Transporting Alberta's Oil Sands Products:

Defining the Issues and Assessing the Risks

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EXECUTIVE SUMMARY

Oil sands are unconventional hydrocarbon deposits that consist of clay, sand, water, and a highly viscous oil known as bitumen. Over the past decade, extracting bitumen from oil sands has become profitable as oil prices have increased and extraction technologies improved. With the rapid growth of oil sands products in Alberta, production is expected to grow from 1.25 million barrels per day (mbl/d) in 2011 to around 3.75 mbl/d by 2030. The majority of oil sands products transported to market will be via existing and proposed pipelines; however, a sharp increase in the use of rail and marine transport can be expected while new pipelines are constructed to match the increasing production of oil sands products.

Alberta bitumen owes its high viscosity and density to its developmental history. These deposits began as standard crude oil reserves but during development the reservoirs never exceeded 80°C, meaning pasteurization did not occur. Therefore, when the conditions were correct, microorganisms began attacking and consuming the smaller molecules leaving only the large molecules that give bitumen its characteristic physical properties. Bitumen densities range from higher than freshwater to lower, making it difficult to conclude whether the substance would sink (higher) or float (lower).

In order to transport bitumen, a diluent must be added to decrease the viscosity. The most commonly used diluent is natural gas condensate, a liquid byproduct of natural gas processing. Typically the mixture of diluent and bitumen (dilbit) consists of 30% diluent and 70% bitumen. The second method is the use of synthetic crude (synbit). Synbit is bitumen that has undergone partial upgrading, which removes larger molecules through coking and hydrolysis. The mixture of synthetic crude and bitumen tends to be 50% synthetic crude and 50% bitumen. Future projections indicate that the use of synthetic crude will increase while the use of natural gas condensate will remain steady resulting from natural gas condensate's high price and decrease in local availability.

Little research is currently available regarding the behavior of oil sands products in water and the process and outcome of weathering after a spill. The only tests that have been conducted were in a laboratory environment so predicting the actual behavior of oil sands products for a range of spills is not currently possible. While the parent bitumen can be denser than water meaning it would sink, after diluent addition, the density decreases to less than water meaning it would float. The environmental conditions present during a spill such as turbidity, water

salinity,, and mixing with sediments can all affect the potential for the oil sands products to float or sink. Responders to the oil sands product spill into the Kalamazoo River reported the presence of floating oil, submerged oil, and sunken oil. Presently there are several research projects in the planning stages addressing the weathering behavior of oil sands products, but only one study has been published to date.

A highly debated topic with oil sands products is the degree of corrosivity with respect to pipeline transport. Oil sands products tend to be higher in sulfur and total acid number than medium and light crude oils, which can contribute to corrosivity. Preliminary conclusions from ongoing research suggest that oil sands products are not more corrosive than standard crude oils and thus do not pose a increased risk for transmission pipeline corrision.

Environmental and human health risks are another concern associated with oil sands development and transportation. The health of the Athabasca River near the oil sands deposits in Alberta serve as background information which will be referenced during future oil spills. Researchers have found raised levels of priority pollutants in the river below oil sands development which exceed those considered safe for aquatic life, but not levels that exceed those listed as safe for human consumption. However, differentiating between river toxicity from bitumen and that from seepage from tailings ponds is difficult. Fish larvae laid on bitumen contaminated substances did have a high rate of death and many of those that survived displayed physical abnormalities including lesions, hematomas, and unusual growths. Poly aromatic hydrocarbons are also present in high levels in the Athabasca River which could contribute to cancer rates although no conclusive evidence has been shown.

If a spill of oil sands products were to occur, responders will have to prepare for both a light, floating oil depending on the diluent used and the potential for a heavy, submerged or sinking oil. Species of concern for floating oil are any that contact the surface of the water frequently, particularly those that may inhale toxic fumes from the oil sands products or the evaporating diluent. Submerged and sinking oil can affect adult fish as well as fish larvae, species that feed on or come into contact with sediments, and benthic habitats such as coral reefs. For responders and citizens living in the vicinity of a spill, it is important to note that during the response to the Kalamazoo spill elevated benzene levels, a known carcinogen, were observed. Also, bitumen tends to be higher in sulfur which could also affect local populations. The diluent, depending on the type, could pose additional problems as it has a low flash point so it can be highly flammable after evaporation and may collect in depressions, as the gas is heavier than air. After the Kalamazoo spill, 331 people reported adverse effects including nausea, respiratory distress, and headaches although none required hospitalization.

There have been only two major spills of oil sands products. In 2007, synthetic crude spilled in Burnaby, B.C. after a pipeline ruptured. The second, in 2010, was a dilbit spill in Marshall, Michigan. Again, a pipeline rupture led to dilbit spilling into the Kalamazoo River. The spilled dilbit initially floated and then went on to sink to the bottom of the river as well as submerge in the water column. The response efforts in Burnaby B.C. were relatively successful whereas the Kalamazoo spill's response effort was extremely challenging. The clean up effort is still occurring in the Kalamazoo River as of March 2013. In both spills, the failure to follow standard emergency shutdown procedures contributed to the intensity of the oil spill.

Planning response to a spill of oil sands product is difficult as it is not enough data exisit to predict whether it will float, submerge or sink. As of now, the ability to detect, monitor, contain, and recover submerged or sunken oil is limited. In addition, it is difficult to interpret the national or regional capacity to respond to a submerged or sunken oil spill as the equipment lists are missing vital processing information. Research and development is currently being conducted to design equipment for responding to a sinking or submerged oil spill.

Regulations and standards governing oil spills can largely be divided into two related categories—requirements for preparing for oil spills and requirements for responding to oil spills. For oil sands products, a number of gaps in regulations currently exist. Two important gaps are the exemption of oil sands products from an excise tax and the lack of specific information required by facilities and transporters regarding the oil product they are handling. There are additional gaps in policies and regulations that warrant attention as transport of oil sands products increases. The Federal Railroad Administration has traditionally spent little time on the oversight of oil spill planning. Large oil spills in rail transport have not generally been a threat until recent years, during which oil transport via rail has significantly increased. There is also concern that the recently drafted PHMSA contingency plans for pipelines are not well integrated with regional and area plan as required. In addition, while many current regulations give agencies the authority to effectively regulate bitumen products, problems can arise from a lack of resources and experience dealing with potentially non-floating oils.

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Acronyms

ACP	Area Contingency Plan
API	American Petroleum Institute
ATM	Unit of Atmospheric Pressure
Bbl	Barrels
BNSF	Burlington Northern Santa Fe
BS&W	Water Content Measure
CAPP	Canadian Association of Petroleum Producers
CN	Canadian National Railway
CNOOC	Chinese National Offshore Oil Corporation
COFR	Certificates of Financial Responsibility
cP	Unit of Viscosity
CPR	Canadian Pacific Railway
DEP	Maine Department of Environmental Protection
DOT	U.S. Department of Transportation
EFSEC	Washington's Energy Facility Site Evaluation Council
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
EU	European Union
FOSC	Federal On-Scene Coordinators
FRA	Federal Railroad Administration
FRP	Facility Response Plans
FWCA	Fish and Wildlife Coordination Act
Gal	Gallons
GCDWQ	Guidelines for Canadian Drinking Water
CDP	Gross Domestic Product
GHG	Greenhouse Gases
HCA	High Consequence Area
IEA	International Energy Agency
IM	Integrity Management
IRS	U.S. Internal Revenue Services
JCP	Joint Marine Pollution Contingency
KOH	Potassium Hydroxide
LDS	Leak Detection Systems
MARPOL	International Convention for the Prevention of Pollution From Ships
MLV	Main Line Valve
MMBO	Million Barrels of Oil.
MPC	Marine Pollution Control
MSDS	Material Safety Data Sheets
NCP	National Contingency Plan
NEB	National Energy Board
NEPA	National Environmental Policy Act
NRT	National Response Team

NOAA	National Oceanic and Atmospheric Administration
NPFC	U.S. Coast Guard National Pollution Funds Center
NPRA	National Petrochemical and Refiners Association
NRDC	National Resources Defense Council
NSFCC	National Strike Force Coordination Center
NTSB	National Transportation Safety Board
NWACP	Northwest Area Contingency Plan
OGJ	Oil & Gas Journal
OPA	Oil Pollution Act
OPS	Office of Pipeline Safety
OSC	On-scene coordinator
OSHA	Occupational Safety and Health Administration
OSLTF	Oil Spill Liability and Trust Fund
PAC	Polycyclic Aromatic Compounds
PADD	Petroleum Administration for Defense District
PAH	Polycyclic Aromatic Hydrocarbon
PHMSA	Pipeline and Hazardous Materials Safety Administration
PPE	Priority Pollutants
QI	Qualified Individual
RAC	Railway Association of Canada
RAMP	Regional Aquatics Monitoring Program
ROVs	Remotely Operated Underwater Vehicles
RRT	Regional Response Team
SARA	Superfund Amendments and Reauthorization Act
SCA	Site Certification Agreement
SCAT	Shoreline Cleanup and Assessment Technique
SCP	Subarea Contingency Plans
SINOPEC	China Petrochemical Corporation
SOLAS	International Convention for the Safety of Life at Sea
SOPEP	Shipboard Oil Pollution Plans
TAN	Total Acid Number
TM	Trans Mountain
UC	Unified Command System
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WRRL	Western Response Resource List

1 BACKGROUND

1.1 Introduction to Oil Sands

Oil sands are unconventional hydrocarbon deposits that consist of clay, sand, water, and a highly viscous oil known as bitumen. According to the U.S. Geological Survey (2006), oil sands is a "generic term that has been used for several decades" to describe this type of hydrocarbon deposit." Extracting bitumen from oil sands was previously uneconomical as bitumen is more difficult to extract and transport than conventional crudes due to its thick consistency and the need to dilute the oil for it to flow through pipelines. Over the past decade, extracting bitumen from oil sands has become profitable as oil prices have increased and extraction technologies improved.

The dramatic increase in the extraction of bitumen from oil sands deposits in Alberta is just one part of a larger movement towards development of unconventional oils—those oils not extracted through conventional oil wells. According to the Department of Energy, unconventional oils are those that fall into one of three categories:

1. Petroleum-like material produced through heating the kerogen from oil shale deposits;
2. Bitumen extracted from oil sand deposits;
3. Low gravity crude oil from conventional reservoirs, but require heat for production.

Although conventional oils were historically less expensive to bring to market, extraction technologies have drastically reduced the price of producing unconventional oils—the production of the Alberta oil sands is just one example.

In this report we examine the issues associated with the transport of products from Alberta's oil sands through the U.S., focusing on how this increased activity might change the spill risks in various ways. We begin with an introduction to oil sands development and transportation, highlighting the economic drivers of that development and the environmental impacts in Alberta. The bulk of the report focuses in on a number of key issues, including a summary of past and projected spills of dilbit and other oil sands products; a detailed outline of where oil sands products are being transported; the chemical and physical properties of oil sands products; an introduction to potential environmental and human health impacts of oil sands products; an outline of risk mitigation approaches in oil transport, planning, and spill response; and a summary of the regulations pertinent to oil transport and spills. We conclude with a section that summarizes the gaps in information, research, and policy that we have uncovered throughout our research related to oil sands transport and oil spills in general, with some recommendations for how policymakers, researchers, and stakeholders might proceed in the future.

Common Oil Sands Terms[1]	
Oil Sands or Tar Sands[2]	Used synonymously, the combination of bitumen, clay, sand, and water. EIA (2013): "Naturally occurring bitumen-impregnated sands that yield mixtures of liquid hydrocarbon and that require further processing other than mechanical blending before becoming finished petroleum products."
Bitumen	A semi-solid or solid petroleum deposit. Thick like molasses at room temperature, it must be heated or diluted with lighter hydrocarbons to flow (ENE, 2009).
Diluent	Any "lighter viscosity petroleum products that are used to dilute bitumen for transportation in pipelines (CAPP, 2012).
Synthetic Crude	Also syncrude or SCO, according to CAPP (2012), "a mixture of hydrocarbons, similar to crude oil, derived by upgrading bitumen from oil sands."
Dilbit	Short for diluted bitumen, bitumen combined with any diluent for transport.
Synbit/Dilsynbit	Bitumen combined with synthetic crude/and synbit combined with a diluent.
Oil Sands Products	A term we use to describe products derived from oil sands, including bitumen, diluted bitumen, synthetic crude, synbit, and dilsynbit.

Table 1-1: Common Oil Sands Terms

[1] For a full glossary of oil sands terminology, visit: http://www.energy.alberta.ca/OilSands/1708.asp
[2] Oil sands and tar sands mean the same thing. They are used by different groups in order to frame the issue politically. We chose to use oil sands and oil sands products throughout this report for consistency and because it is more scientifically correct.

1.1.1 Reserves

Twenty-three countries have known deposits of oil sands. The largest reserves are located in three major deposits in northern Alberta, Canada—the Athabasca, Cold Lake, and Peace River deposits. The Government of Alberta estimates its total reserves of bitumen at approximately 170 billion barrels (CAPP, 2012). Significant reserves also exist in Venezuela and Russia. U.S. reserves are minimal in comparison but contain twenty-nine accumulations totaling 36,000 MMBO[3] (USGS, 2006).

As of February 2013, bitumen is not being produced at the same quantity, quality, or with the same product specifications anywhere else in the world. However, there are three other countries that are producing products or will soon produce products similar to Canada's dilbit and synbit:

- *Venezuela*: Venezuela has bitumen reserves estimated to be 513 billion barrels of recoverable oil located in the Orinoco Belt (USGS, 2009). Orimulsion is Venezuela's bitumen-based fuel, which consists of bitumen, 30 percent fresh water, and a small amount of surfactant (Rayaprolu, 2013). Orimulsion is not a homogenized mixture and the bitumen drops out of suspension when left undisturbed for an extended period of time (Rayaprolu, 2013). Orimulsion is not being exported to the United States, and Venezuela continues to decrease its orimulsion program due to political volatility (Rayaprolu, 2013).
- *Kazakhstan*: Russian oil company Gazprom Neft purchased a bitumen production facility in Kazakhstan in January of 2013. The facility has an annual production capacity of 280,000 tons (Energy Resources, 2013).
- *Russia*: Russian oil company Gazprom Neft is investing $446 million in renovating the Moscow Oil Refinery to refine bitumen, which is expected to produce up to 1.7 million tons of refined product a year (Moscow Times, 2012).

[3] MMBO, million barrels of oil.

1.1.2 Production of Oil Sands Products

Oil sands products are produced in two ways: surface mining and in situ recovery. The method used depends on the proximity of the deposit to the surface. Surface mining is used for deposits within 75 meters of the surface and requires the clearing of trees and topsoil before removing the oil sand deposits using trucks and shovels. After removal, the oil sands are trucked to an on-site processing facility to remove bitumen from sand and clay. Historically, surface mining has been the predominant method, but its share of production will significantly decline in the near future, as nearly 80 percent of reserves are too deep to mine (Energy Information Administration, 2013). The second method of production, in situ recovery, refers to a method where two wells are drilled, one for a steam or solvent injection pipe and another to pump the separated bitumen to the surface. The steam separates the bitumen and also lowers the viscosity making it easier to pump to the surface, where it is blended with a diluent and transported via pipeline to an upgrading facility (NPR, 2012).

1.1.2.1 Extraction and Upgrading

Extraction separates the bitumen from the oil sands. In-situ extraction uses steam to separate the bitumen while mining requires an additional step at an extraction facility. Here the oil sands are mixed with hot water—creating a slurry—and separated into sand, water, and bitumen and sent to a primary upgrading facility by pipeline (NPR, 2012). According to the Energy Information Administration (EIA), "in order to flow in a pipeline, the bitumen must be diluted with condensate or other light oils or 'upgraded' by complex processing units into a light, sweet 'synthetic' crude oil (SCO). Upgrading is "the process by which heavy oil and bitumen are converted into lighter crude by increasing the ratio of hydrogen to carbon, normally using either coking or hydroprocessing"—and normally occurs in two steps according to Alberta Energy (2012).

Of all the crude oil and equivalent production in Canada in 2011, roughly 28 percent was synthetic crude oil and 25 percent was non-upgraded crude bitumen" (EIA, 2012). There are currently five upgrading facilities in Alberta where oil sands products were upgraded to synthetic crude oil in 2011, according to Alberta Energy (Alberta Energy, 2012). Maps and information on oil sands deposits, extraction, and upgrading facilities can be found here: http://environment.alberta.ca/apps/osip/

1.2 The Economics of Oil Sands Products

The oil industry has long been aware that large reserves of oil sands exist in Canada and parts of the United States. However, production of oil sands products is a more difficult and expensive process than production of conventional crude oils. The profitability of extracting oil sands products depends on a certain, relatively narrow, range of economic conditions. The price of crude oil needs to remain at or above $65/barrel and possibly as high as $95/barrel in order for oil sands products to be profitable (Reuter, Cogan, Sasarean, Lopez Alcala, & Koehler, 2010). As conventional sources of crude oil have become scarcer and extraction technologies for oil sands products improved, the cost-benefit equation has changed and made oil sands products a more attractive commodity.

1.2.1 Economic Drivers

According to the International Energy Agency (IEA), the global supply of conventional oil already has or will soon peak, and only a dramatic increase in supply from non-conventional oil or renewable sources will prevent significant leaps in oil prices (IEA, 2012). However, little has been done to actually retool how economic systems work to reduce our dependency on oil, and until renewable sources are further developed and become commonly available as the status quo, the economic forces driving the extraction and refinement of oil sands remain strong.

The United States and Canada both continue to look for ways to achieve North American energy security and independence. According to Alberta Energy—the ministry that oversees Alberta's non-renewable energy resources—Alberta supplies the U.S. with 1.4 million barrels of oil a day from oil sands products (Alberta Energy, 2012). And, although environmental objections have been fierce, it is appealing in importing oil from a neighboring country that is considered more stable and friendlier to U.S. political and economic interests than potentially volatile OPEC countries[4].

1.2.2 Main Economic Players on the Supply Side

According to the EIA, "Canada is one of the world's five largest energy producers and is the principal source of U.S. energy imports (EIA, 2012). [Their] unconventional oil sands products are a significant contributor to the recent and expected growth in the world's liquid fuel supply and comprise the vast majority of the country's proven oil reserves, which rank third globally. According to *Oil & Gas Journal* (*OGJ*), Canada had 173.6 billion barrels of proven oil reserves as of the beginning of 2012. Canada controls the third-largest amount of proven reserves in the world, after Saudi Arabia and Venezuela." (EIA, 2013; Reuter et al., 2010). The Canadian government, on both a national and provincial scale, stands to increase GDP significantly by developing these resources. Canadian oil companies Enbridge, Suncor, and Nexen are all heavily involved in the process (Reuters, 2012). American oil companies Exxon Mobil (Exxon Mobil also owns Imperial Oil and Esso), Shell, Conoco-Phillips, and Chevron are also invested in Canadian oil sands products.

[4] Organization of the Petroleum Exporting Countries

Chinese state-owned oil companies SINOPEC, the China National Petroleum Corp. (parent company of Petro-China), and the Chinese National Offshore Oil Corporation (CNOOC) are increasing their presence in Alberta (The Economist, 2012). Since 2005, CNOOC has been acquiring minority interests in Canadian oil companies, and recently acquired Calgary-based Nexen outright[5] (Reuters, 2012; Armstrong, 2012). The U.S., China, and Canada currently comprise the major industrial stakeholders in Canadian oil sands deposits, but others may emerge on a smaller scale. For a more comprehensive list of the oil sands products major players, see the stakeholder list in Appendix 1.

1.2.3 The Main Economic Players on the Demand Side

After extraction, bitumen may be blended with lighter grades of crude oil and is not typically identified as oil sands products when transported (Owens, 2012). However, several major markets are receiving the majority of the oil sands products oil coming out of Canada. The first is the United States. According to Alberta Energy, the U.S. buys 2.5 million barrels of oil from Canada per day (Alberta Energy, 2012). For perspective, those 2.5 million barrels per day accounts for 18.2 percent of total U.S. oil consumption, more than the 11 percent that the U.S. imports annually from Saudi Arabia (Consumer Energy Report, 2012).

The other primary markets for oil sands products oil are in Asia (Gunn, Foschi, & Sexsmith, 2012) and potentially Europe, although these supply lines are still less developed. China has shown interest in Canadian oil development, and has already invested heavily in oil development capacity in Alberta. Additionally, Canada’s Prime Minister Harper has spoken openly about diversifying Canada’s export of oil to Asian markets, and although it is still a relatively small piece of the total exports, some tankers already carry Canadian oil to china from

[5] Final negotiations went through on 2/ 26. $15.1 billion deal approved.

Canada's west coast (Austen, 2011). As new terminals go online—like the one planned for Kitimat, B.C.—the transport of oil sands products through U.S. and Canadian waters will increase dramatically. According to a presentation given to investors by Ian Anderson, the President of Kinder Morgan's Canada Group, tanker traffic in Port Metro Vancouver alone could increase to 288 annually by 2016, up from only 71 in 2010 (Anderson, 2011). On the U.S. side of the border, tanker traffic in the Strait of Juan de Fuca is predicted by Kinder Morgan to increase from 4 tankers to 6 tankers daily, with a total increase of 500 tankers annually in the region (Kinder Morgan, 2013a). Other sources have also estimated as many as an additional 500 tankers a year moving through Puget Sound[6] (Luk, 2012). While Europe is a major oil importer, the European Union (EU) has been reluctant to open itself to oil sands products (Carrington, 2012). In February 2012, the EU held a vote to determine if oil sands products should be labeled more polluting, which would have made them an infeasible energy source under current climate policies. The vote ended in a stalemate and it seems likely that Canadian lobbyists trying to open trade of oil sands products to Europe will continue to face resistance (Carrington, 2012).

1.2.4 Who Benefits?

Oil companies enjoy significant profits from oil sands products. The oil industry, including American oil giants Exxon Mobil, Conoco Philips, and Chevron have already invested significant resources and plan to invest an additional $120 billion over the next decade (Rainforest Action Network, 2012). As conventional crudes become scarcer, there is increased probability that oil prices will rise significantly, which may cause people to pursue alternatives more aggressively. This scenario could equate to massive financial losses and economic

[6] This increase is dependent on the approval and construction of the Enbridge Northern Gateway pipeline. According to some sources it is also contingent on additional new ports that would be built because of the new pipeline system, but according to Kinder Morgan the capacity already exists.

depression if the oil industry cannot adapt (Reuter et al., 2010). Developing Canada's oil sands products reserves is one way that the industry is keeping up with demand and prolonging its ability to provide relatively cheap energy at a profitable level, but its success is not guaranteed.

The Canadian national and provincial governments stand to gain from developing oil sands reserves, something that the current Conservative Party Prime Minister, Stephen Harper has made a national priority. Canada's economy benefits from revenues brought in by becoming a significant oil exporter. At the provincial level, Alberta will reap the majority of the financial rewards, although there have been some disputes between Alberta and British Columbia over potential royalties B.C. would receive for allowing pipelines to cross the province. Twice, in 2010 and again in 2012 B.C. municipal politicians have voted against the Enbridge Northern Gateway pipeline project, expressing feelings that while it may benefit Ottawa and Alberta, B.C. stands to gain little and bears most of the environmental risks (Market Wire, 2010; Huffington Post, 2012). Mining areas like Fort McMurray have also experienced significant economic growth from the development of oil sands products.

Additionally, the United States also stands to benefit from oil sands products development. According to Alberta Energy, for every two jobs created in Canada from oil sands products extraction, a third is created in the U.S. (Alberta Energy, 2012). Alberta Energy claims "oil sands development is projected to generate $521 billion in economic activity in the U.S. over the next 25 years" (Alberta Energy, 2012).

1.2.5 Economic Trade-offs

Although the numbers differ depending on the source, it is clear that there are significant economic benefits associated with developing oil sands products. The dramatic increase in production has turned places like Fort McMurray into boom towns, and has had wide reaching economic impacts through job creation, increased Canadian GDP, and large injections of revenue into the budgets of the federal, provincial, and local governments at a value estimated to be in the billions of Canadian dollars (Timilsina, LeBlanc, & Walden, 2005). However, these monetary gains must be weighed against the negative economic impacts and environmental costs associated with bitumen extraction and potential spills (Skinner & Sweeney, 2012).

1.3 Environmental Impact of Oil Sands Products

Development of oil sands products results in a higher number of negative environmental impacts when compared to lighter crude oils. Heavier forms of oil like bitumen require more energy for extraction and processing, resulting in higher greenhouse gas emissions. In addition, oil sands extraction is more disruptive than conventional extraction techniques, leading to significant local impacts in water use, land use, and on wildlife.[7]

1.3.1 Greenhouse Gas Emissions

Although all fossil fuel development results in greenhouse gas emissions—primarily carbon dioxide and methane—production of oil sands products has higher emissions intensity. A number of studies have analyzed the overall emissions associated with oil sands products in comparison to other crude oils from a lifecycle perspective.[8] These analyses come in two categories, 'well-to-wheel' and 'well-to-tank'. Well-to-wheel life-cycle assessments consider emissions from extraction, transportation, upgrading and refining, distribution, and combustion while well-to-tank assessments focus on production and extraction. A survey of these studies by

[7] In addition, all crude spills pose potential environmental and health risks. Some organizations have expressed concern over the possible negative impacts of the diluents blended with oil sands in the event of a spill, namely higher exposure to hydrogen sulfide, benzene, and other toxins that affect humans and wildlife. These impacts are discussed below in section 6.

[8] See Alberta Energy Research Institute/Jacobs Consultancy, Life Cycle Assessment Comparison of North American and Imported Crudes, 2009; Alberta Energy Research Institute/TIAX LLC, Comparison of North American and Imported Crude Oil Lifecycle GHG Emissions, 2009; National Energy Technology Laboratory, Development of Baseline Data and Assessment of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels, November 26, 2008; National Energy Technology Laboratory, An Evaluation of the Extraction, Transport and Refining of Imported Crude Oils and the Impact of Life Cycle Greenhouse Gas Emissions, March 27, 2009.

the Congressional Research Service found that Canadian oil sands products emit on average 14-20 percent (well-to-wheel) and 72-111 percent (well-to-tank) more greenhouse gases (GHG) than crudes they would displace in U.S. refineries (Lattanzio, 2012). The higher emissions intensity stems from two sources:

1. *Mining*: mining oil sands products requires more energy-intensive methods and in-situ methods use natural gas to heat steam; and
2. *Extraction and Processing*: extracting oil sands products requires more energy-intensive methods due to bitumen's high viscosity.

1.3.2 Water-Use Impacts and Tailing Ponds

One of the most pertinent local environmental concerns is water use and disposal. The extraction and processing of oil sands products requires large quantities of water, particularly in surface mining operations. A barrel of oil requires approximately 3.1 barrels of net fresh water for mining and 0.5 barrels for in-situ (CAPP, 2012). After extraction, bitumen is separated from sand and clay by mixing it with warm water—and the water, clay, sand, and leftover oil (tailings) is moved to large storage ponds (CAPP, 2012). There are concerns around potential negative impacts on aquatic ecosystems from large tailings ponds and removal of water from the watershed (Birn & Khanna, 2010).

Like all mining techniques, surface mining for oil sands generates tailings after separating the bitumen. The tailings—water, sand, clay, and residual bitumen—are sent to a 'tailings pond' to be recycled. The tailings are placed in large pools that allow sediment to settle, which can take years, and the water skimmed off and reused. It is currently estimated that tailings ponds encompass an area of over 130 km^2 in Alberta. A number of studies argue that the Government of Alberta's efforts to manage the tailings ponds have been unsuccessful and that leakage, or 'seepage,' of toxic chemicals continues to happen at a high rate. A 2010 study showed that the oil sands industry "releases 13 elements considered priority pollutants (PPE) under the U.S. Environmental Protection Agency's Clean Water Act, via air and water, to the Athabasca River and its watershed"—seven of which exceeded Canadian standards for an aquatic environment (Kelly et al., 2010).

1.3.3 Land-Use and Wildlife Impacts

The Canadian oil sands reserves are located within Canada's boreal forest, part of the largest terrestrial ecosystem in the world. Like water-use, land-use impacts differ based on in situ extraction versus surface mining operations, but both have negative implications for the land. Mining necessitates the removal of vegetation and topsoil; and the topsoil is then stored for later use in the reclamation process. In situ extraction has a smaller footprint but still requires the construction of roads, pipelines, well pads, and facilities. According to the National Energy Board, "the proposed future reclaimed landscape will be significantly different—with 10 percent less wetlands, more lakes, and no peatlands." The government of Alberta requires companies to restore land to at least its previous biological productivity but reclamation requires a long time investment and its long-term success is still the subject of debate.

Wildlife organizations like the National Wildlife Federation argue that oil sands production has disrupted caribou and moose populations, with populations around Fort McKay decreasing 70 percent and 60 percent, respectively (NWF, 2012). For birds, the warm tailing ponds provide an open but harmful body of water during the spring migration season when other bodies of water remain frozen, resulting in large numbers of bird deaths each year (Timoney & Lee, 2009).

1.4 Mode of Transporting Crude Oil in North America

The energy sector in North America transports various crude oil, petroleum and natural gas products from source (e.g., wells) to destination (e.g. refineries and industrial complexes). This section briefly describes various modes of transporting oil sands products from source to destination. Canada has been the main supplier of crude oil products to the U.S. since 2010, with the U.S. importing an average of 2.5 million barrels per day (mbl/d) or 27 percent of total U.S. imports (EIA, 2013).

With the rapid growth of oil sands products in Alberta, production is expected to grow from 1.25 million barrels per day (mbl/d) in 2011 to around 3.75 mbl/d by 2030, an average annual growth rate of 11.5 percent (Canadian Province of Alberta [AB], 2012; Canadian Association of Petroleum Producers [CAPP], 2012). The majority of oil sands products transported to market will be via existing and proposed pipelines; however, a sharp increase in the use of rail can be expected while new pipelines are constructed to match the increasing production of oil sands products (CAPP, 2012; CNEB, 2009; CNEB, 2006).

The U.S. Department of Energy has divided the U.S into five regions for planning purposes (Figure 1-1). Each region is called a petroleum administration for defense district (PADD). As of the 3rd quarter of 2012, the U.S. PADD II region was the largest recipient with 1.6 mdl/d (71 percent), followed by PADD IV (11 percent), PADD V (9 percent), PADD I (5 percent) and PADD III (4 percent) (EIA, 2013; CNEB, 2012). The largest markets for synthetic crude oil in the U.S. were PADD II (76 percent) and PADD V (12 percent), while the largest markets for blended bitumen were PADD II (79 percent) and PADD III (10 percent) (EIA, 2013; CNEB, 2012).

Figure 1-1: US DOE EIA: Petroleum Administration for Defense Districts

1.4.1 <u>Major Crude Oil Pipeline Networks in North America</u>

1.4.1.1 Existing Networks of Crude Pipelines

Canada's main pipelines include Enbridge's Mainline, Kinder Morgan's Trans Mountain, and Kinder Morgan's Express pipeline. This pipeline network has a capacity of roughly 3.5 million barrels per day (mbl/d) (Table 1-2) and runs through much of North America, connecting Canadian oil fields to transit ports and refineries in Canada and the U.S. (Figure 1-2) (CAPP, 2012; CNEB, 2009).

The Enbridge system in Canada combined with the Lakehead system in the U.S. is the world's largest crude oil pipeline network (CAPP, 2012; CNEB, 2009). This network is the primary transporter of crude oil from western Canada to markets in eastern Canada and the U.S. Midwest for regional consumption and transfer to the other PADD regions. The system currently delivers about 2.1 mbl/d of crude oil products, including oil sands products, and after future expansion this capacity could increase to 3.5 mbl/d by 2020 (subject to approval of Keystone XL pipeline in the U.S. Midwest – refer to section 4.1.1.3 for more information). The mainline originates at Edmonton, Alberta and meets with the US Lakehead system at Sarnia, Ontario (CAPP, 2012; CNEB, 2009).

The Kinder Morgan Express pipeline supports refineries in the U.S. West. The Express Pipeline system is a batch-mode, in which the shipper receives the exact blend that it tendered for transport, and is comprised of the Express Pipeline and the Platte Pipeline. It connects Canadian and U.S. crude oil producers to refineries in PADD IV. The pipeline originates at Hardisty, Alberta, and terminates in Casper, Wyoming with capacity of 0.28 mbl/d (CAPP, 2012).

The Kinder Morgan Trans Mountain pipeline system, which directly affects Washington State's energy portfolio, connects Alberta's oil to the Pacific Coast for use by U.S. refineries and export to Asian markets. The Trans Mountain pipeline transports crude oil and petroleum products from Edmonton, Alberta, to Vancouver, British Columbia, and an offshore terminal via the Westridge Docks in British Columbia for customers in U.S. PADD V region and Asian markets, primarily China and Japan with current capacity of 0.30 mbl/d (CNEB, 2009).

A subsection of the Enbridge pipeline network connects Canadian crude oil products from Sarnia, Ontario to Montreal, Quebec and from there to Portland, ME for customers in U.S. PADD I (CAPP, 2012).

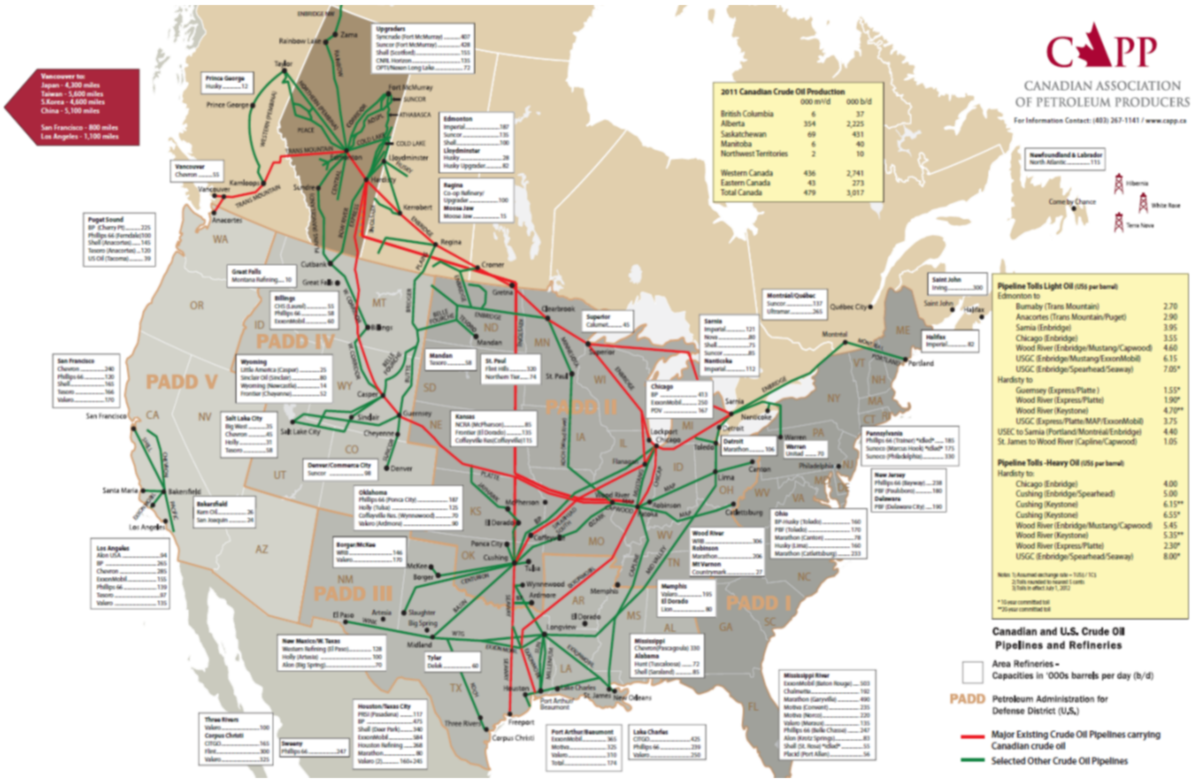

Figure 1-2: Existing North American Crude Oil Pipeline Network

Pipeline Network	Crude Type	Capacity (mbl/d)	
Enbridge	Light	1.08	2.33
	Heavy	1.25	
TransCanada	Light / Heavy (25% / 75%)	0.59	
Kinder Morgan Trans Mountain	Light / Heavy (80% / 20%)	0.30	
Kinder Morgan Express	Light / Heavy (35%/ 65%)	0.28	
Total Existing Capacity		**3.50**	

Table 1-2: North America's Existing Crude Oil Pipeline Network

1.4.1.2 Proposed Crude Oil and Bitumen Pipelines

The U.S. and Canadian pipeline industry is currently working on many expansion proposals and construction projects (dotted lines in Figure 1-3) that will increase the current networks capacity by 61 percent to approximately 5.6 mbl/d (Table 1-3). The proposed Enbridge Southern Lights, Enbridge Northern Gateway, and Kinder Morgan Cochin Conversion are intended to transfer increased Canadian crude oil export to markets in North American and Asia (CAPP, 2012; CNEB, 2009).

Figure 1-3: North American Crude Oil Pipeline – Existing + Proposed

Pipeline	Crude Type	Capacity (mbl/d)	Origin	Destination	Consumer Markets	Year Active
TransCanada Keystone XL	Light / Heavy / Diluent	0.33	Hardisty, AB	Steele City, NE	PADD III	2016
		0.55	Cushing, OK	Nederland, TX	PADD III	2014
Enbridge Northern Gateway	Heavy / Diluent	0.53	Kitimat, BC	Edmonton, AB	Asia	2017
Kinder Morgan Trans Mountain Expansion	Heavy	0.45	Edmonton, AB	Burnaby, BC	PADD V Asia	2017

Pipeline	Crude Type	Capacity (mbl/d)	Origin	Destination	Consumer Markets	Year Active
Enbridge Alberta Clipper & Southern Light Expansion	Heavy / Diluent	0.12	Flanagan, IL	Edmonton, AB	PADD II	2014
Enbridge Line 9 Reversal	Light / Heavy / Diluent	0.10	Montréal, Québec	Sarnia, ON	PADD I Europe	2014
Kinder Morgan Cochin Conversion	Diluent	0.07	Kankakee County, IL	Fort Saskatchewan, AB	Alberta	2014
Total Proposed Capacity		**2.15**				

Table 1-3: North America's Proposed Crude Oil Pipeline Expansion

1.4.2 Transport of Oil Sands Products via Rail

Rail is becoming an increasingly larger proportion of the crude oil transportation network because companies can increase their carrying capacity relatively quickly by buying more railcars—and because the freight rail infrastructure is already in place throughout North America. Rail transport of all types of crude oil products has increased roughly 55 percent between March of 2011 and March of 2012 (Table 1-4) (CN, 2012). Rail could provide a short-term alternative to pipelines, as it allows companies to increase production and transportation without investing in significant new infrastructure; however, due to its logistical limitations, it remains to be seen how much of crude oil transport will be done by rail in the long term.

Date	Rail Cars (#)	Weight (Metric Tons)
March-12	8,823	707,647
March-11	5,602	458,696
Growth Rate	**57%**	**54%**

Table 1-4: Growth in use of Rail for Transportation of Crude Oil in North America

Canada's two major rail companies, Canadian National (CN) and Canadian Pacific (CPR), are in position to take advantage of increased oil production in Alberta. Both companies have track as far north as the Alberta oil sands fields and are already major transporters of mining and in situ extraction supplies for the oil companies. CN and CPR have an extensive North American network that could support transport of crude products from the source to refineries and shipping ports (Figures Figure **1-4**, Figure **1-5**, Figure **1-6**, Figure **1-7**) (CN, 2012; CPR, 2012).

In anticipation of the growth in transportation volume, rail companies are studying several options to reduce their transportation costs and increase the effectiveness of rail transport as an alternate to pipelines. These include (CAPP, 2012):

- Test runs transporting light crude and condensate from California, Texas, and Louisiana.
- The potential of using heated rail cars to transport non-upgraded bitumen that could then be blended to specifications at terminals near the destination refineries. Heated railcars would allow for speedier loading and unloading of high viscosity oil sands products
- The transportation of Alberta oil sands products by electric rail to an existing marine terminal at Valdez, Alaska for Asian markets.

Figure 1-4: Canadian National Rail (CN) Network

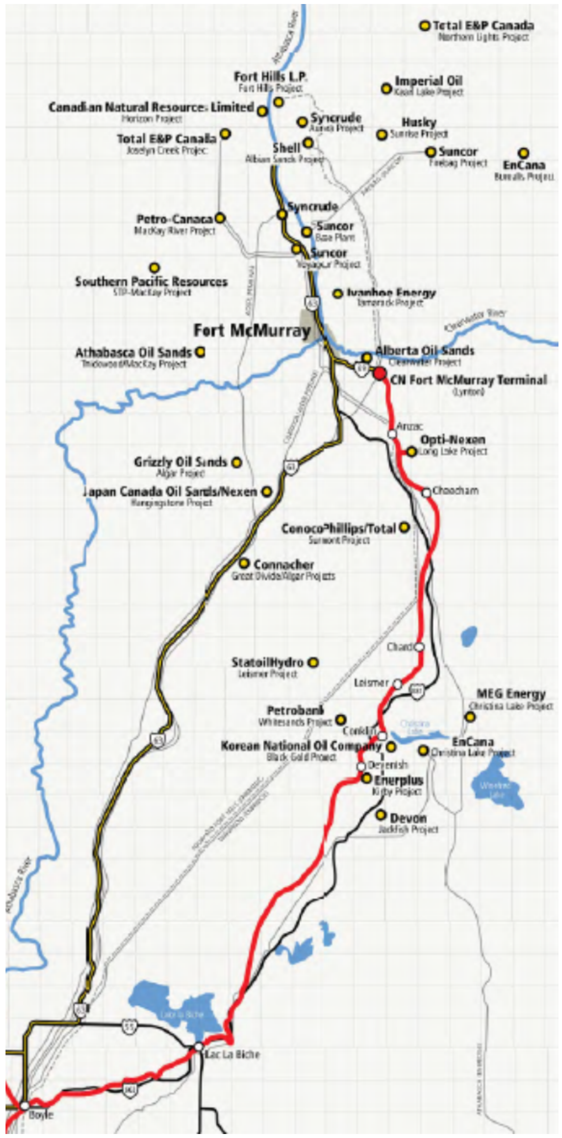

Figure 1-5: Canadian National Rail (CN) Northern Alberta Connection

Figure 1-6: Canadian Pacific Rail (CPR) Network

Figure 1-7: Canadian Pacific Rail (CPR) Alberta Connections

1.4.3 Transport of Oil Sands Products via Waterways

In anticipation of tremendous growth in the production and transportation of oil sands products and due to uncertainties in development of new pipelines, oil transport companies are exploring the option of shipping oil sands products via barges through North American waterway networks, specifically the Mississippi River for U.S. PADD II and III markets (Break Bulk I, 2011; Break Bulk II, 2011; Gabriela Alcocer; Seana Lanigan, 2012). The option of using barges in North American waterways would most likely be a viable alternative on the Pacific Coast (e.g., Puget Sound) and the Great Lakes region where waterway distances between crude terminal and refineries are relatively short (Jensen & Pilkey-Jarvis, 2012). There are currently shipments of heavy and extra heavy crude oil products via barges from terminals in British Columbia to Puget Sound refineries in Anacortes and Tacoma (Figure 1-8) (Jensen & Pilkey-Jarvis, 2012).

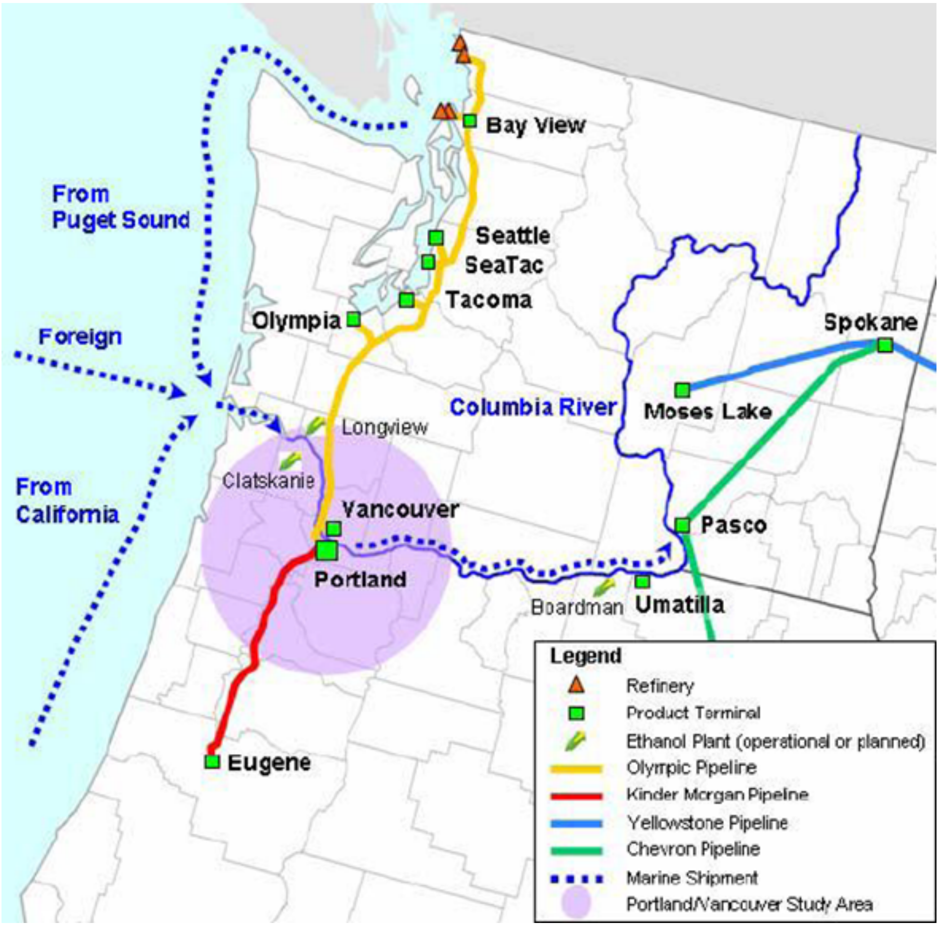

Figure 1-8: WA Department of Ecology: Marine and Pipeline Routes in Puget Sound Region

2 SPILLS OF DILUTED BITUMEN

Four significant spills of diluted bitumen have occurred in the U.S. and Canada over the past two and a half years. These include spills on Enbridge pipelines in Michigan and Illinois, a Kinder Morgan Canada pipeline spill in Burnaby, B.C., and one spill at a TransCanada operated Keystone Pipeline pump station in North Dakota. Further information on the Enbridge Michigan and the Kinder Morgan Burnaby spills and response efforts are provided in section 7.2.

2.1 Recent Spills of Diluted Bitumen Oil

2.1.1 Marshall, Michigan Enbridge Spill

The largest dilbit spill, and largest inland oil spill in U.S. history, occurred on Enbridge's Line 6B pipeline on July 25, 2010 in Marshall, Michigan (Young, 2012). Line 6B is a 293-mile section of the Lakehead system, which originates in Edmonton, Alberta. The rupture was not discovered for more than 17 hours and the total release was estimated to be 20,082 barrels (bbl)[9] of dilbit (NTSB, 2010). The rupture in the line measured 6 feet 8.25 inches in length and 5.32 inches at maximum width (NTSB, 2010). Of the total oil that spilled, 8,033 bbl reached Talmadge Creek and the Kalamazoo River (Enbridge, 2012a).

Notably, Enbridge did not initially report that the pipeline was carrying dilbit, and according to media outlets one Enbridge executive denied that the pipeline was carrying oil sands products (Lydersen, 2010). Disclosure of this information is not required, and thus it took more than a week for federal and local officials to discover they were dealing with a dilbit spill (McGowan & Song, 2010).

[9] 1 barrel (bbl) of oil=42 gallons (gal)

The U.S. Environmental Protection Agency (EPA) mobilized an Incident Management Team in response to the spill that included federal, state, and local agencies. The EPA reports that the spill was contained on July 28, 2010 about 80 miles from Lake Michigan and estimates that 27,359 bbl of oil have been recovered as of October 22, 2012 although the official estimated spill release was reported to be only 20,082 bbl (EPA, 2012; NTSB, 2012). Although large-scale cleanup was ongoing as of this report, the estimated response costs, including the role of the federal government in cleanup, were about $767 million as of October 31, 2011 (NTSB, 2012). Evaluations of air, water, and fish are ongoing. While no impacts on drinking water have been reported and contamination levels of fish were not high enough to trigger fish eating guidelines, an assessment of air contamination is still pending. (MDCH, 2001-2012).

2.1.2 Romeoville, Illinois Enbridge Spill

Two months after the spill in Michigan, Enbridge was responsible for another spill on the Lakehead System on Line 6A in Romeoville, Illinois. On September 9, 2010 a rupture resulted in a spill of about 6,095 bbl of dilbit. The spill resulted from a 2.5-inch long puncture on the bottom of the pipeline, likely caused by rocks lodged under the structure, although an official report is yet to be issued (Hood, 2010). As with the Michigan spill, Enbridge press releases describing the pipeline do not explicitly state that it carries dilbit.

The EPA oversaw the spill response with assistance from state and local agencies. The EPA reported the successful completion of its response on October 28, 2010, and transferred the cleanup of contaminated groundwater to the Illinois EPA. In total, the EPA reported in November 2010 that response efforts resulted in about 20,476 bbl of total oily liquids collected—including water and oil (EPA, 2012). Media outlets report that Enbridge cleanup costs for the spill were expected to be $40-$60 million (Huffington Post, 2010).

2.1.3 Burnaby, British Columbia, Kinder Morgan

Three years prior to the Enbridge spills in the U.S., there was a spill of approximately 1,400 bbl of synthetic crude oil in British Columbia. On July 24, 2007, a spill resulted from an excavator bucket striking the Westridge Transfer Line in Burnaby, British Columbia during excavation for a new storm sewer line. The pipeline is operated by Kinder Morgan Canada and is owned by Trans Mountain Pipeline L.P. It runs from the Burnaby terminal to the Westridge Dock, where it delivers oil to tankers (TSB, 2008a).

The oil flowed from the ruptured line into Burnaby's storm sewer systems until it reached the Burrard Inlet resulting in damage to the marine environment and affecting 1,200 meters of shoreline (TSB, 2008a). Cleanup took months and cost roughly $15 million and resulted in the recovery of 1,321 bbl of oil (CBC, 2011).

2.1.4 Keystone Pipeline Spills

In its first two years of operation, the Keystone Pipeline has experienced 35 spills, 14 of which were in the U.S. (Cornell University, 2012). Although most of these have been small spills, an accident in North Dakota resulted in a 500 bbl spill of dilbit.

2.1.4.1 Ludden, North Dakota, TransCanada

A failure at a North Dakota pump station resulted in a spill of about 500 bbl dilbit on May 7, 2011 causing the entire pipeline system to shut down for nearly one week. Reports from the North Dakota Public Service Commission assert that the spill was not due to the pipeline itself, but rather resulted from a failed fitting for a valve on the line's discharge piping (Crowl, 2011).

Under the leadership of private contractors and a regional incident management team, clean up and analysis of the spill commenced on May 7. All but approximately five bbl of the spilled oil were contained within the boundaries of the pumping station. Immediately following this spill, a U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a corrective action order requiring operators to replace similar fittings on all Keystone pump stations (USDOT PHMSA, 2011).

3 PROJECTIONS OF FUTURE SPILLS

3.1 Do Oil Sands Products Increase Pipeline Spills?

Although several studies and reports suggest that pipelines carrying dilbit have a higher frequency of spills than those carrying conventional crude due to the physical characteristics of dilbit, finalized studies as well as those underway suggest this is not the case. Citing PHMSA spill data, a Cornell University report found that between 2007 and 2010 pipelines transporting dilbit experienced three times more spills per mile in the northern Midwest than the national average for conventional crude oil due to the corrosive nature of the material (Skinner & Sweeney, 2012). The added corrosivity of oil sands-derived products is, however, a contested issue. Although the National Resources Defense Council (NRDC) echoed these findings in saying dilbit is "more likely to cause corrosion" in pipelines and tankers (NRDC, 2011); data from several studies suggest that oil sands products are not significantly more corrosive.

Recent studies on dilbit and oil sands products characteristics carried out by Heather Dettman of Natural Resources Canada (NRC) and J. Zhou and J. Been as commissioned by Alberta Innovates. Noting that water content is the paramount factor in pipeline corrosion, Dettman and Zhou and Been use an analysis of sediment content, water content, and other characteristics to assert oil sands products are not significantly different than comparable heavy crudes and are not more highly corrosive enough to be a concern to pipeline operators (Dettman, 2012; Zhou, Been, 2011). For a further discussion of oils sands and pipeline corrosion, refer to section 5.5.

3.2 Available Spill Risk Assessments

To determine potential risk of oil spills, public agencies and private consulting firms have carried out assessments on spill predictions for the Keystone, Keystone XL, Enbridge Alberta Clipper, and Northern Gateway pipelines. Assessments to provide spill predictions for the Kinder Morgan Trans Mountain pipeline expansion and the Enbridge Line 9 Reversal in Eastern Canada are respectively planned and underway.

3.2.1 Pipelines

Based on U.S. Department of Transportation's statistics, transmission of oil and petroleum products via pipeline is the safest mode in terms of ratio of accidents per amount transported per year (Tables Table **3-1**, Table **3-2**) (Furchtgott-Roth, 2012; Pipeline & Hazardous Materials Safety Administration [PHMSA], 2013).

In compliance with U.S. and Canada governmental requirements to carry out environmental impact assessments, spill risk data are available for the TransCanada Keystone, proposed TransCanada Keystone XL, and Enbridge Northern Gateway pipelines. Assessments are pending for the Kinder Morgan Trans Mountain expansion and Enbridge Line 9 Reversal pipelines. Spill risk data are not available for the Enbridge Lakehead System (Alberta Clipper and Bakken expansions), Kinder Morgan Express, and current Kinder Morgan Trans Mountain pipelines. As U.S. and Canadian reporting and assessment requirements differ and accessibility of documents vary, the amount, source, and presentation of data on spill risk is not consistent across these studies.

Comparative Statistics for Incident Rates Onshore Transmission Pipelines vs. Road and Railway (2005-2009)			
Mode	**Billions Ton Miles of Shipment**	**Average Hazmat Incidents per Year**	**Average Hazmat Incidents per Billion Ton Mile**
Road	23	14,963	650.6
Railway	35.1	718	20.5
Hazardous Liquid Pipeline (Onshore)	584.1	354	0.61
Gas Transmission Pipeline (Onshore)	338.5	300	0.89

Table 3-1: Incident Rates Onshore Transmission Pipelines vs. Road and Railway (2005-2009)

Year	Number	Fatalities	Injuries	Property Damage as Reported ($ million)	Gross Barrels Spilled	Net Barrels Lost	% of Volume Recovery
1993	445	17	111	$67.3	116,802	57,559	51%
1994	467	22	120	$160.6	164,387	114,002	31%
1995	349	21	64	$53.4	110,237	53,113	52%
1996	381	53	127	$114.5	160,316	100,949	37%
1997	346	10	77	$79.8	195,549	103,129	47%
1998	389	21	81	$126.9	149,500	60,791	59%
1999	339	22	108	$130.1	167,230	104,487	38%
2000	380	38	81	$191.8	108,652	56,953	48%
2001	341	7	61	$63.1	98,348	77,456	21%
2002	644	12	49	$102.1	97,255	77,953	20%
2003	673	12	71	$139.0	81,308	50,889	37%
2004	673	23	60	$271.8	89,311	69,003	23%
2005	721	14	48	$1,246.8	138,094	46,246	67%
2006	642	21	36	$151.1	137,693	53,905	61%
2007	615	15	50	$154.9	94,981	68,941	27%
2008	662	8	57	$565.9	102,076	69,510	32%
2009	627	13	64	$179.0	55,014	32,307	41%
2010	590	22	109	$1,465.3	174,931	123,420	29%
2011	595	14	60	$365.3	139,017	108,140	22%
2012	569	12	56	$188.4	54,061	32,401	40%

Table 3-2: National Pipeline Systems –Reported Incidents Summary Statistics: 1993-2012

3.2.2 Rail

Concerning the risks associated with transporting dilbit via rail, risk assessments are not conducted according to the specifics of the material being transported. However, an EPA report does provide rail specific data of on spills of all types of oil in U.S. inland waterways. Between 1980 and 2003, there were 265 spills attributed to rail, which accounted for 0.05 percent of the total number of spills over that timeframe. The average volume per spill was 8,185 gallons (Etkin, 2006). Further discussion on rail transport and regulation are provided in sections 4.2 and 8.3.3.2.

3.2.3 Waterways and Terminals

Regarding spills at coastal terminals and waterways, Enbridge has published spill risk assessments for their pipeline to the Kitimat Terminal and a recent risk assessment was conducted for the Aleutian Islands. These are discussed below. However, risk assessments for other terminals expected to handle oil sands products will not be conducted until upgrades to facilities are underway and regulations require assessments to take place.

3.3 Keystone XL Pipeline

The State Department has released two Environmental Impact Statements (EIS) of the Keystone XL, the most recent of which was released in March, 2013 accounts for a re-routed pipeline through Nebraska.

The 2013 draft EIS of Keystone XL reports spill releases as distributed by volume. Basing their figures on historical spill data from PHMSA, the State Department asserts that for all spills along all pipeline components, 79 percent will be less than 50 bbl, 17 percent will be 50-1,000 bbl, and 4 percent will be 1,000-20,000 bbl. Moreover, they predict that there will be .00313 incidents per mile-year of which 21 percent would be greater than 50 bbl. Notably, the final EIS discusses the fact that an undetected leak along a buried section of the pipeline could saturate soil with the potential for the material spilled to reach groundwater. The Final EIS also provides information on pipelines mileage that could affect water bodies. Narrowing their analysis to water bodies in Montana, South Dakota, and Nebraska, they assess that there are about 355 miles, 129 miles, and 278 miles of pipeline in these respective state that are prone to spills of more than 50 bbl that could affect water bodies (U.S. Department of State, 2013)

The first EIS of the Keystone XL Pipeline provides figures for “significant spills,” or those predicted to exceed 50 bbl. Drawing on historical spills from the PHMSA database, the estimated projection for significant spills is 1.18 spills per year (.0007 per mile over 1,682 miles). This equates to nearly 59 spills greater than 50 bbl over the 50-year design life of the pipeline.

The EIS indicates that the maximum spill volume is 66,666 bbl, which, due to topographic conditions, is only possible along less than 1.7 miles of the proposed route. Taking factors such as shutdown time, structural failure, flow rate, and line drainage volumes into account; for about 50 percent of the proposed pipeline route the maximum spill volume would be about 16,000 bbl , which could result from a “complete structural failure of the pipeline” (U.S. Department of State, 2011). The EIS also asserts that spill volumes would be much lower at river crossings because main line valves (MLVs) occur on either side of each river crossing (U.S. Department of State, 2011).

Two additional assessments of the Keystone XL pipeline provide different figures. An assessment carried out by TransCanada contractor DNV consulting, found the likelihood of significant spills (greater than 50 bbl) to be .21 (.00013 per mile) or about 11 spills over 50 years. John Stansbury of the University of Nebraska argues that these figures are “highly questionable” because the firm failed to take into account the historical PHMSA spill data that accounts for 23 percent of historical pipeline data (Stansbury, 2011). Taking the PHMSA data into account and using dilbit’s increased acidity and sulfur rates to substantiate his claims of the material's increased corrosiveness and abrasiveness, Dr. Stansbury's spill prediction for Keystone XL is 1.83 (.00109 per mile) or 91 significant spills over 50 years (Stansbury, 2011). However given data showing that dilbit is not more corrosive than other crude oils, Dr. Stansbury's results might be overstated.

Dr. Stansbury also provides worst-case spill scenarios for major Keystone XL river crossings and the Sandhills region of Nebraska. At the Missouri River Crossing, his worst-case spill prediction is 122,867 bbl. For the Yellowstone River, the worst-case prediction is 165,416 bbl. At the Platte River crossing, the worst-case prediction is 140,950 bbl (Stansbury, 2011).

Keystone Pipeline

A DNV Energy analysis carried out for TransCanada provides estimates for spills greater than 50 bbl on the Keystone pipeline. Providing data specifically for spills of diluted bitumen, DNV states in a section on uncertainties that their estimates assume failure causes are identical to crude oil (DNV Energy, 2011). The DNV estimates are 0.094 and 0.151 spills per year respectively for the mainline and the mainline plus the Cushing extension (DNV Energy, 2011). Over a fifty-year period, this equates to 4.70 and 7.55 spills respectively.

Regarding worst-case spills, Dr. Stansbury uses Keystone figures to support his analysis of Keystone XL. He asserts that TransCanada estimated worst case spills for the Keystone pipeline (at Hardisty Pumping Station) to be 41,504 bbl, while Stansbury's estimate is closer to 88,000 bbl (Stansbury, 2011). The principal difference in arriving at these estimates is the assumed shut-down time, 19 minutes for TransCanada and two hours for Stansbury (Stansbury, 2011).

3.4 Northern Gateway Pipeline

Enbridge provides data on spill risks for their Northern Gateway pipeline, the Kitimat Terminal, and associated waterways in a 2011 General Oil Spill Response Plan (Enbridge, 2011). The estimated spill frequency data in the report is provided in spill return years (number of years per spill). Converting these figures to yearly spill likelihoods, the company predicts there will be about 0.036 spills per year greater than 62.8 bbl on the pipeline in the region between Alberta and Kitimat. The maximum spill volume along the pipeline is predicted to be 49,060 bbl at kilometer point (KP) 165 near Mayerthorpe. The assessment also states that the pipeline is designed to limit spill volumes at watercourse crossings to less than 12,579 bbl. For spills at the Kitimat Terminal involving a tanker at berth, there will be an estimated 0.002 spills greater than 62.8 bbl per year. A separate, third party assessment carried out by University of British Columbia engineering professors puts the estimated spill rate per year at 0.014 (Gunn, Foschi, & Sexsmith, 2012) The maximum spill volume at the terminal is predicted to be 10,063 bbl. And for waterway spills associated with tanker traffic, there will be an estimated 0.003 spills per year of any volume and 0.002 spills per year greater than 31,449 bbl. The maximum spill volume for a waterway spill is predicted to be 226,433 bbl.

3.5 Unimak Pass

An assessment of worst case spills in the Aleutian Islands is relevant to the report given the likelihood that oil sands products will be shipped via great circle routes through the islands and Unimak Pass for export to Asia. Data presented here comes from The National Fish & Wildlife Foundation, U.S. Coast Guard, and State of Alaska Department of Environmental Conservation multi-phase risk assessment of maritime transportation in the Bering Sea and the Aleutian Archipelago. Providing baseline and future accident estimate predictions for all vessels

(8.67 for 2008/2009 and 9.61 for 2034), a summary report of the assessment estimates that collisions with crude oil tankers along this route would result in a spill of 428,080 bbl (Aleutian Islands Risk Assessment Management Team, 2011).

4 TRANSPORTATION METHODS

As stated in section 1.4 pipelines, rail, barges and tankers are the primary modes of transporting crude oil products from source to markets in North America. Canada produced roughly 1.2 billion barrels in 2012 (approximately 3.5 mbl/d), 55 percent of which were oil sands products (upgraded bitumen and non-upgraded bitumen) (CNEB, 2012). As of 2011, 65 percent of Canadian crude oil production was destined for the U.S (CNEB, 2012; EIA, 2012). The most widely used mode of exporting Canadian crude oil to the U.S. is the use of pipelines. Canada exported 89 percent of its crude oil via pipelines, 10.8 percent via marine transportation and 0.2 percent via rail (CNEB, 2012). However, due to environmental and political challenges to pipeline expansion, the use of rail is rapidly growing (EIA, 2013; CNEB, 2012). From 2007 to 2011, the use of pipelines grew by only 5.3 percent yearly and use of marine (tankers and barges) shrank by 2.4 percent yearly, while use of rail has increased by over 7000 percent yearly (EIA, 2013; CNEB, 2012). The rapid growth in use of rail stems from the facts that almost no crude oil was transported via rail in 2007 and 2008 (EIA, 2013; CNEB, 2012).

The U.S. accounts for 97 percent of Canadian crude oil export (CNEB, 2012). In 2012 Canada's crude oil export to the U.S. included conventional light ($30 < API$), conventional medium ($25 < API < 30$), conventional heavy ($API < 25$), synthetic (upgraded bitumen or upgraded heavy crude oil of any API), and blended bitumen (bitumen blended with light hydrocarbons and/or synthetic crude oil) (CNEB, 2012). As of the 3rd quarter of 2012, oil sands products were the largest type of crude oil product exported to the U.S. (31 percent), followed by conventional heavy (24 percent), synthetic (24 percent), conventional light (18 percent) and conventional medium (3 percent) (CNEB, 2012). This makes the U.S. consumer of 99 percent of the Canadian oil sands crude products destined for export (CNEB, 2012).

There are major policy and research gaps related to transportation of oil sands products (pipelines, rail or marine) that must addressed in order for both the policy makers and governmental organizations to assess ecological, environmental, social and economic risks and uncertainties surrounding integration of oil sands products into the global economy. Sections 8.8 and 9 outline major gaps in both policy and research.

4.1 Pipelines

Pipelines are the primary mode of transportation for oil products in North America. Approximately 71 percent of crude oil and petroleum products (including crude oil and post refining products) are shipped via pipelines on the ton-mile basis (mass in tons * distance in miles) (Bureau of Transportation Statistics [BTS], 2012). Tanker and barge traffic account for roughly 23 percent of oil shipments, and rail about 3 percent (Table 4-1) (BTS, 2012). By focusing on the crude oil products, including all types of crude oil, the numbers swing even more towards pipelines. In 2009 roughly 80 percent of all crude oil transport in ton-miles in North America was via pipelines, while tankers and barges accounted for 19 percent and rail 0.3 percent respectively (Table 4-1) (BTS, 2012).

Crude Oil and Petroleum Products Transported in the United States by Mode (billions)						
	2008			**2009**		
	Tonne-Kilometers	**Ton-Miles**	**%**	**Tonne-Kilometers**	**Ton-Miles**	**%**
Crude oil, total	**543.1**	**372.0**	**100.0%**	**490.6**	**336.0**	**100.0%**
Pipelines	447.2	306.3	82.3%	391.6	268.2	79.8%
Water carriers	92.3	63.2	17.0%	95.0	65.1	19.4%
Motor carriers	2.5	1.7	0.5%	2.5	1.7	0.5%
Railroads	1.0	0.7	0.2%	1.5	1.0	0.3%
Refined petroleum products, total	**709.4**	**485.9**	**100.0%**	**692.2**	**474.1**	**100.0%**
Pipelines	437.1	299.4	61.6%	438.3	300.2	63.3%
Water carriers	191.0	130.8	26.9%	177.7	121.7	25.7%
Motor carriers	48.8	33.4	6.9%	47.0	32.2	6.8%

Crude Oil and Petroleum Products Transported in the United States by Mode (billions)						
	2008			2009		
	Tonne-Kilometers	Ton-Miles	%	Tonne-Kilometers	Ton-Miles	%
Railroads	32.6	22.3	4.6%	29.1	19.9	4.2%
Combined crude and petroleum products, total	**1,252.5**	**857.9**	**100.0%**	**1,182.7**	**810.1**	**100.0%**
Pipelines	884.3	605.7	70.6%	829.8	568.4	70.2%
Water carriers	283.2	194.0	22.6%	272.7	186.8	23.1%
Motor carriers	51.2	35.1	4.1%	49.5	33.9	4.2%
Railroads	33.6	23.0	2.7%	30.5	20.9	2.6%

Table 4-1: Crude Oil and Petroleum Products Transported in the US by Mode

There are three major types of pipeline systems that support transfer of oil from its source to destination; they are for gathering, crude oil, and refined products, with sizes ranging from 2 inches to 42 inches in diameter (Figure 4-1) (BTS, 2012). The U.S. has a network of 175,000 miles of these pipelines for the purpose of onshore and offshore transmission of crude oil and petroleum products (BTS, 2012). Gathering pipeline systems gather crude oil from production wells, crude oil pipeline systems transport crude oil from the gathering systems to refineries, and refined products pipeline systems transport refined products such as gasoline, kerosene and many industrial feedstock petrochemicals from refineries to the end user or to storage and distribution terminals (BTS, 2012).

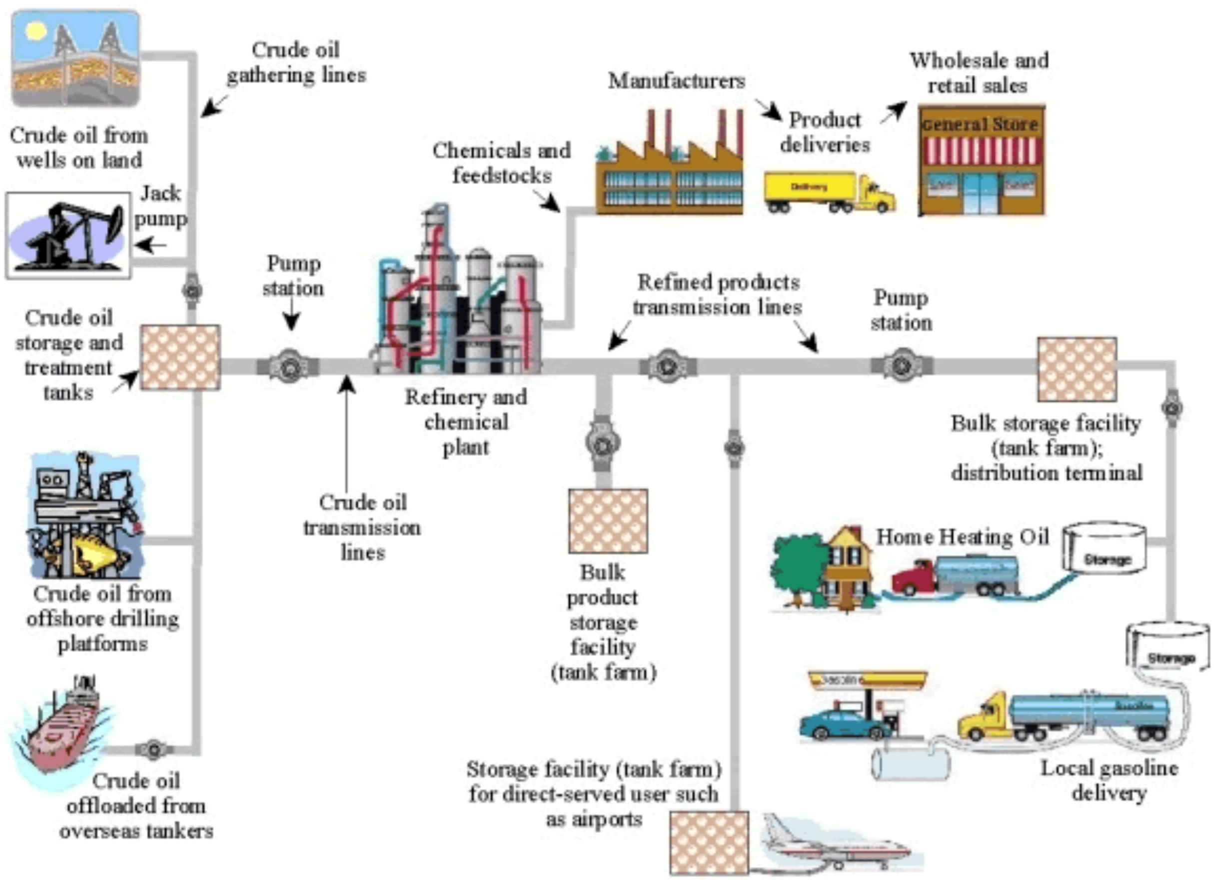

Figure 4-1: US DOT, PHMSA's Petroleum Pipeline Systems

4.1.1 Networks of Crude Pipelines in North America

As stated in section 1.4.1, there are four major networks of crude pipelines in North America that carry crude products from the source (wells and mines) to the destination (refineries and offshore drop off terminals for tanker shipment) with an average capacity of 3.5 mbl/d (CAPP, 2012; CNEB, 2009).

It is worth mentioning that Canadian heavy-crude prices have declined relative to their U.S. and international benchmarks due to lack viable transportation mechanism to transfer the increased production capacity to market (Olson & van Loon, 2013). According to Bloomberg News, Western Canada Select, a blend refined from oil-sands bitumen, had fallen over 20 percent during the past six months amid uncertainty over approvals for Keystone XL, Enbridge's Northern Gateway and Kinder Morgan Energy Partners LP (KMP)'s TransMountain pipelines (Olson & van Loon, 2013).

4.1.1.1 Enbridge Mainline Pipeline System

The Enbridge pipeline system delivers crude oil and other refined products from western Canada, Montana, and North Dakota to markets in western Canada, the U.S. PADD II (**Error! Reference source not found.**), and Ontario (CAPP, 2012; CNEB, 2009). The system connects to a number of regional pipelines in the U.S. PADD II region, such as the Minnesota Pipeline at Clearbrook, MN and Spearhead South at Flanagan, IL (CAPP, 2012; CNEB, 2009). The Enbridge system has the capacity of 2.3 mbl/d (CAPP, 2012; CNEB, 2009; CNEB, 2006).

The Enbridge network is currently being expanded through upgrades to two of its main pipelines, Alberta Clipper and Southern Access (CAPP, 2012; CNEB, 2009). By 2014, when the expansion projects are completed, the Alberta Clipper will have an additional 0.12 mbl/d capacity and the Southern Access with have an addition 0.16 mbl/d capacity (CAPP, 2012; CNEB, 2009; CNEB, 2006).

4.1.1.2 Kinder Morgan Express and Trans Mountain Pipeline Systems

Kinder Morgan Canada, Inc. is the parent company of both Kinder Morgan and Trans Mountain Pipelines (CAPP, 2012; CNEB, 2009). The Trans Mountain system originates in Edmonton, Alberta and transports crude oil and petroleum products to delivery points in British Columbia, which include the Westridge dock for offshore exports to final destinations that include the U.S. PADD V (primarily CA and WA) and Asia (CAPP, 2012; CNEB, 2009; CNEB, 2006).

The system also includes the Express Pipeline system, which is comprised of the Express Pipeline and the Platte Pipeline (CAPP, 2012; CNEB, 2009). This system connects Canadian and U.S. crude oil producers to refineries in the U.S. PADD II and PADD IV (CAPP, 2012; CNEB, 2009). The Express Pipeline originates at Hardisty, Alberta and ends at the Casper, WY facilities on the Platte Pipeline with a capacity of 0.280 mbl/d (CAPP, 2012; CNEB, 2009; CNEB, 2006). The Platte Pipeline runs from Casper, WY to refineries and interconnecting pipelines in Wood River, IL with the capacity of 0.15 mbl/d (CAPP, 2012; CNEB, 2009).

4.1.1.3 TransCanada Keystone Pipeline System

The existing Keystone pipeline system runs from Hardisty, Alberta to terminals in Wood River and Patoka, IL (CAPP, 2012; CNEB, 2009). The latest extension to the Keystone pipeline is the Cushing Extension, which runs from Steele City, NE to Cushing, OK (CAPP, 2012; CNEB, 2009). The system has a capacity of 0.591 mbl/d to either Wood River or Cushing depending on market requirements (bidirectional) (CAPP, 2012; CNEB, 2009; CNEB, 2006).

TransCanada's future expansion plan includes the Keystone XL pipeline. The purpose of this pipeline will be to transfer oil sands products from Alberta to refineries on the Gulf Coast (PADD III), and from there to international markets. The initial routing plan faced fierce objections from a variety of stakeholders, including several state governments and environmental groups (Avok, 2011). A new revised route has been selected to address the environmental concerns related to the original routing in state of Nebraska. This new route proposal resulted in NE governor approving the passage of pipeline through his state (Gardner & Quinn, 2013). On March 1, 2013, the U.S. State Department issued a revised environmental impact statement for the Keystone XL pipeline. The statement, although, "made no recommendation about whether the project should be built, it presented no conclusive environmental reason that it should not be"

(Broder, 2013). Thus, the report raised the possibility of final approval by the U.S. government (Broder, 2013). The approval of the proposal now depends on President's Obama's decision. TransCanada will begin the construction of the pipeline in the first half of 2013 with a targeted in-service date of 2015 if the project is approved (TransCanada; Gardner & Quinn, 2013). The Keystone XL would originate at Hardisty, Alberta and end at Steele City, NE (TransCanada). The proposal has the transfer capacity of 0.83 mbl/d and its primary function would be to transport synthetic crude oil and dilbit from the Athabasca oil sands region to multiple destinations in the U.S. PADD II, III and IV (CAPP, 2012; CNEB, 2006).

4.1.2 Regional Crude Pipelines in the U.S.

Table 4-2 lists all major crude pipelines connecting Canadian sources to various regions of the U.S. The table is divided into multiple U.S. PADD regions (CAPP, 2012; CNEB, 2009; CNEB, 2006).

Summary of Crude Oil Pipelines to the U.S. East Coast - U.S. DOE PADD I				
Pipeline	**Originating Point**	**Destination**	**Status**	**Capacity (mbl/d)**
Enbridge Line 9	Sarnia, ON	Montréal, QC	Operating	0.24
Enbridge Line 9 Reversal	Montréal, QC	Sarnia, ON	Changed Direction – 1999	
Portland-Montreal	Montréal, QC	Portland, ME	Operating	0.60
TransCanada East Coast Pipeline Project	Montréal, QC	Saint John, NB	Proposed – 2015	0.63
Summary of Crude Oil Pipelines to the U.S. Midwest & Rocky Mountain - U.S. DOE PADD II & PADD IV				
Pipeline	**Originating Point**	**Destination**	**Status**	**Capacity (mbl/d)**
Minnesota Pipeline	Clearbrook, MN	Minnesota refineries	Operating	0.47
Enbridge Mainline	Superior, WI	Multiple delivery points	Operating	1.56
Spearhead North Expansion	Flanagan, IL	Spearhead North Chicago, IL	Proposed – 2014	0.10
Enbridge Spearhead	South Flanagan, IL	Cushing, OK	Operating	0.19
Enbridge Flanagan South	Flanagan, IL	Cushing, OK	Proposed – 2014	0.59
Enbridge Mustang	Lockport, IL	Patoka, IL	Operating	0.10

Kinder Morgan Express-Platte	Guernsey, WY	Wood River, IL	Operating	0.15
Trans Canada Keystone to Patoka or Wood River	Hardisty, AB	Patoka, IL	Operating	0.59
Trans Canada Keystone to Cushing	Steele City, NE	Cushing, OK	Operating	
Summary of Crude Oil Pipelines to the U.S. Gulf Coast - U.S. DOE PADD III				
Pipeline	**Originating Point**	**Destination**	**Status**	**Capacity (mbl/d)**
ExxonMobil Pegasus	Patoka, IL	Nederland, TX	Operating	0.10
Seaway Reversal Phase 1	Cushing, OK	Freeport, TX	Operating – May 2012	0.15
Seaway Reversal Phase 2			Proposed – Early 2013	0.25
Seaway Twin Line			Proposed – Mid 2014	0.45
TransCanada Gulf Coast	Cushing, OK	Nederland, TX	Proposed – Mid 2014	0.55
Summary of Crude Oil Pipelines to the West Coast - U.S. DOE PADD V				
Pipeline	**Originating Point**	**Destination**	**Status**	**Capacity (mbl/d)**
Kinder Morgan Trans Mountain	Edmonton , AB	Burnaby, BC	Operating	0.30
Kinder Morgan Trans Mountain Expansion			Proposed – 2017	0.45
Enbridge Northern Gateway	Bruderheim, AB	Kitimat, BC	Proposed – 2017	0.53

Table 4-2: Major Crude Pipelines Connecting Canadian Sources to the U.S. Destinations

4.1.3 Diluent Pipelines

Table 4-3 summarizes the proposed pipelines for transport of diluent in reverse direction to the where oil sands upgrading occurs. These pipelines will address the potential demand by western Canadian oil sands producers for additional diluent supply needed to transport growing volumes of bitumen-derived products (CAPP, 2012; CNEB, 2009; CNEB, 2006).

Summary of Diluent Pipelines				
Pipeline	**Originating Point**	**Destination**	**Status**	**Capacity (mbl/d)**
Enbridge Southern Lights	Flanagan, IL	Edmonton, AB	Operating	0.18
Enbridge Northern Gateway	Kitimat, BC	Edmonton, AB	Proposed – 2017	0.19

Summary of Diluent Pipelines				
Pipeline	**Originating Point**	**Destination**	**Status**	**Capacity (mbl/d)**
Kinder Morgan Cochin Conversion	Kankakee County, IL	Fort Saskatchewan, AB	Open Season – Ends May 2012	0.08
Portland-Montreal Bitumen Expansion	Montréal, QC	Portland, ME	Proposed – 2017	

Table 4-3: Summary of Major Diluent Pipelines

4.2 Rail Transportation

The increase in production of crude products in North America and the costly and lengthy process of obtaining permits for new pipelines have made rail the transport mode of choice for crude oil products, especially at new crude production sites (Black, 2013). The number of crude oil carrying rail cars tripled to more than 200,000 units between 2011 and 2012, and is expected to continue to grow in the foreseeable future (Black, 2013). Furthermore, an analysis conducted by the U.S. Department of State indicated that with modest expansion and upgrades to the existing infrastructure, railroad networks in the U.S. can handle all new oil produced in western Canada through 2030 (Efstathiou, 2012; U.S. Department of State [DOS], 2013).

The biggest players in transport of crude products via rail in North America are Canadian National Rail (CN), Canadian Pacific Rail (CPR) and Burlington Northern Santa Fe (BNSF). These companies, along with other rail companies and major oil car manufacturers in North America, foresee continuous growth in their sector for a foreseeable future due to the slow process of granting permits for new pipelines (Vanderklippe, 2013).

Since trains haul commodities by their weight (typically in tons or carloads) and pipelines move oil products by the barrels/day, comparison of the two modes of transport is difficult (Furchtgott-Roth, 2012; Vanderklippe, 2013). Despite that, studies have been conducted to compare the two modes of transporting oil products (Furchtgott-Roth, 2012; Vanderklippe, 2013). A report by the Manhattan Institute aggregated data from U.S. Department of Transportation and looked at risks associated with the transport of crude oil and petroleum products via pipelines, rail, trucks, and ships. The study found that the average hazmat incidents per billon-ton mile were 0.61 spills for pipelines, 20.5 for rail and 650.6 for road (trucks and etc.) (Furchtgott-Roth, 2012). Comparing pipelines vs. rail, that is a spill rate 34 times higher for rail (Furchtgott-Roth, 2012). The American Association of Railroads (AAR), however, disputes that analysis. According to AAR's internal study, there is a much smaller spill ratio of 2.6 times the pipeline rate (Association of American Railroads [AAR], 2013). AAR's study also determined that trains on average leak smaller amounts than pipelines (AAR, 2013). It must be noted that AAR's claims have not been independently assessed and verified. The association website said "railways spill less of their hazardous liquid product than do pipelines, 9 percent less per billion barrel miles over the 20-year period 1990-2009 and 35 percent less over the 2002-2009 period" (AAR, 2013).

The Railway Association of Canada (RAC) also claims that unlike pipelines, oil sands crude, which they refer to as "bitumen" can be moved by train without dilution (Vanderklippe, 2013). Because of bitumen's physical characteristics, in the case of a spill due to derailment, "it's like molasses in January coming out. So you're not going to have a huge problem," said Michael Bourque, president of the RAC in an interview with the Globe and Mail (Vanderklippe, 2013). It is worth mentioning that Mr. Bourque's claim has not been independently assessed and verified.

Putting aside the apparently conflicting statistics presented by the rail and pipeline industries, both means of transporting crude oil have experienced accidental spills in recent years. For example, CN trains leaked roughly 4,400 barrels of Bunker C in Lake Wabamun, Alberta in 2005 and a derailment and explosion near Rockford, IL lost 7,700 barrels in 2009 (Vanderklippe, 2013). Pipelines are also subject to spills as discussed in Section 2.

Rail will be used to ship oil sands products from Alberta to U.S. markets. According to TransCanada's president, Alex Pourbaix, even if all of the proposed pipeline were delayed, oil-sands development would continue because of the possibility of crude exports by rail even though shipping oil by rail is about two to three times more costly than by pipeline (Olson & van Loon, 2013).

4.3 Marine Shipment

Shipment of crude and petroleum products via barges across North America and tankers to Asia and other consumer markets is expected to grow dramatically (International Energy Agency, 2012). It is expected that tanker traffic will increase primarily in Puget Sound, the Gulf of Mexico, and Maine if the proposed Enbridge Gateway (West Cost), TransCanada's Keystone XL (Gulf Coast) and Kinder Morgan Trans Mountain Expansion of Portland-Montreal's Bitumen Expansion (East Coast) are approved (CAPP, 2012).

Due to the limited availability of data for other regions, the remainder of this section will focus on increased vessel traffic in Pacific Northwest, especially in Puget Sound, Strait of Juan de Fuca and Unimak pass and Aleutian Islands.

4.3.1 Puget Sound Waters – British Columbia to Washington

The increased traffic in the Puget Sound Area would be primarily due to barges that carry crude oil products from British Columbia to refineries in Washington State, with most barges transiting from Vancouver, BC to refineries in Cherry Point and Tacoma (Jensen & Pilkey-Jarvis, 2012).

4.3.2 Strait of Juan de Fuca – British Columbia to Western U.S. States and Asia

The Pacific Northwest also serves as a shipping point for crude oil export from Vancouver, BC, Grays Harbor, WA, and Tacoma, WA to markets in California and across the Pacific region, primarily Asia through Puget Sound and Strait of Juan de Fuca (Figure 4-2) (Jensen & Pilkey-Jarvis, 2012). This potential increase in tanker traffic in the Strait has caused multiple stakeholders in the region, including the Makah Tribe and Puget Sound Partnership, to commission a risk study from a team of scientists at George Washington University called the Vessel Traffic Risk Assessment (VTRA). The purpose of VTRA is to develop a geographic profile for oil spill risk simulation using 2010 vessel traffic data (Hass, 2013; van Dorp, 2013). The study's final report will describe the analysis results of the geographic profiles of 2005 and 2010 oil spills by vessel type and location stated in Table 4-4. The study will analyze the increased traffic due to Gateway and Kinder Morgan's pipeline proposals to ship Canadian crude oil products from British Columbia to Asian markets as well as the increased re-shipment inside Puget Sound waters by barges (Hass, 2013). The study's initial report is due in August 2013.

LOCATION	VESSEL TYPE
Cherry Point Area	Tug without Barge
Puget Sound South	Tug ATB's or ITB's
Strait of Juan de Fuca East	Tug Pushing Ahead
Strait of Juan de Fuca West	Container
Puget Sound North	Tanker
Saddle Bag Area	Bulk carrier
Rosario Strait	Freighter
Haro Strait \ Boundary Pass	Passenger vessel
Guemes Channel	Service vessel
	Public vessel
	Fishing Vessel
	Tug Towing Astern
	Recreational Vessel

Table 4-4: Scope of the VTRA Study Commissioned by Makah Tribe and Puget Sound

The Government of British Columbia and environmental organizations, such as Natural Resources Defense Council, Pembina Institute and Living Oceans Society, also conducted analyzed increased social, economic, and environmental risks resulting from vessel traffic growth in Puget Sound and the Strait of Juan de Fuca waters, especially the rapid growth in tanker traffic (Government of British Columbia [Gov. BC], 2012; Swift, Lemphers et al., 2011). The report categorized risks into four major areas that include:

- “Compromising the lifestyles of First Nations who depend on the region’s lands and waters for their livelihoods, culture, and health”
- “Threatening the economic well-being of the communities of British Columbia that depend on fisheries and forests”
- “Potential devastation from a major oil spill from the pipeline or an oil supertanker, which could destroy economically important salmon habitat, as well as the habitat of Spirit Bears and grizzlies, and whales, orcas, and other marine life that depend on these rich coastal waters”
- “Harm from an oil spill to the Great Bear Rainforest that the province and First Nations have worked hard to protect from unsustainable forestry practices and to shift to a conservation-based economy (Swift, Lemphers et al., 2011).”

Figure 4-3 is the graphical depiction of response processes devised by the Government of British Columbia in case of a major marine spill. The flow of these processes was developed to address some of the concerns raised during that government’s assessment of rapid growth in tanker traffic in Strait of Juan de Fuca (Gov. BC, 2012).

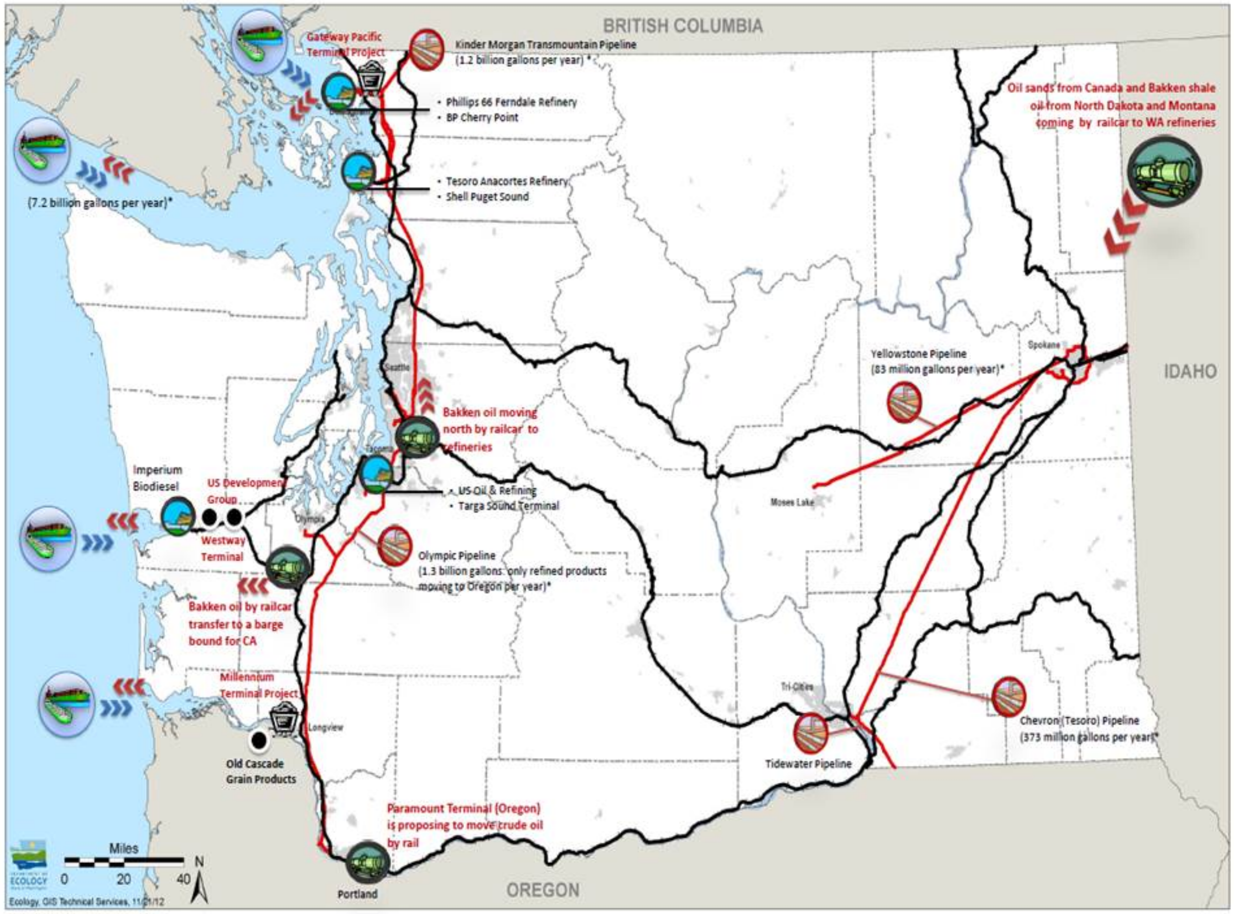

Figure 4-2: Map of Crude Oil Transport in Washington State (WA Dept. of Ecology)

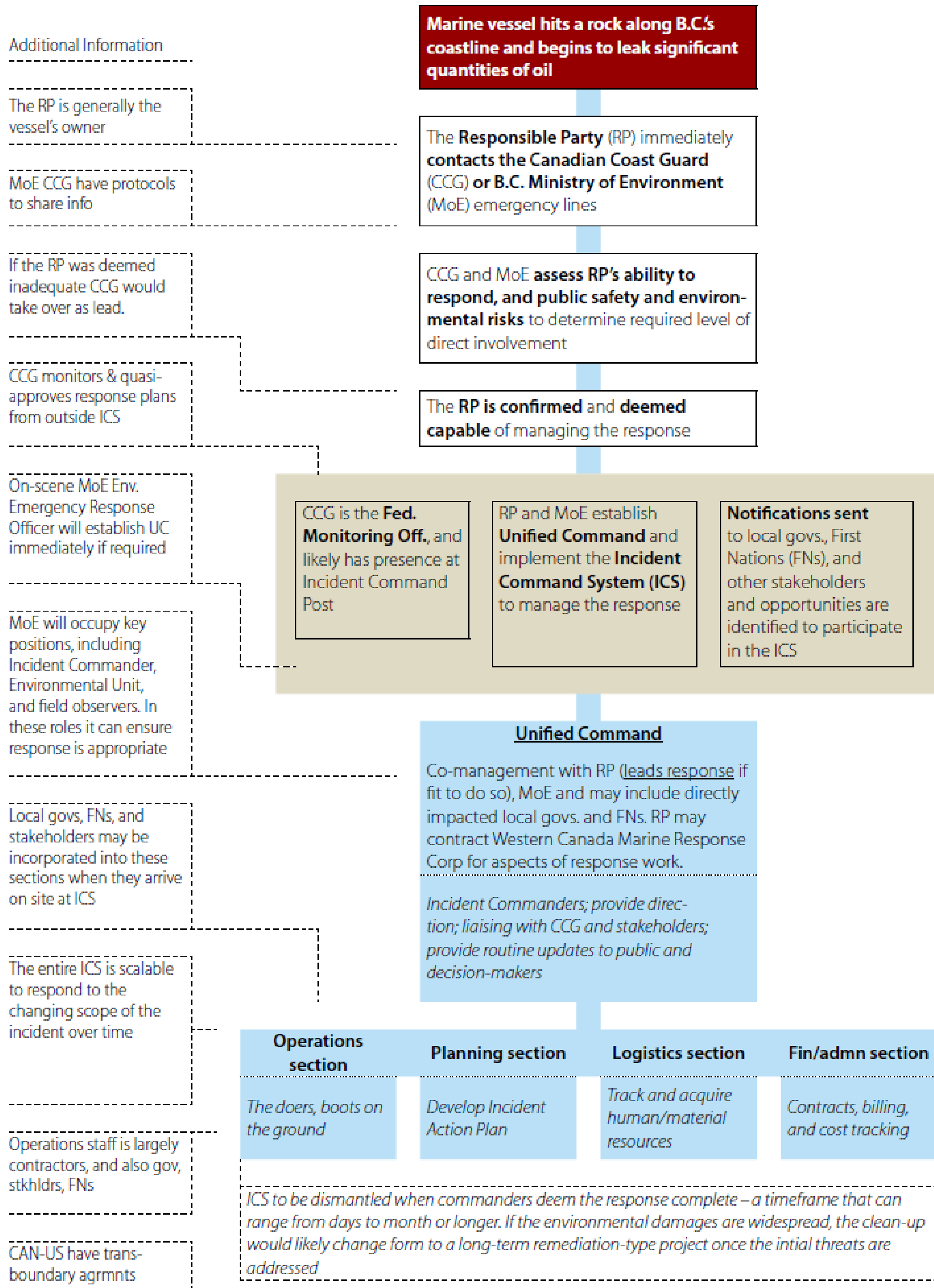

Figure 4-3: Response Plan for a Major Spill in the Marine Environment - Canadian North Pacific

4.3.3 Unimak Pass and the Aleutian Islands – British Columbia to Asia

Upon approval of Enbridge's Northern Gateway pipeline to Kitimat, BC, there will be dramatic surge in tanker traffic from Kitimat to Asian markets through the Aleutian Islands (Hass, 2013). This increase in tanker traffic coupled with dramatic growth in overall transpacific traffic, due to advancement of trade relations across Asia and North America, has amplified the risk of accidents and spills in waters off the coast of the Aleutian Islands (Transportation Research Board of the National Academies [TRB], 2009). The Aleutian Islands' abundant natural resources are quite unique to that region and the main source of that region's economic vitality (TRB, 2009). Any accidents involving these ships cold result in oil spills with serious ecological, environmental, social and economic consequences. To study the risks and put forth recommendations to mitigate them, the U.S. Coast Guard (USCG) commissioned the Transportation Research Board (TRB) within the National Academies conduct a study (TRB, 2009). The final report was called, "Risk of Vessel Accidents and Spills in the Aleutian Islands: Designing a Comprehensive Risk Assessment" that was publishes in 2009.

The primary recommendation of the report was for a more comprehensive long-term study of vessel accident risks around the Aleutian Islands, but it also offered USCG some interim risk mitigation steps:

- "USCG to take appropriate action to expand the AIS tracking network along the Aleutian chain and covering the southern North Pacific Great Circle Route"
- "USCG to investigate the possible structure and costs of a Vessel Traffic Information System within and near Unimak Pass and Dutch Harbor (TRB, 2009)"

Data gathered through the interim steps should also assist with more comprehensive risk assessment study, information about this ongoing work can be found at: http://www.aleutiansriskassessment.com.

5 PROPERTIES, FATE, AND BEHAVIOR OF OIL SANDS PRODUCTS

5.1 Definition of Terms

Specific gravity and API (American Petroleum Institute) gravity are both measures of density relative to water. Although specific gravity is a more common measurement in the broader scientific community, API gravity is standard when comparing the densities of petroleum products.

- **Specific Gravity** in calculated based directly on a material's density and uses pure water as the benchmark, assigning it a specific gravity of 1.0. Anything with a specific gravity greater than 1.0 is denser than water and will sink while anything with a specific gravity less than 1.0 will float.
- **API Gravity** also uses pure water as the benchmark, but assigns it a value of 10.0. The other key difference between the two measurements is that API gravity is an *inverse* measure of relative density compared to water, so as a substance's API value increases, it is getting *less* dense compared to water. Thus, in theory anything with an API gravity of greater than 10.0 will float on pure water, and anything with an API gravity of less than 10.0 will sink. The API gravity for saltwater is ~6, so anything with API gravity greater than 6.0 will float in saltwater and anything with an API less than 6.0 will sink in saltwater. API is expressed mathematically as: $°API = (141.5/SG) – 131.5$.
- **Total Acid Number (TAN)** measures the composition of acids in a crude oil, which can gauge its potential for corrosion of pipes or other equipment during transportation or refining. TAN value is measured as the number of milligrams (mg) of potassium hydroxide (KOH) needed to neutralize the acids in one gram of oil. Crude oils with a TAN greater than 0.5 are considered to be potentially corrosive due to the presence of naphthenic acids (Ramseur, Lattanzio, Luther, Parfomak, and Carter, 2012). However, while increased TAN values do increase the potential for corrosion, according to some experts water content in the oil may be the *key* factor that leads to corrosion in a pipeline (Dettman, 2012).

- **Miscible & Non-Miscible vs. Soluble & Non-Soluble** refers to the ability of one substance (the solute) to mix completely with another substance (the solvent) and become homogeneous. Miscible refers to the mixing of two liquids, whereas soluble refers to a solid dissolving into solution in a liquid.

5.2 Chemical and Physical Differences between Raw Bitumen and Other Crudes

5.2.1 Formation of Oil Sands

Alberta oil sands most likely formed from a standard crude oil deposit that underwent a significant amount of biodegradation (USGS, 2007; Shuqing et al., 2008). The lighter, shorter chain alkanes were subject to degradation by microorganisms leading to the predominance of large molecules. The biodegradation occurred because the bitumen reserves never exceeded 80° C, meaning pasteurization didn't occur (Shuqing et al., 2008). The conditions needed for biodegradation are: a low reservoir temp, the presence of an electron acceptor such as water, an oil-water contact, microorganisms, and nutrients (Shuqing et al., 2008). For more in-depth discussion on development of bitumen reserves in Alberta see Shuqing et al. (2008). The amount of biodegradation that may occur after a spill of oil sands products will be dependent on the extent to which the material was degraded prior to extraction. Therefore, bitumen that has undergone a high degree of biodegradation will probably undergo little biodegradation after a spill (Dettman, 2013). However, there are no experimental data available to fully evaluate the biodegradation potential oil sands products spilled into fresh or salt water systems.

5.2.2 Bitumen Chemical Properties

Biodegradation of oil leads to a relative increase in sulfur, resins, asphaltenes, and metals (Shuqing et al., 2008). In biodegradation, microorganisms initially attack small, organic compounds leaving large compounds behind. Biodegradation of crude oil, in situ, leads to bitumen containing a lower proportion of paraffins (saturated hydrocarbons without rings) and naphthenes (saturated hydrocarbons with rings), and a higher proportion (>50 percent) of aromatics (hydrocarbons with one or more aromatic nuclei), which leads to the increased viscosity and density characteristics of bitumen (USGS, 1990). Netzer et al. (2006) found that aromatics made up 37 percent of the total weight of Athabasca bitumen with resins being second (25.7 percent), followed by saturates and asphaltenes (both 17.3 percent). Yang et al. (2011) found, through gas chromatography, that Alberta bitumen is characterized by large, unresolved compounds (n-C_{10} to n-C_{40}) and a near absence of n-alkanes. Souraki et al. (2012) found that C_{39} and larger molecules made up 56.96 percent of the weight of Athabasca bitumen. See Table 1 in *Heavy Oil and Natural Bitumen Resources in Geological Basins of the World* (USGS, 2007) for a numeric breakdown of many of the chemical properties of bitumen.

5.2.3 Bitumen Physical Properties

Finding information on the physical properties of Alberta oil sands products can be problematic as some of the specific data about physical properties is considered proprietary business information. For this reason it has been difficult for regulators and others in the scientific community to access (Jensen & Pilkey-Jarvis personal communication, 2012).

Bitumen is generally characterized as being denser than standard crude oils (USGS, 2007; Shuqing et al., 2008). The density of bitumen, when compared to water, depends on the specific reservoir and temperature of the source material. Athabasca bitumen tends to be denser than freshwater but less dense than saltwater under standard conditions of 15.56˚C and 20 bara/19.74 ATM (Netzer, 2006; Souraki et al., 2012). Between 25 and 40˚C, Athabasca bitumen becomes less dense than water (Mochinaga et al. 2006). Cold Lake bitumen is denser than freshwater below ~40˚C but not denser than saltwater (Mehrotra & Svercek, 1988). Barrufet &

Setiadarma (2003) found that bitumen is less dense than water at ambient temperature although they do not specify from which reservoir the sample was obtained. As temperature increases, the viscosity and density decrease. Bitumen is orders of magnitude more viscous than conventional oils. At 25°C, the viscosity of conventional crude is ~13.7 cP, while for bitumen it is >1,000,000 cP (USGS, 2007). Athabasca bitumen must exceed 150°C and approach 200°C before its viscosity is similar to standard crude oil viscosity at ambient temperatures (Souraki et al., 2012). Cold Lake bitumen must exceed 120°C before its viscosity is similar to standard crude viscosity at ambient temperature (Mehrota & Svrcek, 1988). See Table 1 in USGS (2007), for a more in depth comparison of the physical properties of bitumen to heavy, medium, and conventional oils.

See below for a comparison of Bitumen to other common crude oils and gas condensates. API values for crude oils range from approximately <22-42. An overview of crude oil and other petroleum product densities is as follows.

- Gas Condensates – ≈ 42 to 55°API
- Light Crude Oils – ≈ 31 to 42°API - varies
- Medium Crude Oils – ≈ 22 to 31°API
- Heavy Crude Oils – ≈ <22°API
- Alberta Bitumen – ≈ 8°API prior to being mixed with diluent
- Water (≈10°API); Gasoline (≈63°API); Fuel Oil #2(≈30-38°API)

See Appendix 2 for more data values and ranges for the relevant oil sands products being exported from Canada (Environment Canada, 2013; USGS, 2007; USDOT PHMSA, 2012).

5.3 API, Specific Gravity, Acidity, and Other Data for Oil Sands Products

5.3.1 Floating, Sinking, and Submerged Oil

5.3.1.1 Floating Oil

Most crude and refined oil products float when spilled. Spill response agencies are most familiar with and best equipped to handle floating oil spills.[10] However, depending on the environment, a spill of a very light conventional crude oil does not always float. In the Deepwater Horizon spill in the Gulf of Mexico, small droplets of light oil released below the surface were kept submerged by the movement of the ocean water despite having API gravity greater than 10, because the turbulence was enough to overcome the buoyancy of the small particles of oil (Joint Analysis Group, 2012). While this oil would have behaved differently had it not been a subsurface release, it demonstrates the variability of oil's fate based on the circumstances under which it is spilled and the environment into which it is spilled.

5.3.1.2 Sinking Oil

Some oils, including Group V (defined as having a specific gravity greater than 1.0) can sink, sometimes reaching the ocean floor or riverbed (National Research Council, 1999). However, specific gravity as used in the regulatory definition of Group V oils, does not adequately characterize all oil types and weathering conditions that produce non-floating oils, which has led to the "non-floating" or "submerged oil" definition below.

5.3.1.3 Non-floating and Submerged Oil

Non-floating oils behave differently and have different environmental fates and effects than floating oils. The resources at greatest risk from spills of floating oils are those that use the

[10] See Section 7 for more on response technology.

water surface and the shoreline. Floating-oil spills have fewer impacts on water-column and benthic resources. In contrast, non-floating oil spills can pose an increased threat to water-column and benthic[11] resources (National Research Council, 1999). This includes Group IV oil, which has a specific gravity of slightly less than 1.0 and "might mix into the water column and sink to the seabed after weathering and interaction with sediments" (National Research Council, 1999). This can make effective recovery difficult if not impossible, because skimmers and other surface technologies as well as ROVs that would be able to recover oil from the bottom are both rendered ineffective (Goodman, 2006).[12] Oils that have density values very close to that of water can become neutrally buoyant, and remain suspended in the water column when they interact with the environment in a variety of ways, including:

- Picking up particles of suspended sediment from turbid water, especially in rivers during flood stage, estuarine waters, or any other water carrying sediment (National Research Council, 1999).
- Turbulence in the water can move neutrally buoyant oil—or oil with a density very close to that of the surrounding water—vertically in the water column. During the Kalamazoo spill response, turbulence along the river bottom caused sunken oil to resurface (Muller, 2013).
- When oil is spilled and enters the environment there is the potential for it to change temperature. Any decreases in temperature will cause the oil's density to increase, further increasing the chance of becoming submerged.

5.3.2 Implications of Physical Properties in Spill Scenarios

5.3.2.1 Saltwater

Due to the salt content, saltwater is denser than fresh water with an API gravity value of approximately 6.0 (specific gravity ranging from 1.02-1.03) (Glencoe, 2002). Raw, undiluted

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[11] The term benthic refers to organisms living on or in sea or lake bottoms.
[12] See Section 7 for more on response technology.

bitumen produced from oil sands products can have API gravity below 10 (specific gravity of 1) depending on the reservoir, meaning that it would sink in fresh water. Dilbit and synbit being transported in pipelines and by rail, which have been blended with lighter petroleum in the form of diluents or processed into “synthetic crude”, have higher API densities (Environment Canada, 2013). This addition of lighter material may change the density enough to allow the product to initially float if spilled in fresh or saltwater. Although other sources listed above show dilbit being lighter that water, the Keystone XL Draft EIS released by the State Department on March 1, 2013 lists specific gravity values for dilbit that range on either side of water. This may be related to the specific samples they were using (U.S. Department of State, 2013). Additionally, having an API density close to 10 means that smaller variations in density due to temperature or other environmental factors could change the way the product acts or reacts in a spill. The density of fresh oil also changes as a result of weathering and biodegradation. For example, as diluents and other lighter molecules begin to evaporate, the remaining material become denser. No experimental data are available to evaluate how oil sands products will behave when spilled in saltwater environments. Of particular interest is whether oil sands products will sink or submerge after weathering, interaction with sediments, or other interactions with the environment.

5.3.2.2 Freshwater

The most well documented example of a dilbit spill into freshwater is the Enbridge spill into Michigan’s Kalamazoo River, which included both Cold Lake Blend and Western Canadian Select crude oil condensate mixtures. These dilbit blends have a reported specific gravity of 0.65 to 0.75 (NTSB, 2010). According to responders and damage assessors who worked on-scene monitoring and advising the response effort from its early stages, the spill presented unique challenges not typical in traditional crude oil spills (Jessica Winter personal communication, 2012; Laurie Muller personal communication, 2013). Because oil begins to weather as soon as it enters the environment, some of these unique challenges are a direct result of the specific environment in which the spill occurred. An additional difficulty is determining definitively what role the physical properties of Cold Lake Blend and Western Canadian Select played in the ultimate fate of the oil spilled. Responders from the EPA, NOAA, and the NTSB report state that containment and cleanup efforts required responding to floating, submerged and sunken oil (NTSB, 2010; Jessica Winter personal communication, 2012; Laurie Muller personal communication, 2013). Initially there was a visible sheen of oil on the water surface, and during the course of the cleanup, responders also found "blobs" of oil moving in the water column and sunken oil on the river bottom (Jessica Winter personal communication, 2012; Laurie Muller personal communication, 2013). Flood conditions, turbidity, and the velocity and volume of the river at the time of the spill all influenced the behavior of the oil once it was spilled (NTSB, 2010). Oil sands products could be particularly challenging in this type of dynamic fresh water environment because the lighter diluents evaporate, leaving the heavy ends of the product behind. If these heavy ends are sufficiently dense—and especially if they mix with sediment—the oil can become submerged or sunken.

5.3.2.3 Estuarine Water and Puget Sound

Estuarine water presents its own set of unique challenges when trying to model or predict the behavior, weathering, and fate of spilled oil. Influx of fresh water from rivers with differing temperatures, salinity, and density can cause the water column to become stratified. In Puget Sound specifically, it is this influx of riverine water that is the primary cause and control of stratification (Climate Impacts Group, 2005). Because this mixing with fresh water dilutes the salinity, estuarine water is less dense than oceanic saltwater. In addition, because it is less dense, the less salty riverine water tends to stay in the top layers, meaning that heavy oil spilled into estuarine water like that in Puget Sound is more likely to become submerged or sunken than the same oil spilled in the open ocean. This is especially a concern in the waters around potential terminal sites like Grays Harbor, WA and Kitimat, B.C., where major rivers flow into the system. Predicting and preparing for a spill of oils sands product in Puget Sound or other estuarine environments requires taking into account these varying factors that affect water density.

5.3.3 Information Gaps for Physical Properties

- The API values listed on the Environment Canada website may be out of date. At least some of the values there were originally published in 1983.
- Physical properties of oil sands derived products fluctuate based on season, customer requirements, and other factors (Dettman, 2013).
- It is difficult to say how realistic it is to expect that pipeline operators will know what is in the pipeline at the location of a release (Dettman, 2013).
- The lack of experimental data on oil products weather significantly limits the ability of spill response organizations to understand and predict the behavior and fate of oil sands products in freshwater, estuarine, and saltwater environments.

5.4 Diluents

5.4.1 Diluents and Synthetic Crude

The diluents being used are light hydrocarbons usually with a density between 0.6-0.775 g/ml, with a maximum weight by percent of 0.5 percent for sulfur, and max viscosity of 2.0 cST (7.5°C) according to Enbridge (2010) specifications. Natural gas condensate, a liquid under standard, ambient conditions that contains pentanes and heavier hydrocarbons produced from processing natural gas, is currently the most commonly used diluent (Bott, 2011). Additional pipelines are being proposed to supply diluent to Alberta and counter the increasing demands but decreasing supply of diluents in Canada (CAPP, 2011). Another approach to upgrading bitumen is to blend it with synthetic crude to make a product called Synbit. Synbit is a mixture of bitumen with synthetic crude, which is bitumen that has undergone upgrading through coking and hyrdrolysis to remove the larger molecules and decrease viscosity (Yui, 2008; Héraud, 2011; U.S. Department of State, 2013). See Yui (2008) for a simplified schematic of the synthetic crude upgrading process. Currently, this method is less expensive than mixing with diluent (Héraud, 2011). Projections are that the use of synthetic crude as a diluting agent will increase over the next decade while the use of natural gas condensate will remain steady (Héraud, 2011). The exact physical characteristics of the diluent will vary depending on the diluent being used. See Crude Quality Inc. (2013) for an in depth list of the physical and chemical properties of multiple diluents.

5.4.2 Dilbit/Diluent and Synbit Composition for Transport

The composition of dilbit tends to be between 25 and 30 percent diluent and 70-75 percent bitumen depending on the viscosity of the bitumen and the density of the diluent (Héraud, 2011). The ratio can be as high as 40 percent diluent for denser bitumen (Bott, 2011). The diluent required for mixture can be decreased if asphaltenes are removed from the parent bitumen (Rahimi & Gentzis, 2006). Because the diluent and bitumen are both hydrocarbon based, the two are completely miscible (Dettman, 2013). For synbit, the mixture is typically 50 percent synthetic crude and 50 percent bitumen (Héraud, 2011).

5.4.3 Gaps in Diluents

The diluent properties will differ depending on the exact diluent being used as they can range from high to low in sulfur content. They have highly variable boiling points so determining at what temperature it will become gas in the event of a spill is difficult.

5.5 Weathering of Dilbit in the Environment

5.5.1 Weathering of Oil Sands Derived Products Compared to Conventional Heavy Crude Oils

Currently, there is very little information about how oil sands products will weather in the environment. A few studies have been conducted at the laboratory level, and covered specific oil sands products rather than looking at the whole range of oil sands products being transported out of Canada (SL Ross, 2012). One of these studies, conducted by SL Ross Environmental Research Limited tested MacKay River Heavy Bitumen and Cold Lake Bitumen that were diluted with synthetic crude (Suncor Synthetic Light) and condensate (CRW condensate), respectively. The study found that oil subjected to weathering tests was measured to have an ultimate density that approached but did not surpass that of the water. At the end of the tests approximately 15 percent of the recovered oil was collected from the tank walls 10 cm below the water surface. The majority (approximately 85 percent) of the oil was recovered from either the surface or stuck to the side walls within 10 cm of the surface. At no point was oil found to submerge, sink, and stick to the bottom of the flume (SL Ross, 2012).[13] It is important to remember that the results SL Ross found represent only one possible weathering scenario, were limited by the experimental conditions, and could vary with different products or experimental environments. Although some more comprehensive studies are being conducted,[14] publically

[13] A complete description of their methods and findings can be found in the report SL Ross published, cited in the references section.

[14] According to a webinar talk given by Kinder Morgan on February 13th 2013 they have engaged O'Brien's Response Management and Polaris to study fate of oils sands products. They have completed the literature review, gap analysis and research plan, and are scheduled to do research March 2013 and issue final report by April 2013. They intend to include tests of

available data are currently limited to what can be gleaned from the response efforts of the few well-documented dilbit spills (See section 7.2 Response Efforts). What is known is that dilbit, synbit, and other bitumen-based products contain more “heavy ends” or large hydrocarbon molecules than conventional crude oils. Additionally, part of the weathering process of conventional crude oil is due to biodegradation by microorganisms, and because oil sands products have already undergone partial biodegradation, there is some question as to whether any further biodegradation would occur in the environment after initial weathering of the diluent portion of the mixture.[15]

5.5.2 Potential Weathering Patterns in the Environment

Anytime oil is spilled into the environment it begins to “weather” due to physical, chemical, and biological conditions of the environment. Effectively modeling the weathering patterns of any oil—including oils sands products—requires knowing the particular properties of that product, including density, pour point, and distillation curves. While environmental agencies, regulators, and responders tend to have good data on the properties of conventional crude oils, less is known or understood about the properties of oils sands products. The current state of knowledge is only useful for predicting the weathering of a specific product—Cold Lake Blend specifically for example—but not any of the other bitumen diluent blends or synbits being produced in the region. Gathering the information necessary to model weathering behavior may be particularly difficult for oil sands products. The physical properties of crude oil from conventional reservoirs typically changes slowly over years making them easier to predict at any given time. In contrast, physical composition of the oil sands products being transported out of

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typical oil sands products under ambient conditions similar to those of the Salish Sea. Tests on API by the National Academy of Science on diluted bitumen are also currently underway.

[15] See section 5.1 for more on biodegradation and the history of Canada’s oil sands deposits.

Alberta can vary greatly. Not only do the physical properties of bitumen deposits vary across the region, but what enters the transmission lines after being upgraded and or diluted can vary on a weekly basis. Each oil sands product entering a pipeline differs based on specifications from the refineries processing the product at the other end of the line (Dettman, 2013). All crude oils contains a spectrum of hydrocarbons, and each segment of the spectrum is used to make different products—i.e. gasoline, asphalt, plastics, etc. Refineries change the mix they request based on demand for specific products.

There is some evidence that because oil sands products are heavier and more viscous than conventional crude oils, they are likely to be more difficult to clean up. In the event of a spill on land, "the heavier and more viscous components (i.e., the asphaltenes) would likely remain trapped in soil pores above the water table. It is also likely that the lighter constituents would partly evaporate and not be transported down through the soil with the heavier components." (Ramseur, et al, 2012). These properties can also make clean up challenging in the event of a spill into water. The potential for the lighter diluent to evaporate quickly, leaving the heavier bitumen behind equates to an increased risk that responders will be dealing with oil not only on the surface, but also sunken oil or oil submerged in the water column. These predictions are consistent with the experience of responders at the Kalamazoo spill (Jessica Winter personal communication, 2012; Laurie Muller personal communication, 2013).

5.5.3 Information and Policy Gaps for Modeling Weathering

- Regulatory and response agencies may lack sufficient information about what product is being transported through a pipeline at any given time, and lag time associated with getting accurate data from the producer or pipeline operator can cause delays to the repose and cleanup efforts.

- Experimental and field data on the potential for further biodegradation of spilled oil sands products.

5.6 Corrosiveness of Oil Sands Products

5.6.1 <u>Overview of Existing Research on Pipeline Corrosion</u>

A recurring theme throughout the debate over the risks of transporting oils sands via pipelines has centered on corrosion, and the potential for oil sands products to be more corrosive than traditional crude oil. Several research reports exist on the subject of oil sands products corrosiveness (see the "Key Sources of Information" below), and although not entirely conclusive, the data suggest that in general oil sands products are not significantly more corrosive than other heavy crude oils. A brief overview of the findings includes the following points:

- Sulfur content of Alberta oil sands products tends to range between 2-5 (weight percent). There are conflicting reports regarding how these sulfur levels compare to other heavy crude oils. The report by Zhou and Been found oil sands products to be generally comparable to other heavy crudes, with the exception of a few specific products (Zhou, Been, 2011). However, a USGS study reports higher sulfur content as a fundamental difference between natural bitumen and conventional crude oils as a result of in situ biodegradation (USGS, 2007).
- TAN values of Alberta oil sands products ranged from .5-2.5 (mgKOH/g), which is comparable to many conventional heavy crudes. Products with TAN values higher than 0.5 are generally considered "potentially corrosive" (Ramseur et al, 2012), but in lab testing the oil sands products were not found to be significantly different than comparable heavy crudes and not corrosive enough to be a concern to pipeline operators (Dettman, 2012), (Zhou, Been, 2011).
- Water content (BS&W) in oil sands products is comparable to other crudes, required maximum allowable threshold is set by pipeline operators (Dettman, 2012), (Owens, 2012).

- Sediment content in dilbit crudes was found to be lower than or comparable to that of conventional crudes, with the exception of one dilsynbit blend that was found to have more than double the solids content of most other crudes (Zhou, Been, 2011). The data, however, only indicates the total amount of sediments and does not provide information on the size distribution. It is unknown how the solids in the conventional crudes compare to those in dilbits (Zhou, Been, 2011).
- Sediment build-up in low or high spots in the pipeline interior can lead to corrosion (Dettman, 2012; NTSB, 2010).
- According to some, water is still the most important factor in the potential for pipeline corrosion (Dettman, 2012).

Our research does not indicate that oils sands products are significantly more corrosive than other heavy crude oils. A National Academy of Sciences study currently underway and scheduled to be complete by the end of 2013 will analyze whether transportation of dilbit by transmission pipeline has an increased likelihood of release compared with pipeline transportation of other crude oils. The National Academy study will primarily be a review of existing literature and will not include any original research. PHMSA data presented to the National Academy show that since 2002 there have been no releases of oil caused by internal corrosion from pipelines carrying dilbit (API, 2012). However, this does not mean that corrosion is not a concern. Together, internal and external corrosion account for 37 percent of non-small pipeline accidents for crude oil (PHMSA, 2012c).

5.6.2 Water and Sediment Content

After being mined from the ground, oil sands go through a series pipelines called "gathering lines" and "feeder lines" during initial extraction and processing. During these early stages the product can have diluent mixed with it, and can also have elevated levels of sediment and water. Consequently, these gathering and feeder lines are more prone to corrosion, and are maintained every three months. Once the product enters the larger "transmission lines" that transport the oil sands products out of Alberta, the sediment and water has been reduced and corrosion is less likely (Dettman, 2012).

Key Sources: Properties, Fate, and Behavior of Oil Sands Products

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Comparison of the Corrosivity of Dilbit and Conventional Crude, By Zhou and Been. Commissioned by Alberta Innovates

Congressional Research Service Report: Oil Sands and the Keystone XL Pipeline: Background and Selected Environmental Issues

Crude Monitor: http://www.crudemonitor.ca/

Environment Canada Oil Properties Database: http://www.etc-cte.ec.gc.ca/databases/OilProperties/oil_prop_e.html

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6 ENIVRONMENTAL AND HUMAN HEALTH EFFECTS OF OIL SANDS PRODUCTS

6.1 Environmental Impacts

6.1.1 Species at Risk During Floating and Sinking Phase

Spills can have both immediate ecosystem impacts as well as long-term consequences resulting from continued chronic exposure (Peterson et al., 2003). Spills of oil sands products impacts include those from the partitioning of diluent into the air and water as well as the components of the source bitumen that could differentially partition into the water column and sediments.

6.1.1.1 Species at Risk During Floating Phase

During floating oil spills, species that contact the water's surface frequently are at highest risk. This can include aquatic and semi-aquatic mammals, sea birds and waterfowl, turtles, and aquatic insects. Aquatic and semi-aquatic mammals, depending on species, can suffer acute mortality through hypothermia from loss of insulation, oil ingestion, and inhalation of toxic fumes (EPA, 1999). Mammals that rely on fur for insulation appear to be most affected (USFWS, 2010). Sea otters, river otters, beavers, and fur seals, are particularly vulnerable resulting from their frequent contact with the water's surface and their reliance on fur for insulation (EPA, 1999). Seabirds and waterfowl are also subject to acute mortality through loss of insulation and oil ingestion. These species at risk would be the same as the species which would be at risk during any similar floating oil spill.

6.1.1.2 Species at Risk During Submerged and Sinking Phase

Fish eggs laid on bitumen contaminated sediments in lab studies showed frequent death or physical abnormalities including spinal deformities, lesions, hematomas, and eye defects

(Colavecchia et al. 2004; Colavecchia et al., 2006; Colavecchia et al., 2007). Therefore, if a spill occurs during spawning periods, fish eggs and larvae may be adversely affected (Peterson et al., 2003). Coral communities may also be adversely affected by submerged oil (White et al., 2012[a], White et al. 2012[b]). Oil can continue to affect marine mammals through ingestion especially in species which have contact with sediments or feed on bivalves (Peterson et al. 2003). Shellfish can be adversely affected if oil sinks or becomes concentrated near shorelines (USFWS, 2010). Through gill uptake or ingestion of oil or contaminated prey, fish may be subject to adverse health impacts (USFWS, 2010). The continued presence of polyaromatic hydrocarbons (PAH) after oil spills are toxic to certain fish species' larva including pink salmon and herring (Peterson et al. 2003).

6.1.1.3 Species at Risk From Diluent

According to the Material Safety Data Sheet for sour natural gas condensate from ConocoPhillips (2012), condensates can cause lasting effects in aquatic environments and are considered to be toxic to aquatic organisms. In general, natural gas condensate is moderately to highly toxic via inhalation and thus could pose problems for all species which breath at or near the surface. As the diluent is liquid under ambient conditions, it could mix with water having detrimental effects for fish and aquatic insects.

6.1.2 Athabasca River

Fish which had contact with tailings associated water had adverse immunological effects (McNeill et al. 2012). Fish eggs laid on bitumen contaminated sediments showed either adverse physical abnormalities including spinal deformities, lesions, hematomas and eye defects or death (Colavecchia et al., 2004; Colavecchia et al., 2006; Colavecchia et al., 2007). While fish physical abnormalities have been reported downstream of oil sands development (Schindler, 2010), a direct causal link is yet to be established. Kelly et al. (2010) found increased levels of the 13 elements considered priority pollutants in either melted snow or water samples from near or downstream of development. Seven of these pollutants—cadmium, copper, lead, mercury, nickel, silver, and zinc—all surpassed either Canada's or Alberta's guidelines for the protection of aquatic life (Kelly et al., 2010). PAH's are also significantly higher downstream of oil sands development, 10 to nearly 50 fold higher, when compared to areas not subject to land disturbance (Kelly et al., 2009). Some of the values exceeded that which were toxic to fish embryos. It is possible during spring snowmelt that PAH values could exceed toxicity levels for both aquatic and terrestrial organisms (Kelly et al., 2009). Changes in mercury levels in fish populations in the vicinity and downstream of oil sands products development is contested. Timoney & Lee (2009) found an increase in mercury levels in fish from 1976-2005, while Evans & Talbot (2012) found a decrease in mercury levels in fish species from 1981-2011. The reason for the conflicting results may be attributable to research methodology (Evans & Talbot, 2012).

6.1.3 Gaps in Environmental Impacts

Current water, snowpack, and air monitoring for toxic outputs near oil sands development are not sufficient (Kelly et al., 2009; Schindler, 2010). A new testing scheme or organization responsible for monitoring needs to be implemented. The Regional Aquatics Monitoring Program (RAMP) is currently in charge of monitoring water quality and fish populations in the Athabasca River but recent literature has elucidated several problems with the current monitoring program (Kelly et al., 2009; Schindler, 2010; Royal Society of Canada, 2010; Jordaan, 2012). Ongoing monitoring of potential fish tainting may also be an important component of an overall monitoring program to determine the impact of oil sands development (Tolton et al., 2012).

6.2 Human Health Impacts

6.2.1 Human Health Concerns Near Oil Sands Products Development

No solid evidence currently exists suggesting people who live in the vicinity or downstream of oil sands sites near the Athabasca River are subject to increased health concerns (Royal Society of Canada, 2010). Two studies have noted that cancer is tied to PAH's and therefore increased PAH levels could cause increases in cancer downstream, but a conclusive link between increased PAH's in the Athabasca river and cancer cases has not been made (Royal Society of Canada, 2010). A higher number of cancer cases than would be expected have been observed 250km downstream from oils sands development in Fort Chipewyan, but this could be due to chance and no connection to oil sands development have been made (Chen, 2009; Royal Society of Canada, 2010). When compared to the values laid out in the Guidelines for Canadian Drinking Water Quality (GCDWQ), antimony, arsenic, cadmium, chromium, copper, lead, mercury, selenium, and zinc did not exceed the recommended values at or below oil sand development sites near the Athabasca River (Kelley et al. 2010; Royal Society of Canada, 2010). Refer to *Environmental and Health Impacts of Canada's Oil Sands Industry* (Royal Society of Canada, 2010) for a more in depth discussion of human health risks in the areas near oil sands products development sites.

6.2.2 Safety of Cleanup Crew and Citizens in the Spill Vicinity

The responders to the dilbit spill in Kalamazoo reported elevated levels of benzene above those recorded at spills of standard crude oils (Lori Muller, 2013). Also, bitumen is characterized as being richer in sulfur (Shuqing et al., 2008). Bitumens tend to be lower in mercury than conventional oil but higher in lead content (USGS, 2007). The added diluent could pose problems due to its low flash point; meaning combustion could be a problem from the evaporation of diluent. Evaporation of diluent could pose an inhalation risk to responders. The MSDS for ConocoPhillips (2012) and Gibsons (2012) natural gas condensate lists the product as extremely flammable. ConocoPhillips (2012) further warns that condensate is toxic and potentially fatal if inhaled resulting from the hydrogen sulfide gas content. The MSDA for Hess (2012) lists sweet natural gas condensate as only marginally toxic through inhalation probably because of lower hydrogen sulfide levels. Benzene, a known carcinogen, is also present in natural gas condensate, which could pose a risk to spill responders. The MSDS for Hess (2012), ConocoPhillips (2012), and Gibsons (2012) recommend spill responders wear air supplied respirators, protective clothing, and eye protection. The MSDS for natural gas condensate for Oneok (2009) warns that condensate, being heavier than air, will accumulate in depressions. These MSDS are for natural gas condensate alone, so the risks from natural gas condensate after blending to form dilbit could be different. After the Enbridge spill in Kalamazoo, MI, 320 community members and 11 spill responders reported adverse health effects which included headaches, nausea, and respiratory issues (Michigan Department of Community Health, 2010; NTSB, 2010). Refer to the report *Acute Health Effects of the Enbridge Oil Spill* (2010) produced by the Michigan Department of Health for a list and statistical breakdown of the observed adverse health effects.

6.2.3 Gaps in Human Health Impacts

Resulting from the unknown specifications of the diluent, impacts to private citizens living in the vicinity of the spill and to responders is unknown because of the potential variability in the diluent and bitumen specifications. Additionally, the evaporation rate of the diluent is often unspecified, so it is not possible to predict whether responders and citizens would face pockets of evaporated natural gas condensate.

Key Sources: Environmental and Human Health Effects of Oil Sands Products

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7 RISK MITIGATION

The U.S. government has in place a number of systems that are meant to mitigate the risks associated with the transportation of oil. In this section, we will look at three issues:

1. The siting process of pipelines at the state and international level;
2. Systems to detect pipeline leaks; and
3. Spill response equipment with the ability to handle heavy oil spills.

These three issues are important in the oil sands debate as they provide insight in the ability and capacity for the U.S. government, as well as private companies, to prepare for and respond to spills of oil sands products.

7.1 Risk Mitigation Techniques

7.1.1 Pipeline Siting

The federal government, through the U.S. State Department, approves or rejects the construction of pipelines whenever the proposed route crosses a U.S. border (Parfomak *et al.,* 2013). However, the federal government is not involved in the siting of any intrastate or interstate pipelines.[16] In both cases, state law determines the appropriate regulatory agency that approves the siting and construction of large energy infrastructure projects. The procedures and regulatory agency in charge of siting pipelines varies from state to state (Parfomak *et al.*, 2013).

[16] The Federal Energy Regulatory Commission (FERC) is in charge of approving construction of interstate natural gas pipelines, however, this authority does not extend to oil pipelines. FERC's involvement with interstate pipeline includes regulating the rates and practices of oil pipeline companies, establishing equal service conditions to provide shippers with equal access to pipeline transportation, and the establishment of reasonable rates for transporting petroleum and petroleum products by pipeline (FERC, 2013).

In this section, we will review the factors that the U.S. State Department considers when making pipeline approval decisions and also examine the state requirements in Washington.

7.1.1.1 Presidential Permit Application

Pipeline operators constructing an international pipeline must apply for a Presidential Permit through the U.S. State Department (the "Department"). The Department has a considerable amount of discretion in its decision-making process, however, its main goal is to determine if the project is within the "national interest" (Parfomak *et al.*, 2013). To accomplish this, the Department looks at (Parfomak *et al.*, 2013):

- Environmental impacts of the proposed project;
- Potential for the proposed project to diversify U.S. energy supplies and meet demand;
- Security of the pipeline at the border crossing, specifically in relation to other modes of transport;
- Stability in the relationship of trading partners;
- Impact of the proposed project on foreign policy goals;
- Economic benefits of the project; and
- Proposed project's impacts on U.S. goals of reducing fossil fuel dependence.

The Department must also take into account any potential impacts the proposed pipeline may have on the National Historic Preservation Act, the Endangered Species Act, the National Environmental Policy Act, and Executive Order 12898 which addresses environmental justice concerns (Parfomak *et al.*, 2013). Of these policies, the National Environmental Policy Act (NEPA) traditionally is the most discussed. NEPA requires federal agencies to consider the environmental impacts of proposed projects and provides a forum for stakeholders to express their concerns (Caldwell, 1998).

NEPA requires the completion of an Environmental Impact Statement (EIS). EISs occur in two stages: a draft stage and a final stage. When a draft EIS is submitted to the State Department, it is then made available to the public for a mandated comment period. The final EIS must incorporate the comments from the public by either explaining why the concern was not considered or by explicitly addressing the concern in the final draft (Caldwell, 1998). The U.S. Environmental Protection Agency (EPA) must publically comment on the draft EIS and evaluate both how well the EIS analyzes the environmental impacts of the alternatives (adequacy) and the level of environmental impact of the proposed action (impact) (EPA, 2012c).

Based on the EPA's ratings of the draft EIS and the public's comments, the project proposer either revisits the draft proposal or incorporates the comments to create a final EIS. After the final EIS is submitted to the State Department, there is a final 90-day review period where the Department gathers information from relevant agencies and stakeholders to determine if the project is within the national interest (Parfomak *et al.*, 2013).

7.1.1.2 Washington State Requirements

In Washington State, all intrastate pipelines carrying crude, refined, or liquid petroleum products must be approved by Washington's Energy Facility Site Evaluation Council (EFSEC). The EFSEC is responsible for evaluating applications and ensuring that all environmental and socioeconomic impacts are considered before a pipeline is approved. Applicants must address over 60 environmental and socioeconomic impact objectives (including measures to mitigate impacts), submit an environmental impact statement, and defend themselves at public hearings before their projects can be approved. After evaluating the application, EFSEC will submit its recommendation to Washington's Governor. If the Governor approves the project, a Site Certification Agreement (SCA) is issued and construction can begin (EFSEC, 2012). EFSEC is also the regulatory agency that provides oversight during the construction and operation of the facility. It has the right to levy fines or halt construction if it deems that the project is violating state laws or the conditions of the SCA (EFSEC, 2012).

7.1.1.3 Stakeholders and other factors in pipeline siting

In order to increase the political feasibility of a large infrastructure project, such as the siting of a pipeline, there are a number of factors that should be taken into account beyond economic and environmental benefits or concerns. These include (Nussbaum, 2012):

- Wildlife management areas, including all parks, national forests, and public lands;
- Other pipelines and utilities that cross the proposed route;
- Roads, railroads, and water crossings;
- Jurisdictional boundaries of states, counties, and cities;
- Native American or First Nation ownership or interests;
- Federal and State threatened or endangered species' habitat;
- Wetlands and other environmentally sensitive properties; and
- Private land.

The proposed pipelines mentioned below have faced opposition and been delayed due a number of these factors. For example, the Enbridge Northern Gateway pipeline is being opposed by First Nations because the proposed route crosses their land, whereas the Keystone XL pipeline has been delayed for multiple years because its proposed route crossed environmentally sensitive areas in Nebraska and because of the additional regulations imposed on pipelines that cross U.S. borders.

Key Sources: Pipeline Siting

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7.1.1.4 Status of Each Proposed Pipeline

Four major pipelines are being planned to increase the transport of oil sands products from Alberta to consumer markets. These pipelines include Enbridge's Northern Gateway pipeline, Kinder Morgan's Trans Mountain (TM) Expansion, TransCanada's Keystone XL, and Enbridge's Line 9 Reversal. Enbridge's Northern Gateway and Line 9 Reversal and Kinder Morgan's TM Expansion[17] are within Canadian borders, whereas the Keystone XL crosses the U.S. – Canadian border. The status of each pipeline, as of March 2013, is as follows:

[17] Note that Kinder Morgan's expansion is occurring between Edmonton, Alberta and Burnaby, B.C. The expansion does not include the segment of the pipeline that crosses the U.S. border, which is why it does not require State Department approval.

Pipeline	Regulatory Status	Start of Construction[18]	Operational	Major Opposition
Northern Gateway	• Began Joint Review Panel on 8/3/2012 to assess environmental impacts, public comments, Aboriginal concerns, and gather information. • Hearings will continue through May 2013 (NEB, 2013a).	Mid-2014 (Enbridge, 2013)	2017 (Enbridge, 2013)	• Fear for Fraser and Skeena River Salmon populations (WCEL, 2012). • Stanch opposition from First Nation Groups, with over 130 Nations signing the "Save the Fraser Declaration" (McKnight, 2012). • Sixty percent of B.C. residents oppose the pipeline (Flegg, 2012)
TM Expansion	• Toll application was submitted in 2012. • Plan to file facilities application in late 2013. • Expect decision from the National Energy Board (NEB) in 2014 (Kinder Morgan, 2013b)	2016 (Kinder Morgan, 2013b)	2017 (Kinder Morgan, 2013b)	• Largest opposition is from local groups in Vancouver that are concerned with the lack of additional marine safety procedures for the harbor. • Traverses Jasper National Park in the Canadian Rocky Mountains and some of Canada's most productive farmland in the Fraser Valley (Lee, 2013)
Keystone XL	• Denied Presidential Permit in 2/2012. • Reapplied in 5/2012 with a new route in Nebraska that avoids the environmentally sensitive Sand Hills region. • Decision is expected in early 2013 (TransCanada, 2013). • All states directly affected by the Pipeline have expressed support (Jones, 2013; Olson 2013). • Received approval from Canada's NEB in 2010 (TransCanada, 2012).	Southern section from Oklahoma to Texas is already under construction. The second section, from Alberta to Nebraska, is expected to begin in mid-2013 (TransCanada, 2012)	Late 2014 or early 2015; Southern section, late 2013 (TransCanada, 2013)	• Main opposition is from environmental groups and landowners. • The largest delay was the opposition from the State of Nebraska, which just recently approved the pipeline route (NPR, 2012).
Line 9 Reversal	• Hearing completed in 5/2012. • Approval to reverse the 9A pipeline was obtained in 7/2012 (NEB, 2013b). • NEB is currently reviewing the request to reverse and expand Line 9B from Ontario to Quebec (Enbridge, 2012b).	No construction (Enbridge, 2012b)	Early 2014 (Enbridge, 2012b)	• Since this isn't a new pipeline, the major opposition has been to the transportation of oil sands products. • To bring the oil to the Atlantic, the Portland/Montreal pipeline will also have to be reversed in the future (Nelson, 2012)

[18] Pending Approval

7.1.2 Pipeline Modes of Failure and Leak Detection Technologies

There are four main categories of pipeline failure (Chris, 2007):

- Pipeline corrosion and wear, caused by corrosive products, atmospheric effects, external corrosion, or leaving a pipeline partially full for a period of time;
- Operation outside design limits;
- Unintentional third party damage; and
- Intentional damage.

The most common source of pipeline failure is from external corrosion, specifically caused by water eroding the outside coating of the pipeline (Dettman, 2013). This may have been a contributing factor in the Kalamazoo spill as there were high floodwaters at the time of the rupture and significant external corrosion was found at the rupture site (Dettman, 2013; NTSB, 2010).

7.1.2.1 Types of Spill Detection

Pipeline operators use a number of techniques to detect pipeline leaks. Spill detection methods are not meant to prevent spills, but to alert operators of spills so they can respond in a timely manner. Traditionally, leak detection methods can be broken down into three different categories (Zhang, 1996):

- *Traditional methods*: using personnel to walk or fly the line and visually inspect unusual patterns on the pipeline route, such as discolored vegetation;
- *Hardware-based methods:* localized leak detection that identifies changes in temperature, noise, presence of gas, and negative pressure at specific points; and
- *Software-based methods or Leak Detection Systems:* various computer programs that monitor the changes in flow, pressure, temperature, and other hydraulic data. The most successful software-based method involves dynamic modeling, which attempts

to mathematically model the flow within the pipeline and detect discrepancies between calculated and measured values.

7.1.2.2 Leak Detection Systems

Currently, software-based methods or Leak Detection Systems (LDS) are the only method of spill detection that offers real-time, continuous monitoring down the length of the pipeline (Song, 2012). LDS work by sensing abrupt changes in the flow rates and pipeline pressure and then triggering an alarm when discrepancies occur.

When analyzing the success of LDS, it is important to consider the ability of the system to detect the location of the leak, the extent of the leak, and the possibility of a false alarm (Jiang *et al.,* 2009). Positives of using LDS include (Song, 2012):

- High success rates in detecting large spills and ruptures;
- 24/7, 365 day monitoring; and
- In theory, these systems can detect a spill and shut down the flow of oil in the affected pipeline segment within 10 minutes.

7.1.2.3 False Alarms and Leak Detection Systems

One of the main issues with LDS is that controllers have to decide whether an alarm is in an actual leak or a false alarm. The more sensitive a system is to the loss of hydrocarbons, the higher the rate will be of false alarms (Shaw, et al., 2012). If a system is sensitive to the loss of hydrocarbons and false alarms are commonplace, it could condition controllers to assume that the majority of alarms are false alarms. This can in turn lead to controllers losing confidence in the system and ignoring real warnings, as was the case in the Kalamazoo spill (Zhang, 1996; Shaw, et al., 2012; NTSB, 2010).

One aspect of pipeline operation that contributes to false alarms is the occurrence of column separation. Column separation, or “slack flow,” is the breaking of liquid columns in a fully filled pipeline (Bergant *et al.*, 2006). This occurs when the pressure in the pipeline becomes low enough to allow the light ends of the oil to vaporize within the pipeline, creating a sort of "bubble." When the pressure of the pipeline naturally rises, the bubble can collapse which will cause the pressure in the pipeline to surge. This phenomenon may occur at high elevation points or when there are large changes in elevation and is common in all crude oil pipelines, not just dilbit (Dettman, 2013). The issue with column separation is that the pressure surges will register a "leak" with an LDS and indicate a false alarm (NTSB, 2010).

7.1.2.4 Criticisms of Leak Detection Systems

Other than the high occurrence of false alarms, there are a number of criticisms about relying on LDS to detect spills. According to a study commissioned by PHMSA (Song, 2012):

- LDS detected only 5 percent of the nation's pipeline spills between 2002 and 2012. The general public detected 22 percent of the spills and on scene employees detected 62 percent.
- LDS are not effective at identifying smaller spills, especially those that leak slowly. Smaller spills of this kind are much more common among pipeline infrastructure.
- Pipelines with variable flow rates, such as the Keystone XL, make it difficult to estimate how much oil is supposed to be in the pipeline at a given time.
- Pipeline companies' procedures have allowed alarms to be ignored by controllers, assuming that the alert is a false alarm instead of a real threat.

Two recent spills document the dangers of relying on LDS to detect spills. In both cases, human error, specifically hesitation in shutting down the system after an alarm sounded, led to excess oil spilling into the natural environment:

- *Kalamazoo Spill:* Enbridge claimed that their spill detection sensors would remotely detect and shut down a rupture in eight minutes. After the initial alarm sounded it took 17 hours for the pipeline operators to confirm the spill and shut down the pipeline segment. The controllers assumed that the alarm was due to column separation and not a leak. As a result, the controllers restarted the line and pumped more oil through the pipeline in order to "fix" the problem. The safety board concluded that the workers had not been sufficiently trained to recognize a spill alarm, which was the primary contributor to the intensity of the spill (NTSB, 2010).

- *Yellowstone Spill:* In 2010, over 1,500 barrels of Exxon Mobil crude oil (not dilbit) was released into the Yellowstone River. The rupture was detected in the control room and the pipeline was partially isolated seven minutes after recognizing failure. However, as Exxon employees were trying to figure out next steps, crude continued to flow into the river for 48 minutes, until the upstream valve was closed and the pipeline segment was fully isolated. Human delay resulted in approximately 6.2 times more crude spilling into the river than if the upstream valve was closed upon the initial alarm (DOT, 2012).

7.1.2.5 Expected Use of LDS with New Pipelines

Both Enbridge and TransCanada have released statements about using LDS to detect spills on their proposed pipelines. In public discussions about LDS, the two companies have made clear that they are aware of the potential failures of relying on LDS and indicated that it will be one of many tools used to detect spills. Regardless of this submission, the two companies continue to use LDS to address citizen concerns regarding spill detection.

TransCanada states that the Keystone XL will have the best LDS technology in the world (TransCanada, 2013). The company estimates that with their LDS they will be able to detect spills at or above 1.5 percent of the pipeline's flow. This translates to spills of 12,450 barrels or larger (Song, 2012). To detect spills smaller than the 1.5 percent threshold, TransCanada states that they will use static pressuring. However, this method does require TransCanada to periodically shut down operations for testing (Song, 2012). TransCanada has also agreed to adopt 57 measures that will hold them accountable to go beyond the legal minimum requirements in risk reduction methods. These conditions include burying the pipeline deeper underground than mandated, installing a higher number of data sensors and remote controlled shut-off valves, and increasing inspections and maintenance (TransCanada, 2013). TransCanada will also conduct aerial patrols every two weeks (TransCanada, 2013). Enbridge stated that it will use multiple approaches for leak detection that include computational pipeline monitoring, controller monitoring, line balance calculations, and aerial patrols at least once every two weeks (NEB, 2012).

Kinder Morgan has not indicated its use of LDS beyond general, nonspecific information on its website (Kinder Morgan, 2012). This may be because Kinder Morgan's Trans Mountain Expansion's projected completion date is further in the future than TransCanada's and Enbridge's projects and therefore may be subject to less scrutiny than the other two companies at this point in time.

Key Sources: Pipeline Modes of Failure & LDS

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Song, L. (2012 19-September). *Few Oil Pipeline Spills Detected by Much-Touted Technology*. Retrieved 2013 11-February from Inside Climate News: http://insideclimatenews.org/news/20120919/few-oil-pipeline-spills-detected-much-touted-technology

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7.1.3 Gaps in Risk Mitigation Factors

In this section, two major risk mitigation methods were discussed: the process of approving the construction of pipelines at the federal and state level and the use of leak detection systems to detect leaks. Three main information and knowledge gaps exist in this discussion:

- In this report, we did not discuss the siting process of interstate pipelines due to time constraints. One main question remains regarding this topic: do pipeline companies need to pursue separate approval processes in every state that the pipeline will cross or is there a separate regulatory agency, or certain states, that are in charge of approving the construction of interstate pipelines?
- There are many criticisms of relying on leak detection systems to detect spills. TransCanada and Enbridge have stepped forward to describe how leak detection systems will be used in their risk mitigation strategies. However, a gap still remains in understanding how much the pipeline operators are relying on leak detection systems to detect spills and if this dependence is providing a false sense of security.
- There is doubt about the ability of operators to differentiate between false and real threats when interpreting leak detection systems' alarms. It is unknown if the training these pipeline companies are providing is adequate to create a reliable detection system.

7.2 Response Efforts

There have been two water-based spills of oil sands products in recent history: the Kalamazoo Spill in Marshall, Michigan (dilbit) and the Burnaby Harbor Spill in Burnaby, British Columbia (synthetic crude). Both spills occurred in unique situations, so our ability to extrapolate how oil sands products will behave in a spill and the success of response efforts and equipment is limited. Due to the small number of case studies, this section will also examine the Wabamun Lake Spill, a railcar derailment that spilled Bunker C oil, a heavy fuel oil, into Lake Wabamun in Alberta, Canada.

7.2.1 Kalamazoo Spill

Two types of dilbit oil were spilled during the Kalamazoo spill: Cold Lake and McKay River Heavy (Miskolzie, 2012). The dilbit initially floated in the fresh water. However, after mixing with sediments and the evaporation of the light hydrocarbons, some oil became heavy and sank (Miskolzie, 2012). As a result, the dilbit simultaneously was floating, submerged in the water column, and on the bottom of the river. Beyond the characteristics of the oil, the water temperature, the presence of sediments, and the speed of the river affected oil recovery (Miskolzie, 2012). See section 2.1.1 for more information about this spill.

7.2.1.1 Technologies Used in Recovery

The most important consideration for oil removal efforts during the Kalamazoo spill was the fast moving water of the Kalamazoo River and Talmadge Creek (NTSB, 2010). Recovering oil in fast moving water is difficult, as oil tends to flow under booms and skimmers necessitating quicker and more efficient responses (USCG, 2001). In these situations, the United States Coast Guard (USCG) recommends installing underflow dams, overflow dams, sorbent barriers, or a combination of these techniques (NTSB, 2010).

Enbridge responders, along with personnel from Terra Contracting and the Baker Corporation, used:

- *Oil booming and sorbent booming* at 33 oil spill containment-and-control points. At the most heavily boomed location, 176,124 feet of boom was deployed (NTSB, 2010).
- One *Gravel-and-earth underflow dam* at the meeting of the contaminated marsh and Talmadge Creek. This site was chosen because it was accessible to heavy equipment. Responders did not have the traditional materials for adjustable underflow dams on site and had to construct one out of surplus materials and therefore were late deploying the technology (NTSB, 2010).
- Three *vacuum trucks* were used to recover oil at the underflow dam. Nine other vacuum tracks were deployed at other sites (NTSB, 2010).
- *Oil skimmers* were also used to recover oil (NTSB, 2010).
- On 25 acres, *dredging* was used to recover oil (NTSB, 2010). This method was the most successful in terms of the amount of oil recovered (Muller, 2013).

- Responders considered plugging the steel culvert pipe under Division Drive with earth to contain the oil upstream, but the quick water flow prohibited attempting this method (NTSB, 2010).

At peak deployment, 2,011 personnel engaged in oil spill recovery (NTSB, 2010). As of March 2013, the cleanup efforts are still ongoing. In October 2012, EPA asked Enbridge to dredge approximately 100 more acres of the Kalamazoo River as oil continues to accumulate in three areas (EPA, 2012d). The main concern with the presence of this oil is that during a flood, the pools of oil could remobilized and contaminate parts of the river that have already been cleaned (Hasemyer, 2012). EPA chose to move forward with dredging because it was deemed the most effective method during the original recovery efforts (EPA, 2012d). Enbridge is fighting EPA's assessment saying that further dredging would do more harm than good to the Kalamazoo River ecosystem (Adams, 2012).

7.2.1.2 Lessons Learned regarding Recovery Efforts

Three main issues are of concern in regards to Enbridge's recovery efforts:

1. *Communication* –The spill occurred during the night and initial responders were not aware of the severity of the spill or the type of oil spilled (Muller, 2013), which led to poor decision-making (NTSB, 2010). Responders had no estimate of a volume release when the first round of containment methods was deployed (NTSB, 2010).
2. *Lack of resources* – Originally, Enbridge responders did not have the resources to contain or control the flow of oil into the surrounding bodies of water (such as materials for underflow dams). Also, Enbridge initially brought in contractors from Minnesota, a 10-hour drive away from the site, which slowed down recovery time (NTSB, 2010). The EPA on-scene coordinator had to provide Enbridge with the contact information for local contractors to keep recovery efforts moving forward (NTSB, 2010).

3. *Lack of Training* – During the initial response, Enbridge personnel placed the containment booms too far downstream to be effective and also used booms that were incompatible with fast-moving water (NTSB, 2010). This had to do both with lack of training and also the lack of communication and knowledge regarding the severity of the spill.

7.2.2 Burnaby Harbor Spill

7.2.2.1 Spill Summary

On July 24, 2007, approximately 1,400 barrels of synthetic crude leaked from the Westridge Transfer Line in Burnaby, British Columbia. After the oil was spilled, it flowed in Burnaby's storm sewer systems until it reached the Burrard Inlet (TSB, 2008a). In total, eleven houses were sprayed from the rupture, fifty properties were affected, 250 residents voluntarily left, and the Burrard Inlet's marine environment and 1,200 meters of shoreline were affected by the spill (TSB, 2008a).

Five minutes after the rupture, the pipeline operator shut down the Westridge Pipeline and the Westridge dock delivery valves were closed. However, the Burnaby Terminal is at a higher elevation than the rupture site, so gravity continued to intensify the release of the oil. Twenty-four minutes after the rupture, the Burnaby Terminal and the Westridge Pipeline were fully isolated. Kinder Morgan established a unified command with the British Columbia Ministry of Environment and the NEB to coordinate the response. The initial failure to fully shutdown the Westridge Pipeline was contrary to Kinder Morgan's standard shutdown procedures (TSB, 2008a). Cleanup took months and cost roughly $15 million and resulted in the recovery of approximately 1,321 barrels of oil (CBC, 2011).

In 2011, three companies – two contracting companies and Trans Mountain Pipeline L.P. – pleaded guilty to violating the Environmental Management Act for introducing pollutants into the environment and will each pay a $1,000 fine and donate $149,000 to the Habitat Conservation Trust Foundation (CBC, 2011). Trans Mountain Pipeline L.P. will be required to pay an additional $100,000 to fund training and education programs (CBC, 2011). See section 2.1.4 for more information on this spill.

7.2.2.2 Technologies Used in Recovery

Kinder Morgan primarily relied on contractors to recover the oil (Ministry of the Environment, 2007). The contractors used three distinct methods to recover the oil which were based on the oil's location (Penner & Sinoski, 2007):

1. *Residential areas*. Peat moss was used successfully to absorb oil on land.
2. *Storm Sewers*. Oil in the storm sewers was vacuumed up. Much of the oil was collected in the pump station.
3. *Burrard Inlet*. The responders were able to set up floating booms outside the storm sewer tunnels to collect oil that made it to the Inlet. To treat the oil that had adhered to the shoreline, responders successfully used the chemical shoreline cleaner Corexit 9580 (Shang *et al.,* 2012).

7.2.2.3 Lessons Learned

The recovery effort during the Burnaby Harbor spill was relatively successful. Because the synthetic crude traveled on a predictable path through the storm sewer system, the responders were able to set up booms in a quick and efficient manner. We were not able to find any reports of the oil sinking or being submerged in the water column. Extrapolating the oil behavior in this case to other potential synthetic crude spills is difficult because most of the oil was able to be collected in the storm sewer systems and on land.

The main issue in this case study was the lack of communication between city contractors and Kinder Morgan during the excavation process. Also, by failing to follow standard emergency procedure after a spill was detected, more oil was released into the natural environment. As with the Kalamazoo spill, failure to follow administrative procedures significantly increased the amount of oil spilled.

7.2.3 Wabamun Lake Spill

7.2.3.1 Spill Summary

Forty-three Canadian National Railway (CN) freight railcars derailed on August 3, 2005 by Lake Wabamun, just west of Edmonton, Alberta. The derailment resulted in 4,400 barrels of Bunker C oil and 554 barrels of a pole treating oil being spilled with approximately 1235 barrels[19] of the oil entering the temperate Lake Wabamun (Fingas, 2010; TSB, 2008b). The spill was caused by a faulty train track that had a least 13 undetected defects (CBC, 2007). Though Bunker C is not an oil sands product it is known to have a density near that of water, which could be similar to that of some kinds of undiluted bitumen. In this case, the oil began to sink with limited amounts of weathering and sedimentation (Goodman, 2006).

CN used an oil response contractor to recover the spilled oil. However, after the contractor's initial efforts, it became clear that they were not experienced in oil spills of this magnitude or of this type of oil. As a result, they were not able to contain the spill and CN eventually had to contract out the cleanup to a more experienced response organization (TSB, 2008b). The response contractors began by using the Shoreline Cleanup and Assessment Technique (SCAT) and then moved to cleaning up individual shore segments (Goodman, 2006). They also cut a number of reed beds because the reeds became a continuing source of surface contamination (Goodman, 2006). In total, approximately 1076 barrels of oil was recovered and the response effort was completed in October 2005 (Severs, 2005).

[19] The amount of oil that entered Lake Wabamun is debated and varies greatly depending on the source. This estimate is an average of the most commonly cited amounts.

During the clean up, there was strong public perception that the government failed to do its job, citing that the recovery efforts were more concerned with getting the track up and working again than any ecological effects. This was compounded by the delay in beginning cleanup efforts due to lack of available equipment (Goodman, 2006). As a result, the Alberta Ministry of the Environment established the Environmental Protection Commission in August of 2005 after the spill (Goodman, 2006) and First Nations sued CN and were awarded $10 million. CN spent approximately $132 million in cleanup costs and paid $1.4 million in fines, as well as made changes to its spill procedures and equipment requirements (Goodman, 2006).

7.2.3.2 Technologies Used in Recovery

Two main elements were taken into consideration during spill response: weather and the type of oil spilled. Both of these elements affected the behavior of the spilled oil, such as when the oil submerged and entered the water column or when the oil sank to the bottom (Fingas, 2010). Responders used the following technologies:

- *Sorbent and containment booms* were the first technologies deployed at the site. Sorbent booms were ineffective in containing the Bunker C oil and there were not enough containment booms to stop the spread of oil due to high winds (Goodman, 2006). Additional equipment had to be brought in from across Canada and the United States (TSB, 2008b).
- *Dykes* were successfully built to stop the flow of oil into the lake. Once the ditches and dykes were completed, no further oil made it to the lake (TSB, 2008b).
- *Vacuum trucks* helped recover the oil (TSB, 2008b).
- *Hand shoveling and skimmers* were relatively successful (TSB, 2008b).
- *Sorbent pads* were used to probe the bottom of Lake Wabamun in order to detect oil that had settled on the bottom. The Bunker C oil had formed a skin and did not adhere to the pads, making this technology ineffective (Goodman, 2006).

- *Video cameras for detection* were only successful in some shallow water situations due to the dispersed nature of the oil (Goodman, 2006).
- *Nets of ten millimeters* were ineffective. Responders had to move toward very fine netting, which inhibited water flow. Ten-millimeter nets were tried due to the success this size of net has had in collecting bitumen (Goodman, 2006).
- Responders had very limited success recovering oil once it reached the bottom (Goodman, 2006).

It is important to note that it was not until much later on August 3rd that responders realized that the pole treating oil had been spilled as well. The pole treating oil being transferred was mixed with other chemicals and is used as a wood preservative. This type of substance may contain toluene, benzene and its derivatives, naphthalene and its derivatives, phenyls, and polycyclic aromatic compounds (PACs) (TSB, 2008b). As a result, the workplace hazard associated with the chemical was neither recognized nor communicated until days later (TSB, 2008b).

7.2.3.3 Lessons Learned from Spill

The spill response effort at Wabamun Lake was not efficient particularly due to management decisions (TSB, 2008b). An emergency operations center under the unified command system (UC) was not set up. Under UC, response agencies collaborate on the response effort. Its main purpose is to provide guidelines for multiple agencies to work together efficiently (TSB, 2008b). This was the Transportation Safety Board of Canada's (2008b) main criticism of CN's response efforts. Other factors to consider during the response effort include:

- *Limited amounts of response equipment in close proximity to the spill.* This was problematic as it led to both negative public relations as citizens saw the oil spreading without an adequate response, as well as responders missing crucial time in containing the spill (Goodman, 2006). Later, it was determined that some response equipment in the region was not made available because it was held in reserve in case of a concurrent environmental disaster (TSB, 2008b).

- *The need for contingency planning.* CN implemented its Dangerous Goods Emergency Response Plan but failed to install a unified command (TBS, 2008b). The lack of a central structure led to considerable confusion in the early stages of recovery as more responders arrived on scene and there was no organizational structure to rely on (Goodman, 2006). Also, the contingency plan CN had in place was generic and had no specific guidelines for the Wabamun Lake area. The plans had not been tested recently and there had been little contact with response groups in the area (Goodman, 2006).
- *Lack of information regarding the behavior of heavy oil when spilled.* In this case, the lack of information regarding the interaction of oil and fine sediments and how the changes in surface water temperature affects submerged oil, tar ball formation, and the long-term fate of submerged oil in marine and fresh water ecosystems affected clean-up efforts (Goodman, 2006).
- *Limited number of tested and effective oil detection technologies.* Response crews lacked appropriate technology for detecting oil once it reached the bottom of the lake (Goodman, 2006).

Key Sources: Response Efforts

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7.2.4 Gaps in Response Efforts

This section concentrated on past response efforts for oil sands products spills and one case of a heavy oil spill. Due to the small number of case studies, a number of research and information gaps remain. One research gap stands out based on the above discussion:

- As the Kalamazoo spill suggests, weathering and sedimentation may lead to the oil being overwashed by water, suspended in the water column, or sinking to the bottom. There is a gap in understanding how oil sands products are affected by the weathering and sedimentation processes and also the time frame when these processes will affect the success of spill response.

The three case studies discussed above also have similarities in the ineffectiveness of management during the spill response. This leads to the question:

- Are the current plans, training procedures, and equipment resources adequate in preventing significant amounts of oil from entering the natural environment?

7.3 Effectiveness of Current Equipment on Sunken and Submerged Oil Spills

7.3.1 Assumptions

The below analysis is based on the assumption that oil sands products will remain on the surface for several hours or days when spilled into saltwater, but as sedimentation and volatilization occurs, some of the oil will submerge or sink (Counterspil Research, 2011). This assumption is further backed up by Enbridge's technical data reports that were released in conjunction with the proposed Northern Gateway pipeline project. The report suggests that in a marine spill scenario 80 percent of the oil will remain on the surface for 120 hours under summer conditions (will not easily sink) but it “will be easily overwashed with water” (Counterspil Research, 2011). Due to the lack of available case studies on oil sands product spills, this analysis looks at equipment effectiveness in past heavy oil spills, where the oil was submerged in the water column or sank. This is relevant to the oil sands discussion as oil sands products may behave like non-floating oils after weathering and other interactions with the environment.

7.3.2 Common Oil Spill Recovery Technologies and Anticipated Effectiveness

7.3.2.1 Detection and Monitoring of Submerged and Sunken Oil

Based on U.S. Coast Guard research, multi-beam and imaging sonars are the most effective technologies for conducting wide area detection surveys and looking for large pools of subsurface oil. They are most effective in detecting subsurface pools if they are deployed before the oil breaks up. However, the resolution of these devices is still relatively low, impairing their effectiveness. Laser systems and narrower beam sonars are better suited to narrow areas and determining the amount of oil present (Hansen *et al.*, 2009). A summary of other detection and monitoring technologies are provided in the table below. For a full analysis of detection and monitoring equipment, see Appendix 3.

Technology	Analysis
Snare Sampler	• Specifically used to detect oil at various depths in the water column • Produces time-series data • Time and labor intensive (Counterspil Research, 2011; Michel, 2006)
Vessel-Submerged Oil Recovery System (V-SORS)	• Can detect both pooled and mobile oil moving along the bottom • Relatively efficient • Time and labor intensive • Susceptible to snagging on bottom (Counterspil Research, 2011; Michel, 2006)
Side-scan sonar data	• Provides good spatial coverage and visualization of large accumulations and bottom features • Effectiveness diminishes as the oil spreads and the water becomes rough • More successful in detecting the trenches and other bottom features that contain pooled oil instead of the oil itself (Counterspil Research, 2011; Michel, 2006)
RoxAnn	• Used to differentiate seafloor bottoms (Michel, 2006; Counterspil Research, 2011)
Remotely-operated underwater video	• Successfully provides estimates of frequency and size of oil accumulations • Cannot always determine exact oil position • Effective with visibility exceeding 0.5 meters, but it does not generate a wide view (Counterspil Research, 2011)
Sorbents attached to weights	• Ineffective (Counterspil Research, 2011)
Sorbent drops and sediment cores	• Not effective for mobile oil in the water column (Michel, 2006)
Snare Sentinels	• Too time and labor-intensive for widespread use (Counterspil Research, 2011; Michel, 2006)
Airborne Hyperspectral fluorescent LiDar	• Successful in detecting oil suspended in the top few meters below the water surface
RESON Sonar System	• Positively identifies 87 percent of sunken oil targets. • Has a false alarm rate of 24 percent (Hansen *et al.*, 2009)
EIC Fluorosensor	• Can be attached to ROVS or other platforms • GIS input fluctuates and direct mapping is not possible (Hansen *et al.*, 2009)
Side-looking Airborne Radar, UV, & IR	• Unable to penetrate water

7.3.2.2 Containment of Submerged and Sunken Oil

Containment of submerged oil is still mostly in the conceptual stage. To the extent that the below technologies have proven effective, it has only been in low-flow zones or depressions (Counterspil Research, 2011).

Technology	Analysis

Trenching and Berming	• Does not work if the oil is suspended
Pneumatic barriers (air bubbles)	• Limited information on this method • May aerate oil, which would change the density and reduce the oil's tendency to sink. • Effective at "protecting a water intake at currents of less than 0.75 knots" (Counterspil Research, 2011)
Deep-skirted booms	• Developed to contain Orimulsion • May be effective, but have limited information (Counterspil Research, 2011)
Bottom booms, filter fense, trenches, and booms	• Can be coordinated with recovery and are quick and easy to deploy • Highly dependent on bottom conditions • Seabed booms for sunken oil have not been tested in a real situation (Counterspil Research, 2011)
Trawl nets	• Have proven effective (other than fine mesh nets) • Made specifically for heavy oil recovery (Counterspil Research, 2011)
Sorbent barrier/fence	• Never tested • Engineering design inadequate to assure it would function properly • If manipulated, it can be easily fabricated to meet site-specific contexts (Michel, 2006)

7.3.2.3 Removal of Submerged and Sunken Oil

If oil is suspended in the water column there can be little done other than detecting the oil (Counterspil Research, 2011). During the DBL-152 heavy oil spill, hydraulic submersibles that featured open impeller chambers, such as the MPC model KMA axial/centrifugal pump, and directed by divers proved to be most successful in removing sunken oil (Counterspil Research, 2011). The U.S. Coast Guard's research suggests that a hopper dredge or large duck-bill system has the highest potential for use in recovery efforts based on timing, operational limits, recovery efficiency, remobilization, cost, and safety (Michel, 2006).

Technology	**Analysis**
Hydraulically-driven submersible dredge pump with a diver-directed suction hose	• Recovered 900 gallons of submerged, pooled oil from small trench during M/T Athos • Diver directed hoses led to a slow recovery, especially since the oil was moving (Counterspil Research, 2011)
Centrifugal Pump	• Resulted in droplet formation • Used with a lower rpm Foilex TDS-150 Archimedes screw pump as well as a 4-stage decanting system to effectively reduce water content (Counterspil Research, 2011)

Clamshell dredges	• Successful when oil solidifies (Counterspil Research, 2011)
ROVs and mini-subs	• Potential to recover oil from greater depths • Marine Pollution Control has been testing a mini submarine mounted with a suction recovery system (Counterspil Research, 2011)
Nets	• Messy and largely ineffective (Counterspil Research, 2011)
Dredging	• Effective • Generally limited to 50 meters water depth • Pneumatic dredgers can operate in greater depths • Fastest method of recovering sunken oil but generates a large volume of sediment and water that needs to be stored • Also need to consider the benefits of removing oil against seabed disturbance (Counterspil Research, 2011)

Based on the current state of recovery technologies, five problem areas need to be refined and addressed for heavy oil or oil sands products cleanup (Counterspil Research, 2011):

1. Nozzle design of hoses to reduce the water intake during underwater pumping;
2. Diver-directed vacuum systems to increase the pumping rate;
3. Remotely-operated vehicles (not divers) development for safe pumping;
4. Dredges modified to minimize water and sediment uptake; and
5. Improvement in oil separation and water decanting technology.

7.3.2.4 Transfer of Viscous Oil

Overall, the transfer of viscous oil should not be a limiting factor in heavy oil or oil sands products recovery. Many modifications to existing technology have already been made to process heavy oils (Counterspil Research, 2011).

Technology	Analysis
Pharos Marine GT185 Skimmer	• Main component of the Canadian Coast Guard recovery inventory. • Unable to recover and pump floating bitumen. Similar with USCG stock equipment, need modifications to process heavy oils (Michel, 2006; Counterspil Research, 2011)
Annular water injection	• Modified pump developed and tested in Denmark, Sweden, Norway, and Finland seems to be successful (Counterspil Research, 2011)

Key Sources: Effectiveness of Current Equipment on Sunken and Submerged Oil Spills

Counterspil Research. (2011). *A Review of Countermeasures Technologies for Viscous Oils that Submerge.* Counterspil Research Inc. West Vancouver: Counterspil Research Inc.

Hansen, K. A., Fitzpatrick, M., Herring, P. R., & VanHaverbeke, M. (2009). *Heavy Oil Detection (Prototypes) -- Final Report.* United States Coast Guard, Research and Development Center. Washington, DC: U.S. Department of Homeland Security.

Michel, J. (2006). *Assessment and recovery of submerged oil: Current state analysis.* Research Planning, Inc. Groton: USCG.

7.3.3 Regional Response Capacity – Heavy Oil Spills

To obtain project approval from governing bodies, companies exploring, transporting, producing, and refining oils are mandated to submit a contingency plan in case of a spill. The majority of oil companies choose to enlist an oil spill cooperative to satisfy oil spill response needs (Allen, 1981). The United States Coast Guard (USCG) does not have the equipment to respond to a submerged oil spill scenario (Hansen, 2013). Nationally, there are two oil spill cooperatives that have a large capability in recovering heavy oil that sits on the bottom of bodies of water: Marine Pollution Control (MPC), based in Detroit, Michigan, and BISSO Marine, based in Houston, Texas (Hansen, 2013). Other cooperatives do have capabilities that include divers that can respond or other special equipment used for recovery of oil inside of vessels.

Currently, there is no uniform method of reporting a region's oil spill response equipment availability. As seen below, the Pacific Northwest and the New England area aggregates its equipment lists into a regional list, which includes publically and privately owned equipment available in multiple states. The Great Lakes Region concentrates on equipment owned and operated by state governments.

In addition, many response organizations publish their equipment lists, but they may not report all the necessary information to determine how the equipment can be used in an oil spill. For example, a response organization may report that it has a sonar in its inventory, but will not include the frequency it is operating at or other vital processing information (Hansen, 2013). This makes it difficult to assess a region's capacity to respond to a heavy oil spill or a spill of oil sands products.

7.3.3.1 Response Capacity in Washington State

In the Pacific Northwest, all equipment maintained by spill response cooperatives in the area is listed at: http://www.wrrl.us. However, this list does not capture all the equipment that may be available to a responder during a spill because it only lists equipment that is geographically close to the spill. This means that oil spill response organizations outside of the Pacific Northwest that are contracted with oil companies operating in the region will not report available equipment to the WRRL. For example, Kinder Morgan theoretically could contract with BISSO but because BISSO's equipment is located in Texas it is not accounted for in the WRRL.

The WRRL contains response equipment that is both dedicated to spill response and those that are not. A considerable proportion of the equipment is not dedicated to spill response. For example, WRRL lists a number of private fishing boats that could be used during a spill response effort. This means, there is a possibility that a piece of equipment listed may not be available during a spill (OSAC, 2009).

7.3.3.2 Response Capacity in the Great Lakes

Through various laws and regulations, the U.S. and Canada have a formal relationship in regards to oil spill preparedness and response programs. This is expanded on further in section 8.4.

The ability for response organizations to respond to a spill in the Great Lakes Region may be hindered significantly during winter conditions. With icy or snowy conditions, access to remote locations may be difficult and some facilities may operate with reduced personnel (Emergency Preparedness Task Force, 2012). The states in the region do not have a large inventory of response equipment (Emergency Preparedness Task Force, 2012). For a full list of equipment available during a spill, broken down by state see Appendix 4.

7.3.3.3 Response Capacity in Maine

As part of Maine's contingency planning, the Department of Environmental Protection created a directory of all spill response equipment located in the New England area. This includes oil response cooperatives, such as Marine Spill Response Corporation, U.S. and Canadian regulatory agencies, U.S. and Canadian Coast Guard contacts, and citizen volunteers who may choose to lend their boat or aircraft to spill response. This document can be found at: http://www.maine.gov/dep/spills/emergspillresp/documents/appendices.pdf. Again, this does not necessarily reflect the response capacity of the region as individual companies may contract with oil cooperatives outside of the area.

Key Sources: Regional Response Capacity

Hansen, Kurt. (2013 11-February). US Coast Guard. Personal Communication.

7.3.4 Gaps in Effectiveness of Current Equipment on Dilbit Spills

There are multiple gaps in policy and research in terms of equipment and mandated response capacity:

- The regional and national equipment lists are missing vital processing information about available oil spill response equipment, which makes it difficult to assess how a particular piece of equipment can be used effectively during a spill response scenario.
- There is a lack of real world testing and experience with equipment on dilbit spills, hindering our ability to assess whether or not a region has equipment that will be effective in an oil sands products recovery effort.
- When an oil spill occurs, the responsible party must respond within a specific period of time. If there is an oil sands products spill, the responsible party will be in compliance with oil spill response requirements as long as they have personnel on the site performing recover efforts, e.g. divers, not necessarily with the appropriate equipment to the specific type of oil spilled. This could mean that the responsible party would have to wait up to 72 hours for the appropriate equipment to reach the site if the spill is in Washington but the needed equipment is in Detroit or Houston.
- Clean up regulations require oil cooperatives to prove that they possess the equipment and can respond to a spill during a specified time period. However, policy does not require them to demonstrate the effectiveness of the equipment on specific oils. As we saw in the case studies, this may affect oil spill response effectiveness.
- Material Safety Data Sheets (MSDS) (discussed further in Section 8.5.1) do not require the properties of the specific type of oil spilled to be noted. In the case of the Kalamazoo Spill, responders were given an MSDS that listed “crude” oil as the material spilled, not dilbit. This affected the responders’ ability to plan their response efforts.
- There is a lack of information and ability to employ oil spill detection and recovery methods when the oil reaches the bottom of a body of water or when the oil is suspended in the water column.

8 SIGNIFIGANT POLICIES AND REGULATIONS

8.1 Introduction

Regulations and standards governing oil spills can largely be divided into two related categories—requirements for preparing for oil spills and requirements for responding to oil spills. The U.S. Coast Guard (USCG), the Environmental Protection Agency (EPA), and the Department of Transportation (DOT) oversee oil spill planning, response, and transportation—and are the primary regulatory actors relevant to the transport of oil sands products. These regulatory categories can overlap and are administered and enforced by multiple federal and state agencies. In this section, we outline:

- Spill planning and response rules derived from the National Contingency Plan and the Oil Pollution Act;
- The primary federal agencies responsible for rulemaking and enforcement in oil spill planning and response, noting any efforts to address the transport of oil sands products (focusing on the USCG, EPA, and DOT);
- The role of states and regions in oil spill response planning, including some recent efforts to address the increase in oil sands products and additional legislation that could relate to oil sands products indirectly; and
- Initial gaps in transportation and spill response and preparedness policies related to oil sands products.

8.2 Contingency Planning and Spill Response Background

In general, contingency plans are protocols detailing the steps responsible parties and government agencies must follow before, during, and after an oil spill and determine who should respond (EPA, 1999). The National Oil and Hazardous Substances Pollution Contingency Plan, commonly referred to as the National Contingency Plan (NCP), outlines the federal government's procedures for oil spill contingency planning and response coordination (40 CFR 300). The NCP's scope has been expanded several times since its original publication in 1968, with the most recent revisions in 1994 following the passing of the Oil Pollution Act (OPA). The NCP has created a multilayer National Response System for coordination of local, state, and federal agencies, industry, and other actors to ensure effective response to spills (EPA 2013). The NCP system is defined by a few key components (40 CFR 300):

- *National Response Team*—established the NRT to plan and coordinate responses to major discharges of oil and to provide guidance to Regional Response Teams (RRTs)
- *Regional Response Team*—established RRTs to coordinate, plan, and respond at the regional level and includes representatives from federal agencies that are members of NRTs plus local and state officials.
- *Federal On-Scene Coordinators(FOSCs)*—established to coordinate federal efforts with local, state, and regional groups with four key responsibilities: assessment of a spill and resources needed, monitoring of responsible parties, federal response assistance if necessary, and evaluation of response actions overall.
- *Unified Command*—established a unified command structure to coordinate personnel and resources of federal and state officials as well as the responsible party.

For federal agencies this regulatory structure requires planning for coordination during oil spills and oversight of response plans. The regulatory framework for responding to a spill was solidified through the OPA amendments, which consolidated all federal spill response laws under one program (Ramseur 2012). The notable oil response provisions of the NCP include establishing (40 CFR 300.15):

- The general responsibilities of FOSCs and authorizing FOSCs to direct response activities at spill site;
- The general pattern of response of FOSCs in determining the threat, classification, size, and type of the release;
- Authorization of FOSCs to determine if a spill poses a threat to public health or welfare;

- Requirements of FOSCs to notify the National Strike Force Coordination Center (NSFCC)[20] in the event of a worst-case discharges, defined as "the largest foreseeable discharge in adverse weather conditions;"
- Provision of funding for oil spill responses under the Oil Spill Liability Trust Fund if certain criteria are met.

The NCP and OPA give responsibility for designating a FOSC to the EPA or the U.S. Coast Guard (USCG) depending on the location of the spill. USCG has the authority to "evaluate, coordinate and direct clean-up" of spills in coastal waters and the Great Lakes and the EPA has the authority for inland spills (US Coast Guard Gulf Strike Team, 2008).

8.2.1 Discharge of Oil Regulation

The Discharge of Oil regulation, commonly known as the "sheen rule," sets the standard for deciding whether or not a spill should be reported to the federal government (Discharge of Oil, 1996). Broadly, under the Clean Water Act, the sheen rule mandates that an oil spill should be reported if the spill poses a threat to public health or U.S. welfare. The rule specifically states that any spills with the following characteristics should be reported:

1. Spills resulting in a discoloration or a sheen on the surface of a body of water;
2. Spills that violate pertinent water quality standards;
3. Spills that cause sludge or emulsion to be deposited beneath the surface of the water or on adjoining shorelines.

8.3 Federal Contingency Planning

The NCP framework has resulted in a web of federal agency responsibilities related to contingency planning and response requirements. This section outlines the main federal agencies that lead contingency planning: the USCG for vessels, the EPA for non-transport-related inland

[20] According to the USCG website, "the National Strike Force (NSF) provides highly trained, experienced personnel and specialized equipment to Coast Guard and other federal agencies to facilitate preparedness for and response to oil and hazardous substance pollution incidents in order to protect public health and the environment… The NSFCC provides support and standardization guidance to the Atlantic Strike Team (AST), Gulf Strike Team (GST) and Pacific Strike Team (PST)."

spills, and the DOT in rail and pipeline transportation. We then discuss the role of regional and state plans and other potentially relevant laws governing increased transport of oil sands products. Throughout, we discuss if and how agencies have thought about the transportation of oil sands products.

Oil spill prevention planning requirements are determined by the potential source of the spill, which for oil sands products primarily includes vessel, facility, pipeline, and rail. The USCG, EPA, and DOT play the most important role in establishing and implementing spill response procedures for operators. The designated federal agency must assess the capacity of the responsible party to effectively respond to a spill, which may include providing oversight of response plans, maintaining contingency plans at various levels, and personnel training (Ramseur 2012).

8.3.1 USCG

The USCG plays a key role in both spill response and clean up, and in spill prevention and preparedness. As the FOSC for maritime oil spills, the USCG is given the authority to ensure an effective response to oil spills in U.S. waters subject to the tide, the Great Lakes, and other specified waters (40 CFR 300.5).[21] USCG jurisdiction in oil spill preparation and planning covers vessels, onshore facilitates with transportation-related activities, and deepwater ports (Ramseur 2008). Contingency plans for maritime oil spills in the U.S. are established at the national and regional level to ensure that for oil transported through Canadian waters, the U.S. is prepared to engage in cleanup if a spill has the potential to cross into U.S. waters or affect U.S. coastlines.

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[21] 40 CFR 300.5 provides a full definition of coastal zone as: "all United States waters subject to the tide, United States waters of the Great Lakes, specified ports and harbors on inland rivers, waters of the contiguous zone, other waters of the high seas subject to the NCP, and the land surface or land substrata, ground waters, and ambient air proximal to those waters."

Under OPA and an international treaty, MARPOL 73/78[22], owners and operators of vessels carrying oil must submit Shipboard Oil Pollution Plans (SOPEP) to ensure tanker crews have a plan to respond to an array of oil spill scenarios (Ramseur 2008). Annex 1, Regulation 37 of MARPOL requires that oil tankers weighing 150 tons gross tonnage or more carry an approved SOPEP (IMO 2013). Although other vessels are required to carry SOPEPs depending on tonnage (400 tons gross or more), oil tankers have specific plans given the large quantities of oil they hold. For U.S. ships, 33 CFR 151.27 requires the Coast Guard to 'review and approve' a vessel plan (USCG 1995). Among other things, a SOPEP contains:

- General information about the ship,
- Procedures to contain a discharge of oil,
- Reporting procedures in case of a spill,
- Drawings of fuel lines,
- Descriptions and locations of oil tanks, and
- Action plans for all crew members at the time of a spill.

A list of the vessel contents are also required, but in the case of vessels carrying oil sands products above an API of 10, a SOPEP would only be required to list "crude oil" instead of the specific product (see section 8.3.4 on Group V oils).

An update to the USCG's FRP requirements went into effect in February 2011. Aimed at improving response preparedness for facilities carrying or handling oil on U.S. navigable waters, the new regulation updated requirements for oil-spill removal equipment, added requirements for plan holders to use new response technologies, and amended procedures for spill response. The new rule applies to facilities already required to hold response plans under the FRP rules (Removal Equipment Requirements and Alternative Technology Revisions, 2009).

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[22] MARPOL 73/78's full name is the International Convention for the Prevention of Pollution From Ships, created in the years 1973 and 1978.

8.3.2 EPA

EPA's main responsibility relevant to oil spills is its responsibility as FOSC for inland oil spills, but it also regulates non-transport related spill planning. EPA provides oversight over Facility Response Plans (FRP), which are required under OPA. A FRP is required for certain facilities that store and use oil and include detailed plans for responding to a worst case discharge. As appropriate, FRPs also outline responses to small and medium discharges. The EPA has created regulations for what facilities must prepare and submit FRPs and what the plans must contain (US EPA, 2002).

OPA requires that "substantial harm" facilities develop FRPs. These include facilities that could cause substantial harm to the environment or navigable waters if a discharge occurred. The specific regulation on "substantial harm" criteria is found in 40 CFR 112.20 and 112.21, appendices B through F. Under the rule, a facility falls in the category if it meets at least one of the following criteria (Facility Response Plans, 2005):

- The facility has a total oil storage capacity greater than or equal to 42,000 gallons and performs overwater oil transfers to or from vessels; or
- The facility has a total oil storage capacity greater than or equal to one million gallons, and meets one of the following conditions:
    - The facility does not have secondary containment for each aboveground storage area; or
    - The facility is located such that a discharge could cause injury to an environmentally sensitive area; or
    - The facility is located such that a discharge would shut down a public drinking water intake; or
    - The facility has had, in the past five years, a reportable spill greater than or equal to 10,000 gallons.

8.3.3 DOT: Pipelines (PHMSA) and Rail (FRA)

The DOT houses two agencies that oversee the transportation of oil via pipeline and rail—the Pipelines and Hazardous Materials Safety Administration (PHMSA) and the Federal Railroad Administration (FRA). Pipeline transport of oil is heavily regulated beginning with pipeline siting, construction, and maintenance and continuing during the planning for potential oil spills and recovery efforts. Regulations for rail transport of oil are less developed. With increased transport of oil sands products from Alberta and crude from the Bakken region, closer oversight of rail transport may be necessary.

8.3.3.1 Regulating Oil Transportation by Pipeline

The Natural Gas Pipeline Safety Act of 1968 and the Hazardous Liquid Pipeline Act of 1979 established the DOT as the federal agency responsible for oversight of pipeline safety in the U.S (Parfomak 2013). The Clean Water Act (as amended by the Oil Pollution Act of 1990) requires regulations that establish oil spill planning requirements, plan review, and plan approval. In 1991, Executive Order 12777 ordered PHMSA to develop regulations that require operators to submit spill response plans and review and approve plans for onshore pipelines (PHMSA 2012). PHMSA's Office of Pipeline Safety now oversees these two primary regulatory areas, along with safety regulations of the design, construction, and maintenance of pipelines (49 CFR Part 195), and response plans for onshore oil pipeline spill response plan requirements (49 CFR Part 194).

Safety

The 1994 Pipeline Safety Act combined the two previous pipeline safety statutes, giving PHMSA authority to maintain the safe and reliable operation of the Nation's pipeline infrastructure. The Office of Pipeline Safety developed prescriptive regulations for pipeline design, inspection in the manufacturing and construction processes, and maintenance and operation oversight through the life of the pipeline. Tools for enforcement included warning letters and compliance orders followed by civil penalties—which are used alongside various information-sharing programs (PHMSA 2012a).

The prescriptive regulations before legislation in the early 2000s largely followed an inspection checklist approach. Accidents led to additional prescriptive requirements and also the inclusion of management-based mandates to analyze risk, identify spill prevention options and evaluate programs. The Pipeline Safety Improvement Act of 2002 established requirements for risk analysis and integrity management (IM) programs for operators (Parfomak 2013). Called the Liquid IM Rule, the program outlined how operators should 'identify, prioritize, assess, evaluate, repair, and validate the integrity of hazardous liquid pipelines that could, in the event of a leak or failure, affect High Consequence Areas (HCAs) with the United States" (PHMSA 2012b). The rules defined HCAs as population centers, ecologically sensitive areas, and commercially navigable waters—and required operators to explore how pipeline risks would impact HCAs.[23] Finally, The Pipeline Inspection, Protection, Enforcement, and Safety Act of 2006 developed rules on corrosion, public awareness, and qualifications for operators and rules on pipeline control room management (Parfomak 2013).

<u>Spill Response</u>

PHMSA reviews contingency plans for pipelines where a major leak could cause harm to the environment. Requirements for an onshore pipeline spill response plan must (PHMSA 2012a):

- Maintain consistency with National and Area Contingency Plans;

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[23] Full name: "Liquid Pipeline Integrity Management in High Consequence Areas for Hazardous Liquid Operators" found in 49 CFR Parts 195.450 and 195.452

- Identify the qualified individual (QI) with authority to respond;
- Identify private personnel and equipment necessary to remove a worst case discharge—and ensure their availability;
- Describe training, testing, drills; and
- Be updated periodically and after major changes.

PHMSA and Oil Sands Products

A number of recent events led to changes at PHMSA that are directly or indirectly relevant to the transportation of oil sands products. The Enbridge spill in Kalamazoo and other pipeline accidents led to The Pipeline Safety Act in late 2011.[24] The legislation had a number of relevant components. First, it increased civil penalty authority for PHMSA for safety and compliance violations. Second, it required DOT to evaluate areas of technology that could increase safety and detect leaks and required PHMSA to evaluate if integrity management requirements should be expanded to more areas. Finally, it led to a study by the Transportation Research Board of the National Academies, which will determine if regulations are sufficient for facilities transporting dilbit (Parfomak 2013). The study will analyze:

1. Dilbit risks to pipelines to determine if dilbit increases the frequency of spills compared with other liquid petroleum products; and
2. If the committee finds that dilbit presents an increased risk, it will review regulations to determine if current rules are sufficient to address the risk.

All tasks are to be completed by December 2013. Recent presentations by PHMSA officials suggest that they found spill risks similar to other U.S. crude oils for corrosiveness or abrasiveness (PHMSA 2012a).

Additional changes at PHMSA have resulted from recent spills (PHMSA 2012a):

- More staff are now dedicated to plan-reviewing;

[24] Full name: The Pipeline Safety, Regulatory Certainty and Job Creation Act of 2011. See www.gpo.gov for the full text.

- The Office of Pipeline Safety (OPS) initiated an internal audit of plan review activities;
- PHMSA continues to revise its plan review criteria and procedures. Previously, only the response plan preparer was involved in the review process whereas now PHMSA includes operator compliance official(s) into reviews;
- During the review process, an operator's history is now considered. This includes incident and accident history; and
- Increased participation in drills by operators.

Moving forward, PHMSA's strategic plan is to integrate OPS, target and expand safety inspections based on the most serious risks, and focus pipeline safety research on methods to identify defects.[25] In addition, PHMSA is also planning to review NTSB's findings and recommendations on response plans, examine opportunities for better alignment with EPA and USCG plan standards, and integrate spill plan responsibilities and the Pipeline Safety Inspection Program (PHMSA 2012b).

8.3.3.2 Regulating Oil Transportation by Rail

The boom in rail transportation of oil in Canada and the U.S. due to increases in supply in Alberta and the Bakken crudes has increased concern over the relative lack of regulatory oversight in rail transport. The Federal Railroad Safety Act of 1970 established the Federal Railroad Administration's (FRA) role in overseeing the safety of rail transport in general, including the safe transport of hazardous materials (GAO 1998). Under 49 CFR 130, the FRA is required to oversee contingency plans for operators carrying 'any liquid petroleum oil in a packaging having a capacity of 3,500 gallons or more." Response plans must follow the general pattern dictated by the NCP; operators must:

- Outline the response procedure for potential discharges,

[25] Also see PHMSA Onshore Oil Pipeline Fact Sheet
http://www.eaovt.org/sbcap/pdf/FS19PipelineTransfer.pdf

- Consider the maximum potential discharge,
- Identify 'private personnel and equipment available to respond to a discharge', and
- Identify relevant agencies to be contacted.

The FRA regulates safety in railcar construction and inspections of rail cars are required by DOT before loading operations begin and again once the car has been loaded. According to the EPA's rules, railroad cars often present an issue of jurisdiction between DOT and EPA:

> "DOT regulates railroad cars from the time the oil is offered for transportation to a carrier until the time that it reaches its destination and is accepted by the consignee. DOT jurisdiction includes railroad cars that are passing through a facility or are temporarily stopped on a normal route. EPA regulates railroad cars after the transportation process ends; that is, when the railroad cars are serving as non-transportation-related storage at an SPCC-regulated facility (EPA 2005)."

In addition, the USCG has regulatory involvement relative to transfers of oil from rail to barges and vice versa.

Due to the relative lack of large-scale oil transport by rail, the Federal Railroad Administration, unlike PHMSA's Office of Pipeline Safety, has no known program to specifically address potential spills of crude oil let alone heavy oils or oil sands products. With expected substantial increases in rail transport throughout North America and the many waterways along rail routes, increased oversight of planning and response to oil spills from train transport should be considered.

8.3.4 Federal Planning Regulations Specific to Group V Oils

At least three federal contingency planning regulations apply specifically to Group V oils, two of which are of particular interest: 40 CFR 112 Appendix E, an appendix to the EPA's oil pollution prevention plans, and 33 CFR Section 155.1052, USCG vessel requirements under the FCP.

1. *40 CFR 112 Appendix E*—sets standards for facility owners or operators dealing with Group V Oils. Owners or operators must have contractual agreements that confirm access to response resources, including things such as sonar and oil locating sampling equipment. Notably, these resources "shall be capable of being deployed (on site) within 24 hours of discovery of a discharge" (Determination and Evaluation of Required Response Resources for Facility Response Plans, 2011).
2. *33 CFR Section 155.1052*—sets 'response plan development and evaluation criteria for vessels carrying group V petroleum oil as a primary cargo.' Owners and operators of vessels must include specific information about the availability of equipment for response 'capable of operating in the conditions expected in the geographic area(s) in which the vessel operates.'

These regulations, as well as contingency plan requirements in the state of Washington, require operators to plan specifically for carrying group V oils as a primary cargo. These regulations do not apply to oil sands products (normally classified as group IV when a diluent is used) even though they have the potential to be non-floating oils when spilled.

8.4 Regional and State Roles in Contingency Planning and Response

8.4.1 Plans for U.S.-Canada Contingent Waters

The Canada-U.S. Joint Marine Pollution Contingency Plan (JCP) is the coordinated system to plan, prepare, and respond to spills of oil and other harmful substances in contiguous waters of the U.S. and Canada. The JCP supersedes previous joint contingency plans and maintains consistency with provisions of Article 10 of the 1990 *International Convention on Oil Pollution Preparedness, Response, and Co-operation* and Annex 9 of the 1972 *Agreement between Government of Canada and the Government of the United States on Great Lakes Water*

Quality. The principle purpose of the JCP is to establish a coordinated system for planning, preparedness, and response to “incidents” of “harmful substances” in contiguous waters by supplementing existing national plans and ensuring cooperative bilateral response planning at the local and national levels (Canada-United State Joint Marine Pollution Contingency Plan, 2003). The JCP also facilitates the coordination of response activities for the parties responsible for a spill and establishes consultation procedures between parties responding to a spill.

Additionally, the JCP includes geographic annexes for five regions to better coordinate localized response efforts. Each geographic annex, referred to as a bilateral plan, serves to strengthen and coordinate the pollution response systems in order to facilitate an efficient cross-border spill response. Each geographic annex defines the roles of that region’s response team and is tested and updated through ongoing exercises. These five geographic annexes, each of which is pertinent to the transportation of oil sands products are as follows:

- *CANUSLANT*: joint pollution response for Atlantic marine boundary between Canada and the U.S. This includes the Gulf of Maine and the Bay of Fundy. Relevant due to the potential of oil sands products passing through Portland, Maine.
- *CANUSLAK*: joint pollution response for Great Lakes boundary between Canada and the U.S. Relevant due to oil sands products passing through the region via pipeline and rail, as seen in the Kalamazoo spill in 2010.
- *CANUSPAC*: joint pollution response for Pacific water boundaries between Canada and the U.S. Relevant due to oil sands products passing through the Strait of Juan de Fuca region.
- *CANUSDIX*: joint pollution response for Dixon Entrance water boundary between Alaska and British Columbia. Relevant due to potential for oil sands products to be transported to Valdez, Alaska via rail.

8.4.2 Regional Contingency Planning

Contingency plans specifically targeted for specific U.S. regions include USCG area contingency plans and the region-specific joint plans with Canada. In addition to the NCP discussed above, OPA requires that area committees are established by region as designated by the President of the United States. Area committees are composed of federal and state agencies that coordinate response actions with the private sector, local governments, and tribal communities. Federal On-Scene Coordinators in each area direct the committees, which are primarily tasked with developing Area Contingency Plans (ACPs), and work with responders to develop procedures to increase the efficiency of decision making for response actions. RRTs, as established in the NCP, are responsible for regional planning and preparedness prior to a response and each of the 13 RRTs maintain a Regional Contingency Plan. During a response, RRTs in each region support FOSC and State On-Scene Coordinators (SOSCs). The principal purposes of ACPs in an oil spill are to:

1. Detail orderly and effective response actions to protect human health, property, and natural resources,;
2. Promote the coordination and strategy for a unified response from federal, state, tribal, local, responsible party, and community actors; and
3. Provide guidance for facility and vessel response planners (Northwest Area Contingency Plan, 2013).

As it concerns the transport of Alberta oil sands products, the following provides a brief overview and links to more information on ACPs in the Pacific Northwest, the Great Lakes Area, the area encompassing Maine, and Alaska. The RRTs that operate in coordination for these regions are:

- Northwest: RRT, Region 10
- Maine: RRT, Region 1

- Great Lakes: RRT, Region 5
- Alaska: RRT Alaska

8.4.2.1 The Northwest Regional Contingency Planning

The Northwest Area Contingency Plan (NWACP) covers the coastal and inland zones of Idaho, Oregon, and Washington. Regarding the ports and coastal waters surrounding Washington State in particular, the NWACP serves as the state's Oil and Hazardous Substance Spill Prevention and Response Plan and applies to all public agencies that manage oil and hazardous substance spills. The Washington State Department of Ecology is Washington's lead agency in overseeing the response, containment, and cleanup of oil spills in state waters.

In December 2012, the Washington State Department of Ecology added a new provision to the Oil Spill Contingency Plan requiring more detail on the type of oil handled to be included in a Material Safety Data Sheet (MSDS) or SOPEP. This new rule requires that responsible parties disclose the name of all oils handled on vessels and at facilities including pipelines as well as the density, gravity, API, oil group number, and sulfur content (Oil Spill Contingency Plan, 2012).[26]

Regarding non-floating oils, a Washington State standard effective January, 2013 requires those plan holders that are "carrying, handling, storing, or transporting" Group V Oils to hold contracts with primary response contractors (PRCs) that "maintain the resources and/or capabilities necessary to response to a spill of Group 5 Oils." This includes sonar, sampling equipment to locate suspended oil, and dredges, among other pieces of cleanup and detection equipment (Planning standards for Group 5 Oils, 2013).

Also notable in the Northwest region is legislation requiring the USCG to conduct a risk assessment regarding the transportation of Canadian oil sands products. Established via H.R.

[26] NWACP website: http://www.rrt10nwac.com/

2838, the Coast Guard and Maritime Transportation Act of 2012 requires the USCG to "assess the increased vessel traffic in the Salish Sea (including Puget Sound, the Strait of Georgia, Haro Strait, Rosario Strait, and the Strait of Juan de Fuca), that may occur from the transport of Canadian oil sands products (Coast Guard and Maritime Transportation Act of 2012, 2012),.[27] More specifically, the assessment must identify:

- The extent to which vessels traffic (for barge, tanker, and supertanker) will increase due to the development of Canadian oil sands products;
- Whether or not transport from the Canadian oil sands products will require navigation through U.S. territorial water;
- The regulations that restrict supertanker traffic and the amount of oil that tankers and barges can transport in U.S. waters as well as whether there are ways to bypass these rules ;
- The spill response capability throughout shared U.S. and Canadian waters including spill response requirements for vessels transiting through the waters of the other nation; and
- Whether oil sands products have different properties from other types of oil, including toxicity and other properties, that may require different maritime clean up technologies.

8.4.2.2 Maine

In the Northeast region, there is an ACP covering Maine and New Hampshire as well as a Maine Department of Environmental Protection (DEP) Marine Oil Spill Contingency Plan. The Maine and New Hampshire ACP was last updated in 2010. Maine law requires DEP to set up a state-specific Marine Oil Spill Contingency Plan to coordinate Maine's response to oil spills. The DEP plan focuses on prevention, preparedness, timely response, and restoration and disposal. Recognizing the development of other contingency plans that apply to Maine, DEP affirms that

[27] The bill can be accessed here (section 722) http://www.govtrack.us/congress/bills/112/hr2838/text/eah

the Marine Oil Spill Contingency Plan does not supersede any other plan and is intended to be carried out in coordination with other contingency plans (Maine DEP, 2011).[28]

8.4.2.3 Great Lakes

For the Great Lakes region, there is series of ACPs and Subarea Contingency Plans (SCPs) that cover the Eastern Great Lakes and Lake Michigan. These include the EPA Region 5 Regional Contingency Plan, the Eastern Great Lakes Area Contingency Plan, and the Sector Lake Michigan Area Contingency Plan.[29]

8.4.2.4 Alaska

In addition to the Alaska-specific RRT, the state has a State Preparedness Plan for Response to Oil and Hazardous Substance Discharges/Releases (the Unified Plan) as well as ten SCPs. These SCPs, in coordination with the Unified Plan, describe the federal, state, and local response strategies for oil spills. The SCP most pertinent to the transportation of oil sands products is the Prince William Sound Subarea Contingency Plan for Oil and Hazardous Substance because of its inclusion of the waters and coastlines near Valdez, a possible terminal for dilbit carrying trains. This plan contains guidelines for operations in the event of an oil spill or discharge of other hazardous material.[30]

8.5 OSHA: Spill Response Planning Safety

In addition to the contingency plans coordinated with EPA, USCG, state agencies, and PHMSA, at national and sub-national levels, the Occupational Safety and Health Administration (OSHA) also participates in oil spill planning and response. In an effort to protect workers in a

[28] EPA Region 1 RRT website: http://www.rrt1.nrt.org/production/NRT/RRT1.nsf/AllPages/rrt1.html
Maine DEP Contingency Plan: http://www.maine.gov/dep/spills/emergspillresp/documents/contplan.pdf
[29] Great Lakes RRT website: http://www.rrt5.org/acp/
[30] Alaska RRT website: http://alaskarrt.org/
Prince William Sound Subarea Contingency Plan website: http://dec.alaska.gov/spar/perp/plans/scp_pws.htm

spill response scenario, OSHA focuses on exposure to toxic chemicals, training, job-specific safety hazards, heat stress, injuries, and illnesses. In order to assess worker exposure and safety, OSHA has set sampling strategies in place to monitor for air pollutants and respond with protective equipment as necessary (OSHA). In order for OSHA to effectively respond to a dilbit spill, it is imperative that the characteristics of the bitumen and the diluents be readily available.[31]

8.5.1 Material Safety Data Sheets (MSDS)

The IMO requires that vessels carrying oil or oil fuel have a MSDS prior to loading, similar to the contents disclosure required in SOPEPs. An MSDS requires the disclosure of "general categories of materials" that would be considered hazardous in the case of exposure, but does not specify the specific type of material (International Maritime Organization, 2009). MSDSs are required by a 2009 amendment to The International Convention for the Safety of Life at Sea (SOLAS) and are also required under the OSHSA Hazard Communications Standard in title III of the 1986 Superfund Amendments and Reauthorization Act (SARA). An MSDS for a vessel carrying oil sands products would list "crude oil" on the sheet and would not have to specify the type of crude.

8.6 Liability

OPA unified oil spill liability statutes hold the responsible party liable for any discharge of oil from a vessel or facility and all cleanup costs incurred by government entities, private parties, injury to natural resources, and loss of personal property.

[31] OSHA Oil Spill website: http://www.osha.gov/oilspills/index.html

8.6.1 <u>USCG National Pollutions Funds Center and the Oil Spill Liability and Trust Fund</u>

Related to the liability issue, Title I of OPA authorized the Oil Spill Liability and Trust Fund (OSLTF). OSLTF makes available up to $1billion per incident to assist the responsible party in oil removal and otherwise uncompensated damages (USCG 2013). Administration of OSLTF, handled by the USCG National Pollution Funds Center (NPFC), ensures funding for a federal response to oil spills and recovers costs from liable parties. The NPFC was established specifically in 1991 with a mandate of implementing Title I of OPA and is committed to protecting the U.S. environment through certifying that oil-carrying vessels have the financial capacity to contribute in the case of a spill.

The OSLTF is split into two major components: the Emergency Fund for response to oil discharges and initial natural resource damage assessment and the Principal Fund to pay claims and fund appropriations by Congress that administer OPA provisions and support research and development. The Principal Fund has five sources of revenue, the largest of which is an eight-cent-per-barrel excise tax collected from the oil industry on petroleum imported to or produced in the United States. Notably, as a result of an Internal Revenue Services (IRS) exemption, dilbit and synthetic crude derived from oil sands are exempt from paying this barrel tax, although spills of oil sands products are covered by the OSLTF (IRS, 2011). See policy gaps section below for further information on the exemption.

Ensuring responsible parties have the funds to be held accountable, the NPFC issues Certificates of Financial Responsibility (COFR), which demonstrates that vessels can pay for damage and cleanup up to OPA's required liability limits. With few exceptions, vessels weighing more than 300 gross tons must have a valid COFR before navigating U.S. waterways. The NPFC also recovers costs from responsible parties, provides quick response funding, and compensates claimants for costs and damages (US Coast Guard, 2012).

8.7 Other Pertinent Regulations

In addition to the policies and regulations discussed above, three additional federal regulations are pertinent to the transport and discharge of bitumen and dilbit. These include the Fish and Wildlife Coordination Act, Marine Mammal Protection Act, and the Endangered Species Act.

8.7.1 Fish and Wildlife Coordination Act (FWCA)

Intended to minimize the adverse impact on fish and wildlife resources and habitat, the FWCA requires federal agencies to consult with the US Fish and Wildlife Service, the National Marine Fisheries Service, and State wildlife agencies for all activities that affect, control or modify any streams or bodies of water ((Fish and Wildlife Coordination Act). This consultation is generally incorporated into the permitting process or licensing requirements required during the construction of pipelines that cross water bodies and for upgrades to shipping terminals.

8.7.2 Marine Mammals Protection Act

The Marine Mammals Protection Act (MMPA), enacted in 1972, serves to protect all marine mammals in U.S. waterways from harm, capture, and harassment. The act was passed due to several findings including the potential risk of extinction or depletion that some marine mammals may face as a result from human action, the fact that marine mammal species must not be permitted to fall below optimum levels for sustainable population, and the understanding that measures should be taken to replenish these species (Marine Mammal Protection Act, 1972). Given the rise in transportation through, over, and adjacent to U.S. waterways resulting from the oil sands industry; this act is important in considering transportation routes and measuring impacts on aquatic organisms.

8.7.3 Endangered Species Act (ESA)

In an effort to conserve endangered and threatened species and their habitats, the ESA mandates that federal departments and agencies ensure that any authorized, funded, or implemented action is “not likely to jeopardize the continued existence of listed species or modify their critical habitat.” NOAA and USFWS are responsible for publishing lists of endangered and threatened species. The ESA would apply to the construction of dilbit transport infrastructure and must also be considered in spill response scenarios (Endangered Species Act, 1973).

8.8 Policy Gaps and Analysis

The outline of regulations governing oil spills and their prevention above has suggested potential gaps in regulations when it comes to increased transport of oil sands products out of Alberta. The two most obvious gaps are the exemption of oil sands products from an excise tax and the lack of specific information required by facilities and transporters regarding the oil product they are handling. However, there are additional gaps in policies and regulations that warrant attention as transport of oil sands products increases. The Federal Railroad Administration has traditionally spent little time concerned with the oversight of oil spill planning as large oil spills in rail transport have not generally been a threat until recent years, during which oil transport via rail has increased. Further, there is a concern that the recently drafted PHMSA contingency plans for pipelines are not well integrated with regional and area plan as required. In addition, while many current regulations give agencies the authority to effectively regulate bitumen products, problems can arise from a lack of resources and experience dealing with potentially non-floating oils.

8.8.1 Dilbit Excise Tax Exemption

As mentioned above, an IRS memorandum exempted dilbit and synthetic crude derived from oil sands from being subject to an eight-cent-per-barrel excise tax that would otherwise go into the Oil Spill Liability Trust Fund. The July 2011 IRS memorandum stated: "tar sands imported into the United States are not subject to the excise tax on petroleum imposed by § 4611 of the Internal Revenue Code" (IRS, 2011). Notably, this fund can be drawn upon to cover spills of oil sands products. "Tar Sands" in this context refers to two materials:

1. *Dilbit*: described in the memo as "bitumen extracted from tar sands and blended with a diluent or other liquid that enables the bitumen to be transported through a pipeline"
2. *Synthetic Crude*: described as "an upgraded oil stream which is a synthetic crude oil derived from tar sands."

The exemption was made at the request of an anonymous company that was referenced only as "Company" in the IRS memorandum.[32]

8.8.2 Disclosing Oil Type and Characteristics

The majority of oil spill contingency plans do not require responsible parties to disclose specific information on the type of oil that could be handled in a spill. As discussed above, this became problematic during the Enbridge pipeline spill in the Kalamazoo River when responders were not informed that they were handling oil sands products until nearly one week after the spill. Further complicating the matter, when regulations do require disclosure of oil types, oil sands or oil sands-derived products are not listed among the types of oils to disclose. For example, the Washington Department of Ecology adopted rules for transferring oil over water

[32] Available online at: http://www.irs.gov/pub/irs-wd/1120019.pdf

that require the delivering facility to submit an Advance Notice of Oil Transfer (ANT) 24 hours prior to transfer. In addition to other reporting requirements, the ANT must provide information on the oil product type and quantity (Advance Notice of Transfer, 2006). However the data available for reporting is based on the Puget Sound/British Columbia (PS/BC) Oil Spill Task Force data dictionary, which does not currently include oil sands products.

Regulators in Washington State are working to close these reporting gaps. As mentioned, Washington State passed a provision to the state's Oil Spill Contingency Plan in 2012 requiring responsible parties to provide the names and physical characteristics of all oils handled by vessels and facilities (Spill Contingency Plan, 2012). Given the unique characteristics of bitumen and dilbit, Washington can be seen as an early actor. Contingency plans, at the national, regional, and state level could build similar provisions into their contingency planning requirements.

8.8.3 Planning for Response to Group V Oils

Linked to the matter of contingency planning and oil type disclosure, there is a concern that in certain scenarios oils sands products could have the characteristics of group V—or non-floating—oils. Oil sands-derived products are normally classified as group IV oils based on physical characteristics once blended with a diluent or a synthetic crude. The contingency planning requirements for group V oils outlined in section 8.3.4 therefore do not apply to oil sands-derived products. However, if diluents were to flash off after a dilbit spill or if unblended bitumen were to be transported via railcar as has been suggested, the material at the spill site could potentially be a non-floating oil based on API levels reported for unblended bitumen. In failing to suggest that bitumen-products could potentially meet the characteristics of group V oils, contingency plans are underestimating the risks and response needs in the case of a spill of oil sands products.

8.8.4 Assessing Risks of Transportation Oil Sands Products

As discussed above, a recent bill will require an assessment of the waterway transportation routes through the Salish Sea as they concern the Canadian oil sands products. This bill also requires an assessment to discern the different properties between Canadian oil sands products and other types of oil. There are not similar efforts underway to assess the risks of transporting Canadian oil sands products in East Coast and Gulf of Mexico waterways, across major river crossings, and near the Great Lakes via rail and pipeline.

8.8.5 Inconsistencies in Contingency Planning: PHMSA

Section 8.3.3 outlines the efforts that DOT and PHMSA have taken to better plan for the transport of oil sands products in light of the Michigan Enbridge pipeline spill. One of the requirements for PHMSA pipeline contingency plans is to ensure consistency with regional and national plans. However, a reported lack of coordination between RRTs and PHMSA raises the concern that the PHMSA plans are not integrated into regional and area plans and vice versa. The fact that RRTs might not have access to PHMSA plans and cannot integrate them accordingly into their plans, could result in inconsistencies between plans and a compromised response effort in the case of a spill. RRT 10 has reported a plan to draft a memorandum of understanding with PHMSA to gain access to pipeline contingency plans, which would potentially solve this problem and set an example for other RRTs as well as national planners (Chris Field personal communication, 2013).

8.8.6 Increased Transport of Oil by Rail

The increase in transport of oil sands products and other oils by rail has raised concern that regulations of rail transport are inadequate. While the Department of Transportation regulations cover the basic contingency planning requirements, the ability of the Federal Railroad

Administration to oversee this dramatic increase in transport is unclear. The Federal Railroad Administration, unlike PHMSA's Office of Pipeline Safety, has no known program to address potential spills of crude oil let alone heavy oils or oil sands products.

Key Sources: Important Policies and Regulations

EPA, Office of Emergency and Remedial Response. (1999). *Understanding oil spills and oil spill response.*

PHMSA. (2012a). Oil Spill Response Plans: A History Lesson. *PHMSA Presentation.* Alan Mayberry. July 12, 2012.

Parfomak, Paul (2013). Keeping America's Pipelines Safe and Secure: Key Issues for Congress. *Congressional Research Service,* Report R41536.

Ramseur, J. L. (2012). Oil Spills in U.S. Coastal Waters: Background and Governance. *Congressional Research Service*, Report RL33705.

9 GAPS IN REGULATIONS AND TECHNICAL INFORMATION

This section summarizes the gaps in information, research, and policy that we have uncovered throughout our research related to oil sands transport and oil spills in general. There are still many questions to be answered associated with the development and transportation of oil sands products. Listed below are the main areas of concern that we have identified, as well as our recommendations for the most efficient ways to address the gaps:

9.1 Policy

Currently, a limited number of policies exist that explicitly address the transportation of oil sands products in the U.S. Below are a number of areas where we find this lack of preparation concerning, categorized by planning, transportation, and response requirements:

9.1.1 Planning

Pipeline spill plans are not consistently integrated with the regional and area contingency planning process. Currently, EPA is in charge of regulating area plans and PHMSA is the ultimate authority on pipeline spill plans. Although PHMSA requires that contingency plans maintain consistency with area and regional plans, PHMSA's role in spill planning varies from state to state, making it difficult to have a consistent relationship with EPA. As a result, in at least some regions, there are no agreements in place for PHMSA to provide EPA access to pipeline spill plans to ensure consistency.

Recommendation: pipeline spill response plans should be made available to Regional Response Teams (RRTs) and incorporated into the regional and area contingency plans.

Companies transporting oil sands products are not subject to the eight-cent-per-barrel excise tax that supports the Oil Spill Liability Trust Fund. However, a spill of oil sands products would still be covered by the fund, bringing into question the long-term viability of the fund if an oil sands product spill occurred.

Recommendation: the tax exemption for oil sands products should be removed. An oil sands product spill would still require significant recovery efforts comparable to if not exceeding a spill of conventional crude that is subject to the tax. The scale of the Kalamazoo spill response and ongoing cleanup efforts support this.

Current preparedness and training requirements do not appear adequate for minimizing the amounts of oil from spilling during a pipeline leak. As demonstrated by the majority of cases discussed, human error caused more oil than necessary to enter into the environment than would have occurred if spill response protocols had been properly followed. This is especially apparent in pipeline operators' inability to differentiate between a false and real alarm.

Recommendation: Enbridge implemented a number of mandated training exercises for its personnel after the Kalamazoo spill that could be required or encouraged at the national level. First, Enbridge increased the number of emergency response simulator sessions that operators were required to attend from one per year to two per year. Two additional training sessions were mandated that looked into human factors that contribute to a response failure and hydraulics. Additional training was also provided on column separation. More recommendations can be found in the NTSB (2010) report under section 1.14.3, Enbridge Actions.

Regulations do not require risk assessments related to water terminals until construction is taking place. Risk assessments are not required for terminals that are expected to handle oil sands products until upgrades to facilities are underway.

Recommendation: risk assessments should be required before permits are granted to ensure that new risks are factored into the decision to expand a terminal's capacity.

9.1.2 Transportation

Rail regulations specific to the transport of crude oil are undeveloped. Although the FRA has plans in place to handle spills of hazardous materials, these do not directly address oil spills in general or oil sands products specifically. The ability of the FRA to oversee and regulate the increase in oil sands products being transported by rail is unclear.

Recommendation: more research needs to be done to understand the regulations that rail companies must adhere to as they transport oil sands products.

Policies do not require pipeline operators to provide information to regulatory authorities on the type of product being transported in a pipeline. The lag time associated with regulatory and response agencies getting accurate data from the pipeline operator may affect their ability to plan for and respond to a spill.

Recommendation: require operators to track the type of oil present in each batch as the material is transported through the pipeline. Regulatory and response agencies will have access to this information at the time a spill is reported. This will allow pipeline operators, regulatory, and response agencies to know what product is spilled when the response is initiated.

9.1.3 Response

The responsible party does not have to demonstrate ability to have appropriate oil spill equipment on site within the mandated time. If there is a spill of oil sands products, the responsible party is in compliance with oil spill response requirements if they have implemented a response effort, but it is not necessary that they have the appropriate equipment on site to deal with oils that my submerge or sink over time. Initial response time with product appropriate equipment could be especially critical with a spill of oil sands products, given the uncertainty of weathering and the potential for the oil to submerge over time.

Recommendation: contingency planning requirements could be expanded to require companies to demonstrate their ability to get the appropriate equipment to a potential spill site based on the type of product they are transferring.

Oil spill response regulations require oil cooperatives to prove that they can deploy the equipment in their inventory, but not demonstrate the equipment's effectiveness. As we saw in the Wabamun Lake case, this significantly impacted the response effort's ability to contain the oil.

Recommendation: while assessing inventories, regulators should require a demonstration to illustrate the ability to deploy and effectively use the equipment.

MSDSs are not required to disclose the specific type of oil being transported. As we saw in the Kalamazoo spill, the MSDS noted that "crude oil" had been spilled and did not specify that dilbit was the actual product in the pipeline. This affected the clean up crew's response and resulted in public and environmental health concerns.

Recommendation: adopt the Washington regulation discussed in Section 8.4.2.1 as national requirment.

Response plans do not address the potential for oil sands products to act as non-floating oils in the case of spill. There is a concern that in certain scenarios oil sands products could have the characteristics of group V—or non-floating—oils. However, the contingency planning requirements for group V oils outlined in section 8.3.4 do not apply to oil sands products.

Recommendation: regional and area response plans should reflect the fact that in the case of a spill of oil sands products, there is the potential for the material to sink or be suspended in the water column unless there is sufficient laboratory or field data to demonstrate otherwise.

Our regional and national capacity to respond to a oil sands products spill is unknown as most equipment lists are missing vital processing information that would allow us to understand how a piece of equipment can be used in a spill.

Recommendation: require oil spill response organizations to list their inventory, as well as necessary performance information on a national list, to understand how the equipment can be used in a spill.

9.2 Research

In general, there is a lack of published independent oil sands related research . There are a number of studies under way, but the results have not been published. Research is needed in three categories: the physical properties and behavior of oil sands products, the increased risk associated with transporting oil sands products, and the effectiveness of current oil spill equipment on an oil sands products spill. For each gap, we recommend conducting independent research that will look into the missing information. Specifically:

9.2.1 Physical Properties & Behavior of Dilbit

The properties, behavior, and potential public health concerns of the diluent have not been adequately addressed at this point. The health risks for responders may differ depending on the exact diluent being used. Therefore, there is a gap in research regarding the properties of the diluent and also a gap in policy requiring the diluent to be named on an MSDS or be made available during a spill response. Also, because the flash point of diluents can differ by type, the rate of evaporation could be difficult to predict during a spill.

There are unknowns regarding how weathering and sedimentation may lead to oil sands products being overwashed by water, suspended in the water column, or sinking to the bottom. Importantly for spill response, the timing of when the oil may potentially leave the surface is unknown.

Research regarding how oil sands products will further biodegrade in the environment is not sufficient. This has implications for response efforts during an oil sands products spill because the degree to which the product has already biodegraded will affect how much biodegradation the oil sands products are subject to.

When research is conducted, a variety of bitumen products should be tested. Bitumen properties vary both by deposit as well as over time within the same deposit. Therefore, there is a need to test a number of different samples to assess the true range of properties.

9.2.2 Transportation Risks

The risks associated with increased waterborn transport oil sands products are unknown. There is at least one study planned assessing the risk associated with an increase of traffic through the Salish Sea, however, there are no studies as of March 2013 that examine potential increases in tanker or rail traffic in or near East Coast and Gulf of Mexico waterways, major river crossings, or the Great Lakes. There is a risk assessment planned for transport through the Aleutian Islands, but it does not specifically address the transport of oil sands products.

Recommendation: conduct risk assessments examining the increased traffic in the Aleutian Islands, East Coast and Gulf of Mexico waterways, major river crossings, the Great Lakes, and other waterways that could see increased transportation of oil sands products. Each risk assessment should explicitly look at the potential increases in oil sands products transport.

9.2.3 Response Effectiveness

There is a lack of real world testing and experience with recovery equipment on oil sands products. This hinders our ability to determine whether or not a region will be prepared to handle an oil sands products spill and which equipment will be effective.

Recommendation: controlled experiments looking at current equipment's effectiveness on oil sands products should be conducted. A range of oils should be used to test the equipment including different product types (dilbit, synbit, synthetic crude, etc.) and different sources (Cold Lake, McKay River Heavy, etc.).

Information is lacking on the ability to recover oil when it sinks or is suspended in the water column.

<u>Recommendation</u>: continue the U.S. Coast Guard's work in researching and developing new methods of detecting, monitoring, containing, and recovering sunken or submerged oil.

9.2.4 <u>Other Gaps</u>

LDS are not predicting a significant portion of the spills. More research and development should be dedicated to improving the accuracy of LDS. Additionally, more training may be necessary for pipeline operators to help them determine the difference between a real and false alarm.

Some of the API values listed in this report are based on research completed in the 1980s. If possible, these values should be updated in order to have a more reliable understanding of where oil sands products fit on the spectrum of API values.

10 APPENDICES

10.1 Appendix 1

Oil Sands Major Players List*		
Individual/ Organization	**Description of Involvement**	**Additional Information**
Energy Companies		
BP Canada Energy Trading Company	BP uses in situ extraction at three jointly owned mines: Sunrise oil sands (50% owner, Husky Energy operator); Pike oil sands (50% owner, Devon Energy operator); Terre de Grace oil sands (75% owner and operator). These projects have not begun producing yet, but the first is expected to go online in 2014. BP also signed a long-term contract with Kinder Morgan's (KM) Trans Mountain Pipeline and has both downstream and upstream facilities.	http://www.bp.com/sectiongenericarticle.do?categoryId=9036695&contentId=7067648 http://www.transmountain.com/news-releases/trans-mountain-updates-customer-commitments-for-proposed-expansion-project
Canadian Natural Resources	Canadian Natural Resources is the operator and owner of the Kirby, Grouse, and Primrose and Wolf Lake In Situ Oil Sands Projects. It also signed a long-term contract with KM's Trans Mountain Pipeline and is a strong supporter of the Enbridge Line 9 Reversal project.	http://www.cnrl.com/operations/north-america/north-american-crude-oil-and-ngls/thermal-in situ-oilsands/ http://www.transmountain.com/news-releases/trans-mountain-updates-customer-commitments-for-proposed-expansion-project
Cenovus Energy Inc.	Cenovus owns and operates two in situ extraction sites in Foster Creek and Christina Lake in conjunction with ConocoPhillips (50% share). It jointly owns two refineries in the U.S., with a 50% interest in ConocoPhillip's Wood River and Borger refineries. Cenovus signed a long-term contract with KM's Trans Mountain Pipeline.	http://www.cenovus.com/operations/index.html
Chevron	Chevron jointly owns the Muskeg River Mine in Alberta which went online in 2011. Its current capacity is approximately 255,000 barrels per day (b/d).	http://www.chevron.com/deliveringenergy/oilsands/

China National Petroleum Corp. (parent company of Petro-China)	In 2007, CNPC was the first Chinese company to win mineral rights to mine bitumen. In August 2009, CNPC bought 60% of the development rights of Athabasca Oil Sands Corp.'s Mackay River and Dover projects. In 2012, this was extended so that CNPC was the owner and operator of the MacKay River oil sands project. In 2005, the company signed a Memorandum of Understanding (MOU) with Enbridge supporting a western pipeline that would help carry crude to China via tankers (Northern Gateway).	http://www.cnpc.com.cn/en/cnpcworldwide/canada/ http://www.scmp.com/article/598721/cnpc-wins-right-work-oil-sands-alberta http://www.theglobeandmail.com/news/politics/chinas-oil-sands-deal-will-have-lasting-impact/article1357620/
Chinese National Offshore Oil Company (CNOOC)	CNOOC is a Chinese state owned multinational oil company that operates in Canada and the U.S. In July of 2012 CNOOC announced plans to buy Canadian oil firm Nexen for $15 billion. It was recently approved by the U.S. Committee of Foreign Investment (Nexen owns assets in the Gulf of Mexico) and the deal officially closed on 2/25/2013. It also owns a 17% stake in MEG Energy, an Alberta oil sands project developer. In 2011, CNOOC acquired equity interest in OPTI, a Canadian oil sands producer.	http://www.cnoocltd.com/encnoocltd/AboutUs/zygzq/Overseas/132.shtml http://www.cnbc.com/id/100454779/CNOOCNexen_Deal_Wins_US_Approval_Its_Last_Hurdle http://business.financialpost.com/2013/02/25/cnooc-completes-contentious-15-1-billion-acquisition-of-nexen/?__lsa=5f87-ac2a
ConocoPhillips	ConocoPhillips holds approximately 1 million net acres of land in northeastern Alberta. Its main operations occur at the Surmont oil sands project, southeast of Fort McMurray where the company employs in situ extraction techniques. The Surmont project is a 50/50 joint venture project with Total E&P Canada Ltd and has the capacity to produce 110,000 b/d. ConocoPhillips is also in a 50/50 partnership with Cenovus Energy. This partnership operates the Foster Creek and Christina Lake projects as well as the proposed Narrows Lake project. The partnership has a total capacity of 428,000 b/d. Most of its oil sands product is piped through the Keystone pipeline to U.S. refineries, specifically the Phillips 66 Wood River Refinery.	http://www.conocophillips.com/EN/oilsands/assets/Pages/index.aspx http://www.conocophillips.com/EN/oilsands/overview/Pages/transportation.aspx
Exxon Mobil/Imperial Oil Ltd./Esso	ExxonMobil Canada and Imperial Oil jointly own the Kearl oil sands project, which is one of Canada's largest open-pit mining operations north of Fort McMurray. Its current capacity is 345,000 b/d. The project is assessing its refining options and will most likely integrate with North American refineries owned by Imperial Oil and ExxonMobil. Enbridge's Line 9A Reversal project was pursued due to a request from Imperial Oil.	http://www.imperialoil.ca/Canada-English/operations_sands_kearl_overview.aspx http://www.enbridge.com/ECRAI/Line9ReversalProject.aspx

Flint Hills Resources/Koch Industries	Flint Hills Resources, which is operated by Koch Industries, is an oil refinery company in the U.S. Its St. Paul, Minnesota refinery is rumored to be refining over 320,000 b/d of oil sands products.	http://www.fhr.com/refining/canada.aspx http://www.sustainablebusiness.com/index.cfm/go/news.display/id/22112
Husky	Husky energy has been exploring oil sands since 1973 and is one of the top holders in oil sands reserves in Alberta. Its Sunrise reservoir alone is estimated to hold 3.7 billion barrels of bitumen as of 12/2011. It jointly owns a refinery near Toledo, Ohio.	
Marathon	Marathon Oil has a 20% share of the Muskeg River and Jackpine mine as well as the Scotford Upgrader. It also has the rights to over 216,000 acres of potentially mineable land in the Alberta region. Marathon owns interests in in situ oil sands leases near Fort McMurray. It is also one of the largest oil refinery companies in the United States.	http://www.marathonoil.com/Global_Operations/Canada/Operations/
Nexen Marketing Inc.	Nexen has an interest in over 300,000 acres in the Athabasca region. It's the 65% owner and operator of the Long Lake reserve, where they use in situ extraction to produce synthetic crude on site. Nexen also has begun developing the Kinosis area and the extracted bitumen will be upgraded at Long Lake. It has a 7% interest in Syncrude's oil sands mining and upgrading facilities and has a 15% non-operating interest in Hangingstone, an extraction project developed by Japan Canada Oil Sands. Nexen signed a long-term contract with KM's Trans Mountain Pipeline. As mentioned before, Nexen was recently purchased by CNOOC.	http://www.nexeninc.com/en/Operations/OilSands/OurOilSandsBusinesses.aspx
PBF Energy	PBF Energy owns nearly 1/3 of U.S. East Coast refining capacity and is expected to refine oil sands products.	http://www.ubs.wallst.com/ubs/mkt_story.asp?docKey=1329-L1E8MQ61A-1&first=0
Shell Oil	Through Shell's Athabasca Project, where it is the majority owner (60%, with Chevron at 20% and Marathon at 20%), Shell both mines and upgrades bitumen and converts it to synthetic crude. It is the joint owner of two mines (the Muskeg River Mine and the Jackpine Mine) and the joint owner of one upgrader (Scotford Upgrader) in Alberta. It currently has the capacity to produce 255,000 b/d of synthetic crude.	http://www.shell.com/global/aboutshell/our-strategy/major-projects-2/athabasca.html

SINOPEC	SINOPEC is a Chinese state owned company that bought a 9% stake in Alberta's Syncrude Canada Ltd. in 2010. It first became involved in Canadian oil sands in 2005 when it formed a joint venture with Canada-based Synenco Energy to form the Northern Lights oil sands project. SINOPEC continues to look for ways to grow its business in Canada.	http://business.financialpost.com/2012/12/12/sinopec-still-keen-to-invest-in-canada-as-long-as-theres-money-to-be-made/?__lsa=5f87-ac2a http://english.caixin.com/2010-04-13/100134471.html
Statoil Canada Ltd.	Statoil uses in situ to extract bitumen from its Leismer Demonstration Project. It also signed a long-term contract with KM's Trans Mountain Pipeline.	http://www.statoil.com/en/environmentsociety/relevanttopics/oilsandincanada/pages/default.aspx
Suncor Energy	Suncor was the original oil sands producer in the Athabasca region. It uses mining and in situ operations to extract bitumen and has two upgrading facilities on site in Fort McMurray and a third upgrader in Edmonton. Suncor has signed a long-term contract with KM's Trans Mountain Pipeline.	http://www.suncor.com/en/about/242.aspx
Syncrude (Majority owner: Canadian Oil Sands, Ltd.)	Syncrude is one of the original oil sands producers and began extracting bitumen in 1973. Currently, its Syncrude Project leases three mines near Fort McKay and it extracts bitumen deposits using in situ and open pit mining extraction techniques. It sends its product by pipeline to three Edmonton area refinieries and to refineries in Canada and the U.S. Through its majority owner, Canadian Oil Sands, Ltd., Syncrude signed a long-term contract with KM's Trans Mountain Pipeline.	http://www.syncrude.ca/users/folder.asp?FolderID=5753
Tesoro Refining & Marketing Company	Tesoro is an oil refiner with seven refineries in the Western United States, including one in Anacortes, WA. Tesoro signed a long-term contract with KM's Trans Mountain Pipeline.	http://www.tsocorp.com/TSOCorp/ProductsandServices/Locations/RefineryLocations/index.htm
Total E&P Canada Ltd.	Total E&P Canada extracts bitumen at its Surmont, Joslyn, Fort Hills, and Northern Lights reserves and upgrades the bitumen at its own Voyageur Upgrader. E&P also has assets unexplored at this time, known as Asphalt Creek and Griffon. It has signed a long-term contract with KM's Trans Mountain Pipeline	http://www.total-ep-canada.com/upstream/upstream.asp
Valero	Valero is the world's largest independent petroleum refiner. It has committed to taking on at least 100,000 b/d from the Keystone XL.	http://www.nationaljournal.com/energy/u-s-oil-giants-poised-to-gain-on-keystone-pipeline-20110804
Pipeline Operators		

Enbridge	Enbridge's oil sands pipeline infrastructure connects six producing oil sands projects. It also operates contract storage facilities for oil sands products. Enbridge is currently sending oil sands products into the U.S. through its Line 6B pipeline and has proposed to increase its capacity through the construction of the Northern Gateway Project and the Line 9 Reversal.	http://www.enbridge.com/MediaCentre/News/regionaloilsandsAAG.aspx http://www.reuters.com/article/2012/05/17/enbridge-idUSL4E8GH0H820120517
Kinder Morgan	Kinder Morgan is a Texas-based pipeline operator that is poised to expand its Trans Mountain pipeline from Alberta to Vancouver in order to increase its capacity to transport oil sands products.	http://www.kindermorgan.com/investor/presentations/013013_KMCanada.pdf http://www.kindermorgan.com/business/canada/tmx_expansion.cfm
TransCanada	TransCanada is the Keystone pipeline operator and is bidding to expand the Keystone pipeline from Alberta, Canada to Houston, Texas. It currently delivers to refineries in Wood River and Patoka, Illinois and Cushing, Oklahoma. Its current capacity is 590,000 b/d.	http://www.transcanada.com/100.html
Rail Companies		
Canadian National Rail	Canadian National Rail (CN) has a rail yard in Fort McMurray, giving them direct access to northern Alberta oil sands products. Their network has direct access to Peace River and Cold Lake deposits.	http://www.cn.ca/en/shipping-north-america-alberta-oil-sands.htm
Canadian Pacific Rail	Canadian Pacific Rail (CPR) directly serves the Edmonton/Fort Saskatchewan area. They have a direct route to the pipeline injection/terminating points at Hardisty and Edmonton. CPR also brings diluent to the pipeline terminal facilities at these locations.	http://www.cpr.ca/en/ship-with-cp/where-you-can-ship/oil-sands/Pages/default.aspx
Burlington Northern Santa Fe (BNSF)	Owned by Warren Buffet, BNSF is taking advantage of the delay in pipeline construction by becoming a more politically stable way to transport oil sands to refineries and beyond. BNSF is currently allowing CNR and CPR to use their tracks to transport oil sands products into the U.S.	http://www.bloomberg.com/news/2012-01-23/buffett-s-burlington-northern-among-winners-in-obama-rejection-of-pipeline.html
Union Pacific	Union Pacific Railroad operates in 23 states across the Western two-thirds of the U.S. Its network is currently set up to handle oil sands products and to deliver oil sands crude to refineries in Texas and Oklahoma.	http://www.uprr.com/customers/chemical/attachments/crude/crude_map.pdf
CSX Transportation	CSX has an extensive rail network in the Eastern U.S. Although it currently is not transporting oil sands products, it is in the position to do so if pipeline construction is further delayed.	http://www.csx.com
Industry Associations		

API	The American Petroleum Institute (API) is an American trade association that represents all aspects of the oil and natural gas industry. It also provides information to the general public about oil sands products and their uses.	http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/oil-sands.aspx
CAPP	The Canadian Association of Petroleum Producers (CAPP) represents companies that explore, develop, and produce natural gas or oil throughout Canada. It provides information and resources to its member organizations and also to the general public.	http://www.capp.ca/canadaIndustry/oilSands/Energy-Economy/Pages/default.aspx
CEPA	The Canadian Energy Pipeline Association (CEPA) works with its members on the many issues associated with moving oil by pipeline. Specifically, CEPA makes information available on the corrosivity of diluted bitumen in pipelines.	http://www.cepa.com/5-more-facts-to-know-about-diluted-bitumen
COSIA	Canada's Oil Sands Innovation Alliance (COSIA) is an alliance of oil sands producers that focuses on accelerating the pace of improvement in environmental performance in Canada's oil sands through collaborative action and innovation.	http://www.cosia.ca
OSDG	The Oil Sands Developers Group (OSDG) is an industry-funded nonprofit that represents oil sands operators and developers. Its members work in cooperation with other stakeholders to address issues related to oil sands development and to communicate information on oil sands activity.	http://www.oilsandsdevelopers.ca
U.S. Regulatory Agencies		
U.S. Coast Guard	The U.S. Coast Guard (USCG) is in charge of facilitating all spill response efforts in coastal waters and the Great Lakes. With the proposed increase in oil sands transport, the USCG is concerned with increases in oil tanker traffic in British Columbia and Washington. Washington State has five major petroleum refineries which could receive oil sands products. As a result, the USCG will study the risk of transporting oil through the Salish Sea waters. This is mostly in response to the proposed Kinder Morgan Trans Mountain pipeline expansion.	http://www.cbc.ca/news/canada/story/2013/01/06/bc-oil-tanker-traffic-review.html
Alaska Department of Environmental Conservation	If the Northern Gateway pipeline were approved, Alaska would see an increase in oil tankers coming through its coastal waters. It also has the potential to see oil sands products traveling to Valdez by rail. The Alaska Department of Environmental Conservation is the agency in Alaska that works to prevent, prepare, and respond to oil spills.	http://www.dec.state.ak.us/spar/index.htm

Federal Railroad Administration	Under the DOT, the Federal Railroad Administration (FRA) is in charge of regulating all railcars traveling throughout the U.S. Since this is likely method of transport for oil sands products, FRA is a pertinent regulatory agency in the oil sands discussion.	http://www.fra.dot.gov/
Maine Department of Environmental Protection	There is a strong possibility that oil sands products will/is being transported to Maine's oil refineries. Maine's Department of Environmental Protection is in charge of enforcing the state's environmental laws. Therefore, it has a stake in understanding how the transport of oil sands products could potentially affect Maine's natural resources.	http://www.maine.gov/dep/spills/index.html
U.S. EPA	The U.S. Environmental Protection Agency (EPA) is in charge of responding to all inland spills and is also the regulatory agency commenting on TransCanada's Keystone XL Environmental Impact Statement. EPA was the key regulatory agency involved in the Marshall, Michigan spill in 2010.	http://yosemite.epa.gov/oeca/webeis.nsf/(PDFView)/20100126/$file/20100126.PDF http://www.epa.gov/region05/cleanup/kalproject/index.htm
U.S. PHMSA - Office of Pipeline Safety	The U.S. Pipeline and Hazardous Materials Safety Administration, a subagency within the U.S. Department of Transportation (DOT), is in charge of regulating pipelines in the U.S.	http://phmsa.dot.gov/about
U.S. State Department	The U.S. State Department approves pipelines that cross international borders. This means that the Keystone XL will not be constructed without the State Department's approval.	http://www.keystonepipeline-xl.state.gov
Washington's Department of Ecology	The Washington State Department of Ecology (DOE) is mostly concerned with the potential increase in tanker traffic in Washington waters due to increased production of oil sands products and the potential for these products to be shipped out of British Columbia. The DOE estimates that about 11% of the gasoline that is refined and consumed in Washington is a derivative of oil sands.	http://www.ecy.wa.gov/programs/spills/about_us/SPPR%202012-2013%20Program%20Plan%20(final).pdf http://www.ecy.wa.gov/climatechange/docs/fuelstandards_112009_presentation.pdf http://dep.ky.gov/Pages/Spills.aspx
Canadian Governmental Bodies		
Alberta Energy	Alberta Energy oversees Alberta's non-renewable resources. Specifically, it operates the Oil Sands Division, which provides administrative and regulatory services for the Oil Sands Royalty Regulations, Oil Sands Tenure Regulation, and Crown and individual agreements to ensure that Alberta receives appropriate royalties and rentals from oil sands development.	http://www.energy.alberta.ca/ourbusiness/oilsands.asp

Canada's Federal Government	Oil sands development adds employment opportunities and contributes to Canada's economic growth. As a result, conservative Prime Minister Stephen Harper has made developing oil sands a national priority and has publically expressed his support for the Northern Gateway pipeline and the Trans Mountain (TM) expansion.	http://www.vancouversun.com/business/Northern+Gateway+pipeline+vital+Canada+interests+Stephen/7053312/story.html
Canada's National Energy Board	The National Energy Board (NEB) regulates pipelines, energy development, and trade at the interprovincial and international level. Therefore, NEB's approval is required for any oil pipeline that crosses into the U.S. (Keystone XL) or crosses provincial boundaries (Northern Gateway, TM Expansion, Line 9).	http://www.neb-one.gc.ca/clf-nsi/rthnb/whwrndrgvrnnc/rrspnsblt-eng.html
Environment Canada	Environment Canada's mandate is to preserve the quality of the natural environment and coordinate environmental policies and programs at the federal level. It is currently the main resource for scientific research performed on the behavior of oil sands.	http://www.ec.gc.ca/inre-nwri/default.asp?lang=En&n=D974A85E-1
Government of Alberta	Given that the oil sands reserves are for the most part contained in Alberta, the Alberta Government is integral in the management and development of oil sands.	http://www.oilsands.alberta.ca
Government of British Columbia	The Northern Gateway pipeline and Kinder Morgan's TM Expansion affect British Columbia residents. There is a large constituency in the province that oppose both the pipelines. However, the Premier Christy Clark sees the export of oil sands products from B.C. ports as a potential economic boost and a source of significant employment opportunities.	http://www.vancouversun.com/business/Clark+likens+potential+Alberta+oilsands/7698187/story.html
Environmental Groups		
Forest Ethics	Forest Ethics is working to reduce the demand for oil sands products in the U.S. Specifically, the organization is focusing its work on the communities surrounding U.S. oil sands refineries.	http://forestethics.org/tar-sands
Living Ocean Society	The Living Ocean Society is an environmental group in Canada that is concerned with marine conservation issues. They have been vocal about their concerns regarding the state of response technologies that could potentially clean up a bitumen-related spill.	http://ecowatch.org/2012/condemns-announcement/
NRDC	The NRDC is leading the charge against the import of oil sands products into the United States. Particularly, they have produced a number of anti-Keystone XL reports.	http://www.nrdc.org/energy/tarsandssafetyrisks.asp

NWF	The National Wildlife Federation (NWF) is mostly concerned with the methods used to extract bitumen and the potential for adverse wildlife impacts if a spill occurs.	http://www.nwf.org/What-We-Do/Energy-and-Climate/Drilling-and-Mining/Tar-Sands.aspx
Sierra Club	The Sierra Club has helped organize a number of anti-oil sands demonstrations in Canada and is specifically working with First Nations to bring their concerns to the table.	http://www.sierraclub.org/dirtyfuels/tar-sands/default.aspx
The Pembina Institute	Oil sands, specifically the greenhouse gases associated with development, is one of the Pembina Institute's focus areas. It has produced a number of reports regarding the responsible development of oil sands in Alberta.	http://www.pembina.org/oil-sands
Other Environmental Groups addressing oil sands development include, but are not limited to:	Greenpeace Canada, Sierra Club Canada, David Suzuki Foundation, Alberta Wilderness Association, Environmental Defense Canada, Dogwood Institute, West Coast Environmental Law, Indigenous Environmental Network, Oil Change International, 350.org, Energy Action Coalition, Climate Action Network Canada, Equiterre, Respecting Aboriginal Values and Environmental Needs (RAVEN), SumOfUs, LeadNow.ca, Ecojustice, DeSmogBlog.com	
First Nations & Native American Tribes		
Chipewyan	The Chipewyan's lands sit in the heart of the Alberta oil sands. The Chipewyan launched a constitutional challenge based on Treaty 8 against Shell Canada, which is looking to expand their Jackpine oil sands mine into the Chipewyan's traditional territories. The Chipewyan are arguing that Shell failed to adequately consult them, violating treaty rights. The Chipewyan also state that they are experiencing adverse health effects as a result of living downstream from the oil sands.	http://indiancountrytodaymedianetwork.com/article/athabasca-chipewyan-launch-treaty-8-challenge-to-shell-canada-over-oil-sands-137632 http://www.tarsandswatch.org/depth-fort-chipewyan
Cree	The Beaver Lake Cree Nation hunts and fishes in and around the Athabasca River. The Cree Nation argues that oil sands development is destroying the habitat that the animals and fish they hunt depend on. They are currently in a legal battle with the Alberta Government with a trial date set for early 2015.	http://www.raventrust.com/beaverlakecree.html
Dene	The Dene Nation is downstream from Alberta's oil sands and depends on the Athabasca River as part of its livelihood. They oppose any new pipelines and expansion of oil sands development because of the potential negative effects it may have on its traditional way of life.	http://www.nnsl.com/northern-news-services/stories/papers/oct21_11pip-nwt.html

Haida	The Haida Nation is opposed to the Northern Gateway pipeline and was part of the NEB hearings in Edmonton. The pipeline route would go through Haida land.	http://www.qciobserver.com/Article.aspx?Id=5631
Haisla	Enbridge's Northern Gateway pipeline would cross Haisla's land. The Haisla Nation is opposed to the pipeline, resulting in legal questions about whether Enbridge will be able to build the pipeline through Haisla's land.	http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/oil-sands-pipeline-hits-its-highest-hurdle/article1357847/
Lakota	The Lakota Nation actively opposes the transport of oil sands products through its lands. For example, in 2012 the Lakota created a human blockade to stop oil sands pipeline trucks from entering their territory.	http://colorlines.com/archives/2012/03/lakota_indians_block_keystone_xl_pipeline_trucks_from_entering_reservation_in_six-hour_standoff.html
Makah	The Makah Nation is active in oil spill preparedness and is concerned with the potential tanker traffic increase in the Strait of Juan de Fuca. The Makah Nation also provided George Washington University (GWU) data for GWU's vessel traffic risk assessment.	http://www.uscg.mil/proceedings/spring2010/articles/51_Bowechop_MakahTribalCouncilOfficeOfficeOfMarineAffairs.pdf http://www.eisgatewaypacificwa.gov/sites/default/files/content/files/Makah_Tribal_Council.pdf
Métis	The Métis community sits in the heart of the next wave of oil sands development in Northern Alberta. They recently signed a deal with Cenovus Energy that will give 300 community members benefits estimated to be worth $40 to $60 million over the next 40 years.	http://www.aawgecdev.ca/deal-between-metis-community-oils-sands-firm-a-turning-poin.html
Nisga'a	Though the pipeline will not run through Nisga'a land, the Nisga'a Nation opposes the pipeline due to concerns over increased tanker traffic.	http://www.cbc.ca/news/canada/british-columbia/story/2012/02/17/bc-cullen-enbridge-hearing.html
Sioux	The Yankton Sioux Reservation is located in South Dakota. The Sioux Nation hosted the historical event, "Gathering to Protect the Sacred From the Tar Sands and Keystone XL," where those attending signed an international treaty to block the Keystone XL.	http://www.ienearth.org/tribes-and-allies-gather-on-yankton-sioux-reservation-to-oppose-the-tar-sands-and-keystone-xl-pipeline/
Squamish	The Squamish protested the Kinder Morgan expansion in 2012 by canoeing from Ambleside to Cates Park to showcase the sanctity of the ocean.	http://dirtyoilsands.org/news/article/squamish_and_tsleil_waututh_paddle_to_protest_kinder_morgan_pipeline
Wet'suwet'en	The Wet'suwet'en is opposed to oil sands products being transported over their land. Recently, the Wet'suwet'en have reaffirmed their declaration of "No Enbridge Northern Gateway Pipeline on Wet'suwet'en Territory."	http://www.wetsuweten.com/media-centre/news/information-clarification-around-the-proposed-northern-gateway-pipeline

Coastal First Nations	Coastal First Nations is an alliance of First Nations on British Columbia's North and Central Coast and Haida Gwaii. The Coastal First Nations include Wuikinuxv Nation, Heiltsuk, Kitasoo/Xaixais, Nuxalk Nation, Gitga'at, Metlakatla, Old Massett, Skidegate, and Council of the Haida Nation. In March 2010, the Coastal First Nations signed the Coastal First Nation Declaration, which bans oil sands pipelines and tankers on the North Coast.	http://wcel.org/sites/default/files/First%20Nations%20that%20have%20declared%20opposition%20to%20proposed%20Enbridge%20tanker%20&%20pipeline%20project.pdf http://www.coastalfirstnations.ca/sites/default/files/cfn-files-public/oil%20tanker%20impacts_1.pdf
Other Stakeholders		
Landowners in South Dakota, Montana, Kansas, Oklahoma, Nebraska, and Texas	Landowners along the proposed Keystone XL route have mixed opinions about the pipeline being routed through their land.	http://billingsgazette.com/news/state-and-regional/montana/landowners-have-mixed-views-of-keystone-xl/article_1031db2c-fd18-5c8d-8250-e1c473ac5ee9.html
Regional Aquatics Monitoring Program (RAMP)	RAMP is currently engaged in the creation of a new monitoring system for the Athabasca oil sands.	http://athabasca.riverawarenesskit.org/ramp/news.aspx?nid=25
The Prince William Sound Regional Citizens Advisory Council (RCAC)	RCAC is an independent non-profit corporation that promotes the environmentally safe operations of the Alyeska Pipeline marine terminal in Valdez. It has an OPA mandate to build trust and provide citizen oversight of environmental compliance by oil terminals and tankers. With the increase in oil sands transportation, the RCAC will have an interested in the increased tanker activity in their region.	http://www.pwsrcac.org/about/index.html
**Note: This is not an exhaustive list, but it hopefully reveals the range of stakeholders participating in the oil sands debate*		

10.2 Appendix 2

Known Characteristics and Data Ranges for Alberta Oil Sands Products

Product:	API Gravity	Density (g/cm^3)	Viscosity (cP;Temp)	Sulfur Content (weight %)	TAN	Pour Point	Benzene (ppm)
Athabasca Bitumen	7.7-9	1.011-1.0133 (15.56C)	19000->300000(15C)	4.41-5.44	3		
Cold Lake Bitumen	9.8-13.2	0.977-1.002(15C)	235000	4.11-6.9	0.97	(-4)-9	
Cold Lake Blend	22.6	0.9172-0.9177(15C)	150(15C)	3.6-4.72	0.8	(-45)-(-46)	1510
Cold Lake Diluent	69.3	0.704(15C)	1(15C)	0.25		< -75	11600
Enbridge Diluent Specs		0.6-0.8(15C)	max = 2(7.5C)	0.5			1.17
Bitumen	5.4		1290254.1(25C)	4.4		72.9	
Heavy Oil	16.3		100947(25C)	2.9		19.7	
Medium Oil	22.4		34(25C)	1.6		8.6	
Conventional oil	38.1		13.7(25C)	0.4		16.3	

Product:	Pour Point	Benzene (ppm)	Total VOC (ppm)	Oil/Salt Water Interfacial Tension (mN/m)	Oil/Fresh Water Interfacial Tension (mN/m)	Aqueous Solubility (mg/L)	
Athabasca Bitumen							
Cold Lake Bitumen	(-4)-9						
Cold Lake Blend	(-45)-(-46)	1510	10500	28.1 at 0 °C, 16.3 at 15 °C.	28.3 at 0 °C, 21.7 at 15 °C.	28 at 25 °C (distilled water)	
Cold Lake Diluent	< -75	11600	68080	7.5 at 0 °C, 6.8 at 15 °C.	8.3 at 0 °C, 8.3 at 15 °C.	58 at 25 °C (distilled water)	
Enbridge Diluent Specs		1.17					
Bitumen	72.9						
Heavy Oil	19.7		4891.1				
Medium Oil	8.6		8209.2				

Conventional oil	16.3		15996.3				
Sources: Environment Canada and the Congressional Research Service report (Ramseur et al, 2012), (Environment Canada, 2013).							

10.3 Appendix 3

ANALYSIS OF DETECTION & MONITORING EQUIPMENT	
Technology	**Analysis**
Snare Sampler	• Used in M/T Athos 1 incident where Bachaquero Venezuelan crude oil spilled • Approximately 100 snare samplers were deployed to measure the spread of oil • Specifically used to detect oil at various depths in the water column • Produces time-series data • Many were lost due to strong currents, rough seas, and vandalism • Time and labor intensive • No calibration of the efficacy of sampling and how it might change over time (Counterspil Research, 2011; Michel, 2006)
Vessel-Submerged Oil Recovery System (V-SORS)	• Deployed V-SORS in M/T Athos 1 and DBL-152 spills • Difficulties with precise locations • Could detect both pooled and mobile oil moving along bottom • Relatively efficient • Provides spatial data on extent of submerged oil • Can be used in vessel traffic lanes • Good positioning capability with onboard GPS • Time and labor intensive • Susceptible to snagging on bottom • Requires use of white snare, which has to be special ordered (Counterspil Research, 2011; Michel, 2006)
Side-scan sonar data	• Used in DBL-152 and M/T Athos 1 • Provided good spatial coverage and visualization of large accumulations and bottom features • Effectiveness diminished as the oil spread and the water became rough • Slow turn around time (days) to validate oil location • Can be used to identify areas of potential accumulation • More successful in detecting the trenches and other bottom features that contained the pooled oil instead of the oil itself (Counterspil Research, 2011; Michel, 2006)
RoxAnn	• Used during DBL-152 with the purpose of differentiating seafloor bottoms • Limited use due to its narrow detection range in relation to the patchiness of submerged oil and the large search size • Less accurate in muddy substrates (Michel, 2006; Counterspil Research, 2011)
Remotely-operated underwater video	• Used in DBL-152 • Successfully provided estimates of frequency and size of oil accumulations • Provides a record for review by others • Could not always determine exact position • Effective with visibility exceeding 0.5 meters, but it does not generate a wide view • Small survey swath because of visibility issues (Counterspil Research, 2011)
Sorbents attached to weights	• Ineffective • Weight of the device pushed the oil away, as seen in the M/T Athos spill (Counterspil Research, 2011)

Sorbent drops and sediment cores	• Results can be used immediately • Low tech solution • Not effective for mobile oil in the water column • Very slow and labor intensive • Rough water conditions restricted vessel operations • Could not safely work in active vessel traffic lanes (Michel, 2006)
Snare Sentinels	• Effective in the DBL-152 spill, but were determined to be too time and labor-intensive for widespread use • High loss rates (Counterspil Research, 2011; Michel, 2006)
Airborne Hyperspectral fluorescent LiDar	• Used in Deepwater Horizon spill • Proved successful in detecting oil suspended in the top few meters below the water surface
RESON Sonar System	• Tested by Coast Guard. • Positively identified 87% of sunken oil targets. • Had a false alarm rate of 24% (Hansen, Fitzpatrick, Herring, & VanHaverbeke, 2009)
EIC Fluorosensor	• Tested by Coast Guard. • Can be attached to ROVS or other platforms • GIS input fluctuated and direct mapping was not possible. (Hansen *et al.*, 2009)
Side-looking Airborne Radar, UV, & IR	• Unable to penetrate water

10.4 Appendix 4

State	**Stated Capacity (Personnel & Equipment**
Illinois	• EPA Personnel located in Springfield, Collinsville, and Des Plaines
Indiana	• On Scene coordinators (OSC) in Evansville and South Bend • Six OSC in Indianapolis • Each OSC is supplied with booms and pads • One equipment trailer • One Command trailer • Three zodiac-style boats • One Airboat • Four boats that patrol Lake Michigan • Intra-red equipment
Michigan	• Personnel located in Lansing, Warren, Jackson, Kalamazoo, Grand Rapids, Bay City, Cadillac, Gwinn, Detroit, Gaylord, Newberry, Crystal Falls, and Calumet
Minnesota	• Relies on two major spill response contractors and several smaller contractors • All major contractors have headquarters in Duluth with some response equipment • Duluth Fire Department and Duluth Safety Department of the U.S. Coast Guard also have response equipment
New York	• Maintains approximately 100 Spill Response vehicles located in nine regions
Ohio	• EPA personnel are equipped with testing kits, booms, pads, and other sorbents
Ontario	• Government agencies in Ontario do not maintain equipment to perform spill recovery operations • Largest spill cleanup response organization is ECRC • ECRC will most likely be deployed during a spill in the Great Lakes
Pennsylvania	• Three vehicles dedicated to emergency response • Emergency response members have safety gear and limited containment supplies
Québec	• Specialized equipment • Flammable gas detectors • PHD Ultra mulitgas detectors.

Wisconsin	• 8 containment booms along Lake Michigan, Lake Superior, and the Mississippi River • Department of Natural Resources has zone contracts with private companies to respond to all types of hazardous material spills • 2 FLIR Units (infrared detection)

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