5.0 RISK ASSESSMENT AND SPILL MANAGEMENT

5.1 Purpose and Background

A spill of oil into the marine environment, arising from an incident involving a Project-related tanker, is a key concern for Trans Mountain, Aboriginal communities, government agencies, the public, and the maritime community. Trans Mountain recognizes that an unmitigated oil spill from a tanker could have immediate to long-term effects on the biophysical and human environment of the West Coast of BC.

Given the existing measures in place to prevent shipping and tanker accidents and tanker-related oil spills, Trans Mountain expects that a Project-related spill from a tanker will continue to be an unlikely event. Regardless, Trans Mountain is committed to continuing to work with Aboriginal communities, the public, pipeline shippers, parties in the maritime community, regulatory authorities and others to ensure that spill prevention, emergency preparedness and response measures are reviewed in a systematic and risk-based manner as part of continual improvement and as a commitment to tanker and shipping safety in this region. Such risk-based measures have been evaluated and improvements have been identified with respect to the Project-related increase in marine transportation, which will ensure that any increase in risk as a result of the Project is mitigated to the extent possible and comparable with the current level of risk of a tanker-related oil spill in this region.

Although Trans Mountain is not directly responsible for the operation of tankers and barges calling at the Westridge Marine Terminal, it is an active member in the maritime community and works with maritime agencies to promote best practices and facilitate improvements focusing on the safety, efficiency, and environmental standards of tanker traffic in the Salish Sea. Trans Mountain is a shareholder of WCMRC and works closely with WCMRC and other members to ensure that WCMRC remains capable of responding to any hydrocarbon spills from vessels transferring product or transporting it within their area of jurisdiction.

The purpose of Section 5.0 is to provide an overview of the probability and consequences of an oil spill from a tanker on the biophysical and human environments, and is organized in the following way:

Section 5.2 provides a summary of the quantitative risk assessment conducted by Det Norske Veritas (DNV) (TERMPOL 3.15, Volume 8C, TR 8C-12). The risk assessment considered regional traffic growth, navigational hazards, vessel construction, and risk controls provided under the existing safety regime. Based on an assessment of the tanker transit route the report identified potential locations for accidents. The report quantified the probability of oil spill incidents and the potential consequence of these incidents in terms of spill volume. These probabilities and consequences were combined to define credible worst case and mean case risks based on spill volume.

Section 5.3 is also a summary of the DNV quantitative risk assessment but focuses on spill prevention measures. This section provides a summary of the risk controls that are currently in place and included in the risk assessment. DNV found that existing risk controls are considered to be state of the art compared to other coastal sailing routes worldwide and in line with global best practices. However, to mitigate the effect of increased tanker traffic a number of enhancements are recommended which, if implemented, will raise the level of care and safety in the Salish Sea to well above globally accepted shipping standards. The primary recommendations include extending tug escorts for laden tankers throughout Strait of Georgia and Juan de Fuca Strait and implementing a moving exclusion zone around laden tankers.

Section 5.4 provides a summary of technical reports that describe the fate and behavior of oil spilled in the marine environment. This section includes a discussion of oil properties in general as well as the results of weathering tests conducted for Trans Mountain on diluted bitumen. Results from these tests along with spill volumes and potential locations identified in the DNV risk assessment were used to conduct stochastic modelling for selected locations. Stochastic modelling generates a probability map for oil exposure for the study area. A different map is generated for each combination of spill volume, location, and season. The stochastic modelling was implemented by executing the spill model, for the specific release, every six hours over a full calendar year, to capture the effects of tides, winds, estuarine flow and forcing from the open Pacific. The resulting probability maps do not provide information on a specific spill, but indicate the area that is at risk. An actual spill would only affect a small part of this area, but all parts are at risk. Section 5.4 concludes with a discussion of the results of testing conducted for Trans Mountain on recovery techniques for diluted bitumen.

Section 5.5 provides a summary of oil spill response capacity in the Salish Sea. Trans Mountain engaged WCMRC to review the risk assessment and fate and behavior studies and to describe enhancements to the existing planning standards that would better accommodate the tanker traffic resulting from the Project. The WCRMC study includes an equipment plan that serves as a practical example of how response capacity could be enhanced.

Section 5.6 discusses potential environmental and socio-economic effects of credible worst case and smaller oil spills described in Section 5.4

Section 5.7 provides an assessment of the spill response enhancements presented in Section 5.5. In this case the results for a single spill event at Arachne Reef in the Turn Point Special Operating Area are compared with and without spill response mitigation to assess the effectiveness of the enhanced response capacity described in Section 5.5.

Pursuant to the CEA Act, 2012 s. 19 (1) (a), the NEB's List of Issues for the Project, and the NEB's Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increase Marine Shipping Activities, Trans Mountain Project (10 September 2013), Trans Mountain is required to consider the environmental effects of potential malfunctions and accidents that might occur related to the Project. Section 4.0 provided an assessment of higher probability and lower consequence potential accidents and malfunctions, excluding the credible worst case and smaller oil spills. Section 5.0 provides an assessment of a lower probability, high consequence incidents resulting in the unplanned release of oil from several locations along the shipping route. Assessments of credible worst case and smaller spill scenarios at the Westridge Marine Terminal are provided in Volume 7, Section 8.0. Together, these sections meet the NEB and CEA Act, 2012 requirements for the consideration of accidents and malfunctions.

5.2 Probability of an Oil Spill from a Tanker in a Marine Environment

The existing Westridge Marine Terminal typically loads five tankers and two or three barges per month. With approval of the Project only the number of tankers is expected to increase with the typical number of tanker loadings increasing up to 34 Aframax tankers per month (Table 2.2.1). An increase in barge traffic as a result of the Project is not expected. As a result of the increase in tanker traffic, the probability of an oil spill will increase. The following sub-sections describe the historical information about oil spills from tankers into the marine environment and discuss the incremental risk of a spill from an oil tanker once the Project is operating.

5.2.1 Historical Casualty Data

As part of the TERMPOL process, Trans Mountain contracted DNV to complete a survey of the available historical casualty data related to marine vessel incidents worldwide and oil spills resulting from those incidents. The complete study is provided in Volume 8C (TERMPOL 3.8, TR 8C-6) and a summary of the results of the study is provided in this section.

5.2.1.1 Background

Det Norske Veritas used data on the following types of incidents related to marine transportation in the casualty data survey:

- collisions and grounding, referred to as wrecking/stranding in the survey;
- fire/explosion; and
- foundering and contact (*i.e.*, an equipment or electrical malfunction resulting in a loss of power).

Det Norske Veritas used multiple sources of data including:

- IHS Fairplay database of worldwide casualty data;
- oil spills recorded by the International Tanker Owners Pollution Federation Limited;
- incidents in Canadian waters collected and published by the Transportation Safety Board of Canada and the CCG;
- incidents on the West Coast of Canada reported in the PPA incident database; and
- incidents in US waters published by the US Department of Homeland Security.

The results of the casualty study provide estimates of incident frequencies per year, where the information is available; however, the casualty data provided does not describe other relevant factors such as weather, local navigational conditions, and other vessel traffic.

5.2.1.2 Global Trend in Maritime Shipping Safety

Det Norske Veritas notes that the global safety record in the marine industry has improved continuously over the past 40 years due to regulatory changes and improved safety procedures taken from the lessons learned from past incidents. In addition, the shift from single-hulled to double-hulled tanker design since 1990 has significantly reduced the number of oil spills from tankers.

Det Norske Veritas reviewed recent studies on the effect of double-hulled tankers compared to single-hulled tankers and concluded that a double-hulled tanker design plays an important role in reducing the number of oil spills that could result from a tanker incident such as a collision or grounding. However, if the double hull of the tanker were fully breached, one of the studies referenced by DNV concluded that the incident would result in the same spill volume from a double-hulled *vs*. a single-hulled tanker given the same cargo tank volume and the same oil type. The benefit of the double-hulled tanker design appears to be the decrease in incidents resulting in a full breach of a double-hulled tanker.

DNV illustrates the positive outcome resulting from a double hull *vs.* single hull design by comparing the groundings of the Exxon Valdez in 1989 and the HS Elektra in 2009. The single hull Exxon Valdez spilled 37,000 tonnes of oil in the Prince William Sound, Alaska, as a result of a hard grounding on Bligh Reef. In comparison, when the double-hulled HS Elektra hit an uncharted rock close to the Chilean Coast in 2009, the collision did not result in any release of cargo oil.

While improved navigational management and safety procedures have resulted in fewer collisions and groundings of marine vessels, and in particular for oil tankers, the double hull design of oil tankers has resulted in fewer releases of oil when a collision or grounding occurs.

5.2.1.3 Global Oil Tanker Incidents and Oil Spills

DNV indicates that the global safety record for oil tankers has improved in step with the global safety record for the maritime industry. Based on the available data, DNV shows that the worldwide incident frequency involving oil tankers is among the lowest of all marine vessels for the period 2002 to 2011 and that only a fraction of the incidents reported for oil tankers resulted in the release of oil. As well, DNV shows that, despite the steady increase in the volume of oil being transported globally, the number of oil spills has decreased in the period 1970 to 2012.

DNV cautions that the global incident data for oil tankers is not directly comparable to the Salish Sea region because the global data does not take into consideration local weather conditions, the navigability of the sailing route, as well as local risk controls implemented that would reduce the likelihood for an incident. However, the global incident data for oil tankers between 2002 to 2011 supports the conclusion that the global safety record for the marine industry continues to improve, in particular for oil tankers. DNV indicated that the change from a single hull to double hull design of tankers, the segregation of oil cargo tanks, improved reliability of machinery, improved navigational aids, and improved risk management are all factors contributing to the reduction of oil spill incidents worldwide.

5.2.1.4 Shipping Incidents in Canadian Waters

Det Norske Veritas collected data from the Transportation Safety Board on shipping incidents in Canadian waters, including the East (Maritimes and Newfoundland regions), Central (Laurentian and Central regions), West, and Arctic Regions. The most recent incident data from the Transportation Safety Board was for the period 2002 to 2011.

Det Norske Veritas indicated that shipping incidents reported in Canadian waters totalled 285 in 2011, which was a 5 per cent decline from 2010 and a 22 per cent reduction compared to the 2006 to 2010 average of 364 incidents. Overall there has been a downward trend in the number of shipping incidents in Canadian waters since 2002, in keeping with the international trend of improved maritime safety.

The vessel type involved in incidents in Canadian waters most frequently reported is fishing vessels. DNV noted since 2002, 45 per cent of vessels involved in shipping incidents in Canadian waters were fishing vessels. With respect to oil tankers, in 2011, DNV notes there were 11 tankers involved in incidents in Canadian waters, the lowest number of all vessel types. No records could be found of any of these incidents resulting in an oil spill.

5.2.1.5 Shipping Incidents and Oil Spills on the West Coast of Canada

Of the 285 shipping incidents in Canadian waters in 2011, DNV reported that 31 per cent of these occurred on the West Coast (89), which was the highest concentration of incidents reported compared to other regions in Canada, likely due to the size of the region and number of vessels. In keeping with global trends, all regions in Canada reported a drop in the number of incidents in 2011, compared to the 2002 to 2010 average. With respect to the West Coast, there were 89 incidents in 2011 and an average of 119 incidents from 2002 to 2010. Of particular note, DNV indicated that the majority of incidents on the West Coast involved fishing vessels, tugs, and barges, not oil tankers.

During the 2002 to 2011 period, there was one incident on the West Coast involving an oil tanker and DNV indicates that this incident did not lead to damage of the tanker's hull or a release of oil to the marine environment.

Det Norske Veritas notes that there is no traffic density data correlated to the Transportation Safety Board data, therefore it is impossible to derive incident frequencies. However, the data published by the Transportation Safety Board gives an indication of the low number of vessel incidents on the West Coast, particularly for oil tankers.

The PPA collects incident data for the types of vessels for which they license pilots, which includes the types of oil tankers calling at the Westridge Marine Terminal. From 1993 to 2012, the PPA data reports 6 incidents with tankers, with an average of 0.3 incidents per year within the region that is the PPA's jurisdiction. DNV emphasized that the type of incidents reported by the PPA varied in severity from minor incidents, such as breaking a fender, to more serious incidents, such as collision or grounding. DNV noted that the PPA's data does not report the environmental consequence of any incidentsand therefore the portion of the reported incidents that might have resulted in an oil spill is unknown.

Det Norske Veritas noted that the majority of the incidents reported to the PPA database for all vessels including oil tankers were the result of contact damage (*i.e.,* contact with the dock while berthing). DNV noted that, on average for the period 1993 to 2012, over 60 per cent of incidents reported involved contact damage and other dock-related incidents.

With respect to oil spills on the West Coast, DNV accessed the most recent and available CCG statistics, which were for the period 2001 to 2009. DNV notes there is no updated data available for 2010 to 2012. Of particular interest, DNV noted that during the 2001 to 2009 period there were no oil spill accidents from tankers on the West Coast.

5.2.1.6 Shipping Incidents in the US Salish Sea

Det Norske Veritas accessed casualty data on incidents in US waters within North America from the Department of Homeland Security's Homeport database. DNV notes that the data is reliable for the period 2006 to 2010; some data before 2006 appears to be missing so the data is questionable, while some incidents reported after 2010 are still under investigation.

Det Norske Veritas notes that the 2006 to 2010 data from the US suggests an increase in the number of all types of vessel incidents on the US West Coast, likely due to the increase in traffic volume.

With respect to tankers in the US waters of the Salish Sea region, DNV noted that the annual number of incidents ranged from eight in 2006 to three in 2007/2008. Most of these incidents occurred in the vicinity of terminals at Cherry Point and Anacortes, Washington. DNV indicated since the data reported covers only five years and the number of vessels is relatively low in the US waters of the Salish Sea, the validity of frequency estimates is low. The data does suggest;

however, that the existing navigational risk controls have had a positive effect on the level of navigational safety in the Salish Sea region, where TMEP-related tankers would transit.

5.2.1.7 Conclusion

The data investigated by DNV from a number of different sources confirms that globally, there has been an increase in marine safety and subsequent decline in the number of marine vessel incidents, in particular those related to oil tankers and those incidents resulting in the release of oil in a marine environment.

With respect to accidental oil spills from tankers transiting the West Coast there were no reported spills from oil tankers in the 2001-2009 period of CCG collecting this type of data. The low number of incidents involving oil tankers on the West Coast may suggest the current scheme to manage navigation and marine traffic on the West Coast is effective.

5.2.2 Probability of a Spill in the Marine Environment Related to the Project

To understand the incremental risk related to the increase in oil tanker traffic created by TMEP, Trans Mountain contracted DNV to conduct a quantitative risk assessment. The quantitative risk assessment is one of the studies carried out for the TERMPOL process and the entire study is provided in TERMPOL 3.15, Volume 8C, TR 8C-12. A summary of the results of the risk assessment is provided in this section.

Det Norske Veritas evaluated the existing marine and shipping network of the Burrard Inlet and Salish Sea to identify:

- the possible types of incidents that could result in an oil spill from a laden tanker;
- the navigational hazards along the route a laden oil tanker would transit between the Westridge Marine Terminal and the Pacific Ocean;
- the navigational risk controls currently that are in use in the Salish Sea region and which have been effective at reducing the frequency of navigational incidents;
- the possible types of incidents that could result in an oil spill from a laden tanker;
- the hypothetical accident locations along the previously mentioned tanker route that could result in an oil spill from a laden tanker;
- the potential for enhanced navigational risk controls to reduce the probability of an oil spill from a laden tanker; and
- the probability and consequences of a credible worst case and smaller accidental oil spill (*i.e.,* a “mean-case” oil spill) from a laden tanker.

Based on an examination of casualty data and TERMPOL requirements, DNV selected five accidents types that could result in an accidental oil spill from a laden oil tanker:

- collision;
- powered grounding;
- drift grounding;
- structural failure; and
- fire/explosion.

As a result of the navigational hazard assessment, DNV defined a study area that included the route a laden oil tanker would transit from the Westridge Marine Terminal to the Pacific Ocean as well as directly adjacent areas, and divided the study area into twelve segments. DNV estimated both the accident and the frequency an accident might result in an accidental oil spill by a laden oil tanker from the Westridge Marine Terminal for each segment, taking into consideration these factors:

- existing and future marine traffic density;
- navigational difficulty;
- existing and proposed additional navigational risk controls; and
- meteorological and oceanographic conditions along the shipping route.

Det Norske Veritas considered existing navigational risk controls that are currently used in the study area to effectively manage marine vessel traffic and reduce the frequency of marine vessel incidents. The existing navigational risk controls DNV considered, and which were previously described in Section 1.4.3, in the quantitative risk assessment included:

- traffic separation scheme and one-way traffic;
- communication systems and oversight such as MCTS;
- mandatory pilotage for oil tankers;
- ship vetting procedures; and
- escort tugs, both tethered and non-tethered.

Det Norske Veritas also recommended two additional navigational risk controls to address the Project-related increase in tanker traffic. The additional navigational risk controls are described in greater detail in Section 5.4.2 and include:

- additional tug escort for laden oil tankers, including both tethered and non-tethered tugs; and
- a moving safety zone around laden oil tankers.

5.2.3 Volume of a Spill in the Marine Environment Related to the Project

To determine the risk of oil spills resulting from Project tankers DNV applied the probability of oil spill accidents, discussed above, to an estimate the consequences discussed here. For the purpose of DNV's analysis the quantification of consequences was limited to oil spill volume.

Expected oil spill volumes were derived from a ship damage model based on International Marine Organization Resolution for Marine Environmental Protection Program methods (IMO 2013c) for collision and grounding events. DNV applied a Monte Carlo simulation to this model to calculate the extent of uncontrolled outflow volume from a partially laden Aframax tanker. The results of the simulation provide a cumulative probability of outflow volume for an oil cargo spill accident. DNV recommended that a credible worst case spill be based on the 90th percentile volume, this is shown along with the mean (50th percentile spill volume) in Table 5.2.1.

TABLE 5.2.1

SIZE OF POSSIBLE ACCIDENTAL CARGO OIL SPILLS FROM A PROJECT-RELATED TANKER

Cases	Volume of Oil Spilled
Credible worst-case spill	16,500 m^3/104,000 bbl
Mean-case spill	8,250 m^3/52,000 bbl

Source: TERMPOL 3.15 (Volume 8C, TR 8C-12)

It is important to note that the credible worst-case spill does not reflect the complete loss of the contents of an oil tanker. DNV noted that, given the current design of an oil tanker with a double hull and segregated cargo compartments, the complete loss of the contents of a tanker leaving the Westridge Marine Terminal (*i.e.*, an Aframax vessel filled to 85 per cent capacity) is so unlikely that it is not a credible event for the purposes of the quantitative risk assessment.

5.2.4 Potential Locations for a Spill in the Marine Environment Related to the Project

As part of the quantitative risk assessment DNV completed a hazard identification exercise to identify locations where there is a higher degree of navigation complexity and probability of an incident due to a navigation issue involving collision or grounding of the tanker due to vessel traffic and/or the narrowness of the passage. The locations along the tanker route identified in the hazard identification exercise are summarized in Table 5.2.2. Five of the eight locations were modelled to develop hypothetical spill scenarios. One of the modelled locations is at the Westridge Marine Terminal and the results of modelling at this location are provided in Volume 7, Section 8.0, leaving four locations which are discussed in this Section 5. Three locations in Table 5.2.2 were not modelled for the reasons provided in the table.

TABLE 5.2.2

POSSIBLE LOCATIONS FOR AN ACCIDENT INVOLVING A PROJECT-RELATED TANKER

ID[1]	Possible location of Accident with Possibility of Oil Spill	Representative Hypothetical Incident	Identified Hypothetical Spill Scenario (Latitude/Longitude: North/West)
A	Westridge Terminal[2]	Oil spill from loading operation or flow line damage.	160 m^3 spill at berth with 20% escaping the pre-deployed oil spill boom (Lat/Long: 49.29150/ -122.95050)
B	English Bay	Possible collision with ships at anchor in English Bay and traffic from Fraser river is low probability	Not considered as viable spill location due to relatively low frequency for an accidental oil cargo spill
C	Roberts Bank	Possible collision with crossing traffic from Fraser river and other crossing traffic is low probability	Not considered as viable spill location due to relatively low frequency for an accidental oil cargo spill
D	Strait of Georgia (main ferry route crossing)	Possible collision with crossing traffic from Fraser River and ferries is a low probability event, but considered because of higher number of crossings per day	Collision (Lat/Long: 48.94303/ -123.21739)
E	Arachne Reef (Turn Point Special Operating Area)[3]	Possible powered grounding is a low probability event due to pilots and tethered tug but this location is rated with greatest level of navigation complexity for the entire passage. Location also has high environmental values.	Powered grounding (Lat/Long: 48.6850/ -123.2930)
F	Brotchie Pilot Boarding Area	Possible collision with other vessel is a low probability event.	Similar to Location G. Chose Location G.
G	Juan de Fuca Strait – (south of Race Rocks)	Possible collision with crossing traffic from Puget Sound and Rosario Strait or grounding at Race Rock is a low probability event, but considered because not all vessels in this location would have pilot onboard.	Collision (Lat/Long: 48.25257/ -123.52687)
H	Buoy J	Possible collision between vessels approaching the confluence of the traffic separation scheme (TSS) at the entrance to Juan de Fuca Strait. It is a low probability event due to high oversight by MCTS and well established TSS.	Collision (Lat/Long: 48.49401/ -124.99440)

Notes: All in-transit hypothetical spill locations have been modelled for both credible worst case (16,500 m^3) and smaller spill size (8,250 m^3)

1 These identifiers correspond to the locations outlined in Figure 5.5.2

2 The hypothetical spill at the Westridge Marine Terminal is described in Volume 7A

3 The hypothetical spill at Arachne Reef in the Turn Point Special Operating Area is the hypothetical scenario described in Section 5.7.

Source: TERMPOL 3.15 (Volume 8C, TR 8C-12)

5.2.5 *Risk of a Spill in the Marine Environment Related to the Project*

Det Norske Veritas's quantitative risk assessment illustrates the risk of an accidental oil spill without the Project proceeding, with predicted 2018 marine traffic volumes and with the current navigational safety regime in Table 5.2.3.

TABLE 5.2.3

RISK OF ACCIDENTAL CARGO OIL SPILL IN 2018, ASSUMING NO PROJECT AND CURRENT NAVIGATION SAFETY MEASURES

Spill Size	Oil Spill Volume (m^3/bbl)	Return Period[1] in Years
Credible worst-case	16,500 m^3/104,000 bbl	1 in 3,093 years
Mean-case	8,250 m^3/52,000 bbl	1 in 619 years
Any	> 0 m^3/0 bbl	1 in 309 years

Source: TERMPOL 3.15 (Volume 8C, TR 8C-12)

Det Norske Veritas's quantitative risk assessment also illustrates the risk of an accidental cargo oil spill from a Project-related Aframax tanker in 2018 with the current navigation safety measures in place and no additional mitigation undertaken (Table 5.2.4). Without additional navigation safety measures, the probability of an accidental oil spill from a Project-related tanker would increase substantially.

TABLE 5.2.4

RISK OF ACCIDENTAL CARGO OIL SPILL FROM A PROJECT-RELATED TANKER WITHOUT ADDITIONAL NAVIGATION SAFETY MEASURES

Spill Size	Oil Spill Volume (m^3/bbl)	Return Period[1] in Years
Credible worst-case	16,500 m^3/104,000 bbl	1 in 456 years
Mean-case	8,250 m^3/52,000 bbl	1 in 91 years
Any	> 0 m^3/0 bbl	1 in 46 years

Source: TERMPOL 3.15 (Volume 8C, TR 8C-12)

In order to reduce the probability of an accident occurring that would result in a spill from a Project-related tanker, Trans Mountain is seeking endorsement from Transport Canada for additional measures to improve navigational safety outlined in Section 5.4.2. If the additional navigation safety controls are implemented, the probability of an oil spill from a Project-related Aframax tanker in 2018 will be substantially reduced, as summarized in Table 5.2.5 and further described in Section 5.4.2. Trans Mountain will require all Project-related tankers to have enhanced tug escort for the entire transit between the Westridge Marine Terminal and the Pacific Ocean.

[1] A *return period* is a calculated estimate of the probability of an event. This term is used as part of a quantitative risk assessment. A return period is mathematically the inverse of an annual frequency. It means that an accident whose annual frequency is 0.01 is likely to happen once every 100 years. Its return period is 100 years. The lower the probability is the higher the return period will be.

TABLE 5.2.5

RISK OF ACCIDENTAL CARGO OIL SPILL FROM A PROJECT-RELATED TANKER WITH ADDITIONAL NAVIGATION SAFETY MEASURES

Spill Size	Oil Spill Volume m^3/bbl	Return Period in Years
Credible worst-case	16,500 m^3/104,000 bbl	1 in 2,366 years
Mean-case	8,250 m^3/52,000 bbl	1 in 473 years
Any	> 0 m^3/0 bbl	1 in 237 years

Source: TERMPOL 3.15 (Volume 8C, TR 8C-12)

5.3 Oil Spill Prevention

5.3.1 Existing Risk Controls

Det Norske Veritas found that within the study area marine navigation is well managed and important risk controls have been established for all traffic and for oil tankers in particular. DNV acknowledges that the existing risk controls for the route a Project-related tanker would transit are considered to be state of the art compared to other coastal sailing routes worldwide. These controls are in line with global best practices. The risk control measures in place today include:

- inspection of vessels under Port State Control;
- screening of vessels by charterer and terminal operator;
- aids to Navigation;
- Traffic Separation Scheme;
- oversight by VTS;
- mandatory pilotage;
- mandatory use of modern navigation equipment Electronic Chart Display and Information System, AIS, Radar;
- mandatory use of escort tugs; and
- mandatory participation in spill response regime.

To offset the effect of increased Project-related tanker traffic, a number of enhancements are recommended which, if implemented, will raise the level of care and safety in the study area to well above globally accepted shipping standards. The primary recommendations include extending tug escorts for laden Project-related tankers throughout Strait of Georgia and Juan de Fuca Strait and implementing a Moving Safety Zone around laden tankers. In addition to these preventative measures Trans Mountain is proposing significant improvements to the oil spill response regime for the area, which will be further modified in accordance with any future Canadian Federal regulations and standards.

The regulatory framework, roles and responsibilities for navigational safety in Canada were described in detail in Section 1.4.

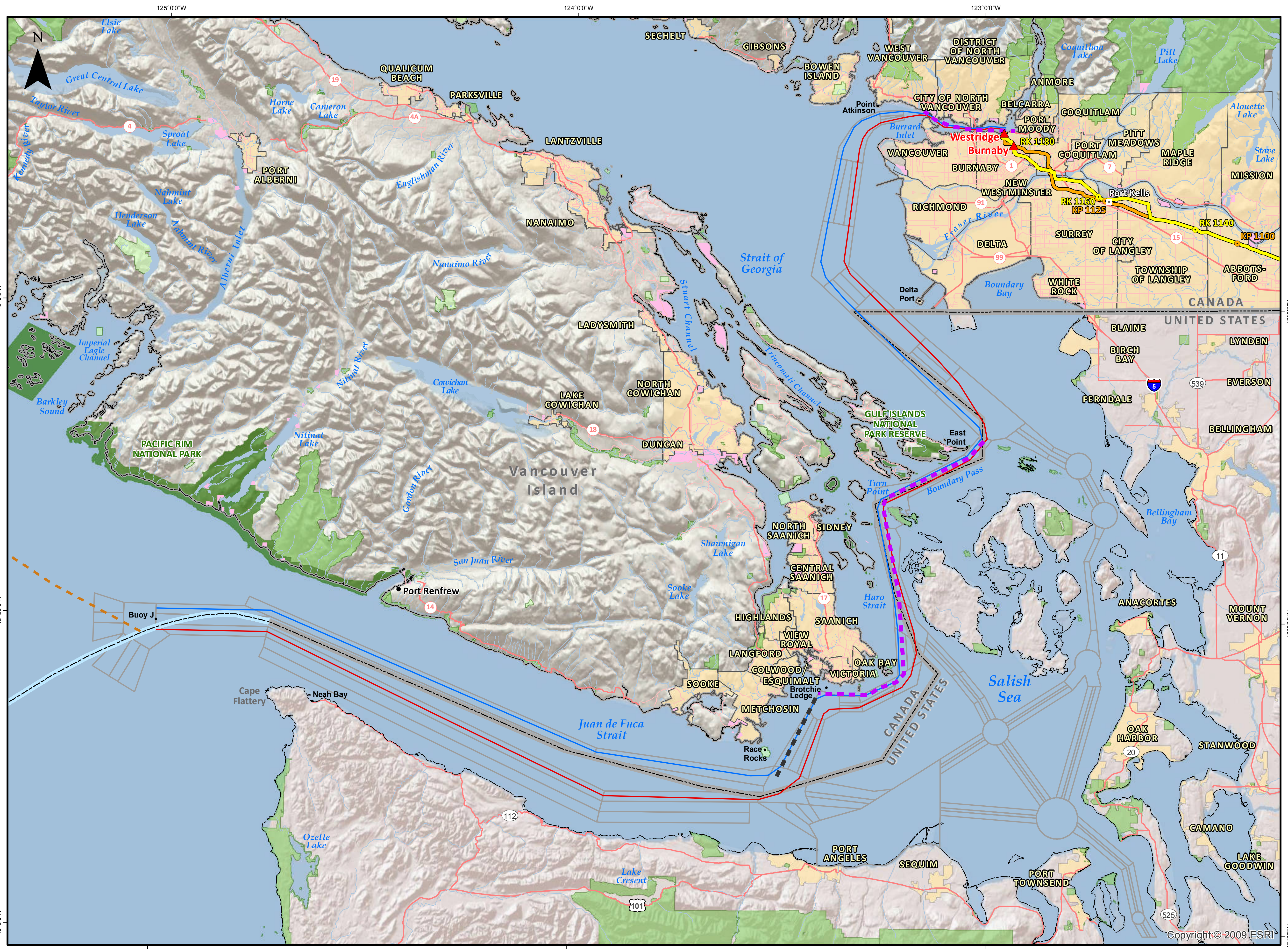
To summarize the key messages in Section 1.4, prevention of spills from oil tankers in the marine environment in Canadian waters emphasizes ensuring navigational safety through a regulatory framework that focuses on:

- **Vessel design and specifications** - All large oil tankers transiting Canadian waters must be of double-hulled design (Government of Canada 2013). A double hull is a type of tanker construction where the bottom and sides of a vessel have two complete layers of watertight hull surface, creating a space between the outer hull and the inner hull (TERMPOL 3.9 Ship Specifications, Volume 8C, TR 8C-7). For an uncontrolled release of oil from a tanker to occur, both layers would need to be breached. As noted in the summary of TERMPOL 3.8 Casualty Data (Volume 8C, TR 8C-6) in Section 5.2.1, a double-hulled tanker design decreases the frequency of tanker accidents that would result in an accidental release of cargo oil.

- **Vessel screening, vetting, and inspection** - Transport Canada participates in an international program that identifies Ships of Particular Interest, and bans them from entering Canadian waters. This program, combined with Canada's Port State Control program, has been highly effective in preventing sub-standard ships from entering Canadian waters. Regular aerial surveillance is a widely recognized and effective deterrent that reduces oil discharges in Canadian waters because potential polluters are aware that Canada has heightened surveillance, for which purpose Transport Canada undertakes the National Aerial Surveillance Program. Upon arrival in Canadian waters, Transport Canada inspects all foreign vessels and again on an annual basis thereafter. Trans Mountain maintains a Tanker Acceptance Standard against which all tankers nominated by pipeline shippers are evaluated and either accepted or rejected at the Westridge Marine Terminal. Pipeline shippers also have their own tanker screening and selection process, which is intended to ensure that tankers nominated to the Westridge Marine Terminal meet international regulations and Trans Mountain's Tanker Acceptance Standard.

- **Vessel operations and movements within the Canadian waters** - Tankers follow established shipping routes with separation schemes, protocols, and communication procedures to minimize the probability of a collision with another vessel or with navigational hazards (Section 1.4.3). In addition, the PPA has established mandatory pilotage requirements for inbound and outbound traffic to the Westridge Marine Terminal and PMV and the PPA have established mandatory tug escort requirements for tankers from the Westridge Marine Terminal (Figure 5.3.1). Tethered escort means escort tugs are physically attached to the oil tanker and can exert enough force to prevent the oil tanker from grounding in the event of a mechanical failure of the oil tanker's equipment. Untethered escort tugs navigate with the outbound oil tanker but are not physically attached to it. In the event the oil tanker experiences a mechanical failure, an untethered escort tug can connect a line and exert enough force to prevent the tanker from grounding but the response time is greater (DNV 2013); the current locations where a tug is tethered have been selected based on similar programs conducted by PMV and PPA that considered areas where immediate response to a failure of the ship systems may be required

- **Training -** To maintain their high level marine navigational safety, tankers need employ trained, qualified and competent officers and crew. In keeping with STCW Transport Canada develops and updates regulations, examinations and training standards for the certification of seafarers, including medical fitness; issues Certificates of Competency to seafarers after they have successfully fulfilled the requirements and passed examinations for the certificate; and keeps complete records of all seafarers who are candidates for or holders of these certificates. Foreign vessels are required to meet similar standards in crew training and competency. The certificates of seafarers serving on the tankers are verified during Transport Canada inspections. Pilots require training and experience to be certified by the PPA and also undertake refresher training on ship handling practices.



TRANS MOUNTAIN

FIGURE 5.3.1

CURRENT TUG ESCORT FOR LADEN OIL TANKERS LEAVING WESTRIDGE MARINE TERMINAL

TRANS MOUNTAIN EXPANSION PROJECT

- Reference Kilometre Post (RK)
- Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal
- Existing Pump Station
- Highway
- Road
- 12 Nautical Mile Limit (Territorial Sea)
- Escorted Tug Route
- Tethered Tug Route
- Limit of Exclusive Economic Zone (EEZ)
- International Boundary
- Marine Vessel Outbound Shipping Lane
- Marine Vessel Inbound Shipping Lane
- Traffic Separation Scheme
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park
- Provincial / State Park
- Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area

Projection: UTM Zone 10N.
Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V6: provided by UPI, Aug. 23, 2013; Facilities: provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007 & ESRI, 2005, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008; CHS: provided by KMC, 2013; Marine Shipping Lanes: Moffatt and Nichol, 2013; Hillshade: TERA, derived from Geobase; US Hillshade: ESRI, 2009.

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MAP NUMBER		PAGE
201310_MAP_TERA_MR_00469_REV0		SHEET 1 OF 1
DATE: December 2013	TERA REF.: 7894	REVISION: 0
SCALE: 1:650,000	PAGE SIZE: 11x17	DISCIPLINE: MR
DRAWN: TGG	CHECKED: CAS	DESIGN: LM

0 5 10 15 20 25 km

ALL LOCATIONS APPROXIMATE

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As described in Section 1.4, many parties share accountability for ensuring navigational safety of vessels within Canadian waters. Based on the results presented in TERMPOL 3.8 Casualty Data (Volume 8C, TR 8C-6), the existing navigational management and safety regime in the Salish Sea region has served Canada well in preventing incidents and possible cargo oil spills from laden oil tankers as a result of these incidents.

5.3.2 Proposed Improvements

Trans Mountain continues to work with other members of the maritime community on various initiatives to improve safety, including for example, a recent PMV-led process to improve safety and efficiency of transit through the Second Narrows MRA.

Trans Mountain has been in consultation with DNV, various maritime authorities such as Transport Canada and PMV, the PPA, BCCPA, COSBC, WCMRC, tug providers, and others in the maritime community to identify potential improvements to existing navigational safety controls related to the predicted increase in tanker traffic as a result of the Project. As a result of these consultations and considering the recommendations of DNV's quantitative risk assessment, the possibility of drift grounding (*i.e.,* a tanker losing power and drifting on to a rocky shore) or collision with another vessel were identified as key areas of navigation where additional mitigation would result in a significant improvement to navigational safety.

Although DNV acknowledges that the existing risk controls for the sailing route are considered to be state of the art compared to other coastal sailing routes worldwide their quantitative risk assessment identified two measures that, if implemented, nearly eliminate the change in overall oil cargo spill risk resulting from the Project. Trans Mountain proposes and seeks endorsement from Transport Canada and the TERMPOL Review Committee for these measures to be implemented to significantly reduce the risk of an accidental oil spill from a Project-related tanker.

5.3.2.1 Additional Dedicated Tug Escort

Figure 5.3.1 shows two portions of the established shipping routes where tug escorts are not provided for an oil tanker. A vessel suffering a loss of power today would depend of tugs of opportunity for assistance in these areas. Tugs of opportunity are defined as those tugs that might happen to be in the vicinity of an incident and available to assist.

As noted in Table 5.3.1, allocating a dedicated escort tug to a tanker in such areas would significantly reduce the overall probability of an incident resulting in an oil spill from a laden tanker as there would be no question of whether or not a tug would be available to assist in the event of an incident. Trans Mountain therefore proposes to require an increase in the existing level of tug escort for laden Project-tankers during their entire passage from the Westridge Marine Terminal to the Pacific Ocean, outside of the PPA and PMV's geographical jurisdiction (Figure 5.3.2). This new requirement would be included in Trans Mountain's Tanker Acceptance Criteria.

Tug operators based in Vancouver have indicated to Trans Mountain that escort tugs with sufficient capability to control a laden oil tanker under conditions prevailing in the study area are now and will continue to be available for this service. Trans Mountain also commissioned an assessment to determine desired capabilities of tugs that might provide this service, especially through Juan de Fuca Strait (Volume 8C, TR 8C-12, S3), An Evaluation of Local Escort and Rescue Tug Capabilities in Juan de Fuca Strait [Robert Allan Ltd. 2013]). Trans Mountain shall continue to work with local tug operators to support continuous improvement initiatives in tug escort training and technology.

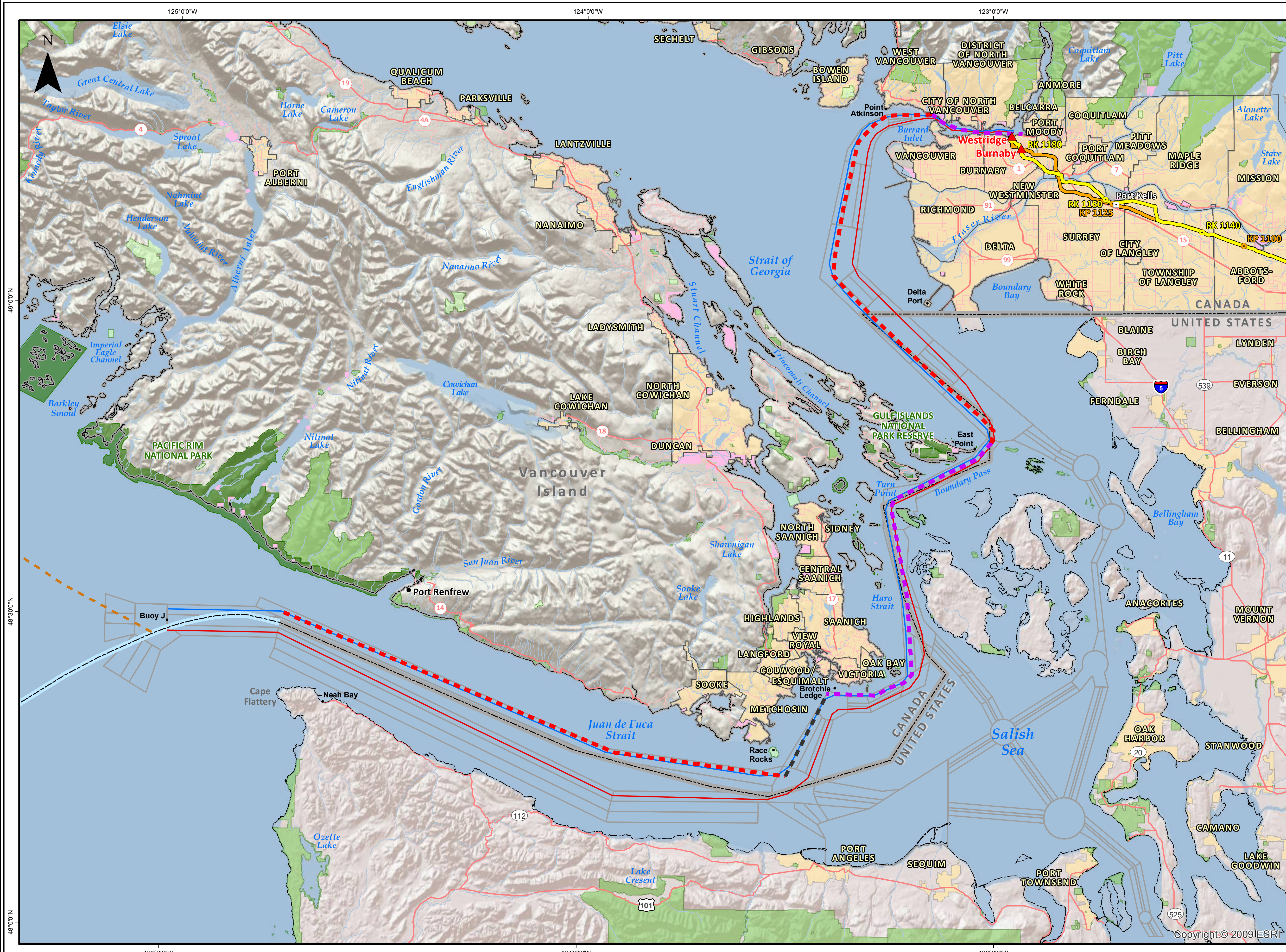

FIGURE 5.3.2

PROPOSED ADDITIONAL TUG ESCORT FOR LADEN OIL TANKERS LEAVING WESTRIDGE MARINE TERMINAL

TRANS MOUNTAIN EXPANSION PROJECT

TRANS MOUNTAIN

- Reference Kilometre Post (RK)
- Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal
- Existing Pump Station
- Highway
- Road
- 12 Nautical Mile Limit (Territorial Sea)
- Escorted Tug Route
- Tethered Tug Route
- Proposed Additional Tug Route
- Limit of Exclusive Economic Zone (EEZ)
- International Boundary
- Marine Vessel Outbound Shipping Lane
- Marine Vessel Inbound Shipping Lane
- Traffic Separation Scheme
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park
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- Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area

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Projection: UTM Zone 10N.
Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V6: provided by UPI, Aug. 23, 2013; Facilities: provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007 & ESRI, 2005, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008; CHS: provided by KMC, 2013; Marine Shipping Lanes: Moffatt and Nichol, 2013; Hillshade: TERA, derived from Geobase; US Hillshade: ESRI, 2009.

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5.3.2.2 Moving Safety Zone

Within Canadian waters users of shipping lanes and users crossing the shipping lanes are required to follow the established mandatory routes shown on navigation charts issued by the Canadian Hydrographic Service (CHS) and also abide by the International Rules for Prevention of Collisions at Sea. The regulation for all non-pleasure vessels over 350 gross tons and pleasure vessels over 500 gross tons to have a pilot onboard east of Victoria is an extremely important measure to prevent marine vessel collisions. Furthermore, the separation of opposing streams of traffic and regulating the flow of traffic at crossing points have reduced the incidence of encounters and the possibility of collision.

The research carried out by DNV for the TERMPOL studies and Trans Mountain's experience suggests that the existing marine transportation management protocols implemented in the jointly managed Canada/US waterways in the Salish Sea region have played a key role in ensuring safety, efficiency, the protection of the environment, and are in keeping with the intent of SOLAS.

An important part of the assessment carried out by DNV on behalf of Trans Mountain was to ascertain what, if any, additional operating procedures could be implemented to improve navigational safety and reduce the probability of a collision or grounding of a laden tanker.

Det Norske Veritas identified that adopting a Moving Safety Zone (MSZ) around laden tankers outbound from the Westridge Marine Terminal would substantially reduce the probability of a vessel collision. A MSZ is defined by Transport Canada as "a defined area, which for safety and environmental purposes access is limited to persons, ships or objects authorized by the Coast Guard. Such a zone may be stationary and described by fixed limits, or it may be described as an area around a ship or object in transit" (Transport Canada 1991).

An MSZ around laden oil tankers has been used successfully in other jurisdictions to reduce the occurrence of vessel collisions. For example:

- In many parts of Europe and Asia, such as in the North Sea and in the approaches to Japanese ports, tanker traffic is further separated from the other shipping traffic navigating within Traffic Separation Schemes and in some cases they are subject to additional regulations.
- In the approaches to Southampton, rules have been established whereby a moving prohibited zone is immediately established around all large vessels once they are underway (Southampton Vessel Traffic Services 2013).
- Under certain circumstances the USCG establishes moving security zones around tankers and other specially designated vessels.

As a result of the TERMPOL studies, and in keeping with examples from other jurisdictions, Trans Mountain is seeking endorsement and support of the Joint Coordinating Group of the CVTS to implement a MSZ. The MSZ would be consistent with safety zones described by Transport Canada (Transport Canada 1991) and the USCG (USCG 2013) and would be established around all laden oil tankers in excess of 40,000 tonnes DWT size, whenever such vessels are underway and are within a VTS zone.

Trans Mountain recommends that the MSZ be implemented in addition to the existing navigational measures previously described that have already proven effective at preventing collisions between marine vessels.

Table 5.3.1 shows the benefit of these two proposed navigational safety measures in reducing the probability of a credible worst-case scenario oil spill from a Project-related tanker.

TABLE 5.3.1

PROBABILITY OF CREDIBLE WORST CASE OIL SPILL RELATED TO TRANS MOUNTAIN TANKER SHOWING EFFECTS OF ADDITIONAL NAVIGATIONAL SAFETY CONTROLS

	2018 (*i.e.*, no Project)	2018 + Project (*i.e.*, no additional navigational safety controls)	Project + Additional Tug Escort of Project Tankers	Project + Tug Escorts And Moving Safety Zone
Combined return period in years for all accident categories	1 in 3,093 years	1 in 456 years	1 in 1,326 years	1 in 2,366 years

5.3.2.3 Conclusion

In its assessment DNV noted that implementing the extra risk controls described in the previous sections would raise the level of care and safety in the study area to well above globally accepted shipping standards.

The quantitative risk assessment carried out by DNV demonstrated that, with the implementation of additional tug escort and the establishment of an MSZ to prevent collisions, the probability of an oil spill from a laden tanker from the Westridge Marine Terminal would improve from a 1-in-456-year probability to a 1-in-2,366-year probability for a credible worst-case oil spill from a Project-related tanker (Table 5.2.4). Provided the proposed additional navigational controls were implemented as a result of the Project, the risk of a credible worst-case oil spill resulting from the Project-related increase in tanker traffic would be about the same as it is today, without the Project.

As noted previously, Trans Mountain is updating its Tanker Acceptance Criteria with the requirement for additional tug escort. As well, Trans Mountain is seeking endorsement for the MSZ from the Joint Coordinating Group of the CVTS. Lastly, Trans Mountain is seeking endorsement from Transport Canada for both of the proposed additional navigational control measures, which would be implemented if the Project were approved and prior to the operation of the Project.

5.4 Fate and Behaviour of an Oil Spill in a Marine Environment

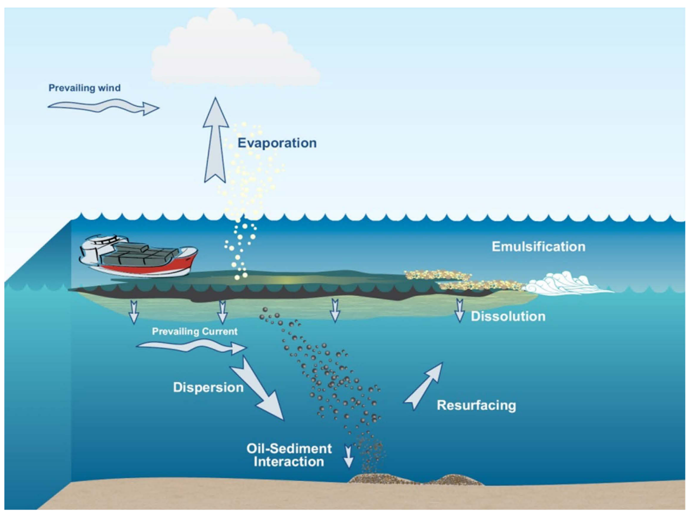
Section 5.4 describes the characteristics of oil spilled in a marine environment, beginning with a general description of these characteristics and gradually narrowing to a discussion of the results of a study and modeling of scenarios of a Project-related spill of diluted bitumen in the marine environment.

5.4.1 Properties and Weathering of Oil Spilled in a Marine Environment

The following overview of the fate and behaviour of marine oil spills is informed with information from the International Tanker Owners Pollution Federation (ITOPF; www.itopf.com).

5.4.1.1 Fate and Behaviour of Oil Spilled in a Marine Environment

As soon as oil is spilled, it starts to spread out over the sea surface, initially as a single slick. The speed at which this takes place depends on the buoyancy of the oil causing it to spread, and its viscosity, attenuating the motion of the oil. Fluid, low viscosity oil spreads more quickly than oil with a high viscosity. Nevertheless, oil slicks quickly spread to cover extensive areas of the sea surface. Spreading is rarely uniform and large variations in the thickness of the oil are typical. The rate at which the oil spreads is also determined by the prevailing conditions such as temperature, water currents, tidal streams and wind speeds. After a few hours the slick will begin to break up and, because of winds, wave action and water turbulence, will then generally form narrow bands or windrows, which may be parallel to the wind direction, but are also deformed because of small-scale motions in the surface water. The more severe the conditions, the more rapid the spreading and breaking up of the oil. The oil movement on the surface while undergoing a number of chemical and physical changes is collectively termed weathering (Figure 5.4.1). The various oil weathering processes are described in the following paragraphs.



Source: Modified from itopf.com

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FIGURE 5.4.1
OIL WEATHERING PROCESSES

Figure 5.4.1 Oil Weathering Processes

The product (*i.e.*, crude oils, aviation fuel, etc.) contains a variety of discrete components each of which has a distinct vapour pressure, boiling point and molecular weight (*i.e.*, hydrocarbons with more lighter and low boiling point products have a higher evaporation rate). The evaporation rate from heavier products is attenuated by the slow rate at which the lighter fractions can diffuse up to the surface of the slick, even for relatively thin slicks

5.4.1.1.1 Evaporation

The product (*i.e.*, crude oils, aviation fuel, etc.) contains a variety of discrete components each of which has a distinct vapour pressure, boiling point and molecular weight (*i.e.*, hydrocarbons with more lighter and low boiling point products have a higher evaporation rate). The evaporation rate from heavier products is attenuated by the slow rate at which the lighter fractions can diffuse up to the surface of the slick, even for relatively thin slicks.

The evaporation rate is also a function of the area or horizontal extent of the spill (*i.e.*, the larger the spill is, the higher is the evaporation rate). Finally, the evaporation rate is generally greater during strong winds compared to calm conditions.

5.4.1.1.2 Vertical Dispersion and Resurfacing

Breaking waves drive small droplets of the oil into the water column. Oil disperses most quickly if the oil is light and of low viscosity and if the sea is very rough. Depending on the natural turbulence in the water and the size and density of the droplets, the dispersed oil will generally stay suspended in the water column and will be prevented from resurfacing as long as the dispersing mechanism, breaking surface waves, remain active. When wind and waves die down, the dispersed oil will generally rise to the surface. The dispersion process is a function of wind speed, wave height, fraction of waves that are breaking, and the size of the droplets.

The size of the droplets is a criterion for a droplet to stay inside the water column because of natural turbulence. It is often seen that droplets larger than 70 microns will resurface in less time than it takes for the surface spill to move.

Since the surface slick moves according to both surface currents and a wind leeway, the oil on the surface and the dispersed oil in the water column do not travel together, but becomes spatially separated, especially during periods of strong winds. Oil that was dispersed and then rises to the surface undergoes evaporation, which is a loss for the dispersed oil fraction, but a gain for the evaporated fraction.

5.4.1.1.3 Emulsification

An emulsion is formed when two liquids combine, with one ending up suspended in the other. Emulsification of crude oils refers to the process whereby sea water droplets become suspended in the oil. This occurs by physical mixing promoted by turbulence at the sea surface. The emulsion thus formed is usually very viscous and more persistent than the original oil and is often referred to as “chocolate mousse” because of its appearance. The formation of these emulsions causes the volume of the oil-water mixture to increase to between three and four times the original oil volume. This slows and delays other processes that would allow the oil to dissipate.

Oils with asphaltene content greater than 7 per cent tend to form stable emulsions which may persist for many months after the initial spill has occurred. Those oils containing a lower per centage of asphaltenes are less likely to form emulsions and are more likely to disperse. Emulsions may separate into oil and water again if heated by sunlight under calm conditions or when stranded on shorelines. The emulsification process will often lead to an increased quantity of oil-water mixture to be dealt with during an oil spill response.

5.4.1.1.4 Sediment Interaction

Some heavy refined products have densities greater than 1.0 g/cm^3 (density of freshwater) and so will sink in fresh or brackish water. Crude oils (even those considered as “heavy”) are normally less dense than freshwater and seawater, which has a density of approximately 1.025 g/cm^3. However in interaction with suspended matter (particles of sediment or organic matter) already in the water, these particles could adhere to the weathered oil forming oil-suspended particulate matter aggregates (OSAs) which are generally sufficiently dense that they sink. Shallow waters are often laden with suspended solids providing favourable conditions for OSA formation, although the sediment must generally be fine-grained and of moderately high concentration. The energy for the formation of these aggregates is generally derived from breaking waves, but turbulent flow in a river could also facilitate formation of these aggregates.

Oil stranded on sandy shorelines often becomes mixed with sand and other sediments. If this mixture is subsequently washed off the beach back into the sea it may then sink. In addition, if the oil catches fire or is ignited after it has been spilled, the residues that sometimes form can be sufficiently dense to sink.

5.4.1.1.5 Dissolution

Water soluble compounds in oil may dissolve into the surrounding water. This depends on the composition and state of the oil, and occurs most quickly when the oil is finely dispersed in the water column. Components that are most soluble in seawater are the light aromatic hydrocarbons compounds such as benzene and toluene. However, these compounds are also those first to be lost through evaporation, a process that is 10 to 100 times faster than dissolution.

5.4.1.1.6 Formation of Tarballs

Tarballs are often formed following a spill. They tend to collect on shorelines and have a solid outer crust surrounding a softer, less weathered interior. Their sizes extend from a few millimetres to several centimetres, and they begin to form as the lighter fractions evaporate and the relative per centage of asphaltene in the slick increases. Oxidation can form an outer protective coating of heavy compounds that result in the increased persistence of the tar balls.

5.4.1.1.7 Beach/Shore Contact

A potential issue of concern is the extent to which oil would come into contact with intertidal sand and mud flats and adversely affect benthic invertebrates and bio-films. In addition to entering beach and mud flat sediment via the shore contact process, oil could become stranded as water levels fell below the level of the beach or sand flat cell.

Each segment of shoreline can retain a certain maximum volume of any oil spilled into the sea. A number of properties determine the amount of oil left on a shoreline including the adhesion properties or “stickiness” of stranded oil.

Low energy shorelines almost always have an extremely fine subsurface substrate (sand or mud), even though the surface veneer is coarse pebble, cobble or boulder. This will have limited oil penetration due to the fine nature of the substrate. Coarse (pebble, cobble, boulder), high-energy shorelines may be coarse to considerable depths, increasing permeability and potential stranded oil retention.

The retention values of the affected shoreline are important planning items to consider if oil spill response activities are taking place.

5.4.1.1.8 Oil Grouping and Persistence

The processes of spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill whilst oxidation, sedimentation and biodegradation are more important later on and determine the ultimate fate of the oil. To understand how different oils change over time whilst at sea, one needs to know how these weathering processes interact.

Studies show that the main properties affecting the fate of spilled oil at sea are specific gravity (its density relative to pure water); distillation characteristics (its volatility); viscosity (its resistance to flow); and pour point (the temperature below which it will not flow). In addition the wax and asphaltene content influence the likelihood that the oil will mix with water to form a water-in-oil emulsion. Oils that form stable oil-in-water emulsions persist longer at the water surface. The resin and asphaltene content determine the likelihood of tar-ball formation.

Oil persistence is often used to classify oils for transportation and allocate resources during an oil spill response. In simple terms less persistent oils once spilled are expected to remain in the environment for lesser time that higher persistence oils. This has led to the terms persistent and non-persistent oils within the shipping, oil response and insurance industries.

Some simple grouping has been developed based on oil type according to their density - generally, oils with a lower density will be less persistent. However some light oils can behave more like heavy ones due to the presence of waxes.

Group I oils (non-persistent) tend to dissipate completely through evaporation within a few hours and do not normally form emulsions. Group II and III oils can lose up to 40 per cent by volume through evaporation but, because of their tendency to form viscous emulsions, there is an initial volume increase as well as a curtailment of natural dispersion, particularly in the case of Group III oils. Group IV oils are very persistent due to their lack of volatile material and high viscosity, which preclude both evaporation and dispersion (Table 5.4.1).

TABLE 5.4.1

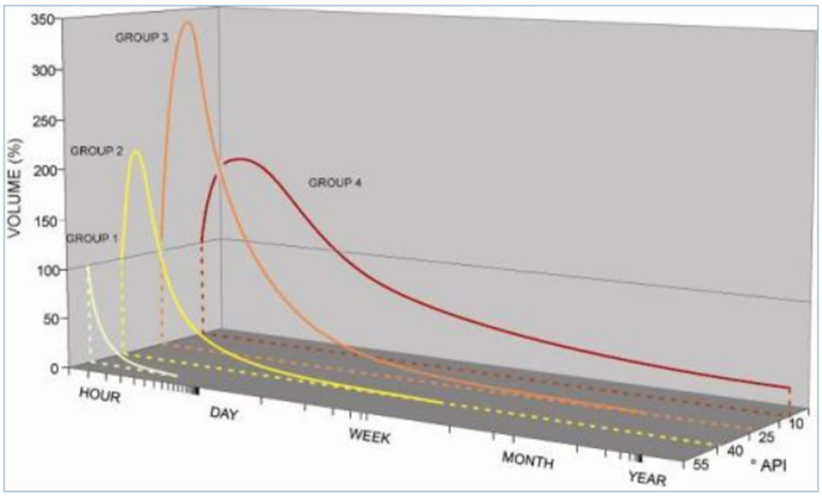
GROUP I TO IV OILS

Group	Density	Examples
Group I	less than 0.8	Gasoline, Kerosene
Group II	0.8 to 0.85	Gas Oil, Abu Dhabi Crude
Group III	0.85 to 0.95	Arabian Light Crude, North Sea Crude Oils (*e.g.*, Forties), diluted bitumen shipped on TMPL and from the Westridge Marine Terminal
Group IV	greater than 0.95	Heavy Fuel, Venezuelan Crude Oils

Source: Government of United States 2013

There is often mention of a fifth classification, termed Group V that is meant to collectively classify oils whose density is higher than that of freshwater, and even of a density higher than that of seawater and thus liable to sink once spilled to the sea.

Figure 5.4.2 provides a simple empirical model based upon the properties of different oil types. This uses the four main groups described above and shows the expected rate at which the volume of oil at the sea surface decreases. It is apparent from the graph that for most oils once the competing process of emulsification has been taken into account there would be an increase in volume in the short term. Response organizations must take the emulsification phenomenon into account when developing response plans and defining equipment requirements.



Source: ITOPF 2013

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FIGURE 5.4.2

VOLUME OF OIL AND WATER-IN-OIL EMULSION REMAINING ON THE SEA SURFACE, AS A PERCENTAGE OF THE ORIGINAL VOLUME SPILLED

Figure 5.4.2 Volume of Oil and Water-in-oil Emulsion Remaining on the Sea Surface, as a Percentage of the Original Volume Spilled

5.4.1.1.9 Summary

Typically, once released into the marine environment oil begins to "weather" and after a period of time can submerge or begin to sink. When released into water, lighter components of hydrocarbons will begin to evaporate, some will dissolve into the water column, and the remainder will float as long as the density of the remaining oil is less than the density of the water into which it was released. Wave action can cause water-in-oil emulsions, which will drive the mixture towards neutral buoyancy. Adhesion to bottom sediment (*e.g.*, beaches, riverbeds) or other sinking material can cause the oil to be submerged. The question then, especially for product like diluted bitumen, which although typically rated as a Group III product displays heavier oil behaviour when weathered, is about the weathering process and the mechanisms that can cause it to submerge or sink.

5.4.2 Hydrocarbon Properties of Product Shipped on TMPL

The TMPL system after the Project is in operation would have the capability to transport a variety of oil products, including both light and heavy crude oils, and those oils often termed as diluted bitumen. Bitumen is the oil product from oil sands deposits.

The main difference between oil sands deposits and those from the rest of the Western Canadian Sedimentary Basin is that oil sands formed nearer to the surface. As a result, oil sands deposits were subject to more microbial activity. Most of the lighter fractions in these deposits, characterized by fewer carbon atoms in their molecules, lower densities and higher vapour pressures, were digested by microbes. What remains are the heavier fractions that result in the denser, more viscous crude oil known as bitumen.

Once sand and water have been removed the remaining bitumen is too dense and viscous to meet pipeline specifications so it is mixed with diluent. Typical diluents are natural gas condensate (light oil recovered from natural gas production) and synthetic crude oil (partially refined bitumen). In effect the diluent is added to replace the light hydrocarbons lost from microbial degradation of the oil sands. Adding diluent creates a stable homogeneous mixture that behaves in a similar manner to other natural crude oils.

The CAPP describes diluted bitumen as a bitumen blend consisting of diluent that has a density of less than 800 kg/m^3. If it has a density greater than or equal to 800 kg/m^3, the diluent is presumed to be synthetic crude oil, and the blend is called synbit (CAPP 2013).

Diluted bitumen is expected to form a large proportion of the crude oil shipped from the Westridge Marine Terminal once the Project is in operation.

Table 5.4.2 describes the characteristics of the hydrocarbon products that may typically be transported on the TMPL and shipped by tanker from the Westridge Marine Terminal.

TABLE 5.4.2

CRUDE COMPARISON (FROM SEPTEMBER 1, 2011 TO SEPTEMBER 1, 2013)

	Light Sour	Light Sweet	Synthetic	High TAN Dilbit[1]	Dilbit[1]	Synbit[2]	Dilsynbit[3]
Basic Analysis							
Density (kg/m^3)	829.5 ± 6.8	828.7 ± 3.9	844.9 ± 18.4	874.2 ± 48.4	928.0 ± 5.2	931.9 ± 6.1	933.2 ± 6.8
Gravity (deg. API)	39.0 ± 1.4	39.1 ± 0.8	35.9 ± 3.6	30.7 ± 9.0	20.9 ± 0.9	20.2 ± 1.0	20.0 ± 1.1
Viscosity centistokes (cSt) @ 5 deg.C	10.6	12.1	10.7	Blended to meet < 350 cSt at Reference Temperature			
Viscosity cSt @ 10 deg. C	8.0	8.0	8.9				
Viscosity cSt @ 15 deg. C	6.9	6.4	7.5				
Reid Vapour Pressure (kPa)	68.9	74.9	31.7	62.9	51.7	20	62.7
Sulphur (wt%)	0.69 ± 0.18	0.42 ± 0.07	0.29 ± 0.12	2.08 ± 1.78	3.78 ± 0.08	3.42 ± 0.38	3.11 ± 0.70
Hydrogen Sulphide (ppm)	< 250	< 10	< 1	< 10	< 10	< 10	< 10
MCR (wt%)	2.13 ± 0.44	1.92 ± 0.18	0.94 ± 0.89	6.06 ± 4.55	10.42 ± 0.30	8.93 ± 1.55	11.50 ± 1.47

TABLE 5.4.2

CRUDE COMPARISON (FROM SEPTEMBER 1, 2011 TO SEPTEMBER 1, 2013) (continued)

	Light Sour	Light Sweet	Synthetic	High TAN Dilbit[1]	Dilbit[1]	Synbit[2]	Dilsynbit[3]
Basic Analysis							
Sediment (ppmw)	-	-	-	136 ± 113	123 ± 92	92 ± 38	378 ± 341
TAN (mgKOH/g)	-	-	-	1.72 ± 0.09	0.98 ± 0.08	1.20 ± 0.24	0.75 ± 0.27
Salt (ptb)	-	-	-	6.2 ± 1.7	10.4 ± 2.3	7.5 ± 3.2	10.7 ± 1.9
Nickel (mg/L)	5.6 ± 2.6	4.2 ± 0.7	1.4 ± 2.9	48.0 ± 33.5	65.8 ± 3.6	59.2 ± 7.4	54.7 ± 12.4
Vanadium (mg/L)	14.9 ± 7.9	8.3 ± 2.4	2.7 ± 6.3	129.1 ± 92.3	172.0 ± 12.8	159.5 ± 15.8	129.6 ± 45.5
Olefins (wt%)	-	ND	ND	ND	ND	ND	ND
Light Ends (vol%)							
Butanes	4.07 ± 1.10	3.98 ± 0.68	3.13 ± 1.09	2.38 ± 1.78	0.91 ± 0.27	0.73 ± 0.27	1.16 ± 0.46
Pentanes	2.80 ± 0.45	3.16 ± 0.70	2.93 ± 0.81	5.81 ± 2.86	6.19 ± 1.10	3.75 ± 2.65	5.82 ± 1.09
Hexanes	5.70 ± 0.38	5.43 ± 0.53	4.75 ± 1.02	6.18 ± 0.89	5.46 ± 0.50	3.67 ± 1.91	5.48 ± 0.48
Heptanes	7.72 ± 0.50	6.87 ± 0.55	5.32 ± 1.77	5.66 ± 1.49	3.51 ± 0.50	2.64 ± 0.89	3.62 ± 0.60
Octanes	7.68 ± 0.84	6.93 ± 0.74	5.60 ± 1.58	4.77 ± 2.41	2.29 ± 0.55	2.33 ± 0.51	2.74 ± 0.86
Nonanes	6.04 ± 0.89	5.46 ± 0.62	4.38 ± 1.21	3.33 ± 2.20	1.42 ± 0.42	1.85 ± 0.66	1.78 ± 0.69
Decanes	3.00 ± 0.54	2.54 ± 0.34	2.12 ± 0.51	1.55 ± 1.03	0.70 ± 0.22	0.99 ± 0.39	0.86 ± 0.32
BTEX (vol%)							
Benzene	0.36 ± 0.07	0.24 ± 0.03	0.22 ± 0.04	0.27 ± 0.05	0.24 ± 0.03	0.15 ± 0.10	0.20 ± 0.06
Toluene	1.10 ± 0.15	0.74 ± 0.11	0.63 ± 0.17	0.64 ± 0.16	0.42 ± 0.09	0.29 ± 0.15	0.37 ± 0.10
Ethyl Benzene	0.26 ± 0.03	0.24 ± 0.02	0.21 ± 0.04	0.15 ± 0.09	0.06 ± 0.02	0.07 ± 0.03	0.08 ± 0.04
Xylenes	1.43 ± 0.22	1.00 ± 0.13	0.82 ± 0.22	0.70 ± 0.34	0.35 ± 0.10	0.33 ± 0.10	0.35 ± 0.11
Distillation (deg. C)							
5% Mass Recovered	52.2 ± 13.78	45.9 ± 15.30	79.0 ± 29.07	43.0 ± 9.85	46.9 ± 10.56	83.6 ± 41.61	46.1 ± 9.46
10% Mass Recovered	85.5 ± 9.09	88.1 ± 8.70	121.9 ± 27.54	80.2 ± 16.19	91.2 ± 18.39	135.2 ± 51.87	93.4 ± 23.50
20% Mass Recovered	125.0 ± 14.82	129.9 ± 8.45	176.5 ± 39.25	184.1 ± 58.65	244.4 ± 19.80	247.6 ± 14.75	243.6 ± 40.89
30% Mass Recovered	172.1 ± 13.87	183.1 ± 11.36	225.1 ± 34.23	286.8 ± 78.88	334.0 ± 13.44	317.7 ± 18.06	356.3 ± 29.83
40% Mass Recovered	223.4 ± 13.64	241.7 ± 13.77	270.7 ± 23.81	359.1 ± 86.29	407.1 ± 12.95	377.1 ± 31.17	421.5 ± 19.49
50% Mass Recovered	278.5 ± 11.80	298.1 ± 15.66	313.1 ± 15.50	426.2 ± 93.01	475.1 ± 14.85	435.9 ± 41.16	478.4 ± 15.05
60% Mass Recovered	334.7 ± 11.27	355.7 ± 20.66	356.7 ± 17.47	502.0 ± 103.98	551.4 ± 19.04	503.1 ± 52.22	538.5 ± 21.26
70% Mass Recovered	398.7 ± 10.90	419.3 ± 25.15	402.9 ± 29.16	580.2 ± 112.62	633.2 ± 20.38	586.1 ± 58.31	605.3 ± 33.58
80% Mass Recovered	468.4 ± 12.20	492.8 ± 41.00	455.9 ± 53.70	599.0 ± 114.00	700.3 ± 16.47	662.3 ± 41.15	667.8 ± 33.97
90% Mass Recovered	567.3 ± 23.96	564.4 ± 20.77	488.1 ± 44.43	562.8 ± 34.51	-	705.1 ± 9.13	703.2 ± 19.40
95% Mass Recovered	628.8 ± 14.41	638.1 ± 32.27	529.9 ± 62.41	635.9 ± 45.89	-	-	-
99% Mass Recovered	699.0 ± 8.66	704.4 ± 15.20	567.1 ± 8.88	-	-	-	-

Source: Crude Quality Inc. 2013; Format is: Average ± std. dev.

Notes: 1 Diluted bitumen

2 Synthetic bitumen

3 Diluted synthetic bitumen

Diluted bitumen falls into an oil group classification noted as Group III hydrocarbons (Government of the United States 2013). That is, the specific gravity of the diluted bitumen is equal to or greater than 0.85 and less than 0.95. Table 5.4.3 provides a point of comparison between the physical properties of diluted bitumen and those of other crude and fuel oils with ranges of specific gravities that overlap with the Group III category. Diluted bitumen and these other commodities have been transported throughout the world and the general behaviour of these oils are quite comparable with respect to fate and weathering and spill countermeasures.

TABLE 5.4.3

RANGES OF PROPERTIES FOR GROUP III AND IV OILS (HEAVY CRUDE AND DILBIT RANGE HIGHLIGHTED)

Property	Units	Light Crude	Heavy Crude/ Dilbit	Intermediate Fuel Oil	Bunker C	Crude Oil Emulsion
Specific Gravity		780 to 880	880 to 1000	940 to 990	960 to 1040	950 to 1000
API Gravity		30 to 50	10 to 30	10 to 20	5 to 15	10 to 15
Viscosity	mPas at 15°C	5 to 50	50 to 50,000	1,000 to 15,000	10,000 to 50,000	20,000 to 100,000
Flash point	15°C	-30 to 30	-30 to 60	80 to 100	>100	>80
Solubility in Water	ppm	10 to 50	5 to 30	10 to 30	1 to 5	-
Pour Point	°C	-40 to 30	-40 to 30	-10 to 10	5 to 20	>50
Interfacial Tension	mN/m at 15°C	10 to 30	15 to 30	25 to 30	25 to 35	NR
Distillation Fractions (% distilled at:)	100 °C	2 to 15%	1 to 10%	-		NR
	200 °C	15 to 40%	2 to 25%	2 to 5%	2 to 5%	NR
	300 °C	30 to 60%	15 to 45%	15 to 25%	5 to 15%	NR
	400 °C	45 to 85%	25 to 75%	30 to 40%	15 to 25%	NR
	residual	15 to 55%	25 to 75%	60 to 70%	75 to 80%	NR

Source: Modified from Fingas (2001)

Table 5.4.4 summarizes the density ranges typical of the five product streams that are representative of the majority of the anticipated throughput of TMPL after the Project is in operation.

TABLE 5.4.4

CRUDE COMPARISON (FROM SEPTEMBER 1, 2011 TO SEPTEMBER 1, 2013)

	Access Western Blend (AWB)	Cold Lake (CL)	Statoil Cheecham Blend (SCB)	Surmont Heavy Blend (SHB)	Albian Heavy Synthetic (AHS)
Density (kg/m3)	923.6 ± 5.3	928.0 ± 5.2	928.1 ± 5.2	931.9 ± 6.1	933.2 ± 6.8
Gravity (o API)	21.6 ± 0.9	20.9 ± 0.9	20.8 ± 0.9	20.2 ± 1.0	20.0 ± 1.1

Source: Crudemonitor.ca; Format is: Average ± std. deviation

In addition to the density of diluted bitumen, other chemical properties are of significance with respect to fate and behaviour, and environmental risk. Tables 5.4.5 and 5.4.6 respectively present the light ends and BTEX compositions of representative diluted bitumen. BTEX is the collective name for the volative, single-ringed aromatic compounds found in crude oil. The behaviour of the four compounds is somewhat similar when released to the environment and thus, they are usually considered as a group.

TABLE 5.4.5

COMPARISON OF THE LIGHT END COMPONENTS OF REPRESENTATIVE CRUDES (FROM SEPTEMBER 1, 2011 TO SEPTEMBER 1, 2013)

Light Ends (vol %)					
	Access Western Blend (AWB)	**Cold Lake (CL)**	**Statoil Cheecham Blend (SCB)**	**Surmont Heavy Blend (SHB)**	**Albian Heavy Synthetic (AHS)**
Butanes	0.64 ± 0.18	0.91 ± 0.27	0.94 ± 0.28	0.73 ± 0.27	1.16 ± 0.46
Pentanes	8.52 ± 1.34	6.19 ± 1.10	5.71 ± 1.54	3.75 ± 2.65	5.82 ± 1.09
Hexanes	6.86 ± 0.55	5.46 ± 0.50	5.36 ± 0.52	3.67 ± 1.91	5.48 ± 0.48
Heptanes	4.32 ± 0.65	3.51 ± 0.50	3.61 ± 0.61	2.64 ± 0.89	3.62 ± 0.60
Octanes	2.40 ± 0.58	2.29 ± 0.55	2.83 ± 1.41	2.33 ± 0.51	2.74 ± 0.86
Nonanes	1.16 ± 0.33	1.42 ± 0.42	1.94 ± 1.24	1.85 ± 0.66	1.78 ± 0.69
Decanes	0.53 ± 0.15	0.70 ± 0.22	0.98 ± 0.63	0.99 ± 0.39	0.86 ± 0.32

Source: Crudemonitor.ca Format is: Average ± std. dev.

TABLE 5.4.6

BTEX COMPARISON OF REPRESENTATIVE CRUDES (FROM SEPTEMBER 1, 2011 TO SEPTEMBER 1, 2013)

BTEX (vol %)					
	Access Western Blend (AWB)	**Cold Lake (CL)**	**Statoil Cheecham Blend (SCB)**	**Surmont Heavy Blend (SHB)**	**Albian Heavy Synthetic (AHS)**
Benzene	0.30 ± 0.04	0.24 ± 0.03	0.21 ± 0.07	0.15 ± 0.10	0.20 ± 0.06
Toluene	0.51 ± 0.10	0.42 ± 0.09	0.38 ± 0.10	0.29 ± 0.15	0.37 ± 0.10
Ethyl Benzene	0.06 ± 0.02	0.06 ± 0.02	0.08 ± 0.04	0.07 ± 0.03	0.08 ± 0.04
Xylenes	0.37 ± 0.09	0.35 ± 0.10	0.38 ± 0.13	0.33 ± 0.10	0.35 ± 0.11

Source: Crudemonitor.ca Format is: Average ± std. dev.

5.4.3 Weathering of Diluted Bitumen

In May 2013, Trans Mountain conducted applied research on the fate and behaviour of diluted bitumen in a marine environment (*i.e.,* the Gainford Study, Volume 8C, TR 8C-12, S7). The Gainford Study included a weathering test of diluted bitumen spilled in a marine environment over a 10-day period. The tests were attended by a wide range of regulators and other agencies that were invited to attend. The Gainford study and other tests have shown that, like other crude oils, while the density increases as the lighter components evaporate, the rate at which this occurs diminishes as the density and viscosity of the oil increases. Although the relative density of the diluted bitumen observed in the Gainford Study reached that of fresh water, it took eight to ten days for this to happen. No evidence of sunken or submerged diluted bitumen was observed during the Gainford Study.

The fate of hydrocarbon releases and factors that affect released oil were discussed in general terms in Section 5.4.1. This section describes the key elements and observations pertaining to representative oils and considers some of those properties that have the potential to influence their fate and behaviour in the marine environment. Section 5.4.4 provides a detailed discussion of the results of oil spill simulations carried out at a number of selected locations using the credible worse case oil volume as well as smaller oil volumes.

5.4.3.1 The Gainford Study Results

Although several detailed studies have been completed that characterize the fate and behaviour of heavy crude oil made from Alberta oil sands, most are laboratory and bench-scale tests. Trans Mountain undertook an initiative to expand upon this knowledge through larger, meso-scale tests of diluted Alberta oil sands bitumen. The initiative is referred to as the Gainford Study (Volume 8C, TR 8C-12, S7).

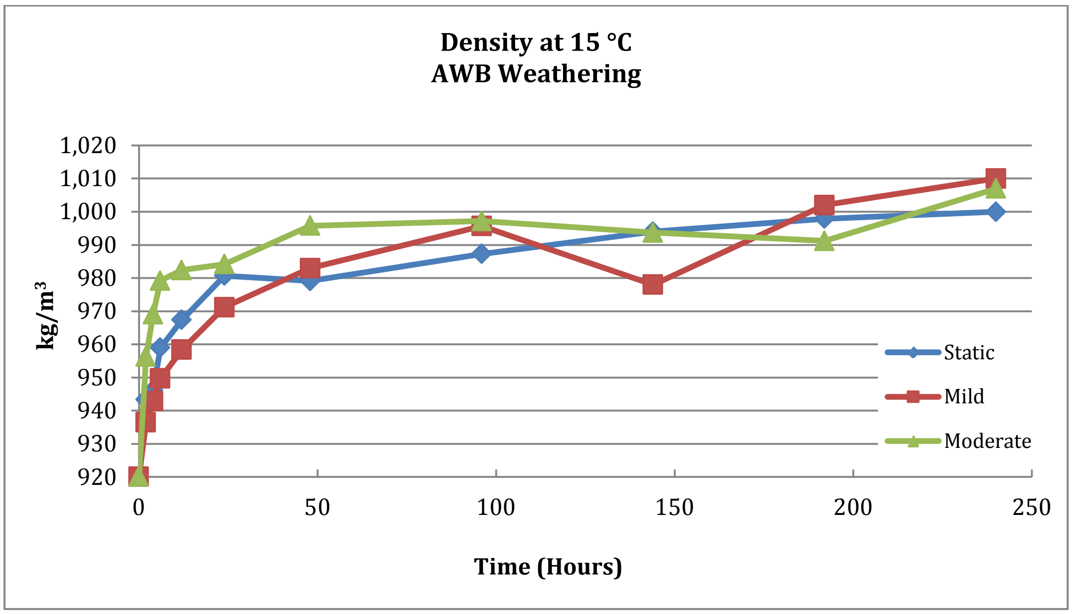
Larger tank tests allowed for simulated wave and current conditions that may be more typical of the marine setting of Burrard Inlet, the export point for diluted bitumen from the TMPL. Induced wave and wind energy on the meso-scale test tanks provide a mechanism to assess shifts in weathering rates as weathering energy increases. Increased energy from wind and waves in a marine setting can be analogous to the increased energy in freshwater system in which increased current speeds and turbulence result in faster weathering rates.

The Gainford Study employed a series of dedicated tanks where Trans Mountain could observe the 10-day behaviour of two types of diluted bitumen: Cold Lake Winter Blend (CLWB) and Access Western Blend (AWB) (Gainford Study, Volume 8C, TR 8C-12, S7). Wind and wave generating devices were used to simulate environmental conditions for the study. Salt was added to the water to achieve a salinity of 20 parts per thousand (ppt) to simulate the brackish waters of Burrard Inlet. Water temperature averaged about 15°C. Oil was applied to achieve approximately 1 cm slick thickness at the moment released (prior to evaporation or weathering processes).

Weathering processes result in changes to the physical and chemical properties of the remaining oil. For the two products tested, the most significant changes noted from the 10-day weathering events, were in density (key factor in floating *vs*. non-floating weathered oil), viscosity (key factor in weathered oil penetration into pore spaces and affects pump ability to recover spilled oil), water uptake and emulsification (affects density, viscosity, and potentially oil recovery systems), and chemistry (light ends). Both AWB and CLWB exhibit water uptake within the weathered oil matrix, although not as a stable, uniform emulsion but rather as a mechanically mixed and unstable oil-water combination. Water content analyses, conducted following procedures for whole oil, showed no systematic uptake or pattern for either product during the weathering process. Given the unstable character of water in oil, sampling and sample processing may result in very different oil-water mixtures at the time of analyses; hence, no conclusions are drawn for those tests other than to note that the maximum water contents measured, above 40 per cent, were noted in samples from three tanks with moderate and mild agitation and after one to three days of weathering. Visual observations of the surface of the oil in the various tanks showed that a crust, or armouring, formed as the oil weathered. There was little evidence of small droplets (natural dispersion) into the water column. Instead, the oil tended to form relatively continuous floating patches on the tank surface. In the end, the behaviour of both products proved to be no different than what might be expected of other heavy crudes when exposed to similar conditions.

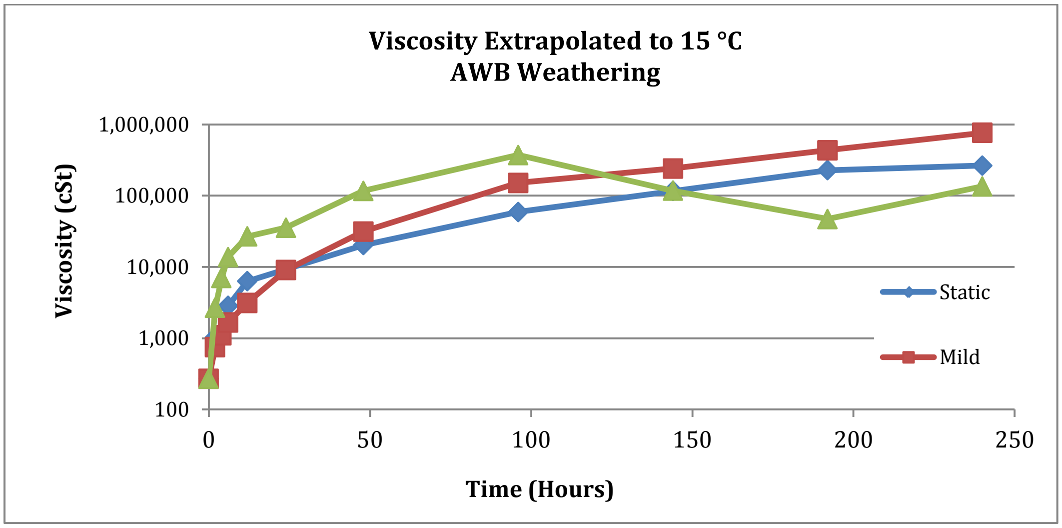
5.4.3.2 Physical Properties of Weathered AWB Diluted Bitumen

The increased density of AWB during weathering was more pronounced with moderate agitation, whereas oil under static conditions and mild agitation had comparable change (Figure 5.4.3). In all cases absolute densities (at 15°C) reached or slightly exceeded 1000 kg/m^3 (freshwater equivalent), but only after eight to ten days of weathering. The increase in AWB pour point and in viscosity as it weathered was pronounced in the first 48 hours, with the latter ranging 108 to over 60,000 centistokes (cSt) within that timeframe (Figure 5.4.4). Loss of a portion of lighter hydrocarbons combined with water inclusion into oil, much as may occur with most heavy crudes, are key factors defining the weathered oil properties.



Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.3 AWB - Absolute Density

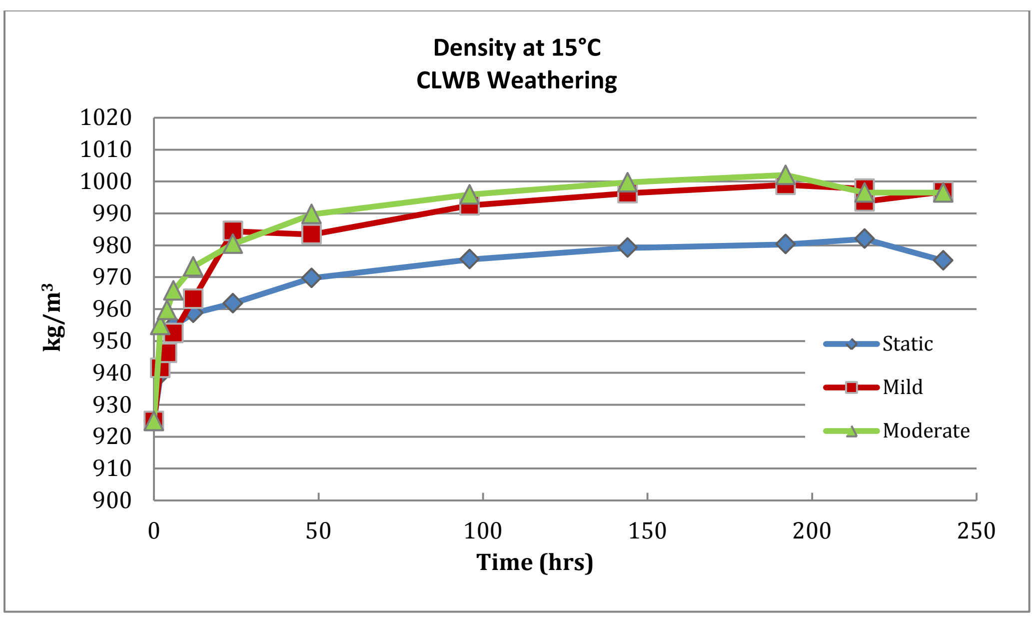


Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.4 AWB Viscosity

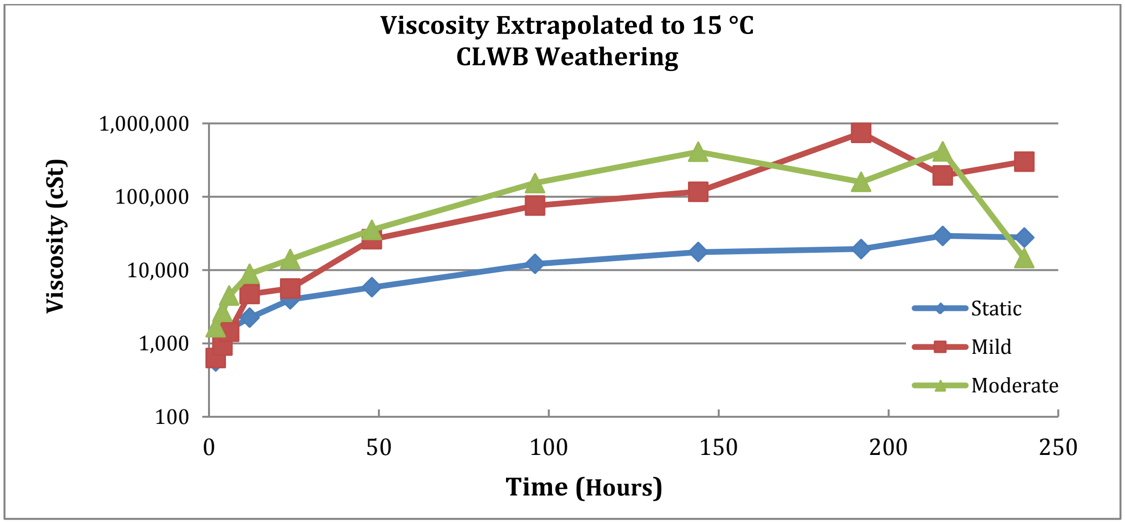
5.4.3.3 Physical Properties of Weathered CLWB

The increase in density of weathered CLWB was more pronounced in the first 24 hours under moderate agitation (Figure 5.4.5) but oils in static and mild agitation tanks achieved similar densities after that time. In all cases absolute densities (at 15°C) never exceeded 1000 (freshwater equivalent) with the exception of a single measurement at 8 days for the CLWB under moderate agitation. Viscosity increased to over 10,000 cSt within the first 48 hours, although increases in viscosity were much less pronounced in the static tank (Figure 5.4.6)



Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.5 CLWB Absolute Density

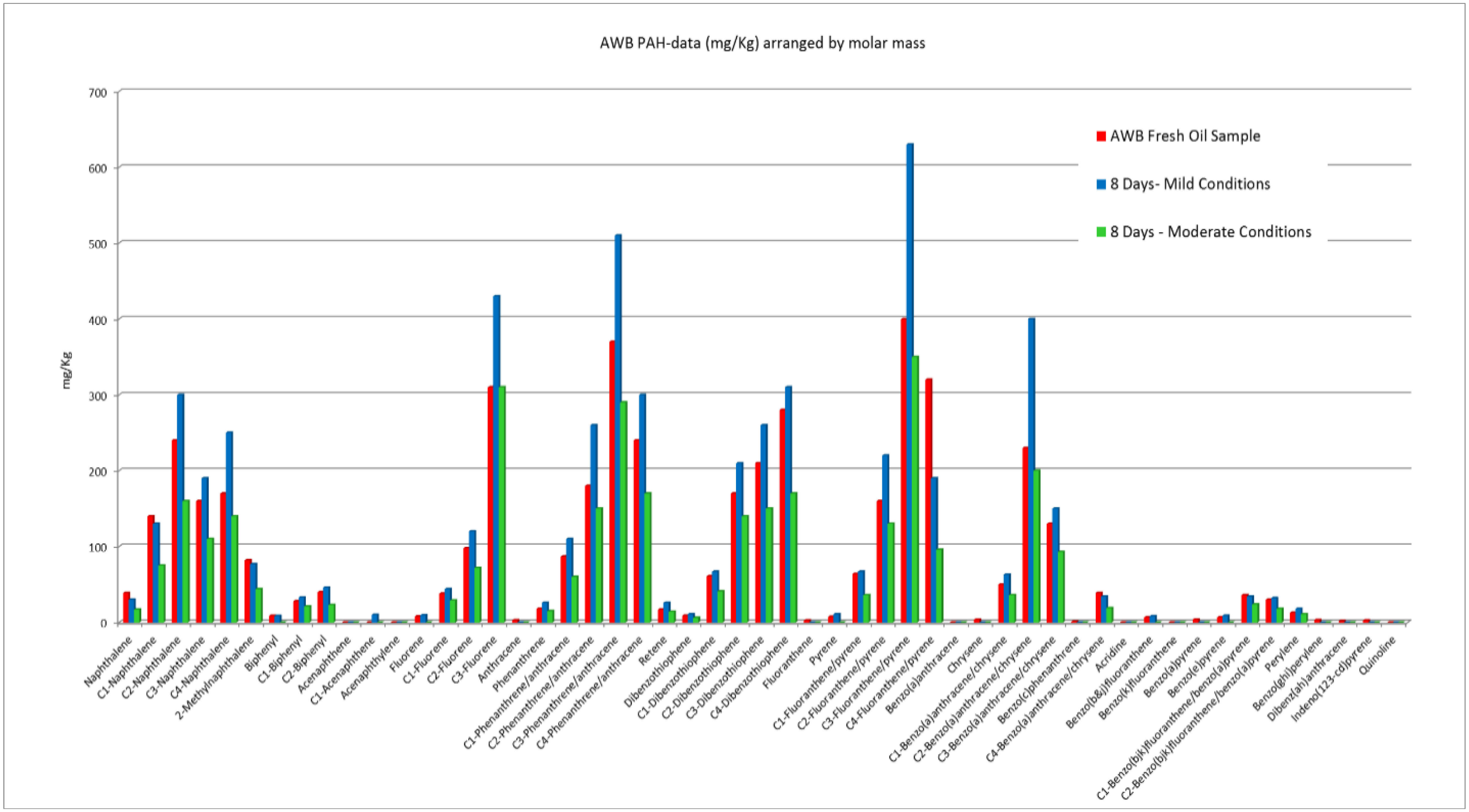


Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.6 CLWB Viscosity

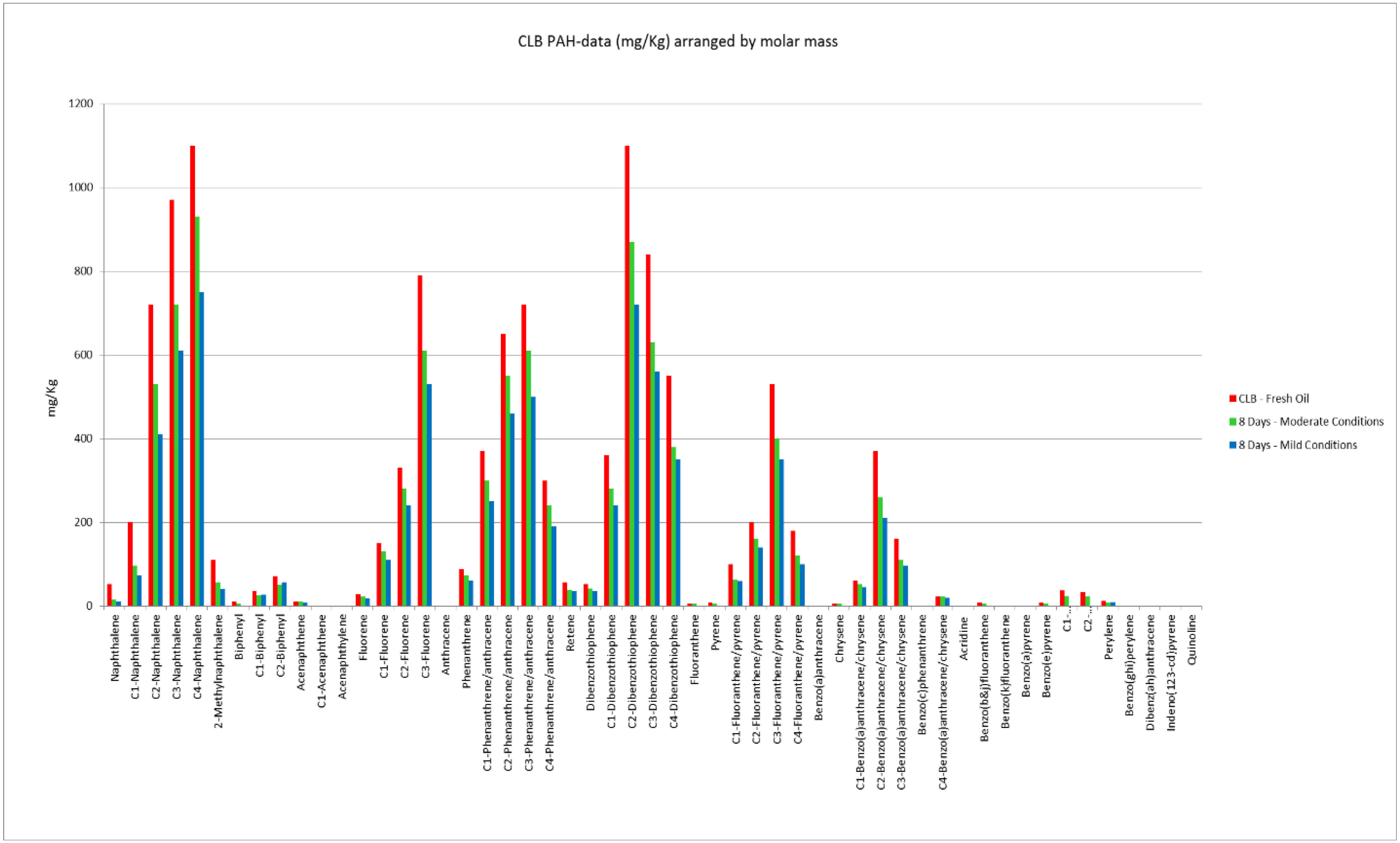
5.4.3.4 Chemical Properties of Weathered AWB and CLWB Diluted Bitumen

Oil chemistry, including light ends (*i.e.*, C1-C30) and PAH analyses, were analyzed to characterize the originating (fresh oil) diluted bitumen and to assess hydrocarbon content and degradation patterns. Figures 5.4.7 and 5.4.8 show PAH data for weathered and fresh AWB oil samples. Figures 5.4.9 and 5.4.10 show relative weight concentration of C1 through C30 compounds in fresh and weathered AWB and CLWB, respectively, and compares changes in these compounds with different levels of induced turbulence. (see Volume 8C, TR 8C-12, S7 or full details).



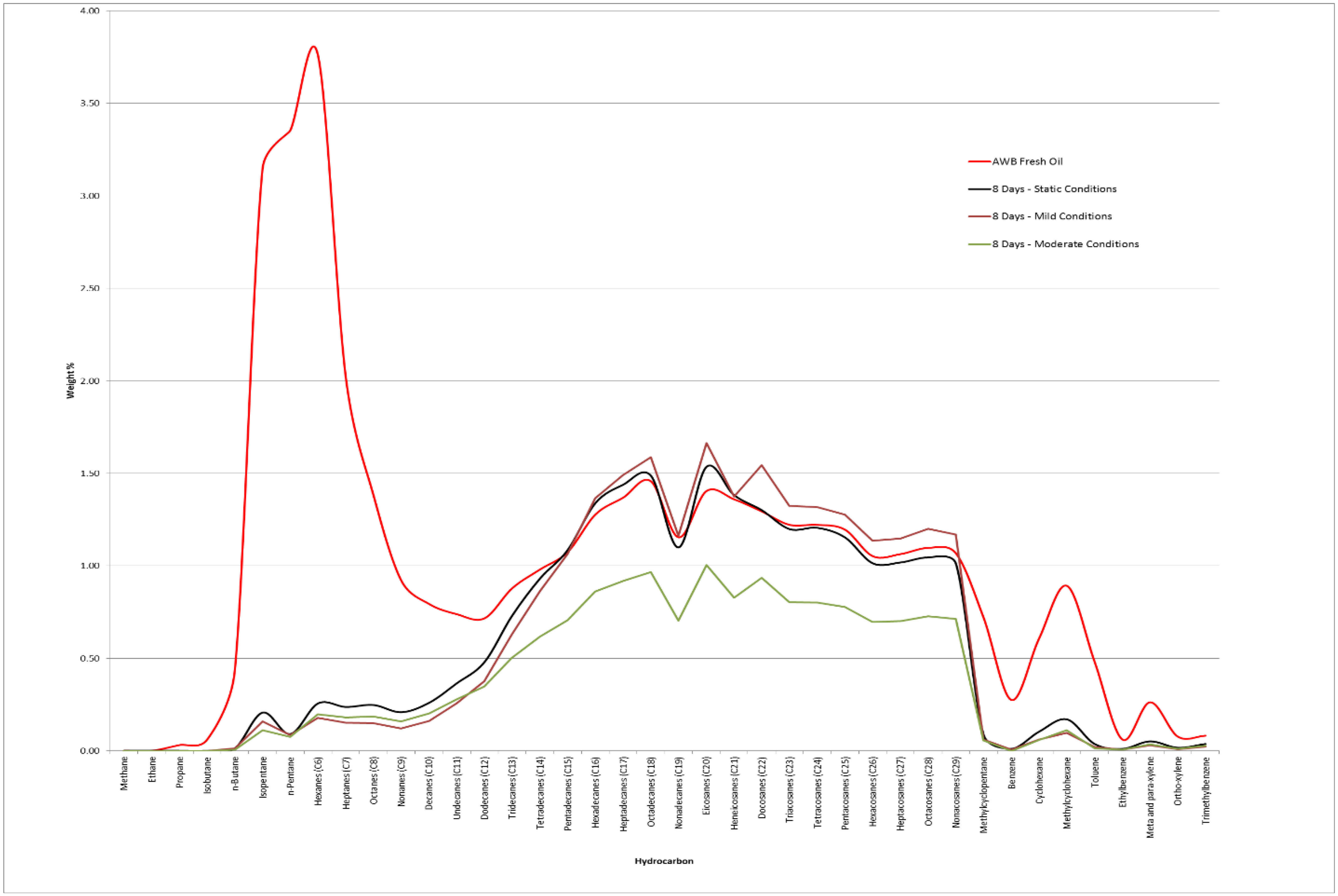
Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.7 Oil Chemistry Data - AWB



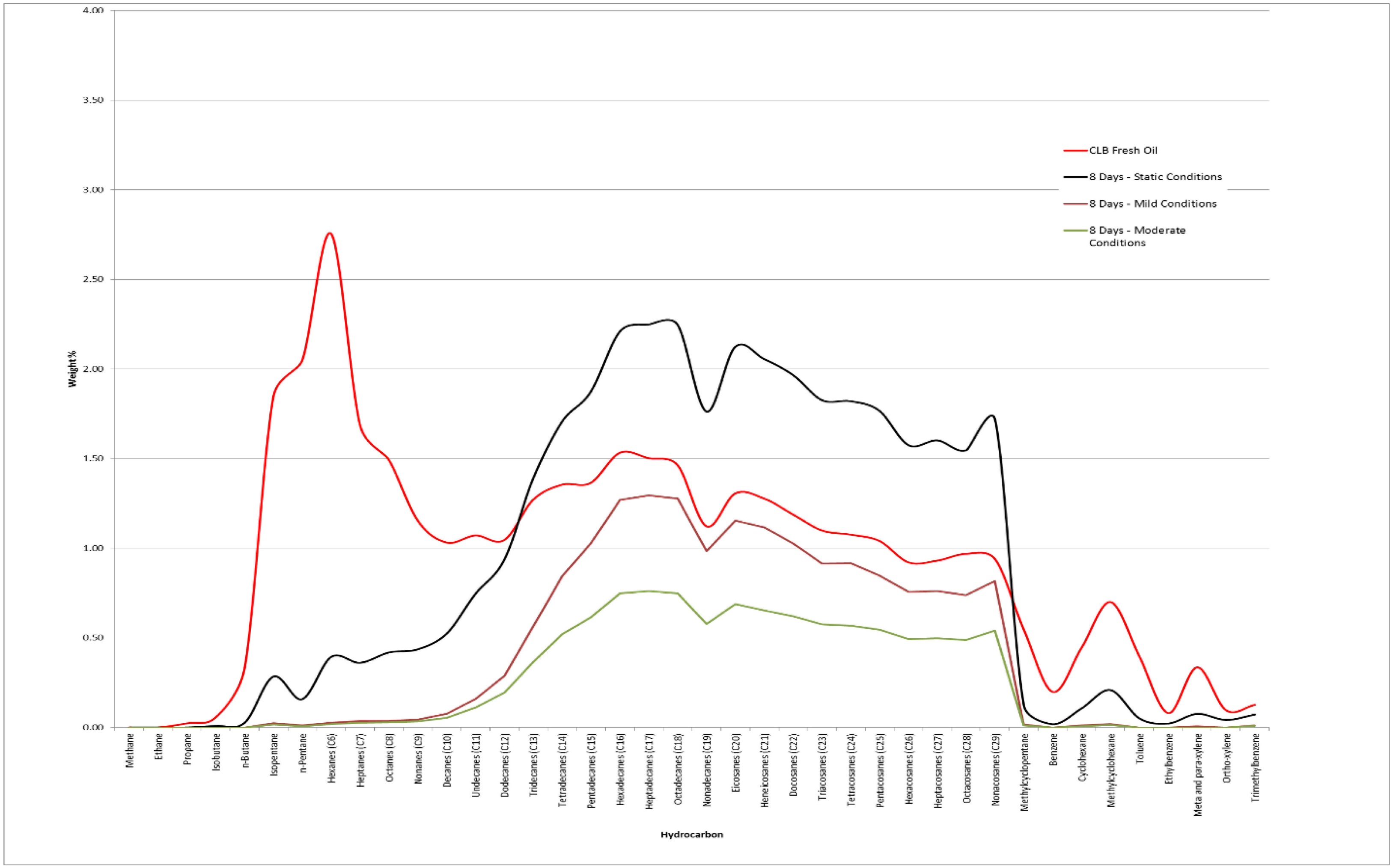
Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.8 Oil Chemistry Data – CLWB



Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.9 Light Ends (C1 – C30) AWB



Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

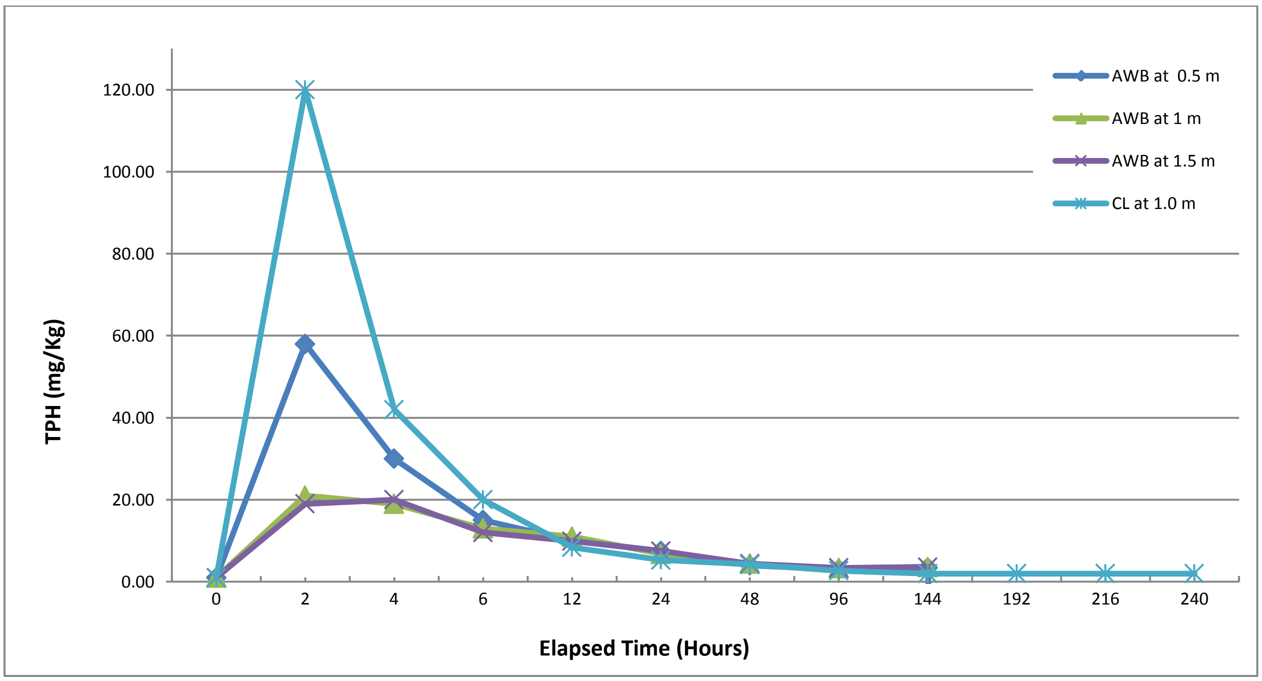
Figure 5.4.10 Light Ends (C1-C30) CLWB

5.4.3.5 Oil Distribution in the Water Column

Oil distribution and partitioning into the water column are provided through total petroleum hydrocarbons (TPH) and BTEX analyses of water samples at specific depths below the water surface (Volume 8C, TR 8C-12, S7). Chemical analyses of the weathered oils and of the water column showed that concentrations of BTEX diminished rapidly within 48 hours and that TPH in the water column only exceeded the detection limit (2 mg/L) during the first 48 hours in tanks with moderate surface agitation, despite the artificial confinement imposed by tanks relative to what may be expected in an open, natural setting

5.4.3.6 TPH the Water Column

TPH measured in the water columns of the AWB and CLWB tanks were in nearly all cases below detection thresholds (<2 mg/L) with the exception of tanks with moderate agitation (S3-AWB and S9A-CLWB). The highest TPH values measured were 120mg/L at 1m below the water surface from the CLWB and 60 mg/L at 50 cm below the water surface for AWB (Figure 5.4.11). By approximately 12 hours, all TPH values, regardless of depth in the water column or oil type, were near 10 mg/L in the tanks with moderate agitation. This pattern demonstrates that the lower molecular weight fractions of TPH tend to be more soluble in water and weather (*e.g.,* volatilize) faster.



Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.11 TPH in Water Column Samples - AWB and CLWB Weathering Under Moderate Conditions

5.4.3.7 BTEX in the Water Column

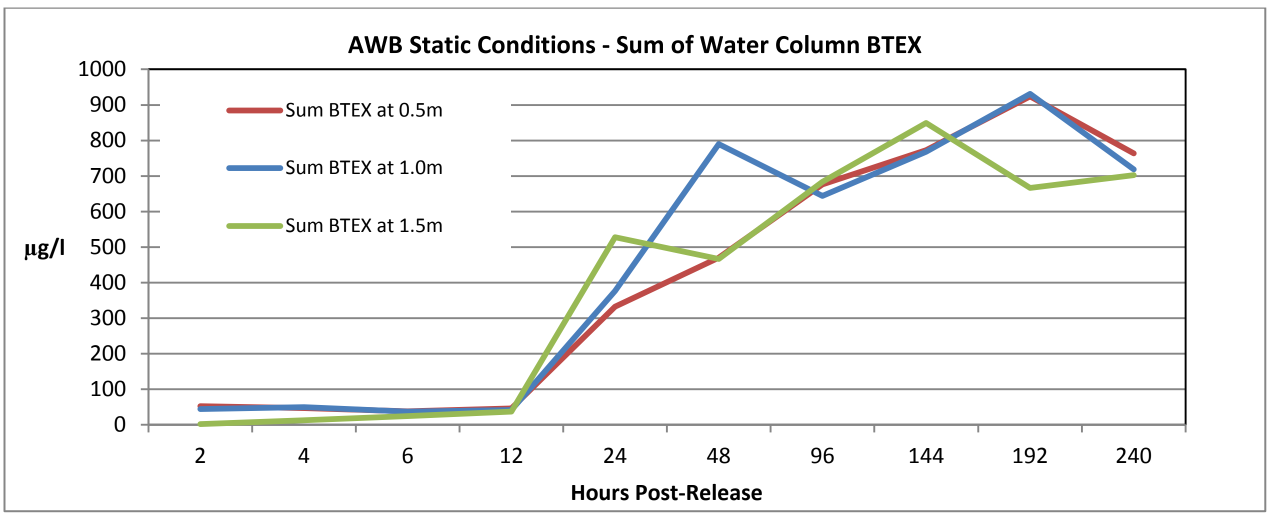
Most crude oil contains BTEX usually from about 0.5 per cent to 5 per cent or more. The CLWB and AWB contain approximately 1 per cent BTEX in the fresh oil samples, consistent with other crude oils. Gasoline can contain up to 40 per cent BTEX. BTEX compounds are volatile and rapidly volatilize producing a net loss of BTEX compounds.

Single-ringed aromatics are also soluble in water at low levels and readily partition out of the heavy crude. In the study of both CLWB and AWB, the BTEX compounds partitioned into the water column evenly at all depths examined (Figure 5.4.12) but behaved somewhat differently overall under different wind and wave conditions. BTEX in both AWB and CLWB behaved very similarly. In the static tests, dissolution of BTEX in the water column increased at 12 to 24 hours with maximum concentrations reaching approximately 900 µg/L (∑ BTEX) at approximately six days (Figure 5.4.12). There was little evidence of a net loss of BTEX in the static water leading up to ten days.

In mild wind and wave conditions, BTEX began to partition into the water column immediately reaching maximum ∑ BTEX concentrations of 1,200 µg/L (CLWB) to 1,500 µg/L (AWB) in 48 hours (Figure 5.4.13). Net loss of BTEX to volatilization was apparent at 48 hours with water concentrations dropping to less than 200 µg/L by eight days. Under moderate wind and wave conditions, (∑ BTEX reached similar, but slightly higher values, and it reached these values almost immediately. (Figure 5.3.14)

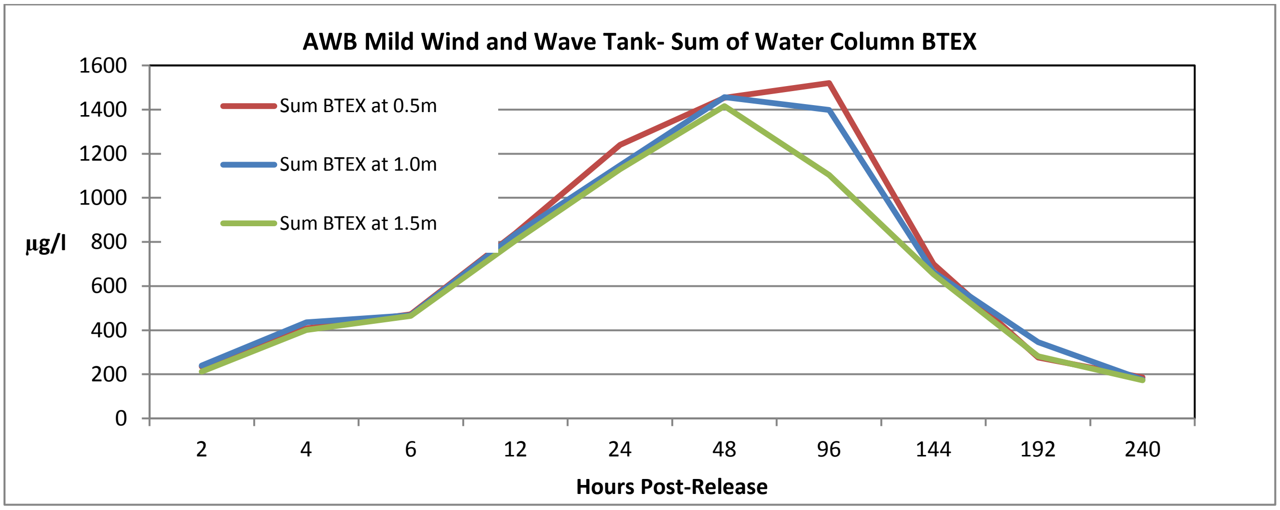
In moderate wind and wave conditions, CLWB ∑BTEX reached 3,000 µg/L almost immediately followed by a net loss to <100 µg/L in 4 days (Figure 5.4.15). The AWB ∑BTEX reached maximum concentrations of approximately 1,700 µg/L after four hours followed by a slightly slower net loss to <200 µg/L after 4 days. It is possible that the CLWB tanks located outdoors resulted in more rapid net loss of BTEX compounds. The higher maximum concentration of BTEX in CLWB could have been the result of a smaller tank.

In general, the results are expected, following the trend of more rapid and complete dissolution with mixing, as well as more rapid net loss.



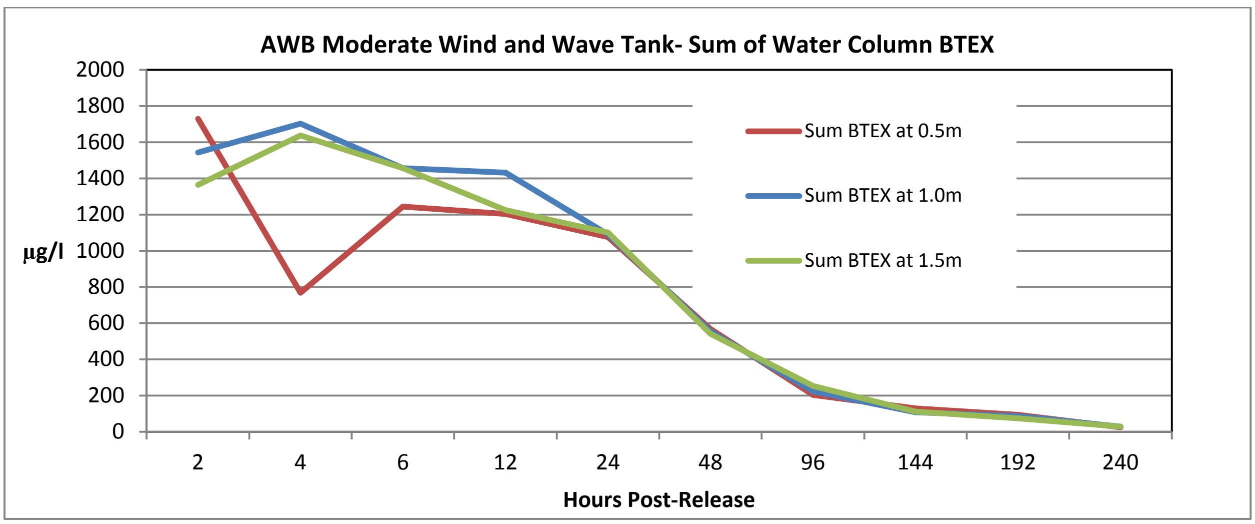
Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.12 AWB Static Conditions - Sum of Water Column BTEX



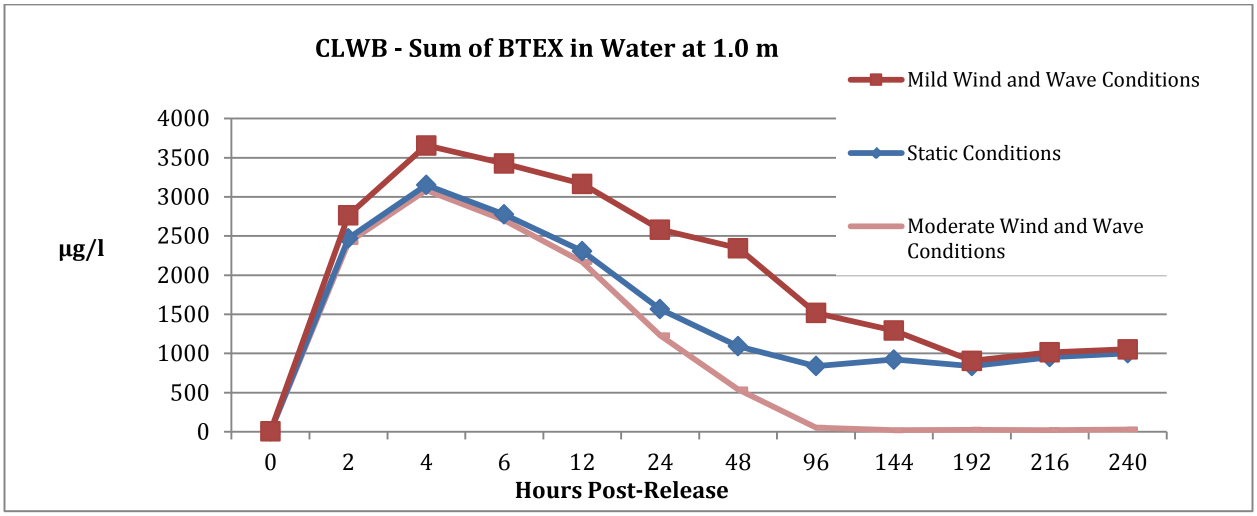
Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.13 AWB Mild Wind and Wave Tank- Sum of Water Column BTEX



Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.14 AWB Moderate Wind and Wave Tank- Sum of Water Column BTEX



Source: Gainford Study Report (Volume 8C, TR 8C-12, S7)

Figure 5.4.15 BTEX in Water Column Samples – CLWB Tanks

5.4.4 Fate and Behaviour of Accidental Project-Related Diluted Bitumen Spills

The fate and behaviour of Project-related spills is discussed in terms of properties of the product (*i.e.*, diluted bitumen), spill behaviour including weathering, and considerations with respect to mitigation. Since general oil properties and weathering have been discussed earlier in Section 5.4.3, this section will concentrate on the particular characteristics of the diluted bitumen proposed for this Project. The description of fate and behaviour was prepared by EBA Engineering Consultants Ltd. operating as EBA, A Tetra Tech Company (EBA), based on their proprietary modeling and the results of the Gainford Study conducted to simulate the weathering of spilled diluted bitumen in a marine environment.

Trans Mountain selected CLWB as a representative product for the purposes of modeling hypothetical spill scenarios since its properties are comparable to other diluted bitumen products transported on the TMPL system and shipped from the Westridge Marine Terminal. CLWB is now, and is expected to continue to be, a major contributor to the total quantity of diluted bitumen shipped on the TMPL system and from the Westridge Marine Terminal. Therefore there is a reasonable probability that in the event of an accidental oil spill, the spilled oil could be CLWB. In addition, the following factors were taken into consideration in selecting CLWB as a representative product for the purposes of spill modeling:

- More research on fate and behaviour has been completed with CLWB than other blends.
- The diluent in CLWB is condensate (a hydrocarbon product derived from natural gas production, that can be described as a light oil, similar in some respects to a crude gasoline). The CLWB contains a relatively large fraction of diluent in order to achieve specifications for viscosity and density under winter shipping conditions. As the condensate is rich in lighter hydrocarbons that are both volatile and relatively water soluble, the CLWB represents a diluted bitumen product that has a relatively high potential to cause acute toxicity to aquatic life (through dissolution of lighter hydrocarbons in water), or to cause

irritation or injury to human receptors (through inhalation of volatile hydrocarbons). CLWB is expected to weather to a state resembling a summer dilbit blend with less condensate within a day.

- The choice of condensate as a diluent is conservative with respect to alternative diluents (such as synthetic oil) that are less water soluble and volatile. The potential for light-end hydrocarbons contained in the CLWB to volatilize, dissolve or be biodegraded in the hours and days following an oil spill leads to a greater potential for the weathering oil to achieve a density that could sink, either through interaction with suspended sediment particles (*i.e.*, as an oil mineral aggregate), or directly if the density of the weathered oil were to exceed the density of the ambient water.

5.4.4.1 Properties of CLWB used for Modeling

To support the discussion of diluted bitumen properties and behaviour in the marine environment, it is worth describing briefly the properties of the CLWB product used for modeling of the spill scenarios.

The Canada Wide Standard for Petroleum Hydrocarbons (CCME 2008) describes a method of characterizing hydrocarbons from a toxicity point of view, using four fractions, F1 to F4, where each fraction (or pseudo-component) represents a range of carbon atoms in the molecule. F1 is the C_6 to C_{10} band, for example. Sub-categories of aromatics and aliphatics are also recognized in the CWS. Based on these considerations, a pseudo-component description with greater resolution (smaller ranges of carbon numbers in each fraction) was developed by the environmental assessment team for this Project. Table 5.4.7 is the pseudo-component description a CLWB sample, using the pseudo-component categories adopted for this Project (Sample BG5490, collected February 19, 2013 at the Westridge Marine Terminal).

TABLE 5.4.7

PROPERTIES OF CLWB

Pseudo-component	Description	Concentration (g/kg)	Molar Fraction	Molecular Weight (g/mol)	Vapour Pressure (Pa)	Solubility in Water (mol/m^3)	Density (@ 20 or 25 °C) (g/cm^3)	Boiling Point (°C)
VOL	Volatiles	72	0.255	70.8	9.98E+04	2.28E+00	612	29
AR1	Benzene	2	0.006	78.1	1.27E+04	2.28E+01	867	80
AR2	TEX	8	0.020	99.0	2.47E+03	2.05E+00	860	125
AR3	Aromatics > C8-C10	3	0.006	120	1.27E+03	3.90E-01	866	150
AR4	Aromatics > C10-C12	4	0.008	130	4.14E+00	2.35E-01	888	200
AR5	Aromatics > C12-C16	22	0.037	150	8.72E-03	1.10E-01	1156	260
AR6	Aromatics > C16-C21	47	0.062	190	2.13E-05	3.10E-02	1235	320
AR7	Aromatics > C21-C34	120	0.125	240	9.16E-08	3.17E-03	1216	340
AL1	Aliphatics > C6-C8	55	0.137	100	6.38E+03	1.42E-01	695	96

TABLE 5.4.7

PROPERTIES OF CLWB (continued)

Pseudo-component	Description	Concentration (g/kg)	Molar Fraction	Molecular Weight (g/mol)	Vapour Pressure (Pa)	Solubility in Water (mol/m^3)	Density (@ 20 or 25 °C) (g/cm^3)	Boiling Point (°C)
AL2	Aliphatics > C8-C10	20	0.038	130	6.38E+02	1.45E-02	721	150
AL3	Aliphatics > C10-C12	16	0.025	160	6.38E+01	1.48E-03	740	200
AL4	Aliphatics > C12-C16	40	0.050	200	4.86E+00	5.51E-05	765	260
AL5	Aliphatics > C16-C21	46	0.043	270	1.11E-01	2.70E-07	781	320
AL6	Aliphatics > C21-C34	60	0.038	390	2.59E-06	6.31E-12	800	467
RES1	F4 (> C34-C50)	110	0.048	570	1.00E-10	5.25E-15	998	---
RES2	Resins	295	0.089	825	1.00E-10	9.55E-08	1008	Na
RES3	Asphaltenes	80	0.013	1599	1.00E-10	3.24E-16	1166	Na

5.4.4.2 Characteristics of the Shipping Route

5.4.4.2.1 Configuration

The shipping route, Figure 1.3.1, was previously described in Section 2.2. As was discussed in greater detail in Section 5.2, the hypothetical locations where an oil spill from a Project-related tanker could occur were described in Table 5.2.2 and are mapped on Figure 5.5.2. These hypothetical locations were used by EBA to model the fate and behaviour of hypothetical accidental oil spills from a Project-related tanker.

An accidental oil spill from a Project-related tanker in transit would spread and move away from the spill site, depending on local currents, driven by winds, tides and estuarine circulation. The waters between Vancouver Island and the mainland and the interconnecting channels form a deep, topographically complex and strongly tidal estuarine system. Freshwater from the Fraser River, as well as other rivers draining into these waters, provide a driving force for a strong estuarine circulation, which leads to a seaward set to currents along the bulk of the shipping route. This estuarine circulation persists out onto the continental shelf, aided by additional fresh water from the Columbia River.

5.4.4.2.2 Meteorology

The descriptions of winds provided hereinafter are informed by the general discussions in Thomson (1981) and two Environment Canada publications (Lange 1998 and 2003), as well as the data that is included in this section. In general, large-scale wind patterns in the Project area (as depicted in Figure 1.3.1) are the result of the relative positions of the Aleutian Low, which is located over the Gulf of Alaska and the Aleutian Islands, and the North Pacific High, located between Hawaii and California. The counter-clockwise circulation around the Low and the clockwise circulation around the High produce a general westerly upper-level flow onto the Southern Coast of BC.

At the surface, the two major pressure systems, the Aleutian Low and the North Pacific High, drive a general circulation characterized by south-easterly winds in the winter, and north-westerly winds in the summer. Additionally, migratory low and high-pressure systems move through the area, producing day-to-day changes in weather and wind patterns. Low pressure systems can develop offshore, more frequently during the winter, either originating from the Gulf of Alaska or as rapidly forming Coastal Lows, referred to as "Coastal Bombs" (Murty *et al.*, 1983) because of their short time scale and high intensity winds. Ahead of these systems, strong south-easterly winds and rain are produced. Often, as the cold front passes, a second band of winds occur, originating from the west or northwest. These north-westerly winds can be particularly strong in spring and occasionally in summer as high pressure begins to rebuild and winds are funnelled down the Strait of Georgia (EC 1999). Often, there are few indicators of the onset of these winds.

On occasion during the winter, outflows occur as cold arctic air deepens over the interior of BC and flows through the Coastal Mountain passes, out over coastal waters. Such events can produce very strong localized winds, particularly through Howe Sound, but are generally infrequent events on the South Coast.

Typically during the summer, the presence of high pressure off the coast and a thermal low over the interior produce a general north-westerly flow. Winds are typically light and are replaced by strengthening onshore winds later in the day as a result of land-sea heating differences. These onshore winds produce inflow winds through Juan de Fuca Strait and Howe Sound.

Thunderstorms are infrequent in the study area, but form with very strong winds and dissipate quickly.

Wind patterns in this coastal region are complicated due to the mountains and coastal topography and the land-sea contrast. Topography heavily influences the winds by restricting and steering horizontal movement and can lead to hazardous conditions in passes or channels and in the vicinity of headlands and islands. During the passage of a storm, a particular location may experience rapid changes in wind direction and wind speed.

5.4.4.2.3 Oceanography

Patterns of currents and waves differ to various degrees from one area to another, due to the complexity of the physiographic, oceanographic and hydrographic settings. Currents are driven by the interaction of freshwater drainage from land, precipitation, the salty waters that originate from the Pacific Ocean, tidal fluctuations, winds and other physical processes. The general description of circulation and wave climate provided in this document is based on Waldichuk (1957), Thomson (1981), Labrecque *et al.* (1994), Masson (2005). Water level and its fluctuations vary from one location to another as a result of the complex processes that are involved in the tidal wave propagation. Added to the tidal fluctuations in water level is storm surge, the difference in elevation between the observed water level and the predicted tidal water level resulting from disturbances propagating in from the open ocean, usually coupled with air pressure gradients. The specific information about water level at various locations provided herein is based on tide books and hydrographic charts published by the CHS.

Wave fields in the study area depend on local wind patterns as well as the degree and direction of exposure to wave attacks. Swell propagating from the Pacific Ocean also plays a major role in governing the wave climate in Juan de Fuca Strait and the Pacific Ocean off the West Coast of Vancouver Island.

5.4.4.3 The Modelling System

EBA's proprietary oil spill model SPILLCALC was used for the simulations described here. SPILLCALC is a stand-alone model, but relies on other models and observational data bases. For this Project, the main models used were:

- a three-dimensional hydrodynamic model, H3D;
- a wave model, SWAN; and
- a spill simulation model, SPILLCALC.

The Technical Report (Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project, contained in Volume 8B, TR 8C-12, S9) provides a more complete description of these models. The relevant features of these models are summarized in the following paragraphs.

5.4.4.3.1 HYDRODYNAMIC MODEL: H3D

Although the dominant currents affecting an oil spill are the surface currents, the best way to obtain realistic currents is to use a three-dimensional model. In this way, processes such as wind-driven currents, river plumes and large-scale estuarine circulation are correctly included in the calculation of surface currents. Surface currents for the oil spill simulations were hindcast using a proprietary three-dimensional hydrodynamic model, H3D. This model is derived from GF8 (Stronach *et al.*, 1993) developed for Fisheries and Oceans Canada. H3D has been used on several studies along the BC coast. An extensive application of an operational version of this model to the St. Lawrence Estuary is described in Saucier and Chassée (2000).

The following key points provide further information on the hydrodynamic characteristics of the model.

- Tidal constituents from the CHS were used to provide water level data at the oceanic boundary of H3D. Tidal currents at the boundaries are generated by the model, and are the response of the basin to the fluctuating water levels on the boundaries.
- Wind forcing causes both currents and water level differences. Consideration of wind forcing is also important because wind energy has a notable effect on vertical mixing, and therefore scalar distributions. Wind stresses acting at the water surface are derived from wind records collected from coastal Meteorological Service of Canada stations and moored buoys.
- The model incorporates inflows from 50 rivers and creeks throughout the model domain. These inflows contribute mass and momentum to the waterbody. Where available, all input river flows are generated from daily hydrographs of the particular river under consideration.
- In addition to wind, other meteorological data are also needed to compute heat flux into the waterbody and thus its temperature structure. These data are obtained from the Halibut Bank buoy, with the exception of cloud cover, which was obtained from the Vancouver International Airport meteorological station. In the summer, heat input leads to increased temperature stratification. In the winter, when salinity stratification is often minimal, cooling can lead to static

instabilities and overturning in the upper part of the water column. H3D's ability to simulate both summer heating and winter cooling has been rigorously verified in simulations done for freshwater lakes, where adequate temperature data is more routinely available over several years (Zaremba *et al.* 2005).

- Turbulence modelling is important in determining the correct distribution of velocity and scalars such as temperature and salinity.
- The model operates in a time-stepping mode over the period of simulation. The time-step length is variable, depending on the maximum velocity present in the model at that particular time-step.
- The model is initialized with salinity and temperature fields obtained by interpolating observations archived at the Institute of Ocean Sciences. An initial condition of zero velocity is chosen, and the water level is set to mean sea level initially. The model is run in prognostic mode from this initial state, with the tide and wind being ramped up over one day. The first 15 days of the run are discarded, as they are deemed to be contaminated by start-up transients.
- Oceanic boundary conditions for salinity and temperature were available via models maintained by the Alaska Ocean Observing System (AOOS). The southern boundary of this model domain is approximately 450 km south of the mouth of the Juan de Fuca Strait, and the AOOS provides and archives model predictions every 4 hours since early 2011. These data were downloaded and used to provide realistic boundary conditions to H3D.

5.4.4.3.2 Wave Model: SWAN

The oil spill model, SPILLCALC, requires wave conditions as an input to its weathering processes. Wave conditions for the simulation period were hindcast using SWAN version 40.72 (Booij *et al.*, 2006). For consistency with the hydrodynamic inputs, wave conditions were simulated on the same set of computational grids as were used for the hydrodynamic modelling.

SWAN is a third-generation wave model for obtaining realistic estimates of wave parameters in coastal areas, lakes, reservoirs and estuaries from given wind and bottom conditions. SWAN utilizes a finite difference scheme to compute random, short-crested wind generated waves. SWAN incorporates physical processes such as wave propagation, wave generation by wind, whitecapping, shoaling, wave breaking, bottom friction, sub-sea obstacles, wave setup and wave-wave interactions in its computations. It is thus well-suited to computing a wave field as it propagates from the Pacific into the Strait of Georgia, Burrard Inlet and the Fraser estuaries.

For the 1-km grid model, covering the Salish Sea and extending out onto the continental shelf, SWAN used the same computational domain and bathymetry as the corresponding hydrodynamic model. The wind inputs were also the same as those used in H3D. Wave boundary conditions along the southwest and northwest edges of the domain were taken from the La Perouse Bank and South Brooks wave buoys. These buoys do not record wave direction. Therefore, to best agree with the wave directions observed at Neah Bay, boundary waves were assumed always to come from the west.

This model also provided boundary condition data for the other nested models: the 200-m grid model of the central Strait of Georgia, the 125-m grid model of Burrard Inlet and the 50 m × 20 m grid model of the Fraser River.

5.4.4.3.3 SPILLCALC

SPILLCALC is a time-stepping model that computes the motion and weathering of liquid hydrocarbon spills. It can be implemented in one of two different versions: stand-alone and embedded within the hydrodynamic model H3D. The stand-alone version contains interfaces to the output from one or more H3D circulation models. SPILLCALC uses currents from this model to move the spill. Oil released on the water surface is represented as a large number of independent floating particles, referred to as slicklets. Individual slicklets are not intended to be physically meaningful. Instead, the cloud of particles as a whole is the area covered by the spill, and its progress is the spill's dispersion and trajectory. Each slicklet knows its volume and the volume fraction of each pseudo-component, age, the amount on intertidal banks, and whether or not the oil is in the form of a tar ball.

5.4.4.4 Oil Weathering Processes

5.4.4.4.1 Evaporation

In SPILLCALC, there are two mechanisms to specify the evaporation process: first, the fairly standard approach of calculating the mass flux based on wind speed, equilibrium pressure for the constituent and molar concentration of the constituent in the total product. This method is used in ADIO 2, for instance. However, SPILLCALC includes an additional mechanism, the effect of the slow rate of molecular diffusion within diluted bitumen. Molecular diffusion is responsible for bringing the lighter fractions to the evaporating surface, to replace the losses due to evaporation. In general the rate of molecular diffusion through the vertical extent of the slick is slower than the rate of evaporation from the surface, so that in fact the controlling mechanism is the internal diffusion process. SPILLCALC calculates both rates, and the slower of the two is used to calculate the rate of evaporation. The diffusion coefficient used was similar to those reported by Afsahi and Kantzas (2006) for pentane diffusion in Cold Lake bitumen, but was adjusted slightly to values that would reproduce the Gainford Study results (Volume 8C, TR 8C-12, S7). Figure 5.4.15 shows the simulation of the observed density in the Gainford Study static CLWB test. The density of the oil is a relatively sensitive indicator of the amount of evaporation: the faster evaporation occurs, the faster the density will increase. The near-exact reproduction of the time rate of change of density in Figure 5.4.15 is a strong indicator that the observation that CLWB does not readily sink in brackish waters is supported by a reasonable theoretical explanation.

5.4.4.4.2 Vertical Dispersion and Resurfacing

Breaking waves drive small droplets of the oil into the water column. Depending on the natural turbulence in the water and the size and density of the droplets, the dispersed oil will generally stay suspended in the water column and will be prevented from resurfacing as long as the dispersing mechanism, breaking surface waves, remain active. When wind and waves die down, the dispersed oil will generally rise to the surface. The process of vertical dispersion has been implemented in SPILLCALC using equations developed by Delvigne and Sweeney (1988), which are also used to compute dispersion in the NOAA ADIOS2 model. The process of resurfacing was implemented in SPILLCALC using the equations developed by Tkalich and Chan (2002). A unique feature of SPILLCALC is that the wave field was generated by a reliable and widely used wave model SWAN, whereas most spill models estimate waves from wind speed and fetch. The use of SWAN provides much more realistic wave energy for computing vertical dispersion.

5.4.4.4.3 Contact with Shorelines

SPILLCALC uses a shoreline provided by Coastal and Ocean Sciences (Methods for Estimating Shoreline Oil Retention in Volume 8C, TR 8C-12, S11). The shoreline is based on BC and Washington State databases, and includes not only shore location, but also coastline type, and a value for oil retention. Oil retention was calculated based on shore types and the know properties of dilbit, especially it's relatively high viscosity.

When a slicklet intersects the shoreline, SPILLCALC activates a shore retention algorithm. If there is capacity for that shoreline segment to retain more oil (*i.e.*, if it has not been filled up by a previous encounter with the oil slick), that amount of oil is taken from the slicklet is transferred to the shoreline, up to the minimum of the amount of oil in the slicket, and the capacity of the shoreline segment to hold additional oil.

5.4.4.4.4 Contact with Beach and Intertidal Areas

A potential issue of concern is the extent to which oil would come into contact with intertidal sand and mud flats and adversely affect benthic invertebrates and bio-films. In addition to entering beach and mud flat sediment via the shore contact process, SPILCALC contains an algorithm to simulate stranding of oil as water levels fell below the level of the beach or sand flat cell. The algorithm used was that all the oil on the water surface in a particular cell would be transferred to the sediment on a falling tide, once the water depth dropped below 2 cm. No provision was made to re-float the trapped oil on a rising tide. This procedure is likely to overestimate the amount of oil that is stranded, and hence overestimates the amount of oil trapped in the intertidal.

5.4.4.4.5 Small-Scale Spreading

In addition to the vertical diffusion within the slick, the area covered by the slick plays a major role in the evaporation subroutine. A spreading experiment conducted at the WCMRC facility showed that the lateral spreading of the oil is limited and that a minimum thickness is observed. This minimum thickness is 0.4 mm, as described in the Spreading Observation Memo, Appendix B of the Technical Report (Volume 8C, TR 8C-12, S9). As a result, an effective area was used in the evaporation process, based on the volume of oil in one cell and the minimum thickness it can reach. The ratio of the effective area over the area ranges between 0 and 1. At the beginning of the simulation, the effective area is very close to the cell area, since the oil slick is very concentrated close to its release point. As time goes by, the effective area becomes smaller, representing the patchiness developing in the slick.

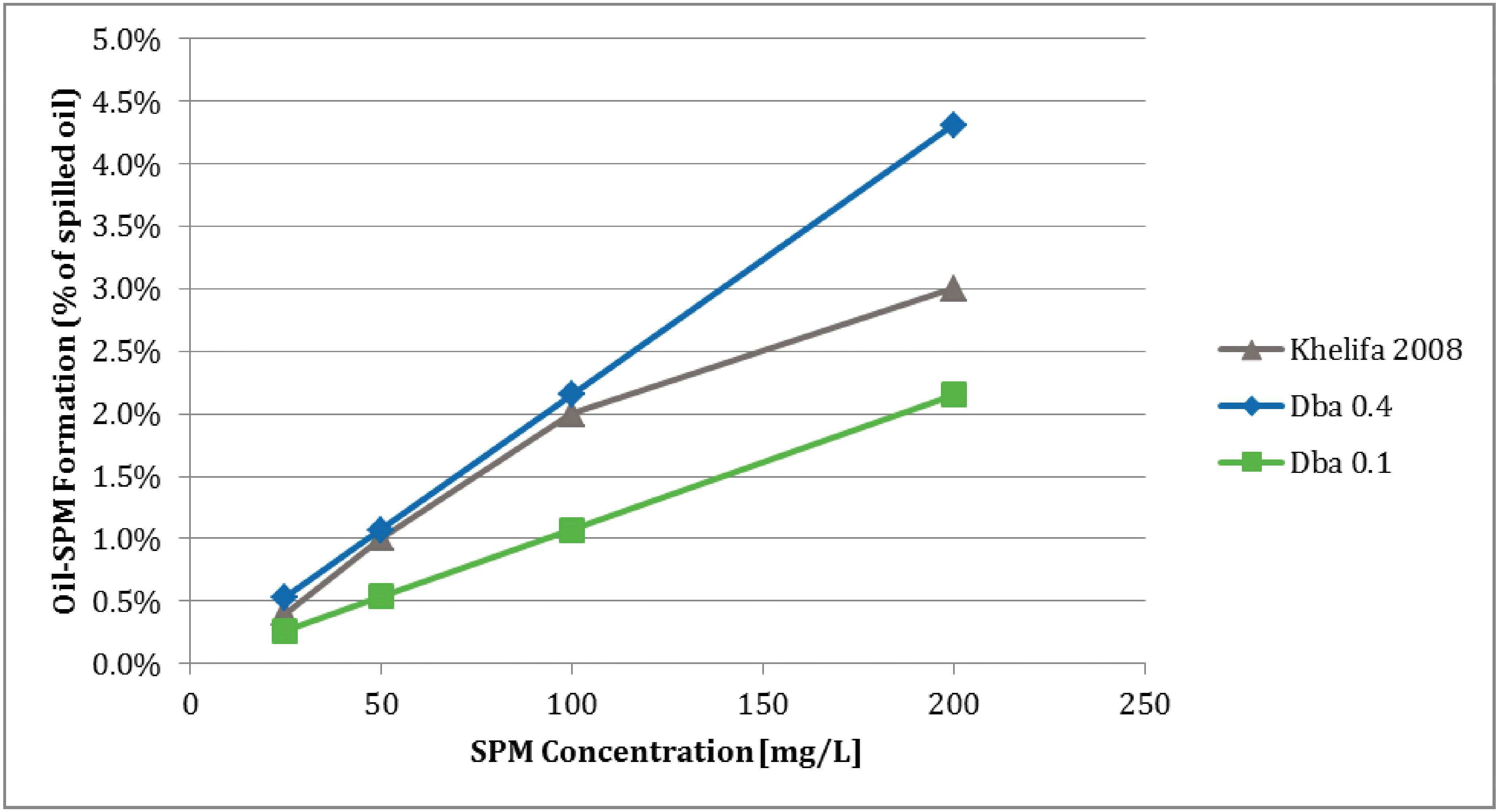
5.4.4.4.6 Oil-Sediment Interaction

The formation of oil-mineral aggregate is another process that can affect the behaviour of an oil slick. In river and estuary areas, where the fine sediment load is usually higher than the one in the ocean, the interaction between oil and fine sediment is crucial in assessing the impact of a spill on the environment.

The method used in the SPILLCALC model follows the same approach as in the NOAA ADIOS2 model. The approach was proposed by J.R. Payne (Payne *et al.* 1987) and incorporates the effect of water turbulence.

The oil spill model, SPILLCALC, uses time-varying wave data computed by SWAN and time-varying sediment concentration computed by H3D to calculate the interaction of oil with sediments, making it difficult to reproduce laboratory conditions.

The calibration and the validation of the SPILLCALC oil-sediment interaction module was conducted using data reported by Khelifa, Fingas and Brown (2008). The rate of energy dissipation in the breaking wave field was used in place of the mechanical agitation energy in the reported s experiments. Good agreement was obtained using the SPILLCALC formulation in a hindcast of these experiments, as shown in Figure 5.4.16.



NOTES

- Conditions from Khelifa's experiment were reproduced to the best extent into the oil spill model SPILLCALC.

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TRANS MOUNTAIN OIL SPILL STUDY

Percentage of Oil-SPM Interaction

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	JAS	0

OFFICE	DATE
EBA-VANC	October 28, 2013

Figure 5.4.16

5.4.4.4.7 Emulsification

Emulsification is a process whereby oil and water co-mingle and form an emulsion, usually requiring wave energy to mix the two liquids. The emulsification process can be qualitatively seen as the opposite of the vertical dispersion process: during oil emulsification, oil takes up water to form the emulsion, whereas during vertical dispersion, the oil droplets are surrounded and mixed in the water content.

The formation of emulsions can change the properties and characteristics of the oil drastically. Depending on the state of the emulsion (stable, meso-stable or unstable), the volume of spilled material may contain 50 per cent up to 80 per cent of water, thus expanding the volume of the spilled material considerably (Xie *et al.*, 2007).

Formulas for the water uptake and the emulsion stability were proposed by Mackay *et al.* (1980) and Mackay and Zagorsky (1982) respectively. Amongst others, the emulsification has a strong impact on the evaporation process. The inhibition of evaporation rises with increasing water content and slick thickness. SPILLCALC follows the method developed by Ross and Buist (1995): evaporation is assumed to have a linear relationship with the water content.

5.4.4.4.8 Dissolution

Some of the lighter hydrocarbon fractions are soluble in water; they will dissolve in the underlying water column. The solubility of the pseudo-components are given in Table 5.4.7. The potential for dissolution is a function of the pure component solubility, the mole fraction of the hydrocarbon and the mass transfer coefficient. The rate of dissolution is computed according to the equation published by MacKay and Leinonen (1977) and uses their value for a mass transfer coefficient: 2.36 e-6 m/s.

This flux is applied as a loss to the oil slick, in a similar manner to the evaporation process. In order to compute concentrations in the water column of these lighter fractions, some of which are quite toxic, SPILLCALC is operated within the hydrodynamic model H3D. The flux from the oil slick enters the top layer of H3D, and is then acted on by the same processes of advection and diffusion that apply to all the other scalars, such as temperature and salinity. This method is applicable to a three dimensional simulation of the dissolved oil in the water column.

5.4.4.4.9 Bacterial Decay

Despite its toxicity, a considerable fraction of petroleum oil entering marine systems is eliminated by the hydrocarbon-degrading activities of microbial communities, in particular the so-called hydrocarbonoclastic bacteria (HCB). *Alcanivorax borkumensis* is one of the HCB family and is an alkane-degrading marine bacterium which naturally propagates and becomes predominant in crude-oil-containing seawater when nitrogen and phosphorus nutrients are supplemented. They are currently thought to be the world's most important oil-degrading organisms.

The biodegradability of the oil components generally decreases in the following order: n-alkanes, branched-chain alkanes, branched alkenes, low molecular-weight n-alkyl aromatics, mono-aromatics, cyclic alkanes, polycyclic aromatic hydrocarbons (PAHs) and asphaltenes (Atlas 1981).

Uncertainty is present regarding the population size of such bacteria along the tanker route. Since the initial bacteria population is rarely well known, most models having a biodegradation module use a first order bacterial decay process in which the rate of oil biodegraded is proportional to the initial mass and an empirical decay coefficient, *i.e.*, m = m0, exp(-kt). The empirical decay coefficient was selected as being in the same order of magnitude than the first order biodegradation rate constants from field studies (Niu *et al.*, 2011 and Zhu *et al.*, 2004)

5.4.4.5 Four Representative Marine Spill Scenarios

In order to understand the fate and behaviour of spilled oil, representative scenarios were selected, and then analyzed using EBA's numerical spill modelling system. Representative scenarios were modeled without spill response measures applied to mitigate the effect of an accidental oil spill in order to provide conservative results. Two considerations entered into the selection of representative spills:

- selecting the areas of highest probability of a spill; and
- selecting areas to represent the range of variability in oceanographic and meteorological conditions.

As described in Section 5.2.2, the quantitative risk assessment (Volume 8C, TR 8C-12) examined the risk of an accidental spill from a laden oil tanker carrying product from the Westridge Marine Terminal. Eight locations along the tanker transit route were selected as possible locations for a hypothetical accident involving a Project-related laden oil tanker and resulting in an oil spill. These 8 locations were described in Table 5.2.2 and are further identified in Figure 5.5.2. Five of the eight locations were modelled for the purpose of a hypothetical spill scenario. One of the modelled locations is at the Westridge Marine Terminal and the results of modelling at this location are provide in Volume 7, Section 8.0, leaving four locations that were modelled along the shipping route a Project-related tanker would travel.

Four of the seven possible locations along the tanker transit route listed in Table 5.2.2 were selected for modelling the oil spill behaviour that is likely to be encountered:

- Strait of Georgia (Location D);
- Arachne Reef (Location E);
- Juan de Fuca Strait (south of Race Rocks) (Location G); and
- Buoy J (Location H).

Three locations in along the shipping route (Table 5.2.2) were not modelled as the incident would not likely result in an oil spill.

5.4.4.6 Stochastic Simulations

Stochastic modelling is widely used to develop an understanding of the likely behaviour of an oil slick without spill response measures applied. Typically, the major driving force for slick motion is wind-driven currents, and it is fairly common to randomly select a number of scenarios, *i.e.*, random sampling of a wind dataset should produce a smaller number of wind events to be modelled, but with the same statistics (means, max, etc.) as the original series. For the simulations conducted to examine the risks associated with the Trans Mountain Expansion Program, it is important to recognize that wind, tide, offshore processes and estuarine flows drive the slick motions. In order to provide a truly random stochastic simulation, many years of numerical model runs would have to be generated before the process of random selection can start. A limitation on these simulations is that high quality boundary condition data, from a large-area model operated by Alaska Fisheries, is only available for the last two years.

Consequently, the approach taken was to simulate a particular period (in this case October 1, 2011 to September 30, 2012), and sample it at 6-hour intervals. That is, every 6 hours, an independent spill is assumed to occur, and its motions and weather are calculated and recorded for a 15-day period. The simulations were segregated into four seasons: winter (January, February and March), Spring (April, May, and June), Summer (July, August, and September) and Fall (October, November and December). For spills starting every six hours, each season contains a compilation of about 360 independent spills. These spills are fully-calculated: motions, weathering, shore contact are all operative. For each season, various statistical summaries were calculated. A complete set of results is presented in the Technical Appendix (Volume 8C, TR 8C-12, S9). For this document, important summary information is presented.

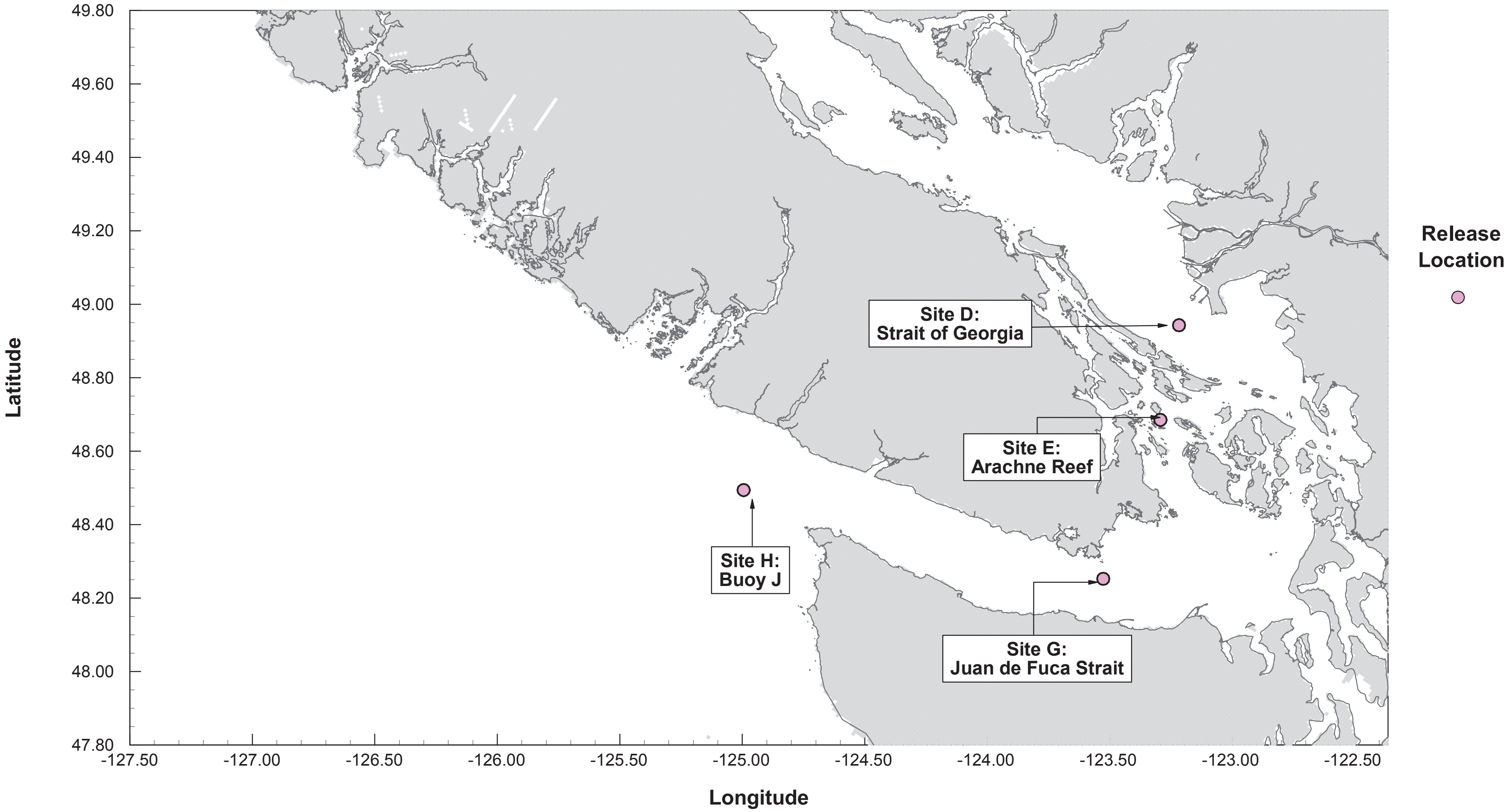
5.4.4.7 Stochastic Results

Each seasonal stochastic model run consists of a compilation of approximately 360 independent simulations. The simulations are constructed on a spatial grid, with individual cells having dimensions of 500 m × 500 m. An extensive set of data products can be generated for each stochastic simulation, and are provided in the Technical Reference (Appendix 8C, TR 8C-12, S9). In this Section, attention is directed to the following sub-set for spills at each location (Figure 5.4.17):

- Stochastic maps: show the probability that a particular 500 m × 500 m piece of water will be contacted by a spill starting at the modelled release point, expressed as per centage contours.
- Amount of oiled shoreline per spill: expressed in kilometres, and shown on a per-spill (member of the 360 stochastic simulation set) basis.
- Mass balance of the fate of the oil at a particular time after the release started: volume on water, volume evaporated, volume that was retained on shorelines, volume that dissolved, volume that was dispersed, volume that bio-degraded, and volume lost through oil-mineral aggregation.

Seasonal similarities and differences can be identified by comparing the previously described statistical properties over all four seasons for a particular location.

All of the scenarios discussed in this section were modelled without spill response intervention, the effects of the spills modelled here are unmitigated by response efforts. A discussion of spill response capacity is included in Section 5.5 and the results of spill models run with response intervention are discussed in Section 5.7.



NOTES

- Sites location based on the DNV Memo, dated February 26, 2013.

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TRANS MOUNTAIN OIL SPILL STUDY

Spill Locations for the Stochastic Simulations

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	JAS	0

OFFICE	DATE
EBA-VANC	October 28, 2013

Figure 5.4.17

5.4.4.7.1 Location D, Strait of Georgia

Location D is located in the Strait of Georgia between the Tsawwassen Ferry Terminal and the Southern Gulf Islands, as shown in Figure 5.5.2. This location has been determined to be representative of a collision with crossing traffic from either the Fraser River or BC ferries. As noted in Section 5.2.1, Table 5.2.1, the potential volume of oil spilled in a credible worst case is predicted to be 16,500 m^3. The simulated duration of the release is 13 hours: 25 per cent of the volume is released in the first hour, and the balance released at a uniform rate over the next 12 hours.

The general wind pattern at Location D is mainly south-east and north-west winds which rarely exceed 20 m/s.

Figures 5.4.18 and 5.4.19 show the 50 per cent (P_{50}) and 90 per cent (P_{90}) probability maps at Hour 24, *i.e.*, 24 hours after the start of the incident, and Hour 48. The contours shown on these maps represent the probability that oil from the compilation of spills lies within the given area; they do not represent the area affected by any single spill. In general, a wider range of probabilities is presented in a typical stochastic probability map, but selecting only two contours simplifies the discussion. Presenting the probabilities at shorter duration (6, 12, 24, and 487 hours) is useful when discussing mitigation measures and the response time needed for effective mitigation. These are provided in Volume 8C (TR 8C-12, S9).

Figure 5.4.18, for 24 hours, illustrates the importance of using an adequate hydrodynamic model: the combination of prevailing northwest winds and the influence of the Fraser River are key factors in determining the seasonal variability, which causes the summer P_{50} contours to extend over an area about 50 per cent larger than the winter P_{50} region. As well, northwest winds and the estuarine flow, causing surface water to leave the Strait and flow toward the open Pacific, lead to an elongation of the spill to the southwest in the summer and fall. After 48 hours, the P_{50} contour has moved into Boundary Pass and almost to the top end of Haro Strait. The most striking difference between the situation at 25 hours and at 48 hours, regardless of season, is two- to three-fold increase in the area within a particular probability contour. This comparison illustrates profoundly the benefit to be gained by developing mitigation strategies that are in the field and operational within a very few hours of the start of the incident. Although not shown here, the minimum time to reach a particular location or shoreline is also helpful in developing mitigation strategies.

The length of shoreline oiled is relevant for determining potential ecological damage, and for estimating shoreline clean up resources that would be required in the event of a spill. Figure 5.4.20 illustrates the length of shoreline contacted by oil for each member of the summer simulations. The variability across all the spills within one season is quite remarkable, and illustrates the significant day-to-day changes in winds and currents that can occur in the study area. Basic statistics on shoreline oiling for all seasons are presented in Table 5.4.8.

TABLE 5.4.8

STATISTICS FOR SHORELINE CONTACT FOR A CREDIBLE WORST CASE SPILL AT LOCATION D (NO MITIGATION APPLIED)

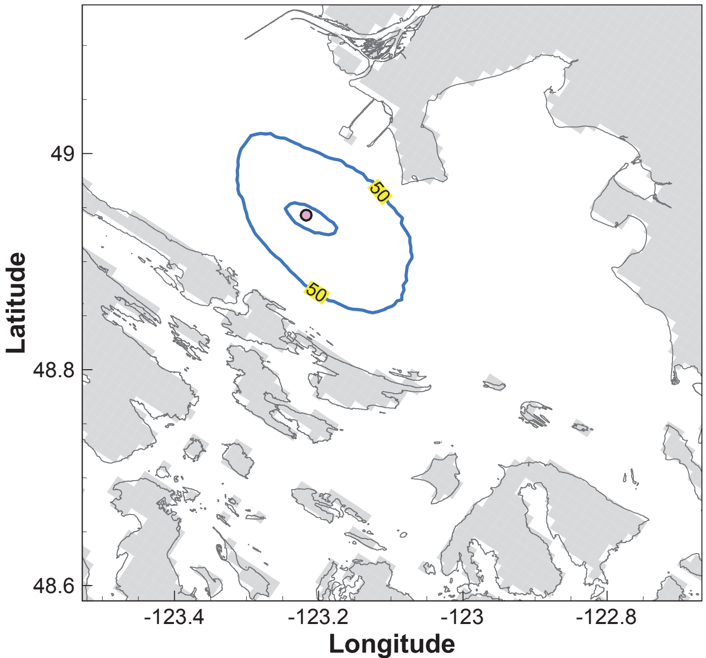
	Median (km)	Average (km)	Maximum (km)	Minimum (km)
Winter	271	263	388	105
Spring	296	291	436	97
Summer	284	279	414	71
Fall	296	293	425	106

The mass balance of the spilled oil provides a good summary of a particular spill, or, when averaged across all spills, a good understanding of spill behaviour for a spill that would occur in a particular season. Figures 5.4.21 and 5.4.22 show the mass balance for the summer spill scenario. Figure 5.4.21 shows the major components: on water, on shore and evaporated, and Figure 5.4.22 shows the minor components: dispersed, bio-degraded, on banks and dissolved. Table 5.4.9 summarizes the mass balance for all four seasons at the end of the 15-day stochastic simulation period. The amount of oil bound up in oil-mineral aggregations was negligible, even for this site, which would be influenced by the Fraser River Plume.

TABLE 5.4.9

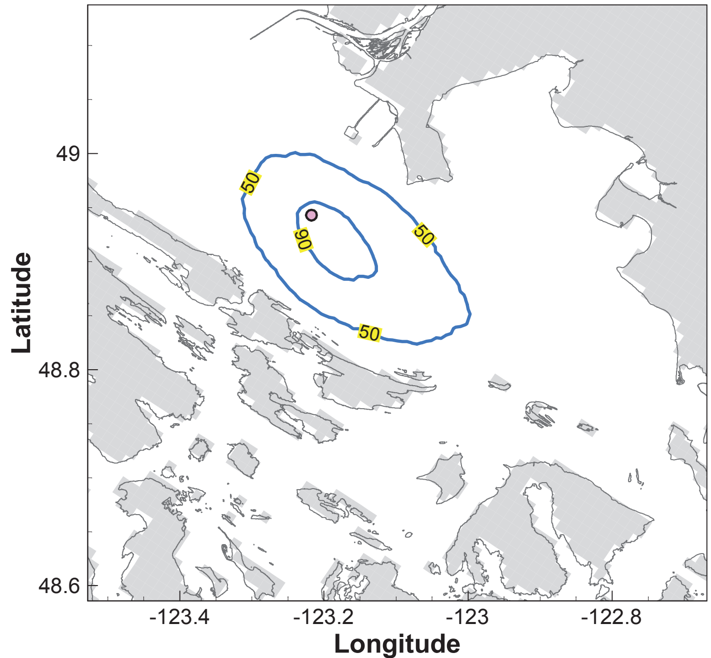
MASS BALANCE SUMMARY FOR A CREDIBLE WORST CASE SPILL AT LOCATION D (NO MITIGATION APPLIED)

Component	Winter	Spring	Summer	Fall	Yearly Average
On Shore	63.8	67.4	66.4	66.8	66.1
Evaporated	21.7	19.8	19.3	20.7	20.4
On Water	2.6	1.7	2.4	1.4	2.0
Dissolved	6.7	6.8	6.7	6.9	6.8
Biodegraded	3.2	2.8	2.7	2.8	2.9
On Banks	1.9	0.7	2.4	1.4	1.6
Dispersed	0.1	0	0	0.1	0.1



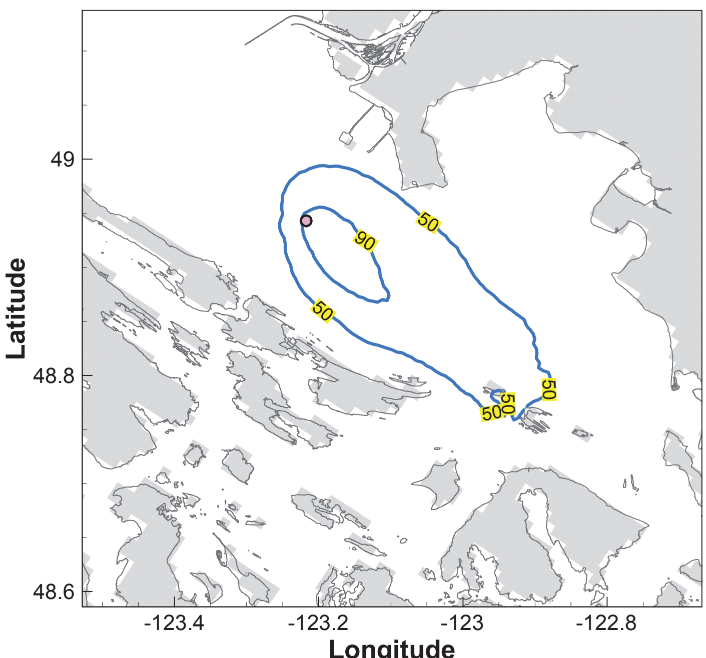
Winter 2012

Area within the P_{50} Contour Line:	217.5 km^2
Area within the P_{90} Contour Line:	9.8 km^2
Average Thickness within the P_{50} Contour Line:	48 um
Average Thickness within the P_{90} Contour Line:	100 um
Average Shore Oiled:	9.5 km



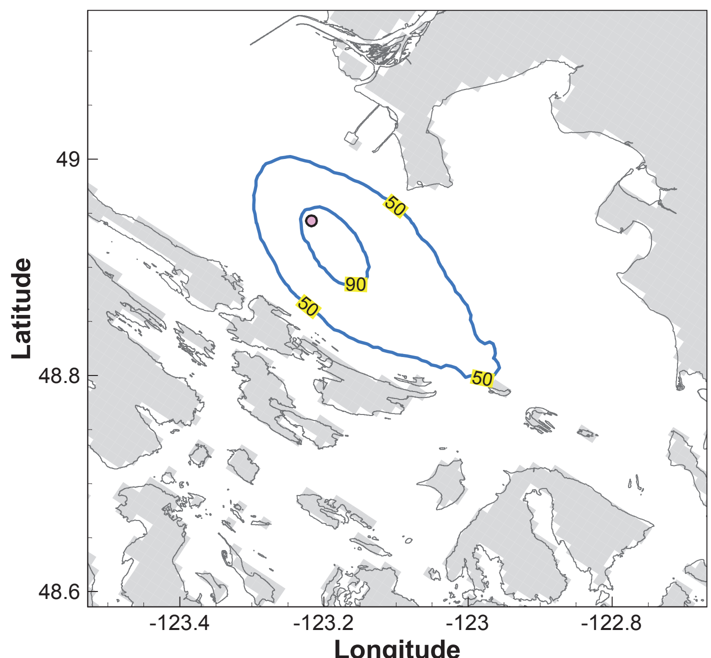
Spring 2012

Area within the P_{50} Contour Line:	285.0 km^2
Area within the P_{90} Contour Line:	41.8 km^2
Average Thickness within the P_{50} Contour Line:	42 um
Average Thickness within the P_{90} Contour Line:	63 um
Average Shore Oiled:	13 km



Summer 2012

Area within the P_{50} Contour Line:	364.2 km^2
Area within the P_{90} Contour Line:	48.8 km^2
Average Thickness within the P_{50} Contour Line:	34 um
Average Thickness within the P_{90} Contour Line:	57 um
Average Shore Oiled:	14.7 km



Fall 2011

Area within the P_{50} Contour Line:	308.0 km^2
Area within the P_{90} Contour Line:	36.3 km^2
Average Thickness within the P_{50} Contour Line:	37 um
Average Thickness within the P_{90} Contour Line:	62 um
Average Shore Oiled:	13 km

NOTES

● Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.
P_{50}: after 24 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.
P_{90}: after 24 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.
Statistical results for each season based on independent spills occuring every 6 hours for three months.
Tracking time for each spill was 24 hours.
The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
ISSUED FOR REVIEW

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A TETRA TECH COMPANY

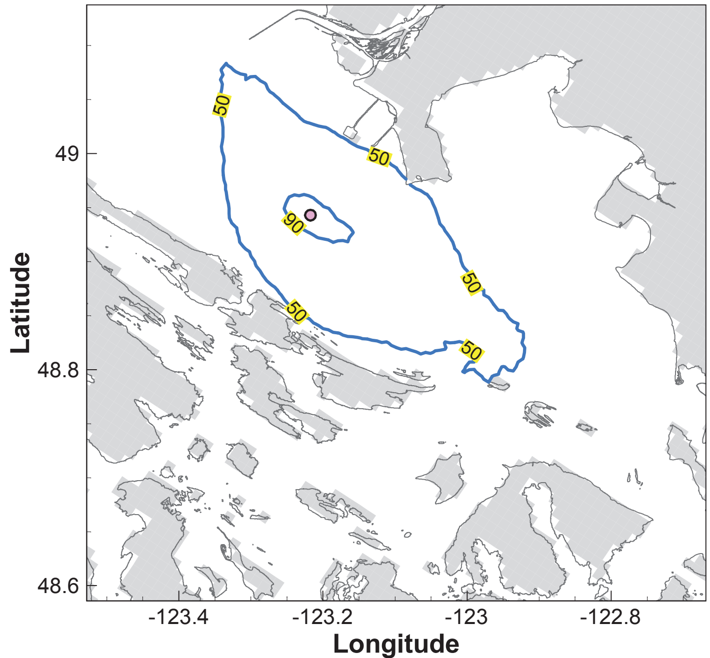
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Site D (16,500 m^3)
P_{50} and P_{90} after 24 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

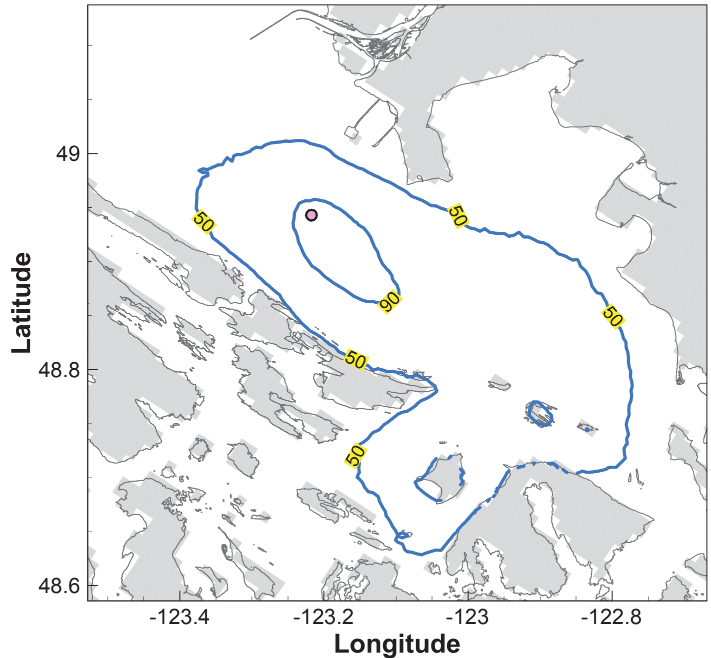
OFFICE	DATE
EBA-VANC	October 25, 2013

Figure 5.4.18



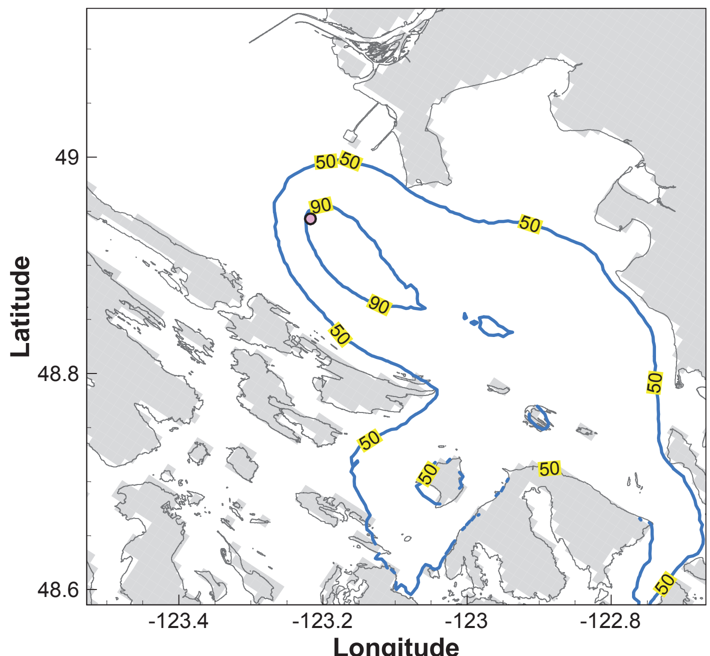
Winter 2012

Area within the P_{50} Contour Line:	495.2 km^2
Area within the P_{90} Contour Line:	19.8 km^2
Average Thickness within the P_{50} Contour Line:	25 um
Average Thickness within the P_{90} Contour Line:	67 um
Average Shore Oiled:	39 km



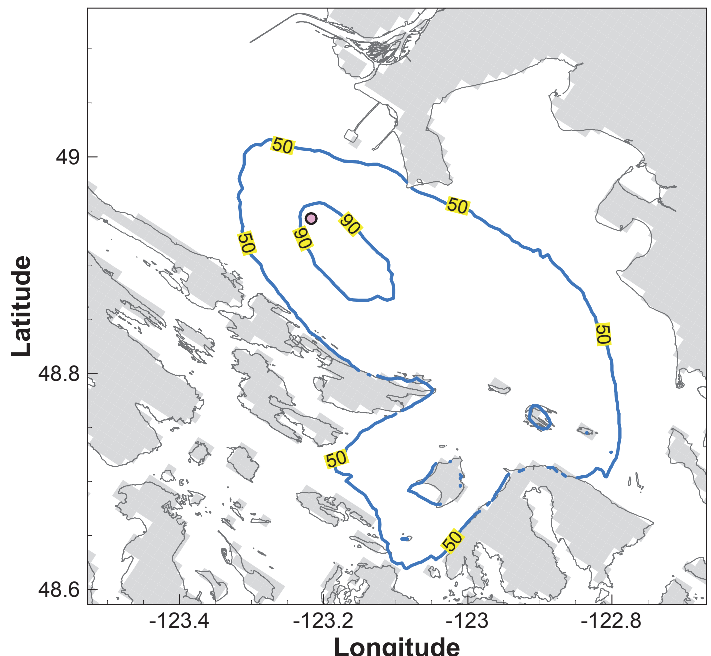
Spring 2012

Area within the P_{50} Contour Line:	957.5 km^2
Area within the P_{90} Contour Line:	66.8 km^2
Average Thickness within the P_{50} Contour Line:	15 um
Average Thickness within the P_{90} Contour Line:	44 um
Average Shore Oiled:	63 km



Summer 2012

Area within the P_{50} Contour Line:	1032.7 km^2
Area within the P_{90} Contour Line:	65.8 km^2
Average Thickness within the P_{50} Contour Line:	15 um
Average Thickness within the P_{90} Contour Line:	46 um
Average Shore Oiled:	77.5 km



Fall 2011

Area within the P_{50} Contour Line:	929.7 km^2
Area within the P_{90} Contour Line:	58.8 km^2
Average Thickness within the P_{50} Contour Line:	14 um
Average Thickness within the P_{90} Contour Line:	43 um
Average Shore Oiled:	63 km

NOTES

Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.
P_{50}: after 48 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.
P_{90}: after 48 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.
Statistical results for each season based on independent spills occuring every 6 hours for three months.
Tracking time for each spill was 48 hours.
The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
ISSUED FOR REVIEW

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TRANS MOUNTAIN OIL SPILL STUDY

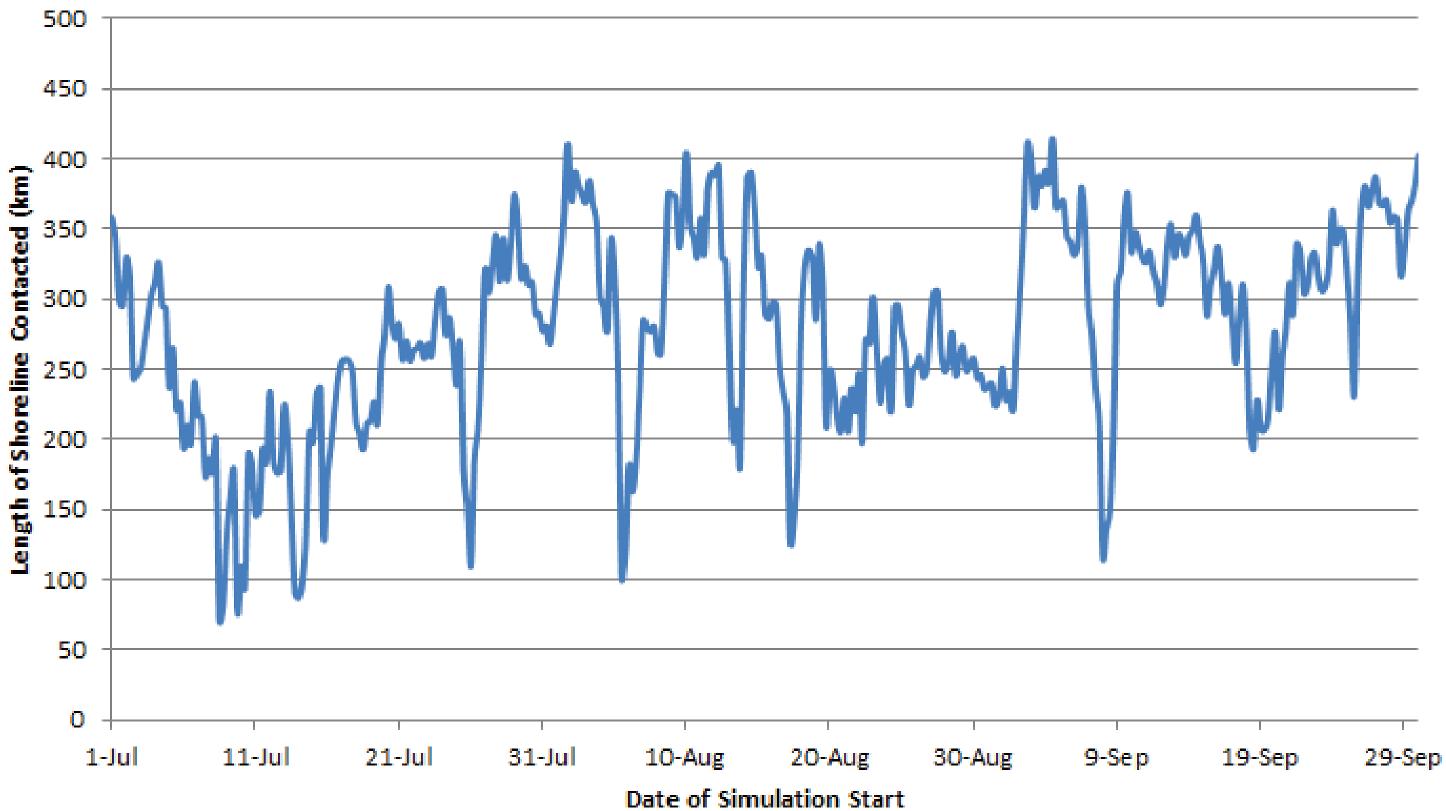
Stochastic Simulation
Site D (16,500 m^3)
P_{50} and P_{90} after 48 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

OFFICE	DATE
EBA-VANC	October 25, 2013

Figure 5.4.19

C:\Users\daniel.potts\Documents\Local_work\KinderMorgan\04-SPILLCALC\551-Stochastic_SOG_16500m3\Results_AllSeasons\14-stochastic_map_lines_48h.lay 25 Oct 2013 17:06:02



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.

- Tracking time for each spill was 15 days.

STATUS
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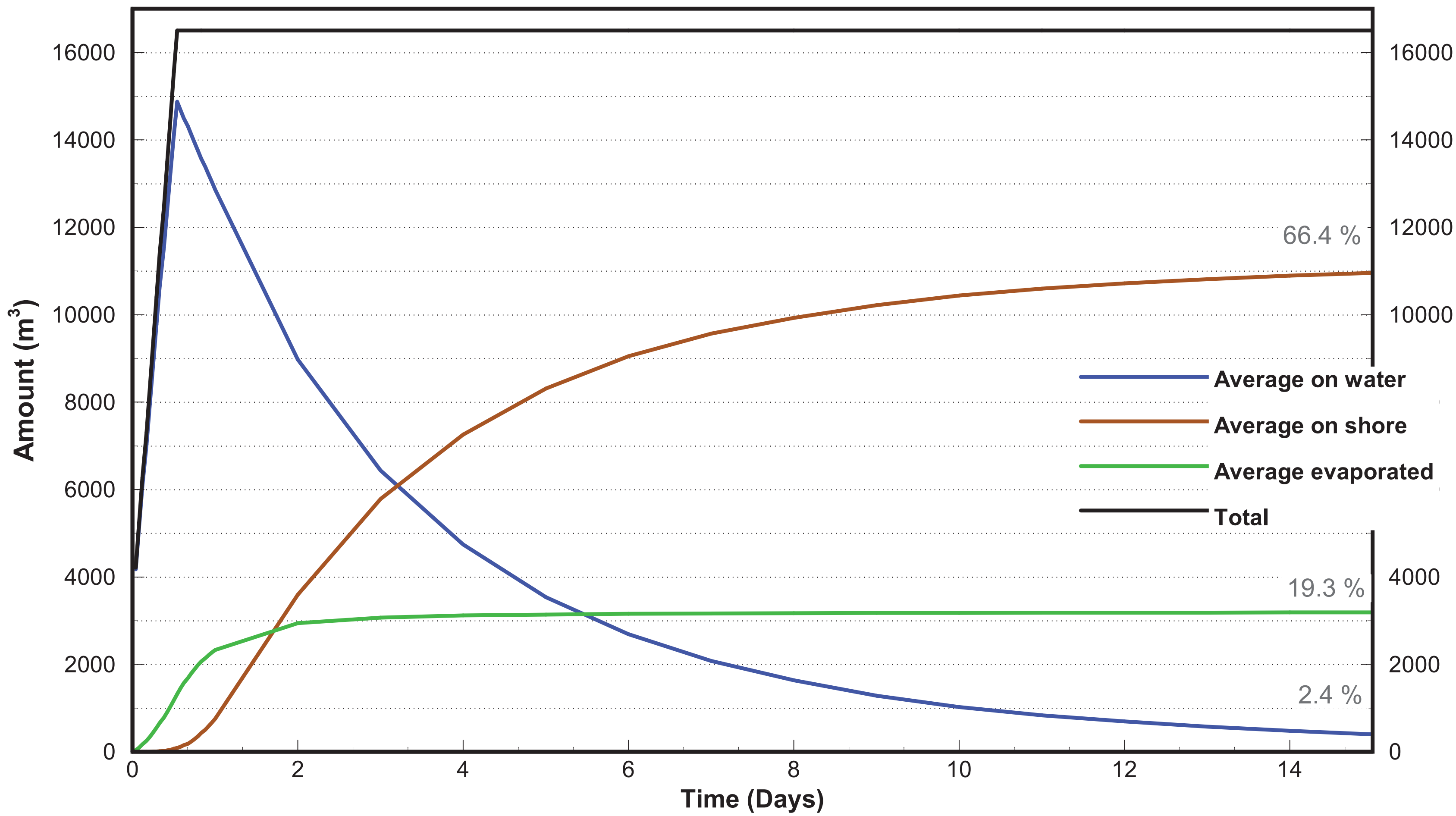
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site D (16,500 m^3)
Length of Shoreline Contacted

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 15, 2013

Figure 5.4.20



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00.
- Tracking time for each spill was 15 days.
- The major components of the mass balance are shown above.

STATUS
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A TETRA TECH COMPANY

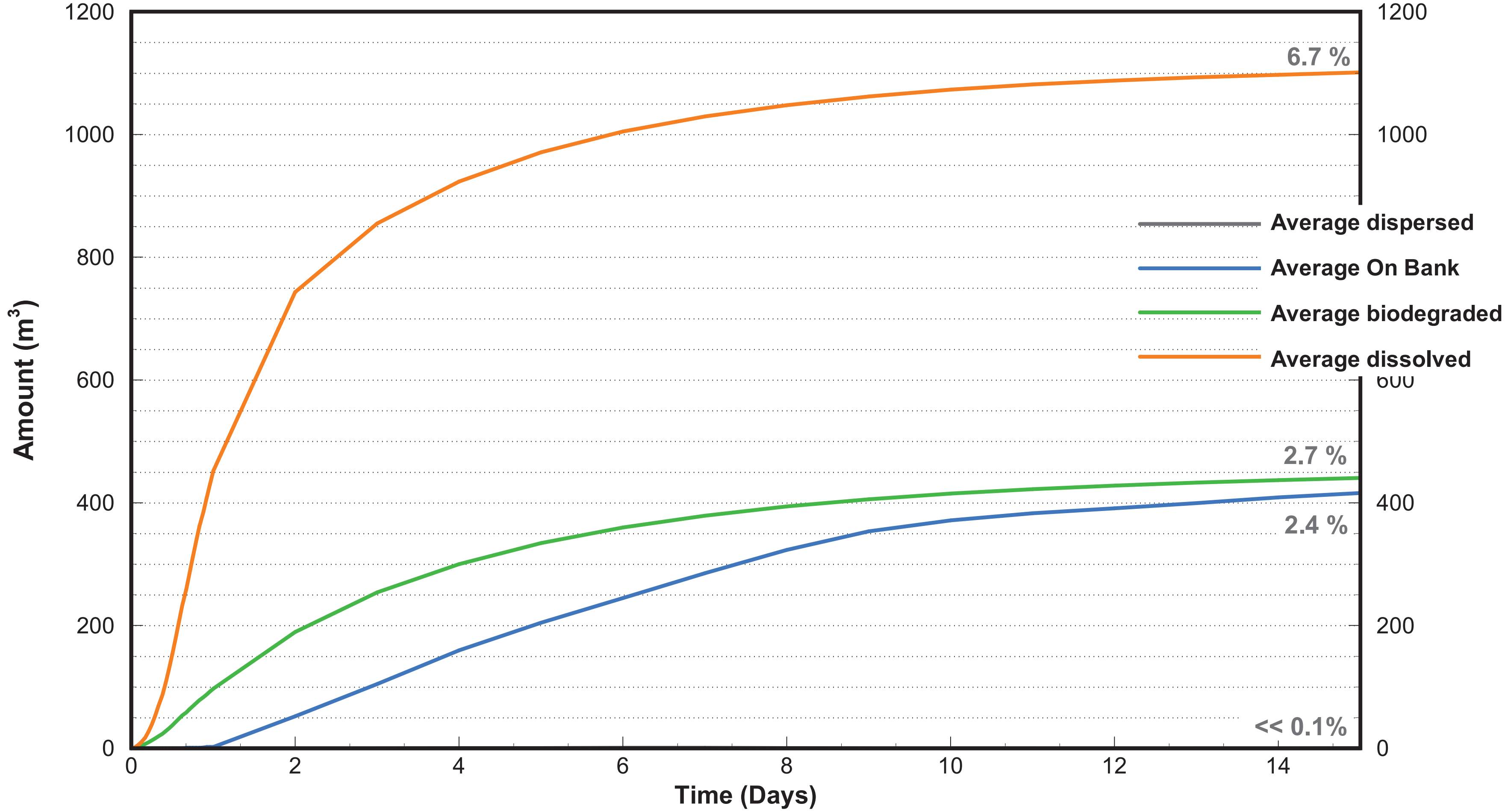
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2011, Site D (16,500 m^3)
Major Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 4, 2013

Figure 5.4.21



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to Sepetember 30 23:00.
- Tracking time for each spill was 15 days.
- The minor components of the mass balance are shown above.

STATUS
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TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Summer 2011, Site D (16,500 m^3) Minor Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 4, 2013

Figure 5.4.22

5.4.4.7.2 Location E, Arachne Reef

Location E is located at Arachne Reef, at the northern end of Haro Strait. This location has been determined to be representative of an incident resulting from powered grounding and/or a collision. The potential volume of oil spilled was determined by DNV (TERMPOL 3.15, Volume 8C, TR 8C-12): the credible worst case scenario probability of side damage would result in 16,500 m^3 spilled. The simulated duration of the release is 13 hours with 25 per cent of the oil released in the first hour, and a constant hourly spill rate for the next 12 hours.

Winds at Location E (as recorded at Kelp Reef) are mainly oriented north-south with strong storms occurring in the fall-winter periods with winds reaching 20 m/s. The spring-summer period is characterized by weaker winds, rarely exceeding 10 m/s.

Figures 5.4.23 and 5.4.24 show the 50 per cent and 90 per cent probability maps at Hour 24, *i.e.*, 24 hours after the start of the incident, and Hour 48. In general, a wider range of probabilities is presented in a stochastic probability map, but selecting only two contours simplifies the discussion. Presenting the probabilities at 24 hours and 48 hours is useful when discussing mitigation measures and the need for prompt response.

The length of shoreline oiled is relevant for determining potential ecological damage, and for estimating shoreline clean up resources that would be required in the event of a spill. Figure 5.4.25 illustrates the length of shoreline contacted by oil for the summer simulation. Basic statistics on shoreline oiling for all seasons are presented in Table 5.4.10.

TABLE 5.4.10

STATISTICS FOR SHORELINE CONTACT FOR A CREDIBLE WORST CASE SPILL AT LOCATION E (NO MITIGATION APPLIED)

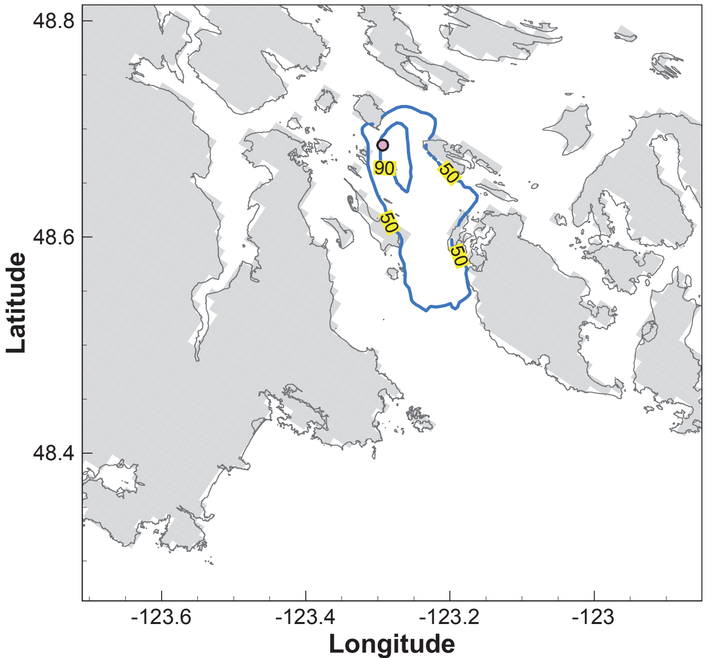
	Median (km)	Average (km)	Maximum (km)	Minimum (km)
Winter	290	292	387	162
Spring	304	306	427	206
Summer	312	309	407	174
Fall	301	301	391	169

The mass balance of the spilled oil provides a good summary of a particular spill, or, when averaged across all spills, a good understanding of spill behaviour for a spill that would occur in a particular season. Figures 5.4.26 and 5.4.27 show the mass balance for the summer spill scenario. Figure 5.4.26 shows the major components: on–water, on-shore and evaporated, and Figure 5.4.27 shows the minor components: dispersed, biodegraded, on banks and dissolved. Table 5.4.11 summarizes the mass balance for all four seasons at the end of the 15-day stochastic simulation period.

TABLE 5.4.11

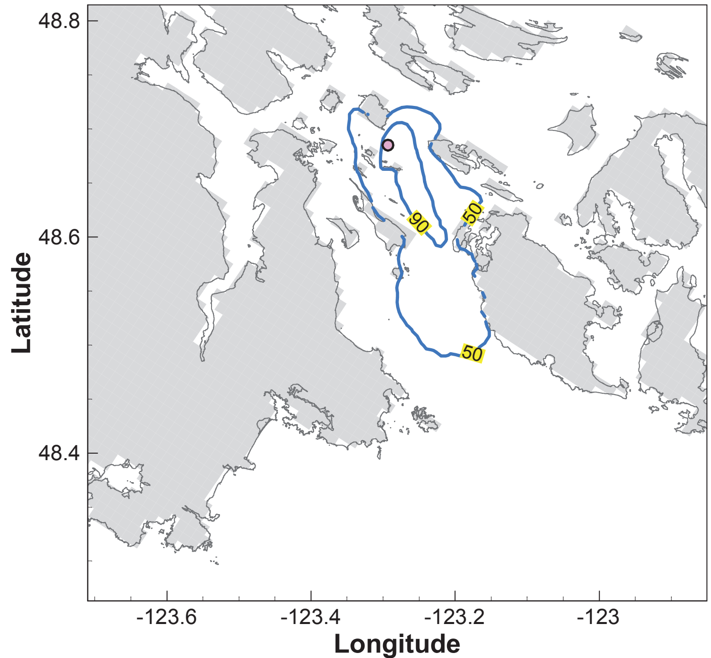
MASS BALANCE SUMMARY FOR A CREDIBLE WORST CASE SPILL AT LOCATION E (NO MITIGATION APPLIED)

Component	Winter	Spring	Summer	Fall	Yearly Average
On-Shore	68.9	69.5	69.8	71.1	69.8
Evaporated	21.5	19.7	18.8	19.1	19.8
On-Water	1.6	2.3	2.9	1.9	2.2
Dissolved	5.2	5.8	5.7	5.3	5.5
Biodegraded	2.8	2.7	2.8	2.6	2.7
On-Banks	0	0	0	0	0.0
Dispersed	0	0	0	0	0.0



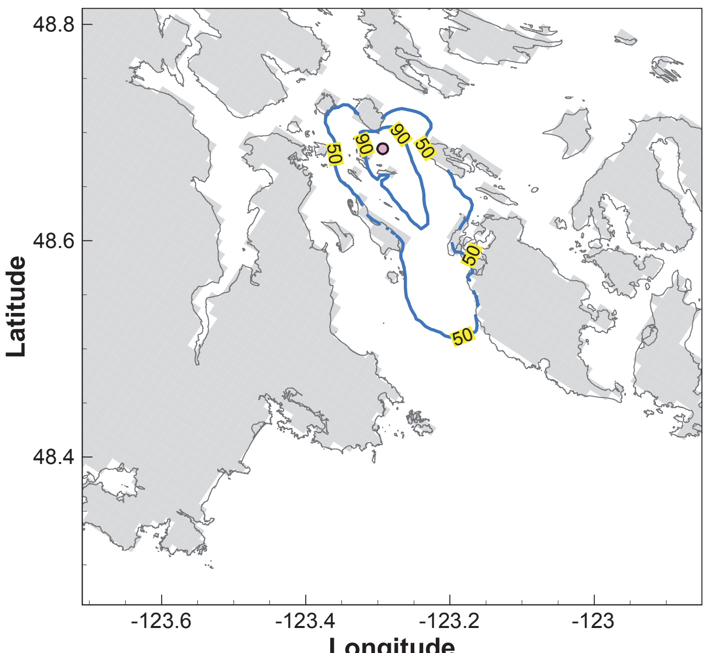
Winter 2012

Area within the P_{50} Contour Line:	139.3 km^2
Area within the P_{90} Contour Line:	16.3 km^2
Average Thickness within the P_{50} Contour Line:	54 um
Average Thickness within the P_{90} Contour Line:	133 um
Average Shore Oiled:	29 km



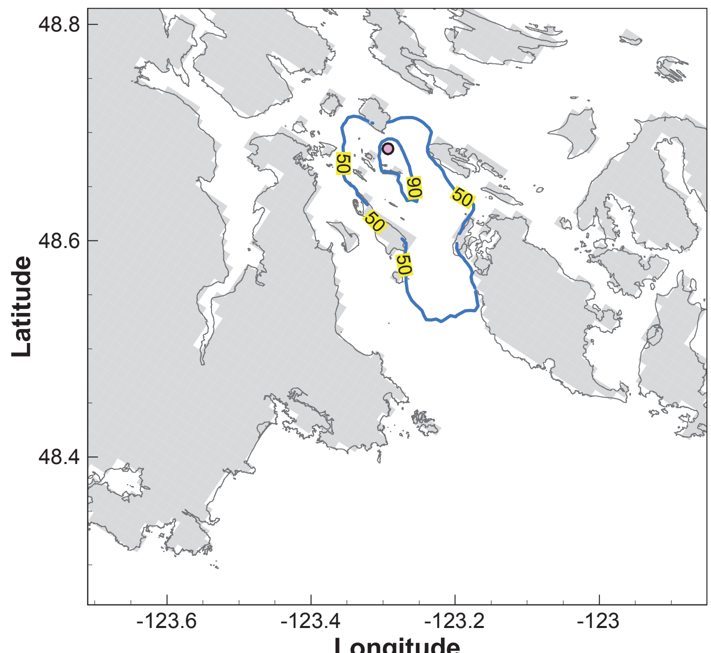
Spring 2012

Area within the P_{50} Contour Line:	210.0 km^2
Area within the P_{90} Contour Line:	36.0 km^2
Average Thickness within the P_{50} Contour Line:	41 um
Average Thickness within the P_{90} Contour Line:	89 um
Average Shore Oiled:	35 km



Summer 2012

Area within the P_{50} Contour Line:	196 km^2
Area within the P_{90} Contour Line:	37.8 km^2
Average Thickness within the P_{50} Contour Line:	36 um
Average Thickness within the P_{90} Contour Line:	78 um
Average Shore Oiled:	36 km



Fall 2011

Area within the P_{50} Contour Line:	167.5 km^2
Area within the P_{90} Contour Line:	12.8 km^2
Average Thickness within the P_{50} Contour Line:	43 um
Average Thickness within the P_{90} Contour Line:	133 um
Average Shore Oiled:	34 km

NOTES

Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.

P_{50}: after 24 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.

P_{90}: after 24 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.

Statistical results for each season based on independent spills occuring every 6 hours for three months.

Tracking time for each spill was 24 hours.

The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
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A TETRA TECH COMPANY

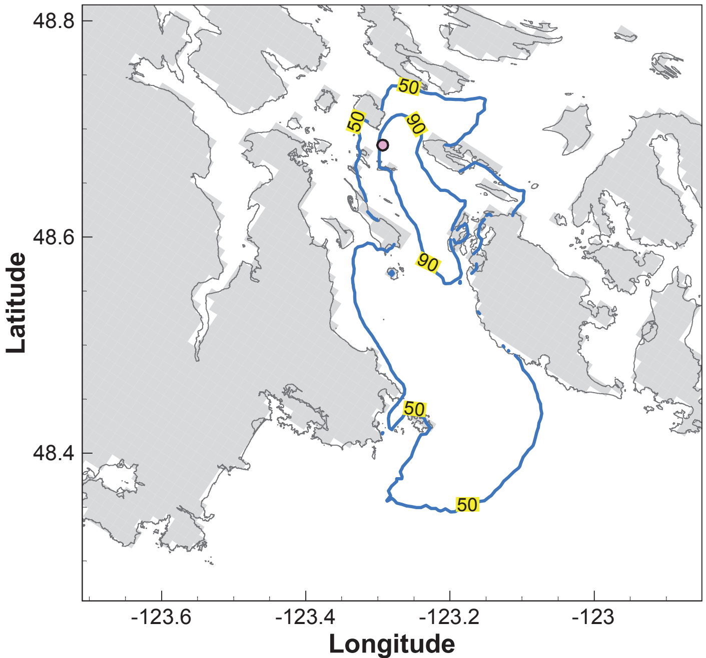
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Site E (16,500 m^3)
P_{50} and P_{90} after 24 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

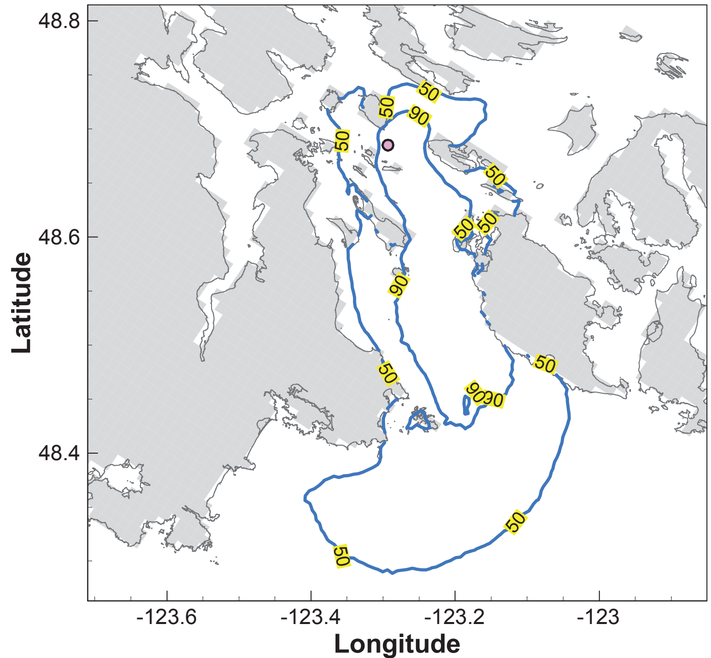
OFFICE	DATE
EBA-VANC	October 25, 2013

Figure 5.4.23



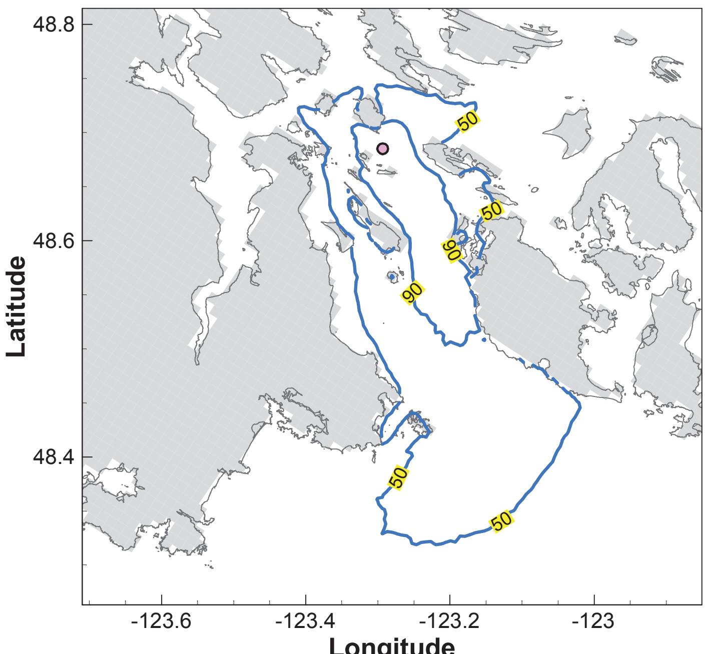
Winter 2012

Area within the P_{50} Contour Line:	516.5 km^2
Area within the P_{90} Contour Line:	69.3 km^2
Average Thickness within the P_{50} Contour Line:	17 um
Average Thickness within the P_{90} Contour Line:	47 um
Average Shore Oiled:	75 km



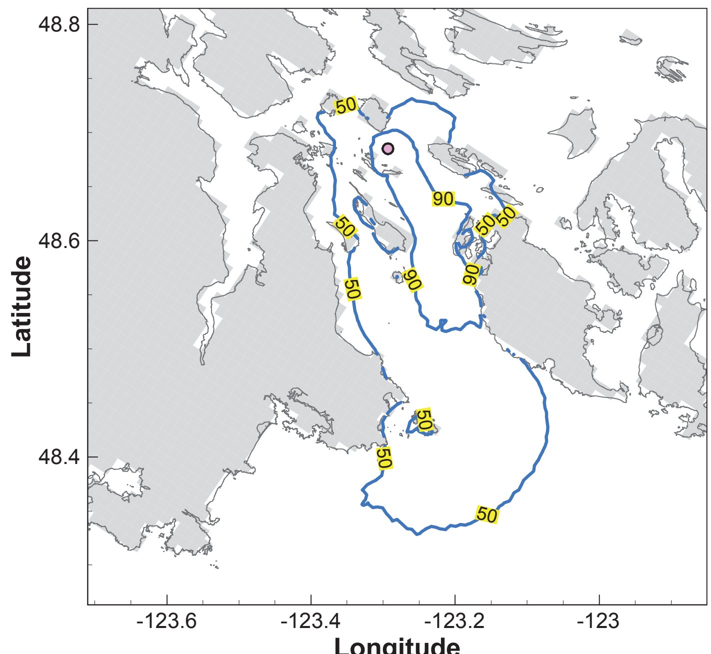
Spring 2012

Area within the P_{50} Contour Line:	767.5 km^2
Area within the P_{90} Contour Line:	227.0 km^2
Average Thickness within the P_{50} Contour Line:	10 um
Average Thickness within the P_{90} Contour Line:	21 um
Average Shore Oiled:	90 km



Summer 2012

Area within the P_{50} Contour Line:	646.0 km^2
Area within the P_{90} Contour Line:	132.3 km^2
Average Thickness within the P_{50} Contour Line:	11 um
Average Thickness within the P_{90} Contour Line:	27 um
Average Shore Oiled:	85 km



Fall 2011

Area within the P_{50} Contour Line:	603.7 km^2
Area within the P_{90} Contour Line:	106.8 km^2
Average Thickness within the P_{50} Contour Line:	12 um
Average Thickness within the P_{90} Contour Line:	28 um
Average Shore Oiled:	83 km

NOTES

● Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.

P_{50}: after 48 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.

P_{90}: after 48 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.

Statistical results for each season based on independent spills occuring every 6 hours for three months.

Tracking time for each spill was 48 hours.

The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
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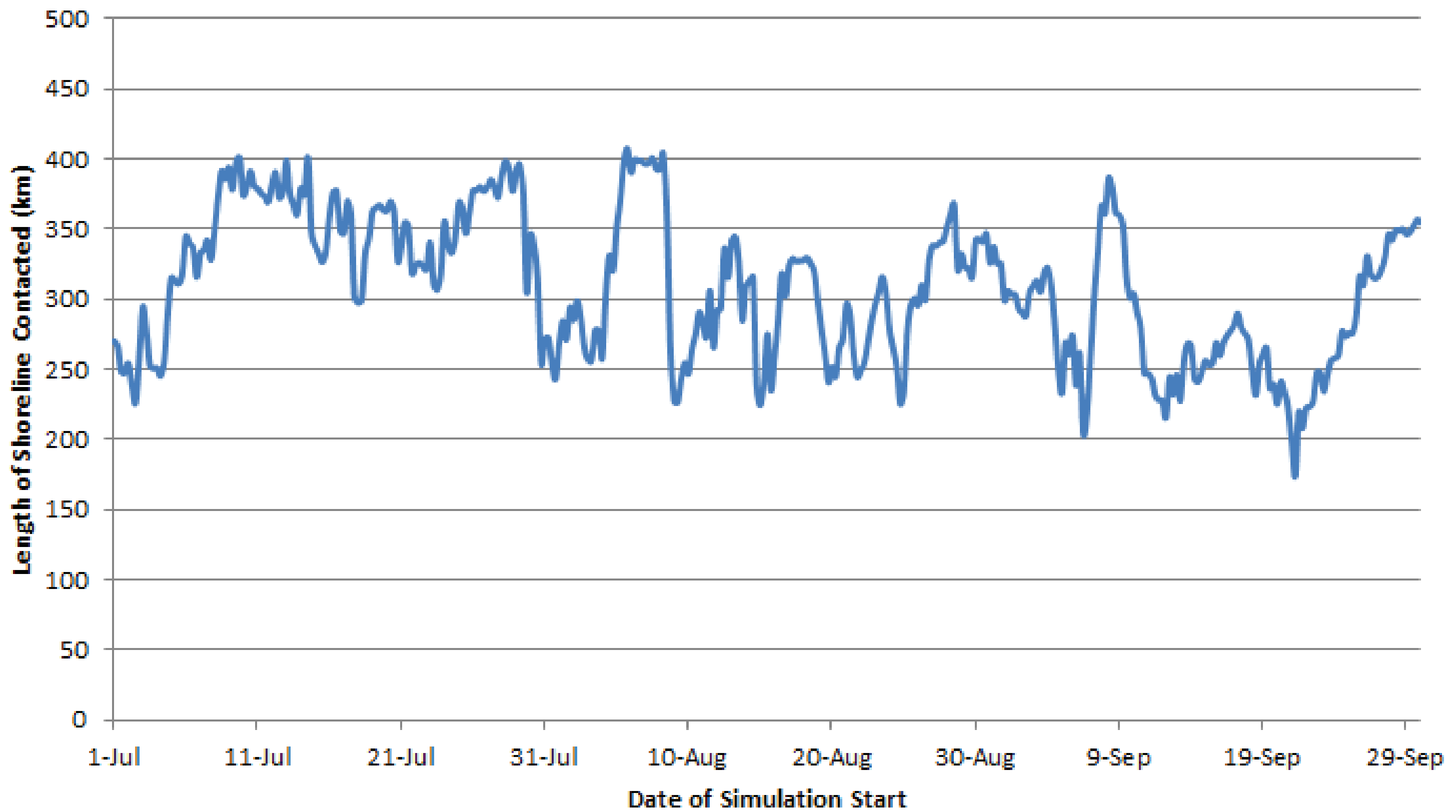
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Site E (16,500 m^3)
P_{50} and P_{90} after 48 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

OFFICE	DATE
EBA-VANC	October 25, 2013

Figure 5.4.24



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.

- Tracking time for each spill was 15 days.

STATUS
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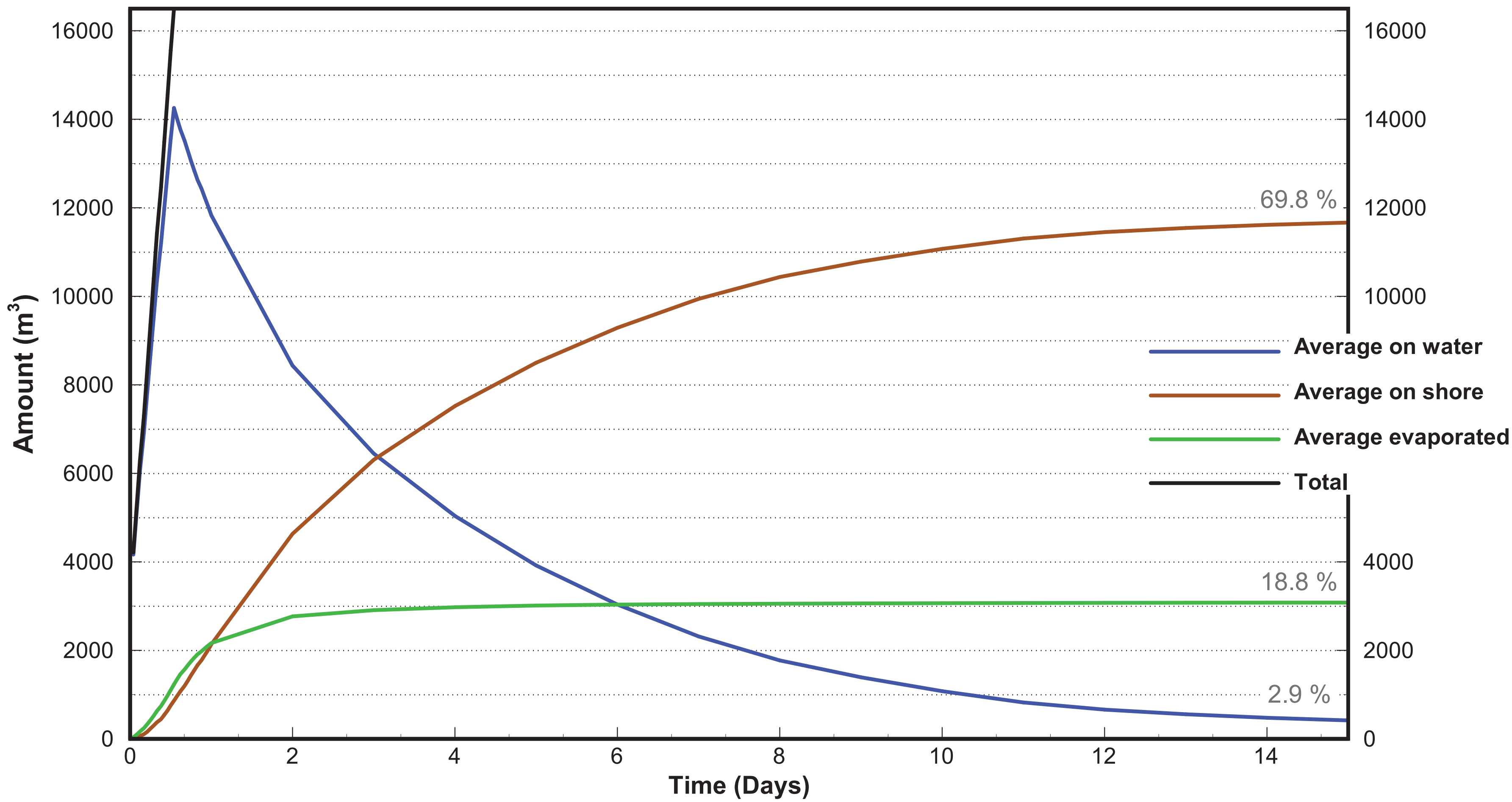
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site E (16,500 m^3)
Length of Shoreline Contacted

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	**Figure 5.4.25**
OFFICE	DATE				
EBA-VANC	September 29, 2013				



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 15 days.
- The major components of the mass balance are shown above.

STATUS
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CLIENT
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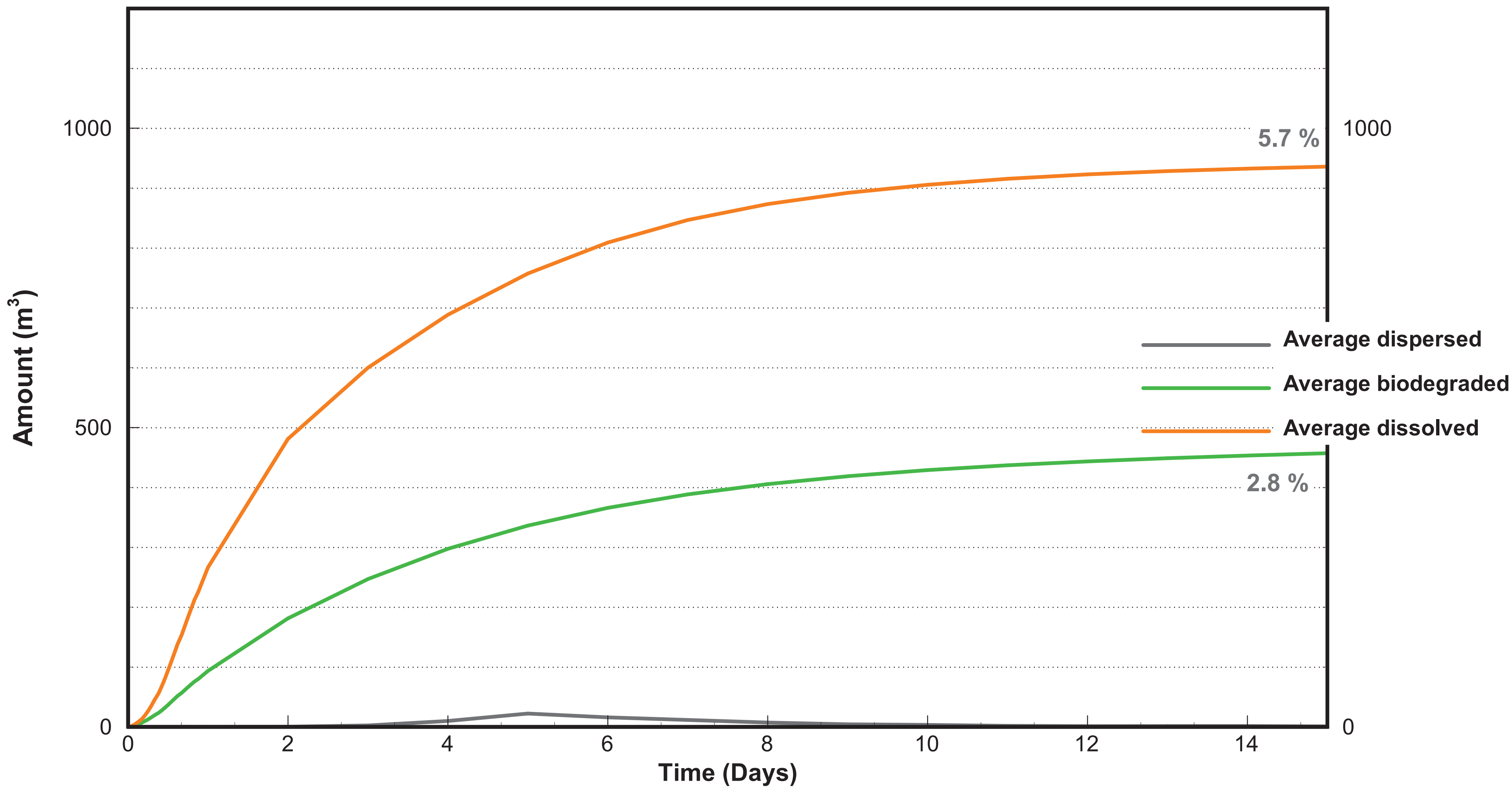
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site E (16,500 m^3)
Major Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	September 29, 2013

Figure 5.4.26



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 15 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site E (16,500 m^3)
Minor Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	**Figure 5.4.27**
OFFICE	DATE				
EBA-VANC	September 29, 2013				

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5.4.4.7.3 Location G, Juan de Fuca Strait off Race Rocks

Location G is located in the Juan de Fuca Strait between Race Rocks and Port Angeles, as shown in Figure 5.4.17. This location has been determined to be representative of a hypothetical collision with crossing traffic from Puget Sound and Rosario Strait. The potential volume of oil spilled was determined by DNV to be 16,500 m^3 for the credible worst case. 25 per cent of the oil would be released in the first hour, and the balance over the succeeding 12 hours

The winds at Location G (as recorded at Port Angeles) blow either along the Strait from the northwest or off the land from the south-southwest. The winds blowing along the Strait are frequently up to 10 m/s and occur almost continuously in spring and summer but only intermittently in fall and winter. The winds coming off the land; however, are typically less than 5 m/s and dominate the fall and winter periods.

Figures 5.4.28 and 5.4.29 show the 50 per cent and 90 per cent probability maps at Hour 24, *i.e.*, 24 hours after the start of the incident, and Hour 48. In general, a wider range of probabilities is presented in a stochastic probability map, but selecting only two contours simplifies the discussion. Presenting the probabilities at 24 hours and 48 hours is useful when discussing mitigation measures and the need for prompt response.

The length of shoreline oiled is relevant for determining potential ecological damage, and for estimating shoreline clean up resources that would be required in the event of a spill. Figure 5.4.30 illustrates the length of shoreline contacted by oil for the summer simulation. Basic statistics on shoreline oiling for all seasons are presented in Table 5.4.12.

TABLE 5.4.12

STATISTICS FOR SHORELINE CONTACT FOR A CREDIBLE WORST CASE SPILL AT LOCATION G (NO MITIGATION APPLIED)

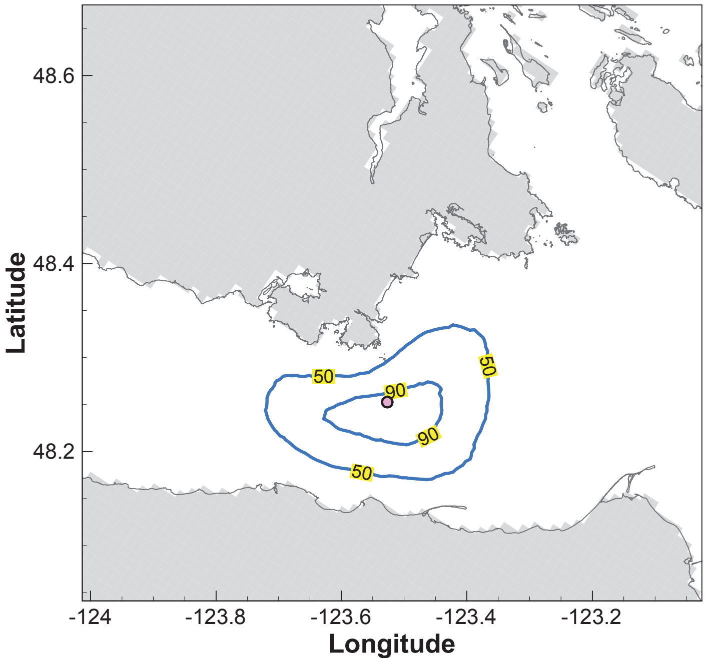
	Median (km)	Average (km)	Maximum (km)	Minimum (km)
Winter	183	175	316	33
Spring	129	136	259	44
Summer	110	114	196	44
Fall	140	141	296	42

The mass balance of the spilled oil provides a good summary of a particular spill, or, when averaged across all spills, a good understanding of spill behaviour for a spill that would occur in a particular season. Figures 5.4.31 and 5.4.32 show the mass balance for the summer spill scenario. Figure 5.4.31 shows the major components: on water, on shore and evaporated, and Figure 5.4.32 shows the minor components: dispersed, bio-degraded, on banks and dissolved. Table 5.4.13 summarizes the mass balance for all four seasons at the end of the 15-day stochastic simulation period.

TABLE 5.4.13

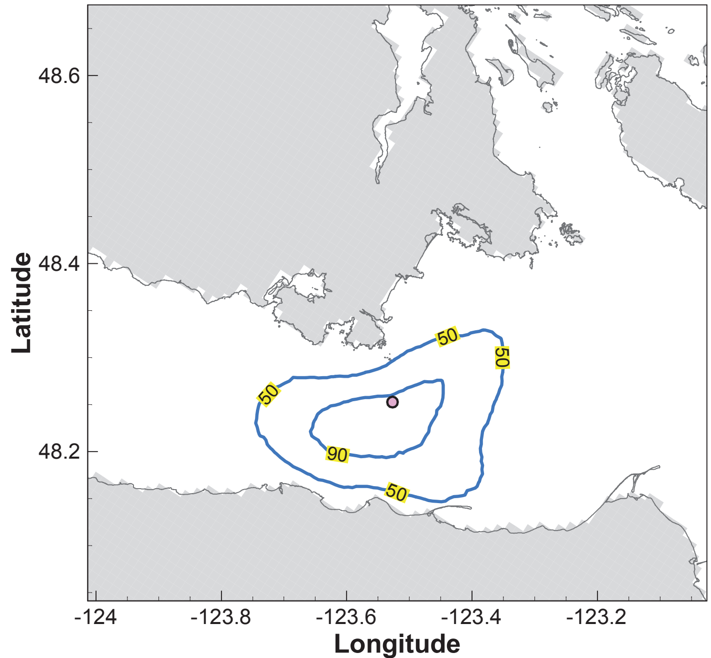
MASS BALANCE SUMMARY FOR A CREDIBLE WORST CASE SPILL AT LOCATION G (NO MITIGATION APPLIED)

Component	Winter	Spring	Summer	Fall	Yearly Average
On Shore	66.5	65.7	67.1	66.1	66.4
Evaporated	20.9	20.3	19.7	20.1	20.3
On Water	2.9	4.5	4.3	4.2	4.0
Dissolved	6.6	6.4	6.1	6.6	6.4
Biodegraded	3.1	3.1	2.7	2.9	3.0
On Banks	0	0	0	0	0.0
Dispersed	0	0	0	0	0.0



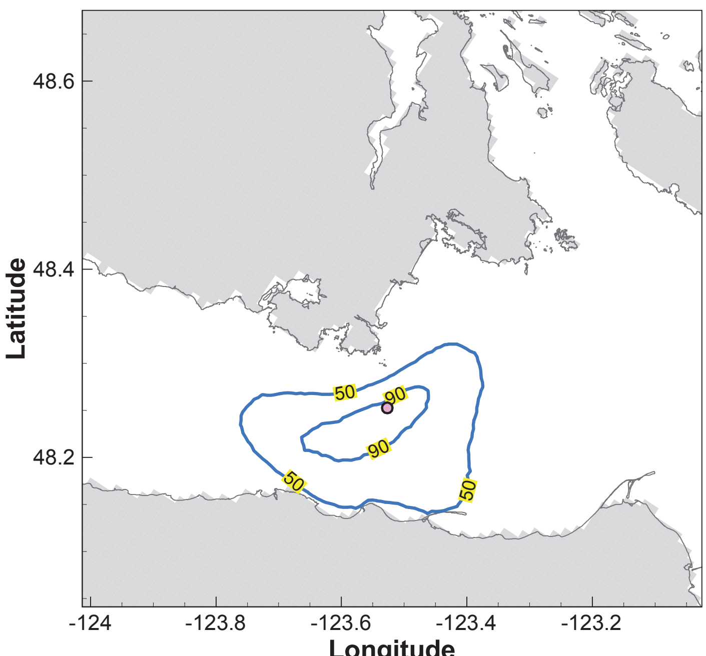
Winter 2012

Area within the P_{50} Contour Line:	326.5 km^2
Area within the P_{90} Contour Line:	68.5 km^2
Average Thickness within the P_{50} Contour Line:	38 um
Average Thickness within the P_{90} Contour Line:	69 um
Average Shore Oiled:	4.3 km



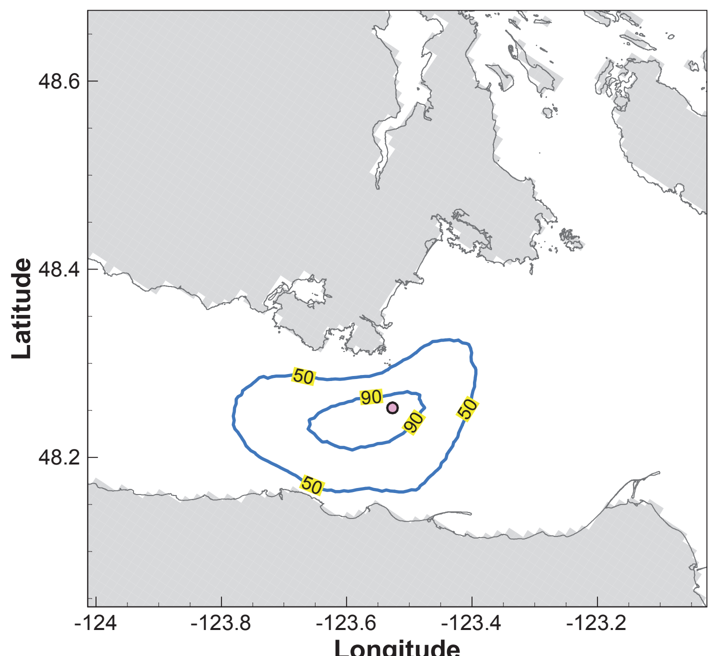
Spring 2012

Area within the P_{50} Contour Line:	395.0 km^2
Area within the P_{90} Contour Line:	95.0 km^2
Average Thickness within the P_{50} Contour Line:	33 um
Average Thickness within the P_{90} Contour Line:	48 um
Average Shore Oiled:	5.6 km



Summer 2012

Area within the P_{50} Contour Line:	372.2 km^2
Area within the P_{90} Contour Line:	64.3 km^2
Average Thickness within the P_{50} Contour Line:	35 um
Average Thickness within the P_{90} Contour Line:	54 um
Average Shore Oiled:	6.8 km



Fall 2011

Area within the P_{50} Contour Line:	347.5 km^2
Area within the P_{90} Contour Line:	61.8 km^2
Average Thickness within the P_{50} Contour Line:	37 um
Average Thickness within the P_{90} Contour Line:	57 um
Average Shore Oiled:	5.3 km

NOTES

● Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.

P_{50}: after 24 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.

P_{90}: after 24 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.

Statistical results for each season based on independent spills occuring every 6 hours for three months.

Tracking time for each spill was 24 hours.

The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
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A TETRA TECH COMPANY

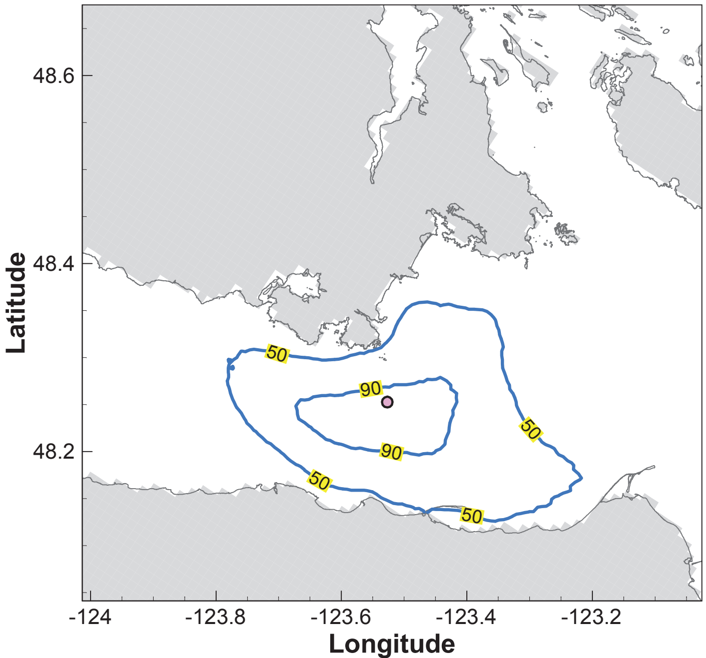
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Site G (16,500 m^3)
P_{50} and P_{90} after 24 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

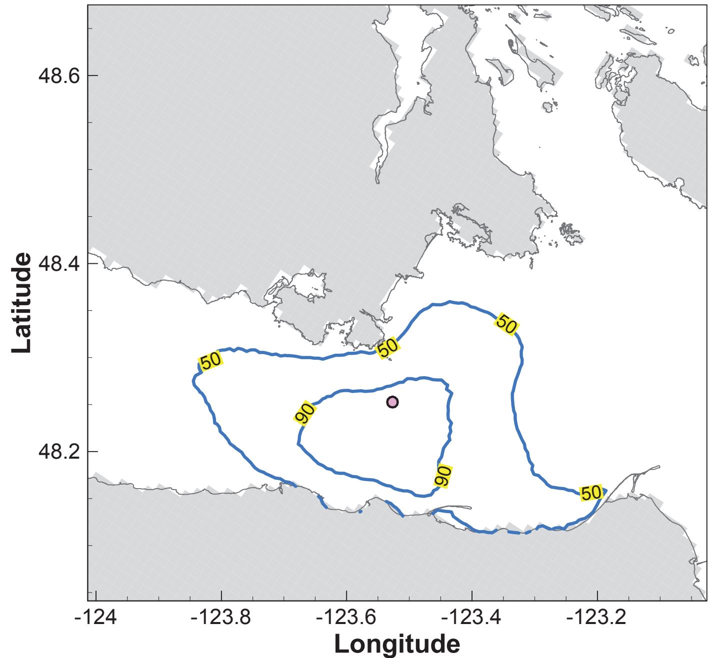
OFFICE	DATE
EBA-VANC	October 25, 2013

Figure 5.4.28



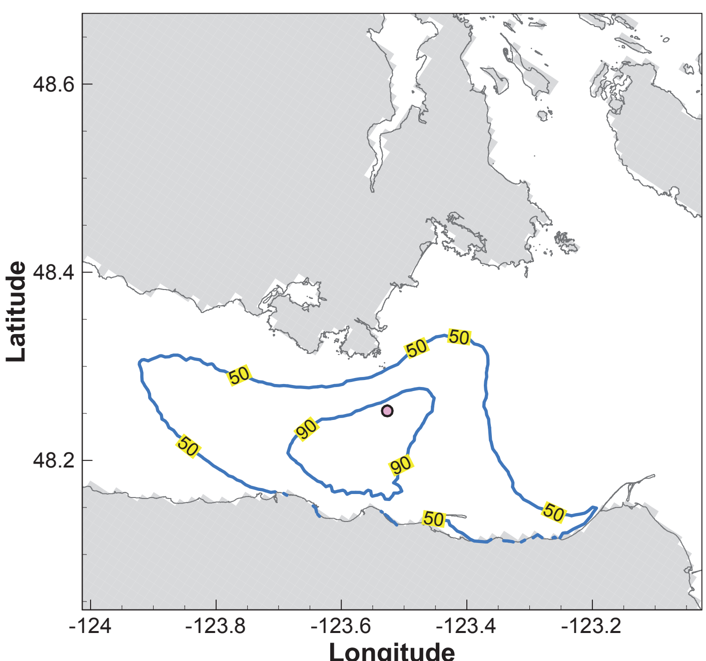
Winter 2012

Area within the P_{50} Contour Line:	639.3 km^2
Area within the P_{90} Contour Line:	122.8 km^2
Average Thickness within the P_{50} Contour Line:	21 um
Average Thickness within the P_{90} Contour Line:	35 um
Average Shore Oiled:	23.5 km



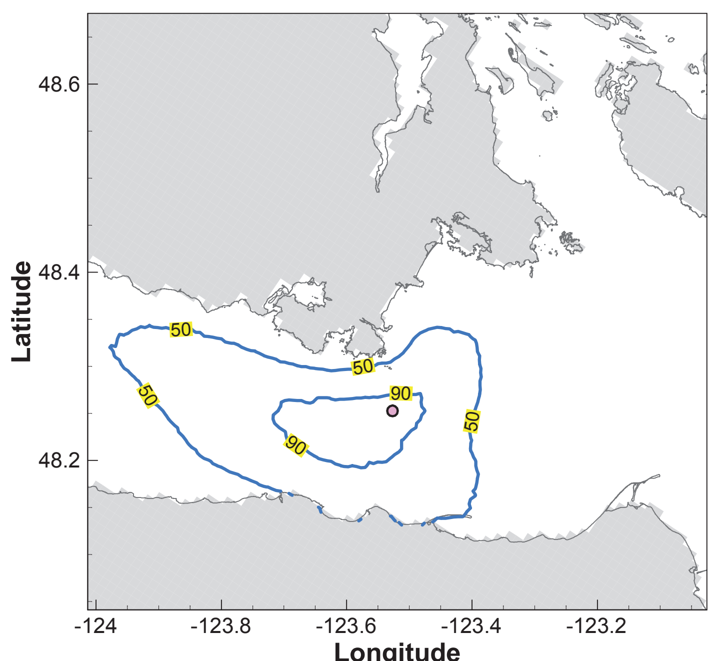
Spring 2012

Area within the P_{50} Contour Line:	748.2 km^2
Area within the P_{90} Contour Line:	182.8 km^2
Average Thickness within the P_{50} Contour Line:	18 um
Average Thickness within the P_{90} Contour Line:	29 um
Average Shore Oiled:	27.4 km



Summer 2012

Area within the P_{50} Contour Line:	674.0 km^2
Area within the P_{90} Contour Line:	128.3 km^2
Average Thickness within the P_{50} Contour Line:	20 um
Average Thickness within the P_{90} Contour Line:	33 um
Average Shore Oiled:	29.4 km



Fall 2011

Area within the P_{50} Contour Line:	675.2 km^2
Area within the P_{90} Contour Line:	38.7 km^2
Average Thickness within the P_{50} Contour Line:	21 um
Average Thickness within the P_{90} Contour Line:	39 um
Average Shore Oiled:	25.9 km

NOTES

● Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.

P_{50}: after 48 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.

P_{90}: after 48 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.

Statistical results for each season based on independent spills occuring every 6 hours for three months.

Tracking time for each spill was 48 hours.

The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
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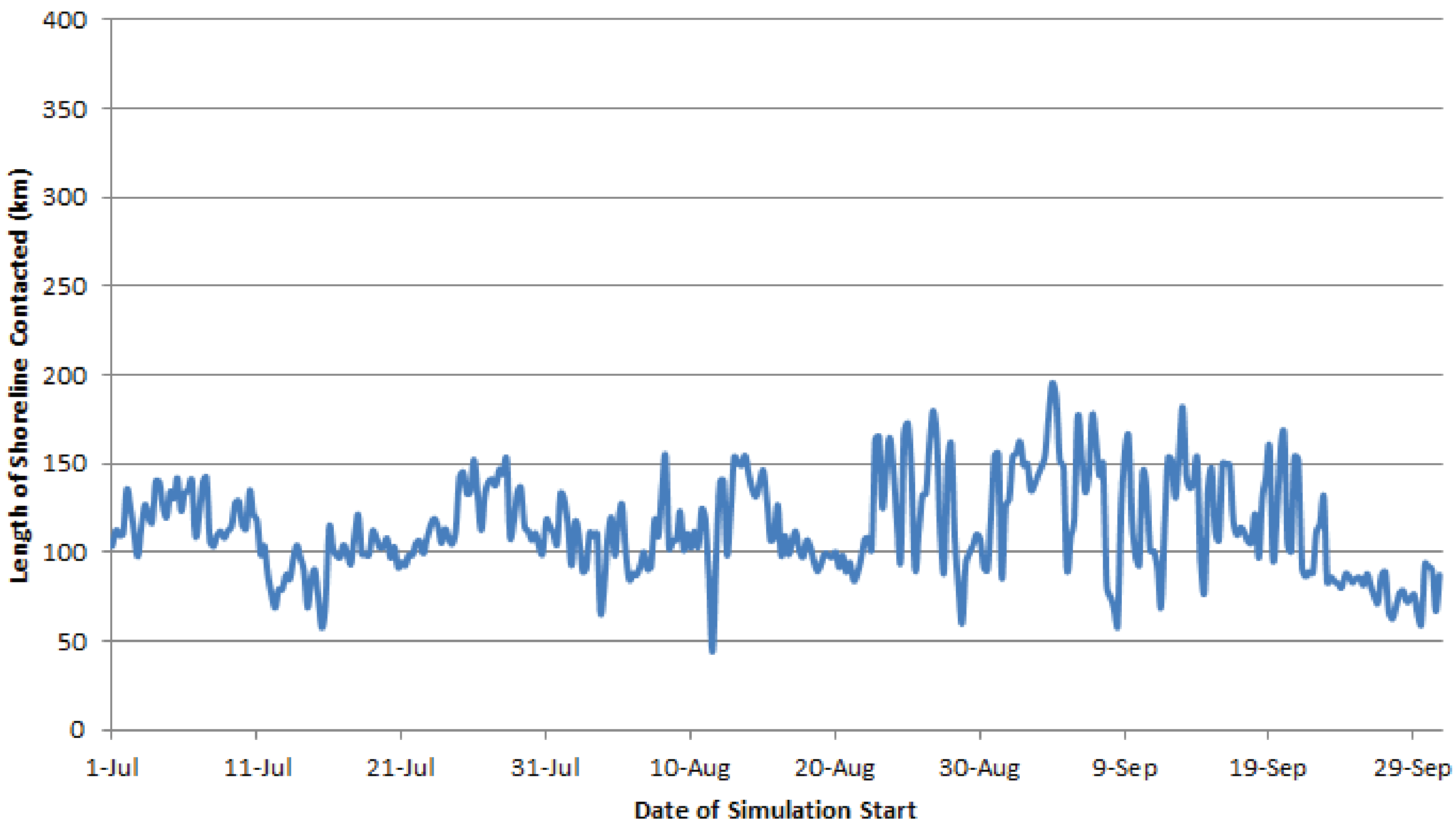
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Site G (16,500 m^3)
P_{50} and P_{90} after 48 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0
OFFICE	DATE			
EBA-VANC	October 25, 2013			

Figure 5.4.29



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 15 days.

STATUS
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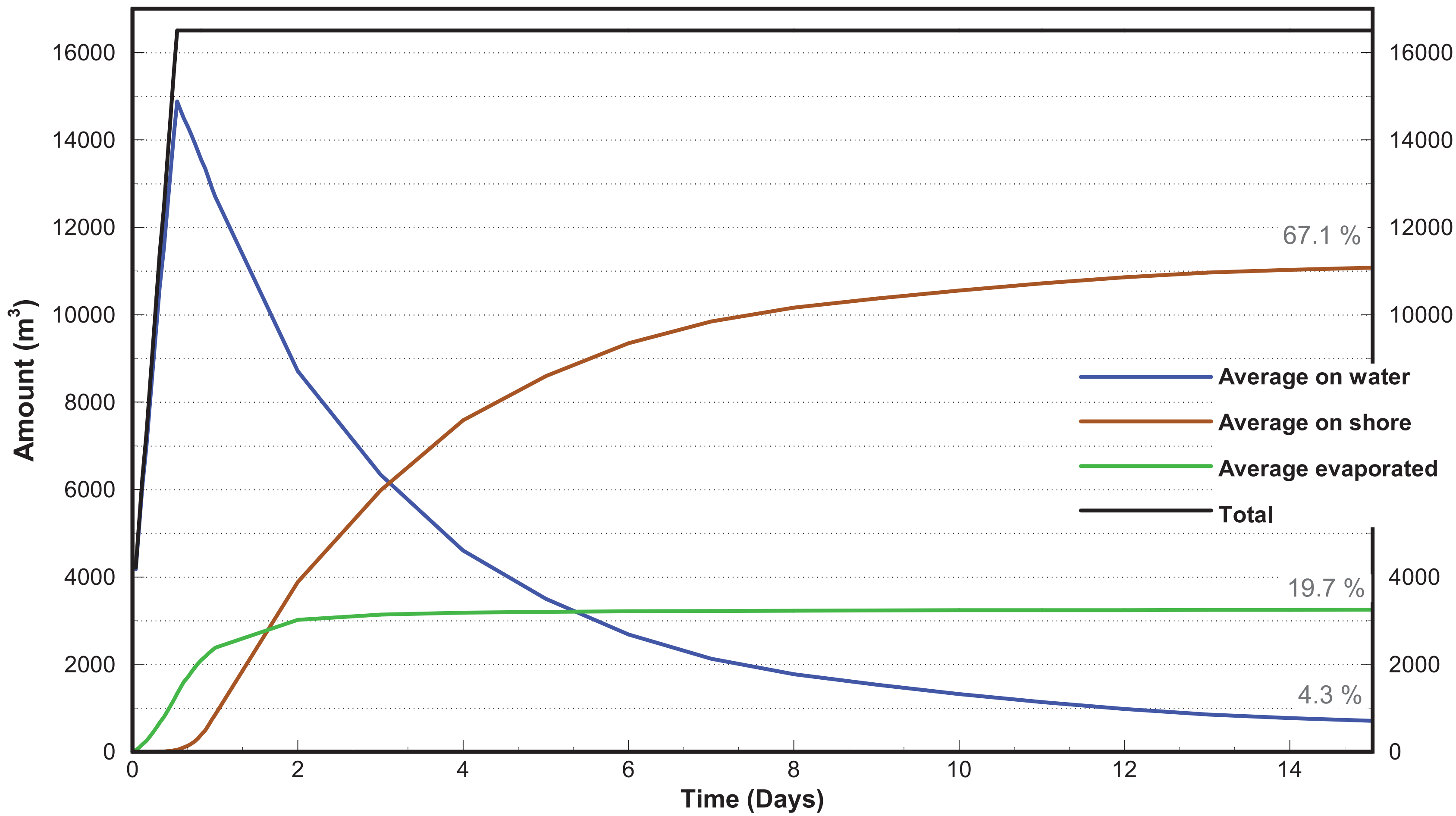
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site G (16,500 m^3)
Length of Shoreline Contacted

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	**Figure 5.4.30**
OFFICE	DATE				
EBA-VANC	October 21, 2013				



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 15 days.
- The major components of the mass balance are shown above.

STATUS
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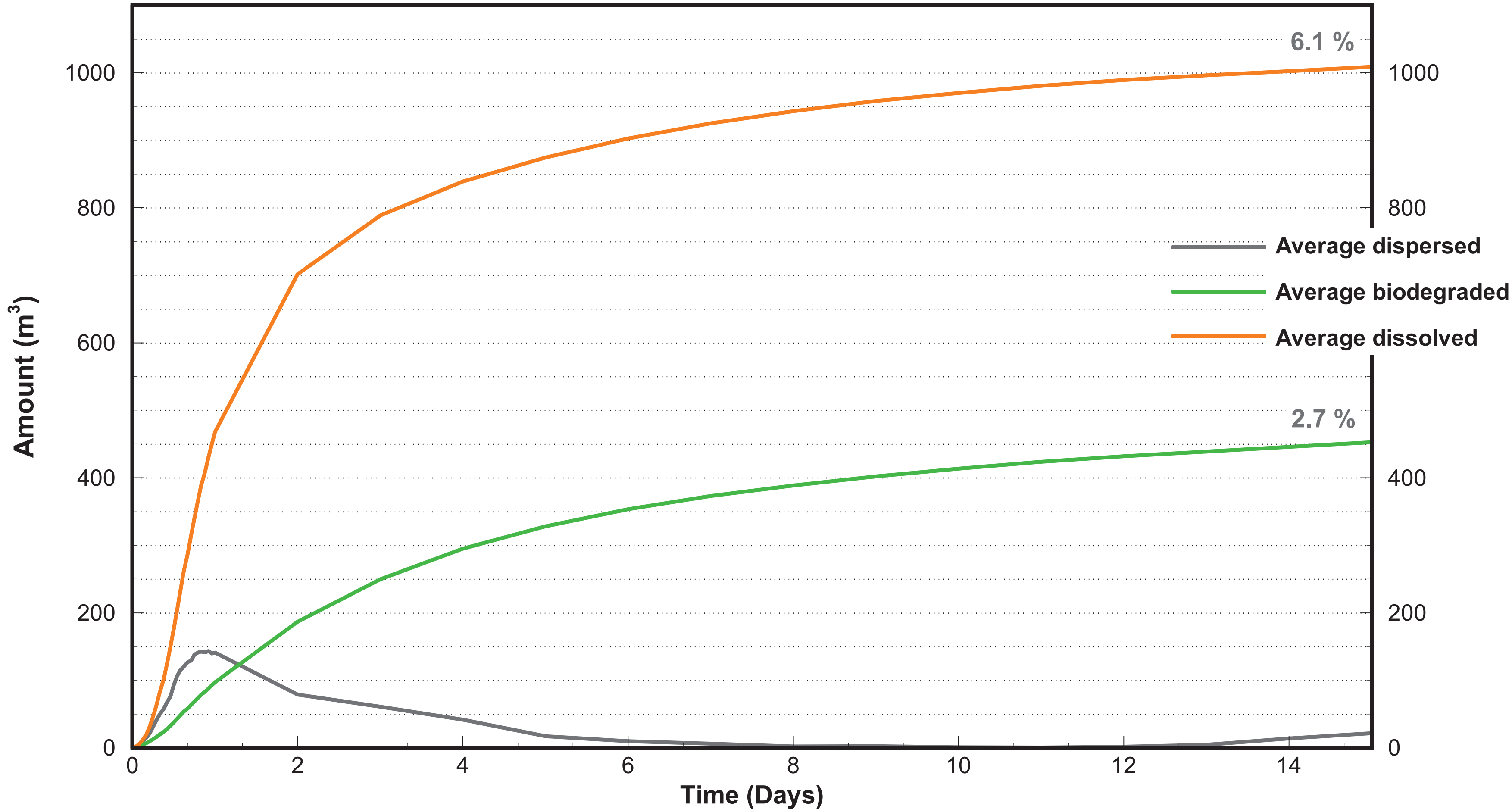
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site G (16,500 m^3)
Major Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 21, 2013

Figure 5.4.31



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 15 days.
- The minor components of the mass balance are shown above.

STATUS
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TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site G (16,500 m^3)
Minor Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 21, 2013

Figure 5.4.32

T:\TMEP\working\AH\02-SPILLCALC\541-Stochastic_Race_Rocks_16500m3\Results_Summer\Tecplot\09-statistics_MB_2.lay 21 Oct 2013 10:46:56

5.4.4.8 Location H, Buoy J

Location H is located at the entrance of the Juan de Fuca Strait at Buoy J, as shown in Figure 5.5.2. This location has been determined to be representative of a hypothetical incident resulting from a collision. The potential volume of oil spilled was determined by DNV as 16,500 m^3 for a credible worst case. 25 per cent of the spill would be released in the first hour, and the balance at a uniform rate over the succeeding 12 hours. This location has very low probability for an oil spill from a laden tanker. However, this location represents the outer part of the assessment area, hence should be modelled.

Winds at Location H are primary from the south. Strong storms are observed in the fall-winter periods with winds reaching 20 m/s. The spring-summer period is characterized by weaker winds, about 10 m/s.

Figures 5.4.33 and 5.4.34 show the 50 per cent and 90 per cent probability maps at Hour 24, *i.e.*, 24 hours after the start of the incident, and Hour 48. In general, a wider range of probabilities is presented in a stochastic probability map, but selecting only two contours simplifies the discussion. Presenting the probabilities at 24 hours and 48 hours is useful when discussing mitigation measures and the need for prompt response.

The length of shoreline oiled is relevant for determining potential ecological damage, and for estimating shoreline clean up resources that would be required in the event of a spill. Figure 5.4.35 illustrates the length of shoreline contacted by oil for the summer simulation. Basic statistics on shoreline oiling for all seasons are presented in Table 5.4.14.

TABLE 5.4.14

STATISTICS FOR SHORELINE CONTACT FOR A CREDIBLE WORST CASE SPILL AT LOCATION H (NO MITIGATION APPLIED)

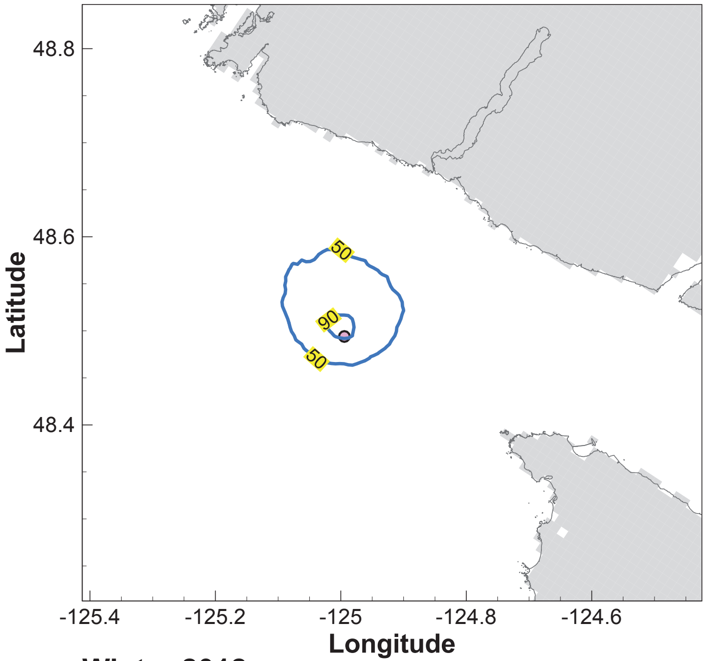
	Median (km)	Average (km)	Maximum (km)	Minimum (km)
Winter	183	175	316	33
Spring	129	135	259	44
Summer	110	114	196	44
Fall	107	114	314	0

The mass balance of the spilled oil provides a good summary of a particular spill, or, when averaged across all spills, a good understanding of spill behaviour for a spill that would occur in a particular season. Figures 5.4.36 and 5.4.37 show the mass balance for the summer spill scenario. Figure 5.4.36 shows the major components: on water, on shore and evaporated, and Figure 5.4.37 shows the minor components: dispersed, bio-degraded, on banks and dissolved. Table 5.4.15 summarizes the mass balance for all four seasons at the end of the 15-day stochastic simulation period.

TABLE 5.4.15

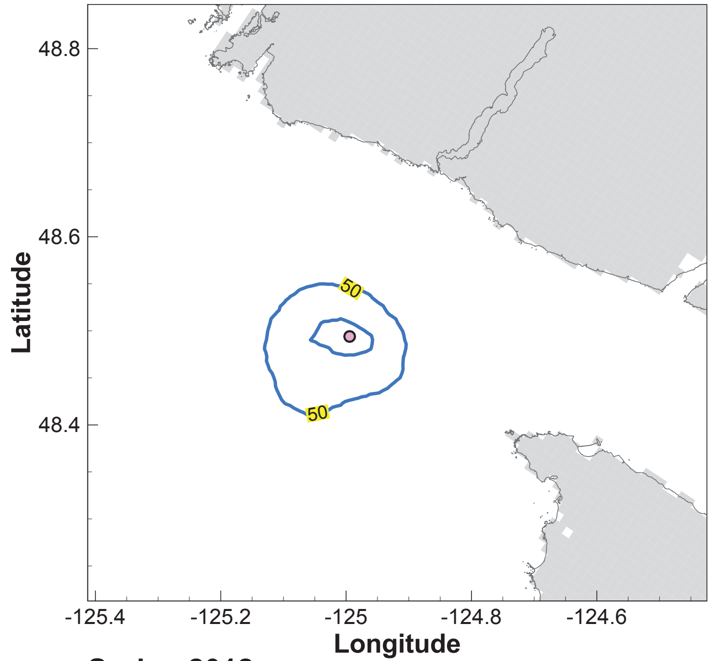
MASS BALANCE SUMMARY FOR THE 16,500 M^3 SPILL AT LOCATION H (NO MITIGATION APPLIED)

Component	Winter	Spring	Summer	Fall	Yearly Average
On Shore	59.6	34.3	28.2	41.5	40.9
Evaporated	22.7	23.6	24.2	23	23.4
On Water	6.9	26.4	31	21.5	21.5
Dissolved	6.9	9.5	10	8.8	8.8
Biodegraded	3.9	6.1	6.6	5.3	5.5
On Banks	0	0	0	0	0.0
Dispersed	1	2.2	8.7	1	3.2



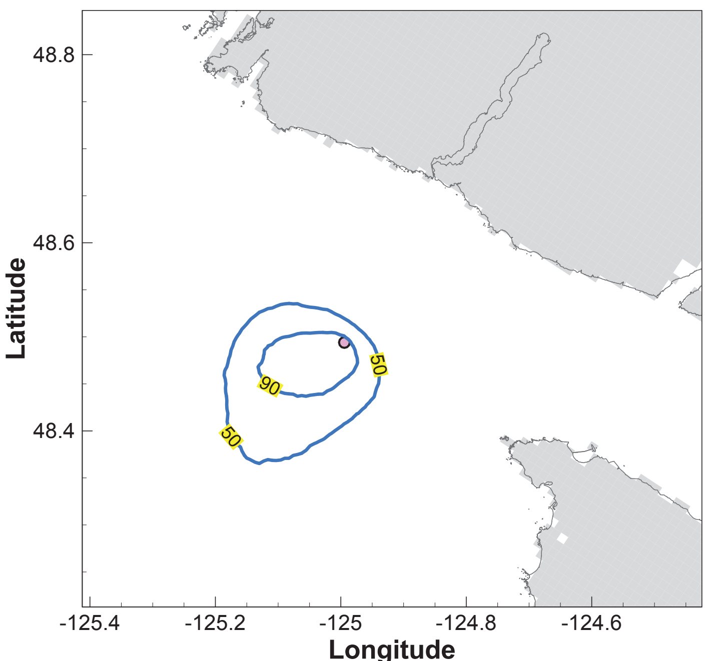
Winter 2012

Area within the P_{50} Contour Line:	146.3 km^2
Area within the P_{90} Contour Line:	7.5 km^2
Average Thickness within the P_{50} Contour Line:	59 um
Average Thickness within the P_{90} Contour Line:	108 um
Average Shore Oiled:	XX km



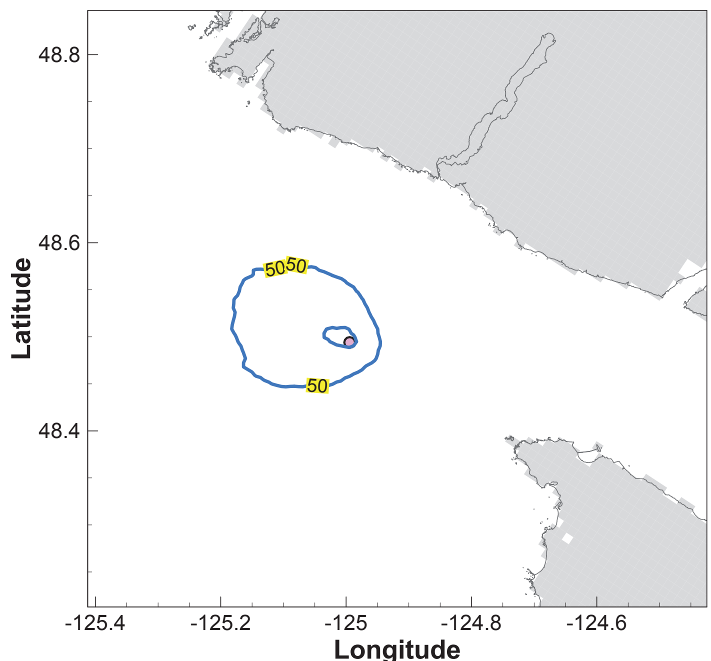
Spring 2012

Area within the P_{50} Contour Line:	195.0 km^2
Area within the P_{90} Contour Line:	22.0 km^2
Average Thickness within the P_{50} Contour Line:	53 um
Average Thickness within the P_{90} Contour Line:	87 um
Average Shore Oiled:	XX km



Summer 2012

Area within the P_{50} Contour Line:	260.8 km^2
Area within the P_{90} Contour Line:	69.3 km^2
Average Thickness within the P_{50} Contour Line:	48 um
Average Thickness within the P_{90} Contour Line:	61 um
Average Shore Oiled:	XX km



Fall 2011

Area within the P_{50} Contour Line:	200.5 km^2
Area within the P_{90} Contour Line:	6.5 km^2
Average Thickness within the P_{50} Contour Line:	54 um
Average Thickness within the P_{90} Contour Line:	115 um
Average Shore Oiled:	XX km

NOTES

○ **Release Location**

Probability of oil presence is the percentage of simulations in which oil was present at a given location.
P_{50}: after 24 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.
P_{90}: after 24 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.
Statistical results for each season based on independent spills occuring every 6 hours for three months.
Tracking time for each spill was 24 hours.
The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
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TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Site H (16,500 m^3)
P_{50} and P_{90} after 24 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

OFFICE	DATE
EBA-VANC	November 7, 2013

Figure 5.4.33

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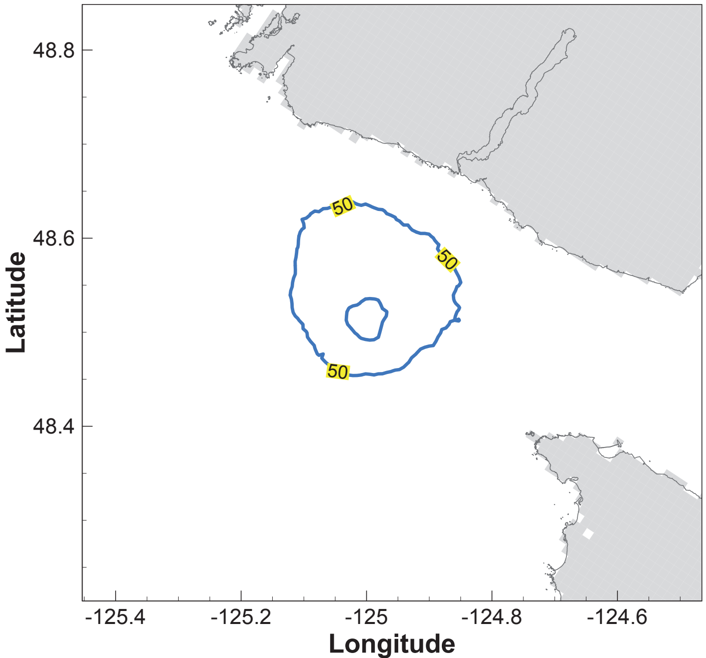
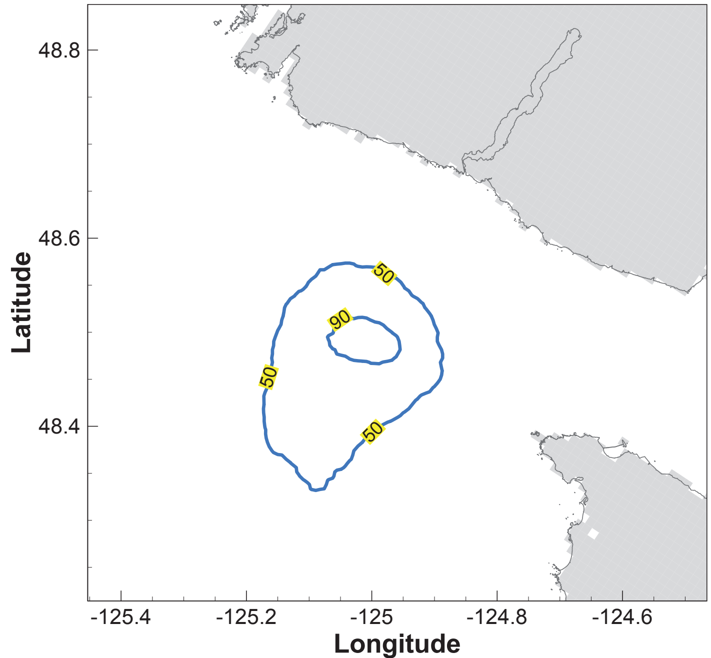


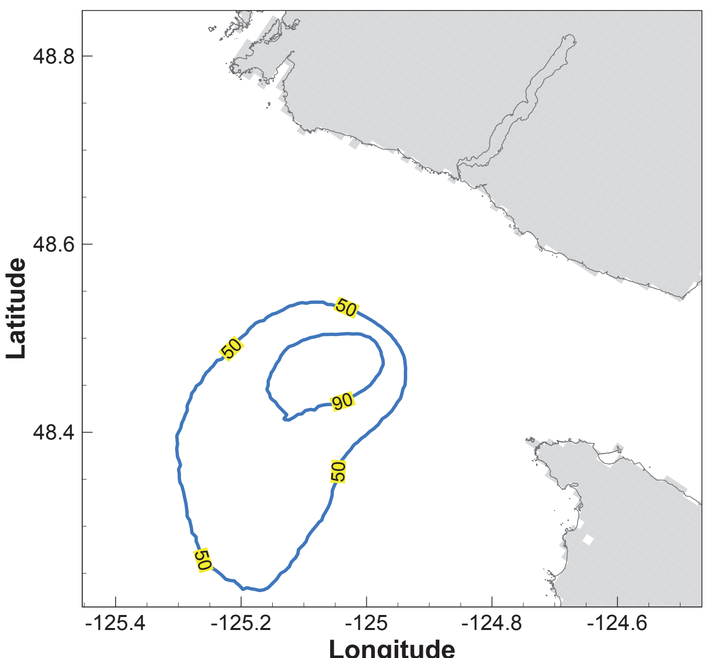
Winter 2012

Area within the P_{50} Contour Line:	308.5 km^2
Area within the P_{90} Contour Line:	17.3 km^2
Average Thickness within the P_{50} Contour Line:	40 um
Average Thickness within the P_{90} Contour Line:	74 um
Average Shore Oiled:	XX km



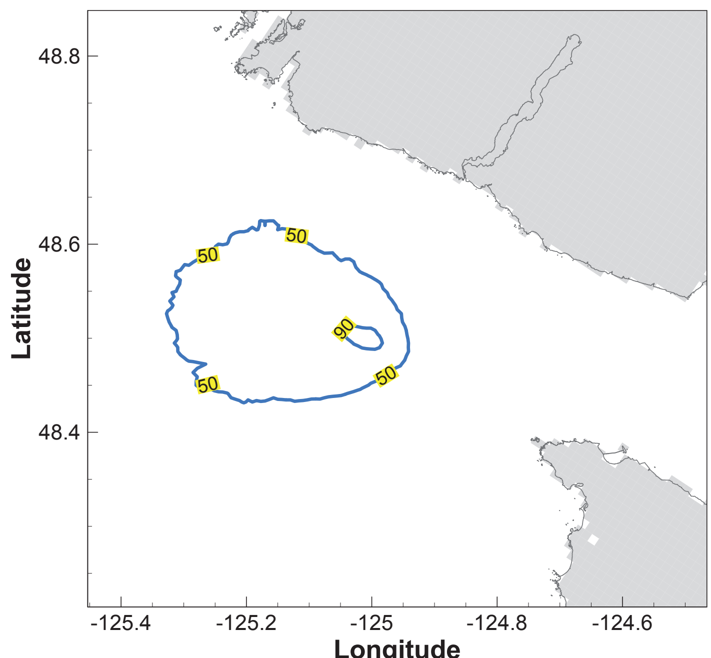
Spring 2012

Area within the P_{50} Contour Line:	378.7 km^2
Area within the P_{90} Contour Line:	34.5 km^2
Average Thickness within the P_{50} Contour Line:	32 um
Average Thickness within the P_{90} Contour Line:	64 um
Average Shore Oiled:	XX km



Summer 2012

Area within the P_{50} Contour Line:	591.7 km^2
Area within the P_{90} Contour Line:	95.78 km^2
Average Thickness within the P_{50} Contour Line:	29 um
Average Thickness within the P_{90} Contour Line:	50 um
Average Shore Oiled:	XX km



Fall 2011

Area within the P_{50} Contour Line:	440.7 km^2
Area within the P_{90} Contour Line:	9.5 km^2
Average Thickness within the P_{50} Contour Line:	34 um
Average Thickness within the P_{90} Contour Line:	99 um
Average Shore Oiled:	XX km

NOTES

● Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.

P_{50}: after 48 hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.

P_{90}: after 48 hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.

Statistical results for each season based on independent spills occuring every 6 hours for three months.

Tracking time for each spill was 48 hours.

The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

STATUS
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TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Site H (16,500 m^3)
P_{50} and P_{90} after 48 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

OFFICE	DATE
EBA-VANC	November 7, 2013

Figure 5.4.34

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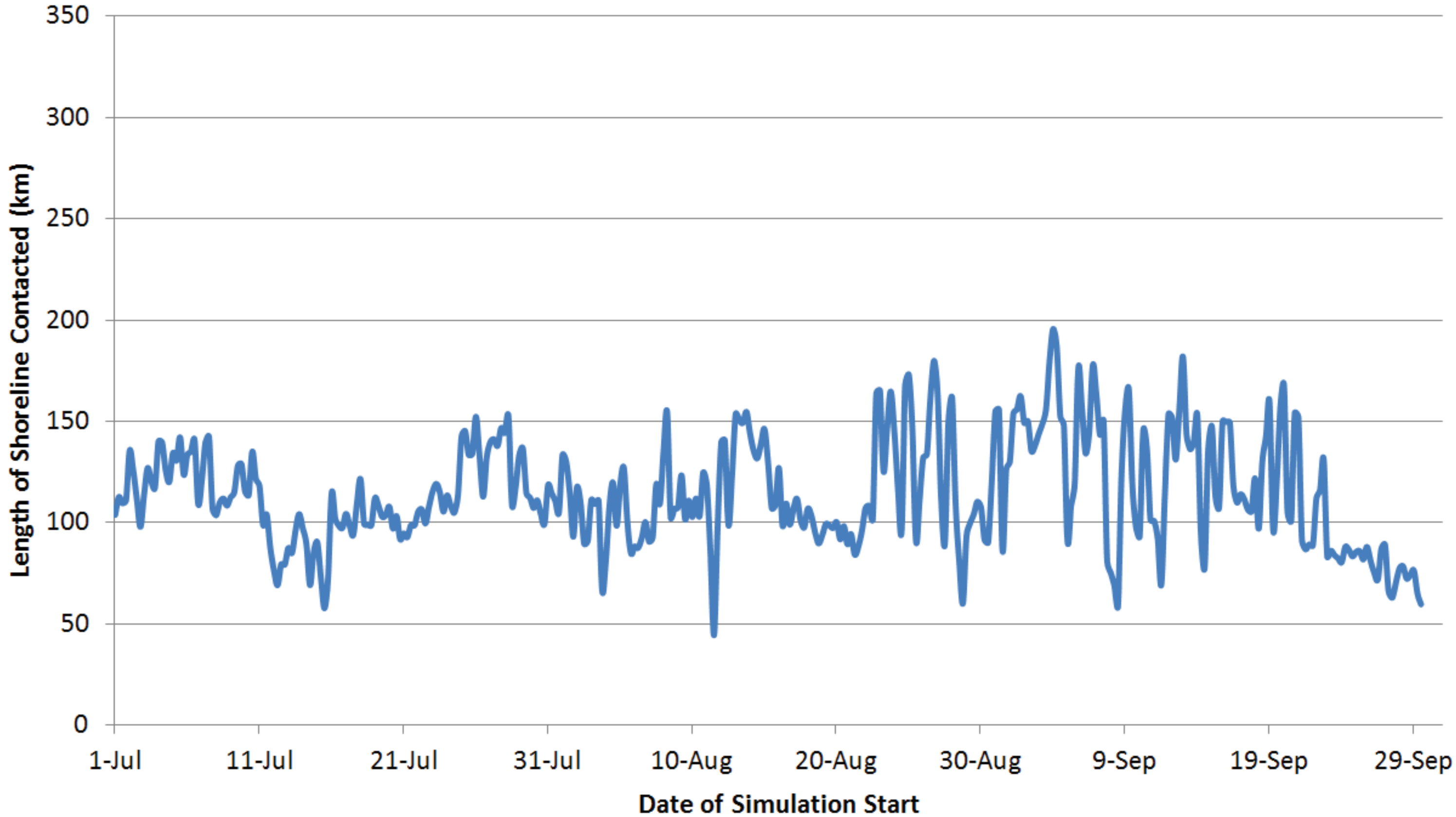

NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.

- Tracking time for each spill was 15 days.

STATUS
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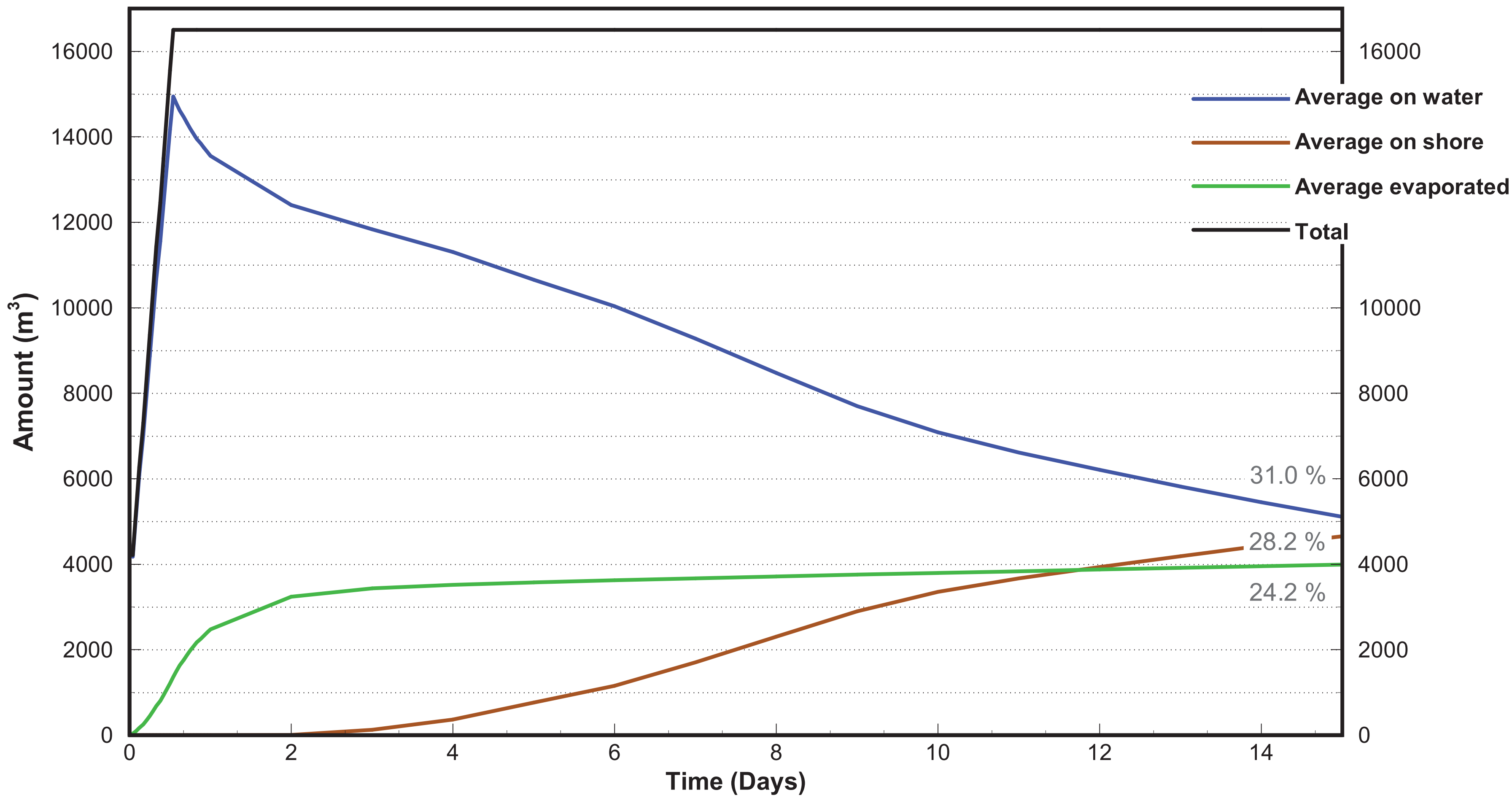
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, SiteH (16,500 m^3)
Length of Shoreline Contacted

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	**Figure 5.4.35**
OFFICE	DATE				
EBA-VANC	October 30, 2013				



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 15 days.
- The major components of the mass balance are shown above.

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TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site H (16,500 m^3)
Major Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 30, 2013

Figure 5.4.36

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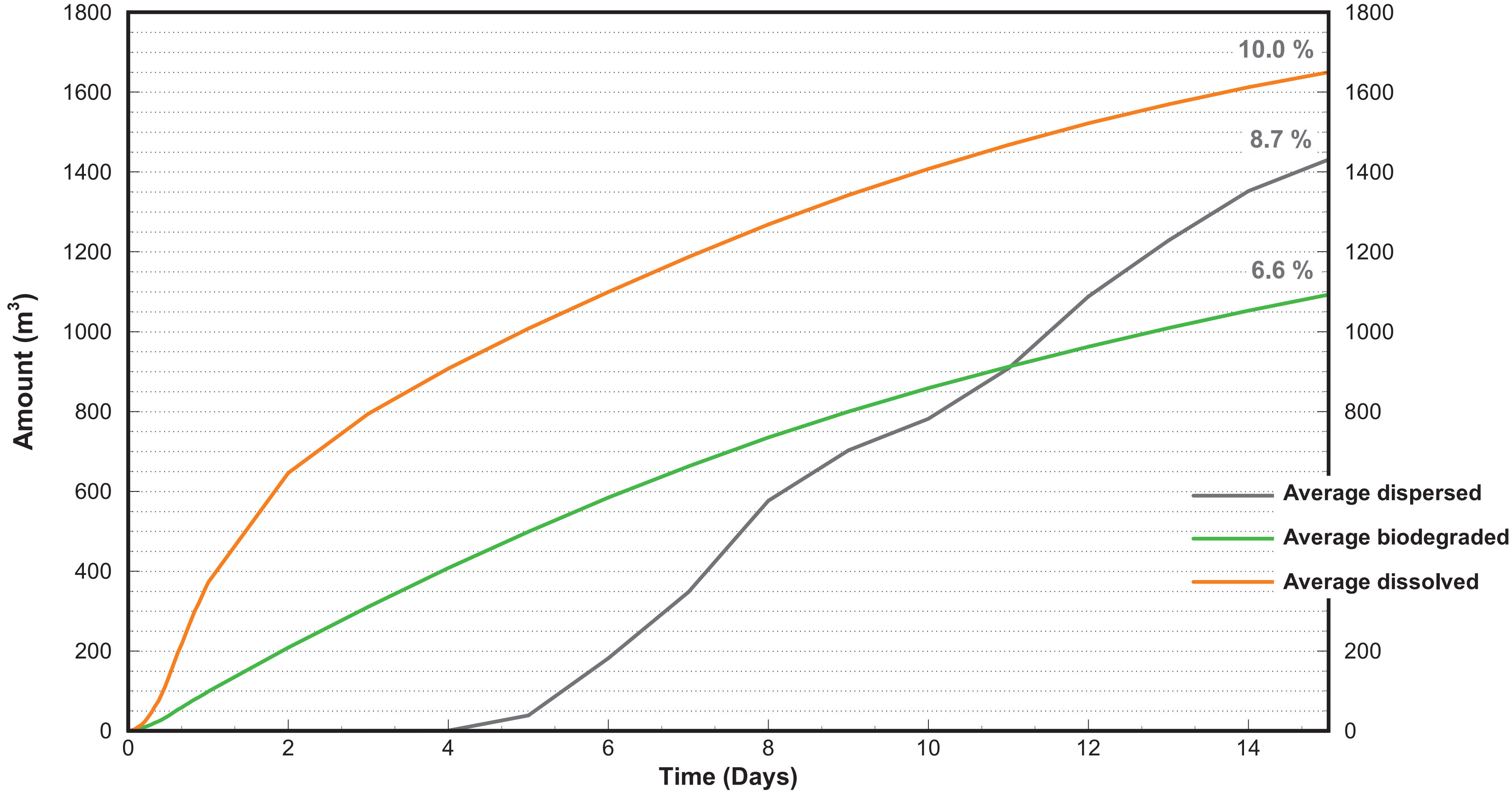
30 Oct 2013 11:26:00



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 15 days.
- The minor components of the mass balance are shown above.

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TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site H (16,500 m^3)
Minor Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 30, 2013

Figure 5.4.37

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30 Oct 2013 10:50:08

5.4.4.9 Summary of Stochastic Results

In order to obtain a general understanding of spill behaviour, the results presented in the preceding sections are summarized into the following Table 5.4.16.

TABLE 5.4.16

SUMMARY OF STOCHASTIC MODELLING RESULTS (NO MITIGATION APPLIED)

Property Modeled	Location D (Strait of Georgia)	Location E (Arachne Reef)	Location G (Juan de Fuca Strait - Race Rocks)	Location H (Buoy J)	Group Average
P_{50} area at 24 hours (km^2)	293.7	178.2	360.3	146.3	244.6
P_{50} area at 48 hours (km^2)	853.8	633.4	684.2	308.5	620.0
Shore oiled at 24 hours (km)	12.6	33.5	5.5	4.3	14.0
Shore oiled at 48 hours (km)	60.6	83.3	26.6	23.5	48.5
Shore oiled at 15 days (km)	282	302	142	135	215.3
Fraction on shore at 15 days (%)	66.1	69.8	66.4	40.9	60.8
Fraction evaporated 15 days (%)	20.4	19.8	20.3	23.4	21.0
Fraction on water at 15 days (%)	2.0	2.2	4.0	21.5	7.4
Fraction dissolved at 15 days (%)	6.8	5.5	6.4	8.8	6.9
Fraction biodegraded at 15 days (%)	2.9	2.7	3.0	5.5	3.5
Fraction on banks at 15 days (%)	1.6	0.0	0.0	0	0.4
Fraction dispersed at 15 days (%)	0.1	0.0	0.0	1	0.3

From the summary table, it is clear that there are substantial differences between the hypothetical locations modeled. Spills in the inshore waters are generally larger in aerial extent than a spill at Buoy J (Location H), on the continental shelf. The extent of shoreline oiling depends on the proximity of land, and on the complexity of currents at the site: currents at the Juan de Fuca (Race Rocks) site (Location G) and at Buoy J (Location H), in summer, are dominated by the large-scale estuarine flow in these areas, whereas in the Strait of Georgia (Location D) and Arachne Reef (Location E), currents tend to be more tidal. The fraction evaporated is relatively constant for all four sites. The amount remaining on the water surface is much less at the inshore sites, because of the close proximity of shorelines. The dissolved fraction is larger at Buoy J (Location D), possibly because the flow and winds are more unidirectional, so the slick is always moving over new water which has not been exposed to the dissolved constituents: this would lead to an increased mass transfer rate at the oil-water interface. Biodegraded fractions are generally small, and it is not clear why the greatest biodegradation occurs at Buoy J (Location H). The fraction on banks is highest at the Strait of Georgia site (Location D), because of the proximity of Roberts and Sturgeon Banks, and the fraction dispersed is highest at Buoy J (Location H), because of the greater wave action in the open waters.

These stochastic simulations show the consequences of the oceanographic and meteorological factors in the area, as well as the consequences of the particular characteristics of the transported product CLWB. These results have also been used to inform mitigation planning, and as part of the environmental risk assessment, discussed in the next sections.

5.4.4.10 Mitigation Methods

The testing documented in the Gainford Study also assessed the effectiveness of mechanical skimming equipment, dispersants, beach cleaning agents, and in-situ burning on CLWB. This section provides a summary of the results. The results of these tests are discussed below. The effectiveness of alternate oil spill response methods such as the use of dispersants and in-situ burning were not found to be as effective as mechanical means. However weathered CLWB up to 24 hours did ignite in in-situ burn tests. Further details of all tests are available in the Gainford Study Report.

The Gainford Study also showed that fresh-to-very-weathered CLWB could be effectively removed from a hard substrate through a combination of shoreline cleaner (Corexit 9580) and low-to-moderate water pressure flushing. These techniques may not be suited for all types of shorelines; however, they are generally appropriate for coarse-grained materials (gravel, cobbles, and boulders, including coarse sediment mixes).

During the Gainford Study, WCMRC arranged to test several types of skimmers on progressively weathered CLWB. Throughout the allotted time period of 10 days, all of the skimmers proved effective in recovering the product, whether it was fresh, emulsified, or naturally weathered after a 10-day exposure to ambient element conditions. There were no conditions during the testing period under which any of the three skimmers failed to operate.

At discharge the CLWB product was less viscous than anticipated by the skimmer vendors, prompting them to state they would have preferred to use oleophilic discs at the outset of the test and then switch to brushes later as the oil became more viscous. It is obvious from the results of these tests that the responders would be well served to adjust their equipment in keeping with the pace of oil weathering, when dealing with spilled diluted bitumen. This observation is similar to what responders have faced when dealing with other types of oil and should not cause any issues in response management or oil recovery.

Table 5.4.17 and Table 5.4.18 provide a summary comparison of the changes in key physical properties and chemistry of crude oil products that are currently shipped from and to the West Coast of North America, including crude oil from the Alaska North Slope (ANS). Although general perceptions may conceive of dilbits as being very different types of oil from other commodities transported via pipelines and tankers, the fact is that the general physical and chemical properties of dilbit as it weathers are not significantly different than other heavy crude oil products, such as those illustrated in the following tables.

Emergency responders have developed procedures and techniques to respond to accidental spills of the heavy crude oil products shown in the following tables. Since dilbit behaves similarly to these products due to the effects of weathering, emergency response procedures and clean-up techniques for dilbit would be similar to these other heavy crude oil products.

TABLE 5.4.17

COMPARISON OF CHANGES IN KEY PHYSICAL PROPERTIES OF CRUDE OIL PRODUCTS AS THEY WEATHER

	Weathering (weight %)	API	Water (vol %)	Flash Point (C)	Density (g/mL) @ 0/15		Pour Point (C)	Dynamic Viscosity (cP) @ 0/15		Adhesion (g/m²)	Surface Tension (mN/m) @ 0/15		Oil/Brine (33 ppt) Interfacial Tension (mN/m) @ 0/15		Oil Freshwater Interfacial Tension (mN/m) @ 0/15		Emulsion Formation: Visual Stability	Emulsion Formation: Complex Modulus (Pa)	Emulsion Formation: Emulsion Water Content (%)	Reference
					0°C/1°C*	15°C		0°C/1°C*	15°C		0°C	15°C	0°C	15°C	0°C	15°C	15°C/14°C*			
ANS Crude Oil	0	30.89	< 0.1	< -8	0.877	0.8663	-32	23.2	11.5	20	27.3	26.4	22.5	20.2	26.7	23.6	Unstable			1
	10		< 0.1	19	0.9054	0.894	-20	76.7	31.8	35	29.8	28.4	25.3	23.1	28.1	25.5	Unstable			1
	22.5		< 0.1	75	0.9303	0.9189	-9	614	152	38	31.2	30.4	26.8	24.2	30.8	27.7	Unstable			1
	30.5		< 0.1	115	0.9457	0.934	-6	4,230	614.7	40	33.1	31.8	30.1	25.6	33.2	30.2	Mesostable	155	72.9	1
Fuel Oil #5	0	11.5	3.1	94	1.0034	0.9883	-19	18,600	1,410	34	NM	NM	NM	NM	NM	NM	Stable	1,590	78.3	1
	7.2		< 0.1	136	1.016	1.0032	-3	72,000	4,530	47	NM	NM	NM	NM	NM	NM	Stable	2,490	72.8	1
Heavy Fuel Oil	0	11.47	0.1	111	1.0015	0.9888	-1	241,000	22,800	100	NM	NM	NM	NM	NM	NM	Entrained	752	57.7	1
	2.5		< 0.1	133	1.0101	0.9988	11	3,600,000	149,000	240	NM	NM	NM	NM	NM	NM	Entrained	984	24.1	1
CLWB	0	21.4^{+}	0.9	-4.5	0.0948*	0.936	< -24	1,363*	368					23.2			Mesostable*		53	2/3
	14.3	14.3^{+}		4	0.987*	0.977	-15	57,548*	9,227					24.7			Unstable*		0	2/3
	17	12.1^{+}		4	0.990*	0.981	-12	98,625*	14,486					>27			Unstable*		0	2/3
	23^{+}	10.2	33.4	56		0.9986	9													3

Source: Fingas 2001.

TABLE 5.4.18

COMPARISON OF CHANGES IN KEY CHEMICAL PROPERTIES OF CRUDE OIL PRODUCTS AS THEY WEATHER

	Weathering (weight %)	Benzene		Toluene		Ethylbenzene		Xylenes		BTEX		Reference
		% vol	ug/g	% vol	ug/g	% vol	ug/g	% vol	ug/g	% vol	ug/g	
ANS Crude Oil	0	0.283	2,866	0.592	5,928	0.132	1,319	0.616	6,187	1.624	16,300	1
	30.5	0	0	0	0	0	0	0	0	0	0	1
Fuel Oil #5	0	0	0	0.017	149	0.014	124	0.070	612	0.101	890	1
	7.2	0	0	0	0	0.000	1	0.000	2	0.000	0	1
Heavy Fuel Oil	0	0.005	40	0.016	136	0.007	58	0.045	396	0.072	630	1
	2.5	0	0	0	0	0	0	0	0	0	0	1
CLWB	0	0.24	2,247	0.43	3,983	0.06	555	0.36	3,346	1.25	10,132	3

Source Fingas 2001.

Observations at the end of the 10-day test period did not provide any instances where the buoyancy of the CLWB product was observed to have been compromised either neutrally downward in the water column or sunken to the bottom of the tank. Visual observations of the tanks during final decontamination further affirmed the absence of sunken oil. Vendors and contractors both agreed that under the test conditions the CLWB product behaved no differently than other crude oils and proved to be mechanically recoverable by the skimming units tested. As mentioned previously, due to the light viscosity, recovery of the early discharged CLWB product would have been improved by the use of drum and disc skimming attachments. It was not until after a few days of weathering that the vendors would have opted to use the brush/belt attachments. Participation in the Gainford Study has augmented WCMRC's knowledge and experience effectively address oil spills involving dilbit.

The effectiveness of alternate oil spill response methods such as the use of dispersants and in-situ burning were not found to be as effective as mechanical means. However weathered CLWB up to 24 hours did ignite in in-situ burn tests. Further details of all tests are available in the Gainford Study Report.

As the Gainford Study and similar lab and meso-scale tests have shown that CLWB remained on the surface throughout the test period spill containment strategies and tactics for floating oils are thereby applicable to diluted bitumen. Changes in spilled oil behaviour and movement on water can be influenced by numerous factors. Effective containment requires adjusting strategies and tactics to changing conditions for a spill of any oil type. Oil response organizations can take effective steps to limit the amount of oil adversely affecting the environment and shorelines if they are able to respond to an oil spill quickly. This is discussed with assistance of an oil spill response simulation exercise involving a hypothetical oil spill at Location E in Section 5.7.

5.5 Oil Spill Preparedness and Response

5.5.1 Current Capacity

The conversions provided in Table 5.5.1 were calculated by WCMRC (WCMRC 2013b) based on an assumed density of 940 kg/m^3 and are used throughout this section.

TABLE 5.5.1

CONVERSION FROM CUBIC METRE TO TONNE

m^3	Tonne
8,250	7,750
10,600	10,000
16,500	15,500

The regulatory framework, roles and responsibilities for emergency response and preparedness for an oil spill in a marine environment in Canada were described in detail in Volume 8A, Section 1.4. The *Canada Shipping Act,* 2001 is administered by Transport Canada and provides the overall regulatory framework for spill prevention, emergency preparedness and response in the marine environment. Under the *Canada Shipping Act, 2001* a federally certified response organization is required to have prescribed levels of equipment and resources available to carry out oil spill response activities upon request of one of their members or upon direction of the designated Authorities (*i.e.*, CCG or Transport Canada). This section describes the current capacity of the response organization for the West Coast of BC, WCMRC.

WCMRC, as a response organization, is required to submit an OSRP to Transport Canada every three years to maintain certification. The OSRP is developed by WCMRC to work within a framework of other federal, provincial and local emergency response plans, as well as tankers' SOPEP and oil handling facilities' OPEP and an on-site Oil Pollution Prevention Plan (WCMRC 2012).

WCMRC's area of operation for oil spill recovery (as designated by Transport Canada) and clean-up covers all of Canada's West Coast and all internal navigable waters and is referred to as the Geographic Area of Response (WCMRC 2012). Within the Geographic Area of Response, there are particular areas designated by Transport Canada as needing more rigorous planning standards given the increased risks associated with greater traffic density, convergence of vessels, and volume of oil transported. These particular areas are termed Designated Ports, Primary Area of Response, and Enhanced Response Areas (WCMRC 2012):

- **Designated Port** - The Port of Vancouver within PMV's jurisdiction is defined as a designated port due to the volume of oil handled, marine traffic volume, and marine traffic convergence. The Westridge Marine Terminal is within this area. Through this designation, WCMRC is required to maintain a dedicated package of response equipment that is capable of responding to a 150 tonne spill within 6 hours. Trans Mountain has jurisdiction over the Westridge Marine Terminal and would be responsible for undertaking response using Trans Mountain's own and WCMRC resources.

- **Primary Area of Response** - As the majority of large spills (> 1,000 tonnes) occur outside port boundaries where shipping lanes converge a Primary Area of Response is designated as an area associated with the Port of Vancouver, a Designated Port. The Primary Area of Response for the Port of Vancouver extends from the Port boundary to a distance of 50 nautical miles in all directions. WCMRC has specific levels of response within designated times to which it must demonstrate capability.

- **Enhanced Response Area** - Marine areas not covered in the previous designations but that hold a higher risk of oil spills due to traffic convergence and volume of shipping are identified as Enhanced Response Area. The Enhanced Response Area encompasses all Canadian waters between the western boundary consisting of a line running between Carmanah Point on Vancouver Island, to Cape Flattery, Washington State, and the eastern boundary consisting of a line running from Victoria due east to the Canada-US border.

Figure 5.5.1 illustrates these special areas. WCMRC's existing response capacity is summarized in the following paragraphs.

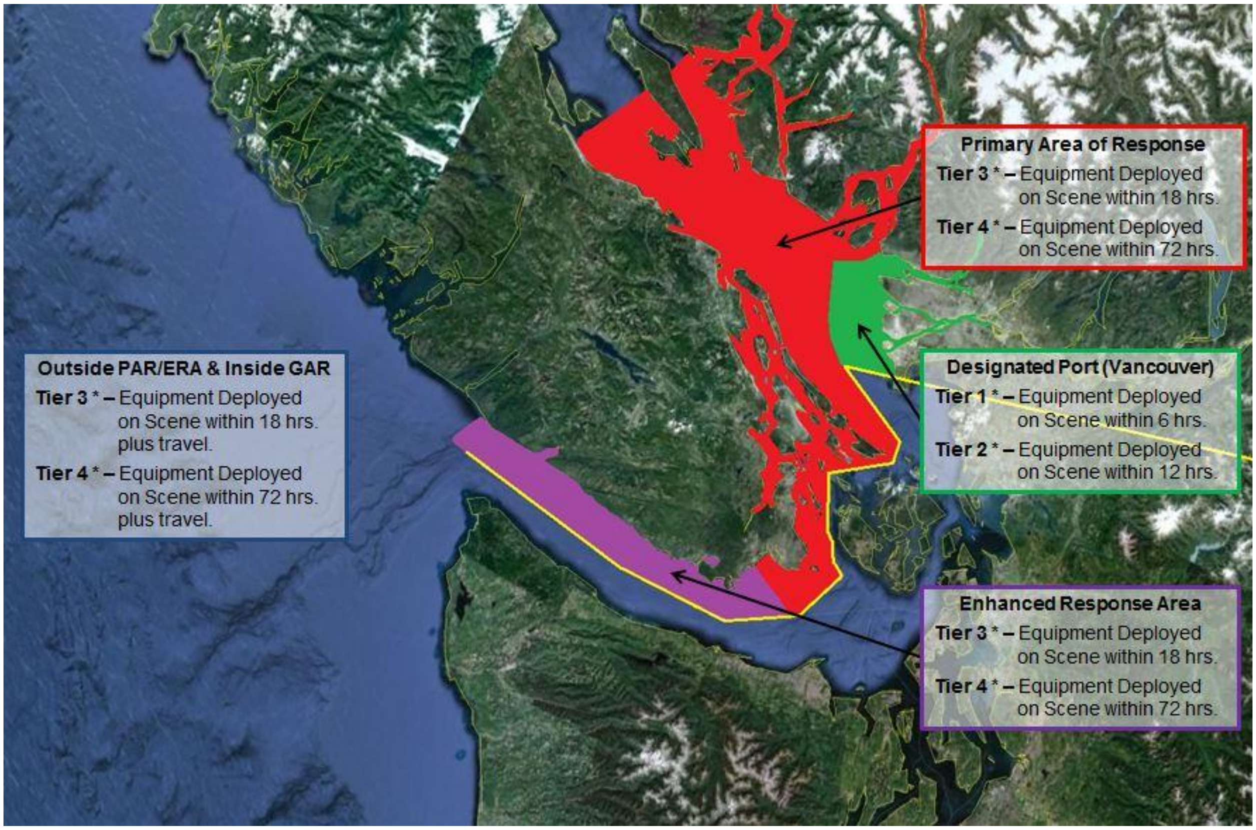


Figure 5.5.1 Map of WCMRC's Special Areas (WCMRC 2012)

Although the Primary Area of Response and Enhanced Response Area are defined separately the planning standards are effectively the same for both.

5.5.1.1 Planning Standards for Response times and Capacity

WCMRC must demonstrate to Transport Canada that it has logistical arrangements in place to meet the following Response Time Planning Standards (Table 5.5.2) within the Geographic Area of Response. The Planning Standards are more rigorous in the areas of special designation.

TABLE 5.5.2

WCMRC RESPONSE TIME PLANNING STANDARDS

	150 tonnes (Tier 1)	1,000 tonnes (Tier 2)	2,5000 tonnes (Tier 3)	10,000 tonnes (Tier 4)
Inside Designated Port boundary	Deployed on-scene in Designated Port boundary 6 hours	Deployed on-scene in Designated Port boundary 12 hours	N/A	N/A
Inside Primary Area of Response/ Enhanced Response Area	N/A	N/A	Delivered on-scene in Primary Area of Response / Enhanced Response Area boundary 18 hours	Delivered on-scene in Primary Area of Response / Enhanced Response Area boundary 72 hours
Outside Primary Area of Response/ Enhanced Response Area	N/A	N/A	Delivered on-scene outside Primary Area of Response / Enhanced Response Area 18 hours + travel time	Delivered on-scene outside Primary Area of Response / Enhanced Response Area 72 hours + travel time

Note: On water recovery operations for spills in sheltered and unsheltered waters are to be completed within 10 operational days from initial deployment of equipment.

Source: WCMRC 2012

Currently, WCMRC is certified to Tier 4, which is the highest certification level available to a Canadian spill response organization and has more than the capacity required to respond to an oil spill up to 10,000 tonnes. WCMRC's current certification is based on a network of personnel and equipment capable of providing response to the spills to meet the Tier 4 requirement and ability to cascade the necessary resources within the federally required time allocated for doing so.

5.5.1.2 Personnel

With respect to personnel, WCMRC maintains a team of full-time and part-time employees, and has more than 20 contractor and 30 advisory agreements in place at any time (WCMRC 2012). Another key component of WCMRC's marine response capability is the Fishers Oil Spill Emergency Team (FOSET). More than 100 vessels and crews from along the West Coast are registered with FOSET and WCMRC provides spill response training for this team.

5.5.1.3 Training and Inspections

Each year WCMRC undertakes a program of training for its personnel, FOSET members, and contractors to ensure they are ready for their spill response tasks (WCMRC 2012).

In addition to formal training, WCMRC conducts a program of equipment deployment and tabletop exercises over the 3-year certification cycle:

- Annually:
  - 150 tonne dedicated equipment deployment within the Port of Vancouver; and
  - 1,000 tonne tabletop exercise based on a scenario.
- Every two years:
  - 2,500 tonne equipment deployment.
- Every three years:
  - 10,000 tonne tabletop based on a scenario.

As well, WCMRC participates in annual joint exercises under the Canada-US Joint Contingency Plan, and cross border mutual aid exercises with partners in Washington and Alaska.

Transport Canada inspects the entire WCMRC equipment inventory over a continuous 3-year cycle (WCMRC 2012).

5.5.1.4 Equipment

WCMRC exceeds, the equipment requirements for Tier 4 certified response organizations by maintaining (WCMRC 2012):

- A dedicated fleet of specialized oil spill response vessels, with a combined skimming capacity of 280 tonnes/hour (*Canada Shipping Act, 2001* requirement is 27 tonnes/hour).
- More than 30,000 m of containment boom (*Canada Shipping Act, 2001* requirement is 15,000 m).
- The capacity to clean-up 1,500 m of shore line/day (*Canada Shipping Act, 2001* requirement is 500 m of shore line/day).
- Incident Command Post kits containing all the materials and equipment required to establish and operate a complete Incident Command Post. Three of these kits are currently stored in trailers ready to be mobilized in Burnaby, Duncan, and Prince Rupert, BC.
- A communications network that includes fixed and portable repeaters and a mobile communications vehicle for supporting remote operations.
- Equipment caches in Haida Gwaii, Prince Rupert, Kitimat, Shearwater, Port Hardy, Campbell River, Powell River, Sechelt, Port Alberni, Duncan, Nanaimo, Vancouver, and Victoria.

In addition to WCMRC's capability, the CCG operates three large equipment depots in Victoria, Richmond, and Prince Rupert and maintains equipment caches in an additional ten locations along the West Coast. WCMRC maintains mutual aid agreements with US oil spill response organizations in Washington and Alaska.

WCMRC personnel are trained in non-mechanical methods of oil spill clean-up, including the use of oil spill dispersants and in-situ burning of oil; however, because these methods are not pre-approved by Transport Canada they would only be considered on a case-by-case basis through consultation with Federal and local authorities and experts (WCMRC 2012).

5.5.1.5 Mutual Aid Agreements

WCMRC also has a number of mutual aid agreements in place with both Canadian and US counterparts that provide WCMRC the ability to call on those resources for assistance and equipment in case of a large oil spill. Mutual Aid is a formal agreement among responders to lend assistance across jurisdictional boundaries when required. Mutual Aid Agreements have been formed between WCMRC and three other organizations:

- Southeast Alaska Petroleum Response Organization (SEAPRO);
- Eastern Canada Response Corporation (ECRC); and
- Marine Spill Response Corporation (MSRC).

As a result of these agreements, organizations train and exercise together, ensure equipment is compatible, share communication frequencies and as well as best management practices. In addition, there are Joint Marine Contingency plans that exist between Canada and the US, France and Denmark.

5.5.1.6 WCMRC Participation in Fate and Behaviour Study

In May 2013 Trans Mountain conducted applied research on the fate and behaviour of diluted bitumen in a marine environment. WCMRC supported the testing of skimming equipment.

Diluted bitumen is expected to form a large proportion of the crude oil shipped from the Westridge Marine Terminal. Participants observed the diluted bitumen is a homogeneous substance and does not separate into bitumen and diluent when spilled on water. During the weathering tests conducted over a 10-day period the diluted bitumen remained floating and no product was observed to sink. While initially low, the viscosity of the diluted bitumen increased sharply over 48 hours and began to exhibit properties typical of heavy “conventional” crude oil. The tests were attended by a wide range of regulators and other agencies who were invited to attend.

WCMRC arranged for oil skimmer manufacturers to conduct tests with their equipment at various times during the oil weathering process. These equipment tests did not highlight any performance shortcomings on the part of the recovery equipment available to WCMRC. Operational adjustments to compensate for increased diluted bitumen viscosity were no different than field adjustments during any actual spill event involving crude oil and intermediate to heavy fuel oil.

The study tested in-situ burning of the spilled diluted bitumen and the use of dispersants and shoreline cleaning agents.

The study concluded that, given the appropriate safety, environmental and operating conditions, dispersants may be effective within the first day of a spill before weathering results in oil that is too viscous to effectively disperse.

With respect to in-situ burning, the study concluded that, given the appropriate safety, environmental and operating conditions, in-situ burning might be effective but likely only for a short time, during the first 12 to 24 hours of a spill, before weathering results in diluted bitumen that is too viscous to effectively ignite and sustain combustion.

With respect to shoreline cleaning agents the study concluded that fresh to very weathered diluted bitumen can be effectively removed from a hard substrate through a combination of a shoreline cleaner and low to moderate water pressure flushing. These techniques may not be suited for all types of shorelines; however, they generally are appropriate for coarse-grained materials (gravel, cobbles, and boulders and including coarse sediment mixes).

5.5.2 Proposed Improvements

Trans Mountain acknowledges that despite the substantial measures that will be in place to reduce the probability of an oil spill from a Project-related tanker (Section 5.3), it is necessary to have resources and plans to minimize the effects of an oil spill, make the best efforts to control the spread of oil, and ensure that clean up is timely and effective.

The results of the fate and behaviour studies indicate that a prompt response can significantly reduce the consequences of a spill. As well, the diluted bitumen tested remained floating over the 10-day test period; therefore, to be effective, planning standards for on-water operations should be based on removing free oil with in 10 days.

WCMRC's current equipment capability exceeds requirements for Tier 4 (10,000 tonnes) certification. In theory, given the calculation for a credible worst-case oil spill from an oil tanker leaving the Westridge Marine Terminal (*i.e.*, 16,500 m^3 or 15,500 tonnes; Table 5.2.1), and the actual capacity of equipment currently owned by WCMRC, there is sufficient response equipment available to meet the credible worst-case scenario response requirements under current Canadian standards of response.

Trans Mountian asked WCMRC to develop emergency response measures capable of handling one credible worst case oil spill at any location along the tanker route within the Salish Sea region (*i.e.*, up to the 12 nautical mile limit [Buoy J]). WCMRC, in consultation with Trans Mountain, examined its current equipment locations and capacity, and the mandated response times against the results of the fate and behaviour study (Volume 8C, TR 8C-12), the results of the quantitative risk assessment (Volume 8C, TR 8C-12), known meteorological and oceanographic data, and hypothetical accidental oil spill locations (Figure 5.5.2) and concluded that certain improvements could be undertaken to improve the effectiveness of its current emergency preparedness and response capacity with respect to the increase in Project-related tankers. The results of their assessment are provided a report authored by WCMRC in Volume 8C, S12.

While the credible worst case spill volume based on partially laden Aframax tankers is 16,500 m^3 or an approximate 15,500 tonne release of heavy crude, this volume was increased for the WCMRC report to reflect the fact that larger cargos, not related to the Project, transit the WCMRC's Geographic Area of Response. DNV calculated that under the same conditions the credible worst case for a fully laden Aframax (not related to the Project) would equate to approximately 21,000 m^3 or a 20,000 tonne release of heavy crude oil. A fully laden Aframax was used as the basis to develop enhanced response capacity because at up to 120,000 DWT, a fully laden Aframax corresponds with the US federal regulation (33 CFR 156.1303) that effectively limits the maximum size of tankers calling in Puget Sound to 125,000 DWT. Laden vessels calling in Puget Sound transit through Canadian waters. While a 20,000 tonne credible worst case oil spill volume is larger than what is required for Project-related tankers it has been chosen to reflect the size of the largest oil cargo expected within WCMRC's area of response.

WCMRC and Trans Mountain also consulted with spill and response organizations including other response organizations in Canada, the US and Norway. The equipment specifications associated with the proposed enhancements (including size, speed and capabilities) have been determined in part from an assessment of response organizations around the world.

Since there is difference in planning standards for the existing Enhanced Response Area and Primary Area of Response a simplified division WCMRC's Geographic Area of Response has been proposed by WCMRC to combine the Primary Area of Response and Enhanced Response Area into one region that is referred to as the Increased Response Area (IRA). The IRA encompasses the area affected by Project-related marine traffic. Thus there would be three areas of response under the enhanced planning standards: inside the designated port (PMV), the IRA, outside the IRA.

The potential enhancements to current planning standards and WCMRC's current response capacity are summarized in Table 5.5.3, which compares the improvements to WCMRC's existing capacity that was described in detail in Section 5.5.1. It is important to note that the potential improvements to WCMRC's current capacity focus on the area potentially affected by the increase in Project-related tankers, specifically, Westridge Marine Terminal to Buoy J and the shipping lanes in between (see Figure 1.3.1). Of particular note are the more stringent response times.

TABLE 5.5.3

PROPOSED IMPROVEMENTS TO WCMRC'S EMERGENCY RESPONSE CAPACITY

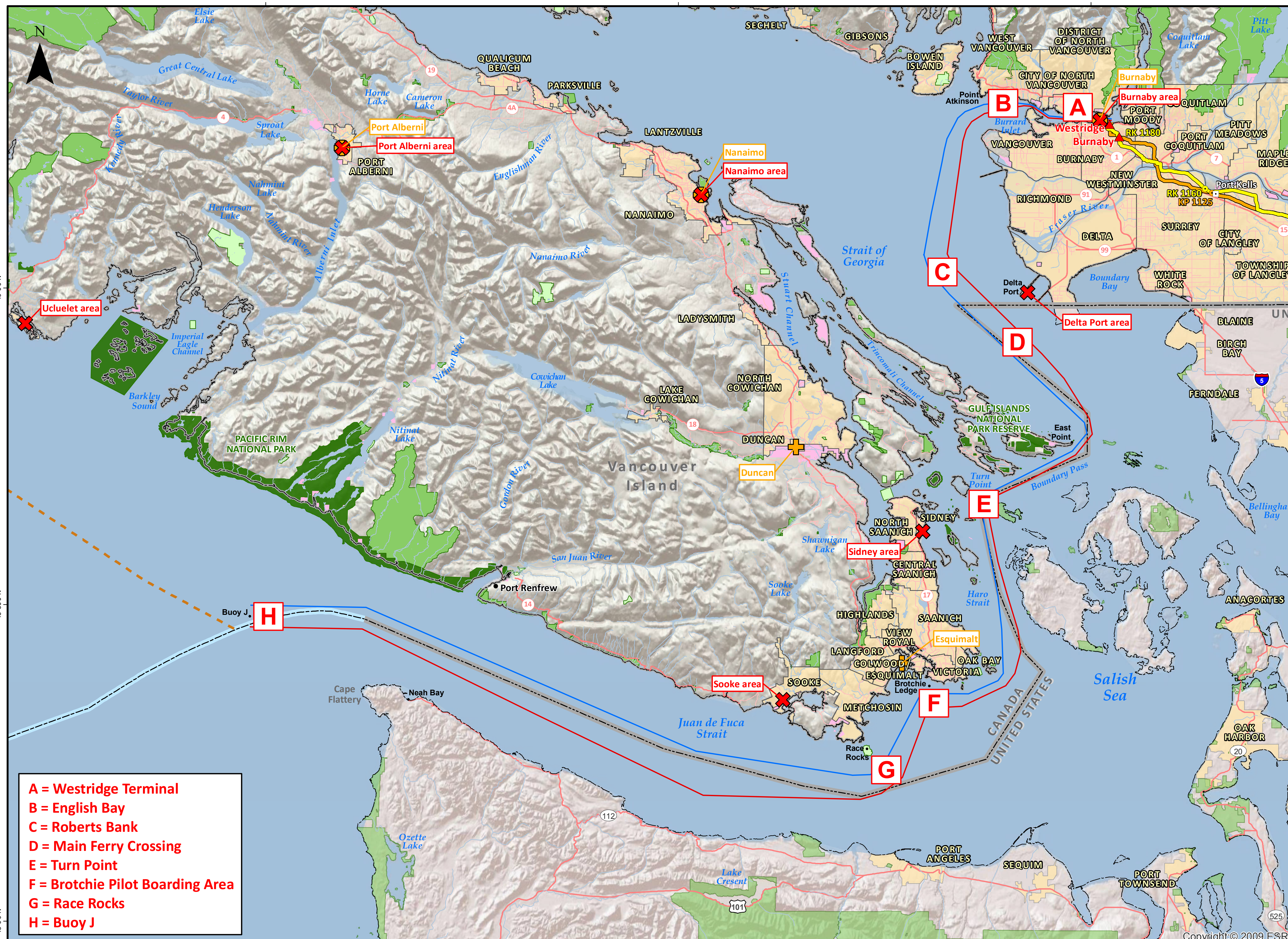
Topic	Existing Requirement or Capacity	Recommendation for Improved Capacity
Special Areas Designation	• Designated Port: Port of Vancouver • Primary Area of Response: 50 NM in any direction from the boundary of the Port of Vancouver • Enhanced Response Area: all Canadian waters between the western boundary consisting of a line running between Carmanah Point on Vancouver Island, to Cape Flattery, Washington State, and the eastern boundary consisting of a line running from Victoria due east to the Canada-US border.	• Designated Port would remain the same. • Replace the Primary Area of Response and Enhanced Response Area designations with an IRA designation. The IRA would cover the Port of Vancouver and the transit route travelled by Project-related tankers, specifically from Delta Port to Buoy J, reflecting the more stringent response times outlined below.
Response Capacity	• Response organizations are certified based on their capacity to respond to oil spills of certain volumes: – Tier 1 (150 tonnes); – Tier 2 (1,000 tonnes); – Tier 3 (2,500 tonnes); and – Tier 4 (10,000 tonnes). • WCMRC is currently certified as a Tier 4 response organization capable of responding to a spill of up to 10,000 tonnes or 10,000 m^3	To account for a credible worst case oil spill and addition to the existing Tiers 1 to 4, create a new category of capacity: • Tier 5 (20,000 tonnes or 21,000 m^3). • WCMRC would be required to maintain Tier 5 capacity, which unless certified by Transport Canada shall be verified by an independent organization.
Response Times	• The current response times for WCMRC as a Tier 4 certified response organization were outlined in Section 5.5.1, Table 5.5.1 (WCMRC Response Time Planning Standards).	• Commence deployment of equipment and resources, provided safe to do so according to the tiered structure: – Tiers 1, 2 and 3: for a spill within Port of Vancouver, within 2 hours of notification; – Tiers 1, 2 and 3: for a spill within the IRA, within 6 hours of notification; and – Tiers 4 and 5: ▪ commence response within timeframe corresponding to the Designated Port or IRA; ▪ cascade equipment and response based on scale of spill and type of product; ▪ deliver response equipment suitable for Tier 5 response within 36 hours of notification; and ▪ request assistance of mutual aid responders. • Response times include travel time. • On water recovery operations for spills in sheltered and unsheltered waters are to be completed within 10 operational days from initial deployment of equipment.
Shoreline Clean-Up	• WCMRC is required to have the capacity to treat 500 m of shoreline/day • WCMRC currently has the capacity to treat 1,500 m of shoreline/day	• Increase WCMRC's capacity to treat up to 3,000 m of shoreline/day. • Identify and train a suitable level of responders to meet this capacity.
Response Plan Contents	Currently, the WCMRC OSRP is required to address the following information (WCMRC 2012): • declaration and submission process; • response organization details; • relationship to other plans and management systems; • geographical area of response; • call-out procedures; • personnel and equipment resources; • oil spill exercise program; • training plan; • health and safety program; • response counter-measures; and • wildlife protection and rehabilitation.	Additions to the WCMRC OSRP should include: • An organizational structure that adhere to requirements of the ICS management system approach • Include a list of response equipment and their location • Response equipment must be of types that are effective for the local environment and appropriate for the product carried on oil tankers. • Identification of ecologically sensitive areas in the IRA. • Identification of economically sensitive areas in the IRA. • Procedures to protect identified locations of shore line that might be affected by oil. • Clean-up methods that include both conventional and unconventional response methods including dispersant use, in-situ burning, oil herders, for example. • The ability for both marine and air transport and surveillance options. • Procedures to treat oiled wildlife. • Procedures to manage oiled waste, identifying cooperation with suppliers, government agencies. • A list of mutual aid programs with other response organizations and marine service providers in Canada and in the US.
Response Exercises	• Training and exercise program carried out over the three-year certification cycle mandated under *Canada Shipping Act, 2001* • Annually: – 150 tonne dedicated equipment deployment within the Port of Vancouver; and – 1,000 tonne tabletop exercise based on a scenario. • Every 2 years: – 2,500 tonne equipment deployment. • Every 3 years: – 10,000 tonne tabletop exercise based on a scenario. • Also conduct: – Cross border/mutual aid exercises; – Canada-US Joint Contingency Plan exercises; and – Member exercises	• The same training and exercise requirements would apply and would expand to include the new Tier 5 category. • Every 3 years: – 20,000 metric ton tabletop exercise based on a scenario. • Exercises are intended to validate response strategies and demonstrate capabilities of all those involved in a response, including government agencies and mutual aid providers.
Personnel Training	• Must provide the name of each person who has received basic oil spill response training. • Must provide description of the training provided to personnel and volunteers. • Training program is vetted by Transport Canada.	• Maintain a list of personnel providers. • Maintain a list of persons trained in ICS requirements. • Maintain a list of persons and vessels of opportunity (*e.g.*, FOSET). • Conduct training of pre-identified support staff, training to be refreshed every 5 years.
Equipment	• WCMRC must ensure all equipment is in a ready state. • WCMRC must ensure a current inventory of equipment.	• Maintain up to date inventory of equipment identified to support Trans Mountain tankers, which must be in ready state, except that up to 10% of equipment of any one type may be de-mobilised for maintenance at any given time.
Audits	• Transport Canada conducts an annual audit of WCMRC against *Canada Shipping Act, 2001* requirements for a Tier 4 response organization.	• unless certified by Transport Canada shall be verified by an independent organization.

TRANS MOUNTAIN

FIGURE 5.5.2

EXISTING AND PROPOSED SPILL RESPONSE EQUIPMENT STAGING AREAS

TRANS MOUNTAIN EXPANSION PROJECT



- Reference Kilometre Post (RK)
- Kilometre Post (KP)
- Trans Mountain Pipeline (TMPL)
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Terminal
- Existing Pump Station
- Highway
- Road
- 12 Nautical Mile Limit (Territorial Sea)
- Limit of Exclusive Economic Zone (EEZ)
- International Boundary
- Marine Vessel Outbound Shipping Lane
- Marine Vessel Inbound Shipping Lane
- Existing Staging Area
- Proposed Staging Area
- Potential Hypothetical Accident Site
- Traffic Separation Scheme
- City / Town / District Municipality
- Indian Reserve / Métis Settlement
- National Park
- Provincial / State Park
- Protected Area/Natural Area/ Provincial Recreation Area/Wilderness Provincial Park/Conservancy Area

Projection: UTM Zone 10N.
Routing: Baseline TMPL & Facilities: provided by KMC, 2012; Proposed Pipeline Corridor V6: provided by UPI, Aug. 23, 2013; Facilities: provided by KMC, 2012; Transportation: BC Forests, Lands and Natural Resource Operations, 2012 & ESRI, 2005; Geopolitical Boundaries: IHS Inc., 2011, BC FLNRO, 2007 & ESRI, 2005, Natural Resources Canada, 2012; First Nation Lands: Government of Canada, 2013 & IHS Inc., 2011; Hydrology: IHS Inc., 2004, United States National Imagery and Mapping Agency, 2000, Natural Resouces Canada, 2010; Parks and Protected Areas: Natural Resources Canada, 2013, BC FLNRO, 2008; CHS: provided by KMC, 2013; Marine Shipping Lanes & Spill Response Locations: Moffatt and Nichol, 2013; Hillshade: TERA, derived from Geobase; US Hillshade: ESRI, 2009.

tera ENVIRONMENTAL CONSULTANTS

Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

MAP NUMBER		PAGE
201310_MAP_TERA_MR_00471_REV0		SHEET 1 OF 1
DATE December 2013	TERA REF. 7894	REVISION 0
SCALE 1:650,000	PAGE SIZE 11x17	DISCIPLINE MR
DRAWN TGG	CHECKED CAS	DESIGN LM

0 5 10 15 20 25 km

ALL LOCATIONS APPROXIMATE

201310_MAP_TERA_MR_00471_Rev0.mxd

The WCMRC report (Volume 8C, TR 8C-12, S13) describes an enhanced response regime that would be capable of delivering 20,000 tonnes of capacity within 36 hours with dedicated resources staged within the study area. This represents a response capacity that is double and a delivery time that is half the existing planning standards. These enhancements would reduce times for initiating a response to two hours within Vancouver Harbour and six hours for the remainder of the study area and parts of the West Coast of Vancouver Island. These reduced times would be achieved by creating new base locations along the tanker route. Meeting the response capacities within the designated times requires redundancy of equipment, and as a result of the redundancy, the overall capacity of dedicated response equipment available in the Salish Sea region would be in excess of 30,000 tonnes equivalent when calculated under the current Federal guidelines for response organizations.

While the probability of the worst case scenario (total loss of containment for an Aframax tanker) is so low that it is not, in DNV's assessment, a credible planning scenario, this event could be addressed by cascading equipment from other areas. In addition to the resources that would be based in the Salish Sea region, WCMRC has, through its existing mutual aid assistance agreements, access to supplementary resources to provide sufficient capacity to respond to a spill larger than the credible worst case defined in this Application.

The effectiveness of the enhanced response was tested under simulated conditions by EBA with input from WCMRC for a credible worst case oil spill event. The results of these simulations are summarized in Section 5.7.

The WCMRC study serves as a practical example of how response capacity could be enhanced to accommodate the Project. Implementation of the plan would be subject to a number of factors and requires knowledge that will be gained through the outcome of the Federal and Provincial reviews of marine spill response, the TERMPOL process, and further consultation with Aboriginal groups and other marine communities.

While recognizing that there are alternative means to achieve similar results, Trans Mountain is supportive of the enhanced capacity and the general means of implementation described by WCMRC.

Table 5.5.3 summarizes and compares WCMRC's existing and proposed future capacity for emergency response and preparedness.

In order to meet these stricter response times and to ensure appropriate equipment (both type and quantity) is available, WCMRC study recommends the addition of five new spill response bases along the tanker route. New and existing bases are identified on Figure 5.5.2. The letter references on this figure correspond with the identifiers discussed in Table 5.2.2 (Volume 8A, Section 5.2.4). The locations are the hypothetical locations DNV identified as a result of their quantitative risk assessment where an accidental oil spill from a laden tanker leaving Westridge Marine Terminal might occur. The distance between the proposed equipment staging areas and the hypothetical oil spill locations is identified in Table 5.5.4.

The capacity of equipment at the existing and new equipment staging areas is described in more detail in Table 5.5.5.

TABLE 5.5.4

DISTANCE FROM PROPOSED EQUIPMENT STAGING AREAS TO HYPOTHETICAL OIL SPILL LOCATION

	(NM)							
	Hypothetical Spill Location							
Proposed Equipment Staging Area	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Burnaby	2	10	25	35	50	75	80	130
Nanaimo	40	30	25	35	45	70	75	125
Delta Port	35	25	8	5	25	50	55	105
Sidney	55	45	30	20	8	25	30	80
Sooke	95	85	70	65	45	20	10	45
Ucluelet	180	170	155	150	130	110	100	40

Table 5.5.5 provides an example of how the total response capacity in the region could be distributed on a risk informed basis, subject to further development of geographic response plans.

TABLE 5.5.5

PROPOSED RESPONSE BASE CAPACITY FOR FUTURE OIL SPILL EQUIPMENT STAGING AREAS

Example of Distribution of Proposed Equipment to Staging Areas	Response Capacity*	
	m^3	Tonnes
Burrard Inlet (Burnaby) [1]	9,550	9,000
Delta Port area [1]	1,350	1,250
South Vancouver Island (Nanaimo – Chemainus area)	2,800	2,650
North Saanich Peninsula (Sidney area) [1]	11,900	11,200
South Vancouver Island (Victoria – Sooke area)	4,700	4,400
Southwest coast of Vancouver Island (Port Renfrew – Ucluelet area)	1,600	1,500
Total capacity at bases	31,900	30,000
Community response packages will be allocated (150 tonnes) × ten locations	1,600	1,500

Notes: 1 These locations would require full-time staff, based on 24 hours/day, 7 days/week.
* Calculated basis current federal guidelines to Canadian response organizations.

These improvements would result in WCMRC having the capacity to respond quickly to spills in excess of the credible worst case oil spill predicted for a Project-related tanker. This would help minimize the adverse environmental and socio-economic effects potentially resulting from an accidental oil spill in the Salish Sea area.

5.5.3 Financial Liability and Compensation Regime in the Event of an Oil Spill

The framework for financial liability and compensation respecting an oil spill in the marine environment from a vessel was outlined in Section 1.4.1.6. Through a combination of the Responsible Party's insurance, sources of international funding, and the Canadian SOPF, a party may be compensated for costs and damages related to an oil spill from a vessel in

Canadian waters in the following manner:

- The first level of funding for emergency response, clean up and compensation to affected parties is from the Responsible Party's protection and indemnity insurance. A protection and indemnity association of ship owners and operators known as the International Group of P&I Clubs offers insurance coverage to ship owners and charterers against third-party liabilities encountered in their commercial operations (Transport Canada 2013b). The Responsible Party's liability is limited based on vessel tonnage to a maximum of about CAD 136.76 million.

- If the Responsible Party's insurance is not adequate to cover costs and compensation, funds are available through the International Oil Pollution Compensation Fund (CAD 172.50 million) and the Supplementary Fund Protocol (CAD 833.34 million).

- Lastly, if the international funding is exhausted, Canada maintains its own source of funding called the SOPF, which has up to CAD 161.29 million of funding available.

In total, there is approximately CAD 1.3 billion in funding available to address the costs of emergency response, clean up and compensation in the event of an oil spill from a tanker.

The SOPF can also be a fund of first resort for claimants, including the Crown. Any party may file a claim with the SOPF administrator respecting loss or damage related to oil pollution from a vessel in Canadian waters. The SOPF administrator has the duty to investigate and assess claims filed with the SOPF. While a potential claim is paid out of the SOPF, the administrator is obliged to take all reasonable measures to recover the amount of compensation paid to the claimant from the Responsible Party.

5.6 Environmental and Socio-Economic Effects of an Oil Spill from a Tanker

This section discusses potential environmental and socio-economic effects of credible worst case and smaller oil spills as specified in the Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, received by Trans Mountain on September 10, 2013. Although the historical casualty data and the Project-specific risk assessment summarized in Section 5.2 demonstrate that the probability of a Project-related tanker spills is low, Aboriginal groups and the public-at-large consulted about this Project were concerned about catastrophic spills - those that are least likely but of highest consequence. In addition to fulfilling regulatory requirements, the assessment of potential environmental and socio-economic provides information to regulatory authorities and emergency responders that can be used to identify mitigation opportunities and improvements to current spill response planning and preparedness.

The spill effects methodology and discussion provided here and in Volume 7A for the pipeline and facilities differs from that adopted for routine pipeline, facility and tanker activities because spills represent low-probability, unpredictable events (Section 5.2). Rather than estimating potential residual effects and significance for each element and indicator discussed for routine activities (Section 4.0), spill evaluations identify the potential consequences of credible worst-case spills using a structured risk assessment approach patterned on a process developed to support the Aleutian Islands Risk Assessment (AIRA 2013):

- This section (Section 5.6) provides a qualitative assessment of potential environmental and socio-economic consequences based on evidence from past oil spills and scientific studies as well as stochastic oil spill fate modelling conducted for the Project (Section 5.4.4). This considers a range of spill volumes (credible worst case and smaller) and locations along the shipping route a Project-related tanker would travel. While it focuses on documented effects, it does not explicitly factor in the way that emergency response approaches described in Section 5.4.4 could reduce these potential effects. Although the Aleutians Island Risk Assessment recommends that an initial qualitative evaluation such as this focus solely on the extent and concentrations of oil as a surrogate for effects on natural resources, the discussion provided in Section 5.6 incorporates information on actual effects observed to be more thorough. A more focused and detailed ERA and HHRA to verify conclusions provided here and inform specific mitigation and emergency response plans will be completed for the Arachne Reef Turn Point SOA scenario and submitted to the NEB in early 2014.

- More detailed assessments of credible worst case and smaller spill scenarios at the Westridge Marine Terminal are provided in Volume 7A, Section 8.0. The potential ecological and human health effects of this representative scenario assume that CLWB (the representative crude oil described in Section 5.4.4) is released during tanker loading. The general fate of oil under both mitigated and unmitigated conditions is described for this scenario. A qualitative ERA then assesses potential effects for a variety of marine ecological receptors making the conservative – and unrealistic – assumption that the mitigation previously described for hypothetical worst-case event would not be implemented. Finally, a qualitative HHRA assesses the potential for people's health to be affected by a spill, including sub-populations known to show heightened sensitivity to chemical exposures, such as young children, the elderly and people with compromised health.

5.6.1 Socio-Economic Effects

Marine oil spills can affect the human environment in various ways. Spills can have community and regional economic effects, can contribute to changes in human health, and can affect the sense of individual and community well-being. Potential socio-economic effects of credible worst case and smaller spills will vary depending on the exact location and nature of the incident, and will be influenced by factors including:

- distance from human settlements;
- size and population density of nearby human settlements (*e.g.*, rural versus urban areas);
- particular patterns of resource use in the vicinity (*e.g.*, commercial, recreational, traditional); and

- key economic activities and sectors in areas that may be reached by the spill, in particular the presence of resource-based economic activities (*e.g.*, tourism, commercial fisheries, traditional uses by Aboriginal people).

This section provides a summary of how credible worst-case and smaller spills from a Project-related tanker could affect the health, economy and general well-being of people in the Salish Sea.

The discussion provided in Section 5.5 describes the spill response measures that would be undertaken by the ship owner, WCMRC, CCG and Transport Canada to respond quickly to an accidental oil spill thus minimizing the adverse environmental and socio-economic effects potentially resulting from an accidental oil spill in the Salish Sea region. Where applicable, the information provided here reflects issues identified by Aboriginal peoples, residents, land users, service providers and regulatory authorities. The complexity of predicting socio-economic effects, particularly for hypothetical scenarios, is a function of numerous factors including:

- the constant change that is occurring in socio-economic conditions of any community or region, influenced by an array of economic, political and cultural factors;
- a lack of precise information about goods, services, and employment demands for hypothetical spill scenarios;
- the role of human interpretation and its influence on individuals' physical and perceptual experiences of social effects; and
- inherent uncertainty regarding individuals' abilities, willingness and confidence to respond to change (Loxton *et al.* 2013).

Given the complexity of predicting socio-economic outcomes, this discussion of the potential socio-economic effects of marine oil spills references past spills and other relevant incidents as examples of actual documented effects rather than evaluating one or more specific scenarios. The Exxon Valdez Oil Spill (EVOS) is the largest and best studied example of the effects of a large oil spill on many aspects of the coldwater marine environment, and of communities and residents who live near, or depend on marine resources. The Exxon Valdez Oil Spill Trustee Council (EVOSTC) publishes periodic updates on the status of resources affected by the EVOS; the most recent assessment was published in 2010 (EVOSTC 2010). Many of the socio-economic studies following the EVOS are relevant to the shipping route a Project-related tanker would travel, although differences in regional human population, resource use patterns, and other economic, political and cultural factors are acknowledged.

A growing body of literature shows that both positive and adverse effects can occur, influenced by the spill volume, location, nature of the resources affected, the extent of traditional and non-traditional activities in the affected area, and the duration of clean-up and recovery. The assessment of potential socio-economic effects provided below can be used to:

- understand the types of effects that might result from credible worst case and smaller spills;
- highlight particularly vulnerable groups and resource uses; and
- help inform spill prevention, preparedness and response activities.

5.6.1.1 Economy

Marine spills can have both positive and negative effects on local and regional economies over the short- and long-term. Spill response and clean-up creates business and employment opportunities for affected communities, regions, and clean-up service providers, particularly in those communities where spill response equipment is, or would be, staged (Section 5.5). This demand for services and personnel can also directly or indirectly affect businesses and resource-dependant livelihoods. The net overall effect depends on the size and extent of a spill, the associated demand for clean-up services and personnel, the capacity of local and regional businesses to meet this demand, the willingness of local businesses and residents to pursue response opportunities, the extent of business and livelihoods adversely affected (directly or indirectly) by the spill, and the duration and extent of spill response and clean-up activities. As an example, positive spill-related economic effects were documented for major spill clean-up areas following the EVOS (McDowell Group 1990). Negative effects on tourism and commercial fishing were also documented, as described below.

5.6.1.1.1 Commercial Fishing

Commercial fishing and aquaculture is an important economic activity in the Salish Sea region and available information on important fishery areas and effort are provided in Fishery Resources Survey (TERMPOL 3.3, Volume 8C, TR 8C-3). A marine spill, particularly a large one that affects one or more important commercial fishing areas, would likely result in loss of commercial fishing income due to regulated or voluntary closures and possibly reduced demand due to concerns about fish quality. For example, following the EVOS, emergency fishing closures were instituted for salmon, herring, crab, shrimp, rockfish and sablefish immediately following the spill. All fisheries were re-opened the next year, but income from commercial fishing decreased substantially (EVOSTC 2010). Changes to commercial fishing income persist, but as with other resources affected by the EVOS (Section 5.6.2.1), other factors have influenced this change and discerning what is spill-related has been difficult (EVOSTC 2010).

5.6.1.1.2 Tourism and Recreation

The shipping route for Project-related tankers passes through or directly adjacent to areas important for boating, recreational fishing, ecotourism, kayaking, coastal camping and scuba diving. During stakeholder meetings, some attendees expressed concern over the potential of a pipeline spill affecting tourism in areas such as the Gulf Islands. A Project-related tanker spill could affect the tourism and recreation industry both by directly disrupting the activities of tourists and recreationalists and by causing economic effects to recreation or tourism-based businesses.

In the event of a spill, recreational fishing, boating and beach use may be restricted or prohibited near the spill site and in clean-up areas. These restrictions would typically apply during the active clean-up period, but voluntary and regulated changes in recreational use patterns could extend until affected areas and resources are stable or recovered. In addition, resident and non-resident visits to spill-affected areas may decrease due to lack of available business services such as accommodations and charter boats (McDowell Group 1990; EVOSTC 2010).

Effects on recreation or tourism-based businesses appear to be greatest during the clean-up period, both due to decreased demand by visitors, and labour shortages associated with service industry workers seeking higher paying spill clean-up jobs (McDowell Group 1990). Although money and jobs generated in this industry have grown since the EVOS, and future tourism projections are promising, EVOSTC (2010) does not currently consider recreation and tourism to be fully recovered because some ecological resources are not rated as recovered (see discussion of ecological resources in Section 5.6.2.1).

5.6.1.1.3 Property Damage

Marine spills could potentially damage marinas, boats, and business/commercial establishments and infrastructure, resulting in costs for individuals and lost income for affected neighbourhood businesses. Municipalities may also incur infrastructure repair and replacement costs. In such cases, and other instances of economic loss, the vessel responsible for the spill would be responsible for compensating those who suffered damage.

5.6.1.2 Human Health

In order to experience physical effects from hydrocarbon exposure, a person must inhale, ingest or touch the spilled product, and be exposed for a long enough period for it to be harmful. This can happen through a number of pathways, including:

- inhaling vapours released from spilled oil;
- direct contact with contaminated soil, or ingesting food that grows in contaminated soil;
- drinking from a source contaminated by a spill; and
- eating plants, fish or animals contaminated by a spill.

When discussing human health effects, the potential effects associated with short-term and long-term exposure to hydrocarbons are referred to as acute and chronic effects, respectively. In the event of a marine spill, the tanker owner, CCG, WCMRC, and Transport Canada will initiate spill response and notify municipal, provincial and federal authorities responsible for the protection of public health. Evacuation of affected areas will occur if health and safety of the public is threatened and this will limit opportunities for short-term exposure to hydrocarbon vapours and potential for acute effects. Involvement of local, provincial and federal public health officials will also ensure that controls to limit long-term exposure and chronic effects potential will be implemented if warranted. Examples of such controls include closure of recreational or commercial fisheries, beach closures, the issuance of drinking water or food consumption advisories, and forced evacuation. This will limit long-term exposure from all pathways, including: inhalation; ingesting contaminated food, fish, plants, or animals; drinking from a contaminated source; or incidental skin contact with oil.

Over the short-term, the primary risk factor for human health is lighter end, volatile and semi-volatile hydrocarbons (C_1 to C_{12}) that are present in the air as vapours at or near the source, and then disperse in a downwind direction. COPC include BTEX as well as simple polycyclic aromatic hydrocarbons (PAHs). Trace amounts of sulphur-containing chemicals and longer-chain, semi-volatile hydrocarbons (C_{13} to C_{21}) also could be present. Based on the known health effects of these COPC, potential effects would likely be dominated by irritation of the eyes and/or breathing passages, possibly accompanied by nausea, headache, light headedness and/or dizziness. These effects could range from barely noticeable to quite noticeable, depending on the exposure circumstances and the sensitivity of the individuals exposed (see below). Odours might be apparent, dominated by a hydrocarbon-like smell, with some prospect for other distinct odours due to the presence of sulphur-containing chemicals in the vapour mix.

The odours themselves could contribute to discomfort, irritability and anxiety. The exact nature and severity of any health effects will depend on several factors, including:

- The circumstances surrounding the spill, including the time of year and meteorological conditions at the time. These circumstances will affect the extent to which chemical vapours are released from the surface of the spilled oil and the manner in which these vapours will disperse.
- A person's whereabouts in relation to the spill, including their distance from the source and their orientation to the spill with respect to wind direction. Exposures would be highest immediately downwind of the source, declining with increasing distance and the potential for health effects to occur as well as the severity of any effects will follow the same pattern. The potential for health effects at cross-wind or upwind locations will be lower or zero.
- The timeliness of emergency response measures. Measures taken to either remove the hazard from the general public (*e.g.*, spill isolation, containment and mitigation) or remove the general public from the hazard (*e.g.*, securing the spill area, evacuation of people from the area) will reduce exposure and probability of any associated health effects. The sooner these measures can be implemented, the lower the likelihood of any effects.
- A person's sensitivity to chemical exposures. It is widely accepted that a person's age, health status and other characteristics can affect the manner and extent to which they respond to COPC exposure, with the young, the elderly and people with compromised health often showing heightened sensitivity.

5.6.1.3 Community Well-Being

There is great diversity in the communities and regions along the shipping route a Project-related tanker would travel. Marine oil spills may adversely affect community well-being by affecting cultural and heritage resources, traditional lands, culture, and practices, and psychological well-being. Stakeholder engagement activities conducted for the Project indicate that in almost every geographic region people are currently concerned about the effects an oil spill would have on human and environmental health. In the event of a spill, it is likely that this concern would evolve into stress and anxiety among some residents.

5.6.1.3.1 Cultural and Heritage Resources

Heritage resources could be affected by a spill in a number of ways. Oil and clean-up activities can directly damage artifacts and sites or disturb their context, which may result in permanent loss of information critical to scientific interpretation. Looting or vandalism of heritage sites was also reported immediately following the EVOS, but subsequent measures to manage the activities of spill response personnel appear to have been effective in preventing additional loss (EVOSTC 2010).

5.6.1.3.2 Aboriginal Culture and Subsistence Use

Aboriginal peoples have historically used or presently use the shipping route to maintain a traditional lifestyle and continue to use marine resources throughout the Salish Sea region for a variety of purposes including fish, shell-fish, mammal and bird harvesting, aquatic plant gathering, and spiritual/cultural pursuits as well as through the use of waters within the region to access subsistence resources, neighbouring communities and coastal settlements.

The EVOS affected subsistence harvest of Aboriginal communities and individuals. Adverse effects resulted from reduced availability of fish and wildlife, concern about possible health effects of eating fish and wildlife, and disruption of traditional lifestyle due to participation in, or disturbance by, clean-up activities. Fears about food safety have diminished over time and harvest levels have increased since the spill, but the increase has been variable, and composition of harvested species has changed. Other factors have influenced this change and discerning what is spill-related is difficult (Palinkas et al 1993, EVOSTC 2010; see also Section 5.6.2.1).

5.6.1.3.3 Local Infrastructure and Services

In the event of a spill, particularly a credible worst-case incident, demands are likely to be placed on local, municipal, regional and independent emergency responders (fire, police, ambulance, disaster agencies), hospitals, clinics, social service and relief organizations, and local, municipal, regional and federal government officials and staff. Actual effects would depend on the size and nature of a spill, the number of people potentially affected and the availability of proper equipment and trained personnel. Mutual aid agreements described in Section 5.5 have been reached to help responders lend assistance across jurisdictional boundaries if required.

5.6.1.3.4 Psychological Effects

Research has shown that in the event of an oil spill, affected communities and individuals may experience a number of psycho-social effects. Culture is an important factor that affects the potential psycho-social effects of a spill. Documented effects include: declines in traditional social relations with family members, friends, neighbours and coworkers; a decline in subsistence production and distribution activities; perceived increases in the amount of and problems associated with drinking, drug abuse, and domestic violence; and a decline in perceived health status and an increase in the number of medical conditions verified by a physician including depression, anxiety and post-traumatic stress disorder. These effects may be short-term or persist for years in individuals or groups most directly affected by a spill (Palinkas *et al.* 1992, 1993; Picou and Gill 1996; Lyons *et al.* 1999, Arata *et al.* 2000, Gill *et al.* 2012). Psychological effects did not extend throughout the entire community; for example, the estimated rate of generalized anxiety disorder was around 20 per cent and post-traumatic stress disorder was about 9.4 per cent (Palinkas *et al.* 1993). Strongest predictors of stress were family health concerns, commercial ties to renewable resources, and concern about economic future, economic loss, and exposure to oil (Gill *et al.* 2012).

Regardless of the actual exposure, the possibility of exposure and the perception that contamination has occurred may be sufficient to cause anxiety or psychological effects in some people (Aguilera *et al.* 2010). Evidence from past incidents indicates that psychological effects would be most likely in the event of a large spill affects an important subsistence or commercial resource. Individuals and groups who would be at greatest risk of adverse effects include:

- those involved in the clean-up efforts;
- those who already have chronic physical or mental illness;

- those whose jobs and livelihoods are directly affected by the spill, including family members; and
- Aboriginal peoples who participate in subsistence hunting and gathering and whose families rely on subsistence foods to support healthy diets.

5.6.2 Environmental Effects

As with socio-economic effects, numerous factors contribute to the complexity of predicting environmental outcomes of hypothetical worst case and smaller spills. However, the ecological risk assessment process provides an established, accepted and transparent method to evaluate potential acute and chronic effects of hypothetical spill scenarios for a suite of ecological receptors. For this reason, an ecological risk assessment process was applied to assess environmental effects, rather than the qualitative approach adopted to evaluate potential socio-economic effects of marine oil spills.

5.6.2.1 Ecological Risk Assessment Methods

This section summarizes results of the preliminary quantitative ecological risk assessment (ERA) completed to evaluate the effects of hypothetical credible worst case and smaller spills of CLWB along the shipping route a Project-related tanker would travel.

The ERA discusses the range of potential effects to ecological resources by considering the probability of exposure to predicted surface oil slicks, the probability that oil will impinge upon shorelines, and the characteristics and sensitivity of potentially affected aquatic and shoreline habitats within the study area. Potential environmental effects were visualized and quantified using GIS overlays of data layers containing information on biological resources, sensitive habitats and other areas of ecological importance, and the results of seasonal oil spill modelling summarized in Section 5.4.

The ERA followed a standard protocol composed of the following stages:

- problem formulation;
- exposure assessment;
- hazard assessment;
- risk characterization; and
- discussion of certainty and confidence in the predictions.

5.6.2.1.1 Problem Formulation

Problem formulation defines the nature and scope of the work and establishes the boundaries so that the ERA is directed at the key areas and issues of concern. Data were gathered to provide information on the general characteristics of the study area, the oil being considered, the hypothetical scenarios being considered, potential ecological receptors and any other relevant issues.

A summary of information on the study area, ecological receptors and relevant findings from the EVOS, and the hypothetical scenarios considered by the ERA is provided here.

Spatial Boundaries

The spatial boundaries for this ERA were based on the oil spill modeling domain (Volume 8C, TR 8C-12, S9 and S10). The following spatial boundaries were considered in the ERA:

- oil spill footprint - the area predicted to be directly affected by oil as a result of a release at various locations along the shipping route; and
- RSA - The area of ecological relevance where environmental effects could potentially result from accidents and malfunctions within the limits of the domain for the stochastic oil spill modelling. The RSA is generally centered on the marine shipping route, which extend from the Westridge Marine Terminal through Burrard Inlet, south through the southern part of the Strait of Georgia, the Gulf Islands and Haro Strait, westward past Victoria and through the Juan de Fuca Strait out to the 12 nautical mile limit of Canada's territorial sea. The western boundary of the RSA extends further out to sea than the western boundary of the Salish Sea and the northern boundary of the RSA is limited to the southern portion of the Strait of Georgia. Puget Sound is excluded from the RSA.

Ecological Receptors

This section describes the ecological receptors selected for the marine spill ERA and also summarizes findings relevant to these receptors from monitoring conducted following the EVOS (1989).

i) The Exxon Valdez Oil Spill (EVOS)

The EVOS is the largest and best studied example of the effects of a large oil spill on many aspects of the coldwater marine environment. This spill is directly relevant to the Project for the purposes of an ERA as many of the ecological receptors studied following the EVOS also occur along the shipping route a Project-related tanker would travel, or in the Salish Sea more generally. That being said, despite the relevance from an ERA perspective, it is not predicted an EVOS type of oil spill would happen related to the Project. Improvements in tanker construction (*i.e.,* double *vs.* single hull; segregated cargo compartments) and navigational safety measures have resulted in fewer tanker accidents and few accidents resulting in the accidental release of oil (see Section 5.2) since EVOS.

Despite the intensive studies that followed the EVOS, findings on actual effects and recovery remain controversial. The EVOSTC publishes periodic updates on the status of resources affected by the EVOS; the most recent assessment was published in 2010 (EVOSTC 2010). The EVOSTC recognizes that as time passes, the ability to distinguish oil-related effects from other factors affecting fish and wildlife resources diminishes. Some resources currently identified as not having recovered from the spill may have been in decline regionally, and elsewhere, prior to the spill, so that recovery of the resource to its pre-spill status may be an unrealistic expectation.

Two major reviews of the ecological significance and residual effects of the EVOS (Peterson *et al.* 2003, Harwell and Gentile 2006) reached different conclusions. Peterson *et al.* (2003) concluded that unexpected persistence of sub-surface oil and chronic exposures at sublethal levels continue to affect wildlife, and that cascading indirect effects of oil exposure delayed recovery from the oil spill. Harwell and Gentile (2006) concluded that no ecologically significant effects were detectable across a suite of more than 20 ecological receptors including primary producers, filter feeders, fish, and bird primary consumers, fish and bird top predators, a bird scavenger, mammalian primary consumers and top predators, biotic communities, ecosystem level properties of trophodynamics and biogeochemical processes, and landscape level properties of habitat mosaic and wilderness quality.

A key point identified by Peterson *et al.* (2003) is the emerging appreciation of more complex, chronic, or ecosystem-based effects of oil spills than was previously understood under an "old paradigm" that considered primarily acute or short-term effects of spilled oil. The marine spills ERA summarized here integrates this understanding of acute and chronic effects of oil spills on ecological receptors.

ii) ERA Ecological Receptors

Potential environmental effects of the tanker marine spill scenarios are evaluated for four main ecological receptor group/habitat combinations:

- shoreline and near shore habitats;
- marine fish community and supporting habitat;
- marine birds and supporting habitat; and
- marine mammals and supporting habitat.

The EVOSTC (2010) lists 32 'injured resources' and ecosystem services and evaluates the recovery status for each. Table 5.6.2.1 groups many of these resources together to represent the ecological resources being evaluated through the ERA .

TABLE 5.6.2.1

RELATIONSHIP BETWEEN ERA ECOLOGICAL RECEPTORS AND 'INJURED RESOURCES' ASSESSED BY EVOSTC (2010)

Ecological Resource in ERA	Injured Resources Assessed by EVOSTC (2010)	Recovery Status from EVOSTC (2010)
Shoreline Habitats	Clams Mussels Intertidal Communities	Recovering Recovering Recovering
Marine Fish Community	Pacific Herring Pink Salmon Sockeye Salmon Rockfish Subtidal Communities Sediments	Not recovering Recovered Recovered Very likely recovered Very likely recovered Recovering
Marine Birds and Marine Bird Habitat	Black Oystercatcher Cormorant Common Loon Harlequin Duck Barrow's Goldeneye Common Murre Kittlitz's Murrelet Marbled Murrelet Pigeon Guillemot	Recovering Recovered Recovered Recovering Recovering Recovered Unknown Unknown Not recovering

TABLE 5.6.2.1

RELATIONSHIP BETWEEN ERA ECOLOGICAL RECEPTORS AND 'INJURED RESOURCES' ASSESSED BY EVOSTC (2010) (continued)

Ecological Resource in ERA	Injured Resources Assessed by EVOSTC (2010)	Recovery Status from EVOSTC (2010)
Marine Mammals	Harbour Seal Killer Whales – AB Pod Killer Whales – AT1 Population River Otter Sea Otter	Recovered Recovering Not recovering Recovered Recovering

Each of the four ERA ecological receptor groups includes a variety of individual receptors and/or habitats with differing sensitivity to oil exposure. For this reason, each receptor group was divided into sub-categories that reflected their sensitivity to oil exposure. These sub-categories, termed biological sensitivity ranking factors (BSF), ranged from a value of 1 (low sensitivity) to a value of 4 (very high sensitivity). The potential for negative environmental effects of oil exposure at any given location was indicated by the overlap of the probability of oil presence (from the oil spill modeling results), and the sensitivity of the receptor or habitat present at that location. Where a specific receptor had status as an endangered species, the status was considered as an additional factor. Likewise, the presence of provincial and national parks or other designated conservation areas represented an additional factor for consideration (*i.e.,* societal values) in addition to intrinsic biological sensitivities.

The discussion provided here summarizes information on the four ERA ecological receptors, their biological sensitivity, and relevant findings from EVOS monitoring. Further detail on these receptors and their biological sensitivity ranking factors is provided in Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B, TR 8B-7).

a. Shoreline Habitats

The shoreline habitats receptor includes 13 different shoreline and near shore habitat types in the intertidal or littoral zone, including the area of the foreshore and seabed that is exposed at low tide, and submerged at high tide. Substrate types for these habitats range from sand through to rock, with additional classes for marsh, as well as rip rap or wood bulkheads or pilings such as may be used for shoreline protection. In addition, areas of eelgrass are also considered to fall within the shoreline habitat, giving a total of fourteen different shoreline habitat types.

Low-energy or protected shorelines almost always have a fine subsurface substrate (sand or mud), even though the surface veneer may be coarse pebble, cobble or boulder. The presence of a water-saturated fine subsurface layer is an important factor that affects sensitivity to oil exposure because it provides a barrier that limits oil penetration of sub-surface sediment, and hence limits long-term retention of oil. In contrast, coarse (pebble, cobble or boulder) shorelines that are highly exposed may be coarse to considerable depth, increasing permeability and the potential for retention or sequestration of stranded oil.

Tidal marshes are often associated with river mouths and estuaries, behind barrier islands, or on tidal flats where low-energy wave action and fine-grained sediment accumulation provides an elevated surface where marsh vegetation can become established. Eelgrass beds are also typically found in soft sediments of protected bays, inlets and lagoons.

The ERA biological sensitivity ranking for each shoreline type was generally correlated with the tendency for shoreline types to absorb or retain spilled oil, they also represent habitat complexity and the ability of the different habitat types to sustain biodiversity and productivity. Exposed bedrock or sand substrates were considered to be subject to high levels of natural disturbance, and to have relatively low levels of biodiversity and productivity, and were assigned a low sensitivity ranking (BSF 1), whereas sheltered rocky substrates capable of supporting a rich and diverse intertidal community, marshes, and eelgrass beds were assigned high (BSF 3) or very high (BSF 4) biological sensitivity rankings.

The recovery status categories used by the EVOSTC to describe the status of injured resources are obviously critical to their assessment. The status of "recovering" (Table 5.6.2.1) means that the resources are demonstrating substantive progress toward recovery objectives, but are still being adversely affected by residual impacts of the spill or are currently being exposed to lingering oil. The recovery status of the Shoreline Habitats receptor group is impeded by effects on the seaweed and intertidal community exacerbated by isolated pockets of oil that became sequestered in beach substrates as well as oil spill response activities. With the advantage of hindsight, certain oil spill response activities (*e.g.,* hot water washing, pressure washing, and physical removal of oiled substrates) have been concluded to be more damaging than beneficial. For clams, both oil exposure and oil spill response activities affected the community, but baseline information on most clam species is lacking. The EVOSTC concede that clam populations found on oiled but untreated beaches have likely recovered from the effects of the spill. However, it appears that disturbance of the rock armoring on beaches impedes subsequent recovery, and this is an important finding that has been incorporated into oil spill response techniques. For mussels, bioaccumulation of PAHs continues to be a primary concern. In most instances, concentrations of oil in mussels from the most heavily oiled beds were indistinguishable from background by 1999. However, small areas of lingering or sequestered oil continue to hold back an assessment of "recovered".

Harwell and Gentile (2006) address the question of residual sources of oil exposure. In their view, the important question is not whether sources of hydrocarbon from the EVOS still exist, as they clearly do; but rather whether they pose a substantial risk to populations and communities comprising the Prince William Sound ecosystem. The beach surface area contaminated by subsurface oil in 2001 was estimated to be 6.7 ha, and the quantity of oil involved was estimated to represent about 6.5 m^3 of total residual oil from the EVOS. This compares to estimates that approximately 782 km of shoreline in Prince William Sound, and about 1,315 km of shoreline in the Gulf of Alaska were oiled to some degree. This comparatively small area of residual oiling in shoreline habitats is the rationale for EVOSTC "recovering" conclusion, but masks the fact that the vast majority of shoreline habitat had recovered within 10 years of the oil spill, notwithstanding inappropriate methods used during the oil spill response activities.

A key finding of the EVOS was that the negative effects of high-pressure hot water washing were substantial. Oiled but untreated shoreline sites recovered more quickly than oiled sites where aggressive cleaning techniques were applied. Whether cleaned or not, intertidal communities had recovered within 5 years after the EVOS (Harwell and Gentile 2006); recovery of oiled shoreline habitat within 2 to 5 years following a large oil spill is a reasonable expectation with the implementation of appropriate oil spill response activities.

b. Marine Fish Community

The ERA marine fish community receptor includes marine fish and marine invertebrates (*e.g.,* mollusks and crustaceans), but not marine mammals or birds. Acute effects of spilled oil on fish and marine invertebrates are rarely observed, except in situations where oil is confined and dispersed into shallow water. Hydrocarbon effects on fish are generally caused by exposure to relatively soluble components of the oil. BTEX compounds or light polycyclic aromatic hydrocarbons (PAHs) such as naphthalenes are usually considered to be the most likely contributors to acute toxicity, although some light aliphatic hydrocarbons may also contribute to toxicity. These compounds also tend to be volatile and are rapidly lost to the atmosphere, so the initial 24 to 48 hours following an oil spill is the period when acute toxicity is most likely to occur.

Two major mechanisms of toxicity to marine fish are recognized (although other more specific mechanisms may also exist). These are:

- Non-polar narcosis, whereby reversible exposure to and accumulation of hydrocarbons from the water column causes interference with intracellular functioning at a target lipid site, potentially causing death if a critical hydrocarbon concentration is exceeded in the target lipid. Salmonid fish are sensitive to the narcosis pathway, and small fish are more sensitive than large fish.
- Blue sac disease (BSD), whereby exposure to 3- and 4-ring PAH compounds results in a syndrome of cardiac, craniofacial, and/or spinal deformity and death in developing embryos. Sensitivity to BSD is greatest in newly fertilized eggs, and decreases with the hardening of the egg membrane, and with increasing developmental stage. Embryos of herring and salmon species are among those more sensitive to BSD.

Due to the behaviour of oil spilled on water, the potential for toxicity to the marine fish community is greatest near the surface where more soluble hydrocarbons can dissolve from the floating fresh oil, or form droplets that can be temporarily dispersed down in to the water column by wave action. However, extensive formation and dispersion of oil droplets into the water column is unlikely to occur in sheltered waters. The potential for acutely toxic concentrations of hydrocarbons to extend down into deep water is very low, due to the limited solubility of hydrocarbons, and the dilution that would accompany mixing into deep water.

For the non-polar narcosis mode of toxic action (see Ecological Risk Assessment of Marine Transportation Spills Technical Report [Volume 8B, TR 8B-7]), toxicity of a sensitive species, is defined as representing the 5th percentile on a species sensitivity distribution (Di Toro *et al.* 2000). Assuming that this synthetic sensitive species is the same regardless of the specific habitat under consideration, for the ERA, the sensitivity of the marine fish community is related to the degree of exposure of the particular habitat to dissolved hydrocarbons. Therefore, deep water habitat is assigned a low sensitivity rank (BSF 1) and shallow water habitat a high sensitivity rank (BSF 3). The very high biological sensitivity rank (BSF 4) is assigned to developing eggs and embryos in shallow water habitat (represented here by herring spawning areas).

The ERA Marine Fish Community ecological receptor group is represented in the EVOSTC (2010) assessment by a variety of fish species, as well as sediments and subtidal communities. Most of these are concluded to be “recovered” or “very likely recovered” (Table 5.6.2.1); the latter designation reflecting limited scientific research in recent years, but a low probability that there are any residual effects of the spill (EVOSTC 2010). Sediments (including both intertidal and subtidal areas) are listed as “recovering”, primarily because lingering or sequestered oil is present on some armored oiled beaches. No oil was found in sub-tidal sediments at previously oiled sites when re-sampled in 2001. Harwell and Gentile (2006) note that while just over one third of nearshore sediment samples collected after two years at heavily oiled sites had detectable residual traces of EVOS oil, results suggest that the vast majority of the approximately 4,500 km^2 seafloor of Prince William Sound had no detectable traces of oil from the EVOS within two years of the spill.

The most controversial EVOSTC recovery assessment for the Marine Fish Community receptor is for Pacific herring. Prior to the spill, the herring population (or harvest) was increasing as documented by record harvests in the late 1980s. The EVOS occurred at a time when herring were spawning, and there is no doubt that herring spawn was exposed to spilled oil and dissolved PAH at sufficient concentration to cause local effects (such as developmental deformities). Notwithstanding this exposure, the herring population continued to increase until four years after the spill when there was a crash in the adult herring population. Although many studies published in the 1990s and 2000s suggested that the herring population crash resulted from the EVOS, the cause of the decline and poor recovery of the Prince William Sound herring population has been described as perplexing by scientists working on behalf of the EVOSTC (Rice and Carls 2007). Pearson *et al.* (2011) argue that the underlying cause of the population collapse was poor nutrition, and perhaps disease associated with the very large herring population size, and generally low abundance of zooplankton. Harwell and Gentile (2006) conclude that the population loss resulting from direct mortality attributable to the EVOS is not clear. On balance, the population collapse four years after the spill was likely caused by factors other than the EVOS, suggesting that there are no remaining ecologically significant effects on Pacific herring that can be attributed to the spill.

Effects of the EVOS were generally localized and short-term on marine fish populations as a whole (EVOSTC 2010). Intertidal fishes showed declines in density and biomass at oiled sites relative to reference sites in 1990, but this could reflect changes in habitat quality as well as oil exposure. Rockfish utilize the nearshore environment as young-of-the-year and juveniles, and may have been affected in this manner, but studies have not identified any conclusive link between exposure to Exxon Valdez oil and endpoints such as larval growth of fish in 1989, or lesions associated with oil exposure. Pink salmon spawning in intertidal areas near Prince William Sound were potentially exposed to hydrocarbons in water, and in some cases to hydrocarbons in spawning substrates. Although potential for developmental effects on pink salmon embryos, including mortality was demonstrated at some locations, no convincing change in pink salmon population size was documented. Sockeye salmon appear to have been affected by the fishery closure, as more spawners than normal appear to have entered freshwater habitat in 1989, resulting in overgrazing of planktonic food webs in nursery lakes. This led to lower than optimal growth rates in juvenile sockeye that were never exposed to oil, which in turn appears to have led to a subsequent decrease in returns of adult spawners some years later.

Effects of the EVOS on marine fish and fish habitat were generally limited to areas where oil was driven into near-shore areas, and these effects were for the most part short-term (days to weeks, rather than years). Evidence has been presented for longer-term effects on some habitats, such as intertidal pink salmon spawning areas where sequestered oil may have leached into spawning gravels up to several years after the spill. However, these areas were very limited and did not result in effects at the population level for pink salmon. Evidence for the marine fish community receptor suggests that the EVOS did not have substantial effects on marine fish populations initially, or recovery occurred within one or two years at most.

c. *Marine Birds*

Seabirds can be highly sensitive to oil spills, due principally to the effects of oiling on feathers (*i.e.,* loss of insulative properties and buoyancy), as well as to ingestion of oil or contaminated food. In addition, birds that are gregarious are potentially at greater risk of population-level effects if oil is present in an area where they congregate or feed. The waters of the Strait of Georgia, Haro Strait, Juan de Fuca Strait and the Gulf Islands provide migratory, nesting, feeding and wintering habitat for a wide variety of shorebirds, gulls, waterfowl and alcids (auks).

Four biological sensitivity ranking classes are defined for the ERA marine bird receptor, on a scale of 1 (low sensitivity) to 4 (high sensitivity). The ranking scheme reflects guild membership, as is appropriate considering the similar lifestyle, behaviour, and exposure mechanisms that accompany each guild. A low sensitivity rank (BSF 1) is assigned to shoreline dwelling species and waders that are generally widely distributed. Medium sensitivity (BSF 2) is assigned to species with a life history that is not exclusively marine, such as gulls and terns. Ducks and other waterfowl that tend to be moderately sensitivity to oil exposure and may congregate are assigned a high sensitivity (BSF 3). Finally, a very high sensitivity (BSF 4) is assigned to species that tend to rely heavily on the marine environment or have high sensitivity to oil exposure, such as auks and divers. These birds tend to nest in colonies and also often congregate in feeding areas.

Additional consideration is also given to known breeding colony locations and Important Bird Areas (IBAs) located within the RSA. A description of each of these IBAs, including recorded species and corresponding seasonality (as available), is presented in Table 5.6.2.2. The location of known bird colonies is shown in Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B, TR 8B-7).

TABLE 5.6.2.2

SUMMARY OF IMPORTANT BIRD AREAS (IBAS) WITHIN THE RSA FOR MARINE TRANSPORTATION

Identification Number	Site Name	Description	Bird Species	Seasonality
Canada				
BC001	McFadden Creek Heronry	The McFadden Creek Heronry is a relatively small (0.5 km²), fully forested IBA, located on the north side of Saltspring Island, British Columbia.	Great Blue Heron (BC Coast)	Breeding
BC015	Active Pass	The Active Pass IBA comprises the water body (approximately 17 km²) between Galiano and Mayne Islands in the southwest region of the Strait of Georgia.	Bald Eagle	Breeding Spring Migration Summer Non-Breeding Wintering
			Bonaparte's Gull	Fall Migration Spring Migration
			Brandt's Cormorant	Wintering
			Pacific Loon	Spring Migration Wintering
BC017	Boundary Bay – Roberts Bank – Sturgeon Bank (Fraser River Estuary)	This IBA represents the Fraser River Delta including Boundary Bay, Roberts Bank and Sturgeon Bank as well as agricultural lands in and around Richmond, Surrey and White Rock. It is a large (approximately 750 km²) complex IBA encompassing several types of habitats, including marine, estuarine, freshwater and agricultural habitats.	American Wigeon	Fall Migration Wintering
			Barn Owl (BC)	Breeding Wintering
			Black-bellied Plover	Fall Migration Summer Non-Breeding Wintering
			Brant	Spring Migration Wintering
			Dunlin	Fall Migration Spring Migration Wintering
			Glaucous-winged Gull	Wintering
			Great Blue Heron (BC Coast)	Spring Migration Summer Non-Breeding Wintering
			Mallard	Fall Migration Wintering
			Mew Gull	Fall Migration Spring Migration Wintering
			Northern Pintail	Fall Migration Wintering
			Peregrine Falcon (BC)	Fall Migration Spring Migration Wintering
			Red-necked Grebe	Fall Migration Spring Migration Wintering

TABLE 5.6.2.2

SUMMARY OF IMPORTANT BIRD AREAS (IBAS) WITHIN THE RSA FOR MARINE TRANSPORTATION (continued)

Identification Number	Site Name	Description	Bird Species	Seasonality
Canada				
BC017	Boundary Bay – Roberts Bank – Sturgeon Bank (Fraser River Estuary)	This IBA represents the Fraser River Delta including Boundary Bay, Roberts Bank and Sturgeon Bank as well as agricultural lands in and around Richmond, Surrey and White Rock. It is a large (approximately 750 km²) complex IBA encompassing several types of habitats, including marine, estuarine, freshwater and agricultural habitats.	Snow Goose	Fall Migration Wintering
			Surf Scoter	Fall Migration Spring Migration Wintering
			Thayer's Gull	Fall Migration Wintering
			Trumpeter Swan	Wintering
			Western Grebe	Fall Migration Spring Migration Wintering
			Western Sandpiper	Spring Migration
BC018	Pacific Spirit Regional Park	The Pacific Spirit Regional Park IBA is a relatively small IBA (less than 2 km²) located on Point Grey, British Columbia. This IBA is bordered to the east by residential areas and to the west by the University of British Columbia Farm.	Great Blue Heron (BC Coast)	Breeding
BC020	English Bay & Burrard Inlet	This large IBA (140 km²) comprises English Bay, False Creek and Burrard Inlet including Vancouver Harbor, Indian Arm and Port Moody Arm. It incorporates numerous types of habitats with industrial encroachment in and around Vancouver to less impacted areas in Indian Arm.	Barrow's Goldeneye	Fall Wintering
			Great Blue Heron (BC Coast)	Summer Non-Breeding
			Surf Scoter	Fall Migration Wintering
			Waterfowl	Wintering
			Western Grebe	Fall Wintering
BC023	Squamish River Area	The Squamish River Area IBA is located at the northeastern tip of Howe Sound in proximity to Squamish, British Columbia. It comprises the Squamish, Mamquam and Cheakamus rivers and their respective shorelines (approximately 50 km²).	American Dipper	Year-Round Resident
			Bald Eagle	Wintering
			Trumpeter Swan	Wintering
BC025	White Islets and Wilson Creek	This IBA comprises the water body south of Wilson Creek and surrounding the White Islets (approximately 30 km²) located west of Howe Sound in proximity of Sechelt, British Columbia.	Glaucous-winged Gull	Breeding
			Harlequin Duck	Other
			Marbled Murrelet	Wintering
			Pelagic Cormorant	Breeding
			Surf Scoter	Other
			Surfbird	Spring Migration

TABLE 5.6.2.2

SUMMARY OF IMPORTANT BIRD AREAS (IBAS) WITHIN THE RSA FOR MARINE TRANSPORTATION (continued)

Identification Number	Site Name	Description	Bird Species	Seasonality
Canada				
BC045	Chain Islets & Great Chain Islet	This IBA is a relatively small IBA (less than 2 km²) surrounding Great Chain Islet and several smaller islets located in waters southeast of Victoria, British Columbia.	Black Oystercatcher	Breeding
			Brandt's Cormorant	Fall Migration
			Double-crested Cormorant	Breeding
			Glaucous-winged Gull	Breeding
			Harlequin Duck	Other
			Pelagic Cormorant	Breeding
			Pigeon Guillemot	Breeding
BC047	Sidney Channel	The Sidney Channel IBA, located in proximity to Sidney, British Columbia, comprises the water body (approximately 90 km²) between Vancouver Island, James Island and Sidney Island. It is located generally east of Haro Strait.	Black Oystercatcher	Breeding
			Brandt's Cormorant	Fall Migration
			Brant	Spring Migration Wintering
			Glaucous-winged Gull	Breeding
			Great Blue Heron (BC Coast)	Breeding Year-Round Resident
			Harlequin Duck	Fall Migration
			Marbled Murrelet	Summer Non-Breeding
			Mew Gull	Spring Migration
			Pigeon Guillemot	Wintering
			Rhinoceros Auklet	Breeding
BC048	Cowichan estuary	The Cowichan estuary IBA includes Cowichan Bay and generally represents the water body (approximately 40 km²) located northwest of Saanich Inlet. Both Cowichan Bay and Saanich Inlet connect to Haro Strait through Satellite Channel.	Colonial Waterbirds/Seabirds	Wintering
			Double-crested Cormorant	Wintering
			Mew Gull	Wintering
			Mute Swan	Wintering
			Pacific Loon	Spring Migration
			Red-necked Grebe	Fall Migration
			Thayer's Gull	Wintering
			Trumpeter Swan	Wintering
			Waterfowl	Wintering
			Western Grebe	Wintering
BC052	Porlier Pass	The Porlier Pass IBA (approximately 16 km²) comprises the water body between Valdes and Galiano Islands as well as some of the shorelines of both islands.	Black Oystercatcher	Breeding
			Cormorant species	Wintering
			Glaucous-winged Gull	Breeding
			Mew Gull	Fall Migration
			Scoters	Wintering
BC055	Snake Island	This IBA is relatively small (4 km²) and surrounds Snake Island which is located within the approach to Nanaimo, British Columbia and approximately 3 km from the northwest point of Gabriola Island.	Black Oystercatcher	Breeding
			Glaucous-winged Gull	Breeding
			Pelagic Cormorant	Breeding
			Pigeon Guillemot	Breeding

TABLE 5.6.2.2

SUMMARY OF IMPORTANT BIRD AREAS (IBAS) WITHIN THE RSA FOR MARINE TRANSPORTATION (continued)

Identification Number	Site Name	Description	Bird Species	Seasonality
Canada				
BC073	Carmanah Walbran Forest	This large forested IBA (approximately 250 km²) is generally located inland on the west coast of Vancouver Island and includes Carmanah Walbran Provincial Park.	Marbled Murrelet	Breeding
BC097	Amphitrite and Swiftsure Banks	This relatively large IBA comprises two separate water bodies located west of Vancouver Island: one in and around Amphitrite Bank, and the other around Swiftsure Bank. Only the Swiftsure Bank portion of this IBA (approximately 20 km²) is within the boundaries of the RSA.	Black-legged Kittiwake	Not Specified
			California Gull	Other
			Cassin's Auklet	Other
			Common Murre	Not Specified
			Glaucous-winged Gull	Not Specified
			Herring Gull	Not Specified
			Northern Fulmar	Other
			Rhinoceros Auklet	Not Specified
			Sabine's Gull	Other
			Sooty Shearwater	Other
			Thayer's Gull	Not Specified
			Tufted Puffin	Not Specified
United States				
USWA277	Drayton Harbor / Semiahmoo	This IBA is a relatively small and relatively enclosed water body (approximately 6.5 km²) comprising Drayton Harbor in Blaine, Washington. It is located east of Semiahmoo Bay and generally enclosed by the Semiahmoo Spit.	Bald Eagle Black Scoter Common Loon Greater Scaup Harlequin Duck Horned Grebe Long-tailed Duck Peregrine Falcon Red-necked Grebe Surf Scoter White-winged Scoter	Not Specified
USWA282	Lower Dungeness Riparian Corridor	The Lower Dungeness Riparian Corridor IBA includes the Dungeness River, adjacent riparian forest and estuary. This relatively small IBA (less than 5 km²) is located in Dungeness, Washington.	American Dipper Bullock's Oriole Cedar Waxwing Olive-sided Flycatcher Red-eyed Vireo Warbling Vireo Willow Flycatcher	Not Specified
USWA288	Protection Island	This very small IBA (1 km²) comprises Protection Island located approximately 3 km off Diamond Point, Washington.	Double-crested Cormorant Glaucous-winged Gull Pelagic Cormorant Pigeon Guillemot Rhinoceros Auklet Tufted Puffin	Not Specified

TABLE 5.6.2.2

SUMMARY OF IMPORTANT BIRD AREAS (IBAS) WITHIN THE RSA FOR MARINE TRANSPORTATION (continued)

Identification Number	Site Name	Description	Bird Species	Seasonality
United States				
USWA3289	Deception Pass	The Deception Pass IBA is a very small IBA (1 km²) comprising the water body located between Whidbey Island and Fidalgo Island, Washington.	Black Oystercatcher Pigeon Guillemot Red-throated Loon	Not Specified
USWA3347	Samish / Padilla Bays	This large IBA (approximately 240 km²) comprises Samish and Padilla Bays, located in proximity to Anacortes, Washington.	Black Oystercatcher Brant Dunlin Great Blue Heron Marbled Murrelet Red-necked Grebe Trumpeter Swan Western Grebe	Not Specified
USWA3348	Olympic Continental Shelf	The Olympic Continental Shelf IBA is very large IBA (2,200 km²) generally comprising marine environments. It includes two general areas, one located in the Juan de Fuca Strait, the other in the Pacific Ocean. In the Juan de Fuca Strait, it follows the northwestern shoreline of Washington State, from the city of Port Angeles west to Cape Flattery extending a few kilometers from the mainland. From Cape Flattery, it then extends south to Taholah (located approximately 50 km northwest of Aberdeen, Washington), extending to the edge of the continental shelf, approximately 55 km from the mainland.	Black-footed Albatross Brandt's Cormorant Brown Pelican Cassin's Auklet Common Murre Leach's Storm-Petrel Marbled Murrelet Pelagic Cormorant Pink-footed Shearwater Rhinoceros Auklet Sooty Shearwater South Polar Skua Tufted Puffin	Not Specified
USWA3351	Port Angeles Harbor / Ediz Hook	This IBA is relatively small (approximately 5.5 km²) comprising Port Angeles Harbor bordered to the north by Ediz Hook.	Heermann’s Gull Thayer’s Gull	Not Specified
USWA3786	Sequim Bay	The Sequim Bay IBA (approximately 60 km²), located less than 5 km east of Sequim, Washington encompasses the open waters and intertidal zones of Sequim Bay and is partially enclosed by Travis Spit and Gibson Spit.	Black-bellied Plover Dunlin Heermann’s Gull	Not Specified

Sources: **Canada:** IBA Canada Site Summaries (2012).

United States: Audubon Important Bird Areas Profiles (2013).

The ERA marine bird ecological receptor group is represented in the EVOSTC literature by a variety of species including: cormorants and loons are (listed as “recovered”); black oystercatcher, harlequin duck and Barrow’s goldeneye (“recovering”); Kittlitz’s murrelet and marbled murrelet (“unknown”); and pigeon guillemot (“not recovering”) (EVOSTC 2010; Table 5.6.2.1).

For the marine bird species listed as “recovering” the limiting factor in each case appears to be concern about exposure to lingering oil at sites that represent a small proportion of the available habitat. Only nine carcasses of adult black oystercatchers were recovered following the EVOS, and although the actual number of mortalities may have been several times higher, this represents a small fraction of the population of 1,500 to 2,000 black oystercatchers breeding in south-central Alaska. It is estimated that about 1,000 harlequin duck (about 7 per cent of the wintering population) were killed by oil exposure at the time of the spill. Similarly, an unknown number of Barrow’s goldeneye died as a result of oil exposure, but population-level effects of oil exposure have not been documented since 1990. The listing of these species as “recovering” reflects a measured metabolic response linked to oil exposure (cytochrome P450 induction), but it is not clear whether this has affected on survival, growth or reproduction of individuals, or translates into a population-level effect. Harwell and Gentile (2006) noted that by 1993 population numbers for harlequin duck equalled pre-spill population numbers, and that the area of habitat affected by sequestered oil was so small in relation to the available habitat that no plausible risk remains to the harlequin duck population. The same rationale would also apply to black oystercatcher and Barrow’s goldeneye.

Recovery of marine bird populations following the EVOS was generally rapid and uncomplicated. A major factor causing the EVOSTC to identify certain bird populations as “recovering” rather than “recovered” has been evidence of low-level exposure to hydrocarbons from cytochrome P450 testing. While this measure can identify exposure, it does not identify effects of hydrocarbon exposure on individuals or at a population level. It is reasonable to expect marine bird recovery at a population level within two to five years following a large oil spill.

d. Marine Mammals

The marine waters of the study area provide habitat for a variety of marine and semi-aquatic mammals including:

- terrestrial mammals such as bears and moose, which may frequent and be exposed to oil in shoreline areas, depending upon the availability of food resources they may be seeking;
- pinnipeds, including Steller sea lion and harbour seal;
- cetaceans, including but not limited to southern resident killer whale, humpback whale, various dolphins and porpoises, and other species; and
- river otter, mink and potentially sea otter, which are highly dependent upon the insulative value of their fur, and which are potentially exposed to high rates of oil ingestion through grooming, if their fur becomes oiled.

Aquatic mammals such as otters and mink that rely upon fur for insulation in cold ocean water are extremely sensitive to oiling, as well as having potentially high exposure to oil ingestion, if coastal habitat is oiled. Mammals that rely upon blubber for insulation are less sensitive to external oiling, although the potential for mortality cannot be ruled out due to other exposure pathways or mechanisms.

Oil ingestion remains a potentially important exposure pathway, and fouling of baleen plates can have adverse effects on baleen whales, although this would not be a problem for toothed whales.

Wildlife species that are normally terrestrial (such as bear and moose) could potentially be exposed to oil that strands along shorelines, or accumulates in coastal marshes or estuaries. External oiling and oil ingestion are a possibility for these animals, although these exposures are not likely to result in mortality.

For the ERA marine mammal receptor, a low sensitivity (BSF 1) is assigned to wildlife species that are normally terrestrial. The medium sensitivity (BSF 2) is assigned to pinniped species, such as seal and sea lions. Whales are assigned a high sensitivity rank (BSF 3) and species such as sea otter, river otter and mink that rely upon fur for insulation in cold ocean water are extremely sensitive to oiling, as well as having potentially high exposure to oil ingestion are assigned a very high sensitivity (BSF 4).

The ERA marine mammal ecological receptor group is represented in the EVOSTC literature by a variety of species, including harbour seal and river otter ("recovered"), sea otter and killer whale – AB Pod ("recovering") and killer whale – AT1 Population ("not recovered"; Table 5.6.2.1).

Sea otters were severely affected by the EVOS, with a large number of carcasses being collected throughout the spill area. No apparent population growth occurred for Prince William Sound sea otters between 1989 and 1991. Since that time, areas that were heavily oiled have shown slower rates of population increase than less-oiled areas (EVOSTC 2010). Since 2004; however, even cytochrome P450 biomarker results for sea otters from oiled and unoiled areas have been similar, and population trends in oiled areas have been positive. Harwell and Gentile (2006) concluded that at the scale of Prince William Sound, sea otter populations had returned to, or may exceed pre-spill numbers, and that no continuing ecologically significant effects persisted.

The effects of the EVOS on killer whales are complex and controversial. Two whale groups have received intensive follow-up since the EVOS: the AB pod (resident) and the AT1 population (transient). Resident killer whales feed primarily on fish (especially salmon), whereas transient killer whales feed primarily on seals. Despite being called transient, the AT1 pod appeared to range only through the Prince William Sound and Kenai Fjords region. Both groups lost members and exhibited higher than expected mortality rates following the EVOS, and it is possible that direct inhalation of vapours may have been a cause of mortality for some whales, as they were observed swimming in the freshly-spilled oil near the Exxon Valdez at the time of the spill.

The EVOSTC (2010) has established recovery objectives for killer whales that are specific to these two groups (*i.e.,* a return to the pre-spill number of 36 members in the AB pod, and a stable population trend in the AT1 population). These objectives may not account for natural variability, and both groups of whales were and continue to be subject to pressures external to the EVOS. Harwell and Gentile (2006) note that the AB pod clearly lost members following the EVOS, but this was the exception to the trend in the overall Prince William Sound population of killer whales, which rose from 117 in 1988 to 155 in 2003. Effects of the EVOS on the AB pod may also be compounded by stress introduced to this pod by conflict with the longline fishery prior to the EVOS (Harwell and Gentile 2006). The AB pod was also reported to split into two distinct units subsequent to 1990 (EVOSTC 2010). The AT1 population of killer whales is also subject to external pressures. This group of whales, which feeds preferentially on seals, has been exposed to dietary intakes of PCBs, DDT and DDT metabolites and carries levels of these substances in blubber that cause reproductive problems in other marine mammals (EVOSTC 2010).

Harwell and Gentile (2006) concluded that there is no plausible risk to killer whales from residual toxicity associated with the EVOS, and that such effects were limited to certain groups of whales, even at the time of the spill. The larger populations of both resident and transient killer whales did not show effects, and are showing increase.

Evaluating the recovery of marine mammal populations following the EVOS has been complex. River otter and harbour seal populations appeared to recover quickly. One factor causing the EVOSTC to identify sea otter populations as “recovering” rather than “recovered” has been evidence of low-level exposure to hydrocarbons based on cytochrome P450 testing. While this measure can identify exposure, it does not confirm effects of hydrocarbon exposure on individuals or at a population level. As discussed previously, recovery conclusions for killer whales are complicated by a focus on specific whale groups that are subject to additional stressors and have not recovered, in contrast with population-level trends which are increasing. On balance; however, it is reasonable to expect marine mammal recovery at a population level within five to ten years following a large oil spill.

Hypothetical Oil Spill Scenarios

No hypothetical scenario can represent all potential environmental and socio-economic outcomes, but scenario-based hydrocarbon spill evaluations can provide decision makers and resource managers with a clearer understanding of potential effects pathways, the range of potential outcomes, vulnerable resources, and spill preparedness and response priorities and capabilities. Stochastic oil spill fate modeling completed for three of the four hypothetical spill locations described in Section 5.4 (Figure 5.5.2) was used to evaluate potential ecological effects with a preliminary quantitative ERA (Buoy J) (Location H) was excluded because results of the Strait of Georgia (Location D), Arachne Reef (Location E) and Race Rocks (Juan de Fuca Strait, Location G) reflect the range and extent of ecological effects that could result from a spill along the shipping route a Project-related tanker would travel. The discussion provided in Section 5.5 describes the spill response measures that would be undertaken by the ship owner, WCMRC, CCG and Transport Canada to respond quickly to an accidental oil spill thus minimizing the adverse environmental and socio-economic effects potentially resulting from an accidental oil spill in the Salish Sea area.

The six hypothetical oil spill scenarios evaluated in the ERA are summarized in Table 5.6.2.3. These include scenarios at three locations along the marine transportation route, representing two crude oil spill volumes: a credible worst case spill of 16,500 m^3; and a smaller volume of 8,250 m^3 (see Section 5.2). Each hypothetical spill scenario was evaluated under a range of environmental conditions, including winter, spring, summer and fall. Stochastic spill modelling results are summarized in Section 5.4.

ERA results for the Strait of Georgia, Race Rocks and Arachne Reef scenarios are described in Sections 5.6.2.2, 5.6.2.3 and 5.6.2.4, respectively. An overall summary of potential marine spill ecological effects is provided in Section 5.6.2.5.

TABLE 5.6.2.3

SUMMARY OF HYPOTHETICAL MARINE TRANSPORTATION OIL SPILL SCENARIOS

Scenario	Seasonal Condition	Incident Summary	Release Volume (m^3)	Representative Crude Oil
1	Winter Spring Summer Fall	Strait of Georgia (Location D) - Main ferry crossing. Collision with crossing traffic from Fraser River and ferries is a low probability event, but considered because of higher number of crossings per day. - See Section 5.6.2.2	16,500 m^3	Cold Lake Winter Blend
2	Winter Spring Summer Fall		8,250 m^3	Cold Lake Winter Blend
3	Winter Spring Summer Fall	Arachne Reef (Turn Point SOA, Location E) - Powered grounding is a low probability event due to pilots and tethered tug, but this location is rated with greatest level of navigation complexity for the entire passage. Location also has high environmental value. - See Section 5.6.2.4	16,500 m^3	Cold Lake Winter Blend
4	Winter Spring Summer Fall		8,250 m^3	Cold Lake Winter Blend
5	Winter Spring Summer Fall	Race Rocks (Juan de Fuca Strait, Location G)- Collision with crossing traffic from Puget Sound and Rosario Strait or grounding at Race Rock is a low probability event, but considered because not all vessels in this location would have pilot onboard. - See Section 5.6.2.3	16,500 m^3	Cold Lake Winter Blend
6	Winter Spring Summer Fall		8,250 m^3	Cold Lake Winter Blend

5.6.2.1.2 Exposure and Hazard/Effect Assessment

The ERA exposure and hazard/effects assessment stage identified the probability of oiling at any given location within the modelling area. A low probability of oil exposure was assigned to areas having <10 per cent probability. Areas having a probability of ≥10 per cent but <50 per cent were assigned a medium exposure probability. A high exposure probability was assigned to areas having a probability of oiling ≥50 per cent but <90 per cent, and a very high exposure probability to areas having a probability of oiling ≥90 per cent.

Probability of oiling contours were superimposed on ecological resource sensitivity maps to quantify the length of shoreline (km) or the area of a particular habitat type (km^2) that is potentially affected at low, medium, high or very high probability levels. Because a low probability of oiling indicates that oil exposure is unlikely, the ERA focused on areas having medium, high or very high probability of oil exposure. Analyses were summarized in tabular format, so that the quantity of habitat exposed to different probabilities of oiling could be quantified, and then compared to the total amount of that habitat within the RSA. This approach was repeated for each biological sensitivity rank and each season (Ecological Risk Assessment of Marine Transportation Spills Technical Report [Volume 8B, TR 8B-7]).

5.6.2.1.3 Risk Characterization

The ERA risk characterization stage considered the biophysical characteristics of the marine environments along with results of the exposure and hazard/effects assessments to define risk for each ecological receptor type. The potential ecological consequence of crude oil exposure at any given location were considered to be the product of the probability of oil presence, and the sensitivity of the receptor or supporting habitat that may be present at that location with results expressed in terms of probability ranges.

Potential ecological effects from accidental oil spills were evaluated using a different approach than potential effects from routine Project activities. Project construction or operation activities can usually be described with a high level of confidence. In contrast, serious accidents such as grounding or collision of a tanker with another vessel are expected to have a very low probability of occurring and spills may or may not result from these incidents (Section 5.2). All of the residual environmental effects of an accident leading to a crude oil spill were assumed to be of negative impact balance. ERA conclusions were expressed in terms of the spatial extent of effects and time to recovery of the environmental effects for each ecological receptor. Qualitative magnitude (or degree of injury) ratings were based on the following definitions:

- Negligible: a change from existing conditions that is difficult to detect; or a very low probability that an ecological receptor will be exposed to spilled oil.
- Low: a change that is detectable, but that remains well within regulatory standards; or a situation where an ecological receptor is exposed to spilled oil, but the exposure does not result in serious stress to the receptor.
- Medium: a change from existing conditions that is detectable, and approaches without exceeding a regulatory standard; or a situation where an ecological receptor is stressed, but does not die as a result of exposure to spilled oil.
- High: : a change from existing conditions that exceeds an environmental or regulatory standard; or a situation where a species of management concern dies as a result of exposure to spilled oil.

The temporal context of environmental effects is also important. Rather than focusing on the duration and frequency of accidents, the effects assessment considered the reversibility, and in particular to the expected time to recovery for each ecological receptor in the event of exposure to spilled oil. The recovery assessment phase considered the potential beneficial effects of remediation (such as oil spill cleanup activities) that would be applied following an oil spill to promote biological recovery of affected ecological receptors (Ecological Risk Assessment of Marine Transportation Spills Technical Report [Volume 8B, TR 8B-7]).

5.6.2.1.4 ERA Certainty and Confidence

When conducting ecological risk assessments, it is standard practice to implement conservative assumptions (*i.e.,* to make assumptions that are inherently biased towards safety) when uncertainty is encountered. This strategy generally results in an overestimation of actual risk. For this ERA, prediction confidence is based on the following factors:

- environmental fate modeling;

- selection of marine ecological receptors and derivation/assignment of biological sensitivity factors; and
- exposure and hazard assessment.

In the event of an oil spill, the fate and effects would be strongly determined by specific characteristics of the oil, environmental conditions, and the precise locations and types of organisms exposed. The goal of ERA scenario modelling investigations was not to forecast every situation that could potentially occur, but to describe a range of possible consequences so that an informed analysis can be made as to the likely effects of oil spills under various environmental conditions.

Ecological receptors were selected to represent species believed or known to be sensitive to spills, and which act as indicators of overall environmental health. Each of the four ecological receptor groups includes a variety of individual receptors and/or habitats with differing sensitivity to oil exposure. For this reason, each receptor group was divided into sub-categories that reflected their sensitivity to oil exposure. For nearshore and shoreline littoral (intertidal) habitats, biological sensitivity factors were based on habitat complexity and ability of different habitat types to sustain high levels of biodiversity and productivity. For the marine fish community and marine fish habitat receptor, biological sensitivity factors were based on water depth with the highest biological sensitivity class reserved for developing eggs and embryos in shallow water habitat. For marine birds and marine bird habitats, and marine mammals the classification scheme considered lifestyle, behaviour, and exposure mechanisms, and in particular the role of fur or feathers in providing thermal insulation.

The recovery assessment was carried out primarily based on the recovery of ecological receptors following the 1989 EVOS. That oil spill, while a major disaster caused by the grounding of a large single-hulled oil tanker, shows that marine ecosystems do recover from the effects of oil spills. Most of the instances of delayed recovery are associated with the effects of lingering or sequestered oil affecting a small area of habitat, or relate to effects on specific groups of whales which experienced harm from which they may not fully recover, but which are compensated for by gains made by other groups in the region. The EVOS was also an important learning experience in terms of oil spill response, and some of the oil spill response strategies that were employed at that time were found to be inappropriate. Current oil spill response planning and deployment incorporates those lessons, so that better outcomes can be expected than were observed at some sites following the EVOS. For the four ecological receptor groups considered here: shoreline habitats; marine fish community; marine birds; and marine mammals, recovery predictions and time to recovery are based upon relevant real-world experience, and are accorded a high level of confidence.

A summary of ERA results for the three marine tanker spill scenarios is provided below. Additional information is contained in Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B, TR 8B-7).

5.6.2.2 Location D: Strait of Georgia

The Strait of Georgia (Location D) credible worst case and smaller spill scenarios are described in Sections 5.4.4 and 5.6.2.2 (Figure 5.5.2). This discussion begins with a summary of the modelled fate and behaviour of oil spilled as a result of this hypothetical scenario, specifically relating to the probability of surface oiling and shoreline oiling. Potential effects on each of the four ecological indicators are then described. Additional information is contained in Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B). While not specifically considered here, the mitigation (spill response) measures that would be employed to minimize environmental effects - should such a spill occur - are described in Sections 5.4.4.10 and 5.5.

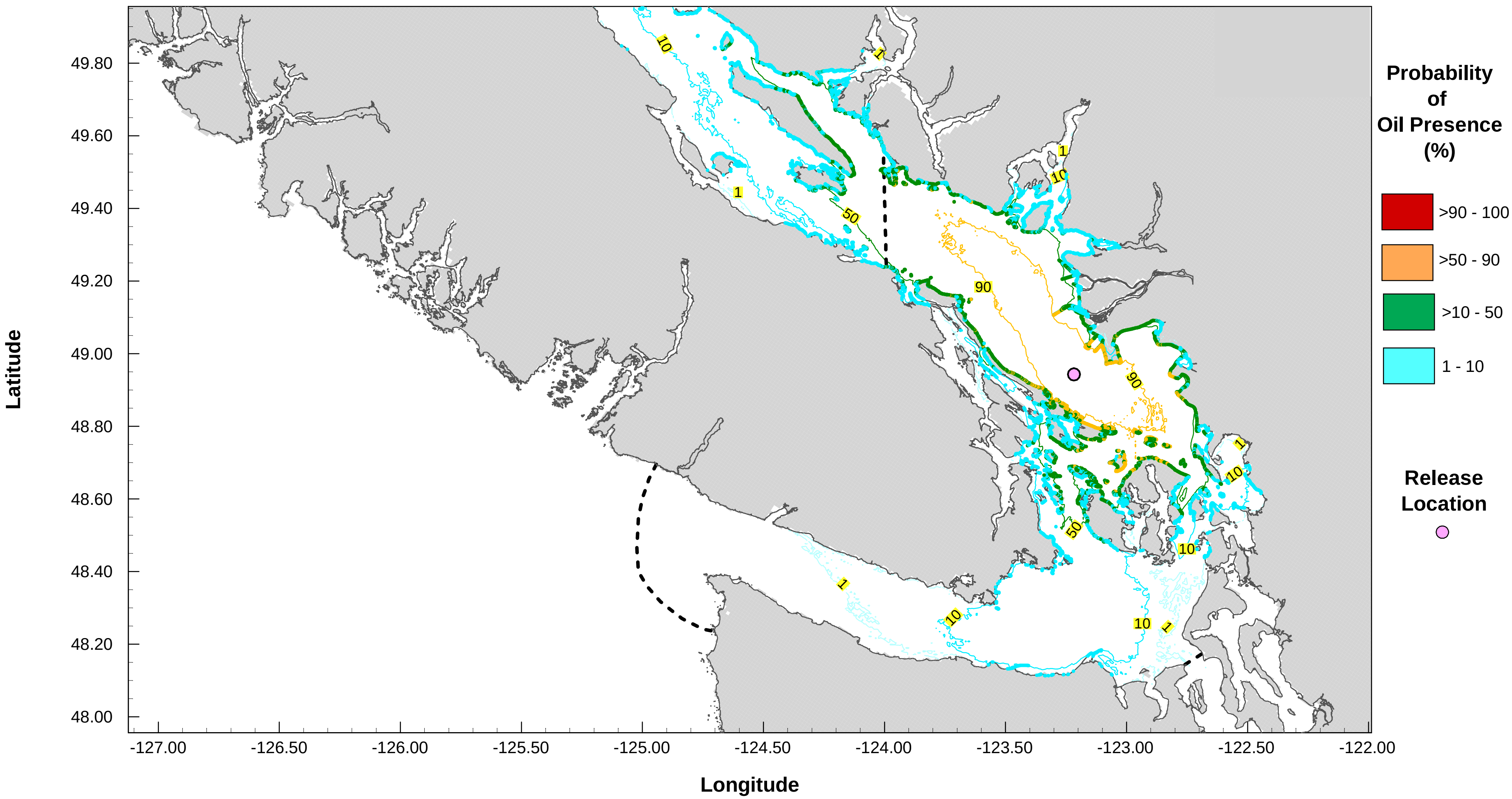
5.6.2.2.1 Fate and Behaviour

Probability of Surface Oiling

Stochastic oil fate modelling predictions indicate that a spill at the Strait of Georgia site (Location D) has a high or very high probability (≥50 per cent) for potential surface oiling to extend beyond the northern boundary of the RSA for both the 16,500 m^3 spill (winter, spring and fall seasons) and 8,250 m^3 spill (winter and spring seasons). In the case of a credible worst case spill, the ≥50 per cent probability contour extends as far north as Powell River during the winter season. In the case of the smaller 8,250 m^3 spill, the ≥50 per cent probability contour extends slightly beyond the RSA into the northern Strait of Georgia off Madeira Park. The ≥50 per cent probability contour does not extend beyond the RSA boundaries to the west or south for either scenario, or any of the seasonal conditions.

Predicted high and very high probabilities of oiling were similar for each scenario and seasonal condition. Slight differences in the seasonal spill trajectories do exist and these primarily result from variations in predominant current or wind direction and speed, as well as the influence of the peak spring and summer discharges from the Fraser River. The largest difference in the predicted surface oiling area occurred under winter conditions for a credible worst case spill where the ≥90 per cent (very high) probability contour extended in the Strait of Georgia from just north of Gibsons, BC to Patos Island (located in US waters) in the south. Refer to Figure 5.6.2.1.

Table 5.6.2.4 provides a summary of the predicted spatial extent of surface oiling (km^2) within the RSA for each spill volume and seasonal combination. Results are presented for each of three probability ranges (≥ 10 per cent, ≥50 per cent and ≥90 per cent). The release location and probability contours for seasonal stochastic surface oiling are shown in Figures 5.6.2.1 to 5.6.2.4 for a 16,500 m^3 spill. Comparable figures for a 8,250 m^3 spill are included in the Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B, TR 8C-7).



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independent spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

STATUS
ISSUED FOR USE

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

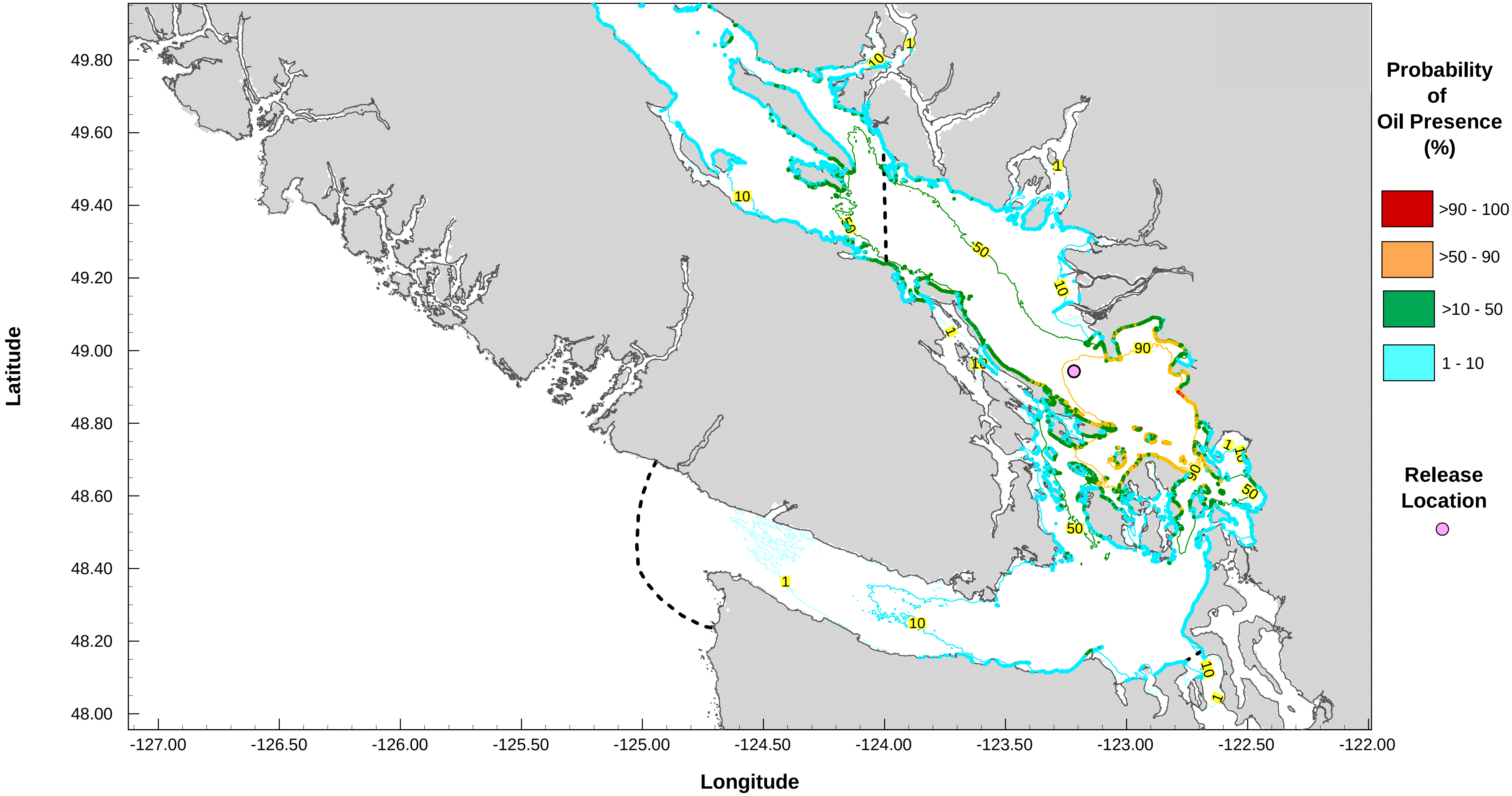
TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Strait of Georgia Stochastic Simulation
16,500 m^3 Spill - Winter Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 6, 2013

Figure 5.6.2-1



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independent spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

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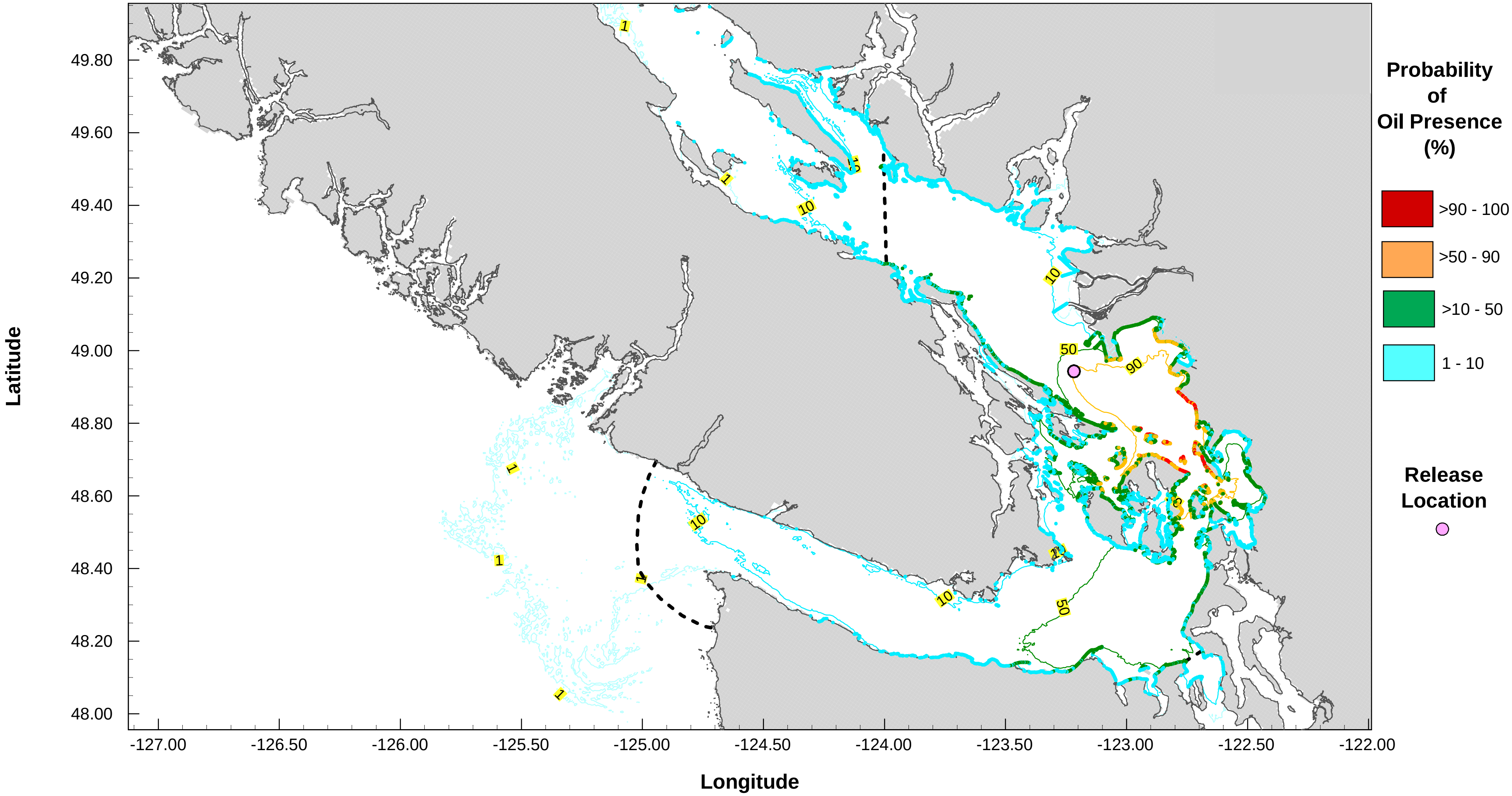
TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Strait of Georgia Stochastic Simulation
16,500 m^3 Spill - Spring Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 6, 2013

Figure 5.6.2-2



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independent spills.

- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.

- Tracking time for each spill was 15 days.

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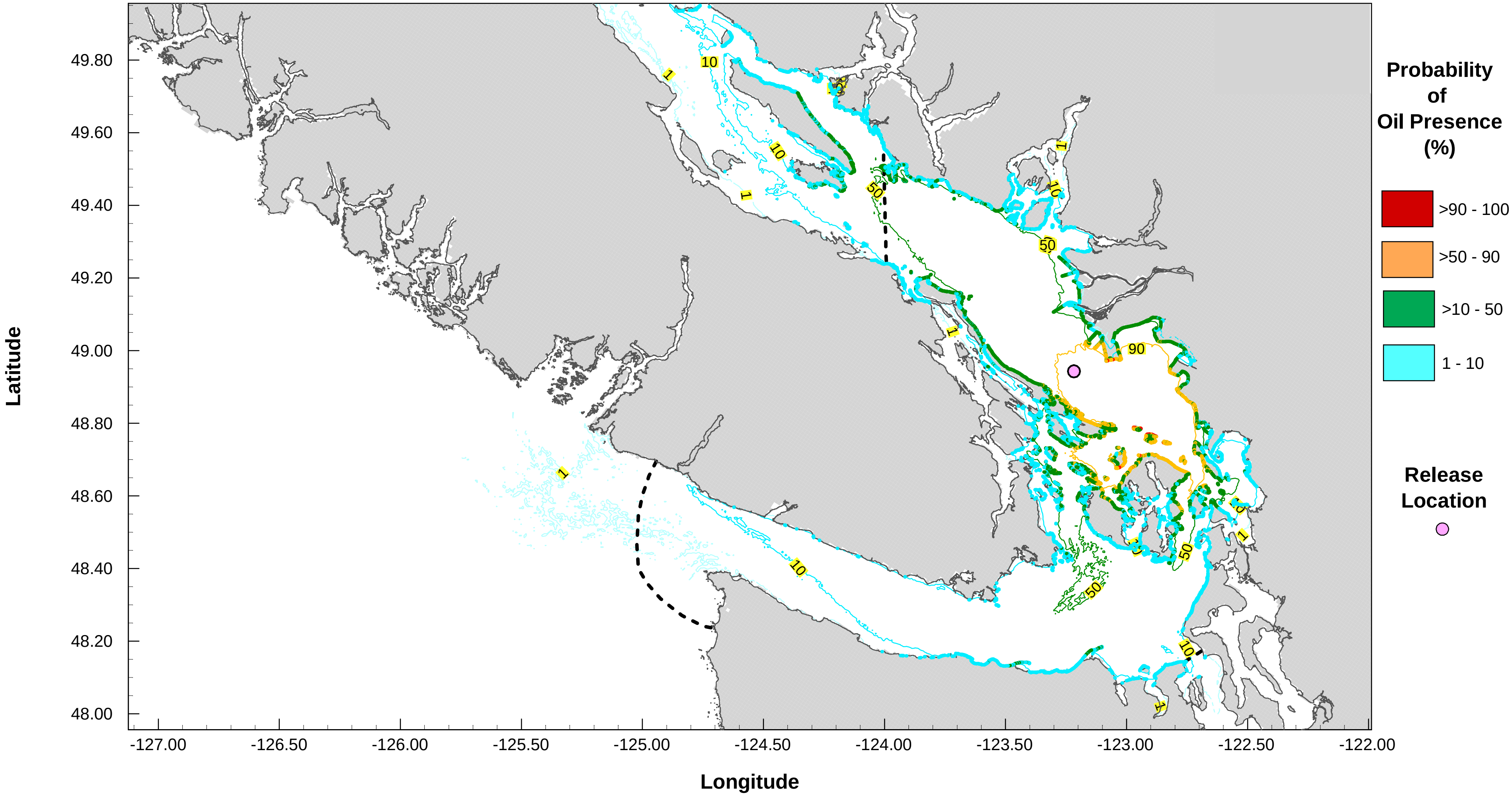
TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Strait of Georgia Stochastic Simulation
16,500 m³ Spill - Summer Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 6, 2013

Figure 5.6.2-3



NOTES

- Statistical results based on independent spills occuring every 6 hours from October 01 00:00 to December 31 23:00, for a total of 368 independent spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

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TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Strait of Georgia Stochastic Simulation
16,500 m^3 Spill - Fall Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 6, 2013

Figure 5.6.2-4

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TABLE 5.6.2.4

AREA OF SURFACE OILING (BY PROBABILITY OF OILING) – STRAIT OF GEORGIA SCENARIOS (LOCATION D)

Scenario	Spill Volume (m^3)	Seasonal Condition	Maximum Average Slick Area (km^2)	Total Affected Surface Area (km^2) by Probability of Oiling		
				≥ 10%	≥ 50%	≥ 90%
1	Credible Worst Case 16,500 m^3	Winter	423	6,461	3,850	1,379
		Spring	435	7,372	3,194	1,143
		Summer	355	8,667	3,311	934
		Fall	425	8,465	4,013	1,267
2	Smaller Spill Case 8,250 m^3	Winter	370	5,302	3,473	431
		Spring	385	6,353	2,561	889
		Summer	308	6,827	2,142	754
		Fall	363	7,129	2,907	985

It is important to correctly interpret the data presented in Table 5.6.2.4. The values presented under the column headed “Maximum Average Slick Area (km^2)” indicate, for the average simulated spill, the largest sea surface area occupied by spilled oil at any point in time during the modelling run. When oil is spilled, the surface area of the slick increases rapidly to a maximum value, and then decreases as oil evaporates and strands on shorelines. Because an oil slick is moved around by tides and winds and is not static, the total area affected by the moving oil is greater than the predicted slick surface area at any given time. Therefore the values presented under the columns headed “Total Affected Surface Area (km^2)” indicate the predicted probability that an individual modelling sea surface grid area contained surface oil during at least one point in time. The three columns indicate the total area of sea surface affected by oil over the length of the oil spill simulation, at probability levels of ≥10 per cent, ≥50 per cent and ≥90 per cent, respectively. Accordingly, the areas presented in these columns of Table 5.6.2.3, and the same data represented by contour outlines in Figures 5.6.2.1 to 5.6.2.4 do not represent the surface area of a single, continuous oil slick.

Additional information on predicted spill fate and behaviour and mass balance is provided in Section 5.4.4 and Volume 8C, TR 8C-12, S9.

Probability of Shoreline Contact

Table 5.6.2.5 provides a summary of predicted shoreline contact within the RSA. Results for the credible worst case spill indicate a high to very high probability (≥50 per cent) of between 143 km and 458 km of shoreline contact, with the greatest shoreline contact occurring during winter conditions. The smaller spill case predicts a high to very high probability of shoreline contact between 94 km and 248 km, with the greatest contact also under winter conditions. Because oil that contacts shorelines tends to be retained on beach substrate, the average length of affected shoreline is more consistent with the total affected shoreline length at ≥50 per cent probability than was the case for water surface affected by oil.

TABLE 5.6.2.5

LENGTH OF SHORELINE CONTACT (BY PROBABILITY OF OILING) – STRAIT OF GEORGIA SCENARIOS (LOCATION D)

Scenario	Spill Volume (m^3)	Seasonal Condition	Average length of Affected Shoreline (km)	Total Affected Shoreline Length (km) by Probability of Oiling		
				≥ 10%	≥ 50%	≥ 90%
1	Credible Worst Case 16,500 m^3	Winter	263	3,397	458	0.2
		Spring	291	814	143	4.4
		Summer	278	648	150	268
		Fall	293	878	181	6.5
2	Smaller Spill Case 8,250 m^3	Winter	185	2,307	248	0.0
		Spring	217	582	94	0.7
		Summer	205	472	101	9.1
		Fall	211	563	120	3.7

The RSA includes approximately 4,130 km of shorelines. Based on this overall length, the modelling predicts the maximum shoreline contacted would be 248 km (6 per cent - smaller spill) to 458 km (11 per cent - credible worst case spill) of the RSA with high or very high probability. However, the average length of shoreline contact for a single oil spill ranges from 185 km (smaller spill) to 293 km (credible worst case spill) representing 4.5 per cent to 7.2 per cent of the shoreline within the RSA.

5.6.2.2.2 Shoreline Habitats

Of the 4,130 km of shoreline habitat in the RSA, 51 per cent (2,125 km) comprises low and high exposure rock and sand, low exposure rip rap and wood bulkheads and high exposure sand and gravel assigned a low biological sensitivity (BSF 1). Shorelines including low exposure veneer over rock, low exposure pebble veneer over sand, high exposure cobble/boulder veneer over rock and high exposure cobble/boulder represent 27 per cent (1,120 km) of the coastline and have medium biological sensitivity (BSF 2). Approximately 15 per cent (619 km) of the RSA has a high biological sensitivity (BSF 3) and includes low exposure cobble/boulder veneer over sand. The highest biological sensitivity (BSF 4) is generally limited to more sheltered bays and represents less than 6.4 per cent (266 km) of the shoreline in the RSA. Summaries of shoreline contact probability for each shoreline sensitivity class for the Strait of Georgia spill scenarios are provided in Table 5.6.2.6 and Table 5.6.2.7 for a 16,500 m^3 and an 8,250 m^3 spill, respectively.

Shorelines with a high to very high probability of oiling (≥50 per cent) generally represent less than 10 per cent of the available habitat belonging to that sensitivity class within the RSA. Results indicate that shorelines with the lowest biological sensitivity factor (BSF 1) have the highest overall probability of oiling under winter conditions where between 15 per cent and 8.2 per cent of the available habitat may be affected for credible worst case and smaller spills respectively.

For a 16,500 m^3 spill, areas with high probability of oiling (≥50 per cent) represent 3.9 per cent to 15 per cent of the total shoreline within the RSA assigned to BSF 1; 2.4 per cent to 8.7 per cent of the total RSA shoreline assigned to BSF 2; 3.9 per cent to 6.6 per cent of the total RSA shoreline assigned to BSF 3, and less than 1 per cent of the total RSA shoreline assigned to BSF 4.

TABLE 5.6.2.6

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – STRAIT OF GEORGIA – 16,500 M^3 SPILL (LOCATION D)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline Oiling Probabilities)					
			Affected Length According to Sensitivity Factor (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	2,125	2,087	317	0.0	98	15	0.0
	2	1,120	835	98	0.2	75	8.7	0.0
	3	619	406	41	0.0	66	6.6	0.0
	4	266	69	1.6	0.0	26	0.6	0.0
Spring	1	2,125	526	91	3.1	25	4.3	0.1
	2	1,120	184	27	0.7	17	2.4	0.1
	3	619	94	24	0.6	15	3.9	0.1
	4	266	9.8	0.7	0.0	3.7	0.3	0.0
Summer	1	2,125	387	83	12.6	18	3.9	0.6
	2	1,120	156	34	7.6	14	3.0	0.7
	3	619	91	33	5.7	15	5.4	0.9
	4	266	15	0.0	0.0	5.7	0.0	0.0
Fall	1	2,125	537	119	6.2	25	5.6	0.3
	2	1,120	214	35	0.3	19	3.1	0.0
	3	619	110	27	0.0	18	4.3	0.0
	4	266	18	0.1	0.0	6.7	0.0	0.0

For the 8,250 m^3 spill scenario, areas with high probability of oiling represent 2.4 per cent to 8.2 per cent of the total shoreline within the RSA assigned to BSF 1; 1.7 per cent to 4.5 per cent of the total RSA shoreline assigned to BSF 2; and 2.7 per cent to 4.1 per cent of the total RSA shoreline assigned to BSF 3.

TABLE 5.6.2.7

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – STRAIT OF GEORGIA – 8,250 M^3 SPILL (LOCATION D)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline contact Probabilities)					
			Affected Length According to Sensitivity Ranking (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	2,125	1,411	175.2	0.0	66	8.2	0.0
	2	1,120	576	50.6	0.0	51	4.5	0.0
	3	619	264	21.7	0.0	43	3.5	0.0
	4	266	56	0.0	0.0	21	0.0	0.0

TABLE 5.6.2.7

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – STRAIT OF GEORGIA – 8,250 M^3 SPILL (LOCATION D) (continued)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline contact Probabilities)					
			Affected Length According to Sensitivity Ranking (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	2,125	371	58.3	0.7	17	2.7	0.0
	2	1,120	136	19.4	0.0	12	1.7	0.0
	3	619	68	16.4	0.0	11	2.7	0.0
	4	266	7	0.0	0.0	2.7	0.0	0.0
Summer	1	2,125	280	51	5.4	13	2.4	0.3
	2	1,120	112	25	1.9	10	2.2	0.2
	3	619	71	25	1.8	12	4.1	0.3
	4	266	9	0.0	0.0	3.4	0.0	0.0
Fall	1	2,125	350	79	3.5	16	3.7	0.2
	2	1,120	130	24	0.2	12	2.1	0.0
	3	619	70	17	0.0	11	2.8	0.0
	4	266	13	0.0	0.0	5.1	0.0	0.0

Predicted oil spill mass balance results indicate that about 2 per cent of the spilled oil may contact mudflats of the Fraser River Delta (*i.e.,* Roberts Bank and Sturgeon Bank) or Boundary Bay. Because the hypothetical spill location is close to the Delta, the time to first contact for these areas is on the order of 1 day for Roberts Bank and 2 to 3 days for Boundary Bay. Owing to the fine-grained (sand and mud) substrates, which are expected to remain water-saturated at low tide, the probability of the oil penetrating the surface of the mudflats is low. Instead, the oil will tend to accumulate near the high tide mark in these areas, so that most of the mudflat areas will experience low levels of oiling. One important aspect of the intertidal habitat associated with the banks and mudflats is the presence of "biofilm", an assemblage of algal and bacterial cells and organic debris that forms an important part of the diet for some migratory birds (*e.g.,* Western sandpiper) as well as other ecological receptors such as marine invertebrates. The presence of oil is unlikely to have long-term negative effects on the biofilm, which has the capacity to recover quickly from physical or chemical disturbance.

Stochastic results for both spill scenarios also suggest that areas throughout the central Strait of Georgia, the Gulf Islands and south into US waters of the Juan de Fuca Strait have a high to very high probability of oiling (≥50 per cent) from a spill at this location (refer to Figures 5.6.2.1 to 5.6.2.4). A number of ecological and socially important sites are located in this area, and prompt and effective response in the event of a spill would help reduce effects on shoreline habitats.

5.6.2.2.3 Marine Fish Community

The RSA comprises approximately 11,111 km^2 of habitat for the marine fish community, and includes habitats for all four biological sensitivity rankings. Habitats classified as low sensitivity (BSF 1) to high sensitivity (BSF 3) are based on water depth, and are deemed to be exclusive with no overlap in area. However, BSF 4 (very high sensitivity) is based on habitats important areas for specific species (such as herring spawning areas), and can overlap areas with other sensitivity factors. Areas with a water depth of 30 m or more (BSF 1) represent slightly more than 78 per cent of the RSA (8,636 km^2). Areas represented by BSF 2 (water depths between 10 and 30 m with medium sensitivity), and areas with BSF 3 (water depths less than 10 m with high sensitivity) represent approximately 12 per cent (1,280 km^2) and 11 per cent (1,196 km^2) of the RSA, respectively. Critical habitats for herring spawn, rockfish and crab combined as BSF 4 (very high sensitivity) overlap with other areas and represent approximately 35 per cent (3,934 km^2) of the RSA.

For a 16,500 m^3 spill, areas with a high to very high (≥50 per cent) probability of oiling represent: 28 per cent (under summer conditions) to 39 per cent (under fall conditions) of the total area with water depths >30m (BSF 1); 24 per cent (under spring conditions) to 42 per cent (under summer conditions) of the total area with water depths between 10 m and 30m (BSF 2); 24 per cent (under spring conditions) to 30 per cent (under summer conditions) of the total area with depths <10 m (BSF 3); and 12 per cent (under spring and summer conditions) to 16 per cent (under winter conditions) of the important habitat for herring spawn, rockfish and crab. The overlap between surface oiling probability and marine fish community sensitivity for the 16,500 m^3 spill scenario is summarized in Table 5.6.2.8.

TABLE 5.6.2.8

SUMMARY OF EFFECTS ANALYSIS FOR THE MARINE FISH COMMUNITY – STRAIT OF GEORGIA – 16,500 M^3 SPILL (LOCATION D)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Surface Water Oiling Probabilities)					
			Area According to Sensitivity Factor (km^2)			Percent Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	8,636	5,233	3,219	1,290	61	37	15
	2	1,280	680	307	44	53	24	3.4
	3	1,196	548	324	46	46	27	3.8
	4	3,934	1,109	609	132	28	16	3.4
Spring	1	8,636	5,931	2,569	902	69	30	10
	2	1,280	818	338	183	64	26	14
	3	1,196	624	287	58	52	24	4.9
	4	3,934	1,118	477	182	28	12	4.6
Summer	1	8,636	7,030	2,421	694	81	28	8.0
	2	1,280	893	532	170	70	42	13
	3	1,196	743	359	70	62	30	5.9
	4	3,934	947	451	163	24	12	4.1
Fall	1	8,636	6,796	3,338	1,013	79	39	12
	2	1,280	972	337	185	76	26	14
	3	1,196	698	339	69	58	28	5.8
	4	3,934	1,195	603	204	30	15	5.2

For a 8,250 m^3 spill, areas with a high to very high (≥50 per cent) probability of oiling represent: 18 per cent (under summer conditions) to 34 per cent (under fall conditions) of the total area with water depths >30 m (BSF 1); 20 per cent (under fall conditions) to 29 per cent (under summer conditions) of the total area with water depths between 10 m and 30m (BSF 2); 20 per cent (under spring conditions) to 22 per cent (under various conditions) of the total area with depths <10 m (BSF 3); and 9 per cent (under summer conditions) to 13 per cent (under winter conditions) of the important habitat for herring spawn, rockfish and crab. The overlap between surface oiling probability and marine fish community sensitivity for the 8,250 m^3 spill is summarized in Table 5.6.2.9.

TABLE 5.6.2.9

SUMMARY OF EFFECTS ANALYSIS FOR THE MARINE FISH COMMUNITY – STRAIT OF GEORGIA – 8,250 M^3 SPILL (LOCATION D)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Surface Water Oiling Probabilities)					
			Area According to Sensitivity Factor (km^2)			Percent Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	8,636	5,820	2,380	834	67	28	9.7
	2	1,280	756	270	122	59	21	9.5
	3	1,196	554	257	29	46	22	2.5
	4	3,934	974	511	8	25	13	0.2
Spring	1	8,636	5,212	2,046	765	60	24	8.9
	2	1,280	633	271	106	50	21	8.3
	3	1,196	508	244	19	43	20	1.6
	4	3,934	900	382	142	23	10	3.6
Summer	1	8,636	5,459	1,507	624	63	18	7.2
	2	1,280	744	371	84	58	29	6.6
	3	1,196	625	264	46	52	22	3.8
	4	3,934	867	362	140	22	9	3.6
Fall	1	8,636	4,322	2,954	424	50	34	4.9
	2	1,280	487	254	6	38	20	0.5
	3	1,196	493	266	1.5	41	22	0.1
	4	3,934	1,028	429	151	26	11	3.8

Of a total of 8,635 km^2 of deep water habitat (> 30 m) in the RSA (BSF 1), between 28 per cent and 39 per cent of this habitat type within the RSA has a high or very high (≥ 50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 18 per cent and 34 per cent has a high or very high probability of oil exposure from an 8,250 m^3 spill. While these ranges represent a comparatively large portion of this habitat type, it is very unlikely that fish in this habitat type would be harmed by exposure to oil due to water depth.

A predicted range of 24 per cent to 42 per cent of the total of 1,280 km^2 of intermediate depth habitat (< 30 to ≥ 10) in the RSA (BSF 2) has a high or very high (≥ 50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 20 per cent and 29 per cent of this medium sensitivity habitat in the RSA has a high or very high probability of oil exposure from an 8,250 m^3 spill. As with deep water habitat, given the water depth this sensitivity rank represents, it is also very unlikely that fish would be harmed by exposure to oil in this habitat type.

Between 24 per cent and 30 per cent of the RSA total of 1,196 km^2 of high sensitivity (BSF 3) shallow water habitat (≤ 10 m) has a high or very high (≥ 50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 244 and 266 km^2 has a high or very high probability of oil exposure from an 8,250 m^3 spill, representing 20 per cent to 22 per cent of this habitat type within the RSA. In circumstances where oil is driven into this shallow water habitat by strong winds, there would be a greater potential for negative effects, including potential mortality of fish, crustaceans and shellfish. While this could occur at any time of year, such windy conditions are most likely to occur during the winter.

Of a total of 3,934 km^2 of RSA habitat with a very high biological sensitivity (BSF 4), between 12 per cent and 16 per cent has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill, and between 9 per cent and 13 per cent has a high or very high probability of oil exposure from an 8,250 m^3 spill. In areas where this very high-sensitivity habitat overlaps with shallow water areas, the potential for negative effects would be greater. Critical time periods for herring spawn would be in the spring, when exposure to PAH in the oil could cause developmental effects on fish embryos. As noted for shallow water habitat, the potential for negative effects would be greatest if the spill were to occur at a time when strong winds cause the oil to be driven into shallow water used as spawning or nursery areas for herring, rockfish or crab.

5.6.2.2.4 Marine Birds

Marine birds were assessed using two approaches. The first assumes that marine birds could generally be present anywhere within the RSA and the potential for shorebirds and other marine birds to be affected was estimated using the stochastic shoreline contact and surface contours, respectively. The second approach considers the potential for spilled crude oil to come into contact with known bird colonies and designated IBAs.

The habitat oiling probability for each marine bird sensitivity group is summarized in Tables 5.6.2.10 and 5.6.2.11 for 16,500 m^3 spills and 8,250 m^3 spills respectively. For shorebirds (BSF 1), potential exposure is determined by the length of shoreline predicted to have a high or very high probability of oiling. For a 16,500 m^3 spill, the seasonal variation in spatial extent represents between 143 km (3.5 per cent) and 458 km (11 per cent) of the available shoreline habitat within the RSA. For an 8,250 m^3 spill, the predicted length of affected shoreline is ranges between 94 km (2.3 per cent) and 247 km (6 per cent) of the available shoreline habitat. Shorebirds generally have low sensitivity to oiling when compared to other guilds, and it is unlikely that lightly oiled individuals would die as a result of low or moderate exposure. Heavily oiled individuals would probably die; however, and even lightly oiled individuals could transfer sufficient oil to eggs to cause egg mortality, if exposure occurred shortly before or during the period when eggs were being incubated. An oil spill that occurred in the Strait of Georgia would be physically close to the important Fraser River Delta area, where shorebirds are present, and seasonal migrants congregate. The threat to birds in this area is mitigated; however, by the low percentage of spilled crude oil that is predicted to contact on Sturgeon or Roberts Banks, or Boundary Bay. Therefore, the environmental effects on shorebirds of crude oil exposure from an accidental spill during marine transportation could be high locally, although medium to Low effects levels are likely to be more prevalent.

For other marine birds (BSF 2, BSF 3, and BSF 4), potential exposure is based on surface water oiling. The seasonal variation in spatial extent for a 16,500 m^3 spill represents between 29 per cent and 36 per cent of the available habitat for these receptors, while for an 8,250 m^3 spill, between 19 per cent and 31 per cent of the RSA habitat is predicted to be affected. Therefore, there is a relatively high probability of exposure for aquatic birds in the event that an oil spill occurs. The environmental effects and effect magnitude of such exposure would depend upon the season (which would determine the numbers and types of birds present) as well as the actual level and duration of exposure, and the relative sensitivity of the exposed birds. Gulls and terns tend to have medium sensitivity, whereas ducks, cormorants, divers and alcids tend to have high to very high sensitivity. However, regardless of these factors, it is likely that seabirds would be exposed to oil, and would die as a result of that exposure, so that the effect magnitude would be high.

TABLE 5.6.2.10

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS AND MARINE BIRD HABITATS – STRAIT OF GEORGIA – 16,500 M³ SPILL (LOCATION D)

Seasonal Condition	BSF	Length or Area in RSA (km or km^2)	Affected Surface Water (by Shoreline or Surface Water Oiling Probabilities)					
			Affected Length or Area According to Sensitivity Factor (km or km^2)			Percent Length or Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	4,130 [1]	3,397 [1]	458 [1]	0.2 [1]	82 [2]	11 [2]	<0.1 [2]
	2	11,112	6,461	3,850	1,379	58	35	12
	3							
	4							
Spring	1	4,130 [1]	814 [1]	143 [1]	4.4 [1]	20 [2]	3.5 [2]	0.1 [2]
	2	11,112	7,372	3,194	1,143	66	29	10
	3							
	4							
Summer	1	4,130 [1]	648 [1]	150 [1]	26 [1]	16 [2]	3.6 [2]	0.6 [2]
	2	11,112	8,667	3,311	934	78	30	8.4
	3							
	4							
Fall	1	4,130 [1]	878 [1]	181 [1]	6.5 [1]	21 [2]	4.4 [2]	0.2 [2]
	2	11,112	8,466	4,014	1,267	76	36	11
	3							
	4							

Notes: 1 Total length of shoreline in the RSA, or length affected (km).

2 Expressed as % length of shoreline in that sensitivity class.

TABLE 5.6.2.11

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS AND MARINE BIRD HABITATS – STRAIT OF GEORGIA – 8,250 M³ SPILL (LOCATION D)

Seasonal Condition	BSF	Length or Area in RSA (km or km^2)	Affected Surface Water (by Shoreline or Surface Water Oiling Probabilities)					
			Affected Length or Area According to Sensitivity Factor (km or km^2)			Percent Length or Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	4,130 [1]	2,307 [1]	247 [1]	---	56 [2]	6.0 [2]	---
	2	11,112	5,302	3,473	431	48	31	3.9
	3							
	4							

TABLE 5.6.2.11

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS AND MARINE BIRD HABITATS – STRAIT OF GEORGIA – 8,250 M^3 SPILL (LOCATION D) (continued)

Seasonal Condition	BSF	Length or Area in RSA (km or km^2)	Affected Surface Water (by Shoreline or Surface Water Oiling Probabilities)					
			Affected Length or Area According to Sensitivity Factor (km or km^2)			Percent Length or Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	4,130 [1]	582 [1]	94 [1]	0.7 [1]	14 [2]	2.3 [2]	0.02 [2]
	2							
	3	11,112	6,353	2,561	890	57	23	8.0
	4							
Summer	1	4,130 [1]	472 [1]	101 [1]	9.1 [1]	11 [2]	2.5 [2]	0.2 [2]
	2							
	3	11,112	6,828	2,142	754	61	19	6.8
	4							
Fall	1	4,130 [1]	563 [1]	120 [1]	3.7 [1]	14 [2]	2.9 [2]	0.1 [2]
	2							
	3	11,112	7,130	2,907	985	64	26	9
	4							

Notes: 1 Total length of shoreline in the RSA, or length affected (km).
2 Expressed as % length of shoreline in that sensitivity class.

Stochastic modeling results were used to identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent) probability for spilled crude oil extending to known colony locations. The number of known colonies affected for each of the marine bird BSF rankings are summarized in Tables 5.6.2.12 and 5.6.2.13 for 16,500 m^3 spills and 8,250 m^3 spills respectively.

For gulls and terns (BSF 2), potential effects on colonies are determined by identifying the probability that crude oil will contact these areas if spilled during the spring or summer seasons. For a 16,500 m^3 spill, crude oil is predicted to have high to very high probability (≥50 per cent) to contact 15 or 16 of the 79 known colonies. For an 8,250 m^3 spill, this is predicted to represent 11 to 13 of the 79 known colonies.

For ducks and cormorants (BSF 3), the 16,500 m^3 spill, crude oil is predicted to have high to very high (≥50 per cent) probability to come in contact with 9 to 14 of the 40 known colonies. For the 8,250 m^3 spill, this is predicted to represent 8 to 10 of the 40 known colonies.

For auks and divers (BSF 4), the 16,500 m^3 spill, crude oil is predicted to have high to very high (≥50 per cent) probability to come in contact with 17 to 28 of the 55 known colonies. For the 8,250 m^3 spill, this is predicted to represent 16 to 22 of the 55 known colonies.

The presence of seabirds at colony locations is seasonal, and the overlap of oil with a colony location does not necessarily indicate that seabirds at nest sites will experience oiling, as their feeding grounds may be located at some distance from the nest site. However, the substantial overlap of high probability areas for oil on the water surface with known seabird colony locations (whether representing gulls and terns, ducks and cormorants, or auks and divers) indicates that the potential for negative effects, up to and including mortality of birds or oiling and mortality of eggs, is high for the Strait of Georgia spill scenario.

TABLE 5.6.2.12

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRD COLONIES – STRAIT OF GEORGIA – 16,500 M³ SPILL (LOCATION D)

Seasonal Condition	BSF	Affected Marine Bird Colonies (by Surface Water Oiling Probabilities)		
		Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	---	---	---
	2	39 of 79 known colony sites affected.	16 of 79 known colony sites affected.	2 of 79 known colony sites affected.
	3	20 of 40 known colony sites affected.	9 of 40 known colony sites affected.	5 of 40 known colony sites affected.
	4	37 of 55 known colony sites affected.	17 of 55 known colony sites affected.	7 of 55 known colony sites affected.
Summer	1	---	---	---
	2	35 of 79 known colony sites affected.	15 of 79 known colony sites affected.	2 of 79 known colony sites affected.
	3	22 of 40 known colony sites affected.	14 of 40 known colony sites affected.	3 of 40 known colony sites affected.
	4	42 of 55 known colony sites affected.	28 of 55 known colony sites affected.	8 of 55 known colony sites affected.

TABLE 5.6.2.13

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRD COLONIES – STRAIT OF GEORGIA – 8,250 M³ SPILL (LOCATION D)

Seasonal Condition	BSF	Affected Marine Bird Colonies (by Surface Water Oiling Probabilities)		
		Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	---	---	---
	2	33 of 79 known colony sites affected.	13 of 79 known colony sites affected.	2 of 79 known colony sites affected.
	3	19 of 40 known colony sites affected.	8 of 40 known colony sites affected.	2 of 40 known colony sites affected.
	4	32 of 55 known colony sites affected.	16 of 55 known colony sites affected.	3 of 55 known colony sites affected.
Summer	1	---	---	---
	2	30 of 79 known colony sites affected.	11 of 79 known colony sites affected.	2 of 79 known colony sites affected.
	3	19 of 40 known colony sites affected.	10 of 40 known colony sites affected.	3 of 40 known colony sites affected.
	4	40 of 55 known colony sites affected.	22 of 55 known colony sites affected.	7 of 55 known colony sites affected.

Stochastic modeling results were used to identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent) probability for spilled crude oil extending to IBA locations. The number of IBAs affected are summarized in Tables 5.6.2.14 and 5.6.2.15 for 16,500 m^3 spills and 8,250 m^3 spills respectively.

There are 19 IBAs that have ≥10 per cent probability of being affected by spilled crude oil, in the event of a credible worst case or smaller oil spill at the Strait of Georgia hypothetical spill location. Of these, 11 and 6, respectively, have a high or very high probability (≥50 per cent) of oil exposure in the event of the credible worst case or smaller spill. The utilization of IBAs by seabirds and other birds is seasonal, but most IBAs are used by one or more species in any season. It is likely that oil exposure at an IBA would result in oiling of birds, with a high potential for mortality of adults, juveniles, and/or eggs in the event of oil being transferred from plumage to incubating eggs. Given the high potential for negative effects on seabirds at IBAs, the effect magnitude is high.

TABLE 5.6.2.14

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – STRAIT OF GEORGIA – 16,500 M³ SPILL (LOCATION D)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC015	≥ 90%	≥ 50%	≥ 10%	≥ 90%
BC017	≥ 90%	≥ 90%	≥ 90%	≥ 90%
BC018	≥ 10%	---	---	---
BC020	≥ 10%	≥ 10%	---	≥ 10%
BC025	≥ 90%	≥ 10%	≥ 10%	≥ 50%
BC045	≥ 10%	≥ 10%	≥ 10%	≥ 10%
BC047	≥ 10%	≥ 10%	≥ 10%	≥ 50%
BC052	≥ 50%	≥ 50%	≥ 10%	≥ 50%
BC055	≥ 50%	≥ 50%	≥ 10%	≥ 10%
BC073	---	---	≥ 10%	≥ 10%
BC097	---	---	≥ 10%	---
United States				
USWA 277	≥ 50%	≥ 50%	≥ 50%	≥ 50%
USWA 282	---	---	≥ 10%	---
USWA 288	---	≥ 10%	≥ 50%	≥ 10%
USWA 3289	---	≥ 10%	≥ 50%	≥ 10%
USWA 3347	≥ 10%	≥ 50%	≥ 90%	≥ 10%
USWA 3348	≥ 10%	≥ 10%	≥ 10%	≥ 10%
USWA 3351	≥ 10%	≥ 10%	≥ 50%	≥ 10%
USWA 3786	---	---	≥ 10%	≥ 10%

TABLE 5.6.2.15

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – STRAIT OF GEORGIA – 8,250 M³ SPILL (LOCATION D)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC015	≥ 90%	≥ 50%	≥ 10%	≥ 90%
BC017	≥ 90%	≥ 50%	≥ 50%	≥ 90%
BC018	≥ 10%	---	---	≥ 10%
BC020	≥ 10%	≥ 10%	---	≥ 10%
BC025	≥ 50%	≥ 10%	≥ 10%	≥ 50%

TABLE 5.6.2.15

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – STRAIT OF GEORGIA – 8,250 M³ SPILL (LOCATION D) (continued)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC045	≥ 10%	≥ 10%	---	≥ 10%
BC047	≥ 10%	≥ 10%	≥ 10%	≥ 10%
BC048	---	---	---	---
BC052	≥ 50%	≥ 50%	≥ 10%	≥ 50%
BC055	≥ 10%	≥ 10%	≥ 10%	≥ 10%
United States				
USWA 277	≥ 50%	≥ 50%	≥ 50%	≥ 50%
USWA 288	---	---	≥ 10%	---
USWA 3289	---	---	≥ 10%	---
USWA 3347	---	≥ 10%	≥ 50%	---
USWA 3348	---	≥ 10%	≥ 10%	---
USWA 3351	---	≥ 10%	≥ 10%	---

5.6.2.2.5 Marine Mammals

Stochastic modelling results identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent), exposure probability for each class of mammals. The overlap between habitat oiling probabilities for each mammal sensitivity class is summarized in Tables 5.6.2.16 and 5.6.2.17 for 16,500 m^3 spills and 8,250 m^3 spills respectively.

TABLE 5.6.2.16

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – STRAIT OF GEORGIA – 16,500 M³ SPILL (LOCATION D)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or length) According to Sensitivity Factor (km^2)			Percent Area (or length) According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	4,130 [1]	3,397 [1]	458 [1]	0.2 [1]	82 [2]	11 [2]	0.0 [2]
	2	2,476	1,228	631	90	50	25	3.6
	3	7,578	4,007	1,883	779	53	25	10
	4	1,196	548	324	46	46	27	3.8
Spring	1	4,130 [1]	814 [1]	143 [1]	4.4 [1]	20 [2]	3.5 [2]	0.1 [2]
	2	2,476	1,441	625	241	58	25	9.7
	3	7,578	5,164	1,923	1,133	68	25	15
	4	1,196	624	287	58	52	24	4.9

TABLE 5.6.2.16

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – STRAIT OF GEORGIA – 16,500 M^3 SPILL (LOCATION D) (continued)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or length) According to Sensitivity Factor (km^2)			Percent Area (or length) According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Summer	1	4,130 [1]	648 [1]	150 [1]	26 [1]	16 [2]	3.6 [2]	0.6 [2]
	2	2,476	1,637	891	240	66	36	9.7
	3	7,578	6,641	3,211	934	88	42	12
	4	1,196	743	359	71	62	30	5.9
Fall	1	4,130 [1]	878 [1]	181 [1]	6.5 [1]	21 [2]	4.4 [2]	0.2 [2]
	2	2,476	1670	676	254	67	27	10
	3	7,578	6,062	2,291	1,253	80	30	17
	4	1,196	698	339	69	58	28	5.8

Notes: 1 total length of shoreline in the RSA, or length affected (km).
2 Expressed as % length of shoreline in that sensitivity class.

For terrestrial mammals (*e.g.,* bears, moose, raccoon, etc., BSF 1), potential exposure is determined by the length of shoreline habitat predicted to have a high or very high probability of oiling. For a 16,500 m^3 spill, the seasonal variation in spatial extent represents between 143 km (3.5 per cent) and 458 km (11 per cent) of the available shoreline habitat; this drops slightly to between 94 km (2.3 per cent) and 248 km (6 per cent) for an 8,250 m^3 spill. These animals have generally low sensitivity to oiling, and it is unlikely that oiled individuals would die as a result of exposure. It is very unlikely that such exposure would result in a measurable effect at the population level.

For pinnipeds such as seals and sea lions (BSF 2), potential exposure is based on habitat having a water depth of ≤30m. The seasonal variation in likely spatial extent for a 16,500 m^3 spill affecting pinniped habitat represents 25 per cent to 36 per cent of the available habitat, whereas for an 8,250 m^3 spill, between 21 per cent and 26 per cent of the habitat could be affected. Therefore, there is a relatively high probability of exposure for seals and sea lions in the event of an accidental oil spill. While some level of negative effect would be expected for animals exposed to oil, the effects would not likely be lethal, except in the case of weaker animals such as pups or older and diseased animals.

For whales such as porpoises, or the humpback and southern resident killer whale (BSF 3), potential exposure is based on habitat having a water depth of ≥10m. For a 16,500 m^3 spill, the seasonal variation in the predicted area of affected habitat ranges between 25 per cent and 42 per cent of the RSA. The predictions for an 8,250 m^3 spill range between 22 and 27 per cent of the available habitat. Therefore, there is a relatively high probability of exposure for whales should an oil spill occur at this location. Some level of negative effect would be expected for animals exposed to oil, but the effects would not likely be lethal, except in the case of weaker animals such as calves or older and diseased animals, or animals that were exposed to heavy surface oiling and inhalation of vapours from fresh oil, as could occur in the immediate vicinity of the spill location.

For furred marine mammals such as otters (BSF 4), potential exposure is based on the available habitat represented by water depths along the coast of ≤10 m. The seasonal variation in spatial extent for a 16,500 m^3 spill for this receptor type represents between 24 per cent and 30 per cent of the available habitat, while for an 8,250 m^3 spill, between 20 per cent and 22 per cent of the habitat is predicted to be affected. Therefore there is a relatively high probability of exposure for some of otters along the marine transportation route, in the event of an oil spill. Some level of negative effect would be expected for animals exposed to oil. Exposure during the winter season would be more stressful than exposure during the summer, but in either case, the combination of hypothermia and damage to the gastro-intestinal system caused by oil ingested through grooming the fur would have the potential to cause death.

TABLE 5.6.2.17

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – STRAIT OF GEORGIA – 8,250 M^3 SPILL (LOCATION D)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or length) According to Sensitivity Factor (km^2)			Percent Area (or length) According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	4,130 [1]	2,307 [1]	248 [1]	0.0 [1]	56 [2]	6.0 [2]	0.0 [2]
	2	2,476	980	519.7	7.5	40	21	0.3
	3	7,578	4,841	1,862	985	64	25	13
	4	1,196	493	266	1.5	41	22	0.1
Spring	1	4,130 [1]	582 [1]	94 [1]	0.7 [1]	14 [2]	2.3 [2]	0.02 [2]
	2	2,476	1,142	515	125	46	21	5.0
	3	7,578	4,271	1,709	890	56	23	12
	4	1,196	508	244	19	43	20	1.6
Summer	1	4,130 [1]	472 [1]	101 [1]	9.1 [1]	11 [2]	2.5 [2]	0.2 [2]
	2	2,476	1,369	635	130	55	26	5.2
	3	7,578	4,896	2,060	754	65	27	9.9
	4	1,196	625	264	46	52	22	3.8
Fall	1	4,130 [1]	563 [1]	119.8 [1]	3.7 [1]	14 [2]	2.9 [2]	0.09 [2]
	2	2,476	1,310	527	151	53	21	6.1
	3	7,578	2,947	1,687	370	39	22	4.9
	4	1,196	554	257	29	46	21	2.5

Notes: 1 total length of shoreline in the RSA, or length affected (km).
2 Expressed as % length of shoreline in that sensitivity class.

5.6.2.3 Location G: Race Rocks

The Race Rocks (Location G; Juan de Fuca Strait) credible worst case and smaller spill scenarios are described in Section 5.4.4. This discussion begins with a summary of the modelled fate and behaviour of oil spilled as a result of this hypothetical scenario, specifically relating to the probability of surface oiling and shoreline contact. Potential effects on each of the four ecological indicators are then described. Additional information is contained in Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B, TR 8B-7). While not specifically considered here, the mitigation (spill response) measures that would be employed to minimize environmental effects - should such a spill occur - are described in Sections 5.4.4.10 and 5.5.

5.6.2.3.1 Fate and Behaviour

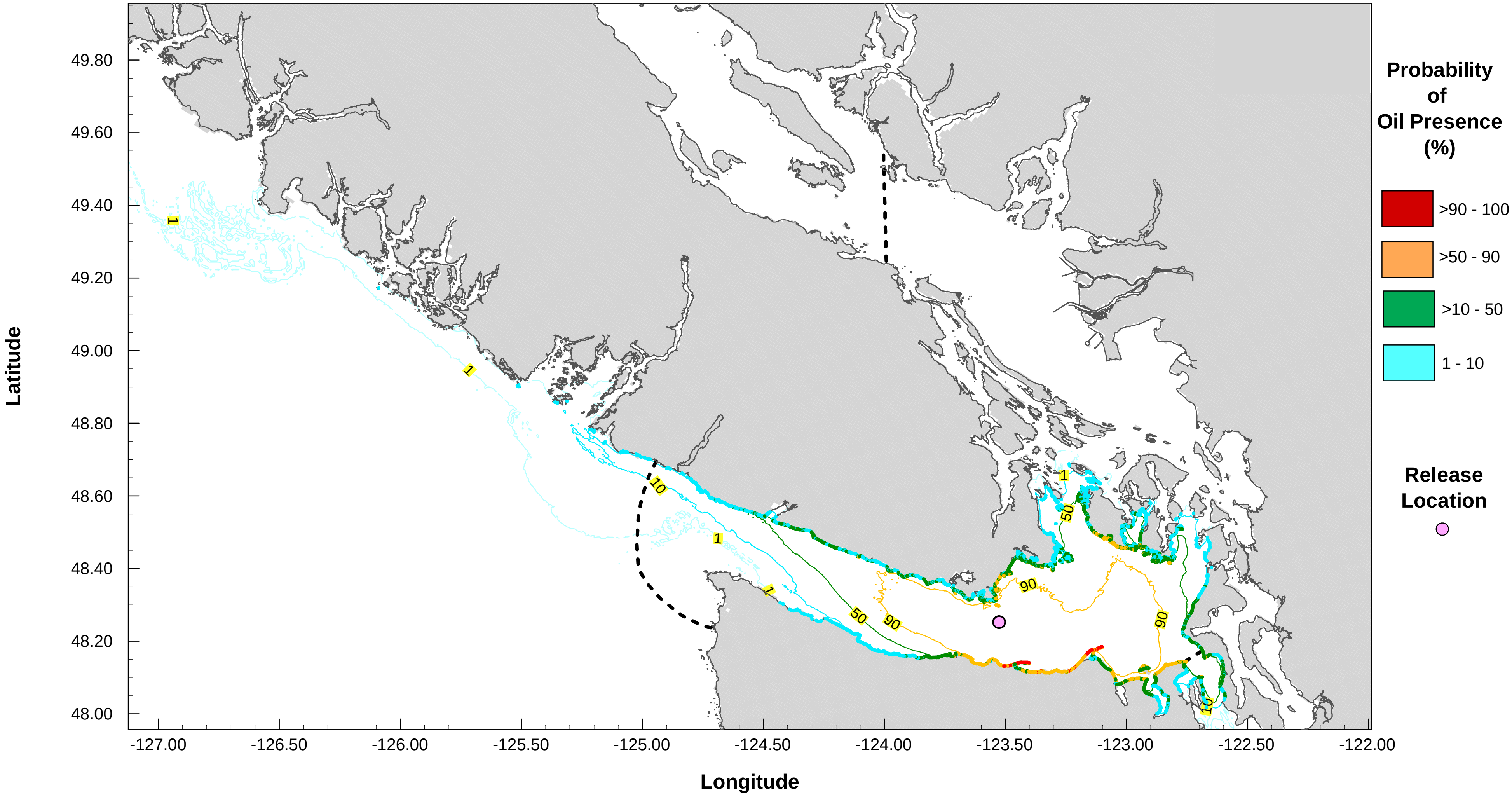
Probability of Surface Oiling

Stochastic oil fate modelling predictions indicate that a spill at the Race Rocks site has a high or very high probability (≥50 per cent) for potential surface oiling from a 16,500 m^3 spill to extend beyond the southern boundary of the RSA under winter, spring and fall conditions and to the west under the fall seasonal conditions (Figures 5.6.2.5 to 5.6.2.8). For an 8,250 m^3 spill, areas with high to very high probability of oiling extend south beyond the RSA only under winter conditions.

Overall the results for the high to very high probabilities of oiling for each scenario were quite similar, however some slight seasonal differences in the seasonal spill trajectories were identified for the lower probabilities, which are primarily due to variations in predominant current direction and speed, and/or predominant wind direction and speed.

Predicted high and very high probabilities of oiling were similar for each scenario and seasonal condition. Slight differences in the seasonal spill trajectories do exist and these primarily result from variations in predominant current or wind direction and speed. The highest probabilities for surface oiling were centered in the Juan de Fuca Strait around Race Rocks, west of the San Juan Islands and east of Canada's 12 nautical mile territorial limit.

Table 5.6.2.18 provides a summary of the predicted spatial extent of surface oiling (km^2) within the RSA for each spill volume and seasonal combination. Results are presented for each of three probability ranges (≥ 10 per cent, ≥50 per cent and ≥90 per cent). The release location and probability contours for seasonal stochastic surface oiling are shown in Figures 5.6.2.5 to 5.6.2.8 for a 16,500 m^3 spill. Comparable figures for an 8,250 m^3 spill are included in the Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B, TR 8B-7).



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 1 00:00 to March 31 23:00, for a total of 364 independant spills.

- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.

- Tracking time for each spill was 15 days.

STATUS
ISSUED FOR USE

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Race Rocks Stochastic Simulation
16,500 m³ Spill - Winter Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 9, 2013

Figure 5.6.2-5

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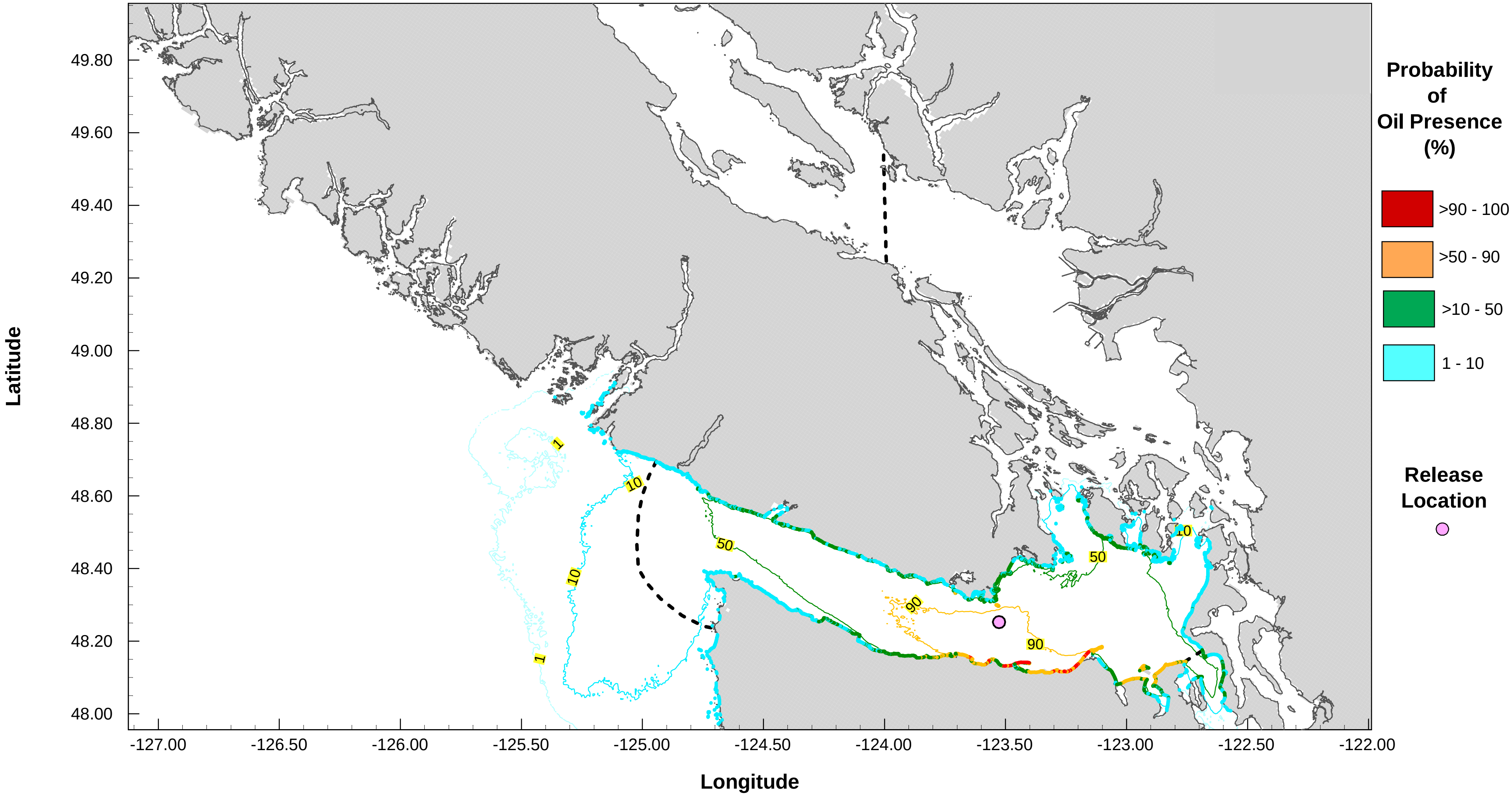

NOTES

- Statistical results based on independent spills occuring every 6 hours from April 1 00:00 to June 30 23:00, for a total of 364 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

STATUS
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TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Race Rocks Stochastic Simulation
16,500 m^3 Spill - Spring Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 9, 2013

Figure 5.6.2-6

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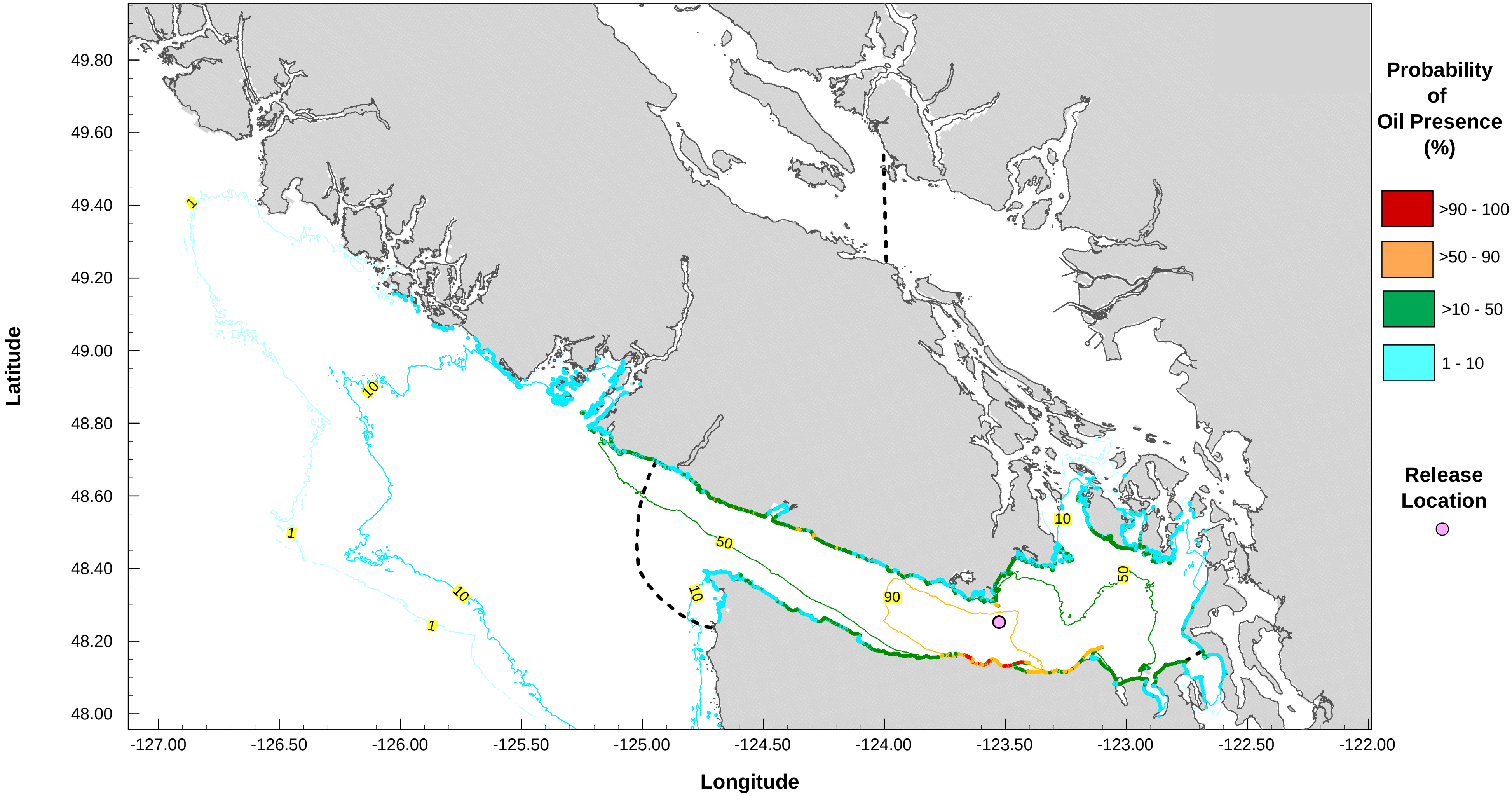

NOTES

- Statistical results based on independent spills occuring every 6 hours from October 1 00:00 to December 31 23:00, for a total of 368 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

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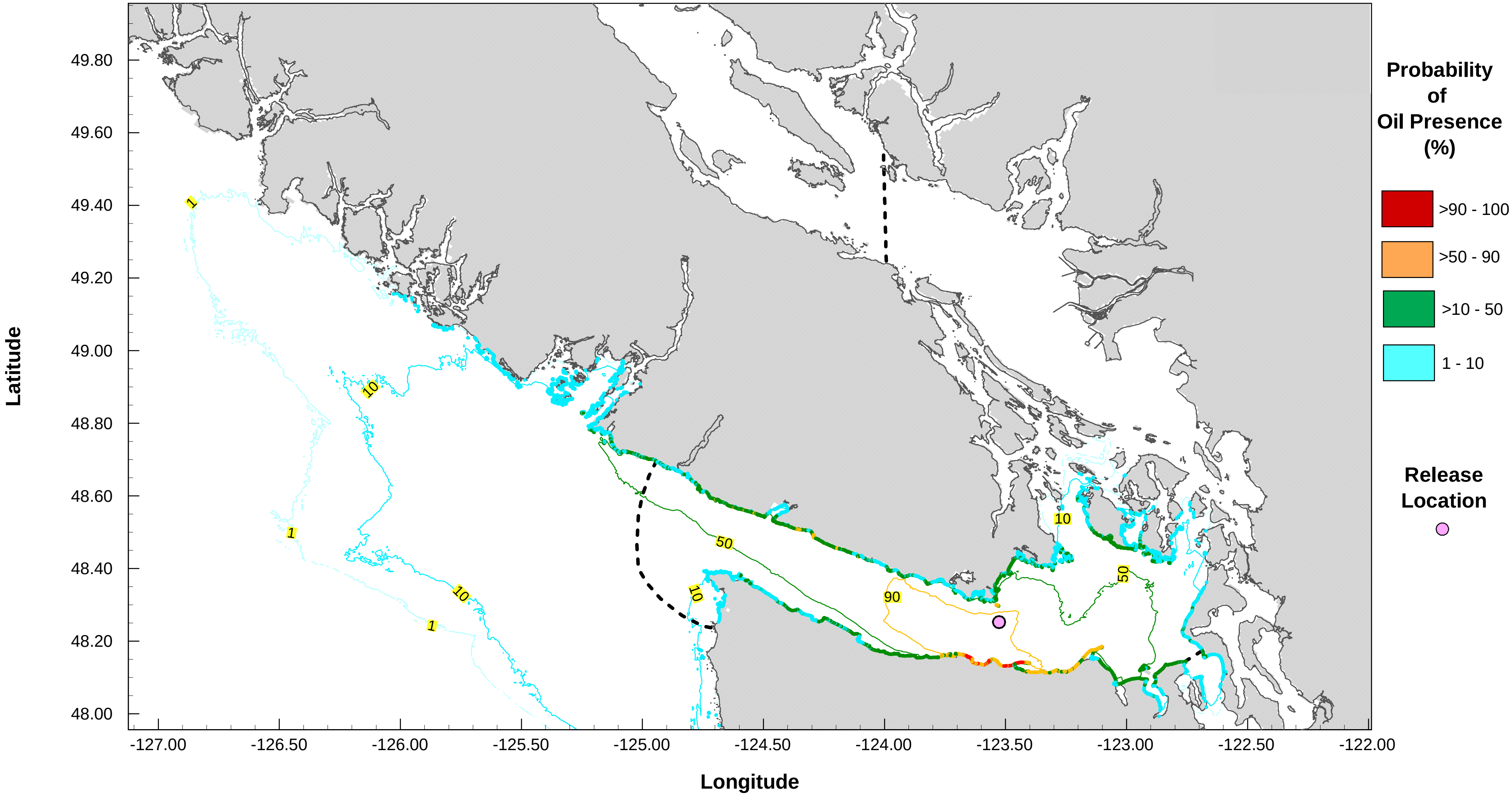
TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Race Rocks Stochastic Simulation
16,500 m^3 Spill - Fall Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 9, 2013

Figure 5.6.2-7



NOTES

- Statistical results based on independent spills occuring every 6 hours from October 1 00:00 to December 31 23:00, for a total of 368 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

STATUS
ISSUED FOR USE

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TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Race Rocks Stochastic Simulation
16,500 m^3 Spill - Fall Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 9, 2013

Figure 5.6.2-8

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TABLE 5.6.2.18

AREA OF SURFACE OILING (BY PROBABILITY OF OILING) – RACE ROCKS SCENARIOS (LOCATION G)

Scenario	Spill Volume (m^3)	Seasonal Condition	Maximum Average Slick Area (km^2)	Total Affected Surface Area (km^2) by Probability of Oiling		
				≥ 10%	≥ 50%	≥ 90%
1	Credible Worst Case 16,500 m^3	Winter	353	4,398	3,382	1,849
		Spring	295	5,244	3,486	701
		Summer	265	4,964	2,549	310
		Fall	375	5,158	3,058	651
2	Smaller Spill Case 8,250 m^3	Winter	310	4,021	2,931	703
		Spring	275	4,841	2,399	495
		Summer	225	4,712	1,675	248
		Fall	355	4,895	2,295	551

It is important to correctly interpret the data presented in Table 5.6.2.18. The values presented under the column headed "Maximum Average Slick Area (km^2)" indicate, for the average simulated spill, the largest sea surface area occupied by spilled oil at any point in time during the modelling run. When oil is spilled, the surface area of the slick increases rapidly to a maximum value, and then decreases as oil evaporates and strands on shorelines. Because an oil slick is moved around by tides and winds and is not static, the total area affected by the moving oil is greater than the predicted slick surface area at any given time. Therefore the values presented under the columns headed "Total Affected Surface Area (km^2)" indicate the predicted probability that an individual modelling sea surface grid area contained surface oil during at least one point in time. The three columns indicate the total area of sea surface affected by oil over the length of the oil spill simulation, at probability levels of ≥10 per cent, ≥50 per cent and ≥90 per cent, respectively. Accordingly, the areas presented in these columns of Table 5.6.2.3, and the same data represented by contour outlines in Figures 5.6.2.5 to 5.6.2.8 do not represent the surface area of a single, continuous oil slick.

Additional information on predicted spill fate and behaviour and mass balance is provided in Section 5.4.4 and Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C, S9).

Probability of Shoreline Contact

Table 5.6.2.19 provides a summary of predicted shoreline contact within the RSA. Results for the credible worst case spill indicate a high to very high probability (≥50 per cent) of between 114 km and 175 km of shoreline contact, with the greatest shoreline contact occurring during fall conditions. The smaller spill case predicts a high to very high probability of shoreline contact between 88 km and 124 km, with the greatest contact under spring conditions. Because oil that contacts shorelines tends to be retained on beach substrate, the average length of affected shoreline is more consistent with the total affected shoreline length at ≥50 per cent probability than was the case for water surface affected by oil.

TABLE 5.6.2.19

LENGTH OF SHORELINE CONTACT (BY PROBABILITY OF OILING) – RACE ROCKS SCENARIOS (LOCATION G)

Scenario	Spill Volume (m^3)	Seasonal Condition	Average length of Affected Shoreline (km)	Total Affected Shoreline Length (km) by Probability of Oiling		
				≥ 10%	≥ 50%	≥ 90%
1	Credible Worst Case 16,500 m^3	Winter	175	408	90	1.0
		Spring	136	297	30	2.5
		Summer	114	161	22	0.2
		Fall	141	399	36	6.7
2	Smaller Spill Case 8,250 m^3	Winter	124	289	33	0.5
		Spring	99	186	24	0.9
		Summer	88	115	17	0.1
		Fall	112	301	25	0.8

The RSA includes approximately 4,130 km of shorelines. Based on this overall length, the modelling predicts the maximum shoreline contacted would be 33 km (0.8 per cent - smaller spill) to 90 km (2.2 per cent - credible worst case spill) of the RSA with high or very high probability. However, the average length of shoreline contact for a single oil spill ranges from 124 km (smaller spill) to 175 km (credible worst case spill) representing 3 per cent to 4.2 per cent of the shoreline within the RSA.

5.6.2.3.2 Shoreline Habitats

Section 5.6.2.2 provides a description and summary statistics for the length of each shoreline type in the RSA for each shoreline sensitivity class. Shoreline contact probability statistics for each shoreline sensitivity class for the for the Race Rocks spill scenarios are summarized in Tables 5.6.2.20 and 5.6.2.21 for a 16,500 m^3 and an 8,250 m^3 spill, respectively.

Shorelines with a high to very high probability of oiling (≥50 per cent) represent less than 3.4 per cent of the available habitat belonging to that sensitivity class within the RSA. Results indicate that shorelines with the lowest biological sensitivity factor (BSF 1) have the highest overall probability of oiling under winter conditions where between 3.4 per cent and 1.1 per cent of the available habitat may be affected for credible worst case and smaller spills respectively.

Stochastic results indicate that shoreline types with highest biological sensitivity factor (BSF 4) have a very low probability of being oiled, with the greatest spatial extent of oiling predicted at 0.2 km for a 16,500 m^3 spill, and 0.0 km of affected shoreline predicted for an 8,250 m^3 spill in this location. Therefore, it is highly unlikely that any individual oil spill originating at this location would result in oiling of these sensitive areas.

For the 16,500 m^3 spill, areas with high to very high probability of oiling (≥50 per cent) represent 0.7 per cent to 3.4 per cent of the total shoreline within the RSA assigned to BSF 1; 0.6 per cent to 1.3 per cent of the total shoreline within the RSA assigned to BSF 2; and 0.0 per cent to 0.2 per cent of the total shoreline within the RSA assigned to BSF 3.

TABLE 5.6.2.20

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – RACE ROCKS – 16,500 M^3 SPILL (LOCATION G)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline Oiling Probabilities)					
			Affected Length According to Sensitivity Factor (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	2,125	293	73.0	0.3	13.8	3.4	0.0
	2	1,120	89	15	0.7	8.0	1.3	0.1
	3	619	23	1.5	0.0	3.7	0.2	0.0
	4	266	3.4	0.5	0.0	1.3	0.2	0.0
Spring	1	2,125	223	21	1.8	10.5	1.0	0.1
	2	1,120	63	9.1	0.7	5.7	0.8	0.1
	3	619	8.6	0.5	0.0	1.4	0.1	0.0
	4	266	2.0	0.0	0.0	0.8	0.0	0.0
Summer	1	2,125	110	15	0.0	5.2	0.7	0.0
	2	1,120	44	6.5	0.2	3.9	0.6	0.0
	3	619	5.4	0.6	0.0	0.9	0.1	0.0
	4	266	2.3	0.0	0.0	0.9	0.0	0.0
Fall	1	2,125	308	24	6.1	14.5	1.1	0.3
	2	1,120	80	12	0.6	7.2	1.1	0.1
	3	619	11	0.2	0.0	1.8	0.0	0.0
	4	266	0.9	0.0	0.0	0.3	0.0	0.0

For the 8,250 m^3 spill, areas with high to very high probability of oiling (≥50 per cent) represent 0.6 per cent to 1.1 per cent of the total shoreline within the RSA assigned to BSF 1; 0.4 per cent to 0.9 per cent of the total shoreline within the RSA assigned to BSF 2; and 0.0 per cent to 0.1 per cent of the total shoreline within the RSA assigned to BSF 3.

TABLE 5.6.2.21

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – RACE ROCKS – 8,250 M^3 SPILL (LOCATION G)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline Oiling Probabilities)					
			Affected Length According to Sensitivity Factor (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥90%)
Winter	1	2,125	209	24	0.1	9.8	1.1	0.0
	2	1,120	63	8.8	0.4	5.6	0.8	0.0
	3	619	15	0.4	0.0	2.4	0.1	0.0
	4	266	2.4	0.0	0.0	0.9	0.0	0.0
Spring	1	2,125	133	17	0.2	6.2	0.8	0.0
	2	1,120	48	6.0	0.7	4.2	0.5	0.1
	3	619	4.7	0.4	0.0	0.8	0.1	0.0
	4	266	1.0	0.0	0.0	0.4	0.0	0.0

TABLE 5.6.2.21

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – RACE ROCKS – 8,250 M^3 SPILL (LOCATION G) (continued)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline Oiling Probabilities)					
			Affected Length According to Sensitivity Factor (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥90%)
Summer	1	2,125	77	12.8	0.0	3.6	0.6	0.0
	2	1,120	35	4.3	0.1	3.1	0.4	0.0
	3	619	2.4	0.1	0.0	0.4	0.0	0.0
	4	266	0.3	0.0	0.0	0.1	0.0	0.0
Fall	1	2,125	227	15	0.8	11	0.7	0.0
	2	1,120	66	10	0.0	5.9	0.9	0.0
	3	619	7.0	0.0	0.0	1.1	0.0	0.0
	4	266	0.9	0.0	0.0	0.3	0.0	0.0

Stochastic results for both spill scenarios indicate areas with a high to very high probability of oiling (≥50 per cent) from a spill at this location range from west of the Gulf Islands, south into US waters and throughout the Juan de Fuca Strait to the 12 nautical mile limit (refer to Figures 5.6.2.5 to 5.6.2.8). A number of ecological and socially important sites are located in this area, and prompt and effective response in the event of a spill would help reduce effects on shoreline habitats.

5.6.2.3.3 Marine Fish Community

Section 5.6.2.2 provides a description and summary statistics for the area of each type of marine fish community habitat within the RSA. Summaries of shoreline contact probability predictions for each marine fish sensitivity class are shown in Table 5.6.2.20 and Table 5.6.2.21 for the 16,500 m^3 and the 8,250 m^3 spills respectively.

For a 16,500 m^3 spill, areas with a high (≥50 per cent) probability of oiling represent: 26 per cent (under summer conditions) to 36 per cent (under spring conditions) of the total area with water depths >30 m (BSF 1); 15 per cent (under summer conditions) to 26 per cent (under winter conditions) of the total area with water depths between 10 m and 30 m (BSF 2); 7.7 per cent (under summer conditions) to 13 per cent (under winter conditions) of the total area with depths <10 m (BSF 3); and 1.6 per cent (under fall conditions) to 4 per cent (under winter conditions) of the very high sensitivity habitat for herring spawn, rockfish and crab. The overlap between surface oiling probability and marine fish community sensitivity for the 16,500 m^3 spill scenario is summarized in Table 5.6.2.22.

For the 8,250 m^3 spill, areas with a high (≥50 per cent) probability of oiling represent: 17 per cent (under summer conditions) to 29 per cent (under winter conditions) of the total area with water depths >30 m (BSF 1); 10 per cent (under summer conditions) to 22 per cent (under winter conditions) of the total area with water depths between 10 m and 30 m (BSF 2); 6.1 per cent (under fall conditions) to 9.8 per cent (under winter conditions) of the total area with depths <10 m (BSF 3); and 0.6 per cent (under fall conditions) to 2.8 per cent (under winter conditions) of the important habitat for herring spawn, rockfish and crab (BSF 4). The overlap between surface oiling probability and marine fish community sensitivity for the 8,250 m^3 spill is summarized in Table 5.6.2.23.

TABLE 5.6.2.22

SUMMARY OF EFFECTS ANALYSIS FOR THE MARINE FISH COMMUNITY – RACE ROCKS – 16,500 M^3 SPILL (LOCATION G)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Surface Water Oiling Probabilities)					
			Area According to Sensitivity Factor (km^2)			Percent Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	8,636	3,675	2,899	1,654	43	34	20
	2	1,280	460	331	145	36	26	11
	3	1,196	263	152	50	22	13	4.2
	4	3,934	268	158	56	6.8	4.0	1.4
Spring	1	8,636	4,541	3,063	594	53	36	6.9
	2	1,280	442	298	75	35	23	5.9
	3	1,196	261	126	32	22	11	2.7
	4	3,934	233	85	0.6	5.9	2.1	0.0
Summer	1	8,636	4,321	2,267	263	50	26	3.0
	2	1,280	408	189	36	32	15	2.8
	3	1,196	234	93	11	20	7.7	0.9
	4	3,934	116	71	0.0	3.0	1.8	0.0
Fall	1	8,636	4,472	2,709	597	52	31	6.9
	2	1,280	426	250	38	33	20	3.0
	3	1,196	261	98	16	22	8.2	1.3
	4	3,934	193	64	0.0	4.9	1.6	0.0

TABLE 5.6.2.23

SUMMARY OF EFFECTS ANALYSIS FOR THE MARINE FISH COMMUNITY – RACE ROCKS – 8,250 M3 SPILL (LOCATION G)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Surface Water Oiling Probabilities)					
			Area According to Sensitivity Factor (km^2)			Percent Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	8,636	3,381	2,529	608	39	29	7.0
	2	1,280	411	285	73	32.1	22	5.7
	3	1,196	229	117	23	19.1	9.8	1.9
	4	3,934	233	110	3.4	5.9	2.8	0.1
Spring	1	8,636	4,232	2,100	401	49	24	4.6
	2	1,280	393	210	67	31	16	5.2
	3	1,196	215	89	27	18	7.4	2.3
	4	3,934	192	66	0.6	4.9	1.7	0.0
Summer	1	8,636	4,111	1,467	210	48	17	2.4
	2	1,280	392	130	30	30.6	10	2.3
	3	1,196	203	78	8.4	17.0	6.5	0.7
	4	3,934	110	46	0.0	2.8	1.2	0.0
Fall	1	8,636	4,253	2,045	506	49.2	24	5.9
	2	1,280	408	177	31	31.9	14	2.4
	3	1,196	234	73	14	19.6	6.1	1.2
	4	3,934	174	24	0.0	4.4	0.6	0.0

Of a total of 8,635 km^2 of deep water habitat (>30 m) in the RSA (BSF 1), between 26 per cent and 36 per cent of this habitat type within the RSA has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 17 per cent and 29 per cent has a high or very high probability of oil exposure from an 8,250 m^3 spill. While these ranges represent a comparatively large portion of this habitat type, it is very unlikely that fish in this habitat type would be harmed by exposure to oil due to water depth.

A predicted range of 15 per cent to 26 per cent of the total of 1,280 km^2 of intermediate depth habitat (<30 to ≥ 10) in the RSA (BSF 2) has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 10 per cent and 22 per cent of this medium sensitivity habitat in the RSA has a high or very high probability of oil exposure from an 8,250 m^3 spill. As with deep water habitat, given the water depth this sensitivity rank represents, it is also very unlikely that fish would be harmed by exposure to oil in this habitat type.

Between 7.7 per cent and 13 per cent of the RSA total of 1,196 km^2 of high sensitivity (BSF 3) shallow water habitat (≤10 m) has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill. Predictions for the smaller spill scenario indicate that between 7.7 per cent and 13 per cent of this habitat type within the RSA has a high or very high probability of oil exposure. In circumstances where oil is driven into this shallow water habitat by strong winds, there would be a greater potential for negative effects, including potential mortality of fish, crustaceans and shellfish.

Of a total of 3,934 km^2 of RSA habitat with a very high biological sensitivity (BSF 4), between 1.6 per cent and 4.0 per cent has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill, and between 0.6 per cent and 2.8 per cent has a high or very high probability of oil exposure from an 8,250 m^3 spill. In areas where this very high-sensitivity habitat overlaps with shallow water areas, the potential for negative effects would be greater. Critical time periods for herring spawn would be in the spring, when exposure to PAH in the oil could cause developmental effects on fish embryos. As noted for shallow water habitat, the potential for negative effects would be greatest if the spill were to occur at a time when strong winds cause the oil to be driven into shallow water used as spawning or nursery areas for herring, rockfish or crab.

5.6.2.3.4 Marine Birds

The same two approaches discussed in Section 5.6.2.2 were applied to Race Rocks for the marine bird assessment. The first assumes that marine birds could generally be present anywhere within the RSA and the potential for shorebirds and other marine birds to be affected was estimated using the stochastic shoreline contact and surface contours, respectively. The second approach considers the potential for spilled crude oil to come into contact with known bird colonies and designated IBAs.

The habitat oiling probability for each marine bird sensitivity group is summarized in Tables 5.6.2.24 and 5.6.2.25 for 16,500 m^3 spills and 8,250 m^3 spills respectively. For shorebirds (BSF 1), potential exposure is determined by the length of shoreline predicted to have a high or very high probability of oiling. For a 16,500 m^3 spill, the seasonal variation in spatial extent represents between 22 km (0.5 per cent) and 90 km (2.2 per cent) of the available shoreline habitat within the RSA. For an 8,250 m^3 spill, the predicted length of affected shoreline is ranges between 17 km (0.4 per cent) and 33 km (0.8 per cent) of the available shoreline habitat. Shorebirds generally have low sensitivity to oiling when compared to other guilds, and it is unlikely that lightly oiled individuals would die as a result of low or moderate exposure. Heavily oiled individuals would probably die; however, and even lightly oiled individuals could transfer sufficient oil to eggs to cause egg mortality, if exposure occurred shortly before or during the period when eggs were being incubated. An oil spill that occurred at the Race Rocks site would be physically close to the shorelines of the Juan de Fuca Strait which exhibits areas with medium, high and very high probability of oiling. Therefore, the potential for environmental effects on shorebirds of crude oil exposure from an accidental spill at this site is high.

For other marine birds (BSF 2, BSF 3, and BSF 4), potential exposure is based on surface water oiling. The seasonal variation in spatial extent for a 16,500 m^3 spill represents between 23 per cent and 31 per cent of the available habitat for these receptors, while for an 8,250 m^3 spill, between 15 per cent and 26 per cent of the RSA habitat is predicted to be affected. Therefore, there is a relatively high probability of exposure for aquatic birds in the event that an oil spill occurs. The environmental effects and effect magnitude of such exposure would depend upon the season (which would determine the numbers and types of birds present) as well as the actual level and duration of exposure, and the relative sensitivity of the exposed birds. Gulls and terns tend to have medium sensitivity, whereas ducks, cormorants, divers and alcids tend to have high to very high sensitivity. However, regardless of these factors, it is likely that seabirds would be exposed to oil, and would die as a result of that exposure, so that the effect magnitude would be high.

TABLE 5.6.2.24

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS – RACE ROCKS – 16,500 M^3 SPILL (LOCATION G)

Seasonal Condition	**BSF**	**Length or Area in RSA (km or km^2)**	**Affected Surface Water (by Shoreline or Surface Water Oiling Probabilities)**					
			Affected Length or Area According to Sensitivity Factor (km or km^2)			**Percent Length or Area According to Sensitivity Factor (%)**		
			Medium (≥ 10%)	**High (≥ 50%)**	**Very High (≥ 90%)**	**Medium (≥ 10%)**	**High (≥ 50%)**	**Very High (≥ 90%)**
Winter	1	4,130 [1]	408 [1]	90 [1]	1.0 [1]	9.9 [2]	2.2 [2]	<0.1 [2]
	2							
	3	11,112	4,398	3,382	1,849	40	30	17
	4							
Spring	1	4,130 [1]	297 [1]	30 [1]	2.5 [1]	7.2 [2]	0.7 [2]	0.1 [2]
	2							
	3	11,112	5,244	3,486	701	47	31	6.3
	4							
Summer	1	4,130 [1]	161 [1]	22 [1]	0.2 [1]	3.9 [2]	0.5 [2]	<0.1 [2]
	2							
	3	11,112	4,964	2,549	310	45	23	2.8
	4							
Fall	1	4,130 [1]	400 [1]	36 [1]	6.7 [1]	9.7 [2]	0.9 [2]	0.2 [2]
	2							
	3	11,112	5,158	3,058	651	46	28	5.9
	4							

Notes: 1 Total length of shoreline in the RSA, or length affected (km).

2 Expressed as % length of shoreline in that sensitivity class.

TABLE 5.6.2.25

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS AND MARINE BIRD HABITATS – RACE ROCKS – 8,250 M³ SPILL (LOCATION G)

<table>
<tr><th rowspan="3">Seasonal Condition</th><th rowspan="3">BSF</th><th rowspan="3">Length or Area in RSA (km or km²)</th><th colspan="6">Affected Surface Water (by Shoreline or Surface Water Oiling Probabilities)</th></tr>
<tr><th colspan="3">Affected Length or Area According to Sensitivity Factor (km or km²)</th><th colspan="3">Percent Length or Area According to Sensitivity Factor (%)</th></tr>
<tr><th>Medium (≥ 10%)</th><th>High (≥ 50%)</th><th>Very High (≥ 90%)</th><th>Medium (≥ 10%)</th><th>High (≥ 50%)</th><th>Very High (≥ 90%)</th></tr>
<tr><td rowspan="4">Winter</td><td>1</td><td>4,130 ¹</td><td>289 ¹</td><td>33 ¹</td><td>0.5 ¹</td><td>7.0 ²</td><td>0.8 ²</td><td><0.1 ²</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">4,021</td><td rowspan="3">2,931</td><td rowspan="3">703</td><td rowspan="3">36</td><td rowspan="3">26</td><td rowspan="3">6.3</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="4">Spring</td><td>1</td><td>4,130 ¹</td><td>186 ¹</td><td>24 ¹</td><td>0.9 ¹</td><td>4.5 ²</td><td>0.6 ²</td><td><0.1 ²</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">4,841</td><td rowspan="3">2,399</td><td rowspan="3">495</td><td rowspan="3">44</td><td rowspan="3">22</td><td rowspan="3">4.5</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="4">Summer</td><td>1</td><td>4,130 ¹</td><td>115 ¹</td><td>17 ¹</td><td>0.1 ¹</td><td>2.8 ²</td><td>0.4 ²</td><td><0.1 ²</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">4,712</td><td rowspan="3">1,675</td><td rowspan="3">248</td><td rowspan="3">42</td><td rowspan="3">15</td><td rowspan="3">2.2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="4">Fall</td><td>1</td><td>4,130 ¹</td><td>300 ¹</td><td>25 ¹</td><td>0.8 ¹</td><td>7.3 ²</td><td>0.6 ²</td><td><0.1 ²</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">4,895</td><td rowspan="3">2,295</td><td rowspan="3">551</td><td rowspan="3">44</td><td rowspan="3">21</td><td rowspan="3">5.0</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
</table>

Notes: 1 Total length of shoreline in the RSA, or length affected (km).
2 Expressed as % length of shoreline in that sensitivity class.

Stochastic modeling results were used to identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent) probability for spilled crude oil extending to known colony locations. The number of known colonies affected for each of the marine bird BSF rankings are summarized in Tables 5.6.2.26 and 5.6.2.27 for 16,500 m³ spills and 8,250 m³ spills respectively.

For gulls and terns (BSF 2), potential effects on colonies are determined by identifying the probability that crude oil will contact these areas if spilled during the spring or summer seasons. For a 16,500 m³ spill, crude oil is predicted to have high to very high probability (≥50 per cent) to contact up to 2 of the 79 known colonies. For an 8,250 m³ spill, this is predicted to represent none of the 79 known colonies.

For ducks and cormorants (BSF 3), under both 16,500 m³ and 8,250 m³ spill scenarios, crude oil is predicted to have high to very high (≥50 per cent) probability to come in contact with 1 of the 40 known colonies.

For auks and divers (BSF 4), the 16,500 m³ spill, crude oil is predicted to have high to very high (≥50 per cent) probability to come in contact with 3 or 4 of the 55 known colonies. For the 8,250 m³ spill, this is predicted to represent 2 or 3 of the 55 known colonies.

The presence of seabirds at colony locations is seasonal, and the overlap of oil with a colony location does not necessarily indicate that seabirds at nest sites will experience oiling, as their feeding grounds may be located at some distance from the nest site. However, even though low overlap of high probability surface oiling areas with known seabird colony locations is predicted (whether representing gulls and terns, ducks and cormorants, or auks and divers), results indicate potential for negative effects, up to and including mortality of birds or oiling and mortality of eggs at some sites. The effect rating is high for Race Rocks scenarios.

TABLE 5.6.2.26

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRD COLONIES – RACE ROCKS – 16,500 M³ SPILL (LOCATION G)

Seasonal Condition	BSF	Affected Marine Bird Colonies (by Surface Water Oiling Probabilities)		
		Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	---	---	---
	2	12 of 79 known colony sites affected.	2 of 79 known colony sites affected.	0 of 79 known colony sites affected.
	3	16 of 40 known colony sites affected.	1 of 40 known colony sites affected.	0 of 40 known colony sites affected.
	4	17 of 55 known colony sites affected.	4 of 55 known colony sites affected.	1 of 55 known colony sites affected.
Summer	1	---	---	---
	2	14 of 79 known colony sites affected.	0 of 79 known colony sites affected.	0 of 79 known colony sites affected.
	3	14 of 40 known colony sites affected.	1 of 40 known colony sites affected.	0 of 40 known colony sites affected.
	4	13 of 55 known colony sites affected.	3 of 55 known colony sites affected.	0 of 55 known colony sites affected.

TABLE 5.6.2.27

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRD COLONIES – RACE ROCKS – 8,250 M³ SPILL (LOCATION G)

Seasonal Condition	BSF	Affected Marine Bird Colonies (by Surface Water Oiling Probabilities)		
		Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	---	---	---
	2	7 of 79 known colony sites affected.	0 of 79 known colony sites affected.	0 of 79 known colony sites affected.
	3	10 of 40 known colony sites affected.	1 of 40 known colony sites affected.	0 of 40 known colony sites affected.
	4	12 of 55 known colony sites affected.	3 of 55 known colony sites affected.	0 of 55 known colony sites affected.
Summer	1	---	---	---
	2	9 of 79 known colony sites affected.	0 of 79 known colony sites affected.	0 of 79 known colony sites affected.
	3	9 of 40 known colony sites affected.	1 of 40 known colony sites affected.	0 of 40 known colony sites affected.
	4	11 of 55 known colony sites affected.	2 of 55 known colony sites affected.	0 of 55 known colony sites affected.

Stochastic modeling results were used to identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥ 90 per cent) probability for spilled crude oil extending to IBA locations. The number of IBAs affected are summarized in Tables 5.6.2.28 and 5.6.2.29 for 16,500 m^3 spills and 8,250 m^3 spills respectively.

There are 10 IBAs that have ≥10 per cent probability of being affected by spilled crude oil, in the event of a credible worst case or smaller oil spill at the Race Rocks hypothetical spill location. Of these, 8 and 7, respectively, have a high or very high probability (≥50 per cent) of oil exposure in the event of the credible worst case or smaller spill. The utilization of IBAs by seabirds and other birds is seasonal, but most IBAs are used by one or more species in any season. It is likely that oil exposure at an IBA would result in oiling of birds, with a high potential for mortality of adults, juveniles, and/or eggs in the event of oil being transferred from plumage to incubating eggs. Given the high potential for negative effects on seabirds at IBAs, the effect magnitude is high.

TABLE 5.6.2.28

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – RACE ROCKS – 16,500 M³ SPILL (LOCATION G)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC045	≥ 50%	≥ 10%	≥ 10%	≥ 10%
BC047	≥ 10%	≥ 10%	---	---
BC073	≥ 10%	≥ 50%	≥ 10%	≥ 50%
BC097	≥ 10%	≥ 10%	≥ 10%	≥ 50%
United States				
USWA 282	≥ 50%	≥ 10%	≥ 10%	≥ 10%
USWA 288	≥ 90%	≥ 50%	≥ 50%	≥ 50%
USWA 3289	≥ 10%	≥ 10%	---	---
USWA 3348	≥ 90%	≥ 90%	≥ 90%	≥ 90%
USWA 3351	≥ 90%	≥ 90%	≥ 90%	≥ 90%
USWA 3786	≥ 90%	≥ 50%	≥ 50%	≥ 50%

TABLE 5.6.2.29

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – RACE ROCKS – 8,250 M³ SPILL (LOCATION G)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC045	≥ 50%	≥ 10%	≥ 10%	≥ 10%
BC047	≥ 10%	---	---	---
BC073	≥ 10%	≥ 10%	≥ 10%	≥ 50%
BC097	---	≥ 10%	≥ 10%	≥ 50%
United States				
USWA 282	≥ 10%	≥ 10%	---	≥ 10%
USWA 288	≥ 50%	≥ 50%	≥ 50%	≥ 10%
USWA 3348	≥ 90%	≥ 90%	≥ 90%	≥ 90%
USWA 3351	≥ 90%	≥ 90%	≥ 90%	≥ 90%
USWA 3786	≥ 50%	≥ 50%	≥ 10%	≥ 10%

5.6.2.3.5 Marine Mammals

Stochastic results identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent), exposure probability for each class of mammals. The overlap between habitat oiling probabilities for each mammal sensitivity class are summarized in Tables 5.6.2.30 and 5.6.2.31 for 16,500 m^3 spills and 8,250 m^3 spills, respectively.

For terrestrial mammals (*e.g.,* bears, moose, raccoon, etc., BSF 1), potential exposure is determined by the length of shoreline habitat predicted to have a high or very high probability of oiling. For a 16,500 m^3 spill, the seasonal variation in spatial extent represents between 22 km (0.5 per cent) and 90 km (2.2 per cent) of the available shoreline habitat; this drops slightly to between 17 km (0.4 per cent) and 33 km (0.8 per cent) for an 8,250 m^3 spill. These animals have generally low sensitivity to oiling, and it is unlikely that oiled individuals would die as a result of exposure. It is very unlikely that such exposure would result in a measurable effect at the population level.

For pinnipeds such as seals and sea lions (BSF 2), potential exposure is based on habitat having a water depth of ≤30m. The seasonal variation in likely spatial extent for a 16,500 m^3 spill affecting pinniped habitat represents 11 per cent to 20 per cent of the available habitat, whereas for an 8,250 m^3 spill, between 8.4 per cent and 16 per cent of the habitat could be affected. Therefore, there is a relatively high probability of exposure for seals and sea lions in the event of an accidental oil spill. While some level of negative effect would be expected for animals exposed to oil, the effects would not likely be lethal, except in the case of weaker animals such as pups or older and diseased animals.

For whales such as porpoises, or the humpback and southern resident killer whale (BSF 3), potential exposure is based on habitat having a water depth of ≥10m. For a 16,500 m^3 spill, the seasonal variation in the predicted area of affected habitat ranges between 34 per cent and 46 per cent of the RSA. The predictions for an 8,250 m^3 spill range between 22 and 39 per cent of the available habitat. Therefore, there is a relatively high probability of exposure for whales should an oil spill occur at this location. Some level of negative effect would be expected for animals exposed to oil, but the effects would not likely be lethal, except in the case of weaker animals such as calves or older and diseased animals, or animals that were exposed to heavy surface oiling and inhalation of vapours from fresh oil, as could occur in the immediate vicinity of the spill location.

For furred marine mammals such as otters (BSF 4), potential exposure is based on the available habitat represented by water depths along the coast of ≤10 m. The seasonal variation in spatial extent for a 16,500 m^3 spill for this receptor type represents between 7.7 per cent and 13 per cent of the available habitat, while for an 8,250 m^3 spill, between 6.1 per cent and 9.8 per cent of the habitat is predicted to be affected. Therefore there is a relatively high probability of exposure for some of otters along the marine transportation route, in the event of an oil spill. Some level of negative effect would be expected for animals exposed to oil. Exposure during the winter season would be more stressful than exposure during the summer, but in either case, the combination of hypothermia and damage to the gastro-intestinal system caused by oil ingested through grooming the fur would have the potential to cause death.

TABLE 5.6.2.30

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – RACE ROCKS – 16,500 M^3 SPILL (LOCATION G)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or length) According to Sensitivity Factor (km^2)			Percent Area (or length) According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	4,130 [1]	408 [1]	90 [1]	1.0 [1]	9.9 [2]	2.2 [2]	0.02 [2]
	2	2,476	723	483	195	29	20	7.9
	3	7,578	4,341	3,382	1,849	57	45	24
	4	1,196	263	152	50	22	13	4.2
Spring	1	4,130 [1]	297 [1]	30 [1]	2.5 [1]	7.2 [2]	0.73 [2]	0.1 [2]
	2	2,476	703	424	107	28	17	4.3
	3	7,578	4,832	3,486	701	64	46	9.3
	4	1,196	261	126	32	22	11	2.7
Summer	1	4,130 [1]	161 [1]	22 [1]	0.2 [1]	3.9 [2]	0.5 [2]	0.0 [2]
	2	2,476	643	282	47	26	11	1.9
	3	7,578	4,523	2,549	310	60	34	4.1
	4	1,196	234	93	11	20	7.7	0.9
Fall	1	4,130 [1]	400 [1]	36 [1]	6.7 [1]	9.7 [2]	0.9 [2]	0.2 [2]
	2	2,476	687	349	54	28	14	2.2
	3	7,578	4,816	3,058	651	64	40	8.6
	4	1,196	261	98	16	22	8.2	1.3

Notes: 1 Total length of shoreline in the RSA, or length affected (km).

2 Expressed as % length of shoreline in that sensitivity class.

TABLE 5.6.2.31

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – RACE ROCKS – 8,250 M^3 SPILL (LOCATION G)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or length) According to Sensitivity Factor (km^2)			Percent Area (or length) According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	4,130 [1]	289 [1]	33 [1]	0.5 [1]	7.0 [2]	0.8 [2]	0.01 [2]
	2	2,476	640	402	95	26	16	3.9
	3	7,578	3,992	2,931	703	53	39	9.3
	4	1,196	229	116.9	23	19	9.8	1.9
Spring	1	4,130 [1]	186 [1]	24 [1]	0.9 [1]	4.5 [2]	0.6 [2]	0.02 [2]
	2	2,476	609	299	95	25	12	3.8
	3	7,578	4,614	2,399	495	61	32	6.5
	4	1,196	215	89	27	18	7.4	2.3
Summer	1	4,130 [1]	115 [1]	17 [1]	0.1 [1]	2.8 [2]	0.4 [2]	0.0 [2]
	2	2,476	595	208	38	24	8.4	1.5
	3	7,578	4,288	1,675	248	57	22	3.3
	4	1,196	203	78	8.4	17	6.5	0.7

TABLE 5.6.2.31

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – RACE ROCKS – 8,250 M³ SPILL (LOCATION G) (continued)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling): Area (or length) According to Sensitivity Factor (km^2)			Percent Area (or length) According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Fall	1	4,130 [1]	301 [1]	25 [1]	0.8 [1]	7.3 [2]	0.6 [2]	0.02 [2]
	2	2,476	642	250	46	26	10	1.8
	3	7,578	4,632	2,295	551	61	30	7.3
	4	1,196	234	73	14	20	6.1	1.2

Notes: 1 Total length of shoreline in the RSA, or length affected (km).

2 Expressed as % length of shoreline in that sensitivity class.

5.6.2.4 Location E: Arachne Reef

The Arachne Reef (Location E; Turn Point Special Operating Area) credible worst case and smaller spill scenarios are described in Section 5.4.4. This discussion begins with a summary of the modelled fate and behaviour of oil spilled as a result of this hypothetical scenario, specifically relating to the probability of surface oiling and shoreline contact. Potential effects on each of the four ecological indicators are then described. Additional information is contained in Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B). While not specifically considered here, the mitigation (spill response) measures that would be employed to minimize environmental effects - should such a spill occur - are described in Sections 5.4.4 and 5.7.3.

5.6.2.4.1 Fate and Behaviour

Probability of Surface Oiling

Stochastic modelling predictions for the Arachne Reef (Location E) site indicate that surface oiling would extend beyond the southern boundary of the RSA for both scenarios during the spring and summer seasons. Predicted high and very high probabilities of oiling were similar for each scenario and seasonal condition. Slight differences in the seasonal spill trajectories do exist and these primarily result from variations in predominant current or wind direction and speed. The highest probabilities for surface oiling were centered in the Salish Sea and the Juan de Fuca Strait, west of Stuart Island in the Gulf Islands (Figures 5.6.2.9 to 5.6.2.12).

Table 5.6.2.32 provides a summary of the predicted spatial extent of surface oiling (km^2) within the RSA for each spill volume and seasonal combination. Results are presented for each of three probability ranges (≥ 10 per cent, ≥50 per cent and ≥90 per cent). Figures depicting the release location and probability contours for seasonal stochastic surface oiling for both credible worst case and smaller spill scenarios are included in the Ecological Risk Assessment of Marine Transportation Spills Technical Report (Volume 8B, TR 8B-7).

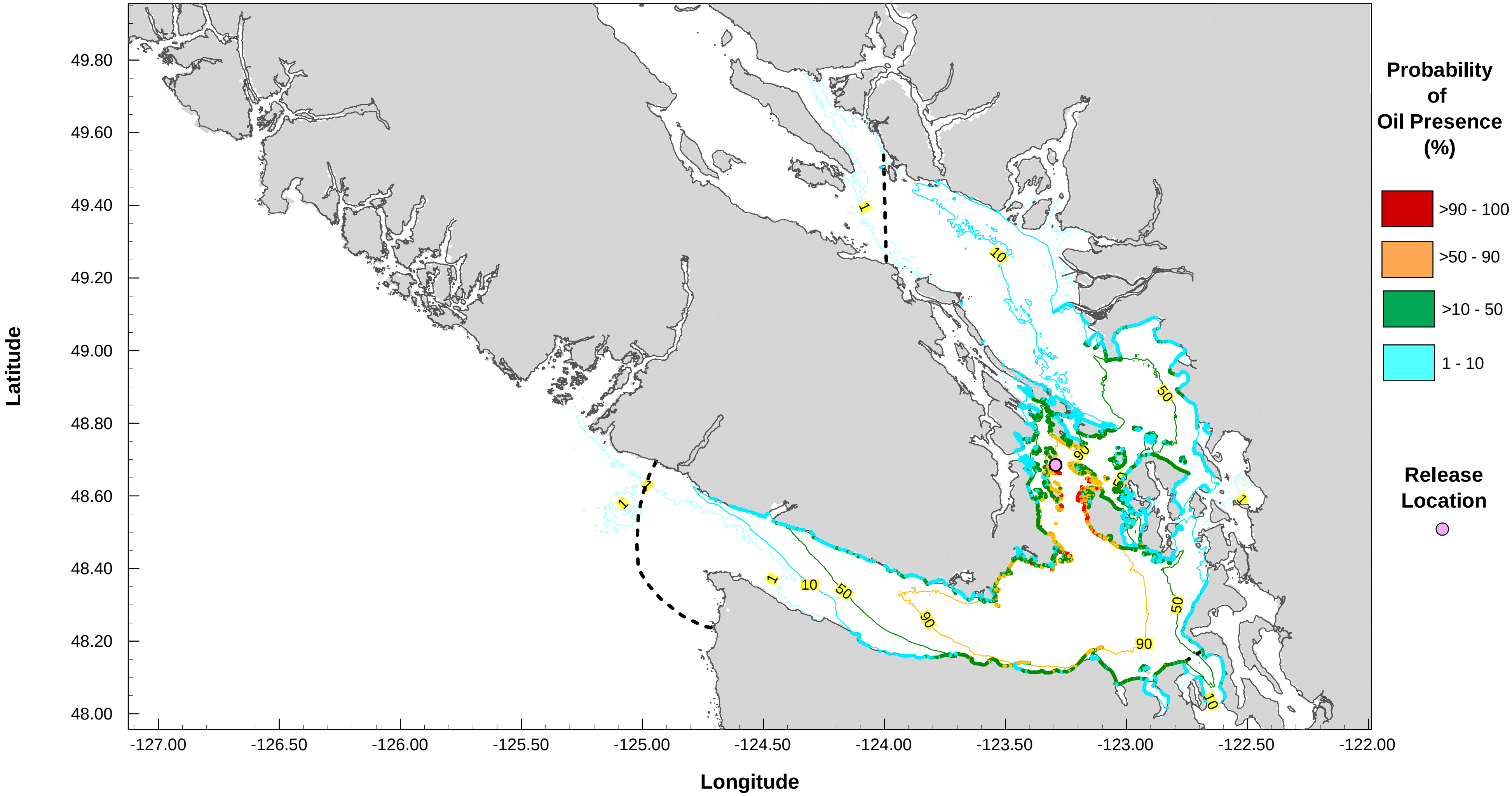
TABLE 5.6.2.32

AREA OF SURFACE OILING (BY PROBABILITY OF OILING) – ARACHNE REEF (LOCATION E)

Scenario	Spill Volume (m^3)	Seasonal Condition	Average Maximum Average Slick Area (km^2)	Total Affected Surface Area (km^2) by Probability of Oiling		
				≥ 10%	≥ 50%	≥ 90%
1	Credible Worst Case 16,500 m^3	Winter	400	6,710	4,156	2,145
		Spring	538	6,665	4,697	2,917
		Summer	480	7,137	4,683	2,386
		Fall	420	7,618	4,439	2,288
2	Smaller Spill Case 8,250 m^3	Winter	320	5,508	3,120	1,394
		Spring	430	5,793	3,815	2,317
		Summer	385	6,748	3,894	1,819
		Fall	320	6,375	3,563	1,723

It is important to correctly interpret the data presented in Table 5.6.2.32. The values presented under the column headed "Maximum Average Slick Area (km^2)" indicate, for the average simulated spill, the largest sea surface area occupied by spilled oil at any point in time during the modelling run. When oil is spilled, the surface area of the slick increases rapidly to a maximum value, and then decreases as oil evaporates and strands on shorelines. Because an oil slick is moved around by tides and winds and is not static, the total area affected by the moving oil is greater than the predicted slick surface area at any given time. Therefore the values presented under the columns headed "Total Affected Surface Area (km^2)" indicate the predicted probability that an individual modelling sea surface grid area contained surface oil during at least one point in time. The three columns indicate the total area of sea surface affected by oil over the length of the oil spill simulation, at probability levels of ≥ 10 per cent, ≥ 50 per cent and ≥ 90 per cent, respectively. Accordingly, the areas presented in these columns of Table 5.6.2.32 do not represent the surface area of a single, continuous oil slick.

Additional information on predicted spill fate and behaviour and mass balance at the Arachne Reel spill scenario site is provided in Section 5.7.2 and Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S9).



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 1 00:00 to March 31 23:00, for a total of 364 independent spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

STATUS
ISSUED FOR USE

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling Arachne Reef Stochastic Simulation 16,500 m^3 Spill - Winter Season

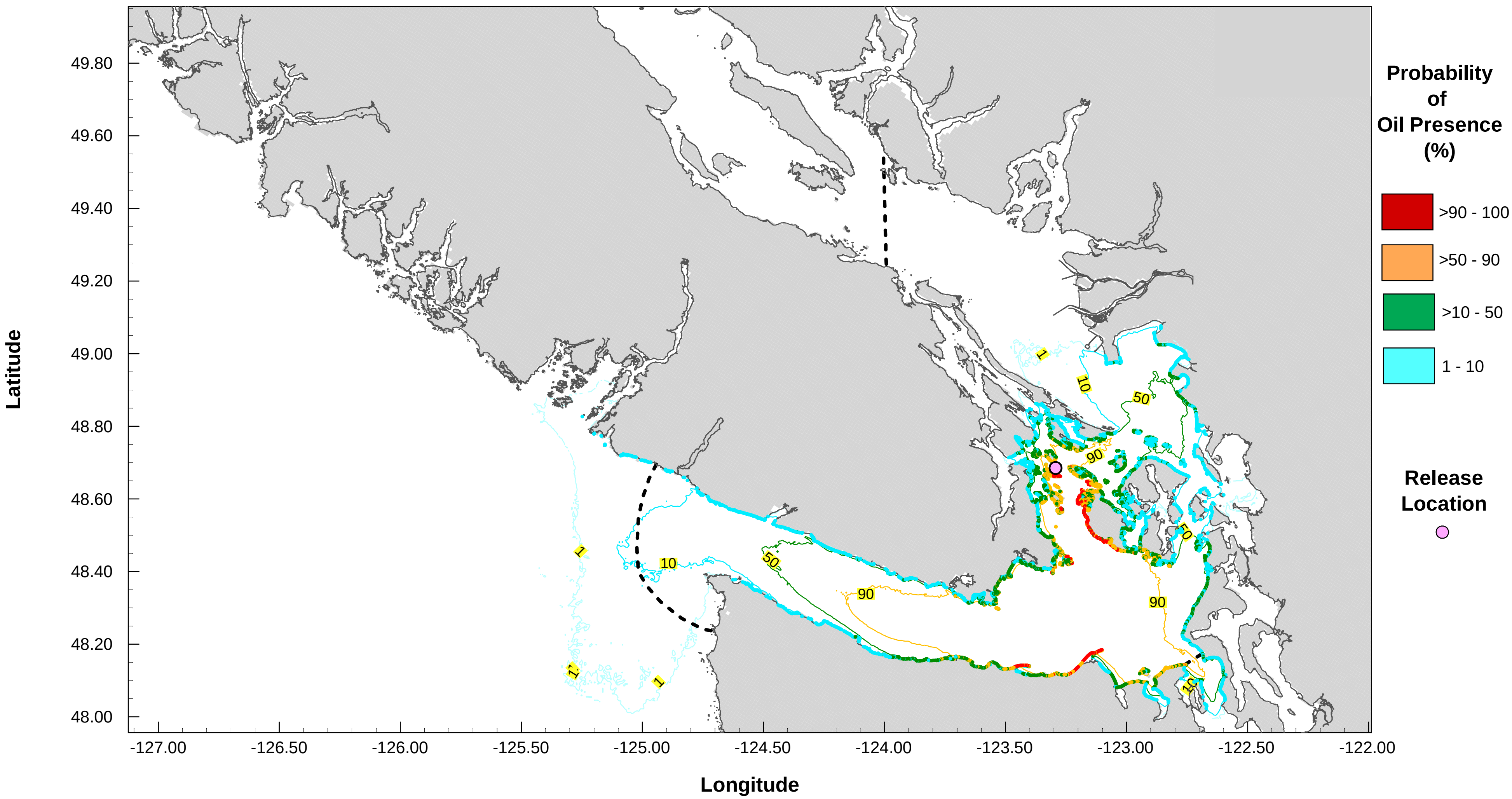
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 9, 2013

Figure 5.6.2-9

T:\TMEP\working\AH\02-SPILLCALC\503-Arachne_Reef_16500m3\Results_Winter\Tecplot\02-stochastic_map_lines_4Stantec.lay

09 Dec 2013 11:44:22



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 1 00:00 to June 30 23:00, for a total of 364 independent spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

STATUS
ISSUED FOR USE

CLIENT
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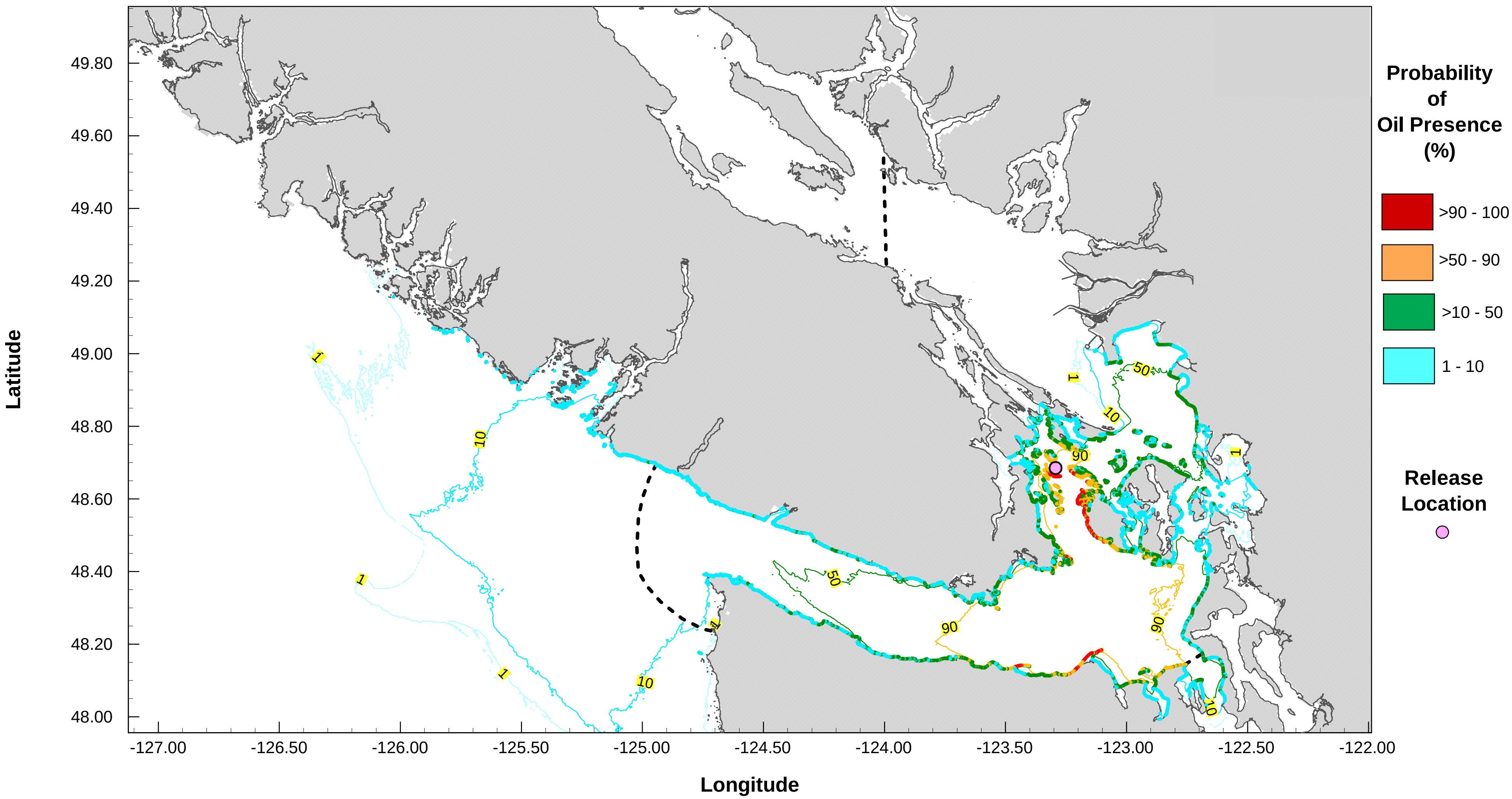
TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Arachne Reef Stochastic Simulation
16,500 m^3 Spill - Spring Season

PROJECT NO.	DWN	CKD	APVD	REV	Figure
V13203022	AH	JAS	MS	0	5.6.2-10
OFFICE	DATE				
EBA-VANC	December 9, 2013				

T:\TMEP\working\AH\02-SPILLCALC\503-Arachne_Reef_16500m3\Results_Spring\Tecplot\02-stochastic_map_lines_4Stantec.lay

09 Dec 2013 11:47:05



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 1 00:00 to September 30 23:00, for a total of 368 independent spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

STATUS
ISSUED FOR USE

CLIENT
TRANSMOUNTAIN

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TRANS MOUNTAIN OIL SPILL STUDY

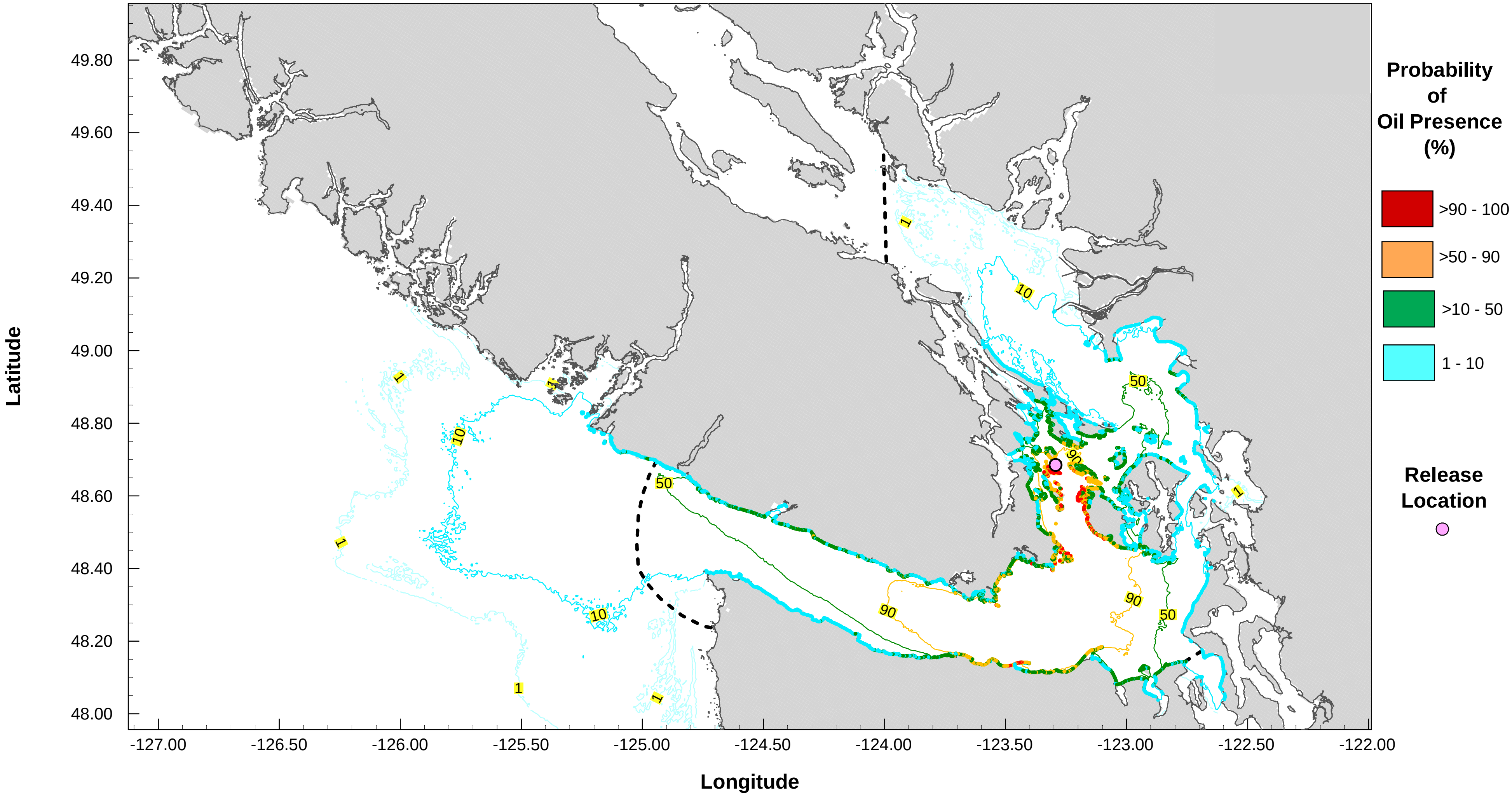
Probability of Oiling Arachne Reef Stochastic Simulation 16,500 m³ Spill - Summer Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0
OFFICE	DATE			
EBA-VANC	December 9, 2013			

Figure 5.6.2-11

T:\TMEP\working\AH\02-SPILLCALC\503-Arachne_Reef_16500m3\Results_Summer\Tecplot\02-stochastic_map_lines_4Stantec.lay

09 Dec 2013 11:50:28



NOTES

- Statistical results based on independent spills occuring every 6 hours from October 1 00:00 to December 31 23:00, for a total of 368 independent spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or on water surface.
- Tracking time for each spill was 15 days.

STATUS
ISSUED FOR USE

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Probability of Oiling
Arachne Reef Stochastic Simulation
16,500 m³ Spill - Fall Season

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	MS	0

OFFICE	DATE
EBA-VANC	December 9, 2013

Figure 5.6.2-12

T:\TMEP\working\AH\02-SPILLCALC\503-Arachne_Reef_16500m3\Results_Fall\Tecplot\02-stochastic_map_lines_4Stantec.lay

09 Dec 2013 11:54:36

Probability of Shoreline Contact

For the credible worst case spill (16,500 m^3), results indicate a high probability of oiling (≥50 per cent) of between 274 km and 300 km of shoreline, with greatest spatial extent of oiling occurring during the fall season. The smaller spill case predicts a ≥50 per cent probability of between 182 km and 207 km of shoreline becoming oiled with the greatest spatial extent being oiled during the spring season. Because oil that contacts shorelines tends to be retained on beach substrate, the average length of affected shoreline is more consistent with the total affected shoreline length at a ≥50 per cent than was the case for water surface swept by an oil slick.

Table 5.6.2.33 provides a summary of predicted shoreline contact within the RSA. The RSA includes approximately 4,130 km of shoreline. Based on this overall length, the modelling predicts a maximum shoreline length of 300 km or 7.3 per cent (credible worst case spill) and 207 km or 5 per cent (smaller spill) of the RSA with high to very high probability of being oiled. However, in this case the maximum average length of shoreline contact for a single oil spill ranges from 309 km (credible worst case spill) to 207 km (average smaller spill) representing 7.5 per cent and 5.4 per cent of the shoreline within the RSA respectively. The average length of shoreline contact for each seasonal condition is slightly larger than the ≥50 per cent probability value, but less than the length represented by the 10 per cent probability of shoreline contact.

TABLE 5.6.2.33

LENGTH OF SHORELINE CONTACT (BY PROBABILITY OF OILING) – ARACHNE REEF (LOCATION E)

Scenario	Spill Volume (m^3)	Seasonal Condition	Average length of Affected Shoreline (km)	Total Affected Shoreline Length (km) by Probability of Contact		
				≥ 10%	≥ 50%	≥ 90%
1	Credible Worst Case 16,500 m^3	Winter	292	836	283	38
		Spring	306	761	299	75
		Summer	309	783	274	55
		Fall	301	816	300	62
2	Smaller Spill Case 8,250 m^3	Winter	207	665	182	16
		Spring	223	594	207	34
		Summer	224	608	190	32
		Fall	211	616	196	27

5.6.2.4.2 Shoreline Habitats

Of the 4,130 km of shoreline habitat in the RSA, 51 per cent (2,125 km) comprises low and high exposure rock and sand, low exposure rip rap and wood bulkheads and high exposure sand and gravel assigned a low biological sensitivity (BSF 1). Shorelines including low exposure veneer over rock, low exposure pebble veneer over sand, high exposure cobble/boulder veneer over rock and high exposure cobble/boulder represent 27 per cent (1,120 km) of the coastline and have medium biological sensitivity (BSF 2). Approximately 15 per cent (619 km) of the RSA has a high biological sensitivity (BSF 3) and includes low exposure cobble/boulder veneer over sand. The highest biological sensitivity (BSF 4) is generally limited to more sheltered bays and represents less than 6.4 per cent (266 km) of the shoreline in the RSA. Summaries of shoreline contact probability for each shoreline sensitivity class for the Arachne Reef spill scenarios are provided in Table 5.6.2.34 and Table 5.6.2.35 for a 16,500 m^3 and an 8,250 m^3 spill, respectively.

Shorelines with a high to very high probability of oiling (≥ 50 per cent) represent 11 per cent or less of the available habitat belonging to that sensitivity class within the RSA. Results indicate that shorelines with the lowest biological sensitivity factor (BSF 1) have the highest overall probability of oiling under spring conditions where between 11 per cent and 7 per cent of the available habitat may be affected for credible worst case and smaller spills respectively.

Stochastic results indicate that shoreline types with highest biological sensitivity (BSF 4) have a very low probability of being oiled, with the greatest spatial extent of oiling predicted at 1.7 km for a 16,500 m^3 spill, and 0.4 km of affected shoreline predicted for an 8,250 m^3 spill.

For a 16,500 m^3 spill, areas with high probability of oiling (≥50 per cent) represent 10 per cent to 11 per cent of the total shoreline within the RSA assigned to BSF 1; 3.1 per cent to 3.5 per cent of the total RSA shoreline assigned to BSF 2; 3.9 per cent to 4.4 per cent of the total RSA shoreline assigned to BSF 3, and less than 1 per cent of the total RSA shoreline assigned to BSF 4.

TABLE 5.6.2.34

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – ARACHNE REEF – 16,500 M^3 SPILL (LOCATION E)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline contact Probabilities)					
			Affected Length According to Sensitivity Factor (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	2,125	544	217	33	26	10	1.6
	2	1,120	175	39	2.9	16	3.5	0.3
	3	619	111	26	1.7	18	4.2	0.3
	4	266	6.3	1.4	0.1	2.4	0.5	0.1
Spring	1	2,125	520	237	64	25	11	3.0
	2	1,120	149	35	6.8	13	3.1	0.6
	3	619	86	25	3.3	14	4.0	0.5
	4	266	6.8	1.6	0.3	2.6	0.6	0.1
Summer	1	2,125	531	216	44	25	10	2.1
	2	1,120	148	32	6.3	13	2.9	0.6
	3	619	99	24	3.7	16	3.9	0.6
	4	266	5.6	1.7	0.3	2.1	0.6	0.1
Fall	1	2,125	555	234	52	26	11	2.4
	2	1,120	156	37	5.1	14	3.3	0.5
	3	619	99	27	5.0	16	4.4	0.8
	4	266	6.3	1.1	0.3	2.4	0.4	0.1

For the 8,250 m^3 spill scenario, areas with high probability of oiling represent 6.7 per cent to 7.8 per cent of the total shoreline within the RSA assigned to BSF 1; 1.8 per cent to 2.0 per cent of the total RSA shoreline assigned to BSF 2; 2.8 per cent to 3.1 per cent of the total shoreline within the RSA assigned to BSF 3; and 0.1 per cent to 0.2 per cent of the total shoreline within the RSA assigned to BSF 4 (Table 5.6.2.35).

TABLE 5.6.2.35

SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE HABITATS – ARACHNE REEF – 8,250 M³ SPILL (LOCATION E)

Seasonal Condition	BSF	Length in RSA (km)	Affected Shoreline (by Shoreline contact Probabilities)					
			Affected Length According to Sensitivity Factor (km)			Percent Length According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	2,125	440	142	14	21	6.7	0.7
	2	1,120	135	22	1.3	12	2.0	0.1
	3	619	85	17.3	0.7	14	2.8	0.1
	4	266	4.4	0.3	0.0	1.6	0.1	0.0
Spring	1	2,125	421	166	30	20	7.8	1.4
	2	1,120	100	22	2.7	8.9	2.0	0.2
	3	619	67	18	1.4	11	3.0	0.2
	4	266	4.8	0.4	0.0	1.8	0.2	0.0
Summer	1	2,125	423	149	26	20	7.0	1.2
	2	1,120	105	22	2.5	9.4	1.9	0.2
	3	619	76	19	2.9	12	3.1	0.5
	4	266	3.8	0.4	0.0	1.4	0.2	0.0
Fall	1	2,125	425	157	24	20	7.4	1.1
	2	1,120	109	20	1.6	9.7	1.8	0.1
	3	619	78	20	1.5	13	3.1	0.2
	4	266	3.91	0.3	0.3	1.5	0.1	0.1

Stochastic results for both spill scenarios also indicate areas with a high to very high probability of oiling (≥50 per cent) from a spill at this location range from the southern Strait of Georgia, throughout the Gulf Islands and south into US waters and the Juan de Fuca Strait (Figure 5.6.2.9 to 5.6.2.12). A number of ecological and socially important sites are located in this area, and prompt and effective response in the event of a spill would help reduce effects on shoreline habitats.

5.6.2.4.3 Marine Fish Community

The RSA comprises approximately 11,111 km² of habitat for the marine fish community, and includes habitats for all four biological sensitivity rankings. Habitats classified as low sensitivity (BSF 1) to high sensitivity (BSF 3) are based on water depth, and are deemed to be exclusive with no overlap in area. However, BSF 4 (very high sensitivity) is based on habitats important areas for specific species (such as herring spawning areas), and can overlap areas with other sensitivity factors. Areas with a water depth of 30 m or more (BSF 1) represent slightly more than 78 per cent of the RSA (8,636 km²). Areas represented by BSF 2 (water depths between 10 and 30 m with medium sensitivity), and areas with BSF 3 (water depths less than 10 m with high sensitivity) represent approximately 12 per cent (1,280 km²) and 11 per cent (1,196 km²) of the RSA, respectively. Critical habitats for herring spawn, rockfish and crab combined as BSF 4 (very high sensitivity) overlap with other areas and represent approximately 35 per cent (3,934 km²) of the RSA.

The overlap between surface oiling probability and marine fish community sensitivity for the 16,500 m³ spill scenario is summarized in Table 5.6.2.36. For a 16,500 m³ spill, areas with a high to very high (≥50 per cent) probability of oiling represent: 40 per cent (under winter conditions) to 46 per cent (under spring and summer conditions) of the total area with water depths >30m (BSF 1); 35 per cent (under fall conditions) to 40 per cent (under summer conditions) of the total area with water depths between 10 m and 30m (BSF 2); 17 per cent (under winter conditions) to 20 per cent (under summer conditions) of the total area with depths <10 m (BSF 3); and 11 per cent (under fall conditions) to 13 per cent (under summer conditions) of the important habitat for herring spawn, rockfish and crab.

TABLE 5.6.2.36

SUMMARY OF EFFECTS ANALYSIS FOR THE MARINE FISH COMMUNITY – ARACHNE REEF – 16,500 M^3 SPILL (LOCATION E)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Surface Water Oiling Probabilities)					
			Area According to Sensitivity Factor (km^2)			Percent Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	8,636	5,372	3,482	1910	62	40	22
	2	1,280	745	475	186	58	37	14
	3	1,196	592	198	51	50	17	4.3
	4	3,934	850	464	206	22	12	5.2
Spring	1	8,636	5,382	3,979	2551	62	46	30
	2	1,280	758	492	268	59	39	21
	3	1,196	526	226	99	44	19	8.2
	4	3,934	714	461	269	18	12	6.8
Summer	1	8,636	5,675	3,930	2,082	66	46	24
	2	1,280	857	517	223	67	40	17
	3	1,196	605	235	82	51	20	6.8
	4	3,934	775	510	234	20	13	5.9
Fall	1	8,636	6,279	3,792	2,014	73	44	23
	2	1,280	784	446	197	61	35	15
	3	1,196	554	202	77	46	17	6.5
	4	3,934	766	434	222	20	11	5.7

For the 8,250 m^3 spill, areas with a high (≥50 per cent) probability of oiling represent: 31 per cent (under winter conditions) to 39 per cent (under summer conditions) of the total area with water depths >30 m (BSF 1); 24 per cent (under winter conditions) to 31 per cent (under summer conditions) of the total area with water depths between 10 m and 30 m (BSF 2); 10 per cent (under winter conditions) to 14 per cent (under summer conditions) of the total area with depths <10 m (BSF 3); and 8.7 per cent (under fall conditions) to 11 per cent (under summer conditions) of the important habitat for herring spawn, rockfish and crab (BSF 4). The overlap between surface oiling probability and marine fish community sensitivity for the 8,250 m^3 spill is summarized in Table 5.6.2.37.

TABLE 5.6.2.37

SUMMARY OF EFFECTS ANALYSIS FOR THE MARINE FISH COMMUNITY – ARACHNE REEF – 8,250 M^3 SPILL (LOCATION E)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Surface Water Oiling Probabilities) – Area According to Sensitivity Factor (km^2)			Affected Surface Water (by Surface Water Oiling Probabilities) – Percent Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	8,636	4,343	2,687	1,270	50	31	15
	2	1,280	698	310	94	55	24	7.4
	3	1,196	466	123	30	39	10	2.5
	4	3,934	734	360	176	19	9.2	4.5
Spring	1	8,636	4,652	3,276	2,030	54	38	24
	2	1,280	698	381	218	55	30	17
	3	1,196	443	158	70	37	13	5.8
	4	3,934	658	372	231	17	9.5	5.9
Summer	1	8,636	5,440	3,333	1,613	63	39	19
	2	1,280	767	399	157	60	31	12
	3	1,196	542	163	49	45	14	4.1
	4	3,934	719	448	187	18	11	4.8
Fall	1	8,636	5,270	3,068	1,554	61	36	18
	2	1,280	723	345	131	57	27	10
	3	1,196	382	149	37	32	13	3.1
	4	3,934	635	342	197	16	8.7	5.0

Of a total of 8,635 km^2 of deep water habitat (>30 m) in the RSA (BSF 1), between 40 per cent and 46 per cent of this habitat type within the RSA has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 31 per cent and 39 per cent has a high or very high probability of oil exposure from an 8,250 m^3 spill. While these ranges represent a comparatively large portion of this habitat type, it is very unlikely that fish in this habitat type would be harmed by exposure to oil due to water depth.

A predicted range of 35 per cent to 40 per cent of the total of 1,280 km^2 of intermediate depth habitat (< 30 to ≥ 10) in the RSA (BSF 2) has a high or very high (≥ 50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 24 per cent and 31 per cent of this medium sensitivity habitat in the RSA has a high or very high probability of oil exposure from an 8,250 m^3 spill. As with deep water habitat, given the water depth this sensitivity rank represents, it is also very unlikely that fish would be harmed by exposure to oil in this habitat type.

Between 17 per cent and 20 per cent of the RSA total of 1,196 km^2 of high sensitivity (BSF 3) shallow water habitat (≤10 m) has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill. Between 123 and 163 km^2 has a high or very high probability of oil exposure from an 8,250 m^3 spill, representing 10 per cent to 14 per cent of this habitat type within the RSA. In circumstances where oil is driven into this shallow water habitat by strong winds, there would be a greater potential for negative effects, including potential mortality of fish, crustaceans and shellfish.

Of a total of 3,934 km^2 of RSA habitat with a very high biological sensitivity (BSF 4), between 11 per cent and 13 per cent has a high or very high (≥50 per cent) probability of oil exposure from a 16,500 m^3 spill, and between 9 per cent and 11 per cent has a high or very high probability of oil exposure from an 8,250 m^3 spill. In areas where this very high-sensitivity habitat overlaps with shallow water areas, the potential for negative effects would be greater. Critical time periods for herring spawn would be in the spring, when exposure to PAH in the oil could cause developmental effects on fish embryos. As noted for shallow water habitat, the potential for negative effects would be greatest if the spill were to occur at a time when strong winds cause the oil to be driven into shallow water used as spawning or nursery areas for herring, rockfish or crab.

5.6.2.4.4 Marine Birds

For the Arachne Reef scenarios, marine birds and their habitats were assessed using two approaches. The first assumes that marine birds could generally be present anywhere within the RSA and the potential for shorebirds and other marine birds to be affected was estimated using the stochastic shoreline contact and surface contours, respectively. The second approach considers the potential for spilled crude oil to come into contact with known bird colonies and designated IBAs.

The habitat oiling probability for each marine bird sensitivity group is summarized in Tables 5.6.2.38 and 5.6.2.39 for 16,500 m^3 spills and 8,250 m^3 spills respectively. For shorebirds (BSF 1), potential exposure is determined by the length of shoreline predicted to have a high or very high probability of oiling. For a 16,500 m^3 spill, the seasonal variation in spatial extent represents between 274 km (6.6 per cent) and 300 km (7.3 per cent) of the available shoreline habitat within the RSA. For an 8,250 m^3 spill, the predicted length of affected shoreline is ranges between 182 km (4.4 per cent) and 207 km (5 per cent) of the available shoreline habitat. Shorebirds generally have low sensitivity to oiling when compared to other guilds, and it is unlikely that lightly oiled individuals would die as a result of low or moderate exposure. Heavily oiled individuals would probably die; however, and even lightly oiled individuals could transfer sufficient oil to eggs to cause egg mortality, if exposure occurred shortly before or during the period when eggs were being incubated. An oil spill that occurred near Arachne Reef would be physically close to the Sidney Channel IBA, where shorebirds are present. The threat to birds in this area is mitigated; however, by the generally low percentage of spilled crude oil that is predicted to strand on Vancouver, James and Coal Islands. Therefore, the environment effects on shorebirds of crude oil exposure from an accidental spill during marine transportation could be high locally, although medium to low effects levels are likely to be more prevalent.

For other marine birds (BSF 2, BSF 3, and BSF 4), potential exposure is based on surface water oiling. The seasonal variation in spatial extent for a 16,500 m^3 spill represents between 37 per cent and 42 per cent of the available habitat for these receptors, while for an 8,250 m^3 spill, between 28 per cent and 35 per cent of the RSA habitat is predicted to be affected. Therefore, there is a relatively high probability of exposure for aquatic birds in the event that an oil spill occurs. The environmental effects and effect magnitude of such exposure would depend upon the season (which would determine the numbers and types of birds present) as well as the actual level and duration of exposure, and the relative sensitivity of the exposed birds. Gulls and terns tend to have medium sensitivity, whereas ducks, cormorants, divers and alcids tend to have high to very high sensitivity. However, regardless of these factors, it is likely that seabirds would be exposed to oil, and would die as a result of that exposure, so that the effect magnitude would be high.

Stochastic modeling results were used to identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent) probability for spilled crude oil extending to known colony locations. The number of known colonies affected for each of the marine bird biological sensitivity rankings are summarized in Tables 5.6.2.40 and 5.6.2.41 for 16,500 m^3 spills and 8,250 m^3 spills respectively.

TABLE 5.6.2.38

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS – ARACHNE REEF – 16,500 M³ SPILL (LOCATION E)

<table>
<tr><th rowspan="3">Seasonal Condition</th><th rowspan="3">BSF</th><th rowspan="3">Length or Area in RSA (km or km²)</th><th colspan="6">Affected Surface Water
(by Shoreline or Surface Water Oiling Probabilities)</th></tr>
<tr><th colspan="3">Affected Length or Area According to Sensitivity Factor (km or km²)</th><th colspan="3">Percent Length or Area According to Sensitivity Factor (%)</th></tr>
<tr><th>Medium (≥ 10%)</th><th>High (≥ 50%)</th><th>Very High (≥ 90%)</th><th>Medium (≥ 10%)</th><th>High (≥ 50%)</th><th>Very High (≥ 90%)</th></tr>
<tr><td rowspan="4">Winter</td><td>1</td><td>4,130 [1]</td><td>836 [1]</td><td>283 [1]</td><td>38 [1]</td><td>20 [2]</td><td>6.9 [2]</td><td>0.9 [2]</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">6,710</td><td rowspan="3">4,156</td><td rowspan="3">2,145</td><td rowspan="3">60</td><td rowspan="3">37</td><td rowspan="3">19</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="4">Spring</td><td>1</td><td>4,130 [1]</td><td>761 [1]</td><td>299 [1]</td><td>75 [1]</td><td>18 [2]</td><td>7.2 [2]</td><td>1.8 [2]</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">6,665</td><td rowspan="3">4,698</td><td rowspan="3">2,917</td><td rowspan="3">60</td><td rowspan="3">42</td><td rowspan="3">26</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="4">Summer</td><td>1</td><td>4,130 [1]</td><td>783 [1]</td><td>274 [1]</td><td>55 [1]</td><td>19 [2]</td><td>6.6 [2]</td><td>1.3 [2]</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">7,137</td><td rowspan="3">4,683</td><td rowspan="3">2,386</td><td rowspan="3">64</td><td rowspan="3">42</td><td rowspan="3">21</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="4">Fall</td><td>1</td><td>4,130 [1]</td><td>816 [1]</td><td>300 [1]</td><td>62 [1]</td><td>20 [2]</td><td>7.3 [2]</td><td>1.5 [2]</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">7,618</td><td rowspan="3">4,439</td><td rowspan="3">2,288</td><td rowspan="3">69</td><td rowspan="3">40</td><td rowspan="3">21</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
</table>

Notes: 1 Total length of shoreline in the RSA, or length affected (km).
2 Expressed as % length of shoreline in that sensitivity class.

TABLE 5.6.2.39

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS – ARACHNE REEF – 8,250 M³ SPILL (LOCATION E)

<table>
<tr><th rowspan="3">Seasonal Condition</th><th rowspan="3">BSF</th><th rowspan="3">Length or Area in RSA (km or km²)</th><th colspan="6">Affected Surface Water
(by Shoreline or Surface Water Oiling Probabilities)</th></tr>
<tr><th colspan="3">Affected Length or Area According to Sensitivity Factor (km or km²)</th><th colspan="3">Percent Length or Area According to Sensitivity Factor (%)</th></tr>
<tr><th>Medium (≥ 10%)</th><th>High (≥ 50%)</th><th>Very High (≥ 90%)</th><th>Medium (≥ 10%)</th><th>High (≥ 50%)</th><th>Very High (≥ 90%)</th></tr>
<tr><td rowspan="4">Winter</td><td>1</td><td>4,130 [1]</td><td>665 [1]</td><td>182 [1]</td><td>16 [1]</td><td>16 [2]</td><td>4.4 [2]</td><td>0.4 [2]</td></tr>
<tr><td>2</td><td rowspan="3">11,112</td><td rowspan="3">5,508</td><td rowspan="3">3,120</td><td rowspan="3">1,394</td><td rowspan="3">50</td><td rowspan="3">28</td><td rowspan="3">13</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
</table>

TABLE 5.6.2.39

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS – ARACHNE REEF – 8,250 M³ SPILL (LOCATION E) (continued)

Seasonal Condition	BSF	Length or Area in RSA (km or km^2)	Affected Surface Water (by Shoreline or Surface Water Oiling Probabilities)					
			Affected Length or Area According to Sensitivity Factor (km or km^2)			Percent Length or Area According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	4,130 [1]	594 [1]	207 [1]	34 [1]	14 [2]	5.0 [2]	0.8 [2]
	2, 3, 4	11,112	5,793	3,815	2,317	52	34	21
Summer	1	4,130 [1]	608 [1]	190 [1]	32 [1]	15 [2]	4.6 [2]	0.8 [2]
	2, 3, 4	11,112	6,748	3,894	1,819	61	35	16
Fall	1	4,130 [1]	616 [1]	196 [1]	27 [1]	15 [2]	4.8 [2]	0.7 [2]
	2, 3, 4	11,112	6,375	3,563	1,723	57	32	16

Notes: 1 Total length of shoreline in the RSA, or length affected (km).
2 Expressed as % length of shoreline in that sensitivity class.

For gulls and terns (BSF 2), potential effects on colonies are determined by identifying the probability that crude oil will contact these areas if spilled during the spring or summer seasons. For a 16,500 m^3 spill, crude oil is predicted to have high to very high probability (≥50 per cent) to contact 21 of the 79 known colonies. For an 8,250 m^3 spill, this is predicted to represent 18 of the 79 known colonies.

For ducks and cormorants (BSF 3), potentially affected colonies and IBAs are determined by identifying contact of the spilled crude oil with these areas. For a 16,500 m^3 spill, crude oil is predicted to have high to very high probability (≥50 per cent) to contact 14 to 16 of the 40 known colonies. For an 8,250 m^3 spill, this is predicted to represent 10 or 11 of the 40 known colonies.

For auks and divers (BSF 4), the 16,500 m^3 spill, crude oil is predicted to have high to very high (≥50 per cent) probability to come in contact with 23 to 27 of the 55 known colonies. For the 8,250 m^3 spill, this is predicted to represent 17 of the 55 known colonies.

The presence of seabirds at colony locations is seasonal, and the overlap of oil with a colony location does not necessarily indicate that seabirds at nest sites will experience oiling, as their feeding grounds may be located at some distance from the nest site. However, the substantial overlap of high probability surface oiling areas with known seabird colony locations is predicted (whether representing gulls and terns, ducks and cormorants, or auks and divers), indicates that potential for negative effects, up to and including mortality of birds or oiling and mortality of eggs, is high for Arachne Reef scenarios.

TABLE 5.6.2.40

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRD COLONIES – ARACHNE REEF – 16,500 M³ SPILL (LOCATION E)

Seasonal Condition	BSF	Affected Marine Bird Colonies (by Surface Water Oiling Probabilities)		
		Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	---	---	---
	2	32 of 79 known colony sites affected.	21 of 79 known colony sites affected.	8 of 79 known colony sites affected.
	3	19 of 40 known colony sites affected.	14 of 40 known colony sites affected.	4 of 40 known colony sites affected.
	4	35 of 55 known colony sites affected.	23 of 55 known colony sites affected.	5 of 55 known colony sites affected.
Summer	1	---	---	---
	2	36 of 79 known colony sites affected.	21 of 79 known colony sites affected.	12 of 79 known colony sites affected.
	3	23 of 40 known colony sites affected.	16 of 40 known colony sites affected.	7 of 40 known colony sites affected.
	4	38 of 55 known colony sites affected.	27 of 55 known colony sites affected.	8 of 55 known colony sites affected.

TABLE 5.6.2.41

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRD COLONIES – ARACHNE REEF – 8,250 M³ SPILL (LOCATION E)

Seasonal Condition	BSF	Affected Marine Bird Colonies (by Surface Water Oiling Probabilities)		
		Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Spring	1	---	---	---
	2	28 of 79 known colony sites affected.	18 of 79 known colony sites affected.	5 of 79 known colony sites affected.
	3	18 of 40 known colony sites affected.	11 of 40 known colony sites affected.	2 of 40 known colony sites affected.
	4	31 of 55 known colony sites affected.	17 of 55 known colony sites affected.	1 of 55 known colony sites affected.
Summer	1	---	---	---
	2	32 of 79 known colony sites affected.	18 of 79 known colony sites affected.	11 of 79 known colony sites affected.
	3	21 of 40 known colony sites affected.	10 of 40 known colony sites affected.	4 of 40 known colony sites affected.
	4	36 of 55 known colony sites affected.	17 of 55 known colony sites affected.	4 of 55 known colony sites affected.

Stochastic modeling results were used to identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent) probability for spilled crude oil extending to IBA locations. The number of IBAs affected are summarized in Tables 5.6.2.42 and 5.6.2.43 for 16,500 m^3 spills and 8,250 m^3 spills respectively.

There are 16 IBAs that have ≥10 per cent probability of being affected by spilled crude oil, in the event of a credible worst case or smaller oil spill at the Arachne Reef hypothetical spill location.

Of these, 9 and 5, respectively, have a high or very high probability (≥50 per cent) of oil exposure in the event of the credible worst case or smaller spill. The utilization of IBAs by seabirds and other birds is seasonal, but most IBAs are used by one or more species in any season. It is likely that oil exposure at an IBA would result in oiling of birds, with a high potential for mortality of adults, juveniles, and/or eggs in the event of oil being transferred from plumage to incubating eggs. Given the high potential for negative effects on seabirds at IBAs, the effect magnitude is high.

TABLE 5.6.2.42

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – ARACHNE REEF – 16,500 M³ SPILL (LOCATION E)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC015	≥ 50%	≥ 10%	≥ 10%	≥ 10%
BC017	≥ 10%	≥ 10%	≥ 10%	≥ 10%
BC025	≥ 10%	---	---	---
BC045	≥ 90%	≥ 90%	≥ 90%	≥ 90%
BC047	≥ 90%	≥ 90%	≥ 90%	≥ 90%
BC052	---	---	---	≥ 10%
BC073	≥ 10%	≥ 10%	≥ 10%	≥ 50%
BC097	---	≥ 10%	≥ 10%	≥ 50%
United States				
USWA 277	≥ 10%	≥ 10%	≥ 10%	≥ 10%
USWA 282	≥ 10%	≥ 10%	≥ 10%	≥ 10%
USWA 288	≥ 50%	≥ 90%	≥ 90%	≥ 50%
USWA 3289	---	≥ 10%	≥ 10%	---
USWA 3347	---	---	≥ 10%	---
USWA 3348	≥ 90%	≥ 90%	≥ 90%	≥ 90%
USWA 3351	≥ 90%	≥ 90%	≥ 90%	≥ 90%
USWA 3786	≥ 50%	≥ 50%	≥ 50%	≥ 50%

TABLE 5.6.2.43

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – ARACHNE REEF – 8,250 M³ SPILL (LOCATIONE)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC015	≥ 10%	≥ 10%	≥ 10%	≥ 10%
BC017	≥ 10%	≥ 10%	≥ 10%	≥ 10%

TABLE 5.6.2.43

SUMMARY OF EFFECTS ANALYSIS FOR IMPORTANT BIRD AREAS – ARACHNE REEF – 8,250 M³ SPILL (LOCATIONE) (continued)

IBA	Highest Oiling Probability (by seasonal condition)			
	Winter	Spring	Summer	Fall
Canada				
BC045	≥ 90%	≥ 90%	≥ 90%	≥ 90%
BC047	≥ 90%	≥ 90%	≥ 90%	≥ 90%
BC073	---	---	≥ 10%	≥ 10%
BC097	---	---	≥ 10%	≥ 10%
United States				
USWA 277	≥ 10%	≥ 10%	≥ 10%	---
USWA 282	≥ 10%	≥ 10%	≥ 10%	≥ 10%
USWA 288	≥ 50%	≥ 90%	≥ 90%	≥ 10%
USWA 3289	---	≥ 10%	≥ 10%	---
USWA 3347	---	---	≥ 10%	---
USWA 3348	≥ 50%	≥ 90%	≥ 90%	≥ 90%
USWA 3351	≥ 50%	≥ 90%	≥ 90%	≥ 90%
USWA 3786	≥ 50%	≥ 50%	≥ 10%	≥ 10%

5.6.2.4.5 Marine Mammals

Stochastic modelling results identify areas of medium (≥10 per cent), high (≥50 per cent), and very high (≥90 per cent), exposure probability for each class of mammals. The overlap between habitat oiling probabilities for each mammal sensitivity class is summarized in Tables 5.6.2.44 and 5.6.2.45 for 16,500 m^3 spills and 8,250 m^3 spills respectively.

For terrestrial mammals (*e.g.,* bears, moose, raccoon, etc., BSF 1), potential exposure is determined by the length of shoreline habitat predicted to have a high or very high probability of oiling. For a 16,500 m^3 spill, the seasonal variation in spatial extent represents between 274 km (6.6 per cent) and 300 km (7.3 per cent) of the available shoreline habitat; this drops to between 182 km (4.4 per cent) and 207 km (5 per cent) for an 8,250 m^3 spill. These animals have generally low sensitivity to oiling, and it is unlikely that oiled individuals would die as a result of exposure. It is very unlikely that such exposure would result in a measurable effect at the population level.

For pinnipeds such as seals and sea lions (BSF 2), potential exposure is based on habitat having a water depth of ≤30m. The seasonal variation in likely spatial extent for a 16,500 m^3 spill affecting pinniped habitat represents 26 per cent to 30 per cent of the available habitat, whereas for an 8,250 m^3 spill, between 18 per cent and 23 per cent of the habitat could be affected. Therefore, there is a relatively high probability of exposure for seals and sea lions in the event of an accidental oil spill. While some level of negative effect would be expected for animals exposed to oil, the effects would not likely be lethal, except in the case of weaker animals such as pups or older and diseased animals.

TABLE 5.6.2.44

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – ARACHNE REEF – 16,500 M^3 SPILL (LOCATION E)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or length) According to Sensitivity Factor (km^2)			Percent Area (or length) According to Sensitivity Factor (%)		
			Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)	Medium (≥ 10%)	High (≥ 50%)	Very High (≥ 90%)
Winter	1	4,130 [1]	836 [1]	283 [1]	38 [1]	20 [2]	6.9 [2]	0.92 [2]
	2	2,476	1,338	674	235	54	27	9.5
	3	7,578	5,850	4,013	2,076	77	53	27
	4	1,196	592	199	51	50	17	4.3
Spring	1	4,130 [1]	761 [1]	299 [1]	75 [1]	18 [2]	7.2 [2]	1.8 [2]
	2	2,476	1,283	719	367	52	29	15
	3	7,578	6,214	4550	2,850	82	60	38
	4	1,196	526	226	99	44	19	8.2
Summer	1	4,130 [1]	783 [2]	274 [1]	55 [1]	19 [2]	6.6 [2]	1.3 [2]
	2	2,476	1,462	752	305	59	30	12
	3	7,578	6,455	4,518	2,309	85	60	30
	4	1,196	605	235	82	51	20	6.8
Fall	1	4,130 [1]	816 [1]	300 [1]	62 [1]	20 [2]	7.3 [2]	1.5 [2]
	2	2,476	1,339	647	275	54	26	11
	3	7,578	6,654	4,273	2,191	88	56	29
	4	1,196	554	202	77	46	17	6.5

Notes: 1 Total length of shoreline in the RSA, or length affected (km).

2 Expressed as % length of shoreline in that sensitivity class.

TABLE 5.6.2.45

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – ARACHNE REEF – 8,250 M^3 SPILL (LOCATION E)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or Length) According to Sensitivity Factor (km^2)			Percent Area (or Length) According to Sensitivity Factor (%)		
			Medium (≥10%)	High (≥50%)	Very High (≥90%)	Medium (≥10%)	High (≥50%)	Very High (≥90%)
Winter	1	4,130 [1]	665 [1]	182 [1]	16 [1]	16 [2]	4.4 [2]	0.4 [2]
	2	2,476	1,165	434	124	47	18	5.0
	3	7,578	5,236	2,996	1,344	69	40	18
	4	1,196	467	123	30	39	10	2.5
Spring	1	4,130 [1]	594 [1]	207 [1]	34 [1]	14 [2]	5 [2]	0.8 [2]
	2	2,476	1,140	538	288	46	22	12
	3	7,578	5,543	3,678	2,260	73	49	30
	4	1,196	443	158	70	37	13	5.8
Summer	1	4,130 [1]	608 [1]	190 [1]	32 [1]	15 [2]	4.6 [2]	0.8 [2]
	2	2,476	1,309	561	206	53	23	8.3
	3	7,578	6,275	3,740	1,761	83	49	23
	4	1,196	542	163	49	45	14	4.1

TABLE 5.6.2.45

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS – ARACHNE REEF – 8,250 M^3 SPILL (LOCATION E) (continued)

Seasonal Condition	BSF	Area in RSA (km^2)	Affected Surface Water (by Probability of Oiling)					
			Area (or Length) According to Sensitivity Factor (km^2)			Percent Area (or Length) According to Sensitivity Factor (%)		
			Medium (≥10%)	High (≥50%)	Very High (≥90%)	Medium (≥10%)	High (≥50%)	Very High (≥90%)
Fall	1	4,130 [1]	616[1]	196 [1]	27 [1]	15 [2]	4.8 [2]	0.7 [2]
	2	2,476	1,105	494	169	45	20	6.8
	3	7,578	6,103	3,407	1,644	81	45	22
	4	1,196	382	149	38	32	12	3.1

Notes: 1 Total length of shoreline in the RSA, or length affected (km).

2 Expressed as % length of shoreline in that sensitivity class.

For whales such as porpoises, or the humpback and southern resident killer whale (BSF 3), potential exposure is based on habitat having a water depth of ≥10m. For a 16,500 m^3 spill, the seasonal variation in the predicted area of affected habitat ranges between 53 per cent and 60 per cent of the RSA. The predictions for an 8,250 m^3 spill range between 40 and 49 per cent of the available habitat. Therefore, there is a relatively high probability of exposure for whales should an oil spill occur at this location. Some level of negative effect would be expected for animals exposed to oil, but the effects would not likely be lethal, except in the case of weaker animals such as calves or older and diseased animals, or animals that were exposed to heavy surface oiling and inhalation of vapours from fresh oil, as could occur in the immediate vicinity of the spill location.

For furred marine mammals such as otters (BSF 4), potential exposure is based on the available habitat represented by water depths along the coast of ≤10 m. The seasonal variation in spatial extent for a 16,500 m^3 spill for this receptor type represents between 17 per cent and 20 per cent of the available habitat, while for an 8,250 m^3 spill, between 10 per cent and 14 per cent of the habitat is predicted to be affected. Therefore there is a relatively high probability of exposure for some of otters along the marine transportation route, in the event of an oil spill. Some level of negative effect would be expected for animals exposed to oil. Exposure during the winter season would be more stressful than exposure during the summer, but in either case, the combination of hypothermia and damage to the gastro-intestinal system caused by oil ingested through grooming the fur would have the potential to cause death.

5.6.2.5 Summary of Potential Ecological Effects and Recovery

5.6.2.5.1 Shoreline Habitat

The ERA indicates that while shoreline habitats would be affected by spilled oil along the marine transportation route, the affected areas generally represent a small fraction of total amount of shoreline belonging to each shoreline sensitivity class within the RSA.

In the case of a 16,500 m^3 spill at the Strait of Georgia (Location D), Arachne Reef (Location E) and Race Rocks (Location G) representative scenario sites, the maximum spatial extent of affected shorelines with a high to very high probability of oiling ranges from: 3.4 per cent to 15 per cent of the available low sensitivity habitat (BSF 1); 1.3 per cent to 8.7 per cent of available habitat RSA for medium sensitivity BSF 2; 0.2 per cent to 6.6 per cent of available habitat for high sensitivity BSF 3; and 0.5 per cent to 1.6 per cent of available highly sensitive habitat. Comparable ranges for an 8,250 m^3 spill are: 1.1 per cent to 8.2 per cent of the available habitat for BSF 1; 0.9 per cent to 4.5 per cent of available habitat for BSF 2; 0.1 per cent to 4.1 per cent of available habitat BSF 3; and 0.0 per cent to 0.2 per cent of available very high sensitivity habitat (BSF 4).

Very little of the potentially affected shoreline habitat is of a type that would tend to sequester spilled oil (*e.g.*, deep gravel or cobble-boulder substrates that are not underlain by fine substrates that will remain saturated at low tide). Although salt marsh and eelgrass habitats are considered to be highly sensitive to oil exposure, these habitats have a very low probability of oiling for these representative scenarios. Shoreline classes with low exposure cobble/boulder veneer over sand would be most affected, but shorelines of this type are more readily restored if oiled, and would recover in a relatively short period of time.

Therefore, it is expected that shoreline clean-up and assessment techniques (SCAT) would be applied to the spilled oil that reached the shore, and that most of this oil would be recovered. Biological recovery from spilled oil, where shoreline communities were contacted by and harmed by the oil or by subsequent clean-up efforts, would be expected to lead to recovery of the affected habitat within two to five years. By comparison, whether cleaned or not, intertidal communities had recovered within five years after the EVOS.

5.6.2.5.2 Marine Fish Community

The ERA indicates that fish habitat would be affected by spilled oil along the marine transportation route for all scenarios and seasonal conditions. The areas with the greatest spatial extent with a high to very probability of oiling can represent a substantial fraction of total amount of each habitat type with up to 46 per cent of the habitat affected in comparison to the overall habitat present within the RSA. Not all fish habitat; however, is of equal sensitivity to oiling.

In the case of a 16,500 m^3 spill at the Strait of Georgia (Location D), Arachne Reef (Location E) and Race Rocks (Location G) sites, the maximum spatial extent of habitat with a high to very high probability of oiling ranges from: 36 per cent to 46 per cent of the available RSA low sensitivity habitat (BSF 1); 26 per cent to 42 per cent of available habitat for medium sensitivity BSF 2; 13 per cent to 30 per cent of available habitat for BSF 3; and 4 per cent to 16 per cent of very high sensitivity habitat within the RSA (BSF 4). For an 8,250 m^3 spill, comparable ranges are: 29 per cent to 39 per cent for BSF 1; 22 per cent to 29 per cent for BSF 2; 9.8 per cent to 22 per cent for BSF 3; and 2.8 per cent to 13 per cent of the available RSA habitat for very high sensitivity BSF 4.

The potential for negative effects to the marine fish community is generally low as a result of the low potential for dissolved hydrocarbon concentrations in water to reach thresholds that would cause mortality of fish or other aquatic life. The representative crude oil has a relatively high viscosity, and this increases with weathering, so that the formation of oil droplets in the water column, that would enhance the dissolution of more toxic hydrocarbon constituents such as BTEX and light PAHs requires high wind speeds and rough water conditions, and even then this affects only the surface water layer in deep water environments. The potential for dissolved hydrocarbon concentrations to reach toxic levels would be greatest in shallow water areas, under weather conditions that caused spilled oil to be driven into shallow areas with wave action, leading to localized high concentrations of dissolved hydrocarbons in the water. This could result in the death of fish and invertebrates as a result of narcosis, or could cause abnormalities in developing embryos if spawn was present. Effects of this type were seen locally following the EVOS, but large-scale effects at the population level were not observed.

Due to the generally low potential for the spill scenarios to cause wide-spread mortality of fish, recovery of the marine fish community would be expected to be rapid. Even under a worst-case outcome event where localized fish kills might be observed, it is expected that the lost biological productivity would be compensated for by natural processes within one to two years. By comparison, effects of the EVOS on marine fish populations, were either not significant to begin with, or recovery occurred within one or two years at most.

5.6.2.5.3 Marine Birds

Ecological risk assessment findings indicate that marine bird habitat would be affected by spilled oil along the marine transportation route for all scenarios and seasonal conditions. The areas with the greatest spatial extent with a high to very probability of oiling can represent a substantial proportion of each sensitivity class, with up to 42 per cent of the habitat affected in comparison to the overall habitat present within the RSA.

In the case of a 16,500 m^3 spill at the Strait of Georgia (Location D), Arachne Reef (Location E) and Race Rocks (Location G) sites, the maximum spatial extent of habitat with a high to very high probability of oiling ranges from: 0.5 per cent to 11 per cent of available shorebird habitat in the RSA (BSF 1); and from 23 per cent to 42 per cent of the available habitat in the RSA for gulls and terns, ducks and cormorants, or auks and divers (BSF 2, 3, and 4, respectively). For an 8,250 m^3 spill the maximum spatial extent of impacted habitat ranges from 0.4 to 6 per cent of the available RSA habitat for shorebirds; and from 15 per cent to 35 per cent of the available habitat in the RSA for the other seabirds.

There is high potential for oiling of marine bird habitat following an accidental spill of crude oil along the marine transportation route. The extent to which this potential could be realized would depend upon the size of the oil spill, the efficacy of measures intended to promptly contain and recover spilled oil, the ability of oil spill responders to capture and treat oiled animals, and the intrinsic sensitivity of the animals to exposure. Shorebirds have generally low sensitivity to oiling, and it is noteworthy that the Fraser River Delta is not predicted to be highly exposed to spilled crude oil in the event of a marine transportation accident. It is likely; however, that some shorebirds would be sufficiently oiled to result in mortality of adult or juvenile birds, or that eggs would become oiled as a result of oil in the feathers of the parent birds during the breeding season, resulting in embryo mortality.

There is also a high probability of exposure for other seabirds (including but not limited to gulls and terns, ducks and cormorants, and auks and divers) in the event of a crude oil spill. Some level of negative effect would be expected for birds exposed to crude oil, up to and including death as a result of hypothermia, loss of buoyancy, and/or oil ingestion. While the actual effects would depend upon the season, as well as other factors related to the oil spill and response activities, an effect magnitude rating of high would result under most if not all combinations of exposure scenarios and seabird sensitivity classes for the credible worst case and smaller spills.

Oil exposure could also extend to affect a large number of known breeding or colony sites for seabirds, as well as a large number of IBAs in the Strait of Georgia, Gulf Islands, and Juan de Fuca Strait region. This exposure is also considered likely to result in mortality of seabirds associated with the nesting sites during the spring and summer, and the IBAs at any time of the year. An effect magnitude rating of high would result.

Recovery of marine bird populations following the EVOS was generally rapid and uncomplicated (see Section 5.6.2.1). A major factor causing the EVOS Trustee Council to identify certain bird populations as “recovering” rather than “recovered” has been evidence of low-level exposure to hydrocarbons based on measured metabolic response linked to oil exposure (cytochrome P450 induction). While this measure can identify exposure, it does not identify effects of hydrocarbon exposure on individuals or at a population level. It is reasonable to expect marine bird recovery at a population level within 2 to 5 years following a large oil spill. Populations of alcid birds, which are considered to be most sensitive to spilled oil, could take longer to recover, on the order of 10 years or longer.

5.6.2.5.4 Marine Mammals

The ERA indicates that mammal habitat would be affected by spilled oil along the marine transportation route for all scenarios and seasonal conditions. The areas with a high to very probability of oiling can represent a substantial fraction of total amount of each habitat type with up to 60 per cent of the habitat affected in comparison to the overall habitat present within the RSA.

In the case of a 16,500 m^3 spill at the Strait of Georgia (Location D), Arachne Reef (Location E) and Race Rocks (Location G) sites, the maximum spatial extent of habitat with a high to very high probability of oiling ranges from: 2.2 per cent to 11 per cent of the available RSF habitat for BSF 1; 20 per cent to 36 per cent of available medium sensitivity habitat in the RSA for BSF 2; 42 per cent to 60 per cent of available high sensitivity habitat for BSF 3; and 13 per cent to 30 per cent of very high sensitivity habitat in the RSA (BSF 4). Comparable ranges for an 8,250 m^3 spill are: the maximum spatial extent of impacted habitat with a high to very high probability of oiling for 0.8 to 6 per cent for BSF 1; 16 per cent to 26 per cent for BSF 2; 27 per cent to 39 per cent for BSF 3; and 9.8 to 22 per cent of very high sensitivity available habitat in the RSA (BSF 4).

There is clearly potential for oiling of marine mammal habitat following an accidental spill of oil along the marine transportation route. The degree to which this potential is realized would depend upon the size of the oil spill, the efficacy of measures intended to promptly contain and recover spilled oil, the ability of oil spill responders to capture and treat oiled animals, and the intrinsic sensitivity of the animals to exposure. Animals that are essentially terrestrial species that could be exposed to oil accumulated along shorelines have generally low sensitivity to oiling, and it is unlikely that oiled individuals would die as a result of exposure. It is very unlikely that such exposure would result in a measurable effect at the population level.

While there is a relatively high probability of exposure for seals and sea lions (BSF 2) in the event of an oil spill, and some level of negative effect would be expected for animals exposed to oil, the effects would not likely be lethal, except in the case of weaker animals such as pups or older and diseased animals. There is also a high probability of exposure for whales (BSF 3). Again, while some level of negative effect would be expected for animals exposed to oil, the effects would not likely be lethal, except in the case of weaker animals such as calves or older and diseased animals, or animals that were exposed to heavy surface oiling and inhalation of vapours from fresh oil, as could occur in the immediate vicinity of the spill location. The killer whales that appear to have suffered the greatest level of negative effects following the EVOS belonged to a group that was exposed to fresh oil at the spill site, and although the fate of these animals remains uncertain, it seems likely that direct exposure, including inhalation of vapours, may have resulted in the death of some of these animals.

For mammals with very high sensitivity to oil exposure such as otters (BSF 4) there is a medium probability of exposure along the marine transportation route in the event of an accidental oil spill. Some level of negative effect would be expected for animals exposed to oil and exposure during the winter season would be more stressful than exposure during the summer, but in either case, the combination of hypothermia and damage to the gastro-intestinal system caused by oil ingested through grooming the fur would have the potential to cause death. Many sea otters died following the EVOS, and the sea otter population has been slow to recover, although river otters were deemed to have recovered within 10 years after the spill.

5.6.2.6 HHRA for Location E: Arachne Reef

Aboriginal communities along the marine shipping lanes, the Vancouver Island Health Authority (VIHA) and the Coast Guard have expressed an interest in understanding the potential human health effects that could result following a spill in a marine environment. This section summarizes findings from a qualitative HHRA completed for marine transportation spills (Qualitative Human Health Risk Assessment of Marine Terminal Transportation Spills Technical Report, Volume 8B, TR 8B-9).

The assessment of the potential human health impacts associated with accidents and malfunctions centered on a series of hypothetical spill scenarios, including a scenario involving a spill associated with a tanker collision at Arachne Reef in the Turn Point SOA (Location E). Details surrounding the spill scenario and the basis of its selection are provided in Section 5.4.4.

When discussing human health effects, the potential effects associated with short-term and long-term exposure to hydrocarbons are referred to as acute and chronic effects, respectively. The HHRA focused on potential health effects that could result from short-term inhalation exposure to chemical vapours released from oil released at the Arachne Reef (Location E) site. Its objective was to establish the overall likelihood, nature and severity of effects as part of a screening-level exercise. However, the approach followed differs from that adopted for the screening-level human health risk assessment of the routine pipeline and facilities operations (see Volume 5D). Routine operations consist of planned activities for which chemical exposures and any associated health risks can be anticipated and assessed on the basis of known or reasonably well-defined exposure scenarios. In contrast, spills represent low probability, unpredictable events for which the exposures and risks must be assumed for strictly hypothetical scenarios. Accordingly, rather than following a conventional risk assessment paradigm with an emphasis on quantifying the potential risks involved, the present assessment was designed to provide a preliminary indication of the prospect for people's health to be affected by a spill, together with an indication of the types of health effects, if any, that might be experienced. Results of this qualitative assessment determine whether or not a more comprehensive assessment is needed to provide further evidence to define the nature and extent of any health effects that people might experience and mitigation measures that could be applied to reduce risks to human health.

The HHRA considered the likelihood and extent to which people's health could potentially be affected by the Arachne Reef hypothetical spill scenarios based on the following factors:

- the volume of oil spilled;
- the types of chemicals contained in the spilled oil to which people could be exposed (see Section 5.4.2);

- the extent to which people could be exposed based on predictions of how the spilled oil and the constituent chemicals would likely disperse in the environment considering time of year, weather patterns, currents and tides, wave action, and the way that spilled oil would partition between air and water over time (see Section 5.4.4);
- the manner and pathways by which people might be exposed to the chemicals;
- the emergency response and other mitigation measures that will be taken to limit people's exposure to the chemicals in the event of a spill (see Section 5.7.3 and 5.5);
- the types of health effects known to be caused by the chemicals as a function of the type, amount and duration of exposure;
- the responsiveness and sensitivity of the people who could potentially be exposed to the chemicals; and
- the types of health effects that have been reported to occur among people following oil spill incidents.

For the Arachne Reef scenario, the HHRA focused on the chemicals that could be released from the surface of the spilled oil though volatilization, resulting in their presence in the air as vapours at or near the source, which would then disperse in a downwind direction. These chemicals would consist principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{12}), including both aliphatic and aromatic constituents. The latter constituents include BTEX as well as PAHs. Trace amounts of sulphur-containing chemicals and longer-chain, semi-volatile hydrocarbons (C_{13} to C_{21}) also could be present. These chemicals represented the COPC that were examined as part of the assessment.

The assessment focused on the potential health effects that could occur among the general public, including people living near the spill location on islands in the channel as well as other individuals in the area (*i.e.*, fishers who might be in the area at the time of the incident or recreational users). It is expected that first responders and other response personnel arriving at the scene will be trained in emergency preparedness and response, will be equipped with appropriate personal protective equipment (PPE), will be oriented to the situation, and will take appropriate precautions to avoid physical contact with the spilled oil itself as well as to limit exposure to any chemical vapours that might be present. These measures will act to limit any potential health effects that could occur among the responders.

The Arachne Reef scenario HHRA focused on the potential human health effects that could result from inhalation exposure to chemical vapours released during the course of the incident, with an emphasis on exposures that might be received on a short-term or "acute" basis. The decision to focus the assessment on this particular type of exposure was based, in part, on the following:

- Concern over the potential health effects that could result if an accidental spill was to occur in a marine environment were expressed by stakeholders at various community meetings, including the potential health effects that might result from inhaling chemical vapours released during the course of the incident. These stakeholders included local island residents and Aboriginal communities. In addition, the VIHA was interested in understanding the potential human health effects that could occur from chemical exposures during a spill.

- In the event of a spill, the WCMRC would be responsible for carrying out spill response activities within the vicinity of Arachne Reef (Location E) as it falls within the WCMRC's Primary Area of Response (PAR) for the Port of Vancouver (see Figure 5.5.1; Section 5.5). Currently, for Tier 3 (2,500 tonnes) and Tier 4 (10,000 tonnes) spills inside the primary area of response, response times for equipment deployed on-scene are 18 and 72 hours, respectively (WCMRC 2012). These response times may improve as a result of proposed improvements WCMRC is currently considering as a result of the Project (see Section 5.5.2).

- Following a spill, the Oil Spill Response Plan (OSRP) submitted to Transport Canada by WCMRC would be activated and this includes information on geographical area of response, call-out procedures, health and safety program and response counter- (WCMRC 2012).

- The OSRP is designed to work within the framework of other federal, provincial and local emergency response plans, including the BC MOE Environmental Emergency Management Program which has an essential role in protecting human health (BC MOE 2013a, WCMRC 2012).

- The BC MOE recently prepared a Marine Oil Spill Response Plan (BC. MOE 2013b). This response plan provides details of the provincial response strategy including incident notification, escalation and support, response organization, Ministry roles and services and provincial support (BC MOE 2013b). The province of BC has a 24-hour reporting number for marine oil spills. If specific human safety and welfare conditions (*e.g.*, poisoning of water or food sources and/or supply, presence of toxic fumes or explosive conditions, need for evacuation) or specific environmental conditions are met, a marine oil spill becomes an "incident" which warrants consideration of invoking part or all of the response plan and whether to declare an environmental emergency. The Technical Specialist Unit falls under the Planning Section of the BC Marine Oil Spill Incident Management Team which, among other things, monitors air quality for hydrocarbons to measure risks to human health (BC MOE 2013b).

- The actions provided by the WCMRC and relevant government agencies, will serve not only to limit any opportunities for exposure of the general public to chemical vapours released from the spill in the short-term, but also to preclude any reasonable opportunity for exposure on a longer-term basis *via* inhalation and/or other exposure pathways such as ingestion of or incidental dermal contact with the spilled chemicals.

- In the event of a spill, and if warranted, local, provincial and/or federal regulatory authorities can implement controls to protect public health under the authority vested in ordinances, Acts and/or Regulations under which the regulatory authorities operate. Examples of such controls include closure of recreational or commercial fisheries, beach closures, the issuance of drinking water or food consumption advisories, and/or forced evacuation. These measures will further reduce the potential opportunities for exposure of people to the chemicals released during a spill on a short-term and long-term basis, with the former controls specifically limiting opportunity for exposure *via* ingestion or incidental skin contact.

- Based on the types of chemicals that might be encountered and their known health effects, the potential health effects would likely be dominated by irritation of the eyes and/or breathing passages, possibly accompanied by symptoms consistent with central nervous system involvement, such as nausea, headache, light headedness and/or dizziness. In this regard, a number of the COPC are capable of acting as irritants and central nervous system depressants. The effects could range from barely noticeable to quite noticeable, depending on the exposure circumstances and the sensitivity of the individuals exposed (see below). Odours might be apparent, dominated by a hydrocarbon-like smell, with some prospect for other distinct odours due to the presence of sulphur-containing chemicals in the vapour mix. The odours themselves could contribute to discomfort, irritability and anxiety. The exact nature and severity of any health effects will depend on several factors, including:

- The circumstances surrounding the spill, including the volume of oil spilled, the tidal patterns, time of year, and meteorological conditions in effect at the time. These circumstances will affect the extent to which chemical vapours are released from the surface of the spilled oil and the manner in which these vapours will disperse.

- A person's whereabouts in relation to the spill, including their distance from the source and their orientation to the spill with respect to wind direction. It is expected that exposures would be highest at distances closest to the source, declining with increasing distance. The prospect for health effects to occur as well as the severity of any effects will follow the same pattern. The prospect for health effects to occur also will be greatest downwind of the spill, with reduced, if any, prospect for effects at cross-wind or upwind locations.

- The timeliness of emergency response measures. Measures taken to either remove the hazard from the general public (*e.g.*, spill isolation, containment and mitigation) or remove individuals from the near spill area will reduce the exposures received and the prospect for health effects to occur. The sooner these measures can be implemented, the lower the likelihood of any effects.

- Once a spill has occurred, DFO (Department of Fisheries and Oceans) is notified. DFO along with other regulatory authorities such as Environment Canada and Canadian Food Inspection Agency (CFIA) will then assess the spill and based on location, size and proximity to human pathways (*e.g.,* finfish, shellfish and beach) they will determine if a closure is necessary. If they feel there is any potential that any of these potential human pathways will be affected, they will issue an emergency closure of that pathway.

- The person's sensitivity to chemical exposures. It is widely accepted that a person's age, health status and other characteristics can affect the manner and extent to which they respond to chemical exposures, with the young, the elderly and people with compromised health often showing heightened sensitivity.

A more focused and detailed HHRA to inform specific mitigation and emergency response plans will be completed and submitted to the NEB in early 2014.

5.7 Hypothetical Spill Scenario: Oil Spill from a Tanker at Arachne Reef

This section provides an assessment of the spill response enhancements presented in Section 5.5. In this case the results for a single spill event at Arachne Reef in the near Turn Point Special Operating Area are compared with and without spill response mitigation. This examination was collaboratively performed by EBA and WCMRC to refine and assess the spill response improvements presented in Section 5.5.2.

Unlike the spill modelling results presented in previous sections (5.4 and 5.6) which were stochastic results and run without any spill response intervention this section compares the results of a single specific spill with and without spill response intervention. The spill response intervention is based on the enhancements described in Section 5.5. Details of this assessment are included in Trans Mountain Expansion Project Oil Spill Response Simulation Study, Arnachne Reef and Westridge Marine Terminal (Volume 8C, TR 8C-12, S13).

5.7.1 Scenario Rationale, Methods and Description

5.7.1.1 Scenario Rationale

The scenario considered is a credible worst case spill (16,500 m^3) near Turn Point, in Haro Strait, resulting from a tanker grounding incident with Arachne Reef (see Figure 5.5.2, Location E). As noted in Section 5.2.2, possible locations for an incident involving a Project-related tanker were selected by DNV as part of the hazard identification component of the quantitative risk assessment (TERMPOL 3.15, Volume 8C, TR 8C-12). Locations along the tanker shipping route were selected as possible sites for an incident involving a Project-related tanker due to complexity of passage resulting from high traffic and/or the narrowness of the passage.

It should be noted that groundings and collisions along the marine route for Project-related tankers have an extremely low probability, particularly in the Haro Strait due to the tanker being piloted by two experienced BC coast pilots and the ongoing use of a tethered tug through this part of the route. However, a hypothetical credible worst case scenario spill was examined so that appropriate oil spill response plans and procedures can be developed.

5.7.1.2 Methods

The approach undertaken for this hypothetical spill scenario combines the skills of operational organizations such as WCMRC and the skills of scientific numerical modellers (EBA). Through this leading-edge combination, the purpose is to demonstrate the pathway toward developing enhanced response capacity.

The approach meets the requirements of a systems approach, as recommend in the West Coast Spill Response Study (Nuka Research 2013). Elements of this systems approach are:

- analysis of the problem;

- considering and evaluating a number of solutions, and develop a blend of solutions;
- creative “outside the box” thinking to ensure that conventional approaches are challenged and determining if new ones have merit; and
- using a disciplined approach, keeping the important priorities in mind.

These elements were implemented through:

- Realistic environmental scenarios, based on high-accuracy numerical models for currents and oil spill behaviour used in the evaluation.
- The resources for mitigation were based on existing and proposed equipment stored in warehouses and caches in accordance with the Future Oil Spill Response Approach Plan, Trans Mountain Expansion Project, which has been prepared by WCMRC (Volume 8C, TR 8C-12, S12).

The oil spill simulations, which form the basis of the mitigation analysis, were conducted using SPILLCALC, a proprietary oil spill tracking model developed by EBA. Its complete description can be found in the EBA Technical Report, Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S12). SPILLCALC uses surface currents that were hindcast using a proprietary three-dimensional hydrodynamic model, H3D. This model is derived from GF8 (Stronach *et al.* 1993) developed for Fisheries and Oceans Canada. H3D has been used on several studies along the BC coast. An extensive application of an operational version of this model to the St. Lawrence Estuary is described in Saucier and Chassée (2000). For the simulation described in this report, a 1,000 m resolution Regional Model was used. This model encompasses the Strait of Georgia - Juan de Fuca - Puget Sound system, extending out onto the shelf at the western end of Juan de Fuca. Figure 5.7.3.3 shows the modelled domain.

To enhance the level of preparedness for the increased traffic associated with the Project, WCMRC described enhancements to respond efficiently to a credible worst case oil spill from a laden Aframax tanker outbound to the Pacific Ocean from the Westridge Marine Terminal through the South Salish Sea (Section 5.5.2; Volume 8C, TR 8C-12, S12). Relying on the ability to cascade resources pre-staged along the shipping route, these proposed enhancements would substantially exceed the current legislated response thresholds detailed in the *Canada Shipping Act, 2001*. The increase in response capacity would follow a systems approach that not only includes additional equipment but also new bases, more personnel, 24 hours/day – 7 days/week - 365 days/year staffing at certain locations, and improved logistics. Figure 5.5.2 shows the proposed spill response equipment staging areas.

The mitigation modelling system combines two components:

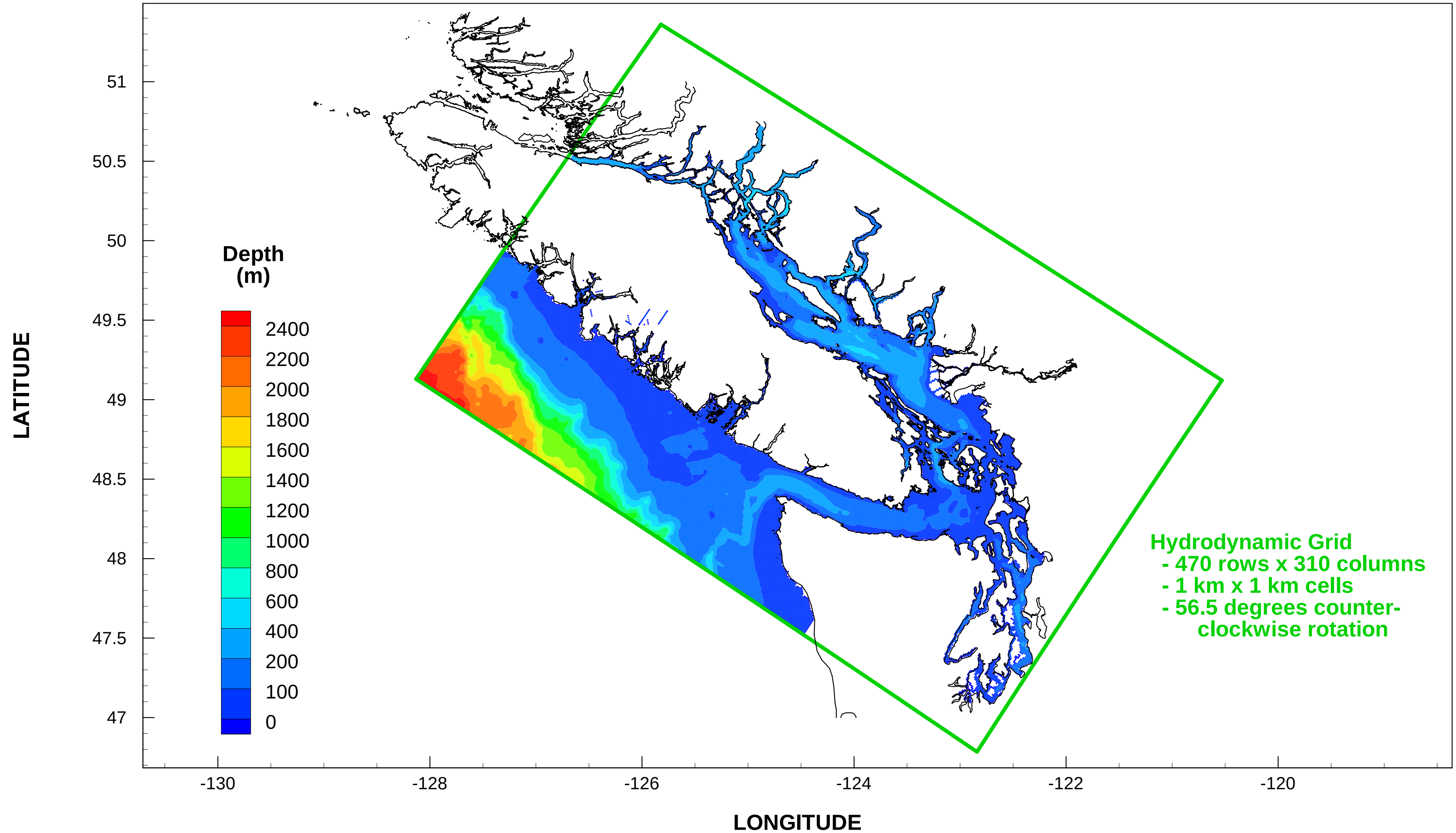
- a schedule of asset assignments (*i.e.,* equipment and staging locations), developed by WCMRC; and
- numerical simulations to evaluate the effect of these assets on the modelled spill, primarily in terms of reducing the amount of oil on the water, and to improve the mitigation strategy plan.

A schedule of asset assignments is constructed as an additional input file to the oil spill model SPILLCALC, listing the asset name, time of deployment, location of deployment, and volumetric capacity over a one-hour period. SPILLCALC steps through the spill evolution, and applies each of the assets at the time it is deployed, removing the specified quantity of oil that each asset can remove in one hour. The spill model computes the oil movement in the hours in which the assets for that hour are active, and produces a mitigated spill map, and a corresponding entry into the mass balance tables. This process is repeated for the length of the simulation, in this case 4 days. The 4 day simulation period was selected based on the slick thickness on water, which becomes too thin to be efficiently recoverable after the end of the fourth day. Thereafter, passive sheen management with sorbent products remains a viable but unquantifiable countermeasure for the response organization to employ.

Notes on the resources that were considered in the scenarios are:

- Primary and secondary containment, essentially sufficient boom to wrap the stranded vessel twice. This tactic is highly effective in containing the spread of oil and assisting in its recovery since the oil within the boom will be thick and fresh, hence amenable to skimming and pumping.

- Skimmers in common use within the WCMRC inventory were assigned to collect oil in the scenario.



NOTES

- Model grid was created in a Mercator projection true at 48 degrees 12 minutes N.

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TRANS MOUNTAIN OIL SPILL STUDY

Hydrodynamic Model Grid Domain

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	AH	JAS	0

OFFICE	DATE
EBA-VANC	November 7, 2013

Figure 5.7.3.3

5.7.1.3 Scenario Description

The waters between Moresby Island and Stuart Island mark the northern entrance to Haro Strait, which runs south-southeasterly between the Gulf Islands on the Canadian side and the San Juan Islands on the US side. Arachne Reef is situated at the northern end of Haro Strait, off to the west side of the Strait. It consists of three drying heads, and has a navigation light. A plausible but highly unlikely event would be a powered grounding of a laden tanker on Arachne Reef near Turn Point. Figure 5.5.2 shows a location map of the incident. The northern entrance to Haro Strait has the greatest level of navigation complexity for the entire passage of a Project-related tanker, as well as numerous vessels transiting the Strait. The location also has a very high environmental and socio-economic value with the potential to affect several distinct areas and habitats, including but not limited to Boundary Bay, the Gulf Islands and San Juan Islands, the Salish Sea, and the Juan de Fuca Strait. The event of a powered grounding of a laden Project-related tanker has low probability due to the proposed use of a tethered tug through this part of the route.

The hypothetical incident is given to have occurred at 22:00 on August 17, 2012 and was selected from the 368 independent simulations of the stochastic modelling for a summer spill event. The selection was based on the representativeness of the resulting spill in terms of environmental and human-health consequences. Specifically, the summer season was selected for the mitigation simulation, as warmer water and air temperatures would facilitate more rapid dissolution and/or volatilization of lighter pseudo-components into water or air, respectively. This is conservative, as the concentration in water or air would be increased by rapid dissolution and/or volatilization. At the same time, generally lower wind speeds during the summer would result in less wave action (hence, less vertical mixing of the water column, and higher concentrations of dissolved hydrocarbons in the surface water layer), as well as less dilution of vapours in air.

5.7.2 Transport and Fate

The weathering processes, which can affect spilled oil in a marine environment, were described in detail in Section 5.4. This subsection describes what happens after the hypothetical incident occurs and oil is spilled from a Project-related tanker.

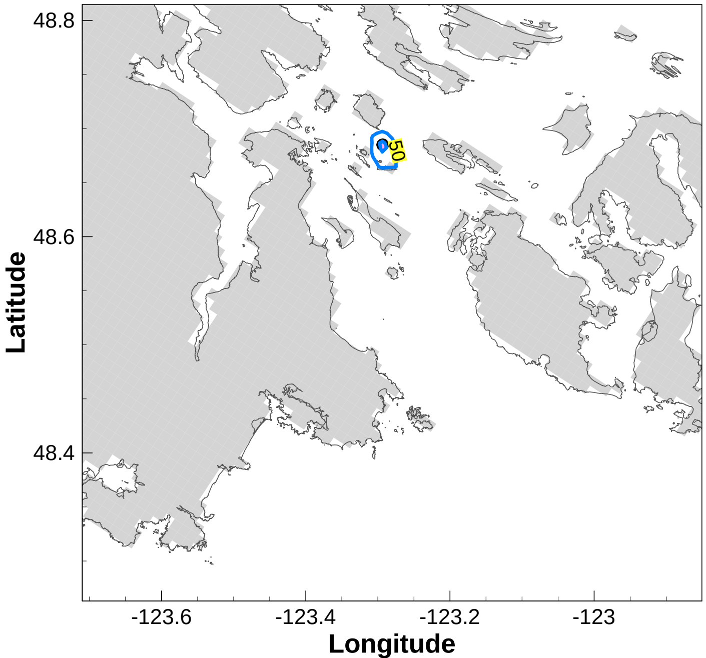
Figure 5.7.3.5 shows the “P_{50}” and “P_{90}” map after 6, 12, 24 and 48 hours. The P_{50} contour indicates that there is a 50 per cent or greater probability for the area within the P_{50} contour line to have been contacted by the oil. Similarly, the P_{90} contour indicates that there is a 90 per cent or greater probability for the area within the P_{90} contour line to have been contacted by the oil.

These maps were built based on the stochastic modelling described in the EBA Technical Report, Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Appendix 8C, TR 8C-12, S9). A total of 368 independent simulations were modelled during the summer period at Arachne Reef. Probability contours were then extracted, based on the combination of those 368 independent simulations.

Figure 5.7.3.6 shows the un-mitigated spill location, in terms of slick thickness as computed by SPILLCALC after 96 hours. Figure 5.7.3.7 shows the mass balance for the un-mitigated case. The key performance indicators (KPI) that will be used to evaluate the effectiveness of response activities are:

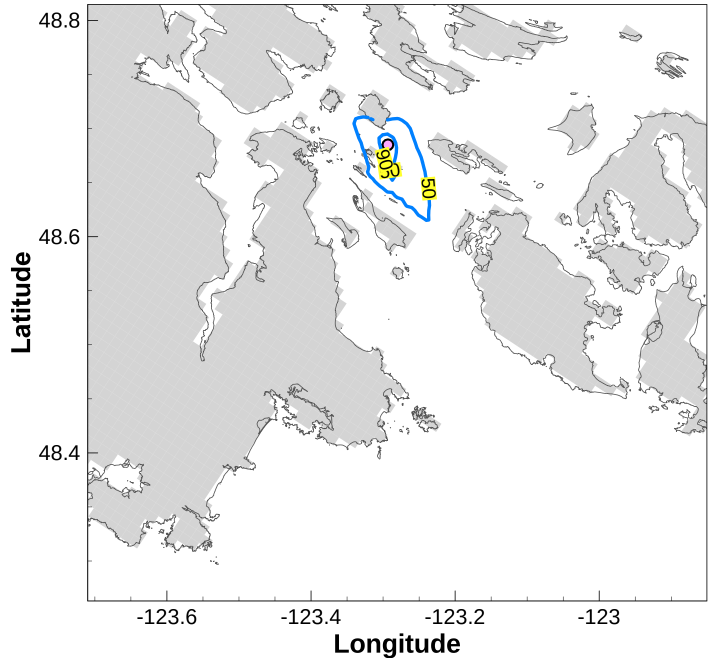
- reduce the extent and thickness of the slick remaining on the water after four days;

- reduce the quantity of oil on water after four days;
- reduce the quantity of oil reaching shore after four days;
- reduce the length of shoreline oiled; and
- account for any oil recovered, ensuring that it is only assessed as recovered once the simulation shows any oil that is contained in a secure tank on a skimmer, barge or supply vessel.



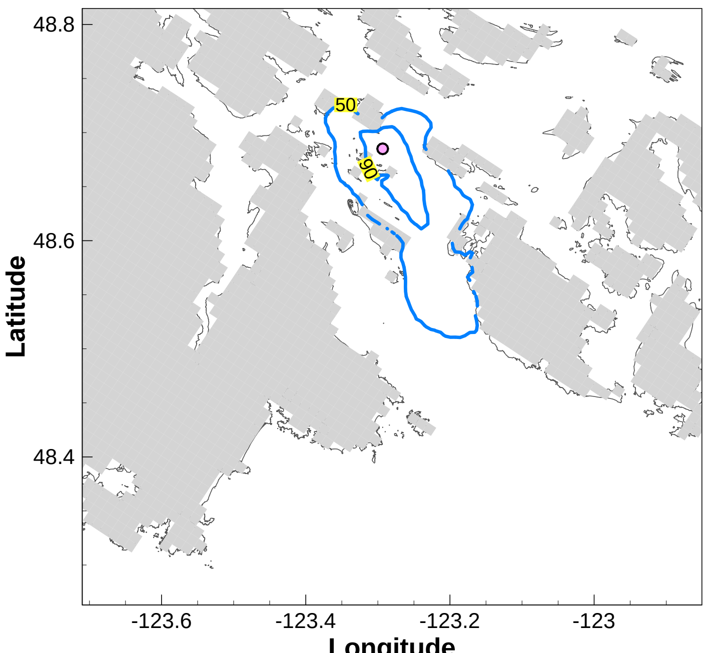
P_{50} and P_{90} after 6 Hours

Area within the P_{50} Contour Line:	8.3 km^2
Area within the P_{90} Contour Line:	0.5 km^2
Average Thickness within the P_{50} Contour Line:	217 um
Average Thickness within the P_{90} Contour Line:	342 um
Average Shore Oiled:	3 km



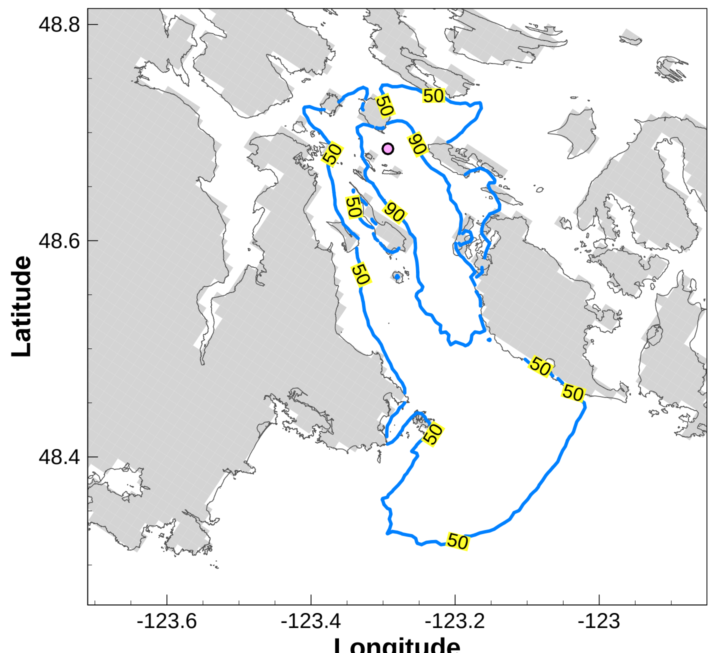
P_{50} and P_{90} after 12 Hours

Area within the P_{50} Contour Line:	47.3 km^2
Area within the P_{90} Contour Line:	4.3 km^2
Average Thickness within the P_{50} Contour Line:	94 um
Average Thickness within the P_{90} Contour Line:	245 um
Average Shore Oiled:	11 km



P_{50} and P_{90} after 24 Hours

Area within the P_{50} Contour Line:	196 km^2
Area within the P_{90} Contour Line:	37.8 km^2
Average Thickness within the P_{50} Contour Line:	36 um
Average Thickness within the P_{90} Contour Line:	78 um
Average Shore Oiled:	36 km



P_{50} and P_{90} after 48 Hours

Area within the P_{50} Contour Line:	646 km^2
Area within the P_{90} Contour Line:	132 km^2
Average Thickness within the P_{50} Contour Line:	10.5 um
Average Thickness within the P_{90} Contour Line:	26.7 um
Average Shore Oiled:	85 km

NOTES

● Release Location

Probability of oil presence is the percentage of simulations in which oil was present at a given location.
P_{50}: after X hours, there is 50% or greater probability for the area within the P_{50} contour line to have been contacted.
P_{90}: after X hours, there is 90% or greater probability for the area within the P_{90} contour line to have been contacted.
Statistical results for each season based on independent spills occuring every 6 hours for three months.
Tracking time for each spill was 15 days.
The average thickness is based on a full coverage of each grid cell that contains oil and lies within the contour line.

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TRANS MOUNTAIN OIL SPILL STUDY

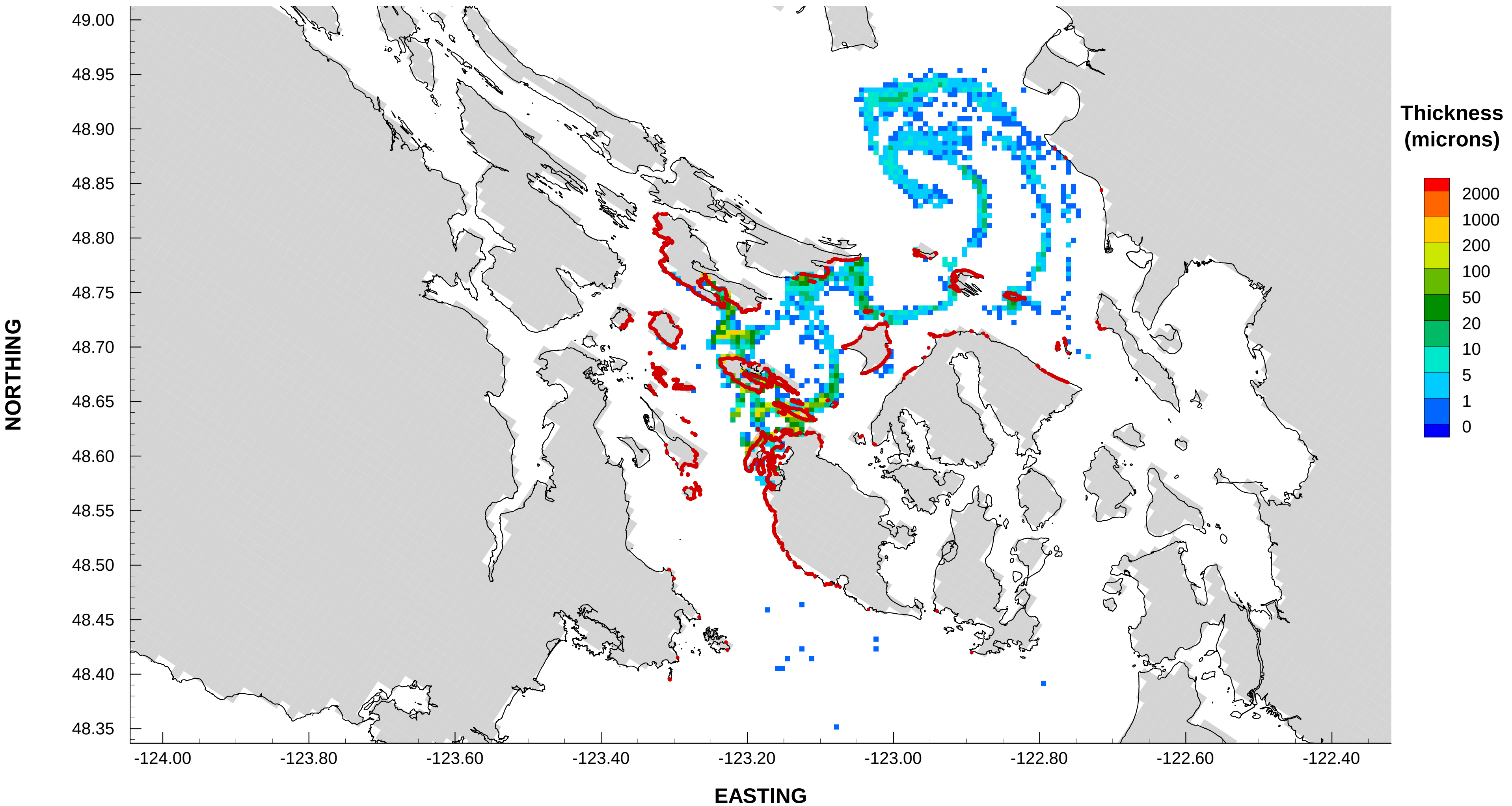
Summer Stochastic Simulation
Arachne Reef (16,500 m^3)
P_{50} and P_{90} after 6 / 12 / 24 / 48 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	-	0

OFFICE	DATE
EBA-VANC	November 6, 2013

Figure 5.7.3.5

2012/08/21 22:00



NOTES

- The graph displays the thickness of the oil on water.
  The thickness of the oil is based on a uniform full coverage of the 500m x 500m model grid cell.

- The oil on shore is displayed as a red line, regardless of the volume retained by the shore.
  The red shorelines are a visual tool only, to indicate the shoreline being contacted by the oil.

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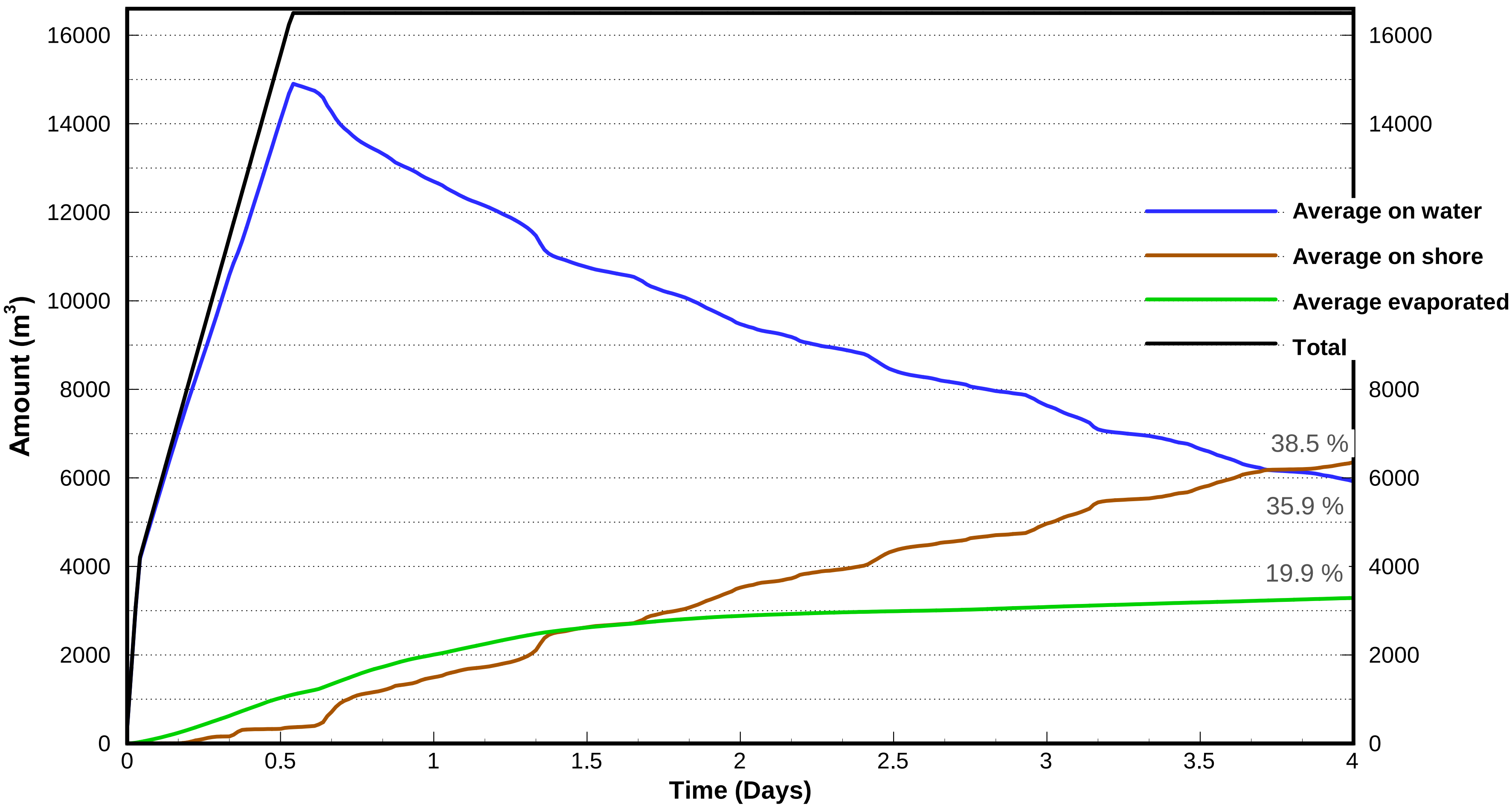
TRANS MOUNTAIN OIL SPILL STUDY

Unmitigated Simulation at Arachne Reef: August 17 2012, 10:00pm Oil Thickness after 96 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	JAS	0

OFFICE	DATE
EBA-VANC	November 4, 2013

Figure 5.7.3.6



NOTES

- Tracking time for the spill was 15 days.
- The major components of the mass balance are shown above.

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TRANS MOUNTAIN OIL SPILL STUDY

Unmitigated Simulation at Arachne Reef
August 17 2012, 10:00pm
Major Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	November 4, 2013

Figure 5.7.3.7

5.7.3 Spill Response

Based on the modelled fate and transport of the spilled oil without any mitigation measures applied, EBA developed the following recommended response to the hypothetical spill for the Project.

5.7.3.1 Establishing Outflow, Retention, and Escapement

The Arachne Reef scenario is based on a total volume of 16,500 m^3 of oil released over 13 hours, the amount DNV calculated as a credible worst case oil spill for a partly loaded Aframax tanker (TERMPOL 3.15, Volume 8C, TR 8C-12). Resulting from the incident, 25 per cent of the impacted tank volume is assumed to be lost in the first hour (elapsed time from the beginning of the spill) with 1,000 m^3 of cargo assumed to flow out of the vessel every hour thereafter until the total spilled volume is reached. Primary containment booms, as the first line of defense, surround the tanker by the end of hour +4 (elapsed time); oil retention and escapement rates from the boom are time–varying due to the variable influences of: 1) currents; 2) entrainment loss; 3) critical accumulation failure; and 4) operational effects. At hour +7 (elapsed time), secondary containment is achieved reducing the escapement outside the double-boom system.

5.7.3.2 Shipboard Emergency Measures

Although shipboard emergency measures were not part of this scenario or factored into the model, for background information it is reasonable to assume that the tanker would have undertaken a certain number of procedures upon recognition that the tanker had run aground. These procedures are described in the Trans Mountain Expansion Project Oil Spill Response Simulation Study, Arachne Reef and Westridge Marine Terminal report (Volume 8C, TR 8C-12, S13).

5.7.3.3 Response Plan

The deployment of the available pieces of equipment over Day 1 for the initial response, and Day 2, 3, and 4 is described in the Trans Mountain Expansion Project Oil Spill Response Simulation Study, Arachne Reef and Westridge Marine Terminal report (Volume 8C, TR 8C-12, S13). The efficiency of the response was maximized through the addition of an offshore supply vessel (OSV) with 1,880 mt (2,000 m^3) of integral storage moored in the Sidney area.

A summary of recovery operations at the end of Day 1 reveals the following information:

- fourteen skimmers have performed 44 individual recovery sorties by the end of the day;
- during the first eight hours of the response, the OSV (with 1,880 mt of integral storage) has acted as a temporary storage bridge until the arrival of a large barge;
- in addition to the OSV, Barge #1 (5,000 mt) will be the only other dedicated storage unit during Day 1; and
- eight 40-tonne mini-barges were deployed throughout the day to extend the recovery times of certain skimmers.

A summary of recovery operations at the end of Day 2 reveals the following information:

- seventeen skimmers have performed 61 individual recovery sorties by the end of the day;
- in addition to the OSV (1,880 mt), Barge #1 (5,000 mt) and Barge # 3 (10,000 mt) will be used as dedicated storage units during Day 2; and
- twenty 40-tonne mini-barges were deployed throughout the day to extend the recovery times of certain skimmers.

A summary of recovery operations at the end of Day 3 and Day 4 reveals the following information:

- eighteen skimmers have performed 58 individual recovery sorties by the end of Day 3;
- eighteen skimmers have performed 48 individual recovery sorties by the end of Day 4;
- in addition to the OSV (1,880 mt), three barges (total storage capacity > 17,000 mt) will be used as dedicated storage units during Day 3 and Day 4; and
- twenty 40-tonne mini-barges were deployed throughout the day to extend the recovery times of certain skimmers.

5.7.3.4 Simulation of Proposed Mitigation

The removal of the oil inside the containment area and the removal of the oil lost at sea were modelled based on the response operation plan described in Volume 8C (TR 8C-12, S13). Four days of mitigation were modelled. After 96 hours (*i.e.,* 4 days), Figure 5.7.3.8 clearly shows that much less oil is left on water, compared to Figure 5.7.3.6, which shows the un-mitigated case.

Figure 5.7.3.9 shows the mass balance in the mitigated case. Recovery of the oil was conducted at sea and in the containment area. Of the total oil outflow from the tanker in this simulated accident, 44.5 per cent was recovered from the sea outside the boom and 18.6 per cent was recovered from within the containment area. Table 5.7.1 shows the mass balance in both unmitigated and mitigated cases.

TABLE 5.7.1

MASS BALANCE COMPARISON

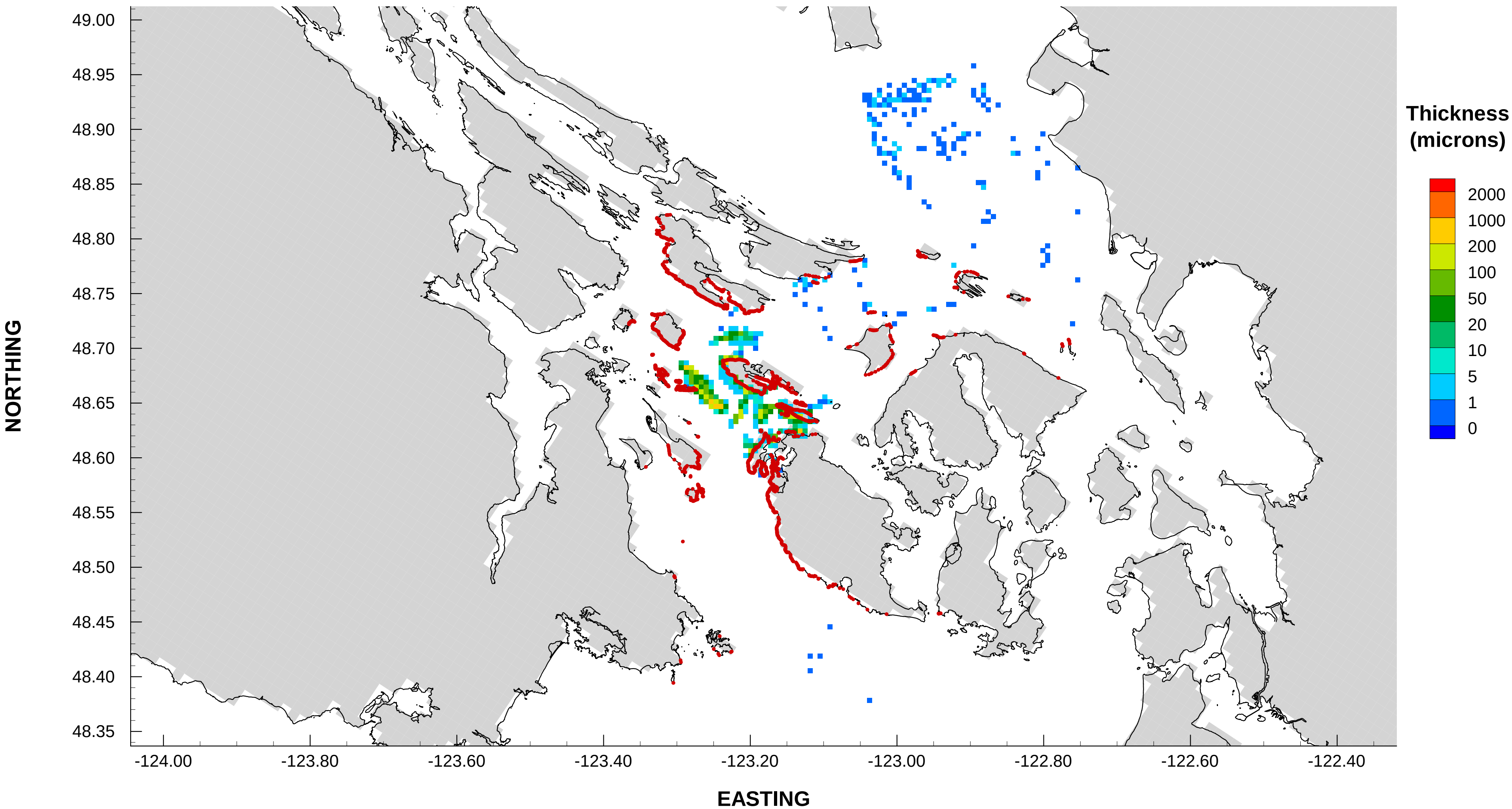
Amount (m_3)	Unmitigated Case	Mitigated Case
On shore after 4 Days	38.5%	15.8%
On shore after 15 Days	70.2%	< 24.6%
Left on water after 4 Days	35.9%	8.8%
Evaporated after 4 Days	19.9%	7.4%
Dissolved after 4 Days	3.8%	3.4%
Biodegraded after 4 Days	1.9%	0.5%
Inside the containment area but not yet recovered	N/A	1%
Recovered from inside the containment boom	N/A	18.6%
Recovered at Sea	N/A	44.5%

After 4 days, there is almost no oil inside the containment boom as a result of the recovery operations. Less than 10 per cent of the spilled oil is left on water. The fraction of spilled oil that contacted shorelines has been reduced from about 70 per cent in the unmitigated case after 15 days, to 25 per cent in the mitigated case (15 per cent of the spilled oil is on shore after 4 days in the mitigated case and 10 per cent is left on water, which is conservatively assumed to end up on shore).

The amount of oil recovered from the water surface during this model investigation represents somewhat more than half of the spill. This amount is very high compared to historical recoveries at large spill incidents. A few reasons explain this high rate of recovery:

- Proper planning when establishing the proposed level of capabilities, with the addition of equipment staging locations and the development of additional bases along the shipping route (Figure 5.5.2).
- Leading-edge tools, primarily an oil spill tracking model using surface currents from a three dimensional hydrodynamic model and waves from a two-dimensional wave model. In an actual spill event, remotely-sensed data would also be available to update information provided by such forecasting tools.
- Input vetting, variable level of synchronization among the different units unloading recovered oil into the storage barges.

2012/08/21 22:00



NOTES

- The graph displays the thickness of the oil on water.
  The thickness of the oil is based on a uniform full coverage of the 500m x 500m model grid cell.

- The oil on shore is displayed as a red line, regardless of the volume retained by the shore.
  The red shorelines are a visual tool only, to indicate the shoreline being contacted by the oil.

STATUS
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TRANS MOUNTAIN OIL SPILL STUDY

Mitigated Simulation at Arachne Reef:
August 17 2012, 10:00pm
Oil Thickness after 96 Hours

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	JAS	0

OFFICE	DATE
EBA-VANC	November 4, 2013

Figure 5.7.3.8

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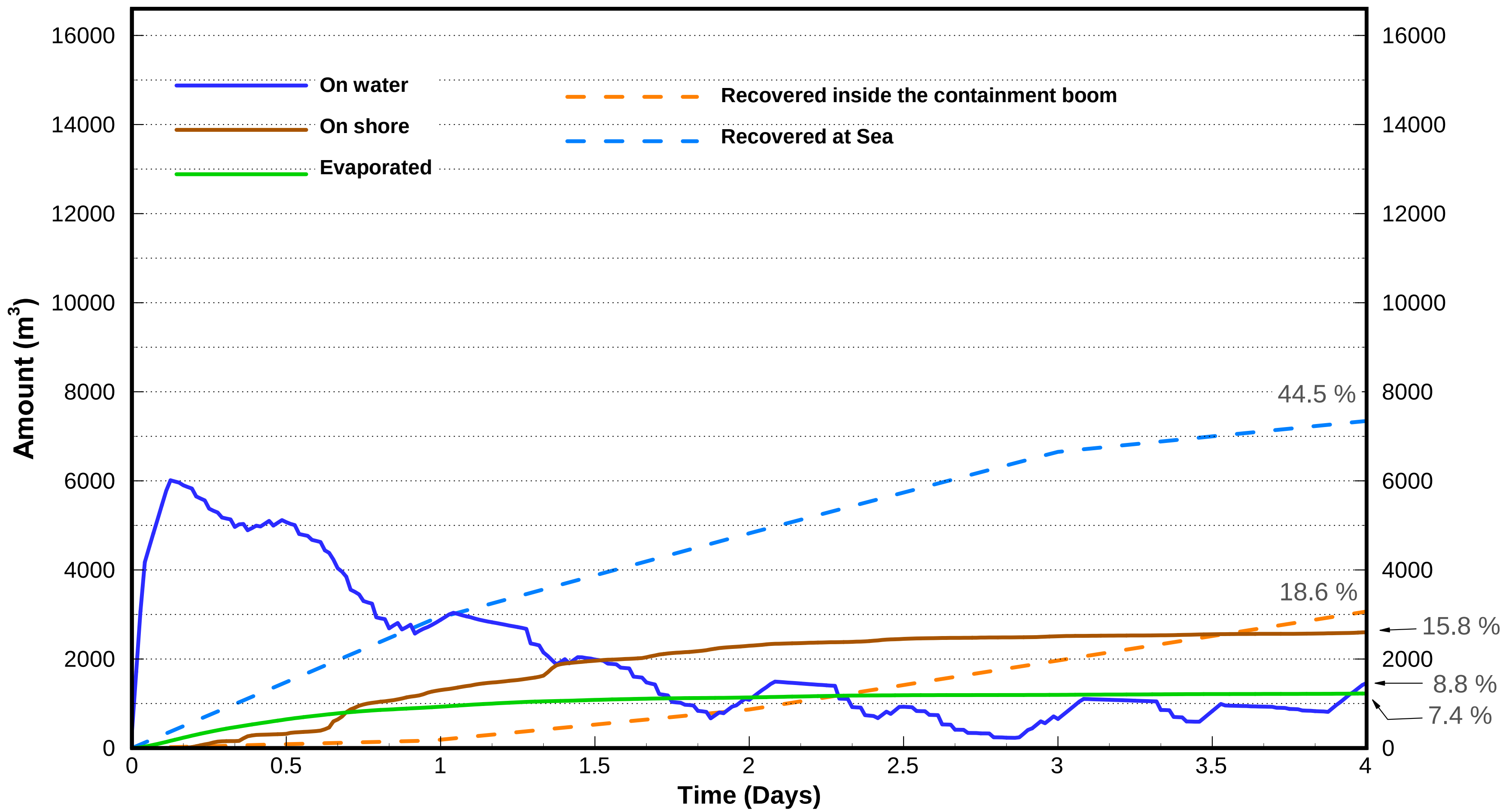

NOTES

- Tracking time for the spill was 4 days. The total amount of oil released was 16,500 m^3.
- The major components of the mass balance are shown above.

STATUS
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CLIENT
TRANSMOUNTAIN

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A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Mitigated Simulation at Arachne Reef
August 17 2012, 10:00pm
Major Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	November 4, 2013

Figure 5.7.3.9

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5.7.4 Summary and Conclusions

It is Trans Mountain's view that the modelling of a hypothetical oil spills involving the credible worst case and smaller spills from a Project-related tanker has been effective to identify where improvements to the existing oil spill preparedness and response capability is necessary to minimize the risk of environmental and socio-economic effects described here. The numerical modelling helped Trans Mountain and WCMRC appreciate the gap between the current mitigation capabilities and the proposed future capabilities, with the improvement that the additional equipment could provide. The understanding of the behaviour of the oil in a marine environment was critical in assessing the mitigation strategy; the approach proved the importance of increasing the number of response bases, the proximity of the different equipment staging locations being key to improved effectiveness. The benefit of improved oil spill preparedness and response is that the volume of oil recovered is much greater than most historical cases.

The mitigation measures simulated in the EBA report, Trans Mountain Expansion Project Oil Spill Response Simulation Study, Arachne Reef and Westridge Marine Terminal report (Volume 8C, TR 8C-12, S13), affirm the premise that oil spill recovery at sea can be effective given adequate equipment, access to equipment staging locations, a timely response, amendable weather conditions, access to good environmental and spill information (through the combination of a 24 hours/day, 7 days/week numerical forecast system and remote sensed data), and the ability to identify and correct inefficiencies before they are replicated throughout the response system. All of the above functionalities and systems contribute to a highly effective and informed ICS system.

Importantly, a good numerical model, especially one that has been fully tuned and validated to the hypothetical spill location, is an ideal tool for forecasting and for planning resource deployment. Remotely sensed data adds to the functionality of the model. In order to meet the expectations of regulatory agencies, government agencies, Aboriginal communities, and the public, and to comply with legislation, it is crucial to implement leading edge technologies as part of the response system, to support the existing planning and training phases.

6.0 CONCLUSIONS

Trans Mountain Pipeline ULC is a Canadian corporation with its head office located in Calgary, Alberta. Trans Mountain is a general partner of Trans Mountain Pipeline L.P., which is operated by KMC, and is fully owned by Kinder Morgan Energy Partners, L.P. Trans Mountain is the holder of the National Energy Board (NEB) certificates for the TMPL system.

The proposed expansion will comprise the following:

- pipeline segments that complete a twinning (or "looping") of the pipeline in Alberta and BC with about 987 km of new buried pipeline;
- new and modified facilities, including pump stations and tanks; and
- three new berths at the Westridge Marine Terminal in Burnaby, BC, each capable of handling Aframax class vessels.

Work proposed at Westridge includes a new dock complex, with a total of three Aframax-capable berths, as well as a utility dock (for tugs, boom deployment vessels, and emergency response vessels and equipment), followed by the deactivation and demolition of the existing berth.

Application is being made pursuant to Section 52 of the *NEB Act* for the proposed Project. The NEB will undertake a detailed review and hold a Public Hearing to determine if it is in the public interest to recommend a CPCN for construction and operation of the Project. Subject to the outcome of the NEB Hearing process, Trans Mountain plans to begin construction in 2015 and go into service in 2017.

Trans Mountain acknowledges that the proposed Project would result in an increase in tanker traffic transiting the Salish Sea Region as tankers enter from the Pacific approaching or leaving Westridge Marine Terminal. The Salish Sea includes Vancouver Harbour, the Strait of Georgia, Boundary Pass, Haro Strait, and the Strait of Juan de Fuca.

Currently, in a typical month, five vessels are loaded with heavy crude oil, primarily diluted bitumen, at the Westridge Marine Terminal. The expanded system will be capable of serving up to 34 Aframax class vessels per month, with actual demand influenced by market conditions.

Trans Mountain recognizes that this increase in traffic volume corresponds to an increase in the probability of an accidental oil spill from a laden tanker leaving the Westridge Marine Terminal. In addition, Trans Mountain acknowledges that the Project-related increase in tanker traffic may also result in potentially adverse environmental and socio-economic effects.

Although Trans Mountain is not legally responsible for the operation of the tankers calling at the Westridge Marine Terminal, Trans Mountain continues to be an active participant in the maritime community, supporting, and sometimes leading, key initiatives to improve the safety and environmental performance of marine transportation in the Salish Sea Region.

In consideration of the potential effects to the marine environment from the proposed increase in tanker traffic as a result of the Project, Trans Mountain extended its stakeholder engagement program to include coastal communities, beyond the pipeline terminus at Westridge Marine Terminal. Trans Mountain engaged communities on Vancouver Island and the Gulf Islands along established marine shipping corridors transited by oil tanker traffic, as well as communities in and around PMV.

The Project team received feedback from public open houses, workshops, one-on-one meetings, public presentations, online discussion and comment forms that have helped shape aspects of the Project. A summary of the input received through the stakeholder engagement program related to marine issues is provided in Table 3.1.3 of Volume 8A. Overall, engagement activities provided feedback on the following:

- determining the scope and nature of the Environmental and ESA;
- identifying potential mitigation measures to reduce risk, and environmental and socio-economic effects; and
- identifying potential local or regional benefits associated with the Project.

Since May 2012, Trans Mountain has also engaged with Aboriginal communities that may be affected by the increase in Project-related marine vessel traffic based on their traditional and cultural use of marine resources to maintain a traditional lifestyle. Of the 27 marine and inlet Aboriginal communities initially engaged on the Project with Trans Mountain, 20 of these communities have been identified as having an interest in the Project or having interests potentially affected by the increased Project-related marine vessel traffic. In addition to engagement activities, Trans Mountain has initiated TMRU studies with the Aboriginal communities that were interested in participating.

The results of engagement have helped refine the ESA for the Project. With this information, Trans Mountain identified issues, responded to questions and addressed concerns. Engagement has also provided Aboriginal communities with an understanding of the Project.

Although a wide range of issues were raised by Aboriginal community members and representatives throughout the Aboriginal engagement process, recurring themes have emerged, including the following:

- potential environmental effects of spills on the marine environment and the related effects to traditional activities;
- increases of Project-related vessel traffic on traditional hunting and fishing areas, travelways and sacred areas;
- rehabilitation and protection of the Salish Sea;
- effect of increased vessel traffic through Burrard Inlet;
- additional economic incentives including preferred procurement opportunities, revenue sharing, community enhancement opportunities and equity participation; and
- ongoing respectful and meaningful engagement including capacity funding and TMRU study funding.

Results of the engagement have been considered and incorporated throughout the marine transportation assessment, including the mitigation measures and effects assessment.

With the interests from Aboriginal communities and stakeholders in mind, and as part of this Application to the NEB, Trans Mountain undertook an environmental and socio-economic assessment to identify potential adverse environmental and socio-economic effects associated with the increase in tanker traffic, and measures to mitigate these effects. As well, Trans Mountain voluntarily initiated a voluntary TERMPOL Review Process. This process, led by Transport Canada, results in an assessment of the effects on navigational safety that may result from the proposed increase in Project-related tanker traffic along with recommendations to ameliorate these effects where necessary.

Recognizing that there has been and continues to be tanker traffic carrying oil transiting the Salish Sea Region and calling at the Westridge Marine Terminal, Trans Mountain focused the ESA and TERMPOL studies on the change in tanker traffic that would result from the Project, specifically, the change from 5 tankers per month calling at the Westridge Marine Terminal to the equivalent of 34 Aframax tankers per month.

The ESA addressed the NEB's *List of Issues* (July 29, 2013) for the Project (NEB 2013a), in particular the issue related to marine transportation:

"The potential environmental and socio-economic effects of marine shipping activities that would result from the proposed project, including the potential effects of accidents or malfunctions that may occur."

The ESA considered the mandatory factors listed in Section 19(1) of the *CEA Act, 2012*, the factors listed in the NEB Filing Manual (NEB 2013c), and pertinent issues and concerns identified through consultation and engagement with Aboriginal communities, landowners, regulatory authorities, stakeholders and the general public. The ESA also considered the NEB's Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project (September 10, 2013) (NEB 2013b), effectively determining the scope of the ESA and the factors to be assessed.

Ten environmental and socio-economic elements potentially interacting with the increased Project-related marine vessel traffic were identified for the purpose of assessing potential effects. These elements included:

- marine sediment and water quality;
- marine air emissions;
- marine GHG emissions;
- marine acoustic environment;
- marine fish and fish habitat;
- marine mammals, marine birds;
- marine species at risk;
- traditional marine resource use;
- marine commercial, recreational, and tourism use; and
- human health risk assessment.

In addition, potential accidents and malfunctions were assessed, as well as the effects of the environment on the Project, and cumulative environmental and socio-economic effects.

Most of the potential environmental and socio-economic residual effects that could arise from increased Project-related marine vessel traffic were considered to be long-term in duration (*i.e.*, lasting for the operational life of the Project), generally of low to medium magnitude and periodic or accidental in nature. There were no situations identified that would result in a significant environmental or socio-economic effect, as defined in Section 4.3, except the potential effect of sensory disturbance of southern resident killer whales and the related effect on traditional marine resource use by Aboriginal communities. Even though the Project contribution to overall sensory disturbance effects would be small, the potential effect of the increase in Project-related marine vessel traffic was determined to be to be high magnitude, high probability and significant but immediately reversible for southern resident killer whales.

DFO's *Recovery Strategy for Northern and Southern Resident Killer Whale* states that: "Both physical and acoustic disturbance from human activities may be key factors causing depletion or preventing recovery of resident killer whale populations" (DFO 2011a). Based on available scientific knowledge, it was concluded that past and current activities (including all forms of mortality, high contaminant loads, reduced prey, and sensory and physical disturbance) have resulted in significant adverse cumulative effects to the southern resident killer whale population. The recent historical decline of the southern resident killer whale population and its current status as endangered support this conclusion. However, given the current state of knowledge, and the ability of threats to interact with one another, it is not possible to completely partition how each threat may be affecting the population.

With or without the Project, the southern resident killer whale population continues to be adversely affected by sensory disturbance caused by all types of marine vessel traffic. The sensory disturbance associated with the Project-related increase in tanker traffic, as stated previously, is a small contribution to existing environmental conditions.

PMV is in the midst of developing a program to look at the current levels of underwater noise in the Strait of Georgia and surrounding waters and to consider options for reducing potential environmental effects of noise from marine vessel traffic on marine mammals. This program will be a collaborative effort, led by PMV, and supported by Transport Canada, DFO, and the CCG. Non-governmental organizations involved in marine-related research will also be invited to collaborate. This initiative will also involve the Chamber of Shipping and Coastal Pilots as key stakeholders, as well as other major marine shipping industry representatives. Trans Mountain is also supportive of opportunities for Aboriginal communities to participate in this initiative.

The program will involve the deployment of a network of hydrophones in the Strait of Georgia and Haro Strait that will be used to measure the acoustic signatures of vessels and to monitor the activities of southern resident killer whales and other cetaceans. Data collected through the program will contribute to the development of mitigation measures aimed at reducing acoustic disturbance to marine mammals. PMV is expected to release more details on the program in early 2014.

Trans Mountain strongly supports this regionally-focused collaborative approach to developing solutions that would be applied to the marine transportation industry as a whole. Trans Mountain met with PMV in late 2013 and expressed its interest in contributing to the development and implementation of the proposed program. Trans Mountain will work with PMV in early 2014 to determine how to participate in this initiative to mitigate industry-wide effects on the southern resident killer whale population and other marine mammals.

Through its extensive engagement activities, Trans Mountain understands that a spill of oil into the marine environment, arising from an incident involving a tanker is a major concern for Aboriginal communities, government and regulatory agencies, the public, and the maritime community. Trans Mountain recognizes that an unmitigated oil spill from a tanker could have immediate to long-term effects on the biophysical and human environment of the Salish Sea.

In light of the increased risk related to the Project and as part of the TERMPOL Review Process, Trans Mountain commissioned a number of studies to understand the effect of the Project on marine navigational safety and management, and to understand what would happen if there were an accident with a Project-related tanker and heavy crude oil were spilled in the marine environment.

An examination of global casualty data indicates there has been an increase in marine safety and subsequent decline in the number of marine vessel incidents, in particular accidents related to oil tankers and specifically, incidents resulting in the release of oil in a marine environment. With respect to accidental oil spills from tankers transiting the West Coast there were no reported spills from oil tankers in the 2001-2009 period of CCG collecting this type of data. Despite the existing safety record for tanker traffic on the West Coast, the increase in Project-related tankers will increase the probability that an accident could occur.

To understand the incremental risk related to the increase in tanker traffic created by the Project, Trans Mountain contracted Det Norske Veritas (DNV) to conduct a quantitative risk assessment. DNV evaluated the existing marine and shipping network of the Burrard Inlet and Salish Sea to identify:

- the possible types of incidents that could result in an oil spill from a laden tanker;
- the navigational hazards along the route a laden oil tanker would transit between the Westridge Marine Terminal and the Pacific Ocean;
- the navigational risk controls currently that are in use in the Salish Sea region and which have been effective at reducing the frequency of navigational incidents;
- the possible types of incidents that could result in an oil spill from a laden tanker;
- the hypothetical accident locations along the previously mentioned tanker route that could result in an oil spill from a laden tanker;
- the potential for enhanced navigational risk controls to reduce the probability of an oil spill from a laden tanker; and
- the probability and consequences of a credible worst case and smaller accidental oil spill (*i.e.,* a “mean-case” oil spill) from a laden tanker.

From the risk assessment DNV concluded the following:

- If the Project did not go into operation by 2018, there would still be a risk of an oil spill from a laden tanker transiting the Salish Sea Region. DNV calculated that the probability of any size of an oil spill would be 1 in 309 years and the probability of a credible worst case oil spill (*i.e.,* 16,500 m^3 of heavy crude oil released) from a laden tanker would be 1 in 3,093 years.

- If the Project were approved and was operational by 2018, but no additional mitigation measures were implemented, DNV calculated that the probability of any size of an oil spill from a laden Project-related tanker would be 1 in 46 years. DNV calculated the probability of a credible worst case spill from a laden Project-related tanker would be 1 in 456 years.
- If the Project were approved and was operational by 2018, and additional mitigation measures were implemented, DNV calculated that the probability of any size of an oil spill from a laden Project-related tanker would be 1 in 237 years. DNV calculated the probability of a credible worst case spill from a laden Project-related tanker would be 1 in 2,366 years.

DNV recommended to Trans Mountain two key measures to improve navigational safety for Project-related tankers, thus reducing the probability of an accidental oil spill from a laden tanker. These two measures included additional tug escort and a Moving Safety Zone around laden tankers. As noted in the bullets above, DNV concluded that, with the implementation of these two key measures, the risk of a credible worst case oil spill from a Project-related tanker would not be substantially more than it is today, without the Project.

Through its updated Tanker Acceptance Criteria, Trans Mountain will require additional tug escort for Project-related tankers for the entire transit between Westridge Marine Terminal and the Pacific Ocean. As well, Trans Mountain is seeking endorsement for the Moving Safety Zone from the Joint Coordinating Group of the CVTS. Lastly, Trans Mountain is seeking endorsement from Transport Canada for both of the proposed additional navigational control measures, both of which could be implemented prior to the operation of the Project and could potentially be applied to all tankers transiting the Salish Sea furthering reducing the probability of a collision.

Although Trans Mountain is not directly and legally responsible for the operation of the vessels calling at the Westridge Marine Terminal, it is an active member in the maritime community and works with maritime agencies to promote best practices and facilitate improvements focussing on the safety, efficiency, and environmental standards of tanker traffic in the Salish Sea. Trans Mountain is a shareholder and member of the Western Canadian Marine Response Corporation (WCMRC) and works closely with WCMRC and other members to ensure that WCMRC remains capable of responding to any oil spill from vessels transferring product or transporting it within their area of jurisdiction.

Trans Mountain continues to work with WCMRC to identify improvements to the existing oil spill response preparedness and response capacity for the Salish Sea region. Trans Mountain recognizes there are complementary initiatives currently underway, led by the BC Government and by the Federal Tanker Expert Safety Panel, which may also result in improvements to the existing emergency preparedness and response capacity in this region. Trans Mountain is supportive of these efforts and will continue to play an active role to support and work with WCMRC, regulatory agencies, Aboriginal groups, and to implement requisite enhancements.

Trans Mountain acknowledges that it is not enough to simply identify the risks and environmental and socio-economic effects of the Project-related increase in tanker traffic; Trans Mountain will continue to play an active role in sharing this information and facilitating the discussion on how to mitigate Project-related environmental and socio-economic effects, increased risks in the marine environment, and to improve existing emergency preparedness and response measures in preparation for the Project.

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8.0 APPENDICES