG intensity of oil sands crude is not reduced, over a 50 year period the additional CO_2-e from oil sands crude transported by the pipeline could be as much as 935 million metric tons. It is this difference in GHG intensity - between oil sands and other crudes - that is a major focus of the public debate about the climate impacts of oil sands crude.

Although the DSEIS describes the GHG intensity of oil sands crude, the DSEIS nevertheless concludes that regardless of whether the Project permit is approved, projected oil sands production will remain substantially unchanged. This conclusion is based on an analysis of crude oil markets and projections of oil sands crude development, including the potential for other means of transport to bring oil sands crude to market. One of the alternative transport possibilities discussed in the DSEIS is the potential construction of other pipelines. As part of this discussion, the DSEIS appropriately recognizes that there is uncertainty about when, if ever, additional pipelines will be built. In light of these uncertainties, the DSEIS examines options for transporting oil sands crude by rail, and concludes that scaling up transport by rail is logistically and economically feasible, and that market forces will result in additional rail transport of oil sands crude if the Project is not built. It is this finding that supports the DSEIS' overall conclusion that approval of the permit will not by itself substantially affect GHG emissions or contribute to climate change.

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[1] DSEIS, Table 4.15-22 "GHG Emissions for Producing Gasoline from Different Crude Sources from NETL 2009 and Estimates of the Impact of Key Assumptions on the Oil Sands - U.S. Average Differential." In addition to lifecycle emissions estimates from the Department of Energy's National Energy Technology Laboratory (NETL) study, the DSEIS also provides estimates from other analyses. See discussion in DSEIS section 4.15.

[2] DSEIS, p. 4.15-106, "Adjusting the NETL results to include other product emissions could increase the differential in incremental emissions from WCSB oil sands compared to the 2005 U.S. average crude oils by roughly 30 percent."

[3] DSEIS p. 4.15-105

The market analysis and the conclusion that oil sands crude will find a way to market with or without the Project is the central finding that supports the DSEIS's conclusions regarding the Project's potential GHG emissions impacts. Because the market analysis is so central to this key conclusion, we think it is important that it be as complete and accurate as possible. We note that the discussion in the DSEIS regarding energy markets, while informative, is not based on an updated energy-economic modeling effort. The DSEIS includes a discussion of rail logistics and the potential growth of rail as a transport option, however we recommend that the Final EIS provide a more careful review of the market analysis and rail transport options. This analysis should include further investigation of rail capacity and costs, recognizing the potential for much higher per barrel rail shipment costs than presented in the DSEIS. This analysis should consider how the level and pace of oil sands crude production might be affected by higher transportation costs and the potential for congestion impacts to slow rail transport of crude.

In its discussion of practicable options for mitigating GHG emissions, the DSEIS outlines ongoing efforts by the government of Alberta to reduce the GHG emissions associated with development of oil sands crude in Alberta. EPA recommends that the Final EIS complement this discussion with an exploration of specific ways that the U.S. might work with Canada to promote further efforts to reduce GHG emissions associated with the production of oil sands crude, including a joint focus on carbon capture and storage projects and research, as well as ways to improve energy efficiency associated with extraction technologies. With regard to the estimated GHG emissions from construction and operation of the proposed Project - primarily emissions associated with electrical generation for the pumping stations - we recommend that the Department of State explore specific commitments that TransCanada might make to implement the mitigation measures recommended in the DSEIS. This would complement the significant efforts already made to reduce the risk of spills and ensure community safety. Specifically, we recommend a focus on pumping station energy efficiency and use of renewable energy, as well as investment in other carbon mitigation options.

Pipeline Safety

We have learned from the 2010 Enbridge spill of oil sands crude in Michigan that spills of diluted bitumen (dilbit)[4] may require different response actions or equipment from response actions for conventional oil spills. These spills can also have different impacts than spills of conventional oil. We recommend that these differences be more fully addressed in the Final EIS, especially as they relate to the fate and transport of the oil and the remediation that will be required. The Enbridge spill involved a 30-inch diameter pipeline, smaller than the 36-inch diameter pipeline for proposed Project, and 20,000 barrels of oil sands crude were released. In that spill, oil sands crude sank to the bottom of the Kalamazoo River, mixing with the river bottom's sediment and organic matter, making the oil difficult to find and recover. After almost three years of recovery

[4] As noted in the DSEIS, transporting oil sands crude via pipeline requires that it be mixed with a petroleum-based product (called a diluent), such as benzene, naphtha or natural gas condensate, to make a less viscous liquid called dilbit (diluted bitumen).

efforts, EPA recently determined that dredging of bottom sediments will be required to protect public health and welfare and the environment. This determination was based in large part on demonstrations that the oil sands crude associated with the Enbridge spill will not appreciably biodegrade.[5] We recommend that the Final EIS more clearly acknowledge that in the event of a spill to water, it is possible that large portions of dilbit will sink and that submerged oil significantly changes spill response and impacts. We also recommend that the Final EIS include means to address the additional risks of releases that may be greater for spills of dilbit than other crudes. For example, in the Enbridge spill, the local health department issued voluntary evacuation notices based on the level of benzene measured in the air. Given these concerns, it is important to ensure that the future response and remediation plans will protect communities from impacts due to spills.

The DSEIS also outlines specific measures that the Department of State would require TransCanada to undertake to prevent and detect oil discharges. The measures include commissioning an independent engineering analysis to review TransCanada's risk assessment of the potential impacts from oil discharges to surface and groundwater resources, as well as TransCanada's current proposals for placing mainline valves along the pipeline route and installing leak detection equipment. The DSEIS also notes that the Department of State will obtain concurrence from both EPA and PHMSA on both the scope of the engineering analysis and decisions regarding the need for any additional mitigation measures. We recommend that the Department of State provide an opportunity for public review and comment on the scope of the analysis, and an opportunity for public comment on a draft of the analysis when it is completed. We also recommend that the Final EIS consider requiring TransCanada to establish a network of sentinel or monitoring wells along the length of the pipeline, especially in sensitive or ecologically important areas, as well as where water supply wells are located and at stream crossings to provide a practical means for early detection of leaks that are below the proposed detection limit (1.5 – 2%) of the pipeline flow rate.

In addition to prevention measures, we agree with the DSEIS's suggestion that additional mitigation measures regarding preparedness to reduce the impacts of a spill may be appropriate (DSEIS, p. 4.13-79). For example, we recommend including the following measures as permit conditions:

- Requiring that the emergency response plan, as well as contingency plans address submerged oil, as well as floating oil, including in a cold weather response;

- Requiring pre-positioned response assets, including equipment that can address submerged oil;

- Requiring spill drills and exercises that include strategies and equipment deployment to address floating and submerged oil; and

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[5] Order for Removal under Section 311(c) of the Clean Water Act, March 14, 2013 (http://www.epa.gov/enbridgespill/ar/enbridge-AR-1720.pdf)

- Requiring that emergency response and oil spill response plans be reviewed by EPA.

The DSEIS also recognizes that dissolved components of the dilbit that may be transported through the pipeline, such as benzene, polycyclic aromatic hydrocarbons (PAHs), and heavy metals, could be slowly released back to the water column for many years after a release and could cause long-term chronic toxicological impacts to organisms in both the benthic and pelagic portions of the aquatic environment. We recommend that the Final EIS more clearly recognize that this characteristic of dilbit is different from the fate and transport of oil contaminants associated with conventional crude oil and refined product spills from pipelines. For that reason we recommend that as a permit condition TransCanada be required to develop a plan for long term sampling/monitoring in the event of an oil discharge to assess and monitor these impacts as part of the spill response plan. In addition, we recommend that the permit require TransCanada to provide detailed Material Safety Data Sheets and information about the diluent and the source crude oil to support response preparations and address safety concerns in advance of any spills.

Alternative Pipeline Routes

CEQ regulations implementing NEPA require the consideration of project alternatives in an EIS, and characterize the alternatives analysis as the "heart" of an EIS.[6] The DSEIS has been significantly improved by considering more alternative routes, including an alternative that would avoid crossing the Sand Hills Region in Nebraska, reducing impacts to this fragile ecosystem. Another significant issue in the consideration of alternative routes for this Project has been the potential for impacts to the Ogallala Aquifer in the event of a spill. The alternative route in Nebraska has avoided most of the impacts to the Sand Hills Region, but still crosses the Ogallala Aquifer. The alternative laid out in the DSEIS that would avoid the Ogallala Aquifer is the I-90 Corridor Alternative, which largely follows the path of existing pipelines. The I-90 Corridor Alternative would significantly reduce the length of pipeline crossing the Northern High Plains Aquifer system, which includes the Ogallala formation, and would further reduce the potential for adverse impacts to critical groundwater resources.

We are concerned, however, that the DSEIS does not provide a detailed analysis of the Keystone Corridor Alternative routes, which would parallel the existing Keystone Pipeline and likely further reduce potential environmental impacts to groundwater resources. By determining that these routes are not reasonable, the DSEIS does not provide an analysis of their potential impacts sufficient to enable a meaningful comparison to the proposed route and other alternatives. The Keystone Corridor Alternatives were determined not to be reasonable alternatives primarily on the basis that these routes are longer than the proposed Project's route, and that additional pipeline miles would be needed to connect to Bakken MarketLink project, which would allow the proposed Project to also transport crude from North Dakota and Montana. As we have indicated in the past, we believe these alternative routes could further reduce risks to

[6] 40 C.F.R. 1502.14

groundwater resources. We recommend that the Final EIS either provide more detailed information as to why these alternatives were not considered reasonable or analyze these alternatives in more detail.

Community and Environmental Justice Impacts

The DSEIS provides a comprehensive analysis of community demographics, including minority, low-income, and tribal populations, along TransCanada's proposed pipeline route. We are especially appreciative of the effort to identify and contact each of the Local Emergency Planning Committees regarding the status of their emergency response plans, and to provide that information in the DSEIS. We also commend your recognition that environmental justice communities may be more vulnerable to health impacts from a spill, and appreciate your efforts to consider communities' access to health care, including consideration of "Health Professional Shortage Areas and Medically Underserved Areas" located along the proposed pipeline route.

EPA appreciates TransCanada's commitment to conduct cleanup and restoration and to provide alternative water supplies to affected communities in the event of an oil discharge affecting not only surface waters, but also groundwater. We recommend that these commitments be clearly documented as proposed permit conditions. We believe this would give important assurances to potentially affected communities of TransCanada's responsibilities in the event of an oil discharge that affects either surface or groundwater resources.

Conclusion

Based on our review, we have rated the DSEIS as EO-2 ("Environmental Objections – Insufficient Information") (see enclosed "Summary of Rating Definitions and Follow-up Actions").

We look forward to continuing to work with you and to provide assistance as you prepare the Final EIS. We also look forward to working with you as you determine whether approving the proposed project serves the national interest under Executive Order 13337 "Issuance of Permits With Respect to Certain Energy-Related Facilities and Land Transportation Crossings on the International Boundaries of the United States".

Please feel free to contact me or have your staff contact Susan Bromm, Director, Office of Federal Activities, at (202) 564-5400 if you have any questions or would like to discuss our comments.

Sincerely,

Cynthia Giles

Cynthia Giles

Enclosure

Summary of Rating Definitions and Follow-up Action

Environmental Impact of the Action

LO--Lack of Objections
The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC–Environmental Concerns
The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

EO--Environmental Objections
The EPA review has identified significant environmental impacts that must be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU--Environmentally Unsatisfactory
The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. EPA intends to work with the lead agency to reduce these impacts. If the potentially unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the CEQ.

Adequacy of the Impact Statement

Category 1--Adequate
EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2--Insufficient Information
The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3–Inadequate
EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

Volume Estimate for Submerged Line 6B Oil in the Kalamazoo River

Subject: Enbridge Energy, Limited Partnership (Enbridge) Line 6B, Mile Post (MP) 608, Marshall, MI, Pipeline Release

Date: May 1, 2013

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EXECUTIVE SUMMARY

To better understand the effects of the Enbridge Line 6B oil discharge and guide long-term response and remediation activities, the U.S. Environmental Protection Agency (U.S. EPA) requested that its Scientific Support Coordination Group (SSCG) assist in planning a study to quantify the amount of submerged Line 6B oil remaining in the Kalamazoo River. The SSCG is a project-specific assembly of internationally known experts in oil spill science and technology. In response to U.S. EPA's request, the SSCG provided state-of-the-art recommendations covering the following two specific areas for quantification of the Line 6B oil:

1. **Oil fingerprinting analytical methods:** The SSCG identified the latest developments in analytical methods that would enable the identification of Line 6B oil in sediments.
2. **Sediment sample collection:** The SSCG identified improved sampling schemes that would allow an efficient selection of sampling locations and also potentially minimize uncertainty in the overall estimate of the submerged Line 6B oil volume.

Under the direction and oversight of the U.S. EPA, Enbridge implemented these recommendations in conducting its ongoing Submerged Oil Quantification Study. In July and August 2012, Enbridge collected sediment cores from 102 locations along the stretch of the Kalamazoo River affected by the Line 6B oil discharge. Enbridge's laboratory analyzed approximately 400 sediment samples extracted from these cores using U.S. EPA's recommended oil fingerprinting methods. Dr. Gregory Douglas, an expert forensic oil chemist retained by U.S. EPA, interpreted the analytical results and determined concentrations of Line 6B oil in sediment.

Line 6B oil was positively detected in approximately 75 percent of the approximately 400 sediment samples analyzed. The total submerged Line 6B oil volume remaining in the Kalamazoo River as of July and August 2012 was estimated at 180,000 gallons[1]. Overall results for the three impoundment areas (Ceresco Impoundment, Mill Ponds Impoundment, and Morrow Lake Delta) indicate that approximately 12,000 gallons of submerged Line 6B oil was present in the areas with heavy to moderate (H/M) oil

[1] The statistical approach used to estimate submerged Line 6B oil volume also allows for calculation of the uncertainty in the volume estimate. Uncertainty could be reduced through the collection and analysis of additional sediment cores in certain areas of the Line 6B discharge.

sheening based upon poling[2] observations, with approximately 22,000 gallons present in the Light/None (L/N) areas. The three impoundments contain approximately 80 percent of the Line 6B oil in H/M areas across the entire discharge site.[3]

In summary, the calculated estimate of submerged Line 6B oil quantified in sediment supports other assessment and monitoring results. These multiple lines of evidence indicate that submerged Line 6B oil is present and has migrated into depositional areas along the entire 38-mile-long reach of the Kalamazoo River affected by the July 2010 Line 6B oil discharge.

1.0 INTRODUCTION

This technical memorandum documents the approach developed and methods used to estimate the volume of submerged Line 6B oil remaining in Kalamazoo River sediment as of July and August 2012. For the purposes of this technical memorandum, the Line 6B oil discharge site is defined as the 38-mile-long stretch of the Kalamazoo River with the upstream end at the confluence with Talmadge Creek at Mile Post MP 2.0 and the downstream end at Morrow Dam (MP 39.75).

1.1 Project Background

Enbridge was required to quantify submerged oil remaining in sediment in the Kalamazoo River at the Line 6B oil discharge site as part of the U.S. EPA-approved "Consolidated Work Plan from Fall 2011 to Fall 2012" (2012 CWP). Previous efforts to estimate the remaining quantity of Line 6B oil were hampered by the lack of analytical procedures capable of specifically identifying Line 6B oil. In addition, previous efforts to quantify Line 6B oil did not provide an estimate of the uncertainty associated with the quantification estimate.

To address these concerns, the Federal On-Scene Coordinator (FOSC) requested the SSCG to make recommendations regarding the analytical sampling program, statistical approach to sediment sample location, and sample processing. The SSCG-recommended approach (**Appendix 1**) included the following:

- Sediment core collection procedure
- Laboratory analytical procedure for oil fingerprinting analysis of sediment core samples

[2] Poling is a field technique used to determine whether oil is observable on the water surface after agitation of submerged sediment using a hand-held pole with a 6-inch disc attached to the submerged end.
[3] The Submerged Oil Quantification Study data can only provide very general oil volume estimates for specific areas of the Line 6B discharge site. The Study was not designed to provide detailed maps of oiled sediments in the discharge site area or any portion thereof (such as impoundments). Site poling data for Line 6B oil would be a more appropriate database for detailed mapping of oiled sediments.

- Generalized Random Tessellation Survey (GRTS) approach for stratified random sampling locations of cores
- Sample processing of core interval samples using Incremental Sampling Methodology (ISM)

Sediment cores were collected in July and August 2012. Shortly after core collection began, U.S. EPA field oversight personnel observed that sediment in the cores exhibited little visual evidence (either under natural or ultraviolet [UV] illumination) of oil sheens, oil droplets, or oil-stained sediments. This observation was problematic because the core processing and core sample interval selection plan was based on visual evidence of oil. Core processing and subsampling activities were halted until a Pilot Test could be conducted to determine if oil was (1) present but undetectable using current visual observation techniques or (2) not present. Core collection continued through August 2012, but the cores were immediately frozen and held in Marshall, MI, to await processing following the findings from the Pilot Test. On November 15, 2012, U.S. EPA reported that the Pilot Test findings demonstrated that visual identification of Line 6B oil in Kalamazoo River sediment cores was not reliable as a method for selecting sampling intervals for laboratory analysis.

On November 20, 2012, U.S. EPA issued a directive to Enbridge to complete the Submerged Oil Quantification Study (Directive). The Directive provided explicit direction regarding the resumption of subsampling and laboratory analysis of the July and August 2012 sediment cores that had been on hold since the start of the Pilot Test, including the following activities:

- Sediment core logging
- Sediment core subsampling
- Sediment sample laboratory oil fingerprinting analysis

The Directive also stipulated that U.S. EPA would provide Enbridge with a methodology for calculating Line 6B oil concentrations in sediment samples based on the oil fingerprinting analysis performed. This methodology subsequently was provided to Enbridge in a letter dated March 1, 2013 (**Appendix 2**).

1.2 2012 CWP Task Summary

As part of the Submerged Oil Characterization task identified in the 2012 CWP, submerged oil quantification was required using information obtained from sediment cores collected after 2011 submerged oil recovery activities were complete. The purpose of the quantification was to assess the volume of oil remaining in sediment in the Kalamazoo River at the Line 6B oil discharge site. Prior submerged oil quantification efforts relied on the measurement of total petroleum hydrocarbons (TPH) as the analytical method to estimate Line 6B oil concentrations in sediment samples. It became apparent that TPH measurements were unsuitable for this task because of (1) the substantial and varying levels of

interfering organic substances present in Kalamazoo River sediment before the discharge and (2) the inadequate range of hydrocarbons captured by standard TPH analytical methods. An alternative analytical approach was necessary but had not yet been identified.

The 2012 CWP identifies the following basic quantification model to estimate the amount of submerged Line 6B oil:

$$V_{oil_j} = C_{TPH_j}\, \rho_s\, A_j\, D_j\, K\, \rho_{oil}{}^{-1} \qquad \text{(Equation 1)}$$

where

V_{oil_j}	=	Volume of oil for sampling stratum *j*
C_{TPH_j}	=	Representative concentration of oil (TPH) in sediment from stratum *j*
ρ_s	=	Dry bulk density of sediment
A_j	=	Lateral extent of sampling stratum *j*
D_j	=	Depth of oil-impacted layer
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

This model is essentially unchanged for the current quantification efforts described in more detail in Section 3.6.

2.0 APPROACH AND METHODS USED TO ESTIMATE VOLUME OF SUBMERGED LINE 6B OIL AS OF JULY AND AUGUST 2012

One major advancement in the methodology provided to Enbridge (**Appendix 1**) for the design of the submerged Line 6B oil quantification effort was the consideration of stratification of the Line 6B oil discharge site into areas of similar sediment type and oiling categories as discussed in Sections 2.1 and 2.2 below. This stratification enabled the efficient selection of sediment core locations (Section 2.3) that allowed site knowledge to be used to generate a statistical characterization of the submerged Line 6B oil volume and that provided for consideration of statistical uncertainty in the volume estimate. Consistent with previous efforts to determine the submerged Line 6B oil volume, sediment coring was selected as the method to provide vertical sediment profiles for the oil fingerprinting samples (Section 2.3). Sediment sample results then underwent oil fingerprinting analysis (Sections 2.4 and 2.5).

2.1 Sediment Types - Geomorphic Framework

The first stratification performed was based on sediment depositional behavior as defined by river

geomorphology[4]. Tetra Tech, Inc. (Tetra Tech), an Enbridge contractor, first mapped in-channel geomorphic settings in the Kalamazoo River in 2011 for interpreting and predicting areas of sediment and submerged oil deposition (Tetra Tech 2012). The Tetra Tech approach was similar to that used previously for mapping contaminated sediment deposits in other rivers. Geomorphic surface units (GSU) were delineated using a geographic information system (GIS) to facilitate the synthesis of several data sources. In the summer and fall of 2010, Tetra Tech collected channel longitudinal profile and slope data for the Kalamazoo River (Tetra Tech 2011). Fluvial landforms, anthropogenic[5] features, and channel widths were interpreted from aerial orthophotography[6] produced from overflights during leaf-off conditions in April 2011. Streambed sediment type was visually assessed during the Spring 2011 Reassessment poling activities, and observations were classified into eight categories – gravel and larger, sand and gravel, sand, sand and silt, sand over silt, silt over sand, soft sediment, and organic. Water depths measured during the Spring 2011 Reassessment poling were used to guide final refinement of the GSUs. The resultant system of 28 geomorphology-based categories (**Table 1**) was used to delineate areas of the river channel prone to erosion and deposition. Submerged oil occurrence was most frequently associated with depositional GSUs in slower moving areas of the river with soft sediment.

[4] River, or fluvial, geomorphology is the science dealing with the nature of flowing water, sediments, and other products of watersheds in relation to various land forms.
[5] Anthropogenic features have been caused or influenced by humans.
[6] Orthophotography, or orthophotos, have been geometrically corrected to remove distortions caused by terrain, one-point perspective, and to make the scale uniform.

TABLE 1: GSUs MAPPED BY TETRA TECH IN 2011

Fluvial Setting	Delta and Lake	Anthropogenic Surfaces
Backwater	Delta Bar	Anthropogenic Deposit
Channel Deposit	Delta Island Deposit	Anthropogenic Thalweg
Cut Bank	Distributary Channel	Dam Deposit
Cutoff Channel	Distributary Fan	Engineered Channel
Island	Former Channel	Near bank dam deposit
Island Deposit	Former Floodplain	
Mid-Channel Bar	Former Oxbow	
Near Bank High Energy	Lake Fan	
Near Bank Low Energy	Low Energy Deposit	
Near Bank Moderate Energy	Remnant Terrace	
Oxbow		
Point Bar		
Thalweg		
Tributary		

Tetra Tech mapped approximately 1,200 GSUs along the 38-mile-long stretch of the Line 6B oil discharge site in the Kalamazoo River, from its confluence with Talmadge Creek to the Morrow Lake Dam. The areas of the mapped GSUs ranged from 0.05 to 113 acres, with most areas being less than 0.5 acre.

In 2012, the 28 GSU categories were grouped into nine geomorphic settings for specific application in the submerged oil volume quantification efforts by the USGS and WESTON (U.S. EPA Superfund Technical Assessment & Response Team [START] contractor) (**Table 2**). A smaller number of geomorphic settings was needed for use in a stratified random sampling design for targeting sediment core locations associated with the quantification effort. A simple crosswalk by category was preferred, whereby all mapped GSUs of each category were assigned to a single new setting type, but this approach was not feasible because of the targeted design. (The new delta setting retained spatial collocation with its namesake GSU but was more inclusive geomorphically, being composed from a variety of depositional GSUs that occurred near the original delta GSU.) In the process of the re-grouping, the streambed sediment types were reexamined along with aerial photographs reviewed in a GIS overlay of both data types. This reexamination raised the possibility of some GSUs fitting into more than one geomorphic setting. For example, if a cutoff channel GSU had a gravelly substrate and was connected to the main channel, it was put in the channel deposit setting and not cutoff channel. Regardless of the assigned class in the new grouping, the original line work delineated for mapping the GSUs remained the same and the original GSU category assignments were retained in the GIS attribute table. The nine geomorphic settings used for the submerged oil quantification effort are listed in **Table 2** below. Seven of the settings

had soft sediment designations as their dominant sediment type: Backwater, Channel Deposit, Cutoff/Oxbow, Delta, Depositional Bar, Impoundment, and Morrow Lake.

TABLE 2: CROSS-WALK BETWEEN GSUs AND GEOMORPHIC SETTINGS

Geomorphic Setting	GSUs Included in Setting
Anthropogenic Channel	Anthropogenic Deposit
Backwater	Backwater, Near Bank Low Energy (Anthropogenic Deposit, Oxbow)
Channel Deposit	Channel deposit, Cut Bank, Cut Off Channel, Delta Island Deposit, Distributary Channel, Near Bank High Energy, Thalweg (Anthropogenic Deposit, Anthropogenic Thalweg, Island Deposit, Mid-Channel Bar, Oxbow, Point Bar)
Cutoff/Oxbow	Cutoff Channel, Oxbow
Delta	Delta Bar, Distributary Fan, Island Deposit, Low Energy Deposit (Backwater, Delta Island Deposit, Distributary Channel, Mid-Channel Bar, Near Bank Low Energy, Near Bank Moderate Energy, Remnant Terrace)
Depositional Bar	Island Deposit, Mid-Channel Bar, Point Bar (Anthropogenic Deposit, Channel Deposit, Cut Bank, Near Bank Low Energy, Near Bank Moderate Energy)
Impoundment	Dam Deposit, Near Bank Dam Deposit (Anthropogenic Deposit)
Morrow Lake	Former Channel, Former Floodplain, Former Oxbow, Remnant Terrace (Anthropogenic Deposit, Island Deposit)
Morrow Lake Fan	Delta (Backwater, Former Channel, Lake Fan, Remnant Terrace, Thalweg)

Note: GSUs listed in parentheses were secondarily grouped in additional strata.

Appendix 3 includes maps of the Line 6B oil discharge site illustrating the distribution of geomorphic settings used in the submerged Line 6B oil volume quantification.

2.2 Oiling Categories - Spring 2012 Reassessment Poling Summary

The second stratification performed was based on field-determined patterns of submerged Line 6B oil released from sediment after agitation. A survey of the relative amount of submerged Line 6B oil sheen and/or globules appearing at the water's surface after agitation had been performed during late Spring 2012 at approximately 7,700 locations using a pole with a 6-inch-diameter disk to agitate sediment. After agitation, observations of oil droplets and sheen released to the water surface were described using previously defined oiling categories of Heavy (H), Moderate (M), Light (L), and None (N). The decision tree diagram for classifying poling observations into these four oiling categories is reported in Enbridge (2011). This poling process included documentation of location coordinates using global positioning system (GPS) units so that the poling information could be accurately mapped.

Poling information from the Spring 2012 Reassessment was compiled, and polygons representing H, M, L, and N areas were identified. **Appendix 3** includes maps of the Line 6B oil discharge site illustrating oiling categories based on the Spring 2012 Reassessment poling information.

Two further steps were taken. First, the oiling category polygons were overlain on the geomorphic settings to create sampling stratum polygons for the unique combinations of oiling level and geomorphic setting. Second, to provide a larger sample size for descriptive statistics calculations that were later determined to be necessary for handling non-detect results in the oil-concentration data for each sampling stratum, the four oiling categories later were combined into two categories: H/M and L/N. **Appendix 3** includes maps illustrating the final sampling strata based on the overlays of the two oiling categories for each geomorphic setting.

2.3 Sediment Coring

Locations for sediment core samples collected in July and August 2012 were determined using a GRTS design. Prior to field work, core locations were determined randomly within each geomorphic/oiling category or sampling stratum. A total of 102 investigative cores from locations within the Line 6B oil discharge site were collected for oil fingerprinting analysis. **Appendix 3** includes maps showing the locations of the sediment cores collected for the submerged Line 6B oil quantification effort.

At a subset of 32 of the 102 core locations, a paired side-by-side core was collected for bulk density analyses.

Sediment cores for core logging were split and photographed under both visible and UV illumination. Cores were logged for color, texture, and stratigraphic features. At all stages of core logging, the geologist noted any evidence of oil or petroleum in the split core (including globules, sheen, staining, and odors). The top 1 inch of each core was collected for laboratory analysis. Additional vertical core intervals were collected for laboratory analysis, with a preference given to upper stratigraphic layers of soft sediment and also any layer or portion of a layer that exhibited any indication of oil impact. **Appendix 4** provides additional details regarding core locations, subsampling, and processing.

As indicated in Section 1.1, shortly after the start of sediment core logging, U.S. EPA oversight personnel observed little to no visual evidence of oil in the logged sediment cores, which were collected in areas where poling results indicated the presence of submerged Line 6B oil. After completion of a Pilot Test to evaluate visual observation techniques, U.S. EPA concluded that visual observation was unreliable as a guide to select core intervals for laboratory analysis. U.S. EPA's Directive to complete the submerged Line 6B oil quantification included specific instructions for analyzing samples from all upper depositional layers, regardless of the presence or absence of visual evidence of oil. U.S. EPA also selected additional core intervals from previously logged cores for laboratory analysis. These core intervals had been collected and stored frozen at the laboratory pending the results of the Pilot Test. **Appendix 5** includes

logs for the sediment cores collected for the oil quantification effort. The logs also identify the core intervals collected and submitted for laboratory analysis or for laboratory storage.

2.4 Laboratory Analytical Program

Sediment samples designated for oil fingerprinting analysis were analyzed in accordance with the Analytical Quality Assurance Plan (Enbridge Line 6B MP 608 Marshall, MI, Pipeline Release, Version 2.2, February 28, 2012). Samples were analyzed using the following methods:

- **Polycyclic aromatic hydrocarbons (PAH) and sulfur heterocyclic compounds, including alkyl homologues:** Gas chromatography (GC) with low-resolution mass spectrometry (MS) using selected ion monitoring (SIM)
- **Saturate hydrocarbons:** GC with flame ionization detection (FID)
- **Total extractable hydrocarbons (TEH) representing the total aromatic and aliphatic hydrocarbon content of sample extracts after silica gel clean-up and analysis:** GC/FID
- **Petroleum biomarkers:** GC/MS-SIM

Under contract to Enbridge, Alpha Analytical of Mansfield, MA, performed the laboratory analyses for hydrocarbons and petroleum biomarkers.

2.5 Oil Fingerprinting Data Interpretation

The oil fingerprinting analytical data do not provide a direct measurement of Line 6B oil in sediment. Dr. Gregory Douglas of NewFields, an expert forensic oil chemist, examined the oil fingerprinting data for unique chemical features that would allow Line 6B oil to be distinguished from residual background hydrocarbons in Kalamazoo River sediment (**Appendix 2**). Many potential sources contribute to residual background hydrocarbons in river sediment, including sediment from coal tar sources, runoff containing coal-tar-based road and parking lot sealants and road oils, atmospheric deposition of combustion PAHs, and contributions from non-Line 6B oils. Dr. Douglas determined that the Line 6B oil is enriched in a group of biomarker compounds called triaromatic steroids (TAS). He was able to compare the enriched Line 6B oil to other stable but less discriminating biomarker compounds. Sample-specific biomarker ratios were identified with high stability and resolving power and used to distinguish residual background hydrocarbons from Line 6B oil. This methodology is described in detail in **Appendix 2**.

3.0 QUANTIFICATION VARIABLES

At the foundation of the Line 6B oil volume quantification method are (1) a set of five factors identified as affecting the volumetric quantity of submerged Line 6B oil in a volume of bottom material or bed sediment (Sections 3.1 through 3.5) and (2) the mathematical relationship between these factors and the

resulting oil volume (Section 3.6). These factors and the mathematical relationship remain conceptually very similar to those reported in Enbridge (2012).

3.1 Line 6B Oil Concentrations in Sediment

An important distinction in the 2012 quantification of oil volume relative to earlier attempts is the availability of a state-of-the-science data set for oil concentrations in sediment samples that distinguishes the Line 6B oil from other types (undifferentiated) of hydrocarbon residues collocated in the sampled bed sediment. Discussion of the various other hydrocarbon compounds and their distinguishing features in the geochemical suite of analytical results or gas chromatographs is beyond the scope of this technical memorandum. "Other residual background hydrocarbons" are defined to include pyrogenic[7] hydrocarbons, plant-derived organics, naturally occurring hydrocarbons from geologic sources in the watershed, and residues from other discharges of hydrocarbon products (whether recent or historical).

The input variable, concentration of Line 6B oil in sediment, refers to the forensic-chemistry determined concentration of Line 6B oil only, as distinguished from other residual background hydrocarbons present in the sediment and expressed as mass of oil per mass of sediment (milligrams [mg] of Line 6B oil per kilogram [kg] of dry sediment). **Appendix 2** provides more details of the forensic and analytical chemistry methods.

Pre-processing of the Line 6B oil concentration data involved two steps. First, the mean value among replicate analyses (usually field duplicates) was computed and retained for further analysis, while replicate records were removed to retain only one concentration per sampled interval of a core. Where the set of duplicates included one censored value (nondetect) and one quantifiable detection, the value of the quantifiable detection was selected; this approach is justified as erring on the side of including all detections. Where all of the replicates were censored values, the value selected was the average of their Line 6B limits of detectability and coded as a nondetection. Second, all censored values were temporarily marked by arbitrarily adding 0.01 to the concentration at the Line 6B limit of detectability. (Uncertainty estimation and subsequent processing of the censored values are discussed in subsequent sections of this technical memorandum.)

Appendix 6 provides the Line 6B oil concentrations for sediment samples collected during this study.

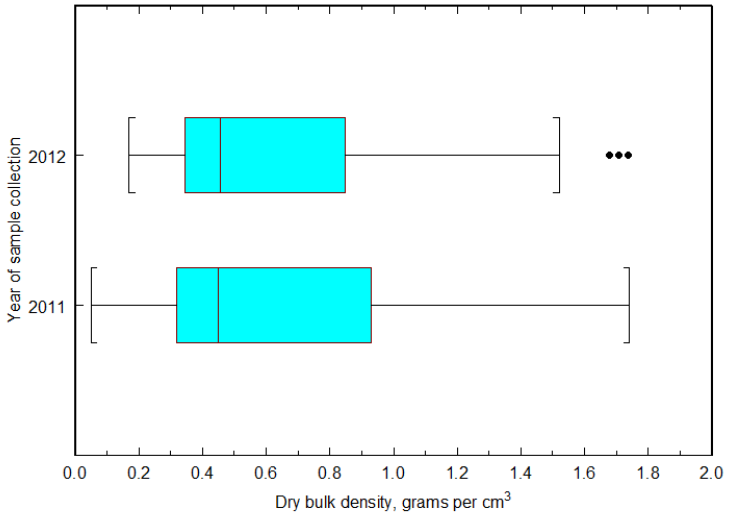
3.2 Sediment Dry Bulk Density

[7] Generated by heat or combustion

An estimate of the bulk density of the discharged oil at the time of sediment coring is required to convert the estimated quantity of Line 6B oil from mass units to volumetric units. The unit of measure for the input variable, dry bulk density of sediment, is mass per unit volume. The mass unit was converted, if necessary, to correspond to the unit of the denominator in oil concentrations discussed in Section 3.1 resulting from forensic-chemistry analysis of Line 6B oil in sediment sample results, expressed in unit mass of oil per unit mass of dry sediment. Sampled volume can be readily determined from a core interval's physical dimensions. Similarly, if the depth of investigation is known and the areal extent of a sampling stratum is known or calculated, then the sediment volume to which a stratum-mean concentration might be applied also is a straightforward calculation.

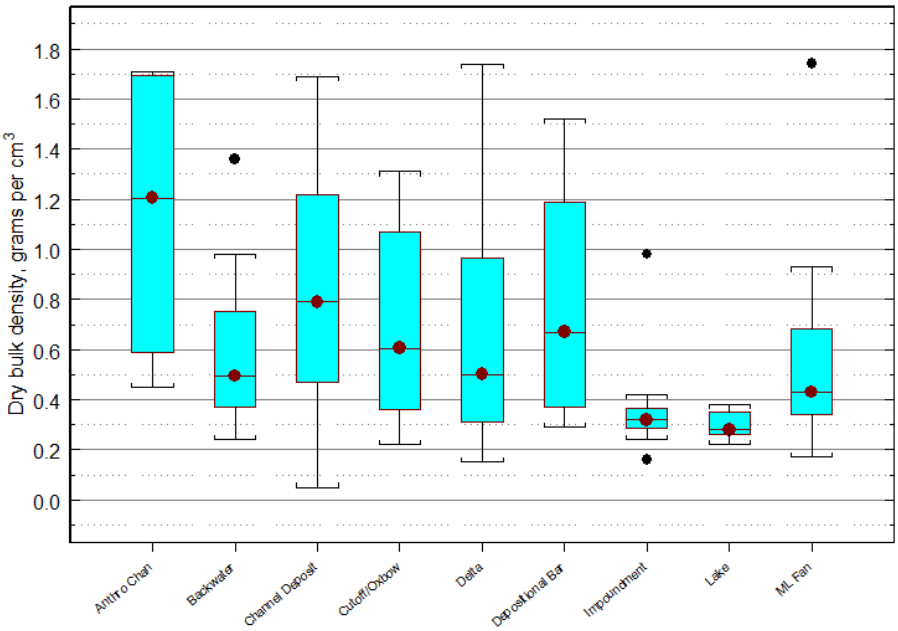
The sources of data for dry bulk density estimation were geotechnical laboratory results for cores collected by Enbridge specifically for this purpose in 2011 and 2012. In 2011, there were 110 coring locations, and a paired core was collected at each boring location for bulk density determined by the core method (Colo. State Univ. Soil, Water and Plant Testing Lab., Fort Collins, CO; Grossman and Reinsch, 2002) and for particle-size analyses. In 2012, the paired cores analyzed for bulk density (Driesenga and Assoc., Holland, MI; ASTM D7263) and particle-size determinations were collected at only 32 coring sites. The result for one core from 2011 was considered spurious and was excluded from the data set. Different laboratories analyzed the samples from each year's streambed sediment sampling, so the results were compared between years to verify there was no significant difference between laboratories or between years (**Figure 1**).

FIGURE 1: BOX PLOT DIAGRAMS OF SAMPLING DISTRIBUTION OF DRY BULK DENSITY FOR SHALLOW CORES COLLECTED IN 2011(N = 109) AND 2012 (N = 32)



Enbridge's previous oil-quantification calculators had applied a single average dry bulk density of sediment for the entire discharge site, but as expected, there are substantial differences among the geomorphic settings (**Figure 2**).

FIGURE 2: BOX PLOT DIAGRAMS OF FREQUENCY DISTRIBUTIONS WITHIN EACH GEOMORPHIC SETTING (USED FOR 2012 OIL VOLUME QUANTIFICATION STUDY)



Note: Total number of values is 141; see **Table 3** for distribution

TABLE 3: SUMMARY OF DRY BULK DENSITY OF SEDIMENT FOR NINE GEOMORPHIC SETTINGS

Geomorphic setting	No. of Values (Cores)	Bulk Density, Dry, Mean (MVUE) (g/cm^3)	Bulk Density, Dry, Std. Dev. (MVUE) (g/cm^3)	Bulk Density, Dry, (*predictMVUE* fit) (g/cm^3)
Anthropogenic Channel	4	1.153	0.734	1.105
Backwater	14	0.583	0.289	0.603
Channel Deposit	33	0.937	0.795	0.895
Cutoff/Oxbow	10	0.710	0.465	0.680
Delta	20	0.667	0.499	0.615
Depositional Bar	11	0.767	0.465	0.755
Impoundment	16	0.350	0.131	0.379
Morrow Lake	13	0.296	0.052	0.336
Morrow Lake Fan	20	0.537	0.308	0.538

Notes:
g/cm^3 Gram per cubic centimeter
MVUE Minimum-variance unbiased estimation
Std. Dev. Standard Deviation

Thus, for the 2012 oil-volume quantification, data analysts calculated a representative bulk density for each geomorphic setting. There were no censored values, and the overall sampling distribution was a log-normal frequency distribution, so subsets for each geomorphic setting were analyzed as log-transformed values and descriptive statistics were retransformed using a minimum-variance unbiased estimation (MVUE) algorithm (Quantitative Decisions 2001). Results from the *ln_mvue.xls* calculator were compared with those obtained using an S-Plus function (*predictMVUE*; TIBCO 2008) that fits an analysis of variance (ANOVA) model with variance pooled across all geomorphic strata (**Table 3**).

Although the group mean values obtained by the two methods (ln_mvue.xls and predictMVUE) could be averaged to produce a possibly more robust estimate, the two methods use different procedures to estimate the uncertainty interval for the group mean. These uncertainties cannot be averaged as comparable (one is a parametric estimate [ln_mvue.xls] and the other is a non-parametric estimate). Therefore, the decision was made to stay with one method for both group mean and uncertainty, and the parametric estimates were used to maintain consistency between means and uncertainty estimates. Differences in particle size, organic matter and moisture content generally account for differences in bulk density among sampling strata. No field duplicates were analyzed for bulk density for either the 2011 or 2012 oil-volume quantification investigations.

3.3 Line 6B Oil Density

An estimate of the bulk density of the discharged oil at the time of sediment coring (the weathered oil density) is required to convert the estimated quantity of Line 6B oil from mass units to volumetric units.

Based on laboratory tests (American Society for Testing and Materials [ASTM] D4052–91, Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter) of Cold Lake blend at 1 °C and 15 °C after 17 percent of initial volume had evaporated (SL Ross Environmental Research 2010; Table 3-3), the average of bulk densities was 0.985 g/cm^3. Enbridge previously reported that about 77 percent of the crude oil released from Line 6B in July 2010 was Cold Lake blend. Diluted bitumen crude oils typically contain more than 17% diluent[8], however, so these laboratory results do not reflect the weathered state of the discharged Line 6B oil.

Oil density varies based on temperature, and the range in density related to a temperature range from 1 °C to 15 °C is 0.008 g/cm^3 for Cold Lake blend (SL Ross Environmental Research 2010).

For the 2012 oil-volume quantification effort, U.S. EPA used 0.985 ± 0.004 g/cm^3 as estimates of the mean and uncertainty of bulk density of Line 6B oil at the time of core collection in Summer 2012. This value is 5.7% larger than the mean oil density value for fresh products discharged from Line 6B (Cold Lake blend [0.9283 g/cm^3] and Western Canadian Select crude [0.9290 g/cm^3]) that was used in previous submerged Line 6B oil volume quantification studies (Enbridge Energy, 2011, 2012).

3.4 Lateral Extent of Sampling Stratum

Oil concentration (mass per mass unit) must be applied to a corresponding sediment mass and volume to produce an oil-volume estimate. The sediment volume is defined by a vertical and lateral extent for each sampling stratum in the stratified study design. The lateral extent of a sampling stratum is a function of the geometric intersection of a geomorphic setting and a submerged-oil category. For the 2011 oil-volume quantification effort, the lateral extent was limited to areas with oil observable on the water surface after agitation of sediment using a hand-held pole (poling); other areas were presumed to contain no (zero) Line 6B oil. In the absence of laboratory analytical data to validate poling results, the Summer 2012 study design included all areas of the Kalamazoo River between its confluence with Talmadge Creek and the Morrow Lake dam (the Line 6B oil discharge site) except the concrete-lined channel reach within Battle Creek, MI.

A stratified-random sampling design produced target coring locations distributed among 34 sampling strata, each of which represented the geometric intersection of a single geomorphic setting (nine types) and a single submerged oiling category (four poling-based classes). Therefore, the lateral extent of a sampling stratum was the summation of the GIS-calculated area of each instance of a unique combination of geomorphic setting and submerged oiling category. The sampling strata generally consisted of

[8] Diluent is a light petroleum (typically natural gas condensate) that is mixed with crude bitumen in order to decrease the viscosity and allow transportation by pipeline.

multiple, discrete, areal units (having more than one polygon feature). Sampling strata formed as combinations with either the "Morrow Lake" or "Morrow Lake Fan" geomorphic setting were confined to a single, contiguous region of the study area, whereas other sampling strata generally were scattered or located at widely separate locales.

The sources of data for lateral extent were geospatial (digital maps) and included digital maps of geomorphic settings and of submerged oiling category map units (polygons). The two sources for the map of geomorphic settings were (1) the bank lines of the Kalamazoo River digitized by Enbridge contractors from high-resolution, low-altitude aerial orthophotography and (2) the map of geomorphic surfaces also compiled and digitized by Enbridge contractors (Section 2.1, e.g. **Appendix 3**). Use of the map of geomorphic surfaces as is would have resulted in too many categories (that is, would have required too many cores and samples), especially after application of the geospatial intersection analysis with the submerged oiling category map. Therefore, the geomorphic surfaces classification was encompassed by a higher-level stratification of the study area that ultimately produced a map of nine geomorphic settings for use in the sampling design (see Section 2.1). Eleven strata initially resulted but were further collapsed to eliminate two strata (tributary mouth and engineered/concrete-lined channel) that were not areally extensive in order to focus all sampling points within the nine strata having greater extent and importance to the task of submerged Line 6B oil quantification. The mapping accuracy of the geomorphic surfaces is unknown.

The map of submerged oiling categories was obtained as range-classed results from an interpolated surface fit to a numerical recoding of the submerged-oil qualitative observations at poling points. The poling observations were recoded under a scheme where "heavy submerged oil" equals 7, "moderate" equals 5, "light" equals 3, and "none" equals 1. After recoding the points as numeric values, the inverse-distance weighting (IDW) interpolation algorithm was applied using a parameter value, $k = 5$, as the exponent applied to distance. The desktop help reference for the IDW spatial analysis function gives guidance on selection of the exponent value as follows: "An optimal value for the power can be considered to be where the minimum mean absolute error is at its lowest" (ESRI 2011). This guidance suggests two analyses that could yet be undertaken (now that results for 102 cores are available) that could be paired with interpolated estimates to measure the *a posteriori* error rates of the IDW interpolations. In addition, if a subset of the poling observations was reserved as validation data, it could be applied to estimate the root mean squared error (RMSE) or other error measures for IDW-interpolated surfaces constructed for varying values of the distance exponent.

In the absence of data on the mapping accuracy of the geomorphic surfaces and the resulting sampling strata, U.S. EPA selected a method to estimate uncertainty of the lateral extent values based on the

uncertainty of their linear boundaries inferred based on the scale, density, and quality of source observations. For submerged Line 6B oil category boundaries, sources of uncertainty considered included (1) surveyed point coordinates and (2) field-survey method points (step-out poling points surveyed). The horizontal uncertainty of points surveyed using real time kinetic (RTK) GPS (typically 1 to 2 cm) was considered negligible relative to the other sources affecting lateral extent estimates. The increment used for the step-out poling method was estimated for two areas with a large number of poling observations spread across the river channel: Ceresco Impoundment and the Morrow Lake Delta. GIS spatial analysis ("Near" function in ArcGIS-10) results yielded an estimated "Range-epsilon band width" (as defined by Dunn et al. 1990), or 2 times epsilon, of 38 feet (ft), where epsilon is assumed to equal one-half of typical spacing between points upon which the actual position of the boundary between "included" in versus "outside" of a given submerged oil class was based. It was assumed that a similar ratio of the Range-epsilon to interquartile range (IQR)-epsilon band widths applied to this application as for the Dunn et al. (1990) study, and an IQR-epsilon band width of 5.9 ft (uncertainty ± 2.95 ft) was used. To apply linear uncertainty to polygon area (two dimensions, x and y), Dunn et al. (1990) multiplied the sum of the perimeters of the polygons composing the particular class by the IQR-epsilon band width.

For geomorphic boundaries located at channel bank lines, it was assumed that at the page scale, aerial photomap resolution supported "national map accuracy standards" (an accuracy of 0.02 inch). Then, assuming that channel bank lines were digitized at a scale of 1:600, the linear offset accuracy was calculated to be ± 1.0 ft RMSE. For a theoretical normal distribution, this value corresponds to an IQR of 1.348 ft (± 0.674 ft). By analogy, Dunn et al. (1990) refer to this error, when extended along a full length of bank line, to be the IQR-epsilon band width. For polygon areas between two bank lines, Dunn et al. (1990) indicate that the areal uncertainty equals the bank-formed perimeter times its epsilon band width. (But this does not include additional uncertainty from perimeter segments not formed by channel banks.)

To apply these IQR-epsilon band widths to submerged-oil map units and sampling stratum boundaries, the GIS-measured lengths of all perimeters bounding the set of polygons forming each sampling stratum (34 strata originally; later collapsed to 17 strata) were used. Each line segment also was coded to indicate if it represented a bank line so that the corresponding epsilon band width could be applied to estimate the total areal uncertainty for each sampling stratum.

Table 4 summarizes the results from the analyses and methods discussed above for determining the lateral extent of sampling strata.

TABLE 4: LATERAL EXTENT OF SAMPLING STRATA USED FOR SUMMER 2012 STUDY

Sampling Stratum	Area of Reporting Stratum (acres)	Area of Sampling Stratum (hectares)	Uncertainty of Area (% of area)	Sum of Perimeters, Channel banks (ft)	Sum of Perimeters, Other (ft)	Uncertainty of Area (hectares)
Anthropogenic Channel – H/M	0.66	0.27	20.7	638.5	1,890.9	0.06
Anthropogenic Channel – L/N	77.31	31.3	1.1	27,224.1	6,541.9	0.35
Backwater - H/M	18.49	7.5	10.2	15,036.8	24,498.5	0.76
Backwater - L/N	77.65	31.4	4.7	67,798.9	38,896.3	1.49
Channel Deposit - H/M	22.59	9.1	18.8	9,990.9	60,556.6	1.72
Channel Deposit - L/N	525.61	212.7	3.3	229,010.9	204,132.4	7.02
Cutoff/Oxbow - H/M	5.62	2.3	9.7	5,376.2	6,835.4	0.22
Cutoff/Oxbow - L/N	19.15	7.8	6.2	20,686.7	12,787.1	0.48
Delta - H/M	34.57	14.0	9.1	9,379.4	44,260.4	1.27
Delta - L/N	43.77	17.7	9.1	16,134.5	55,268.1	1.61
Depositional Bar - H/M	7.95	3.2	16.4	6,461.4	17,751.0	0.53
Depositional Bar - L/N	110.98	44.9	9.1	93,771.5	127,889.4	4.09
Impoundment - H/M	16.36	6.6	7.7	6,059.3	17,191.2	0.51
Impoundment - L/N	43.69	17.7	4.1	11,985.5	23,875.1	0.73
Morrow Lake - L/N	592.67	239.8	0.2	18,600.5	10,449.6	0.40
Morrow Lake Fan - H/M	2.45	0.99	11.5	656.5	4,015.5	0.11
Morrow Lake Fan - L/N	180.20	72.9	0.7	11,537.9	15,109.8	0.49

3.5 Vertical Extent of Investigation

During the 2011 attempt to calculate submerged-oil volume, the depth of investigation was the visually determined depth of oil indications (sheen or globules) observed within the split core examined in the field. For the Summer 2012 study, it was determined that visual indications were not sufficient or reliable for such a determination (K. Lee 2012). Consequently, the vertical extent of investigation was defined for the purposes of the 2012 quantification of submerged Line 6B oil and associated submerged Line 6B oil volume quantification (SOVQ) spreadsheet development to extend to a depth equal to the bottom of the deepest interval where Line 6B oil was detected at a concentration above the Line 6B oil limit of detectability. In tandem with this operational definition, samples from successively greater depths along each collected core were to be analyzed geochemically and forensically until a depth level with an undetectable concentration of Line 6B oil was reached. At the time of preparation of this report, the deepest samples analyzed from numerous cores showed detectable and quantifiable concentrations of Line 6B oil. Across all sampling strata, the mean depth investigated thus far was 1.2 ft; the range among sampling strata mean depths was 0.45 to 1.90 ft.

The uncertainty of the vertical extent of investigation was estimated using the variance among the several cores collected from within the area of each sampling stratum. That is, if the depths of investigation indicated for the individual cores for a sampling stratum were 1.10, 0.90, 1.30, 1.50, and 0.90 ft, then the mean and standard deviation of the vertical extent of investigation for this stratum would be 1.14 ft and 0.261 ft, respectively.

3.6 Equation for Submerged Line 6B Oil Volume Quantification

As discussed in Section 1.2, the mathematical relation for computing submerged oil volume from the input variables described in this section was consistent with the equation developed for the 2011 submerged-oil volume estimates (Enbridge 2012) as follows:

$$V_{oil_j} = C_{TPH_j}\, \rho_s\, A_j\, D_j\, K\, \rho_{oil}{}^{-1} \qquad \text{(Equation 1)}$$

where

V_{oil_j}	=	Volume of oil for sampling stratum *j*
C_{TPH_j}	=	Representative concentration of oil (TPH) in sediment from stratum *j*
ρ_s	=	Dry bulk density of sediment
A_j	=	Lateral extent of sampling stratum *j*
Dj	=	Depth of oil-impacted layer
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

In the 2011 application, Equation 1 was evaluated for the individual vertical increments of uniform thickness (0.1 ft), at least for calculating the representative concentration for each stratum. For the Summer 2012 oil volume quantification study, the following equation was used to estimate the submerged Line 6B oil volume:

$$V_{L6B_j} = \sum_0^{D_j} \left(C_{L6B_{ij}}\, \rho_{s_j}\, A_j\, T_{ij}\, K\, \rho_{oil}{}^{-1} \right) \qquad \text{(Equation 2)}$$

where

V_{L6B_j}	=	Volume of submerged Line 6B oil for the *j*th sampling stratum
$\sum$	=	Summation over the vertical increments, *i*, from *i* = 0 to *i* = D_j; both oil concentration and increment thickness may vary by vertical increment
$C_{L6B_{ij}}$	=	Concentration of oil identified to be from the Line 6B release as distinguished from residual background hydrocarbons for the *jth* sampling stratum

ρ_{s_j}	=	Dry bulk density of sediment for the *jth* sampling stratum
A_j	=	Lateral extent of sampling stratum *j*
T_{ij}	=	Thickness of a single vertical increment, *i*, of the cores, which does vary (at least at the top of the core)
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

There is explicit summation of the right side of the equation across all vertical increments within D_j , the depth of investigation for sampling stratum *j*. An additional change in the equation involves the use of forensic chemistry methods beforehand to provide a concentration, C_{L6B} , that is the oil identified to be from the Line 6B release as distinguished from residual background hydrocarbons. The measurement units were (1) for oil concentration, mg of oil per kg of sediment as dry sediment; (2) for bulk density, g/cm^3; (3) for area, hectares; and (4) for thickness or depth, ft. For these measurement units, and with oil density in grams per cubic centimeter, the value of *K* (constant for unit conversion) is 3.048.

4.0 SUBMERGED OIL VOLUME CALCULATOR SPREADSHEET

An Excel™ spreadsheet tool (the SOVQ spreadsheet) was developed to support attainment of the project objective: a technically sound estimate of the residual volume of spilled, submerged Line 6B crude oil in the Kalamazoo River. The previously existing oil-quantification calculator tool developed for sampling completed in 2011 was not adequate for either the more finely stratified design or the more rigorous analysis of uncertainty in the 2012 study design. Therefore, a new SOVQ spreadsheet calculator was developed specifically for the 2012 study. The scope of SOVQ spreadsheet development was as follows: (1) to retain, to the extent practicable, the concepts embodied in Enbridge's previous oil-quantification spreadsheet (that is, general factors included in the equation for oil volume, the form of the equation, spatially stratified analysis, and use of discrete vertical intervals to standardize treatment of samples across cores within a sampling stratum); (2) to use Line 6B oil concentrations from Dr. Douglas of NewFields that distinguish Line 6B oil from residual background hydrocarbons; (3) to estimate a representative concentration for each sampling stratum by discrete vertical interval; and (4) to estimate a 95-percent confidence interval for the Line 6B oil volume estimates at the sampling-stratum level that takes into account the combined uncertainties for the factors in the equation used for volume estimation.

The SOVQ spreadsheet tool does not calculate the specialized statistics recommended when a data set includes left-censored values (non-detects) among the oil concentrations. Rather, it was presumed that users will apply external statistical analysis software to develop such values, where needed, to refine the required inputs. For the Line 6B volume estimate provided in this technical memorandum, the Kaplan-

Meier Method was used to address non-detects as implemented in U.S. EPA's ProUCL software (version 4.1, U.S. EPA 2013). See **Appendix 7** for a more detailed discussion.

Procedures embodied in the newly developed SOVQ calculator spreadsheet tool include estimation at the sampling-stratum level of a representative value (and uncertainty) for each of the five factors or terms in the oil volume equation discussed in Section 3.0. In the 2011 calculator, the depth of investigation was the visually determined depth of crude oil indications (sheen or globules) within examined split cores, whereas for the Summer 2012 study, the depth of investigation extends to a depth equal to the bottom of the deepest interval where Line 6B oil was detectable. As was the case in the earlier 2011 calculator spreadsheet, the SOVQ spreadsheet uses multiple vertical intervals ("calculation volumes") as a sampled-depth standardization approach because sediment samples from the various cores for a sampling stratum seldom came from an identical series of depth intervals.

Appendix 7 provides an overview of the various sheets composing the SOVQ spreadsheet calculator workbook. Note that the first section of the workbook is composed of overall summaries of the submerged Line 6B oil volume, and the largest section of the workbook comprises the calculation tables for submerged oil volume and for estimated uncertainty of the oil volume quantities. The latter section contains multiple sheets, one per individual sampling stratum, and (or) one per collapsed stratum in case the user desires a larger sample size per stratum.

The stratum-specific calculation spreadsheets implement Equation 2. **Appendix 7** gives details of the oil volume calculation methods. The concept that both oil concentration and thickness of discrete vertical increment may vary with depth (subscript *i* in Equation 2) is embodied in the spreadsheet by an array of concentrations and a corresponding vector of interval thicknesses. The summation over vertical increments, for *i* equal 1 to D_j (depth of investigation for stratum *j*), is represented in the spreadsheet by a vector of weights applied to the calculated oil volumes vector. The weights restrict the summation to the mean depth of investigation among the cores composing the stratum sample of bottom material.

A combined uncertainty estimate for the submerged-oil volume also was calculated for each discrete vertical interval and for the depth of investigation as a lower and upper 95-percent confidence limit for the estimated Line 6B oil volume. The approach to estimate combined uncertainty for each discrete vertical interval used a modification of the simplified general formula for error propagation, which is a linear combination of the relative variance (that is, the square of the coefficient of variation [CV]). The general formula is as follows (Kirchner 2001):

$$\frac{\sigma_x^2}{x^2} = \frac{\sigma_u^2}{u^2} + \frac{\sigma_v^2}{v^2} + \cdots \frac{\sigma_n^2}{n^2} \qquad \text{(Equation 3)}$$

Thus, the relative variance in *x* is the sum of the relative variances in each factor, *u*, *v*, etc. A modification of this general approach is needed when covariance between the errors is not negligible. In the case of the 2012 study, results from 30 pairs of detectable concentrations of Line 6B oil and sediment dry bulk density indicated that a significant correlation exists (Spearman's rho = -0.595, p = 0.0014). In this case, the propagation of uncertainty for *x* will include an additional term, to become as follows:

$$\frac{\sigma_x^2}{x^2} = \frac{\sigma_u^2}{u^2} + \frac{\sigma_v^2}{v^2} + 2\frac{\sigma_u \sigma_v}{u \cdot v}\rho_{uv} + \cdots \frac{\sigma_n^2}{n^2} \qquad \text{(Equation 4)}$$

where

ρ_{uv} = Correlation coefficient for the relation between *u* and *v*

To summarize, the combined uncertainty across the multiple discrete vertical intervals and the relative variance results (from Equation 4) for each vertical interval were combined as a weighted-mean relative variance, where the discrete-interval thicknesses were the weights.

5.0 RESULTS

This section discusses the submerged oil volume estimates and uncertainties (Section 5.1), H/M versus L/M oiling categories (Section 5.2), impoundments (Section 5.3), and uncertainty reduction (Section 5.4).

5.1 Submerged Oil Volume Estimates and Uncertainties

Table 5 summarizes the results for submerged Line 6B oil volume estimates for Summer 2012. The total submerged Line 6B oil volume for the discharge site is estimated to have been 180,000 gallons ± 100,000 gallons when summed over all sampling strata. Major contributors to the total volume come from the following strata:

- Channel Deposit – L/N (81,000 gallons)
- Morrow Lake – L/N (46,000 gallons)
- Depositional Bar – L/N (11,500 gallons)
- Morrow Lake Fan – L/N (11,000 gallons)

These four strata are also the four largest strata (on an areal basis) in the discharge site, accounting for approximately 79 percent of the total area.

Depth-averaged, submerged Line 6B oil concentrations in bottom sediment ranged from 76 mg/kg in the Anthropogenic Channel –(L/N stratum) to 1,140 mg/kg in the Depositional Bar –(H/M stratum).

When standardized for differences in areal extent, the average submerged Line 6B oil volume per acre ranged from 14.7 gallons/acre in the Anthropogenic Channel (L/N stratum) to 218 gallons/acre in the Depositional Bar (H/M stratum).

TABLE 5: LINE 6B OIL VOLUME ESTIMATES

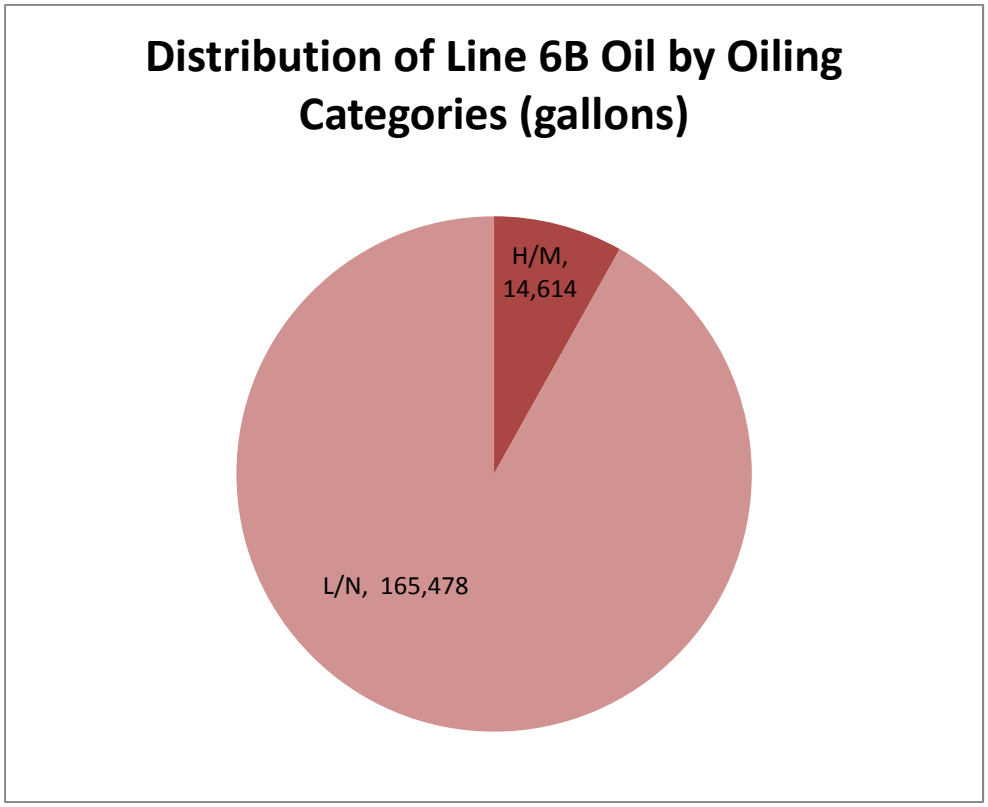
Stratum Name	No. of Cores	Mean Concentration of Line 6B Oil (mg/kg)	Volume of Line 6B Oil (gallons)	Uncertainty of Volume Estimate, Lower-bound (gallons)	Uncertainty of Volume Estimate, Upper-bound (gallons)	Volume of Line 6B Oil (gallons/ acre)	Mean depth of Investigation (ft)	Areal extent (acres)
Anthropogenic Channel – H/M	3	822	110	-51	271	165.6	1.17	0.7
Anthropogenic Channel – L/N	6	76	1,140	-58	2,338	14.7	0.45	77.3
Backwater – H/M	6	249	1,357	175	2,540	73.4	1.12	18.5
Backwater – L/N	6	127	2,400	-1,054	5,853	30.9	1.07	77.7
Channel Deposit - H/M	6	108	1,034	-3,898	5,966	45.8	0.98	22.6
Channel Deposit - L/N	6	279	81,274	-47,193	209,741	154.6	1.30	525.6
Cutoff/Oxbow - H/M	6	200	282	-187	752	50.2	0.77	5.6
Cutoff/Oxbow - L/N	6	173	697	-412	1,805	36.4	0.55	19.2
Delta - H/M	8	428	6,871	-7,319	21,062	198.8	1.36	34.6
Delta - L/N	6	386	6,219	-1,582	14,020	142.1	1.42	43.8
Depositional Bar - H/M	6	1,140	1,735	-1,423	4,893	218.3	0.75	8.0
Depositional Bar - L/N	6	255	11,447	-7,977	30,871	103.1	1.50	111.0
Impoundment - H/M	7	856	3,082	120	6,043	188.4	1.86	16.4
Impoundment - L/N	7	379	4,792	-1,015	10,598	109.7	1.90	43.7
Morrow Lake - L/N	6	957	46,213	9,991	82,436	78.0	1.23	592.7
Morrow Lake Fan - H/M	3	453	142	-24	308	58.1	0.63	2.4
Morrow Lake Fan – L/N	8	710	11,297	-2,120	24,714	62.7	0.89	180.2
Totals	**102**		**180,092**	**77,360**	**282,825**			**1,780**

The vertical extent, or depth of investigation, for which the Line 6B oil volume was calculated may not be finalized as of this writing. The deepest interval analyzed to date from many cores contained a detectable concentration of Line 6B oil, and U.S. EPA potentially could direct that samples from deeper intervals of such cores yet be investigated at the analytical chemistry laboratory. Thus there is potential that additional results for Line 6B oil concentrations in these samples could increase the total estimated volume of Line 6B oil in the Kalamazoo River, but alternatively could decrease the average concentration of oil within a thicker depth of investigation, leading to a decrease in Line 6B oil volume.

5.2 H/M versus L/N Oiling Categories

Figure 3 shows the distribution of Line 6B oil between the two oiling categories (H/M and L/N) summed over all of the geomorphic settings. Approximately 14,600 gallons (8 percent) of Line 6B oil was present in the areas mapped with the H/M oiling category, and approximately 165,500 gallons (92 percent) of Line 6B oil was present in the L/N oiling category areas.

FIGURE 3: SUBMERGED LINE 6B OIL DISTRIBUTION



5.3 Impoundments

The Line 6B oil discharge site contains three impoundments: the Ceresco Impoundment, Mill Ponds Impoundment, and Morrow Lake Delta. Estimating the submerged Line 6B oil volume for one or all three main-stem impoundments was not an objective of the Summer 2012 sampling design, and none of the sampling strata used for this study exactly corresponds to the extent of the impounded reaches. A set of estimates was prepared based on the sampling stratum-level results as applied to the stratified composition of each impoundment reporting area of interest. However, the estimated Line 6B oil volumes and uncertainty limits developed for the sampling strata could differ from corresponding results based on focused sampling designs and core samples collected from within each impoundment specifically to address these questions.

The distribution of Line 6B oil among the three main-stem impoundments at the Line 6B oil discharge site was summed over all of the geomorphic settings located within the areal extent of each feature. **Appendix 3** provides maps showing the location and extent of each impoundment as used for these summaries. Overall results for the impoundments indicate that approximately 12,000 gallons of submerged Line 6B oil was present in the H/M areas of the impoundments and that approximately 22,000 gallons was present in the L/N areas. The 12,000 gallons represents 82 percent of the site-wide total for H/M areas and 35 percent of the impoundments' overall total volume of submerged Line 6B oil (34,000 gallons). Areally standardized oil volumes in the areas mapped as H/M submerged Line 6B oil were fairly consistent among the three impoundment areas, averaging 155 gallons/acre and ranging from 152 gallons/acre in the Morrow Lake Delta to 164 gallons/acre in the Ceresco impoundment.

Ceresco Impoundment

Within the 53-acre Ceresco Impoundment (**Appendix 3**, MP 4.75 to Ceresco Dam), an estimated 1,500 gallons (28 percent) of Line 6B oil occurred in areas mapped as H/M and an estimated 3,900 gallons (72 percent) occurred in areas mapped as L/N areas. The 1,500 gallons corresponds to 10 percent of all the Line 6B oil in H/M areas across the Line 6B oil discharge site. The "Impoundment" geomorphic setting contained about 94 percent of the Line 6B oil collocated with the H/M submerged Line 6B oil map units at the Ceresco Impoundment and about 62 percent of the Line 6B oil collocated with the L/N map units. With a total Line 6B oil volume of an estimated 5,400 gallons summed over all of the geomorphic settings located within its areal extent, the Ceresco Impoundment contained about 3 percent of the site-wide estimated Line 6B oil volume.

Mill Ponds Impoundment

Within the 39-acre Mill Ponds Impoundment (**Appendix 3**, MP 14.6 to Kalamazoo Dam), an estimated 2,100 gallons (35 percent) of Line 6B oil occurred in areas mapped as H/M and an estimated 3,900 gallons (65 percent) occurred in areas mapped as L/N. The 2,100 gallons corresponds to 14 percent of all the Line 6B oil in H/M areas across the Line 6B oil discharge site. The "Impoundment" geomorphic setting contained about 79 percent of the Line 6B oil collocated with the H/M submerged Line 6B oil map units at the Mill Ponds Impoundment and about 42 percent of the Line 6B oil collocated with the L/N map units. With a total Line 6B oil volume of an estimated 6,000 gallons, the Mill Ponds Impoundment contained about 3.3 percent of the site-wide estimated Line 6B oil volume.

Morrow Lake Delta

Within the 150-acre Morrow Lake Delta (**Appendix 3**, 35th Street Bridge to Morrow Lake), an estimated 8,300 gallons (39 percent) of Line 6B oil occurred in areas mapped as H/M and an estimated 13,200 gallons (61 percent) occurred in areas mapped as L/N. The 8,300 gallons corresponds to 57 percent of all the Line 6B oil in H/M areas across the Line 6B oil discharge site. The "Delta" geomorphic setting contained about 83 percent of the Line 6B oil collocated with the H/M submerged Line 6B oil map units at the Morrow Lake Delta and about 47 percent of the oil collocated with the L/N map units. With a total submerged Line 6B oil volume of about 21,500 gallons, the Morrow Lake Delta contained about 12 percent of the site-wide estimated Line 6B oil volume.

5.4 Uncertainty Reduction

It is possible to reduce the uncertainty in the overall estimate of submerged Line 6B oil volume by collecting and analyzing additional sediment cores in selected sampling strata where both the magnitude and uncertainty of the estimate are high at present. The uncertainty interval width is inversely proportional to the square root of the number of samples, so increasing the sample size from 4 to 9 samples, for example, is expected to decrease the concentration-related uncertainty by about 33 percent. If some of those additional samples are paired with additional determinations of bulk density of the sediment, additional reduction of the overall combined uncertainty could be realized. If the decision is made to collect and analyze additional cores, emphasis likely would be given also to specific sampling strata where, based on other, independent lines of evidence (such as February 2012 sampling results, sheen observations, site histories, etc.), Line 6B oil volumes were considered to be overestimated or underestimated.

Another uncertainty issue relates to the apparent presence of Line 6B oil in sediment samples from deeper intervals of cores collected near the downstream end of Morrow Lake. These samples show positive detections of Line 6B oil based on one of the two biomarker ratios used for the calculation of Line 6B oil concentration (ratio of TAS1 and T30). Site information (poling results, absence of spontaneous sheen or globules, absence of oil recovery activities, sampling depth) suggests that samples from this area may be unlikely to contain Line 6B oil. It may be useful to continue the forensic oil investigation of samples from this area to resolve this issue.

6.0 SUMMARY

Previous efforts to estimate the remaining quantity of submerged Line 6B oil were hampered by the lack of specific analytical procedures capable of specifically identifying Line 6B oil. In addition, the previous efforts to quantify submerged Line 6B oil volume did not provide any estimate of the uncertainty associated with the volume estimate. Based on recommendations from the SSCG regarding the analytical sampling program, statistical approach to sediment sampling location, and sample processing, and based on subsequent direction from U.S. EPA, Enbridge developed the 2012 CWP and during Summer 2012 collected 102 sediment cores from the Line 6B oil discharge site to complete the submerged Line 6B oil quantification.

Major advances in the revised approach included in the design of the submerged Line 6B oil quantification effort included (1) application of advanced, higher-resolution analytical chemistry methods and forensic chemical “fingerprinting” to distinguish Line 6B oil from other residual background hydrocarbons, (2) sediment coring locations determined using a model based on probability theory (the GRTS design), and (3) the stratification of the Line 6B oil discharge site into areas sharing similar geomorphic settings and submerged oil poling categories.

The following nine geomorphic settings were used to stratify the discharge site for the submerged oil quantification: Anthropogenic Channel, Backwater, Channel Deposit, Cutoff/Oxbow, Delta, Depositional Bar, Impoundment, Morrow Lake, and Morrow Lake Fan. Seven of the settings had soft sediment designations as their dominant sediment type. The second stratification performed was based on field-measured patterns of submerged Line 6B oil released from discharge site sediments through the poling process. An approximate determination of the relative amount of submerged Line 6B oil had been performed during late Spring 2012 by manually agitating (poling) bottom sediments at numerous locations. After agitation, observations of oil droplets and sheen released to the water surface were described using previously defined oiling categories of Heavy (H), Moderate (M), Light (L), and None

(N). Two further steps were taken with the stratification of site data. First, Spring 2012 oiling category polygons (developed from poling results) were overlain on the geomorphic settings to create sampling strata polygons for unique combinations of oiling category and geomorphic setting. Second, to support summary statistics calculations that were later determined to be necessary for handling non-detect results in the oil-concentration data for each sampling stratum, the four oiling categories were combined into two categories (H/M and L/N).

Prior to field work, core locations were determined randomly within each geomorphic setting/oiling category or sampling stratum. A total of 102 investigative core locations within the Line 6B discharge site were collected for oil fingerprinting analysis in July and August 2012. Bulk density determinations were paired with 32 of the cores collected for oil fingerprinting determinations. The top 1 inch of each core was collected for oil fingerprinting analysis. Additional core intervals were collected for laboratory analysis, with a preference given to upper stratigraphic layers of soft sediment and also any layer or portion of a layer that exhibited any indication of oil impact.

Many potential sources contribute to residual background hydrocarbons in Kalamazoo River sediment, including nonpoint sources of coal tar, atmospheric deposition of combustion PAHs, road runoff, organic material from decomposed vegetation, and contributions from non-Line 6B petroleum-derived compounds. Sample-specific petroleum biomarker ratios were identified with high stability and resolving power and used to distinguish residual background hydrocarbons from Line 6B oil.

For the Summer 2012 oil volume quantification study, the following equation was used to estimate the submerged Line 6B oil volume:

$$V_{L6B_j} = \sum_0^{D_j} \left(C_{L6B_{ij}}\, \rho_{s_j}\, A_j\, T_{ij}\, K\, \rho_{oil}{}^{-1} \right) \qquad \text{(Equation 2)}$$

where

V_{L6B_j}	=	Volume of submerged Line 6B oil for the *jth* sampling stratum
$\sum$	=	Summation over the vertical increments, *i*, from *i* = 0 to *i* = D_j; both oil concentration and increment thickness may vary by vertical increment
$C_{L6B_{ij}}$	=	Concentration of oil identified to be from the Line 6B release as distinguished from residual background hydrocarbons for the *jth* sampling stratum
ρ_{s_j}	=	Dry bulk density of sediment for the *jth* sampling stratum
A_j	=	Lateral extent of sampling stratum *j*

T_{ij}	=	Thickness of a single vertical increment, *i*, of the cores, which does vary (at least at the top of the core)
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

To implement Equation 2 and supporting calculations, a new SOVQ spreadsheet tool was developed specifically for the Summer 2012 study.

The total submerged Line 6B oil volume for the Line 6B discharge site in 2012 estimated to have been 180,000 gallons ± 100,000 gallons, summed over all sampling strata. Major contributions to the total volume come from the following strata:

- Channel Deposit – L/N (81,000 gallons)
- Morrow Lake – L/N (46,000 gallons)
- Depositional Bar – L/N (11,500 gallons)
- Morrow Lake Fan – L/N (11,000 gallons)

These four strata are also the four largest strata (on an areal basis) in the discharge site, accounting for approximately 79 percent of the total area.

Depth-averaged, submerged Line 6B oil concentrations in bottom sediment ranged from 76 mg/kg in the Anthropogenic Channel – L/N stratum to 1,140 mg/kg in the Depositional Bar – H/M stratum.

Approximately 14,600 gallons (8 percent) of Line 6B oil was present in the areas mapped with the H/M oiling category, and approximately 165,500 gallons (92 percent) of Line 6B oil was present in the L/N oiling category areas.

The Line 6B oil discharge site contains three impoundments: the Ceresco Impoundment, Mill Ponds Impoundment, and Morrow Lake Delta. A set of additional estimates was prepared based on the sampling stratum-level results as applied to the stratified composition of each main-stem impoundment area of interest. Overall results for the impoundments indicate that approximately 11,900 gallons of submerged Line 6B oil was present in the H/M areas of the impoundments. The 11,900 gallons represents 82 percent of the site-wide total for H/M areas. Areally standardized Line 6B oil volumes in the areas mapped as H/M submerged Line 6B oil were fairly consistent among the three impoundment areas, averaging 155 gallons/acre and ranging from 152 gallons/acre in the Morrow Lake Delta to 164 gallons/acre in the Ceresco Impoundment.

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Appendices

1. 8/8/2012 SSCG Recommendations to the FOSC on SOVQ
2. 3/1/2013 Technical Memorandum (G. Douglas, NewFields)
3. Overlay of Geomorphic Settings and Spring 2012 Poling Results, with core locations
4. Enbridge Submerged Oil Volume Quantification (Field Guide)
5. Sediment Core Logs
6. Line 6B Oil Concentrations in Sediment Samples
7. User's Guide for SOVQ Spreadsheet

Air Pollution and Greenhouse Gas Emissions from Ships

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CRS Report for Congress
Prepared for Members and Committees of Congress

Summary

This report provides information regarding pollution from ships and port facilities; discusses some of the measures being implemented and considered by local, state, and federal regulatory agencies; discusses the efforts to strengthen Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL); and describes legislation in Congress to control emissions from ships, as well as efforts in Congress to address the applicability of proposed EPA regulations to ships on the Great Lakes.

As pollution from cars, trucks, and land-based stationary sources has been more tightly controlled over the last 40 years, the contribution of ships and port operations to air pollution in port cities has become more important. In the same period, foreign trade has grown dramatically; thus, pollution from shipping and port operations is growing as a percentage of total emissions. In many cities, ships are now among the largest sources of air pollution. As Congress and the Administration turn their attention to climate change, there is also a growing recognition that marine vessels are an important source of greenhouse gas (GHG) emissions.

Controlling these sources of both conventional and greenhouse gas pollutants is complicated by the fact that most ocean-going ships are not registered in the United States and may not even purchase the fuel they are using here. Thus, controlling such pollution would seem to lend itself to an international approach. Such efforts have been slow to yield results: in 1997, the United States and most countries signed an international agreement known as MARPOL Annex VI, setting extremely modest controls on air pollution from ships, but the agreement did not enter into force until 2005, and the United States did not enact legislation to implement it until July 21, 2008 (P.L. 110-280). Negotiations to strengthen Annex VI accelerated in 2008, however, and amendments that will strengthen its provisions have received preliminary approval. Discussions regarding GHG emissions have also begun, although without results to date.

While awaiting congressional action and international agreement, the Environmental Protection Agency (EPA), port cities, and states have begun to act on their own. This report discusses a number of these efforts, including EPA measures that will require cleaner fuels and will greatly strengthen emission standards, and measures being implemented in California to reduce pollution from ships and ports.

In the current Congress, greenhouse gas emissions from ships are addressed in H.R. 2454, the Waxman-Markey climate change bill. As passed by the House, the bill would direct EPA to establish emission standards for nonroad vehicles and engines (a category that includes ships), by December 31, 2012.

In other action, Congress added a provision to the FY2010 EPA appropriation (P.L. 111-88) that prohibits FY2010 funds being used to implement cleaner fuel requirements as they apply to Great Lakes ships. Accompanying report language directs EPA to develop provisions to establish waivers of the low sulfur fuel requirements for Great Lakes ships if the fuel is not available or in cases of serious economic hardship.

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Introduction

Over the last 40 years, air quality in the United States has improved substantially. Since the passage of the Clean Air Act in 1970, annual emissions of the six most widespread ("criteria") air pollutants have declined 180 million tons (59%), despite major increases in population, motor vehicle miles traveled, and economic activity.[1]

Emissions from shipping are a major exception to these trends. Although emission controls have reduced pollution from new cars and trucks by more than 90%, most ocean-going ships operate without any pollution controls at all. New and remanufactured engines on tug boats, ferries, and other smaller ships are subject to emission controls beginning in 2008 and 2009, but most existing engines in vessels of these types remain uncontrolled.

Pollution from ships is also affected by the fuel they use. Marine vessels other than oceangoing ships have been required to use cleaner fuels, but ocean-going ships generally use bunker fuel, a fuel that contains a high level of contaminants: the average fuel used by oceangoing ships contains 27,000 parts per million (ppm) sulfur, for example—almost 2,000 times as much as would be allowed in trucks operating on U.S. roads.

In the Los Angeles-Long Beach area—which is both the nation's busiest port[2] and the nation's most polluted area[3]—the problem is particularly acute. According to the South Coast [L.A.-Long Beach] Air Quality Management District (AQMD):

- Oceangoing vessels are among the largest sources of nitrogen oxides (NOx) in the area, emitting more NOx than all power plants and refineries in the South Coast air basin combined. NOx reacts with volatile organic compounds in the atmosphere to produce ozone/smog.
- 70% of the area's emissions of sulfur dioxide (SO_2) come from ships. These emissions need to be cut by over 90%, according to the AQMD, if the area is to attain the national air quality standard for particulates by the 2014 deadline.
- Particulates from marine vessels also create significant cancer risks; more than 700 premature deaths are caused in the Los Angeles area annually by these emissions, according to the AQMD.[4]

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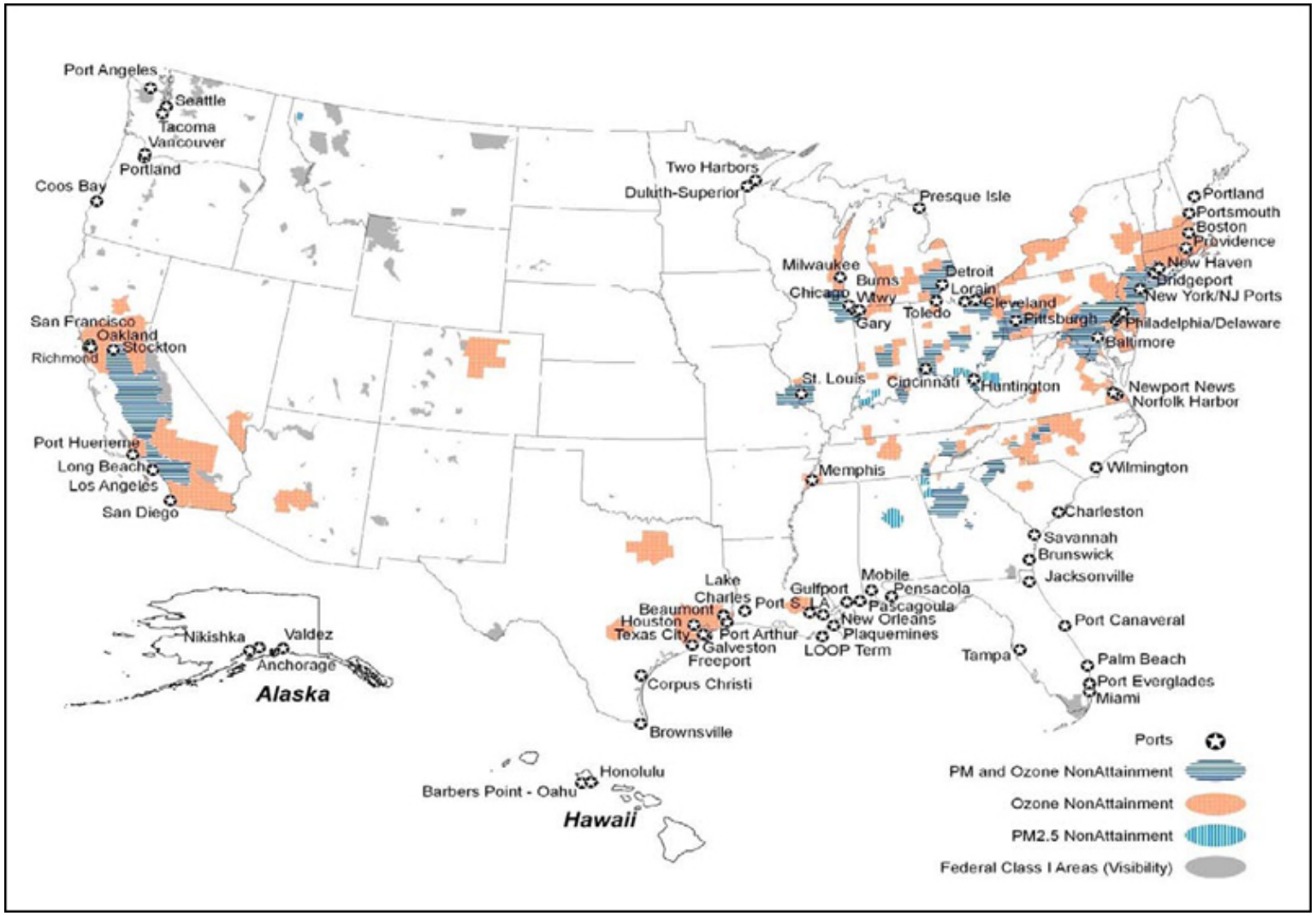
[1] See U.S. EPA, "Air Emissions Summary Through 2005," at http://www.epa.gov/air/airtrends/2006/emissions_summary_2005.html, updated with data from 2008 in U.S. EPA, "Air Quality Trends," at http://www.epa.gov/airtrends/aqtrends.html#comparison. The six criteria pollutants are ozone, particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, and lead.

[2] According to the *Wall Street Journal*, Los Angeles and Long Beach ranked number 1 and number 2 in the value of cargo handled, with a combined total exceeding $248.5 billion in 2003-2004. The port of New York and New Jersey ranked third with $132.4 billion. See "The Busiest U.S. Ports," March 9, 2006, at http://americanfuture.net/?p=1447.

[3] The Los Angeles South Coast Air Basin is the only area that EPA considers to be a "Severe 17" nonattainment area for ozone. The area also has the highest readings in the country for fine particulates ($PM_{2.5}$), and is among only 8 areas classified as "Serious" nonattainment areas for larger particles (PM_{10}). See U.S. EPA, "Green Book," at http://www.epa.gov/oar/oaqps/greenbk/index.html.

[4] See testimony of Barry R. Wallerstein, Executive Officer, South Coast Air Quality Management District, at "Legislative Hearing on the Marine Vessel Emissions Reduction Act of 2007, S. 1499," U.S. Senate, Committee on Environment and Public Works, February 14, 2008, p. 1.

Figure 1. U.S. Ports and Nonattainment Areas



Source: U.S. EPA, March 2009. Nonattainment areas are areas are areas where concentrations of pollution exceed National Ambient Air Quality Standards. Ozone and $PM_{2.5}$ are the pollutants that most commonly exceed the standards. $PM_{2.5}$ refers to particulate matter with a diameter less than or equal to 2.5 micrometers, often referred to as "fine particles."

While the Los Angeles-Long Beach area may be the most extreme example, the problem is not limited to L.A. or to California. According to the Environmental Protection Agency (EPA), more than 40 U.S. ports nationwide are located in "nonattainment" areas[5] for ozone, fine particulates, or both (**Figure 1**).[6] In addition, according to EPA, "... the problem is not limited to port areas alone. Santa Barbara County, which has no commercial ports, estimates that by 2020, 67 percent of its NOx inventory will come from shipping traffic transiting the California coast.... "[7]

Oceangoing ships are perhaps the largest source of port emissions, but they are not the only source. Ports make use of tug boats to guide ships entering and leaving the harbor. Ports make connections to land-based transportation networks, such as railroads, and they generally operate large truck terminals. Ships at rest in the port need a source of power, which often comes from running auxiliary engines. And, in many cases, a harbor is served by substantial local boat or barge traffic, sometimes including ferry service. Thus, addressing the sources of pollution in a port may require a multi-faceted approach.

MARPOL Annex VI

Pollution from ships (not only air pollution, but pollution of all kinds) is governed by the International Convention for the Prevention of Pollution from Ships, first negotiated through the International Maritime Organization (IMO) in 1973. The Convention, known as MARPOL (for "MARine POLlution") 73/78 (the dates referring to the 1973 Convention and its 1978 amendments), applies to all ships of the flag states that have ratified it. About 150 countries, representing over 98.7% of world shipping tonnage, have done so. The Convention also applies to ships of non-signatory states while they are operating in waters under the jurisdiction of parties to MARPOL. Six annexes to MARPOL 73/78 cover various sources of pollution from ships (oil, noxious liquids, sewage, garbage, etc.) and provide an overarching framework for implementation.

Provisions of Annex VI

Annex VI of the Convention, which was adopted in 1997 but did not enter into force until 2005, addresses the Prevention of Air Pollution from Ships. In its 1997 form, the annex represented a small first step toward controlling such pollution, particularly if one compares it to pollution controls that the United States and other developed countries impose on land-based sources. Annex VI:

- limits the sulfur content of the fuel used in oceangoing ships (bunker fuel) to 4.5% (45,000 parts per million (ppm)). By comparison, highway diesel fuel in the United States is limited to 15 ppm;

[5] That is, areas where air quality is worse than the health-based standard for ozone, particulates, or both.

[6] Testimony of Bryan Wood-Thomas, U.S. EPA, Office of Transportation and Air Quality, at "Legislative Hearing on the Marine Vessel Emissions Reduction Act of 2007, S. 1499," U.S. Senate, Committee on Environment and Public Works, February 14, 2008, p. 2.

[7] Ibid.

- allows special sulfur oxide (SOx) Emission Control Areas (currently the Baltic Sea, the North Sea, and the English Channel), where the sulfur content of fuel is limited to 1.5% (15,000 ppm) or SOx emissions are limited;
- limits NOx emissions from new engines and engines that have undergone major conversions to a range of 9.8-17.0 grams per kilowatt-hour (g/kwh), depending on the rated engine speed. By comparison, power plants in the eastern United States are limited to 0.45-0.73 g/kwh;
- allows the regulation of emissions of volatile organic compounds (VOCs) from tankers by parties to Annex VI in their ports and terminals;
- prohibits emissions of ozone-depleting substances;
- prohibits the incineration on ships of polychlorinated biphenyls (PCBs, a class of toxic chemicals widely used in electrical transformers until the 1970s). In the United States, PCB production and use were banned in 1976, and disposal has been strictly regulated since then; and
- prohibits the incineration of garbage containing more than traces of heavy metals and of refined petroleum products containing halogen compounds.

Implementing Legislation (P.L. 110-280)

- The United States is a party to MARPOL 73/78 and most of its annexes, but did not enact legislation to implement Annex VI until the summer of 2008. The Senate gave its consent to ratification of Annex VI on April 7, 2006,[8] but Congress needed to enact implementing legislation before the United States could submit the instrument of ratification. The House passed H.R. 802 to implement the annex on March 26, 2007. The Senate passed the bill, with an amendment, June 26, 2008, and the House agreed to the Senate amendment July 8, 2008. The President signed the bill July 21, 2008 (P.L. 110-280).

The Annex VI standards apply to: any oceangoing vessel that is registered in the United States; ships of any registry in ports, shipyards, terminals, or the internal waters of the United States; ships of any registry bound for or departing from the United States, while they are located in the navigable waters of the United States or designated emission control areas; and ships bearing the flag of any country that has ratified Annex VI traveling through U.S. waters or designated emission control areas, even if they are not bound for or departing from a U.S. destination. To the extent consistent with international law, the Annex also applies to any other ship in the U.S. exclusive economic zone.

Amendments to Annex VI

The United States has participated in negotiations to strengthen Annex VI, and more stringent limits on both fuels and emissions were approved by the IMO, October 10, 2008:

[8] The Senate consented to ratification through Treaty Document 108-7.

- The new limits cut the allowable sulfur content of bunker fuel to 3.5% (35,000 ppm) starting January 1, 2012, with a further drop to 0.5% (5,000 ppm) on January 1, 2020. This provision will have little effect prior to 2020, since bunker fuel currently averages 27,000 ppm sulfur, substantially cleaner than the 2012 requirements.
- New limits will also apply in Sulfur Emission Control Areas—currently the Baltic Sea, North Sea, and English Channel, but potentially including other areas. Sulfur content in those areas, currently capped at 1.5% (15,000 ppm), will be capped at 1.0% (10,000 ppm) effective July 1, 2010, and 0.10% (1,000 ppm) effective January 1, 2015.
- IMO also agreed to reductions in nitrogen oxide (NOx) emissions from marine engines, with the new standards to be phased in. For engines installed on ships constructed after January 1, 2011, but before 2016, NOx limits would be reduced about 20% to a range of 7.7 to 14.4 grams per kilowatt-hour, depending on the rated engine speed. For engines installed on ships constructed after January 1, 2016, the limits would be reduced about 80%, to a range of 2.0 to 3.4 g/kWh while ships are operating in designated emission control areas. Outside emission control areas, the prior limit (7.7 to 14.4 g/kWh) would apply.[9]

EPA Regulations for Ocean-Going Ships

Before Congress enacted the Annex VI implementing legislation in 2008, EPA had already promulgated regulations under the Clean Air Act that were as stringent as the 1997 Annex VI standards, and shipping companies were already generally meeting the standards. In addition, the agency has promulgated standards for smaller engines.

EPA groups ship engines in three categories. The largest of these engines—the main engines on oceangoing ships—are diesel engines with a per-cylinder displacement at or above 30 liters. These are referred to as "Category 3" or "C3" engines. Category 1 and 2 engines (those smaller than 7 liters per cylinder, and those from 7 to 30 liters per cylinder, respectively), are used in boats or smaller ships—tugs, ferries, some Great Lakes freighters, fishing boats, and recreational boats, for example.

Category 3 Engines and Fuels

EPA began addressing emissions from Category 3 engines about a decade ago, and two steps the agency took in 2009 will significantly strengthen its regulations. But it is important to bear three factors in mind, as one considers the potential impact of the new regulations. First, the new EPA emission standards will only apply to engines installed on vessels flagged or registered in the United States. In 2007, only 6.7% of the world's ocean-going ships (and only 1.2%, if measured by carrying capacity) were registered in the United States.[10] Thus, EPA's emission standards for

[9] "International Maritime Panel Sets Limits on Ships' Sulfur, Nitrogen Oxide Emissions," *Daily Environment Report*, October 14, 2008, p. A-6. For a copy of Annex VI as revised by the October 10, 2008 agreement, see the IMO website at http://www.imo.org/includes/blastDataOnly.asp/data_id%3D23760/176%2858%29.pdf.

[10] United Nations Conference on Trade and Development, *Review of Maritime Transport 2007*, p. 36, at http://www.unctad.org/en/docs/rmt2007_en.pdf.

C3 engines by themselves (i.e., apart from the similar Annex VI rules) will have little effect on the overall level of pollution from ocean-going ships. Second, when the more stringent requirements do take effect, they will apply only to new and remanufactured engines, so improvements resulting from the standards will be gradual. Third, EPA will be able to achieve more substantial emission reductions through standards for marine fuel. These will affect emissions from both new and existing engines, and from both U.S.- and foreign-flagged ships. The new C3 standards will require substantially cleaner fuel, a point to which we will return after describing the existing and proposed rules in more detail.

Current C3 engine standards were promulgated February 28, 2003, and went into effect in 2004.[11] These standards mirrored the relatively lenient requirements of Annex VI, adopted by the IMO in 1997. In October 1999, EPA also established a voluntary certification program so that engine manufacturers could show that their new engines were compliant with Annex VI. EPA believes that all marine Category 3 diesel engines sold in the United States since January 1, 2000, have met Annex VI requirements.

When the 2003 standards were promulgated, EPA set itself a deadline of April 2007 to promulgate stronger standards for C3 engines. EPA subsequently reset this deadline to December 2009: the Administrator signed new regulations December 18. Thus, 2009 has seen several developments that will strengthen emission standards for ships and expand the use of cleaner fuels. The new standards are in line with the Annex VI amendments that were negotiated in 2008. EPA has also proposed to add U.S. waters to those areas designated as Emission Control Areas under the annex. Specifically:

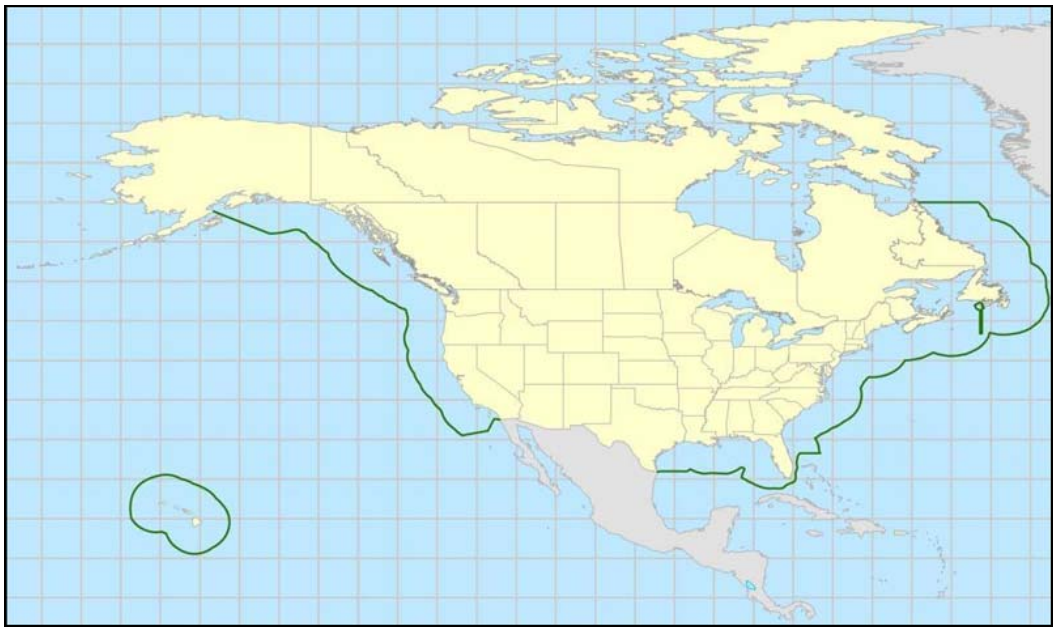
- On March 27, 2009, EPA proposed that the entire U.S. coastline except portions of Alaska be designated by the IMO as an Emission Control Area (ECA), subject to the lower sulfur limits in bunker fuel discussed above. As shown in **Figure 2**, the proposed ECA includes the entire coastline of the contiguous 48 states, Southeastern Alaska, and the main Hawaiian Islands, extending to a distance of 200 nautical miles from shore. EPA anticipates that this amendment will be adopted at the next IMO Marine Environment Protection Committee meeting (MEPC 60) which is scheduled for March 2010. Adoption of the ECA will set sulfur limits of 10,000 ppm as early as August 2012, and 1,000 ppm effective January 1, 2015.
- On July 1, 2009, EPA proposed regulations that will strengthen emission standards for new C3 marine engines and will implement the low sulfur fuel requirements that apply in ECAs starting in 2015. These regulations were finalized, with relatively minor changes on December 18, 2009.[12] New marine engines will be required to meet these standards in two phases: Tier 2, which would apply to new engines beginning in 2011, would require "more efficient use of current engine technologies, including engine timing, engine cooling, and advanced computer controls," resulting in a 15% to 25% reduction in NOx emissions, compared to Tier 1 standards; Tier 3, effective in 2016, would reduce

[11] 68 *Federal Register* 9746, February 28, 2003.

[12] The proposal appeared in the *Federal Register* August 28, 2009: "Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder," 74 *Federal Register* 44442. The final regulations had not yet appeared in the *Federal Register* as of this writing, but a pre-publication copy, as signed by the Administrator on December 18, can be found at http://www.epa.gov/otaq/oceanvessels.htm#regs.

NOx emissions from new engines 80% below current standards through the application of aftertreatment technology such as selective catalytic reduction (SCR), a technology now widely used at electric power plants.

Figure 2. Area Proposed for Emission Control Area (ECA) Designation



Source: U.S. EPA

Reaction to the New Standards

In general, the Category 3 engine standards and the ECA proposal have been supported by the shipping industry and by environmental groups.[13] The World Shipping Council (WSC), whose member companies carry over 90% of the United States' international containerized ocean cargo, in its comments on the C3 standards, stated, "... the WSC and its members fully support the proposal to codify and adopt these standards as proposed in the current rulemaking," although they went on to suggest a number of clarifications and technical improvements.[14] Regarding the ECA proposal, a spokesman for the Pacific Marine Shipping Association was quoted as saying, "We've been waiting for this a long time. We're pleased to see everything moving forward as planned."[15]

[13] See "Industry, Environmental Groups Offer Praise for EPA Proposal to Limit Ship Emissions," *Daily Environment Report*, August 5, 2009, p. A-5. Also see "U.S., Canada Propose Areas for Large Cuts in Emissions from Oceangoing Ships," *Daily Environment Report*, March 31, 2009, p. A-5.

[14] See "Comments of the World Shipping Council Submitted on September 28, 2009 to the U.S. Environmental Protection Agency in the Matter of Proposed Rule, Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder," Docket Number: EPA-HQ-OAR-2007-0121, at http://www.regulations.gov/search/Regs/home.html#docketDetail?R=EPA-HQ-OAR-2007-0121.

[15] T.L. Garrett, Vice President, Pacific Marine Shipping Association, as quoted in "U.S., Canada Propose Areas for Large Cuts in Emissions from Oceangoing Ships," *Daily Environment Report*, March 31, 2009, p. A-5.

The Clean Air Task Force, and 34 other environmental organizations stated, "EPA's proposed C3 Marine Engine rule is a substantial step in the right direction."[16] They would have liked to see the proposed emission standards strengthened to cover all new ships travelling in U.S. waters, no matter where they are registered, and would have liked stronger standards for NOx and particulate matter from the existing fleet of ships. Environmental groups also support the ECA/fuel sulfur proposal, although they would like to see it expanded to include Alaska's Arctic waters.

Costs and Benefits of the Proposed Standards

EPA estimates that the benefits of its new regulations for C3 engines and fuel will outweigh the costs by at least 30 to 1. The benefits include annually preventing between 12,000 and 31,000 premature deaths, 1,500,000 work days lost, and 9,600,000 minor restricted activity days, which the agency values at between $99 billion and $270 billion annually.[17] The reductions in pollution, shown in **Figure 3**, are greatest near the coasts, but more modest reductions would extend a substantial distance inland, according to EPA modeling.

The agency's estimated cost of the proposals is approximately $1.85 billion in 2020, increasing to $3.11 billion in 2030. Of the 2020 costs, nearly 89% are attributable to the use of lower-sulfur fuel in the proposed ECA. These costs are substantial, but they will be spread over such a huge volume of traded goods that they may be little noticed. According to the agency:

> These costs are expected to be completely passed on to the consumers of ocean transportation. The impacts of these costs on society are estimated to be minimal, resulting in a small increase in the goods transported. For example, EPA estimates it will result in an increase of about $0.01 for a pair of tennis shoes, and about $0.03 for a bushel of grain.[18]

Great Lakes Ships

Perhaps the most controversial aspect of the ECA and Category 3 rules was their proposed application to the large ships that ply the Great Lakes. The Great Lakes would be included in the proposed ECA and, therefore, ships operating on the lakes would be required to burn low sulfur fuels under the ECA proposal.

More than 100 U.S.- and Canadian-flagged cargo ships operate on the Great Lakes. These ships generally carry bulk cargoes, including iron ore, coal, limestone, agricultural products, and rock salt. The associations that represent the U.S. and Canadian ship owners estimate that they carry as much as 150 million tons of cargo annually.[19]

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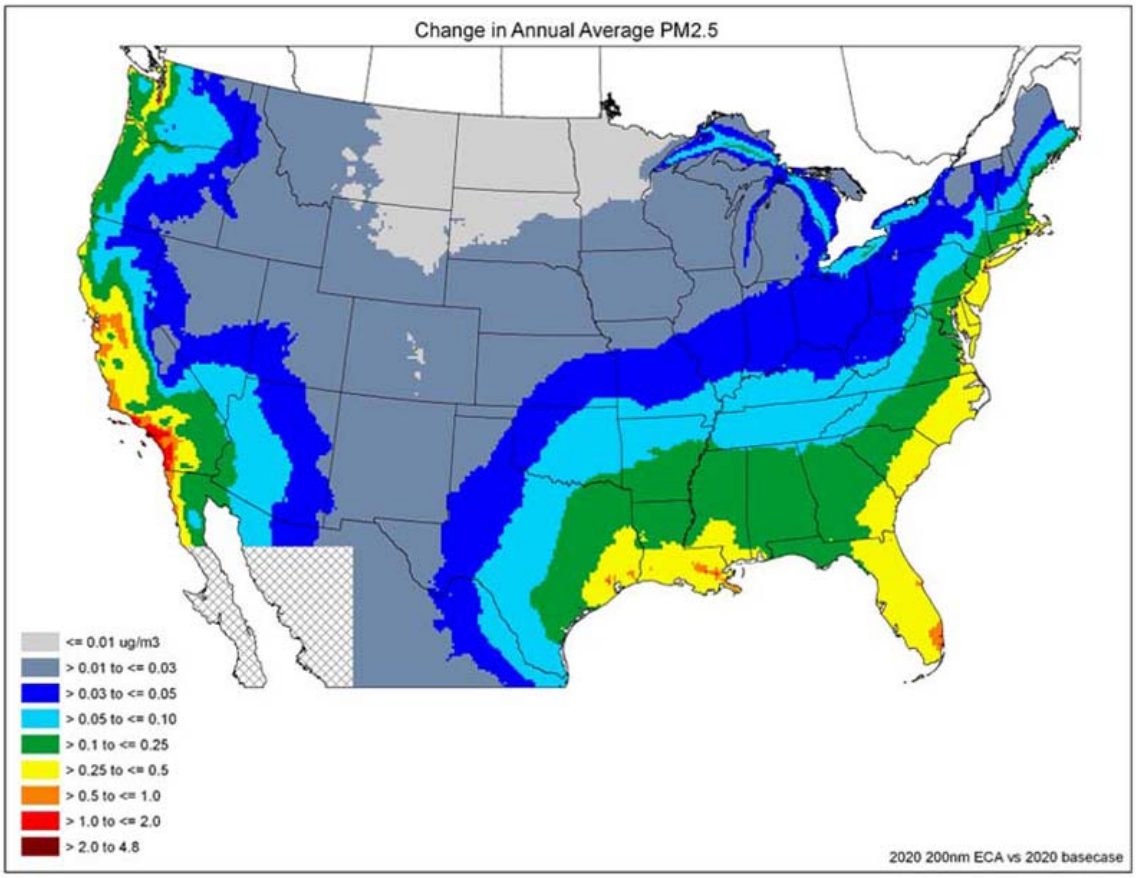
[16] Clean Air Task Force et al., "Comments on Proposed Large Marine Diesel Engine Rule," September 28, 2009, p. 30, Docket Number: EPA-HQ-OAR-2007-0121at http://www.regulations.gov/search/Regs/home.html#documentDetail?R=0900006480a3df87.

[17] U.S. EPA, "Regulatory Announcement: EPA Proposal for Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder," June 2009, at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09029.htm#4.

[18] U.S. EPA, Office of Transportation and Air Quality, "EPA Proposal for Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder," Fact Sheet, p. 4, at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09029.pdf.

[19] The Lake Carriers' Association represents 18 American companies that operate 55 vessels on the Great Lakes. These (continued...)

Figure 3. Potential Ambient Reductions of Fine Particulates ($PM_{2.5}$) from Proposed U.S. ECA, in 2020



Source: U.S. EPA

Many of these ships are old. The Lake Carriers' Association (LCA) identified one U.S.-flagged vessel built in 1906 and 17 others built between 1929 and 1960 that are still in operation. Thirteen of these ships have powerplants that were designed to burn heavy residual fuel. According to the LCA,

> It is theoretically possible to switch the fuel supply system for the boilers to distillate fuel. However, it would require modifications including new fuel pumps, bypass of the fuel heating systems, new burners and burner tips, and possibly new air diffusers. A number of upgrades to the automation system would also have to have been done to ensure the proper air to fuel ratio and that the fuel cut off valves are sufficient to ensure that absolutely no diesel fuel enters the boiler in the off position.[20]

(...continued)

vessels can carry as much as 115 million tons of cargo in a given year, according to the association. The Canadian Shipowners Association represents the owners of 68 Canadian vessels with an annual volume of over 62 million metric tons in 2008, slightly more than half of which were carried between Canada and the United States. See their respective comments on the proposed Category 3 rule at http://www.regulations.gov, Docket Number: EPA-HQ-OAR-2007-0121.

[20] Comments of the Lake Carriers' Association on the proposed Category 3 rule, September 28, 2009, p. 4, at http://www.regulations.gov/search/Regs/home.html#documentDetail?R=0900006480a3e004.

LCA estimated the cost of converting these 13 steamers' powerplants to run on diesel fuel or of converting them to self-unloading barges powered by tugs to be $20 million to $27 million each. Another 13 vessels were identified by LCA as facing significant impacts because of higher fuel prices, even though they are able to safely burn low sulfur distillate fuel.

The case made by the Lake Carriers Association and other industry commenters that older Great Lakes ships will face significant impacts appears not to have been considered by EPA when it proposed the ECA and C3 regulations. The Category 3 Regulatory Impact Analysis did indicate, however, that switching from residual fuel to lower sulfur distillate would increase costs borne by shipping companies $145 per tonne of fuel, or 44%.[21] For ocean-going ships, this cost increase is not as great as it might seem, since they operate in an ECA only a small percentage of the time and can burn dirtier fuel outside of ECAs. Great Lakes ships, however, operate in the proposed ECA 100% of the time, and thus would face a greater increase in costs.[22]

The Great Lakes shipping companies made a sufficiently persuasive case that Congress addressed their concerns. Section 442 of H.R. 2996, the FY2010 appropriations for Interior, Environment, and Related Agencies, signed by the President, October 30, 2009 (P.L. 111-88), provides that:

> None of the funds made available for the Environmental Protection Agency in this Act may be expended by the Administrator of the Environmental Protection Agency to issue a final rule that includes fuel sulfur standards applicable to existing steamships that operate exclusively within the Great Lakes, and their connecting and tributary waters.

This prohibition applies only to the period covered by the appropriation, i.e., FY2010. But language in the accompanying Conference Report (H.Rept. 111-316), states that EPA has received comments detailing significant negative economic impacts for carriers that operate Category 3 engine vessels exclusively within the Great Lakes, and the report adds:

> Because of these economic impacts, EPA should include waiver provisions similar to those in other EPA rules in the final rule—one to waive the 10,000 ppm sulfur standard for Great Lakes Category 3 diesel engine vessels that burn residual fuel if EPA determines that 10,000 ppm residual fuel is not available; and one to waive fuel requirements for an owner/operator of a Great Lakes Category 3 diesel engine vessel based upon a showing of serious economic hardship. It is important that EPA structure such a waiver provision similar to the other fuels rules, where parties can apply for and receive a waiver in sufficient time prior to the implementation of the requirements. Finally, EPA should perform a study and issue a report

[21] U.S. EPA, Office of Transportation and Air Quality, "Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines," June 2009, p. 5-58, available at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420d09002.pdf. The RIA found no substantial increase, however, for ships switching from distillate fuel to lower sulfur distillate fuel. For this group, the additional fuel cost was less than $1.00 per barrel, about 2 cents a gallon.

[22] How this cost increase would affect the shipping companies and their customers is a different question. The ships have a large cost advantage over other modes of transportation because they use significantly less fuel per ton-mile: according to the Army Corps of Engineers, Great Lakes carriers use 90% less fuel per ton-mile than trucks, and 66% less than trains. The Corps estimated that Great Lakes shipping annually saves its customers $3.6 billion in transportation costs compared to the next least expensive mode of transportation. Furthermore, the low sulfur fuel requirements for shipping companies are not happening in a vacuum. Both trucks and trains also face lower sulfur fuel requirements: in both cases, the sulfur limit will be 15 parts per million, as compared to the 1,000 ppm allowed on ships in the proposed ECA. Thus, although Great Lakes ships would undoubtedly incur costs to comply with the C3 and ECA proposals, higher costs would not necessarily eliminate the huge cost advantage they hold over competing modes of transportation. Rather, the impacts on them will depend on the degree to which they can pass on higher costs to their customers and the ability of those customers to do the same, a question that was not analyzed in EPA's RIA.

> within six months that evaluates the economic impact of the final rule on Great Lakes carriers.[23]

The final C3 rule provides the two Great Lakes waivers discussed in the report language.

Category 1 and 2 Engines

Category 1 and 2 engines (those smaller than 7 liters per cylinder, and those from 7 to 30 liters per cylinder, respectively), are used in boats or ships that operate in U.S. waters—tugs, ferries, smaller Great Lakes freighters, fishing boats, and recreational boats, for example—virtually all of which are registered in the United States. While smaller than Category 3 engines, these engines are still rather large: they generate at least 800 horsepower.

EPA is further along in regulating the emissions of these categories, as compared to Category 3. Regulations that will reduce emissions of NOx from new or remanufactured engines by 24% and emissions of particulates by 12% when fully implemented, were promulgated in 1999 and began taking effect between 2004 and 2007. More stringent standards were promulgated May 6, 2008, and will take effect between now and 2014.[24] The final 2014 standards will require ultra low sulfur diesel fuel (15 ppm sulfur) and high efficiency catalytic emission controls capable of reducing particulate matter emissions by 90% and NOx emissions by 80%, along with "sizeable reductions" of hydrocarbon, carbon monoxide, and air toxic emissions, according to EPA.[25]

As with the new Category 3 regulations, EPA estimates that benefits of the May 2008 rule will substantially exceed the costs of compliance – in this case, by a figure of at least 9 to 1. The principal benefits that the agency estimated are health benefits: a reduction of between 1,150 and 1,400 premature deaths, 120,000 work days lost, and approximately 1,000,000 minor restricted-activity days annually. The agency estimates that these benefits will be worth between $8.4 billion and $11 billion in 2030, whereas the annual social costs will be approximately $740 million in that year. The impact of these costs on society is expected to be manageable, with the price of marine transportation services estimated to increase by about 1.1%.[26]

California Emission Reduction Measures

California, being more adversely affected than most other areas, has also played a leadership role in identifying and implementing emission reduction measures applicable to shipping. The state has focused on port activities, in addition to fuel and emission standards for marine vessels. California's measures fall into four categories: (1) requiring the use of lower sulfur fuel; (2) requiring emission controls on harbor vessels and shore-side equipment; (3) providing alternative

[23] U.S. Congress, House, "Department of the Interior, Environment, and Related Agencies Appropriations Act, 2010," Conference Report to Accompany H.R. 2996, October 28, 2009, pp. 109-110.

[24] 73 *Federal Register* 25097, May 6, 2008.

[25] For information, see U.S. EPA, Office of Transportation and Air Quality, "Diesel Boats and Ships," at http://www.epa.gov/oms/marine.htm.

[26] For additional information, see the EPA Regulatory Impact Analysis at http://www.epa.gov/otaq/regs/nonroad/420r08001a.pdf.

(electric) power to ships while they are docked at marine terminals; and (4) providing grants for the re-powering of harbor craft and short-haul trucks with cleaner engines.

Low Sulfur Fuels

The California Air Resources Board (CARB), at a July 24, 2008, meeting, approved regulations that required both U.S.- and foreign-flagged vessels sailing within 24 miles of its coast to use low sulfur fuels in both main and auxiliary engines beginning July 1, 2009. Compliant fuels are marine diesel oil with 5,000 ppm or less sulfur or marine gas oil with 15,000 ppm or less sulfur. In January 2012, sulfur in both types of fuel will be limited to 1,000 ppm. The rules replace low sulfur fuel requirements that the state implemented in 2007, but which were overturned by the U.S. Court of Appeals for the Ninth Circuit in February 2008.[27] The original rules would have set a 1,000 ppm limit two years earlier, in 2010.

Emission Controls

California has, in general, led the nation in imposing more stringent requirements on diesel engines. In addition, the ports of Los Angeles and Long Beach have developed procedures to require that trucks serving the ports will be replaced by newer, less-emitting models. According to a description of the ports' plan:

> ... all pre-1989 trucks will be barred from entering the ports' terminals beginning Oct. 1 [2008]. Effective Jan. 1, 2010, all 1989-1993 trucks and any 1994-2003 trucks without certified pollution control equipment will be banned. By Jan. 1, 2012, all trucks entering the port must meet the 2007 federal standard for heavy-duty diesel trucks....
>
> A $35 gate fee for each 20-foot container unit that passes through the port will generate funds to help underwrite subsidies to upgrade and replace trucks.[28]

The Port of Los Angeles estimates that truck emissions have been reduced about 70% since October 1, 2008, as a result of these requirements.[29]

In addition, CARB has adopted regulations for harbor craft, including ferries, tugboats, and tow boats, which will require the replacement of unregulated engines beginning in 2009, and will

[27] Pacific Merchant Marine Ass'n v. Goldstene, 517 F.3d 1108 (9th Cir. 2008). The court held that the state's Marine Vessel Rules were preempted by the federal Clean Air Act because the regulations set emission standards for marine engines without California having received a waiver from EPA to do so. California has since asked EPA for a waiver to enforce the original rules, in addition to developing the rules applying only to fuels. If the waiver is granted, the original (2007) requirements would be enforced. See "California Air Board Seeks Federal Waiver to Enforce Ship Auxiliary Engine Rules," *Daily Environment Report*, May 13, 2008, p. A-1. See also, CARB, "Advisory on Plans to Implement a Proposed ARB Regulation on Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels," October 2008, at http://www.arb.ca.gov/ports/marinevess/documents/advisory1008.pdf.

[28] "Los Angeles Harbor Commission Approves Program to Replace Older Diesel Trucks," *Daily Environment Report*, March 24, 2008, p. A-9.

[29] "January 1, 2010 Truck Restrictions Will Bring More Clean Trucks to Port of Los Angeles, Continue to Reduce Harmful Air Emissions," Port of Los Angeles News Release, December 4, 2009, at http://www.portoflosangeles.org/newsroom/2009_releases/news_120409_ctp_truck_ban.asp.

accelerate the adoption of EPA's Category 1 and Category 2 marine engine pollution controls. These rules became effective November 19, 2008.[30]

Alternative Power

In June 2004, the Port of Los Angeles opened the world's first Alternative Maritime Power (AMP) terminal for container ships, where cargo ships can plug in to power instead of operating auxiliary engines to generate electricity while at berth. The electrification project was the result of a lawsuit brought by the Natural Resources Defense Council and other groups, who sued the city claiming it failed to fully weigh air quality and other environmental impacts of a new container terminal. As a result of the suit, a state appeals court halted work on the terminal in October 2002, and Los Angeles subsequently agreed to electrify the terminal to cut diesel emissions while ships are at docks, among other measures.[31] A second terminal was outfitted with AMP capability in 2005. To encourage shippers to use the AMP facilities, in December 2004, the Los Angeles Board of Harbor Commissioners passed a policy resolution to help each existing Port customer underwrite the cost of building or retrofitting their first container or cruise ship to run on electrical power when docked, a cost estimated at $320,000-$830,000 per vessel.[32] Cruise ship terminals in San Francisco and Seattle are also implementing AMP, and CARB obtained final approval of regulations to require the use of AMP at the state's six largest ports, in December 2008.[33]

Grants

CARB, the Ports of Los Angeles and Long Beach, and the South Coast Air Quality Management District also intend to provide substantial amounts of financial support for the replacement of older, high-emitting engines and the conversion to lower emitting power sources. CARB awarded $247 million in FY2007-FY2008 funds for "goods movement emission reduction" projects (about $137 million of which was designated for ports); another $250 million was appropriated in FY2008-FY2009, and a third cycle of $250 million was appropriated in the FY2009-FY2010 state budget. According to CARB, most requests for the funds came from trucking companies, which would replace older engines or trucks with new models that reduce emissions as much as 90%.[34]

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[30] Information on these regulations can be found at http://www.arb.ca.gov/regact/2007/chc07/chc07.htm.

[31] Natural Resources Defense Council v. City of Los Angeles, 126 Cal. Rptr. 2d 615 (Cal. App. 2002).

[32] See Port of Los Angeles, "Alternative Marine Power," at http://www.portoflosangeles.org/environment/alt_maritime_power.asp. Also see "Alternative Maritime Power "Off and Running," presented by Eric Caris, at http://www.ffca2006.com/documents/presentations/marine/Eric%20Caris.pdf.

[33] See California Air Resources Board, "Rulemaking to Consider Adoption of Proposed Regulations to Reduce Emissions from Diesel Auxiliary Engines on Ocean-Going Vessels While at Berth at a California Port," at http://www.arb.ca.gov/regact/2007/shorepwr07/shorepwr07.htm. The December 2008 regulation will require container vessels, passenger vessels, and reefers (refrigerated ships for perishable cargo) to reduce on-board power generation 50% by 2014, 70% by 2017, and 80% by 2020. Tankers, vehicle carriers, and bulk and general cargo ships are not affected by the regulation.

[34] See CARB, "Emissions Reduction Plan for Ports and Goods Movement in California: *Update on Implementation*," Staff Presentation, Air Resources Board Meeting , Oakland, CA, April 24, 2008 at ftp://ftp.arb.ca.gov/carbis/board/books/2008/042408/08-4-7pres.pdf.

In February 2009, CARB noted that state funding for bond programs had been suspended, pending "effective resolution of the current fiscal year budget crisis and a restoration of the state's ability to access the bond market." This affected FY2007-FY2008 funds awarded to local agencies under the Goods Movement Program, as well as the FY2008-FY2009 funds that had not yet been awarded.[35] Some funding has since been freed up, but a Department of Finance directive prohibited CARB from making allocations for the second and third installments ($250 million each) appropriated for this program.

In addition to the CARB funding, the ports of Los Angeles and Long Beach, as noted earlier, will provide subsidies for truck and engine replacement from a fund generated by a $35 to $70 per container fee. The grants will provide $20,000 for the cost of each truck compliant with EPA's 2007 emission standards used by port concessionaires. The ports began distributing $44 million in incentive checks in December 2008, for the first 2,200 low-emission trucks purchased under the program.[36]

These grants have also experienced funding problems. The per-container fees that are to fund the system were to have been collected beginning in November 2008, but implementation was delayed by the Federal Maritime Commission (FMC), which maintained that the ports' program (referred to as the PortCheck Agreement) is anti-competitive and interferes with interstate commerce. FMC delayed implementation of the fees by requiring two 45-day review periods. These actions delayed the start of fee collection until February 18, 2009.[37]

The Port of Los Angeles is also collaborating with the South Coast Air Quality Management District to provide up to $100,000 for each natural gas (LNG or CNG) truck purchased by port concessionaires and up to 80% of the cost of electric trucks. This has led to the purchase of more than 400 alternate fuel trucks. About 8.5% of the cargo moves at the port were being made by these alternative fuel trucks as of October 2009.[38]

Besides state and local funding, U.S. EPA has become a source of funds for diesel emission reductions at ports. The stimulus package (the American Recovery and Reinvestment Act of 2009, P.L. 111-5) contained $300 million for diesel emission reduction grants. This money may be used for purposes authorized under Title VII, Subtitle G of the Energy Policy Act of 2005 (P.L. 109-58), including retrofit of diesel trucks, marine engines, and cargo handling equipment, not only in California, but in other states as well. Of the first $156 million awarded, at least $29

[35] Although funds are appropriated to ARB as part of the state's budget process, ARB must obtain the cash through the Pooled Money Investment Board. See CARB, "Prop 1B/Goods Movement Update" (e-mail to listserve on February 4, 2009), at http://www.arb.ca.gov/bonds/gmbond/docs/2_4_2009_email_update_to_listserv.pdf. Additional information was provided on July 1 at http://www.arb.ca.gov/bonds/gmbond/docs/july_2009_semi_annual_report_to_dof.pdf.

[36] "Port of Los Angeles Begins Estimated $44 Million Pay-Out Process to Clean Truck Program Concessionaires that Applied for Port's 2007-Compliant Incentive Program," Press Release, December 23, 2008, at http://www.portoflosangeles.org/environment/ctp.asp.

[37] Trucking interests also sued the ports to prevent implementation of PortCheck, focusing on the mechanism it uses (i.e., its requirement that truckers be concessionaires of the ports and submit to numerous administrative, financial, training, maintenance, and insurance requirements, in addition to using cleaner trucks). See American Trucking Ass'ns Inc. v. City of Los Angeles, C.D. Cal., No. 08-4920. In April 2009, the U.S. District Court for the Central District of California blocked the ports of Los Angeles and Long Beach from enforcing the concessionaire requirements of the PortCheck program on the grounds that they interfered with interstate commerce. The Port of Long Beach subsequently settled with the trucking associations. See "Port of Long Beach, Calif., Settles Lawsuit Over Clean-Truck Program," *Daily Environment Report*, October 22, 2009, p. A-3.

[38] http://www.portoflosangeles.org/CTP/CTP_Cargo_Move_Analysis.pdf

million went for diesel reduction activities at ports, including $8 million to California ports. There is an additional $60 million in diesel emission reduction grant money in P.L. 111-88, the Fiscal Year 2010 Interior, Environment, and Related Agencies Appropriation, signed by the President October 30, 2009.

Greenhouse Gases

Ships are also an important source of greenhouse gas (GHG) pollutants. Although there is a wide range of estimates, the International Maritime Organization's consensus is that international shipping emitted 843 million metric tonnes of carbon dioxide, 2.7% of global CO_2 emissions in 2007. Including domestic shipping and fishing vessels larger than 100 gross tonnes, the amount would increase to 1.019 billion tonnes, 3.3% of global emissions.[39] At these levels, only five countries (the United States, China, Russia, India, and Japan) account for a higher percentage of the world total of CO_2 emissions.[40]

In addition to the CO_2 emissions, the low quality fuel (bunker fuel) that ships use and the absence of pollution controls result in significant emissions of black carbon and nitrogen oxides, which also contribute to climate change. The refrigerants used on ships (hydrofluorcarbons and perfluorocarbons—HFCs and PFCs) are also potent greenhouse gases when released to the atmosphere. Thus, the total impact of ships on climate may be somewhat greater than 3%.

International Efforts to Address GHGs

For the most part, these emissions occur in international waters, and the sources are vessels not registered in the United States. Addressing the emissions, therefore, is likely to require international agreement. On the international level, however, there has been disagreement over who should take responsibility to abate GHG emissions. Rather than cover these emissions under the Kyoto Protocol, nations agreed to look to the IMO for sector-specific provisions to reduce GHG emissions from shipping.[41] The IMO's Marine Environment Protection Committee has begun negotiations on the issue, and has stated that the issue is "high on the Committee's agenda." Thus far, however, it has agreed only on voluntary guidelines on ship design and operational efficiency, while continuing to discuss market-based instruments to reduce GHG emissions.[42] Some in the industry, including shipping industry associations from several European countries, have suggested applying a cap-and-trade scheme to shipping's GHG emissions. At U.N.-sponsored climate negotiations, on the other hand, there has been talk of imposing a tax on bunker fuel.[43]

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[39] International Maritime Organization, *Updated Study on Greenhouse Gas Emissions from Ships*, Executive Summary of Phase 1 Report, 1st September 2008, p. 5 at regserver.unfccc.int/seors/attachment/file_storage/6ep77qqvcujba7k.doc. Both estimates exclude emissions from naval vessels. Cited below as "IMO 2008 Update."

[40] Oceana, *Shipping Impacts on Climate: A Source with Solutions*, p. 2, at http://www.oceana.org/fileadmin/oceana/uploads/Climate_Change/Oceana_Shipping_Report.pdf.

[41] Under the UN Framework Convention on Climate Change, emissions from internationally used fuels (both ships and aviation) are calculated by countries but reported separately from national emissions, such as those subject to the United Nations Kyoto Protocol.

[42] For information on IMO discussions, see http://www.imo.org/Environment/mainframe.asp?topic_id=1737.

[43] "U.N. Climate Talks Consider Carbon Tax on Air, Sea Transport; Progress on Draft Text," *Daily Environment Report*, October 7, 2009, p. A-14.

As with many other sectors, the European Union has been a driving force in getting international consideration of controlling the shipping sector's GHG emissions. The EU has considered adding the shipping industry to its cap-and-trade system, the EU Emissions Trading Scheme (ETS), but for now is deferring to the IMO. Approving a broad package of climate measures on December 17, 2008, the European Parliament left shipping out of the package, pending the outcome of the IMO discussions. Satu Hassi, a Finnish lawmaker from the Parliament's Green Group, who oversaw negotiations on emission reduction targets for non-ETS sectors, was quoted as saying the "EU will act unilaterally" should IMO discussions not produce sufficient results.[44]

Shipping vs. Other Transport Modes

Ocean-going ships are already by far the most efficient means of goods movement. As noted by the United Nations Conference on Trade and Development (UNCTAD):

> While in absolute terms GHG emissions from international shipping are significant, in relative terms maritime transport – in particular where larger ships are used – surpasses other modes of transport in terms of fuel efficiency and climate friendliness. On a per ton kilometre (km) basis and depending on ship sizes, CO_2 emissions from shipping are lower than emissions from other modes. For example, emissions from rail could be 3 to 4 times higher than emissions from tankers, while emissions from road and air transport could, respectively, be 5 to 150 times and 54 to 150 times higher. Equally, in terms of fuel consumption (kilowatt (kW)/ton/km), a container ship (3,700 twenty-foot equivalent units (TEUs)), for instance, is estimated to consume on average 77 times less energy than a freight aircraft (Boeing 747-400), about 7 times less than a heavy truck and about 3 times less than rail.[45]

But, in general, shipping does not compete with other modes of transport. Only in a small number of cases involving high value or perishable commodities, or relatively short distances between countries that also have land links, are mode shifts between shipping and air, truck, or rail transport possible. Ships move more than 80% of the volume of international trade, and are likely to continue doing so. As the overall volume of trade grows, GHG emissions from shipping are projected to be 2.4 to 3 times the current level by 2050 unless control measures are adopted.[46]

Measures to Reduce Ships' GHG Emissions

A number of measures might be taken to reduce the shipping sector's GHG emissions. One of the more common suggestions is that ships operate at lower speeds. The IMO's 2000 study of GHG emissions from ships concluded that a 10% reduction in speed would result in a 23.3% reduction in emissions.[47] Slowing speeds is not without problems. According to the 2000 IMO report:

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[44] "European Parliament Gives Final Approval to Far-Reaching Climate Protection Strategy," *Daily Environment Report*, December 18, 2008, p. A-1.

[45] "Maritime Transport and the Climate Change Challenge," Note by the UNCTAD Secretariat, 9 December 2008, prepared for the Multi-Year Expert Meeting on Transport and Trade Facilitation, Geneva, Switzerland, 16-18 February 2009, at http://www.unctad.org/en/docs/cimem1d2_en.pdf.

[46] IMO 2008 Update, op. cit., p. 5.

[47] Norwegian Marine Technology Research Institute – MARINTEK et al., for the International Maritime Organization (IMO), *Study of Greenhouse Gas Emissions from Ships*, March 2000, p. 17, at http://unfccc.int/files/methods_and_science/emissions_from_intl_transport/application/pdf/imoghgmain.pdf. This one measure (slow steaming) dwarfed the potential of any of the other technical and operational measures examined in the IMO study: in (continued...)

> For most ship engines, running at reduced speed / slow steaming may ... cause problems. Such problems may be vibrations (critical RPM of engine / shaft) and accelerating sooting in the exhausted gas channel. Sooting problems are normally coincident with incomplete combustion and increasing GHG emission per fuel unit consumed. For ships permanently operating at slow speed, however, engine modifications / de-rating may be a solution.[48]

In addition, of course, cargo owners may consider the lost time in reaching the ship's destination to be more valuable than the fuel and GHG savings. Thus, in a competitive market with low fuel costs, ship owners will tend to offer as swift a service as they can safely provide.

Nevertheless, it is possible without changes in technology or fuels to achieve significant GHG emission reductions, and shipping companies have begun to implement slow steaming policies to reduce their emissions. A.P. Moller – Maersk Group, the world's largest container shipper, for example, reports that it reduced fuel consumption in its transport group 6% in 2008 compared to the fuel used for the same level of business activity in 2007. In addition to slow steaming, the company has implemented waste heat recovery systems on 32 ships, has installed software in containers to reduce energy consumption for cooling, and has developed a voyage planning program to identify the most fuel-efficient routes, and a "just in time" steady running strategy that minimizes engine loads.[49]

Cleaner fuels and emission controls could also lower emissions, particularly if one focuses on emissions of black carbon and nitrogen oxides. Like slow steaming, these could be implemented without the need to replace ship engines or the ships themselves.

The use of alternative power in ports may also reduce GHG emissions, if the shore power is derived from low-carbon sources such as natural gas, or no-carbon sources (hydropower, wind, solar, or nuclear).

New ships may be able to reduce emissions further through better hull design, more efficient propulsion, and propeller coatings, among other options. A detailed discussion of options (in the context of Navy ships) is provided in CRS Report RL33360, *Navy Ship Propulsion Technologies: Options for Reducing Oil Use—Background for Congress*, by Ronald O'Rourke

Conclusion

As pollution from cars, trucks, and land-based stationary sources has been more tightly controlled over the last 40 years, the contribution of ships and port operations to air pollution in port cities has become more important. Simultaneously, foreign trade has grown dramatically, adding to the burden of pollution from these sources. Thus, pollution from ships and the port operations that serve them is now among the most important sources of sulfur oxides, nitrogen oxides, particulates, and other pollutants in numerous U.S. cities.

(...continued)

the short term (10 years), it accounted for nearly 60% of the total reductions identified; over a 20-year horizon, it still accounted for 43% of potential reductions.

[48] Ibid., p. 91.

[49] *Preparing for the Future*, A.P. Moller – Maersk Group's Health, Safety, Security and Environment Report 2008, p. 30, at http://media.maersk.com/da/PressReleases/2009/Documents/Maersk%20HSSE%202008_Final.pdf.

Controlling these sources of pollution is complicated by the fact that most oceangoing ships are registered in foreign countries. As a result, initial efforts at control were focused on international negotiations through the IMO, which established a basic structure (MARPOL Annex VI) that appears likely to be the basis of more stringent future controls. Negotiating, ratifying, and implementing MARPOL agreements has been time-consuming, but now has resulted in significant levels of regulation that will gradually be implemented over the next six years. EPA and state and local agencies (particularly those in California) have also begun to address pollution from ships using the Clean Air Act and comparable state authorities.

Not all pollution from marine vessels comes from foreign ships. Smaller craft, such as ferries, tugboats, and fishing boats do tend to be registered in the United States, and are thus more amenable to control. Even for these smaller craft, the technical issues can be complex, as the vessels include a wide variety of engine sizes and ship configurations. Safety also poses important considerations, as ships must be able to depend on their sources of power in what may be extreme weather conditions and while dealing with a variety of navigational hazards. A particular issue has arisen regarding Great Lakes freighters, many of which were built more than 50 years ago, and might face significant costs in upgrading to burn cleaner fuel. The FY2010 appropriation for EPA has prohibited the expenditure of funds in this fiscal year to issue final fuel sulfur standards applicable to existing steamships operating exclusively within the Great Lakes, and accompanying report language states that EPA should develop waiver provisions available to these ships.

Because ships and port operations are now such significant sources of air pollution, and because of the importance of shipping to the national and world economy, implementation of the emissions regulations for ships and ports, including the cleaner fuels requirements, may continue to be of interest to Congress. In addition, ships are a large and growing source of greenhouse gas emissions; how and whether to regulate these emissions are the subject of IMO discussions and are a small part of the larger debate over legislation to address climate change.

Congress has begun efforts to address these problems, by enacting legislation to implement MARPOL Annex VI in July 2008. But this is likely to be just the start of Congressional attention to air pollution from ships. Action at the state level, in the courts, and at U.S. EPA will continue to bring the issue to Congress's attention, with numerous opportunities for oversight and legislation.

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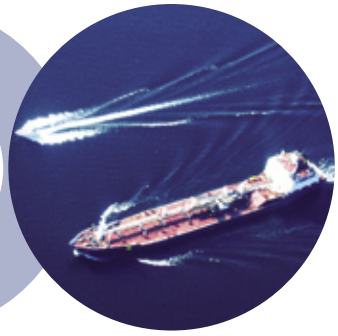

Air Pollution and Greenhouse Gas Emissions from Ocean-going Ships:

Impacts, Mitigation Options and Opportunities for Managing Growth

EXECUTIVE SUMMARY

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

The goal of the International Council on Clean Transportation (ICCT) is to dramatically reduce conventional pollutant and greenhouse gas emissions from personal, public, and goods transportation in order to improve air quality and human health, and mitigate climate change. The Council is made up of leading regulators and experts from around the world that participate as individuals based on their experience with air quality and transportation issues. The ICCT promotes best practices and comprehensive solutions to improve vehicle emissions and efficiency, increase fuel quality and sustainability of alternative fuels, reduce pollution from the in-use fleet, and curtail emissions from international goods movement.

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In a world of global supply chains and rapidly expanding trade, ocean shipping—currently the dominant mode of transport for international cargo—is becoming an increasingly important source of air pollution and greenhouse gas emissions.

Today, ocean-going vessels transport 90 percent of all trade by volume to and from the 25 members of the European Community (EC), and nearly 80 percent by weight of all goods shipped in and out of the United States (EC 2006, US DOT 2003). Over the last three decades, activity in the marine shipping sector, as measured in metric ton-kilometers, has grown on average by 5 percent every year, as shown in Figure ES-1. Since emissions from ocean-going vessels have only been moderately controlled, this growth has been accompanied by a commensurate increase in the sector's contribution to local and global air pollution.

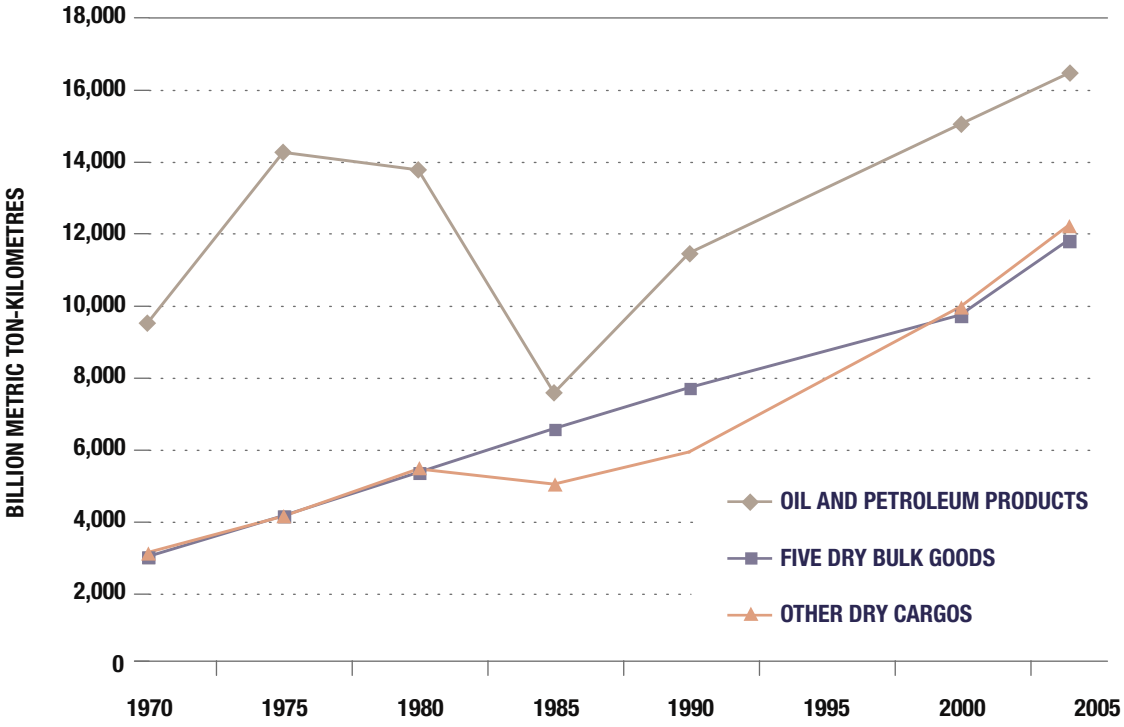

FIGURE ES-1. World Seaborne Freight Transport in Metric Ton-Kilometers by Type of Freight (UNCTAD 2005)

Ocean-going vessels contribute significantly to global emissions of nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM). Indeed it is estimated that by 2020, ship emissions contributions to the European Union (EU) NO_x and SO_x inventories will surpass total emissions generated by all land-based mobile, stationary and other sources in the twenty-five nations (EC 2005). Figure ES-2 and Figure ES-3 show projected NO_x and SO_x emissions from marine and land-based sources in Europe. Air quality impacts from ocean-going vessels are especially significant in port cities and nations with extensive coastlines adjacent to shipping corridors. Studies making use of geographic marine activity data have estimated that about 70–80 percent of all ship emissions occur within 400 km (248 miles) of land (IMO 2000, Corbett et al. 1999). Pollutants such as NO_x, SO_x, and PM have been linked to a variety of adverse public health outcomes, including increased risk of premature death from heart and pulmonary diseases and worsened respiratory disease. Marine emission sources are therefore responsible for a growing share of the public health impacts of exposure to air pollution in many regions. Although ocean-going vessels are among the most efficient modes of freight transport, they also generate substantial quantities of greenhouse gas emissions. Currently, carbon dioxide (CO_2) emissions from the international shipping sector as a whole exceed annual total greenhouse gas emissions from most of the nations listed in the Kyoto protocol as Annex I countries (Kyoto Protocol 1997).

Relative to other sectors, the regulation of commercial marine vessels represents a significant political and legal challenge as ships

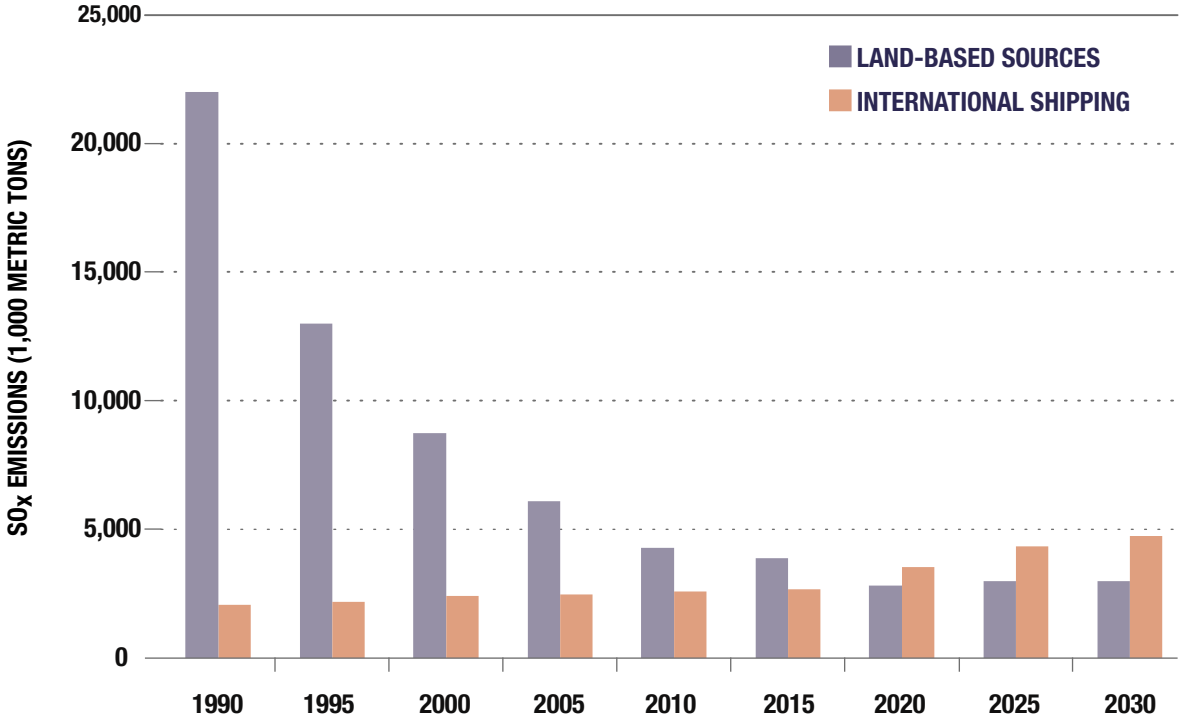

FIGURE ES-2. Inventories and Projections of SO_x Emissions in Europe from Land-based and International Shipping Sources (EC 2005)

operate largely outside of national boundaries. Ocean-going vessels are mainly subject to oversight by the International Maritime Organization (IMO), under the purview of the United Nations. Unfortunately, IMO efforts to mitigate environmental impacts of emissions from global shipping have not kept pace with the industry's growth and the evolution of control technologies for controlling emissions. The international process for establishing new regulatory requirements is further complicated by the complex relationships that exist between those nations to which most ships are registered under so-called "flags of convenience" and the large shipping interests (typically headquartered in other nations) that own most of the ships. As a result, the IMO adopted standards in 1997 that represented only a modest improvement in emissions from unregulated engines. When these standards entered into force they reflected levels already achieved by the average in-use engine. The IMO's current fuel sulfur limit of 4.5 percent is almost twice the average sulfur content of fuels in use in ships today and several thousand times the sulfur level of fuels used on-road in Europe and North America. These standards at best codify the industry's existing practices.

Under these circumstances, accelerated adoption of cleaner marine fuels and wider deployment of existing pollution control technologies and emission reduction strategies could dramatically improve the environmental performance of the shipping sector. To explore these opportunities, the ICCT undertook a review of the status of pollution control measures and programs

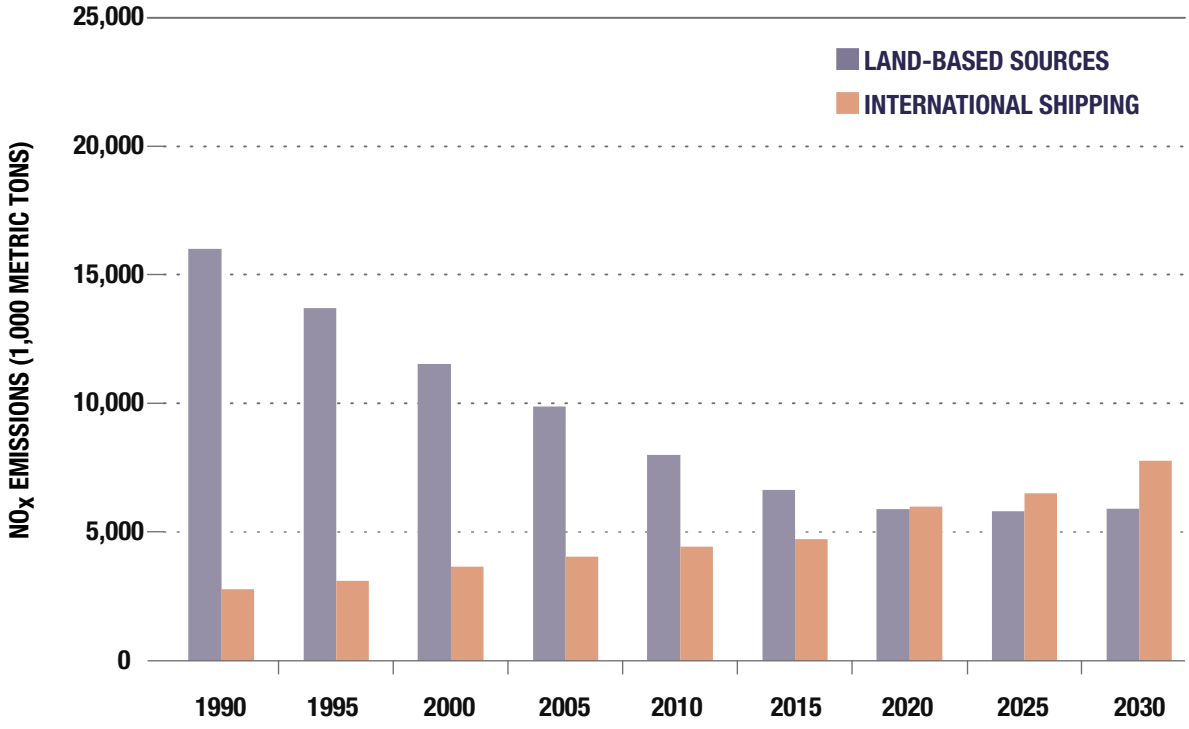

FIGURE ES-3. Inventories of NO_x Emissions in Europe from Land-based and International Shipping Sources (EC 2005)

implemented to date throughout the world. This report describes the results of the ICCT review, focusing on the emission-reduction potential, feasibility, costs, and cost- effectiveness of available environmental mitigation measures for the shipping sector. It also analyzes the legal context within which local, regional, and international programs can be developed. The report concludes with a series of policy recommendations aimed at achieving steady, incremental progress towards reducing emissions from marine vessels that will result in significant environment and public health benefits.

Lower sulfur fuels, optimized engines, and exhaust after-treatment, such as selective catalytic reduction (SCR), have been shown to significantly improve the environmental performance of marine vessels. Other measures such as shore-side electricity and improved auxiliary engines can reduce so-called "hotelling" emissions—that is emissions generated while ships are docked at port. The feasibility and cost-effectiveness of these measures has been demonstrated at several ports. As shown in Figure ES-4, available options for reducing marine NO_x emissions are very cost-effective compared to remaining pollution control options for other mobile and stationary sources, especially in countries that have adopted a range of regulations to limit land-based emissions.

Nations in Europe and North America—along with port cities throughout the world—have deployed a suite of strategies to address air pollution from ships. These strategies have included

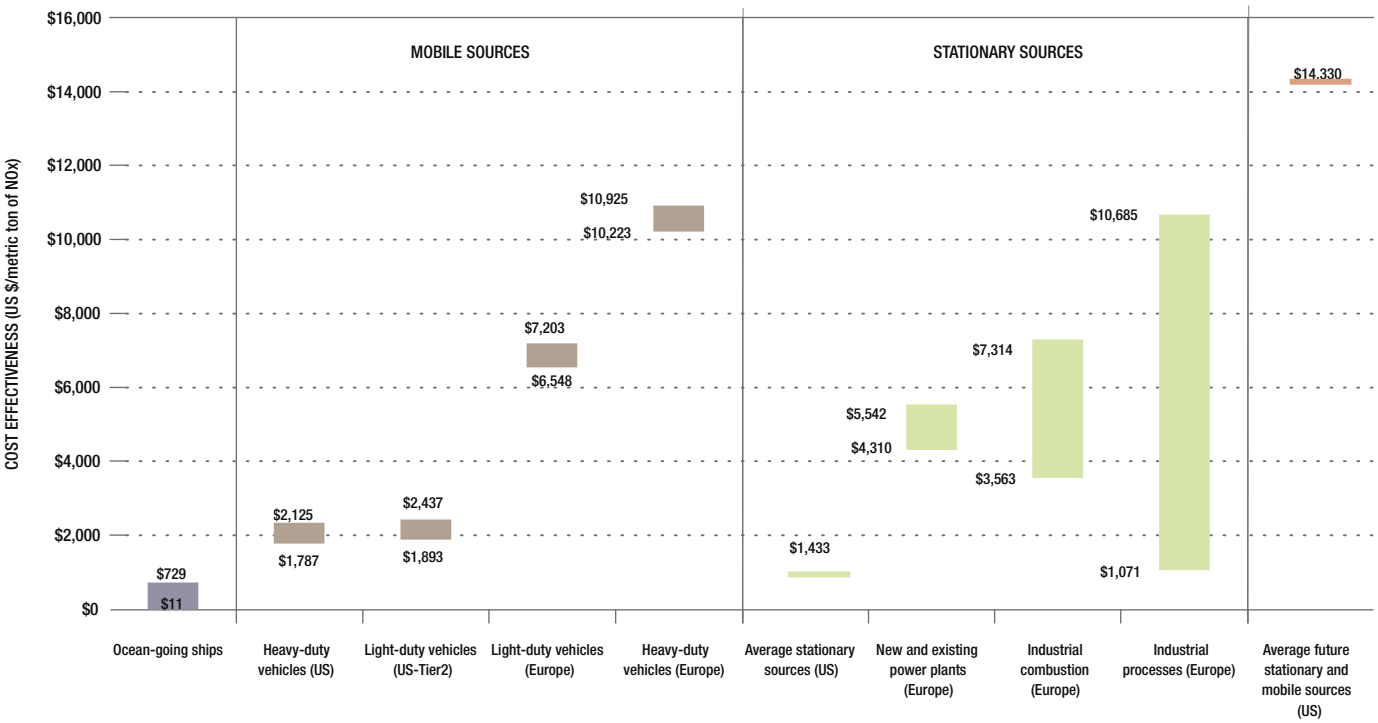

FIGURE ES-4. Comparing the Cost-Effectiveness of NO_x Control Options for Various Source Categories (Entec 2005b, US EPA 1999, 2000, 2005)

regulations, voluntary programs, and market-based programs. Examples of regulatory approaches have included national engine standards for the domestic vessel fleet and fuel sulfur standards for vessels operating in coastal waters and harbors. The voluntary harbor speed limits implemented in the San Pedro Bay by the ports of Los Angeles and Long Beach provide an example of a voluntary approach. Meanwhile, Sweden has experimented with a market-based approach by imposing a system of environmentally differentiated fairway and port dues that vary with ship emissions. This successful program has led to increased use of lower-sulfur fuels and to the installation of SCR systems on a number of ships calling on Swedish ports.

The recommendations advanced in this report identify implementation milestones in each of several distinct categories: (1) marine fuels, (2) new engines, (3) new vessels, (4) existing engines and vessels, (5) greenhouse gas emissions, (6) and in-port emissions. In the near-term, these recommendations generally call for widespread adoption of proven best available technologies in the 2010 timeframe. The ICCT's medium-term recommendations propose intermediary steps to be taken between 2012 and 2017. Finally, technology-forcing, long-term recommendations are proposed for the post-2020 period. Implementing these recommendations will require the active engagement of numerous stakeholders, including ship owners and operators, ports, and regulators. Leadership from the businesses that demand shipping services is also crucial. Shipping customers are uniquely positioned to create incentives for improved performance in the shipping sector because they can require that their goods be transported with the least possible impact on the environment.

MARINE FUELS

Reducing fuel sulfur content is an essential component of any strategy aimed at reducing SO_x and PM emissions from marine vessels. Lower sulfur fuel also enables the use of advanced after-treatment for NO_x reductions. Existing plans to implement SO_x Emission Control Areas (SECAs), starting in 2006 in the Baltic Sea and expected in 2007 for the North Sea and English Channel, mean that a portion of the world's ships are now or will soon be using 1.5 percent sulfur fuels or equivalent after-treatment. In the short term, the ICCT recommends including other major shipping areas, such as the Mediterranean and parts of the North Atlantic and Pacific Rim, in the SECA program. Moreover, decisions concerning future SECAs should take into account sulfur- and particle-related public health impacts as well as impacts on land and sea ecosystems. Finally, ICCT recommends that the fuel sulfur limit in SECAs be lowered from 1.5 percent to 0.5 percent to achieve further emissions reduction in the 2010 timeframe and to facilitate the shift to lower sulfur fuels on a global scale.

As a next step, the ICCT recommends that a uniform global fuel sulfur standard of 0.5 per-

cent be introduced in the medium term. Relative to the 2.7 percent average sulfur content of current marine fuel, this step alone will reduce SO_x emissions by approximately 80 percent and PM emissions by a minimum of 20 percent. At this level of fuel quality, selective catalytic reduction (SCR) will be fully enabled. Although SCR can function at higher fuel-sulfur levels, durability is significantly improved at lower levels.

Some uncertainty remains regarding the widespread availability of lower sulfur fuels in the recommended timeframe. However, there has been significant momentum among various stakeholders to reduce the global fuel sulfur limit. For example, some industry groups have recently expressed support for a global fuel standard requiring the use of 1 percent sulfur distillate fuel in the near term (INTERTANKO 2006). In addition, current regulations in California and Europe require low-sulfur fuels in coastal waters, inland waterways, and at ports ahead of the ICCT-recommended dates. For example, the California auxiliary engine program requires the use of 0.5 percent sulfur fuel in the state's coastal waters and at port by 2007. The allowed sulfur level is lowered to 0.1 percent by 2010. Fuel with 0.1 percent sulfur content will also be required in ports and inland waterways in Europe by 2010

Adoption of a lower global fuel sulfur limit would provide the refining industry the clear signal it needs to invest in upgrading production facilities and ensure increased fuel availability. The ICCT also encourages further efforts to implement lower sulfur fuel ahead of the recommended schedule in coastal waters, inland waterways, and at ports. These programs can facilitate a transition to fleet-wide use of lower sulfur fuels while ensuring emissions reductions in proximity to the potentially impacted populations. In the long-term, fuel standards for marine fuels should be harmonized with standards for on-road fuels (500 ppm to 10–15 ppm).

NEW ENGINES

The IMO's recent decision to review NO_x standards for ocean-going vessels represents an opportunity to make significant progress in improving the performance of marine engines. The ICCT recommends requiring new engines to achieve NO_x limits that are 40 percent lower than the current standard in the near term. This level can be reached primarily through engine upgrades. New engine standards should also be set to ensure significant reductions in PM emissions. A medium-term standard set at a level 95 percent below current standards for NO_x would require the use of additional emission control technologies, including after-treatment controls. Further PM reduction should also be required. These near- and medium-term standards should be adopted at the same time to give manufacturers sufficient lead time to prepare for compliance and to direct their research and development activities accordingly. In addition to more stringent standards, the ICCT recommends that manufacturers be (1) required to

certify engines using fuels that reflect actual in-use fuel quality; (2) be liable for in-use compliance and subject to in-use testing; and (3) be required to demonstrate the durability of emission control systems used to achieve compliance.

The production and use of engines that are significantly cleaner than the proposed standards should be encouraged both in the short and medium term through incentives to engine and technology manufacturers as well as vessel operators. Support for early technology demonstrations is necessary to ensure viable technology options are available to meet increasingly stringent standards. In the long term, the ICCT recommends deploying incentives and other strategies to further promote the use of advanced technologies, especially technologies that achieve near-zero emissions, in promising applications.

NEW VESSELS

Many opportunities exist during a vessel's design and construction phases to make changes that would facilitate the use of low-emission control technologies. In the near term, the ICCT recommends that engine rooms be designed with enough space to allow for retrofit technologies including SCR as well as tank capacity for fuel switching in SECA and coastal areas. New vessels, especially ferries and cruise ships with regular routes and ports of call, should be built with the needed on-board equipment to utilize shore power when port-side facilities exist. Standardization of international shore power requirements is also needed to ensure compatibility between shore-side facilities and ships. The ICCT supports the ongoing efforts within IMO to develop guidelines for shore-side electricity. In the long term, the ICCT encourages the use of advanced vessel design concepts that optimize energy efficiency as well as emissions performance and that incorporate propulsion from renewable energy sources including solar and wind power, where feasible.

EXISTING VESSELS AND ENGINES

Control measures targeted at existing vessels and engines are necessary to significantly impact fleet-wide emissions. A low fleet turnover rate means that the largely uncontrolled vessels that make up the majority of the international marine shipping fleet today will continue to pollute for several decades before they are retired. Most existing control technology options have been developed and demonstrated on in-use vessels, suggesting that a large-scale retrofit program should be technically feasible. In the near term, the ICCT recommends that in-use standards reflecting best available control technologies be developed within the IMO. These standards would allow, for example, future market-based programs (including the range of possible differentiated fee programs) to harmonize their emission requirements. The ICCT further recommends that any in-use standards used in market-based programs be designed to become more stringent over time so as to provide ongoing incentives for adopting the newest control technologies as they become

available, proven, and cost-effective. The program should provide additional incentives to demonstrations of advanced technologies that provide emission reductions beyond the adopted in-use standards. Also in the short term, the ICCT recommends exploring the feasibility of early ship retirement as an extension of the ship recycling programs being developed by the IMO. If determined feasible, this type of program could be implemented in the medium to long term.

GREENHOUSE GASES

The shipping sector's contribution to gases and particles that impact the Earth's climate is only beginning to be fully understood. Here, the ICCT recommends that near-term efforts focus on developing a baseline for the climate impacts of the world's vessel fleet. Once a baseline is established, market-based measures to reduce greenhouse gas emissions can be introduced, also in the near term. If cap and trade programs are developed for GHGs, they should only cover shipping sources and not include land-based sources. If the shipping sector becomes a source of credits for greenhouse gas emissions reductions, steps must be taken—as with any source of credits—to ensure that reductions are recognized only to the extent that they are quantifiable, enforceable, surplus to otherwise mandated reductions, and permanent. The ICCT also recommends that the IMO develop fuel economy standards for ships applicable to new vessels in the near term and existing vessels in the medium term.

AT PORT

The ICCT recommends that emission mitigation measures should be adopted at all major port facilities and be fully integrated with local and/or regional air quality plans. Each port type has access to a range of implementation mechanisms to reduce emissions from ships at berth. For example, landlord ports can include emission reduction requirements in their lease agreements with tenant operators. Operating ports can directly implement some infrastructure measures.

Providing shore power is often the most effective emission-reduction option for vessels while at port. In some locations, however, pollution impacts from electricity generation may make this option less attractive. The ICCT recommends that port authorities and regulators select the strategy or combination of strategies that cost-effectively provides the most environmental benefits. If shore power does not meet these criteria, other options should be implemented including requiring hotelling ships to use the lowest sulfur on-road fuels available and/or engine emission controls. The implementation of shore power and alternative mitigation technologies should prioritize new terminals as well as those that are near residential areas.

In the medium-term, the ICCT recommends that incentives be provided for utilizing low-carbon sources for shore-side power (including renewable solar and wind generators). In

the long-term, the development of cost-effective energy storage technologies and advanced low- or non-carbon generating options should make it possible to achieve near-zero hotelling emissions.

Table ES-1 summarizes the ICCT recommendations towards mitigating the impact of ocean-going vessels on air quality and climate change.

In conclusion, supplemental international action within the IMO is necessary to produce reasonable progress in addressing ship impacts on local air quality and global climate change. National and regional policy-makers are increasingly seeking to accelerate the introduction of emission control technologies and cleaner fuels into the international marine sector. Within the IMO process, several countries including Sweden, Norway, and Germany have emerged as proponents of further measures to reduce emissions from ships. The few environmental organizations that have obtained consultative status with the IMO have also been leading efforts to accelerate progress on these issues. Other environmental NGOs with related activities and expertise should consider applying for consultative status to bolster these efforts. Finally, these efforts within the IMO must be brought to the attention of the larger public. Greater public awareness of the environmental impacts of routine ship activity will undoubtedly result in added pressure to reduce emissions in much the same way that highly publicized oil spills led to an increased focus on accident prevention, impact mitigation, and accelerated phase-out of single-hull tanker ships by the IMO. Best practices and local or national successes should be shared with a global audience to demonstrate that dramatic reductions in emissions from marine vessels, both at sea and in port, are not only feasible but also cost-effective. In the end, collaboration between the public and private sectors and across a wide set of stakeholders will be essential to forge support for sustainable long-term measures to mitigate the public health and environmental impacts of shipping around the world.

TABLE ES-1. ICCT Recommendations for Ocean-Going Vessels

ICCT RECOMMENDATIONS		IMPLEMENTATION MECHANISM
Fuels	— Short term: ○ Lower fuel sulfur level in SO_x Emission Control Areas (SECAs) from 1.5% to 0.5%. ○ Include SO_x/PM related health effects in addition to impacts on air, sea, and land as justification for SECA. ○ Expand SECA program to high ship-traffic areas in Mediterranean, Pacific Rim and North Atlantic. ○ Regional limits in coastal areas, inland waterways, and at ports — Medium term: 0.5% sulfur fuel globally — Long term: Harmonization with on-road diesel fuels (500 ppm to 10-15 ppm over time)	— International standards (IMO)
New engines	— Short term: ○ NO_x standards 40% percent below current IMO standards (2000 level). ○ PM standards ○ Encourage new technology demonstration — Medium term: ○ NO_x standards 95% percent below current IMO standards (2000 level) ○ PM standards further reduced ○ Encourage new technology demonstration — Long term: Encourage the use of advanced technologies, especially near-zero emission technologies in promising applications	— International standards (IMO)
New vessels	— Short term: ○ Adopt international requirements for shore power standardization. ○ All new ships built with shore-side electricity capability, especially cruise ship and ferries — Long term: Promote the use of advanced vessel design concepts in promising applications	— Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges — International regulation (IMO)

Table continues on next page

TABLE ES-1., continued

ICCT RECOMMENDATIONS		IMPLEMENTATION MECHANISM
Existing vessels and engines	— Short term: ○ Adopt emissions performance standards by vessel class and engine characteristics based on demonstrated retrofit potential. ○ Study feasibility and potential impact of programs to promote early ship retirement and environmentally sound disposal	— International standards (IMO) — Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges
GHG	— Short term: ○ Develop GHG emission inventory and fleet baseline ○ Market-based measures for vessels ○ Implement fuel economy standards by vessel class and engine characteristics for new vessels — Medium term: Implement fuel economy standards by vessel class and engine for existing vessels	— Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges — Cap and trade program for shipping sector only — International standards (IMO)
At port	— Short term: Select strategy that provides maximum emissions reduction benefits depending on local fuel availability and environmental performance of electricity generation ○ Shore-side electricity ○ Lowest sulfur on-road fuel and NO_x and PM after-treatment — Medium term: Market-based measures to promote low- or non-carbon energy sources to supply shore-side electricity for docked ships	— Port authority requirement — Preferential contracting of cleanest carriers — Environmentally differentiated fees and charges

Air Pollution and Greenhouse Gas Emissions from Ocean-going Ships: Impacts, Mitigation Options and Opportunities for Managing Growth, both the executive summary and the full report, is available on our website: www.theicct.org.

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Environmental Defense Fund
Environmental Defense Fund is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

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Now in its second century, the American Lung Association is the leading organization working to save lives by improving lung health and preventing lung disease. With your generous support, the American Lung Association is "Fighting for Air" through research, education and advocacy.

National Association of Clean Air Agencies
The National Association of Clean Air Agencies (NACAA) comprises the air pollution control agencies in 53 states and territories and over 165 metropolitan areas across the country. NACAA's members have primary responsibility for ensuring that everyone in our nation breathes clean, healthful air.

Puget Sound Clean Air Agency
The Puget Sound Clean Air Agency is the regional air quality agency for the area including the major container ports of Seattle and Tacoma, Washington. We work together to clean the air we breathe and protect our climate through education, incentives and enforcement.

Cover photo: Ocean-going ship at the port of Los Angeles. Photo by Janea Scott.

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The complete report is available online at www.edf.org.

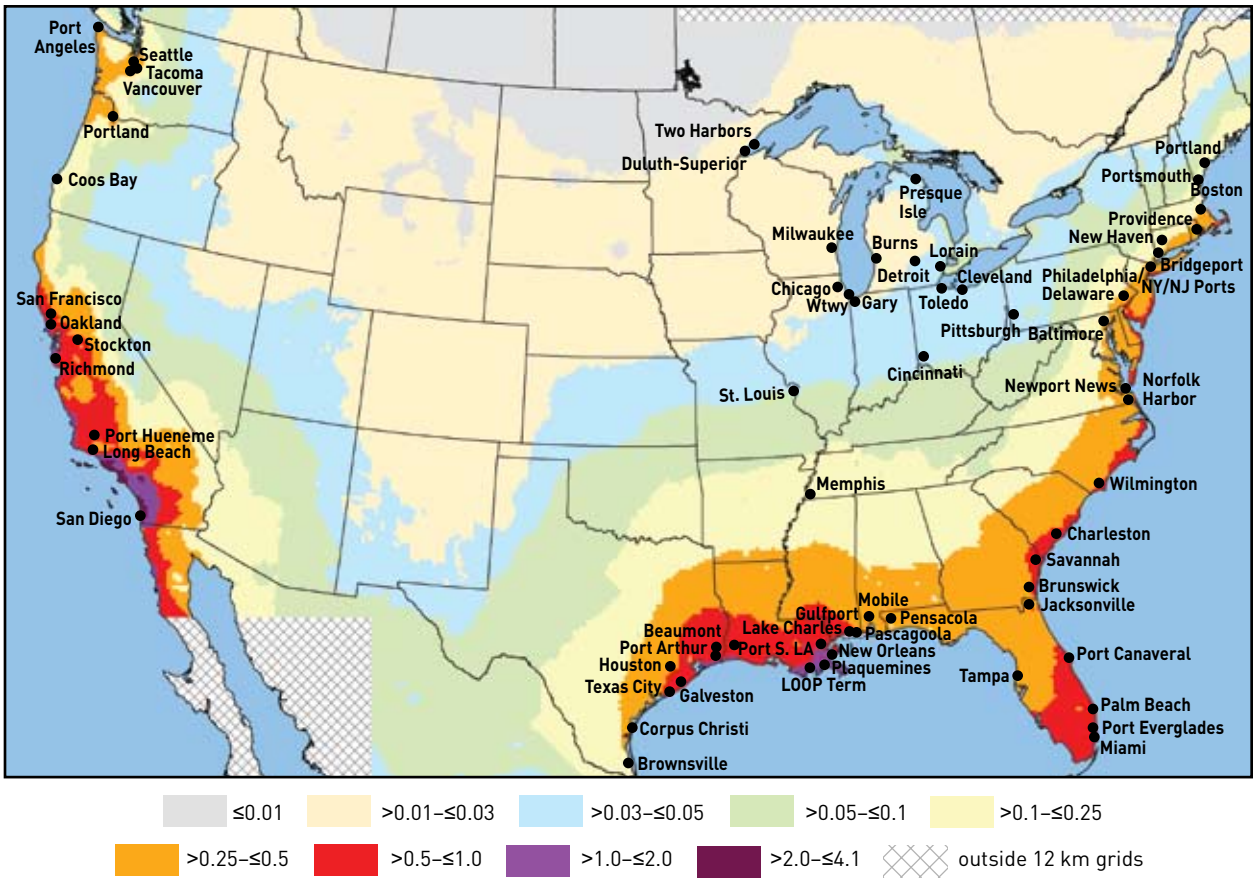
Executive summary

The United States Government can chart a course to achieve healthier air for the millions of Americans impacted by the emissions from ocean-going ships by applying to the International Maritime Organization (IMO) for an Emission Control Area (ECA)—an area where stricter pollution limits apply. Ocean-going ships, sometimes referred to as Category 3 ships, are the largest ships on the water and include container ships, tankers, cruise ships, and bulk carriers. These large vessels travel all over the world, making international shipping a significant factor in U.S. port traffic and emissions. In fact, 90% of ship calls on U.S. ports are made by foreign-flagged vessels. Ocean-going ships impact air quality in U.S. coastal cities and ports and even send pollution hundreds of miles inland.

The American Lung Association (ALA), Environmental Defense Fund (EDF), the National Association of Clean Air Agencies (NACAA), and the Puget Sound Clean Air Agency (PSCAA) strongly support the leadership of the United States Government to fully implement the pollution limits available under international

FIGURE 1

An Emission Control Area for the United States would dramatically reduce particulate pollution from ocean-going ships by 2020 (change in annual concentration μg/m^3)



Difference in annual average SMAT $PM_{2.5}$ (μg/m^3)—2020ce-2020ce—200nm. Source: Power point presentation by Byron Bunker, Center Director of EPA's Office of Transportation and Air Quality given Wednesday, December 17, 2008 at EPA Region 9..

law to reduce harmful marine air pollution. We also respectfully request that the IMO promptly act on the United States ECA application, and give it full consideration at the July 2009 meeting of the IMO Marine Environment Protection Committee (MEPC 59). As Figure 1 illustrates, prompt action to establish an ECA for the United States will secure vital clean air protections for millions of Americans.

- This map depicts the estimated reductions in annual concentrations of harmful particulate pollution in 2020 if the United States establishes an ECA to cover the nation's entire Exclusive Economic Zone, which generally extends a distance of 200 nautical miles from the coast. About 87 million Americans live in port areas that are not meeting basic federal public health standards.

- The Environmental Protection Agency's early estimates indicate the benefits of an ECA would be about 5 times larger than that of the recently finalized commercial ships and locomotives rule.[1]

- ECAs require fuel to be over 60% cleaner than the global average by 2010 and 96% cleaner in 2015, resulting in emissions reductions far greater and faster than by baseline global standards.

- Establishing an ECA for the United States would reduce smog-forming oxides of nitrogen (NO_x) emissions by 80% from existing engine emission levels, particulate pollution (PM) by 85% and sulfur oxides (SO_x) by 95%.

- Estimated 2020 particulate concentration reductions in the United States as a result of an ECA are as high as 4.1 $\mu g/m^3$ (micrograms per cubic meter) in some of the most impacted port areas.

- In some metropolitan areas, like Houston, the expected reductions could mean the difference between meeting and not meeting the health-based federal clean air standards.[2]

Healthier air on deck

The International Maritime Organization has charted a course for deep reductions in air pollution from ships

The IMO, established under the purview of the United Nations, is responsible for coordinating with member nations to establish international pollution standards for ocean-going ships. Annex VI of the International Convention for the Prevention of Marine Pollution from Ships (MARPOL) treaty contains the clean air provisions that apply to all signatory nations. The United States became a party to this treaty in 2008. Annex VI consists of two sets of emissions standards: (1) global standards that apply to all ships arriving at, and departing from, countries that are party to the MARPOL treaty; and (2) more rigorous geographically-based standards that apply in specially designated areas called Emission Control Areas (ECAs).

In October 2008, the IMO updated Annex VI of the MARPOL treaty to be more protective. The new standards require modest global reductions in oxides of nitrogen (NO_x), particulate pollution (PM), and sulfur oxides (SO_x) pollution. They also put in place the framework for more rigorous reductions to be made in ECAs, those areas hardest hit by shipping pollution. We support the U.S. application to the IMO for ECA designation in order to enforce these rigorous standards on all international ships that enter the area.[3] The global and ECA emission control standards are as follows:

NO_x emission control standards

- 20% NO_x reduction beginning in 2011 for new engines.
- 15 to 20% NO_x reduction beginning in 2011 for existing engines.
- **Within an ECA:** 80% NO_x reduction beginning in 2016 for new engines.

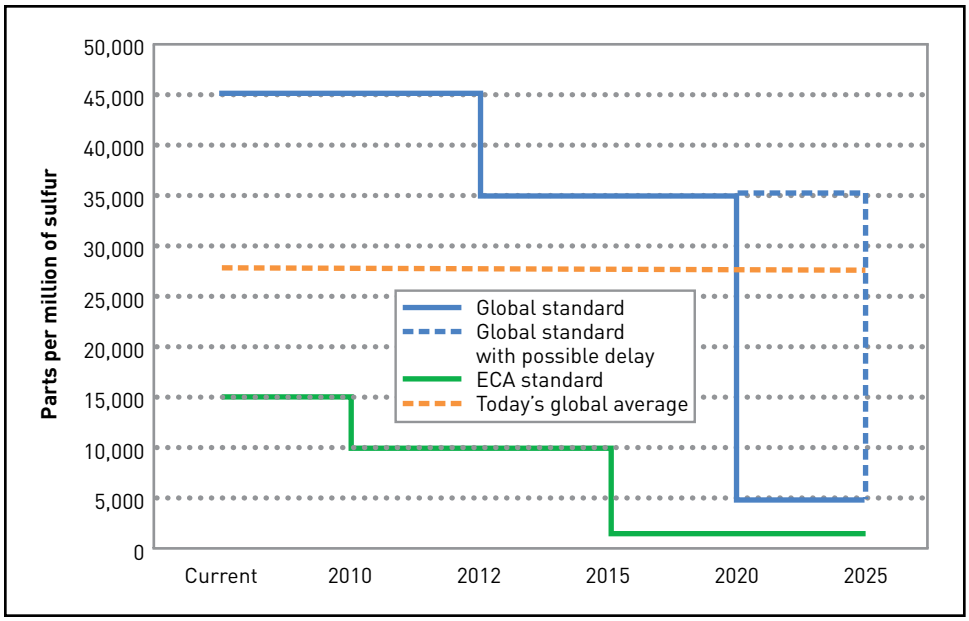
These NO_x standards are based on advanced emission control technology, including selective catalytic reduction (SCR).[4] SCR is a commonly used technology to reduce NOx emissions in all varieties of diesel engines, and has been successfully installed in over 300 marine vessels.[5]

Fuel quality standards

- Beginning in 2012, global sulfur fuel levels will drop from the current standard of 45,000 parts per million (ppm) to 35,000 ppm. However, the current global average is about 27,000 ppm.[6]
- Global sulfur limits will drop to 5,000 ppm in January 2020. However, this deadline may be delayed to 2025 pending a review in 2018 of the availability of the cleaner fuel.
- **Within an ECA:** Sulfur limits will drop from the current standard of 15,000 ppm to 10,000 ppm in August 2010 and to 1,000 ppm in January 2015.[7]

The IMO's action to improve fuel quality is essential because ocean-going ships are currently powered by residual fuel, which is some of the dirtiest fuel on earth.

FIGURE 2
Global sulfur requirements for ocean-going ship fuel under new IMO rule



Source: IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008.

Residual fuel has a high content of ash, metals, nitrogen, and sulfur that result in high SO_x and PM emissions. Since SO_x emissions are directly related to the concentration of sulfur in the fuel, reducing the sulfur in fuels, as required by the IMO, also reduces SO_x emissions.[8] Fortunately, most ship engines that are designed to run on residual fuel are also capable of burning cleaner low sulfur distillate fuel. As a result, no significant ship changes or upgrades are necessary to burn cleaner fuel,[9] so the cleaner fuel required in an ECA can be used immediately.

Figure 2 illustrates the far greater reduction in fuel sulfur content in ECAs compared to the baseline global standards. While the new global standards require ship fuel to reduce sulfur limits to 35,000 ppm in 2012, this will have minimal impact because the global average fuel sulfur level is 27,000 ppm. More significant reductions will be achieved in 2020, when the global standard drops to 5,000 ppm—this is an 80% reduction from the global average. However, this 2020 deadline may be delayed to 2025 pending a review in 2018 of the availability of the cleaner fuel.

In contrast to the global standards, ECAs require fuel to be over 60% cleaner than the global average in 2010 and 96% cleaner in 2015, reducing more pollution far more quickly than under the baseline global standards. Sulfur levels in a U.S. ECA would not drop to 10,000 ppm until 2012[10] and EPA has confirmed that the lower sulfur fuel required will be available at that time.[11]

When fully implemented in the United States, the ECA requirements for engines and fuel would reduce NO_x emissions by 80% from current levels, PM by 85% and SO_x by 95%.[12] These reductions will provide clean air benefits to communities from coast to coast.

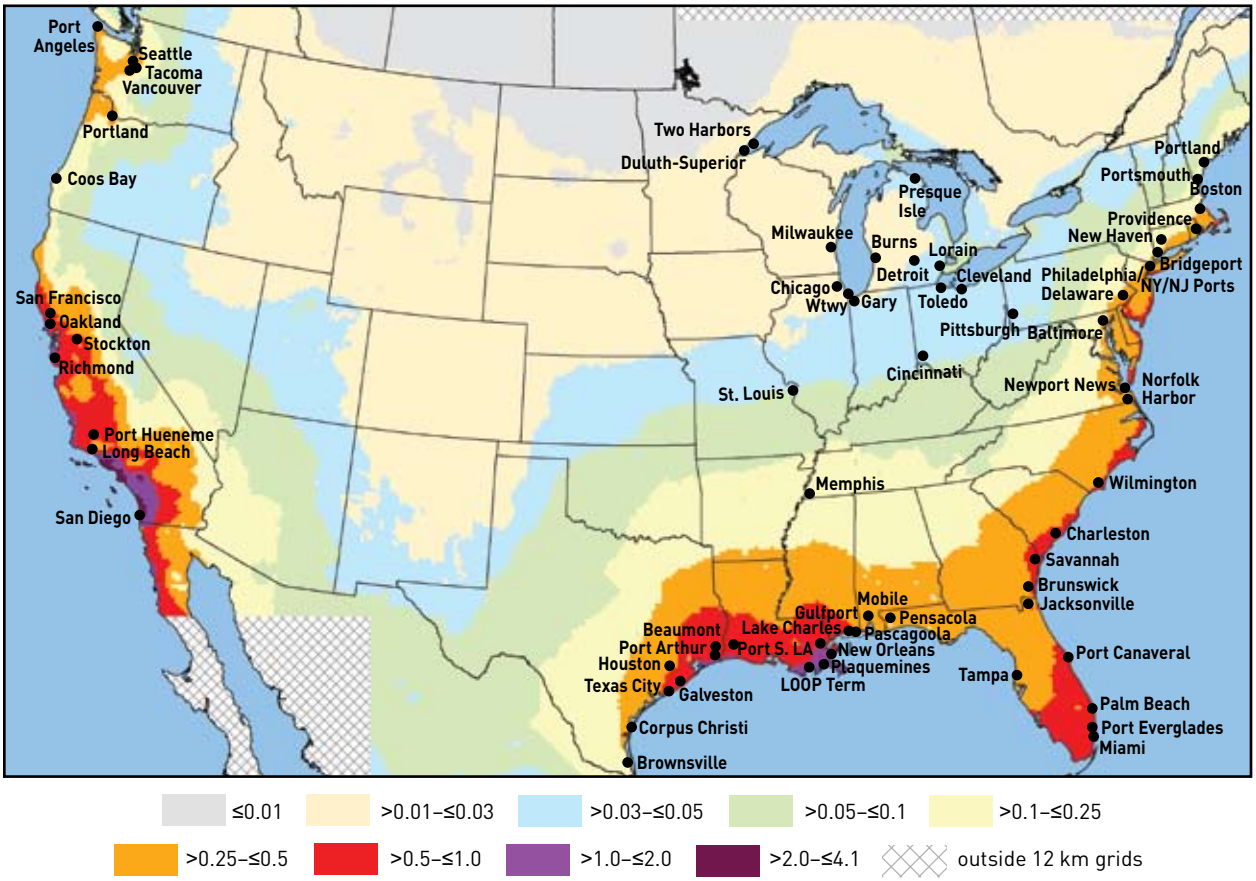
Securing an Emission Control Area for the United States will have a striking impact on air quality across our nation

Diesel exhaust, like that emitted from ocean-going ships, is among the most dangerous and pervasive sources of air pollution. The constituents of diesel exhaust include particulate matter (PM), implicated in a host of respiratory problems and thousands of premature deaths every year; smog-forming oxides of nitrogen (NO_x); sulfur dioxide (SO_2), which forms harmful fine particles and falls back to earth as acid rain; and a noxious brew of toxic chemicals that together pose a cancer risk greater than that of any other air pollutant. Shipping-related PM emissions contribute to approximately 60,000 global deaths annually, with impacts concentrated in coastal regions on major trade routes.[13] The U.S. Environmental Protection Agency (EPA) estimated that in 2001, ocean-going ships emitted:

- more than 54,000 tons of fine particulate matter, which is equivalent to the pollution from 117 coal-fired power plants.[14]
- approximately 745,000 tons of smog-forming NO_x pollution—comparable to the NO_x emissions from more than *800 million* of today's new cars,[15] and

FIGURE 3

Estimated reductions in annual PM concentrations from U.S. ECA in 2020 (ug/m^3)



Difference in annual average SMAT $PM_{2.5}$ (μg/m^3)—2020ce-2020ce—200nm. Source: Power point presentation by Byron Bunker, Center Director of EPA's Office of Transportation and Air Quality given Wednesday, December 17, 2008 at EPA Region 9.

- around 450,000 tons of SO_2, which is more than 40% of the total SO_2 from the U.S. transportation sector.[16] This percentage is due mainly to the low grade residual fuel ocean-going ships use. Residual fuel is the tar-like product left behind after all the lighter petroleum is refined from crude oil and is so viscous that it requires heating before it can be burned.[17]

The diesel air pollution from ocean-going ships has been under regulated. In the past two decades, EPA has set rigorous emission standards for nearly all other mobile sources of diesel, including highway trucks and buses, nonroad sources such as construction equipment, locomotives and smaller commercial ships. Securing an ECA for the United States will put in place rigorous standards for ocean-going ships that are more comparable to the standards set for other diesel sources. Establishing an ECA that covers the nation's entire Exclusive Economic Zone will result in significantly greater emissions reductions than the IMO baseline global standards and will provide much needed air quality improvements across the nation, particularly in densely populated coastal areas.

Figure 3 depicts the air quality benefits the United States could secure by implementing an ECA for the entire coastline of the mainland United States. Figure 3 speaks loudly and clearly: *Every state* in the lower 48 would see an improvement in air quality if large ocean-going ships in U.S. waters met the rigorous pollution control standards that would be required in an ECA—even states that are landlocked. Particulate pollution reductions, represented in annual average concentrations, range from 0.01 to 0.1 $\mu g/m^3$ (micrograms per cubic meter) in the middle of the country up to 4.1 ug/m^3 in some of the hardest hit coastal and port areas. These reductions will translate into significant health benefits across the nation. Additionally, in some metropolitan areas, like Houston, the expected reductions could mean the difference between meeting and not meeting the health-based federal clean air standards.[18]

Given the enormous clean air and public health benefits to be gained from strong emission standards for ocean-going ships, the IMO should promptly act on the U.S. application to establish an ECA.

IMO approval of U.S. Emission Control Area will clear the way for healthier air

When countries apply to the IMO for an ECA designation, they must demonstrate a need to prevent, reduce and control emissions of SO_x, PM, and/or NO_x from ships. The United States has a compelling case for ECA designation. These contaminants are major contributors to unhealthy air pollution in the United States, especially the harmful levels of particulate pollution and ground-level ozone in many communities.

More than half of all Americans live in communities out of compliance with the federal health-based standards for ozone and particulate pollution.[19] And millions live near U.S. port cities that are especially hard hit by shipping pollution. EPA estimates that 87 million Americans live in port areas that are not meeting basic federal health standards.[20]

An ECA application submitted by the United States this spring will be considered by the IMO at the July 2009 meeting of the Marine Environment Protection Com-

mittee (MEPC 59). The IMO will then vote on the U.S. application in 2010. If accepted, the ECA designation will go into effect in 2012.[21] We respectfully urge the IMO to approve the ECA designation for the United States. The need for these clean air measures is clear and convincing.

Pollution from ocean-going ships in U.S. waters impacts public health and revered ecosystems

The large ocean-going ships that travel along U.S. coastlines and dock at our nation's ports deliver considerable amounts of pollution in addition to the goods they bring. Much of the pollution from these large vessels is concentrated in ports and the densely populated metropolitan areas near ports that, in almost every instance, already suffer from unhealthy air.

The health effects of diesel emissions in general are well documented. Diesel air pollution adds to cancer risk all around the United States. In many places, diesel emissions create the greatest contribution to cancer risk from air pollution. For example, in the Seattle area, diesel soot accounts for somewhere between 70% and 85% of the total cancer risk from all air toxics.[22] And in the South Coast Air Basin, which includes Los Angeles, diesel exhaust contributes about 84% of the cancer risk from air toxics.[23]

In addition, because diesel emissions are a complex mixture of chemicals, exposure to this pollution contributes to a wide range of non-cancer health risks, including pulmonary disease, cardiovascular effects, neurotoxicity, low birth weight in infants, premature births, congenital abnormalities and elevated infant mortality rates.[24]

Particulate matter

Particulate matter can aggravate respiratory conditions such as asthma and chronic bronchitis and has been associated with cardiac arrhythmias (heartbeat irregularities), heart attacks and premature deaths. People with diabetes, heart or lung disease, the elderly and children are at highest risk from exposure to particulate pollution.[25]

A recent study calculated that, worldwide, shipping-related PM emissions contribute to approximately 60,000 deaths annually, with impacts concentrated in coastal regions on major trade routes.[26] The study also predicted that under the regulations in place before the amendments to Annex VI were passed in October 2008, and with the expected growth in shipping activity, annual deaths could increase 40% by 2012, increasing the number of deaths associated with shipping pollution to 84,000 every year.[27]

NOx and ozone

Oxides of nitrogen transform into aerosol particulates and also combine with volatile organic compounds in the presence of sunlight to form smog, or ground-level ozone. High ozone levels cause acute respiratory problems, aggravated asthma, decreased lung function, inflammation of lung tissue, an increase in hospital admissions and emergency room visits for respiratory causes, and crop damage. Children with asthma are among those most at risk. Ozone also is associated with premature

death.[28] The national health-based standard for ozone was strengthened in March 2008 to be more protective than the 1997 standard.

Environmental impacts

Pollution from ocean-going ships impacts our environment, in addition to impacting public health. The same fine particles that can be breathed deep into the lungs adversely affecting human health also cause the haze that pollutes scenic vistas in national parks and wilderness areas and creates "brown clouds" in our urban centers.

The constituents of diesel exhaust also contribute to the acid rain that continues to harm sensitive ecosystems across the United States. Acid rain occurs when pollutants like SO_2 and NO_x react with water, oxygen, and other chemicals in the atmosphere to form various acidic compounds. The result is a mild solution of sulfuric acid and nitric acid.[29] When this acid falls back to the earth, it harms our nation's revered ecosystems–causing acidification of lakes and streams and contributing to the damage of trees, like red spruce trees, at high elevations and many sensitive forest soils.[30]

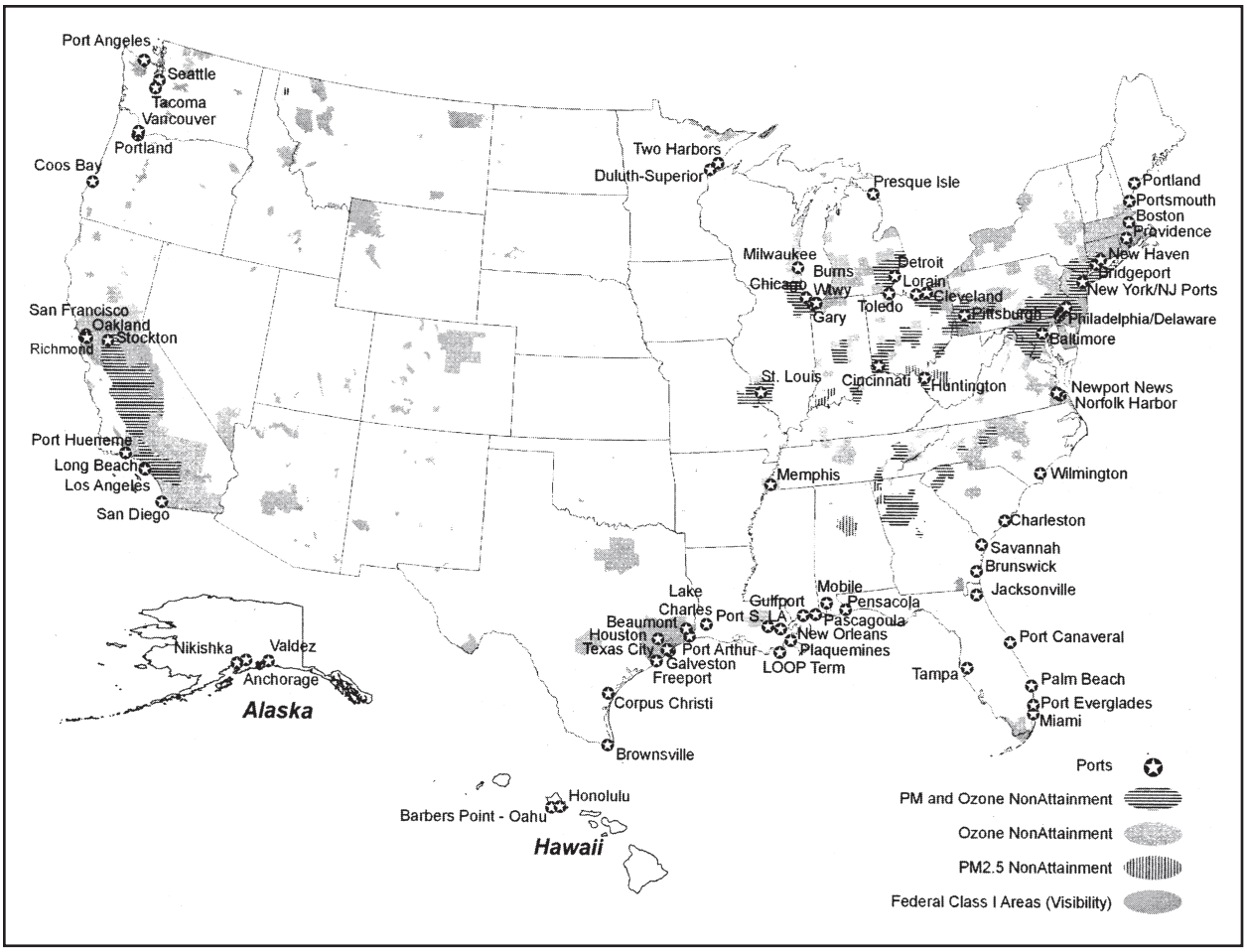
Pollution from ocean-going vessels also contributes to global climate change. In 2006, in U.S. waters alone, these vessels emitted about 55.6 million metric tons of CO_2.[31] Additionally, ocean-going ships contribute about 1.7% of global black carbon emissions every year.[32] Black carbon refers to the solar-absorbing component of soot, which is released during the combustion process, and is another potent global warming pollutant.[33] Studies show that black carbon triggers snow and ice melting, and contributes to Arctic warming.[34] And in some places, including the Alaska region, shipping can contribute an additional 40% to atmospheric concentrations of black carbon.[35] Further, black carbon from shipping could have disproportionate effects on air quality near port areas because of the intensity of shipping in these areas.[36]

Timely reductions in PM and NO_x from ocean-going ships will help states protect human health and achieve cleaner air

Approximately 88 million people nationwide either live in counties that do not meet the 1997 federal air quality standards for fine particles, or their counties contribute to violations elsewhere.[37] About 132 million people live in counties that violate the 1997 eight-hour federal air quality standard for ozone.[38] These standards have recently been updated to be more protective, so the number of people living in communities that violate federal air quality standards will increase.[39]

Ocean-going ships are a major source of harmful fine particles, and their emissions also contribute to harmful smog levels. In Figure 4, EPA identifies 40 ports that are currently located in nonattainment areas. EPA estimates that some 87 million Americans live in these port areas that are not meeting basic federal public health standards for ground-level ozone and particulate pollution.[40] This map, however, is not based on recent updates strengthening the public health-based standards for fine particulate matter and ozone, so air quality problems in U.S. port areas are likely to be more widespread than this map indicates. For example, both the Port of Seattle and

FIGURE 4
Air quality problems are widespread especially in U.S. port areas



Source: Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69528.

Port of Tacoma areas are within a region that is in violation of the new federal ozone standards based on data for Summer 2008.

As illustrated in Figure 1 previously, reducing pollution from these ships will help every state in the nation improve its air quality.

Conclusion: Establishing an Emission Control Area for the United States will dramatically reduce marine shipping pollution and protect public health

The United States has the opportunity to join an international emissions control program that would reduce shipping pollution along U.S. coastlines, at U.S. ports and indeed, in every state in the continental United States. Participation in the ECA program would result in SO_x reductions of approximately 98% and NO_x reductions of up to 80% from each new ship. Prompt action by the IMO can secure healthier air for millions of Americans.

ALA, EDF, NACAA, and PSCAA support the United States' application for a U.S. ECA and respectfully recommend that the IMO promptly approve the application.

Ocean-going vessels from all over the world dock at over 100 U.S. ports. EPA estimates that some 87 million Americans live in port areas that do not meet basic federal public health standards for ground-level ozone and particulate pollution.[41] Fortunately, a pivotal opportunity is on deck to achieve significant reductions in the pollution from ocean-going ships. With U.S. leadership in requesting the establishment of an Emission Control Area, and IMO approval, the nation will be sailing more smoothly towards healthier air.

Notes

[1] Power point presentation by Byron Bunker, Center Director of EPA's Office of Transportation and Air Quality given Wednesday, December 17, 2008 at EPA Region 9.

[2] Based on Texas Commission on Environmental Quality data for the Clinton C403/C304/AH113 monitor, generated at http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo.pl?cams=403. These data show the yearly average for $PM_{2.5}$ concentrations as 15 μg/m^3 in 2005, 16 μg/m^3 in 2006, 15 μg/m^3 in 2007, and 13 μg/m^3 in 2008—the 2008 data, however, is still under review. The three-year average for 2005–2007 is 15.33 μg/m^3 which is just above the current annual fine particle standard at 15 μg/m^3 and the three-year average for 2006–2008 is 14.7 μg/m^3 which is just below the current standard. The reductions from 0.25 to 1.0μg/m^3, expected from establishing an ECA, could help the Houston metropolitan region attain or maintain the current health-based federal clean air standard of 15μg/m^3 for fine particulates.

[3] IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008. http://tinyurl.com/c5w9d3.

[4] IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008. http://tinyurl.com/c5w9d3.

[5] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,539.

[6] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,541.

[7] IMO, Annex 13, Resolution MEPC.176 (58), Revised MARPOL Annex VI, Adopted on 10 October 2008. http://tinyurl.com/c5w9d3.

[8] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,541.

[9] 72 Fed. Reg. 69,522 (December 7, 2007) "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule," at 69,541.

[10] "Given the MARPOL amendment acceptance process and the lead time specified in the regulations, an ECA submitted [by late March or early April] could be expected to enter into force as early as August 2012." EPA Regulatory Update, *Frequently Asked Questions about the Emission Control Area Application Process.* EPA-420-F-09-001, January 2009.

[11] EPA Regulatory Update, "Frequently Asked Questions about the Emission Control Area Application Process," EPA420-F-09-001; January 2009. http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09001.pdf

[12] EPA Program Announcement, "International Maritime Organization Adopts Program to Control Air Emissions from Ocean-going Vessels," EPA420-F-08-033; October 2008. http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f08033.pdf

[13] Corbett JJ, Winebrake JJ, Green EH, Kasibhatla P, Eyring V, Lauer A. 2007. Mortality from Ship Emissions: A Global Assessment. Environ Sci Technol. 41:8512-8518

[14] Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69545-69546. Power plant comparisons are based on 0.25lb/MWh of $PM_{2.5}$ and 4.22 lb/MWh of NO_x for power plants, which are the averages for existing coal plants in the western U.S. Also assumes a typical power plant unit has 500MW capacity and 85% utilization rate.

[15] Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69545-69546. Calculations based on Tier 2 NOx emissions standard (0.07g NOx/mile) for highway vehicles and 12,000 vehicle miles/year. Bureau of Automotive Repair, Engineering and Research Branch, State of California, "Methodology for Calculating Vehicle Miles Traveled (VMT)," September 30, 2000, Report 2000-06, available at http://www.epa.gov/otaq/regs/im/vmt.pdf

[16] Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder; Proposed Rule (December 7, 2007). 72 Fed. Reg. 69522, page 69545-69546.

[17] http://www.atsdr.cdc.gov/toxprofiles/tp123-c3.pdf

[18] Based on Texas Commission on Environmental Quality data for the Clinton C403/C304/AH113 monitor, generated at http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo.pl?cams=403. These data show the yearly average for $PM_{2.5}$ concentrations as 15 μg/m^3 in 2005, 16 μg/m^3 in 2006, 15 μg/m^3 in 2007, and 13 μg/m^3 in 2008—the 2008 data, however, is still under review. The three-year average for 2005–2007 is 15.33 μg/m^3 which is just above the current annual fine particle standard at 15 μg/m^3 and the three-year average for 2006–2008 is 14.7 μg/m^3 which is just below the current standard. The reductions from 0.25 to 1.0μg/m^3, expected from establishing an ECA, could help the Houston metropolitan region attain or maintain the current health-based federal clean air standard of 15μg/m^3 for fine particulates.

[19] $PM_{2.5}$: http://www.epa.gov/oar/oaqps/greenbk/qnsum.html, web resource, last accessed February 13, 2009. Ozone: http://www.epa.gov/oar/oaqps/greenbk/gnsum.html, web resource, last accessed February 13, 2009.

[20] EPA press release: *IMO Sets Sail for Global Action on Pollution from Large Ships,* October 10,2008. http://yosemite.epa.gov/opa/admpress.nsf/0/24A02C8A96574D3F852574DE005B6308.

[21] EPA Regulatory Update, "Frequently Asked Questions about the Emission Control Area Application Process," EPA420-F-09-001; January 2009. http://www.epa.gov/otaq/regs/nonroad/marine/ci/420f09001.pdf.

[22] Puget Sound Clean Air Agency, "Final Report: Puget Sound Air Toxics Evaluation," October 2003. http://www.pscleanair.org/airq/basics/psate_final.pdf

[23] South Coast Air Quality Management District, "Final Report: MATES III," September 2008. http://www.aqmd.gov/prdas/matesIII/MATESIIIFinalReportSept2008.html

[24] Krivoshto IN, Richards JR, Albertson TE, Derlet RW. 2008. The Toxicity of Diesel Exhaust: Implications for Primary Care. J Am Board Fam Med. 21:55– 62.

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[26] Corbett JJ, Winebrake JJ, Green EH, Kasibhatla P, Eyring V, Lauer A. 2007. Mortality from Ship Emissions: A Global Assessment. Environ Sci Technol. 41:8512-8518

[27] Corbett JJ, Winebrake JJ, Green EH, Kasibhatla P, Eyring V, Lauer A. 2007. Mortality from Ship Emissions: A Global Assessment. Environ Sci Technol. 41:8512-8518

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[30] http://www.epa.gov/acidrain/effects/index.html, web resource, last accessed September 18, 2008

[31] Regulating Greenhouse Gas Emissions Under the Clean Air Act; Proposed Rule (July 30, 2008) 73 Fed. Reg. 44354 at 44466

[32] Ramanathan, V. and G. Carmichael (2008) Global and Regional Climate Changes due to Black Carbon, Nature Geoscience. May be accessed online at: http://www-ramanathan.ucsd.edu/publications/Ram_Carmichael-NatGeo1-221.pdf

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[34] Ramanathan, V. and G. Carmichael (2008) Global and Regional Climate Changes due to Black Carbon, Nature Geoscience. May be accessed online at: http://www-ramanathan.ucsd.edu/publications/Ram_Carmichael-NatGeo1-221.pdf Lack, Daniel, et al. (2008) Light Absorbing Carbon Emissions from Commercial Shipping, Geophysical Research Letters, 35:L13815 Flanner, M. G., C. S. Zender, J. T. Randerson, and P. J. Rasch (2007), Present-day climate forcing and response from black carbon in snow, J. Geophys. Res., 112, D11202, doi:10.1029/2006JD008003.

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[36] Lack, Daniel, et al. (2008) Light Absorbing Carbon Emissions from Commercial Shipping, Geophysical Research Letters, 35:L13815

[37] http://www.epa.gov/pmdesignations/2006standards/documents/2008-12-22/factsheet.htm $PM_{2.5}$: http://www.epa.gov/oar/oaqps/greenbk/qnsum.html, web resource, last accessed February 13, 2009

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[40] EPA press release: *IMO Sets Sail for Global Action on Pollution from Large Ships*, October 10, 2008. May be accessed online at http://yosemite.epa.gov/opa/admpress.nsf/0/24A02C8A96574D3F852574DE005B6308

[41] EPA press release: *IMO Sets Sail for Global Action on Pollution from Large Ships*, October 10, 2008. May be accessed online at http://yosemite.epa.gov/opa/admpress.nsf/0/24A02C8A96574D3F852574DE005B6308

Coal Train Traffic Impact Study

NOVEMBER 2012

PRESENTATION

Parametrix
ENGINEERING . PLANNING . ENVIRONMENTAL SCIENCES

Agenda

- Introduction
- Study Purpose
- North Waterfront and SODO Study Areas
- Existing Rail Operations
- Coal Train Assumptions
- Gate Down Times
- Collisions
- Emergency Vehicle Access
- Potential Crossing Improvements
- Summary

Study Purpose

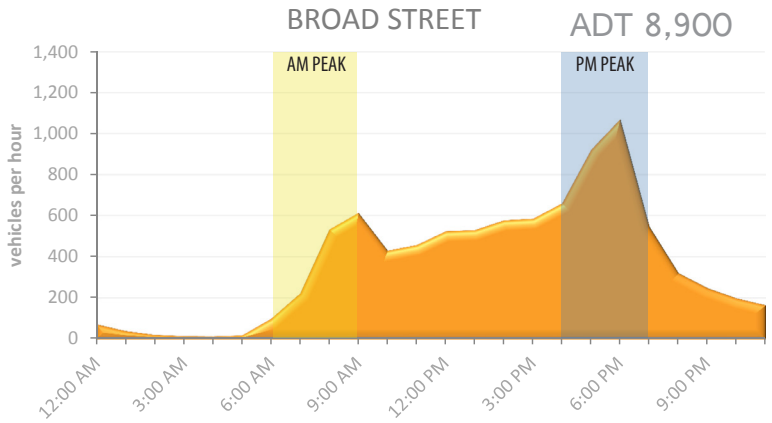
Evaluate the impacts to local roads from potential coal train operations in Seattle.

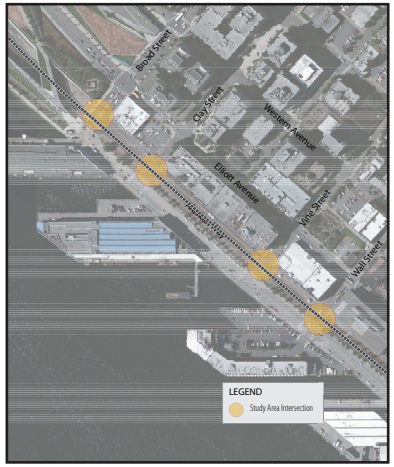
North Waterfront Study Area

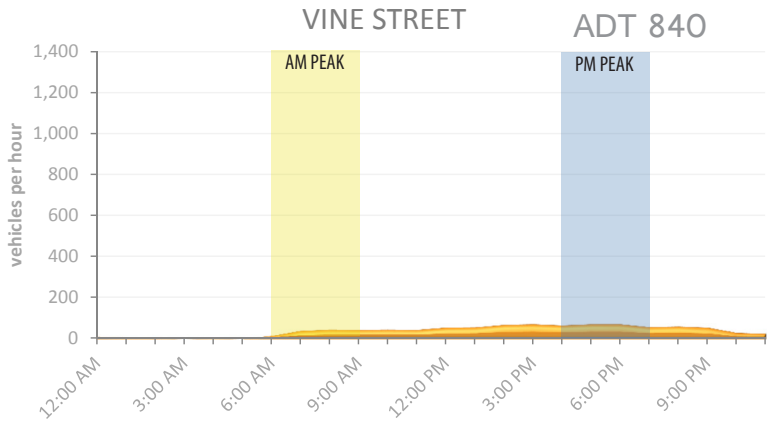
STAKEHOLDERS

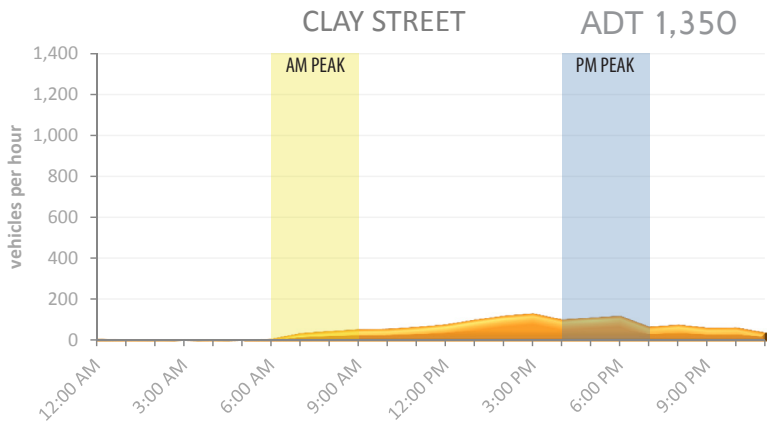
- Port of Seattle
- Cruise ships
- Olympic Sculpture Park
- Victoria Clipper
- Waterfront businesses
- Freight Community
- Area residents
- Edgewater Hotel
- Marriott Waterfront Hotel
- Washington State Ferries

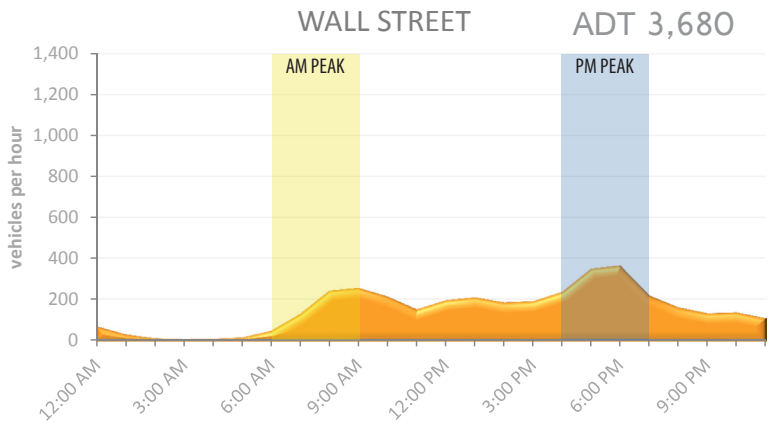
Daily Vehicle Volumes at Railroad Crossings







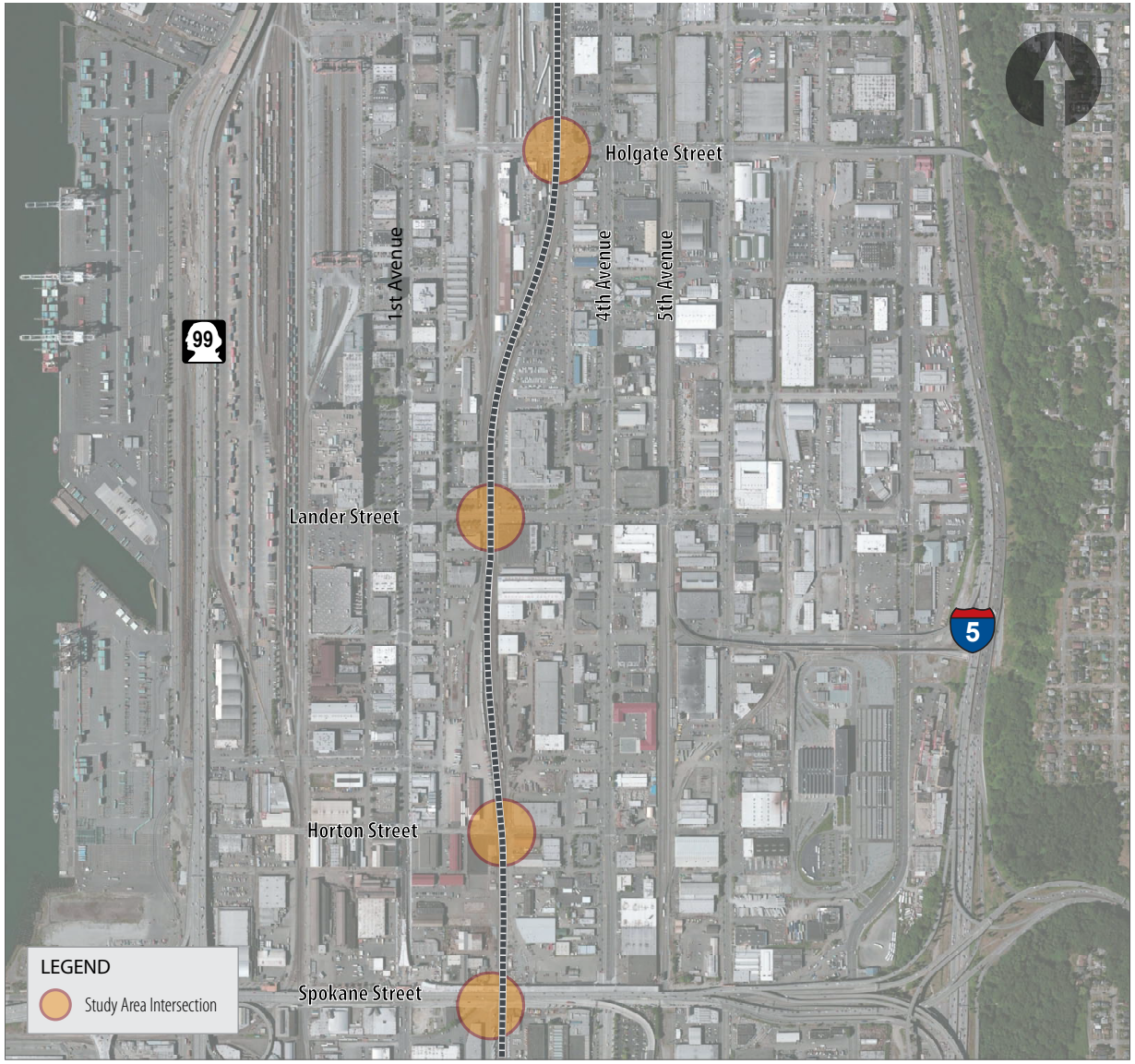




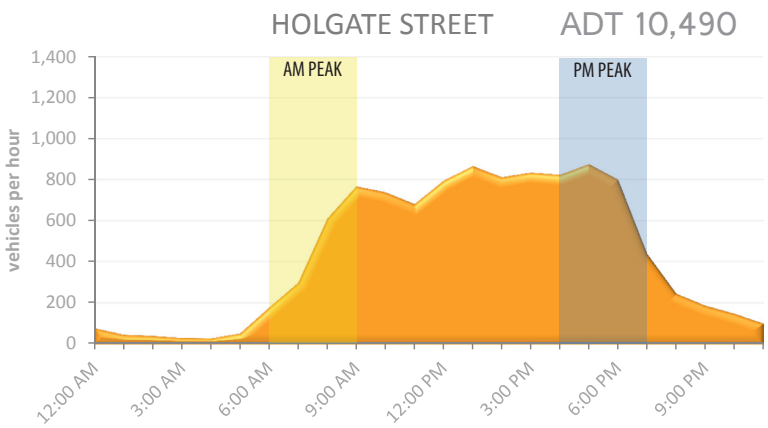
SODO

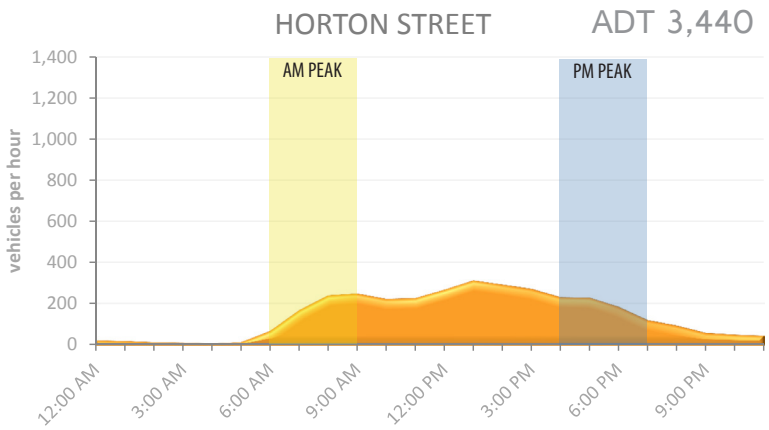
STAKEHOLDERS

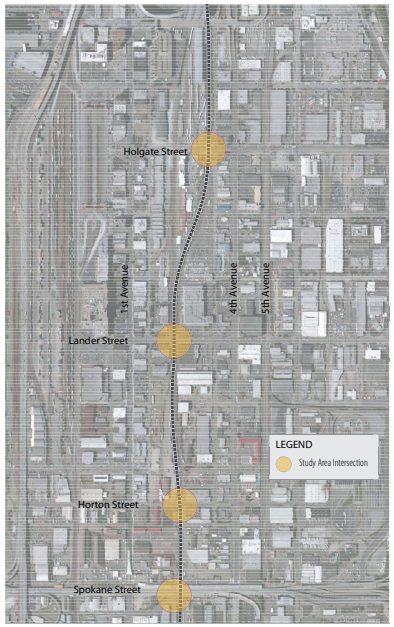
- SODO businesses
- Industries
- Stadiums
- Port of Seattle facilities
- Washington State Ferries

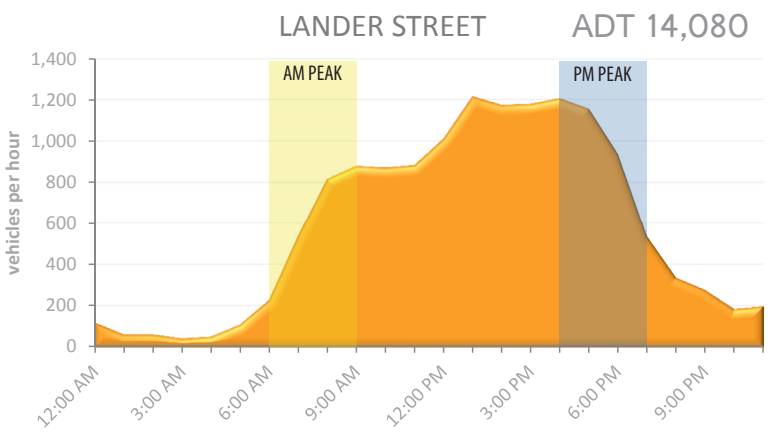


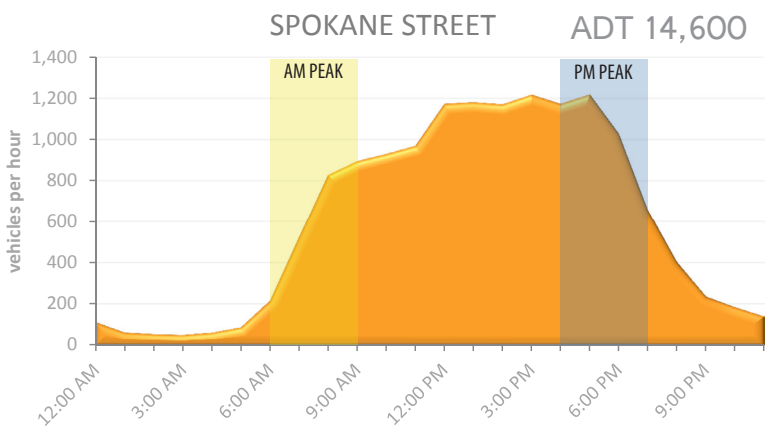
Daily Vehicle Volumes at Railroad Crossings











Existing Rail Operations

FREIGHT RAIL

- Approximately 30 freight trains (North Waterfront) and 65 to 85 freight trains (SODO) each day.
- Includes long-haul trains that are 1.6 miles long.
- Daily train volumes and schedules vary.

PASSENGER RAIL

- Sound Transit operates 4 Sounder trains north and 9 trains south.
- Amtrak operates 14 trains daily through Seattle.
- Sound Transit provides Link light rail service in the downtown transit tunnel.

OTHER RAIL

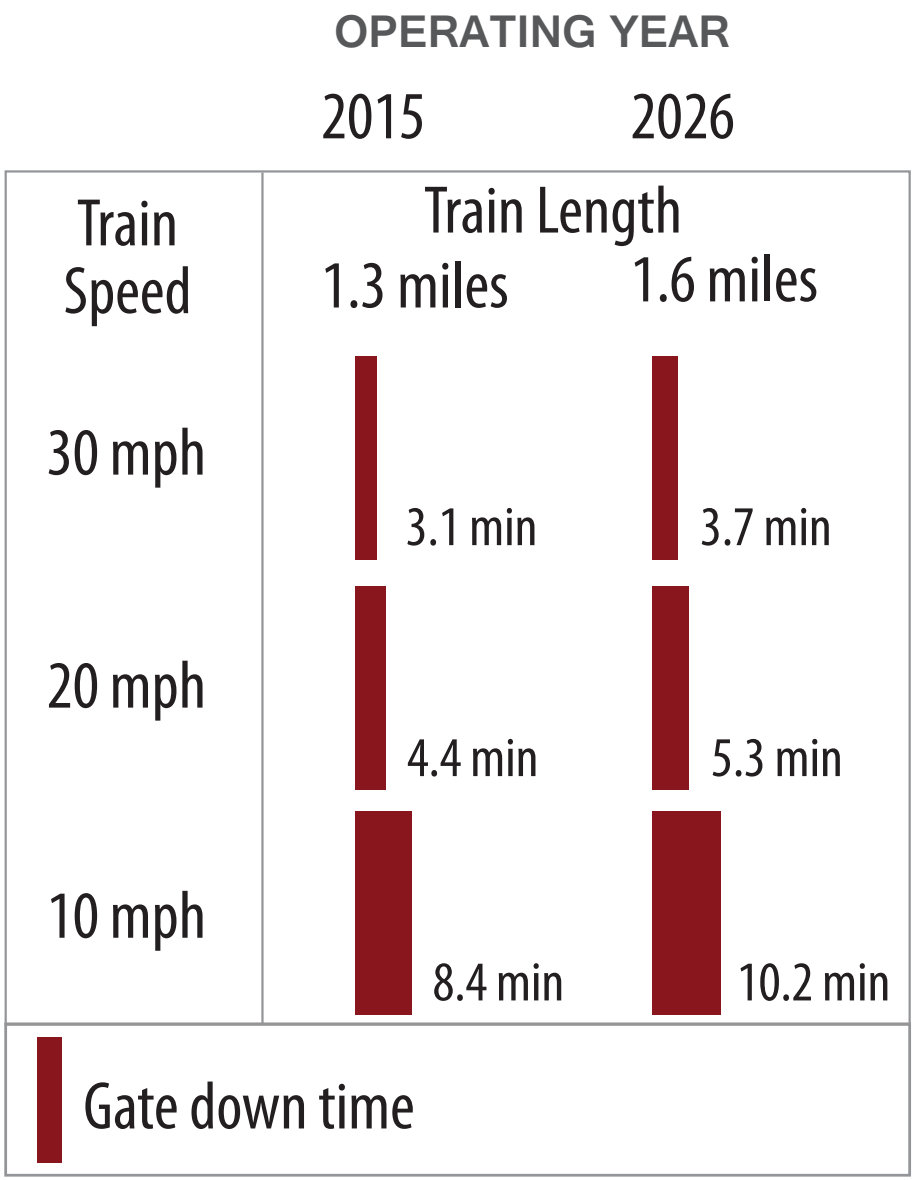
- BNSF operates rail tracks east of East Marginal Way South that serve its Seattle International Gateway (SIG) intermodal terminal.
- A number of spur tracks branch off the BNSF mainline between I-5 and Fourth Avenue.

Existing Rail Operations

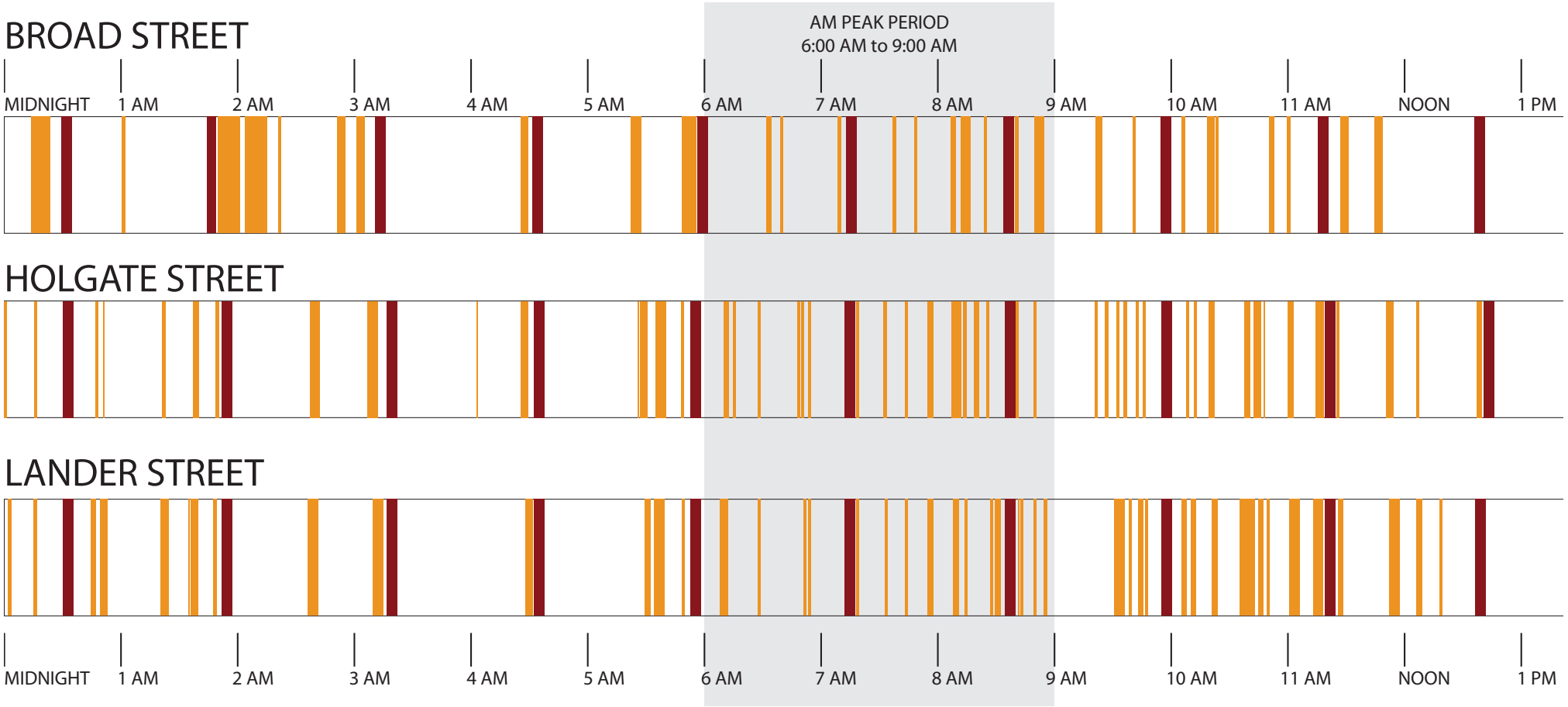
	Broad Street	Holgate Street	Lander Street
Number of Train Crossing Events	52	107	87
Total Gate Down Time (hours)	2.8	3.6	3.7
Average Gate Down Time (minutes)	3.3	2.0	2.5
Minimum/ Maximum Gate Down Time (minutes)	1.1 - 11.6	0.3 – 8.2	0.5 – 8.1
Average Train Speed (mph)	6.7	7.4	8.1
Minimum/Maximum Train Speed (mph)	0.3 – 22.7	0.4 – 24.6	0.5 – 22.9

Coal Train Assumptions

- From: www.coaltrainfacts.org/pid
- 2015: 10 daily 1.3 mile long trains
- 2026: 18 daily 1.6 mile long trains
- Operating speed based on existing track observation (24-hours)



Railroad Track Schedule with Coal Train (AM)

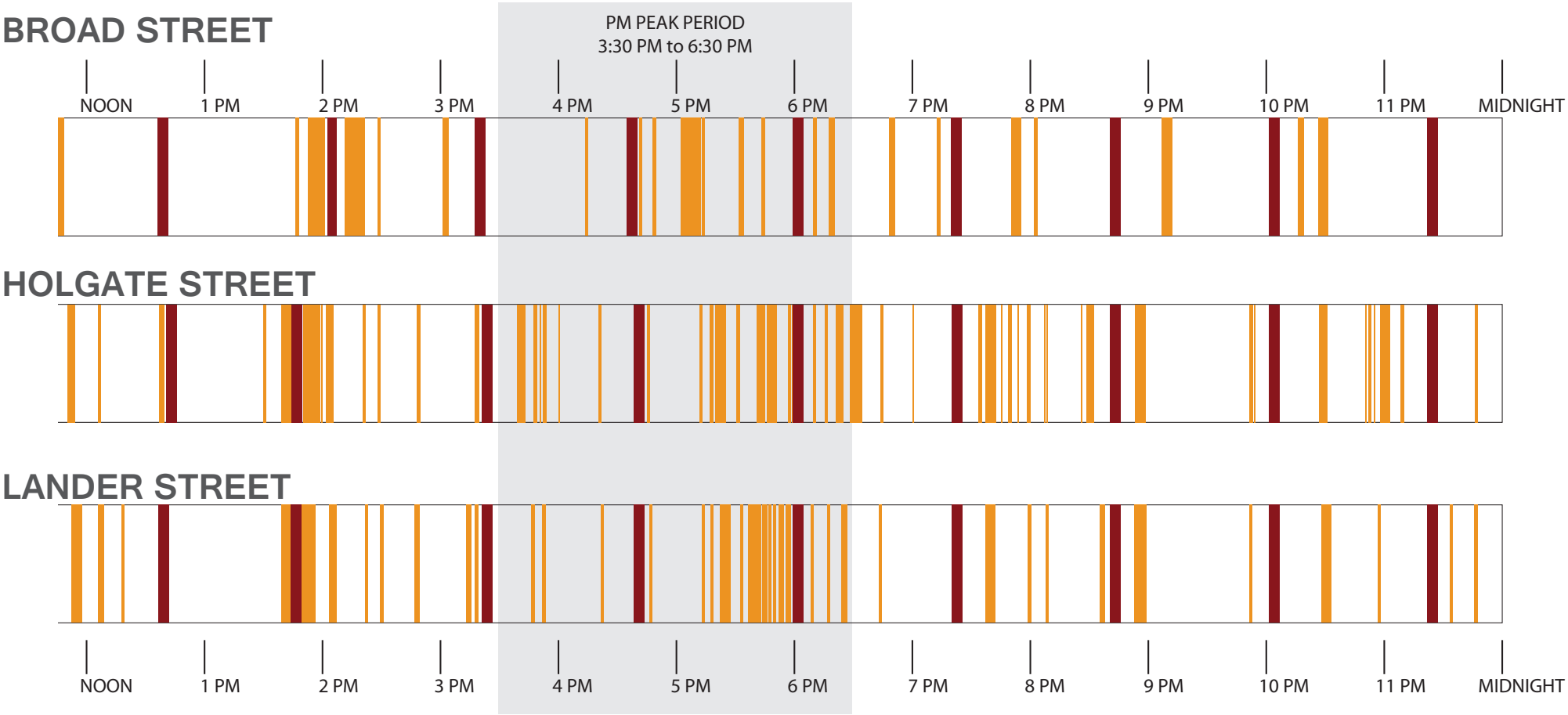


Legend

- Observed Gate Down Time
- Coal Train Gate Down Time

- One day of observed gate down times
- 18 total coal train trips equally distributed (2026)
- Coal trains assumed to be 1.6 miles long, operating at 20 mph

Railroad Track Schedule with Coal Train (PM)



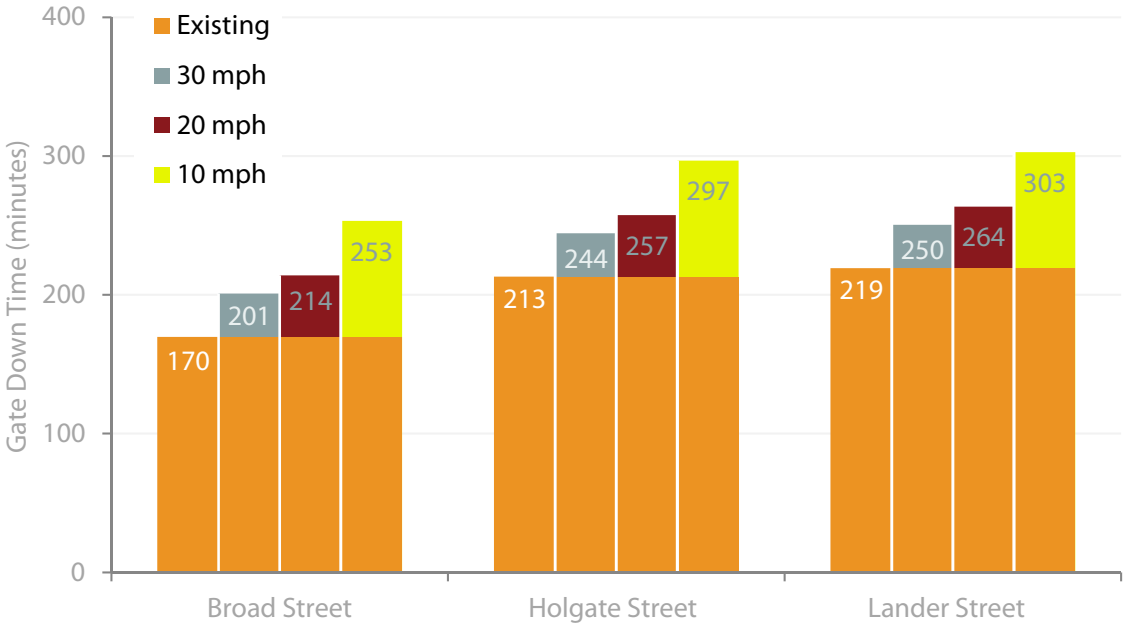
Legend

- Observed Gate Down Time
- Coal Train Gate Down Time

Anticipated Daily Gate Down Times

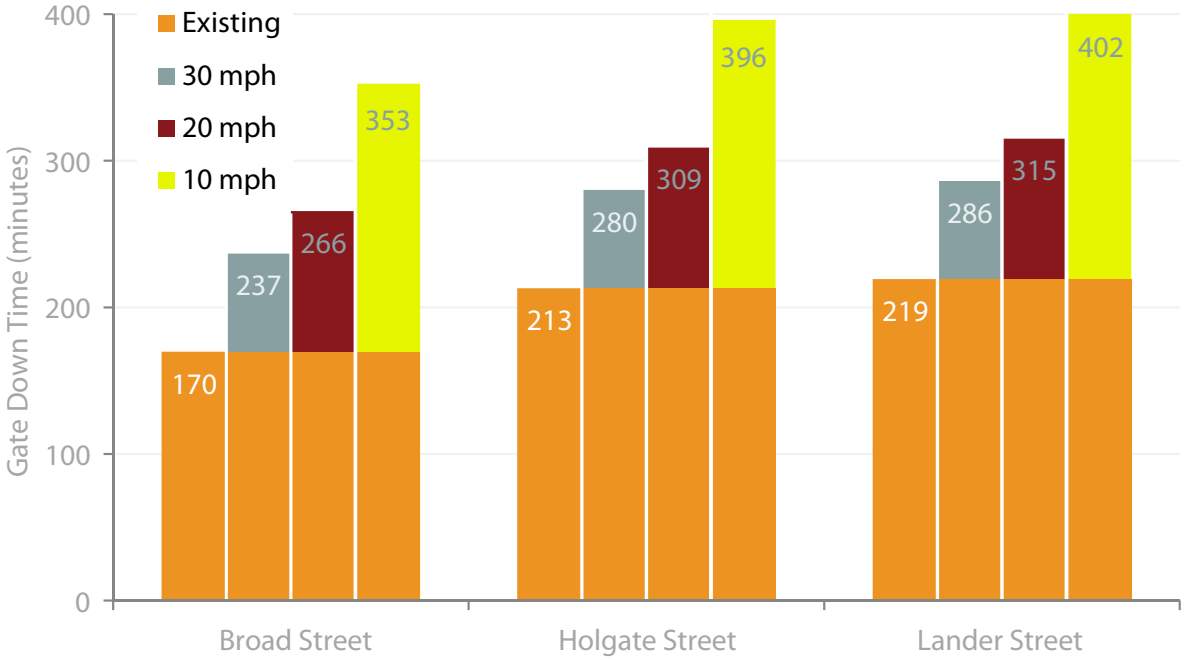
2015 DAILY GATE DOWN TIME

- 10 trains
- 1.3 miles long
- 20 mph



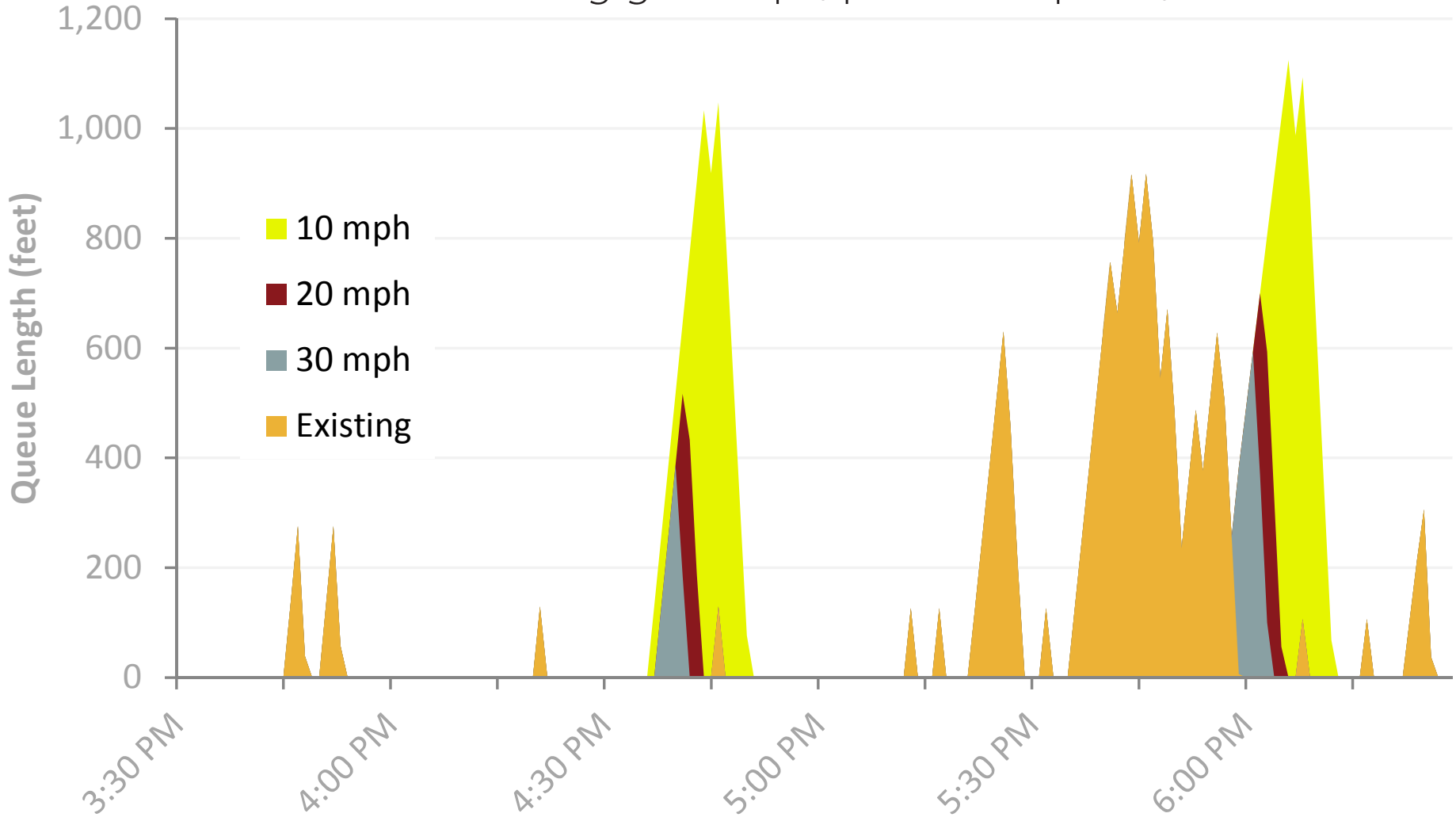
2026 DAILY GATE DOWN TIME

- 18 trains
- 1.6 miles long
- 20 mph



Lander Street Hourly Queues

- Slower coal train operating speed will have a greater impact on vehicles queues.
- Upward trends = Crossing gates down (queue builds)
- Downward trends = Crossing gates up (queue dissipates)



Collisions

- 4 train/vehicle collisions in the past 10 years.
- 127 improper crossings within a 24-hour period at Broad Street, South Holgate Street, and South Lander Street crossings.
- Saftey concerns increase with more trains.

Observed Improper Crossings 2012

	Bicycle	Pedestrian	Vehicle	Total
Broad Street	6	1	26	33
Lander Street	0	15	34	49
Holgate Street	0	0	45	45
Total	6	16	105	127

Emergency Vehicle Access

- Three fire stations directly impacted by rail delays in the SODO and North Waterfront districts.
  - Station 14 - 3224 4th Avenue South (Under Construction)
  - Station 5 - 925 Alaskan Way
  - Station 2 - 2320 4th Avenue
- Blockage from the proposed coal trains would impact emergency vehicle trips to/from the waterfront.
- Delays caused by the coal train affect local area responses and the ability to send emergency resources across the SODO district.

Potential Crossing Improvements

RECOMMENDATION FROM PREVIOUS REPORTS

- Grade separated overpasses at Broad Street and Lander Street
- Closure of Holgate Street
- Other possible improvements include:
  - Streetscape, such as fencing and plantings
  - Consolidating crossing gates
  - Raised medians
  - Pedestrian gates
  - Electronic message signs

Summary

- 10 total coal train trips (5 round trips) are expected each day or one train approximately every 2.4 hours.
- In 2026, the number of daily trains would increase to 18 total daily trips (9 round trips) or one train every 1.3 hours.
- Assumed coal train operating speed of 20 mph; slower speeds would create additional delay.
- In 2015, estimated additional daily gate down time for coal trains could be 31 to 83 minutes; increase of 15% to 49%
- In 2026, the estimated additional daily gate down time for coal trains could be approximately 67 to 183 minutes; increase of 31% to 108%