# ECOLOGICAL RISK ASSESSMENT OF WESTRIDGE MARINE TERMINAL SPILLS

## Technical Report for the Trans Mountain Pipeline ULC

## Trans Mountain Expansion Project

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# EXECUTIVE SUMMARY

Stantec Consulting Ltd. was retained by the project consultant, TERA Environmental Consultants, to evaluate ecological risks that could arise following an accidental crude oil spill at the Westridge Marine Terminal (WMT). This document is a Preliminary Quantitative Ecological Risk Assessment (PQERA) Technical Report prepared for background information for the Section 52 Application for the Trans Mountain Expansion Project (referred to as “TMEP” or “the Project”). In particular, this Technical Report provides support to Volume 7 of the Application. The primary focus of this PQERA is the evaluation of the potential negative environmental effects to marine ecological receptors resulting from hypothetical accidental crude oil spills of Cold Lake Winter Blend (CLWB, a representative diluted bitumen) during marine vessel loading at the WMT. This included the evaluation of a range of hypothetical spill scenarios including a credible worse case (CWC) spill of 160 m$^3$ or a smaller spill that could occur at the WMT during product loading and consideration of a range of weather and marine conditions that could prevail during the spill event, including season-specific behaviour, trajectories, and fate.

Spatial boundaries for this PQERA included the geographic extent where potential effects are expected to be measurable and considered the oil spill footprint as well as the RSA defined as the area of English Bay, Vancouver Harbour, and Burrard Inlet east of the First Narrows, including Indian Arm and Port Moody Arm. Two hypothetical oil spill scenarios were evaluated as part of this PQERA. These include scenarios representing two crude oil spill volumes: a CWC spill of 160 m$^3$ due to a large break in a loading arm (with assumption that 80% is retained by a boom placed around the vessel being loaded); and a smaller volume of 10 m$^3$ (which remains within the containment boom). The credible worst case spill at the Westridge Terminal resulting from an incident during loading of a tanker was assessed, assuming a volume of 160 m$^3$. At 160 m$^3$, this spill is larger than the credible worst case spill resulting from a rupture of a loading arm. It is also substantially smaller than the over 1,500 m$^3$ capacity of the precautionary boom that will be deployed around each berth while any cargo transfer activities are taking place and it is reasonable to expect that the spill would be entirely contained within the boom. In addition, observed weak currents (Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project [Volume 8B]) at the Terminal support the full containment of the oil within the pre-deployed boom. However, as a conservative approach to this scenario, it was deemed that, for oil spill modelling purposes, 20% of the oil released would escape the containment boom (*i.e.,* 32 m$^3$). This condition was chosen to ensure a conservative approach to spill response requirements at the site and does not reflect Trans Mountain's expectation for performance of the precautionary boom which will be in place to fully contain such a release at the terminal. For information of the reader, the credible worst case oil spill volume resulting from this scenario has been calculated by DNV as 103 m$^3$ and deemed as a low probability event with likelihood of occurring once every 234 years.

Each hypothetical spill scenario was evaluated using stochastic fate and transport modeling under a range of environmental conditions, including winter, spring, summer and fall. CLWB was selected as the representative crude oil because it is already transported by Trans Mountain, and is expected to remain a major product transported by the new line. In addition, the diluent in CLWB is condensate (a light hydrocarbon mixture derived from natural gas liquids). As such CLWB was considered to be a conservative choice for the ERA because the volatile and relatively water-soluble hydrocarbons associated with the condensate would present a higher level of risk than would synthetic oil, which is also used as a diluent, but contains fewer volatile and less water soluble constituents.

Separate exposure assessments were conducted for each hypothetical spill scenario. The exposure and hazard/effects assessment steps involved considering first, what the probability of oiling would be for any given location within the RSA. The potential risks of negative environmental effects from crude oil exposure from each spill scenario were evaluated for four main ecological receptor group/habitat combinations including, shoreline and near shore habitats, marine fish and supporting habitat, marine birds and supporting habitat, and marine mammals and supporting habitat. Each of the four ecological receptor groups contains a variety of habitats and/or individual receptor types of differing sensitivity to crude oil exposure (ranked on a scale of low to very high). The potential ecological consequence of crude oil exposure at any given location was considered to be defined by the overlap of the likelihood of crude oil presence, and the sensitivity of ecological habitat or receptors that may be present at that location.

The first scenario considered the hypothetical CWC scenario for the WMT. For this scenario, there is a high to very high probability of water surface oiling and/or shoreline oiling at the confluence of Indian Arm and Burrard Inlet and a low probability of water surface oiling and/or shoreline oiling from a single individual crude oil spill to reach farther into Indian Arm and towards Port Moody, as well as west past Second Narrows. The overall results for each season were very similar, although some slight seasonal differences in the spill trajectories were identified these were mainly attributed to variations in predominant current direction and speed, and/or predominant wind direction and speed. As a result of federal regulations regarding fish habitat and migratory bird habitat, it is considered that any release of crude oil to the marine environment would justify an effect magnitude rating of High. The following sections provide some additional context regarding effects of spilled crude oil on the four ecological receptor types.

For shoreline and near shore habitats, the affected areas generally represent a small fraction of total amount of shoreline belonging to each sensitivity class within the RSA. The area with the highest probability of oiling and negative effects is located near the confluence of Indian Arm and Burrard Inlet. Although salt marsh and eelgrass habitats are considered to be highly sensitive to crude oil exposure, these habitats are not found in proximity to the WMT and have a very low probability of oiling. Shoreline and near shore habitats classes with low exposure cobble/boulder veneer over sand would be most affected. Very little of the potentially affected shoreline and near shore habitats in Burrard Inlet is of a type that would tend to sequester spilled crude oil. It is expected that shoreline clean-up and assessment techniques could be effectively applied to the spilled crude oil that reached shorelines 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.

For marine fish and supporting habitat, the affected areas can represent a substantial fraction (up to 30%) of total amount of some of the habitat types evaluated, however, the potential for negative effects is generally low, due to the limited fetch of Burrard Inlet, and the low potential for dissolved hydrocarbon concentrations in water to reach thresholds that would cause mortality of fish or other aquatic life. This potential would be greatest in shallow water areas under weather conditions causing spilled oil to be driven into shallow areas with wave action, leading to localized high concentrations of dissolved hydrocarbons and hydrocarbon droplets in the water. This could result in the death of fish as a result of narcosis, or could cause abnormalities or death in developing embryos if spawn was present. Shallow water habitat located in proximity to the WMT would have the highest potential to be affected. As a result of the limited spatial extent of potential effects of spilled oil on fish and fish habitat, and the generally low potential for the CWC scenario to cause acute lethality to fish, recovery of marine fish and supporting habitat would be rapid. Even under a worst-case outcome event where a localized fish kill might be observed, it is expected that the lost biological productivity would be compensated for by natural processes within one to two years.

For marine birds and supporting habitat as well as marine mammals and supporting habitat, the affected areas would be small in comparison to the total available habitat present within Burrard Inlet. For birds, less than 15% of the Burrard Inlet Important Bird Area would have a high or very high probability of oiling whereas for mammals this would represent less than 20% of the RSA. Bird colonies and marine mammals located in proximity to the WMT would be most affected. While there is potential for oiling and mortality of seabirds and marine mammals following an accidental spill of crude oil at the WMT, the degree to which this potential would 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 crude oil exposure. Taking into consideration the oil spill recovery and wildlife protection actions that would follow an accidental oil spill, it remains likely that birds and mammals could be harmed (and hence the effect magnitude would be High), but it is also likely that the numbers would be small. At the population level, the lost individuals would likely be compensated for by natural processes within one to two years.

The second scenario considered a smaller volume of spilled oil that would be completely retained within the containment boom, and would not spread across the water surface outside of the boom or impinge directly on the adjacent shoreline. Standard operating procedures in place at the terminal would result in immediate shut-down of transfer operations, and implementation of spill response plans including immediate recovery of the oil using pre-deployed equipment. This mitigation was considered when evaluating potential environmental effects from smaller spills. Based on existing spill response plans, recovery operations for such smaller spills would be expected to be complete within a few days.

Results indicate that the smaller release of CLWB at the WMT during loading operations would not likely affect sediment quality, but could result in a short-term and localized effect on water quality. Acute lethality to aquatic biota is not likely to result. Birds and mammals in direct contact with the oil at the water surface could also be affected. However, due to the presence of the containment boom, and the expected recovery of the oil within a few days, the number of affected animals would be low, and ecological effects would not be persistent at population levels. Therefore, the magnitude of environmental effects on marine ecological receptors of a smaller spill of crude oil at the WMT which remains confined within the containment boom, could be Negligible to Low, provided direct mortality of fish, birds and mammals did not occur.

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# DEFINITIONS AND ACRONYM LIST

| Definition/Acronym | Full Name |
|---|---|
| AB | Alberta |
| acute | short-term |
| ADEC | State of Alaska Department of Environmental Conservation |
| AIRA | Aleutian Islands Risk Assessment |
| ATK | Aboriginal Traditional Knowledge |
| Avoidance | a means to prevent a potential adverse effect through routing/siting of the Project, changes to Project design or construction timing |
| BC | British Columbia |
| BC CDC | British Columbia Conservation Data Centre |
| BC CSN | British Columbia Cetacean Sightings Network |
| BC MCA | British Columbia Marine Conservation Analysis |
| BC MFLNRO | British Columbia Ministry of Forest, Land and Natural Resource Operations |
| BC MOE | British Columbia Ministry of Environment |
| BC MWLAP | British Columbia Ministry of Water, Land and Air Protection |
| BIEAP | Burrard Inlet Environmental Action Program |
| BSD | Blue Sac Disease, a developmental syndrome of fish embryos caused by PAH exposure. |
| BSD | Blue Sac Disease |
| BSF | biological sensitivity factors |
| BTEX | Benzene, Toluene, Ethylbenzene and Xylenes |
| CCME | Canadian Council of Ministers of the Environment |
| CEA | Canadian Environmental Assessment |
| *CEA Act* | *Canadian Environmental Assessment Act* |
| CEA Agency | Canadian Environmental Assessment Agency |
| *CEPA* | *Canadian Environmental Protection Act* |
| chronic | long-term |

| Definition/Acronym | Full Name |
|---|---|
| CLWB | Cold Lake Winter Blend |
| Compensation | a means intended to compensate unavoidable and potentially significant or unacceptable effects any may consist of offsets (no net loss), research, education programs, and financial compensation (considered only when all other options have been exhausted) |
| COPC | Chemical of Potential Concern |
| COSEWIC | Committee on the Status of Endangered Wildlife in Canada |
| CPCN | Certificate of Public Convenience & Necessity |
| CSAS | Canadian Science Advisory Secretariat |
| CWC | credible worst case |
| CWS | Canadian Wildlife Services |
| DFO | Fisheries and Oceans Canada |
| dilbit | diluted bitumen |
| DNV | Det Norske Veritas (U.S.A.), Inc. |
| DQERA | Detailed Quantitative Ecological Risk Assessment |
| DWT | deadweight tonnage |
| EBA | EBA Engineering Consultants Ltd., operating as EBA, A Tetra Tech Company |
| Element | a technical discipline or discrete component of the biophysical or human environment identified in the NEB Filing Manual. |
| EPH | extractable petroleum hydrocarbon |
| EPP | Environmental Protection Plan |
| ERA | Ecological Risk Assessment |
| ERM | Environmental Resources Management |
| ESA | Environmental and Socio-economic Assessment |
| EVOS | Exxon Valdez Oil Spill |
| EVOSTC | Exxon Valdez Oil Spill Trustee Council |
| GHG | greenhouse gas |
| GIS | geographic information system |

| Definition/Acronym | Full Name |
|---|---|
| HHRA | Human Health Risk Assessment |
| HHWM | Higher High Water Mark |
| IBA | Important Bird Area |
| IFMP | Integrated Fisheries Management Plan |
| Indicator | a biophysical, social, or economic property or variable that society considers to be important and is assessed to predict Project-related changes and focus the effects assessment on key issues. One or more indicators are selected to describe the present and predicted future condition of an element. Societal views are understood by the assessment team through published information such as management plans and engagement with regulators, public, Aboriginal, and other interested groups. |
| IPCC | International Panel on Climate Change |
| ISGOTT | International Safety Guide for Oil Tankers and Terminals |
| ISQG | interim sediment quality guideline |
| KMC | Kinder Morgan Canada Inc. |
| MAH | Monocyclic Aromatic Hydrocarbon |
| Measurement Endpoint | one or more 'measurement endpoints' are identified for each indicator to allow quantitative or qualitative measurement of potential Project effects. The degree of change in these measurable parameters is used to characterize and evaluate the magnitude of Project-related environmental and socio-economic effects. A selection of the measurement endpoints may also be the focus of monitoring and follow-up programs, where applicable. |
| Mitigation Measures | mean measures for the elimination, reduction or control of a project’s adverse environmental effects, including restitution for any damage to the environment caused by such effects through replacement, restoration, compensation or any other means. |
| MLLW | Mean Lower Low Water |
| MSERA | Marine Spill Ecological Risk Assessment |
| NEB | National Energy Board |
| *NEB Act* | *National Energy Board Act* |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAA ESI | National Oceanic and Atmospheric Administration Environmental Sensitivity Index |
| NPS | nominal pipe size |
| NRC | National Research Council |
| OD | outside diameter |
| PAH | Polycyclic Aromatic Hydrocarbon |

| Definition/Acronym | Full Name |
|---|---|
| PCB | Polychlorinated Biphenyl |
| PEL | probable effects level |
| PMV | Port Metro Vancouver |
| PNCIMA | Pacific North Coast Integrated Management Area |
| Post-construction monitoring | A type of monitoring program that may be used to verify that mitigation measures effectively mitigated the predicted adverse environmental effects. |
| PQERA | Preliminary Quantitative Ecological Risk Assessment |
| Proposed pipeline corridor | Generally a 150 m wide corridor encompassing the pipeline construction right-of-way, temporary workspace, and valves. |
| QRA | Quantitative Risk Analysis |
| RCA | Rockfish Conservation Areas |
| RSA (Regional Study Area) | The area extending beyond the Local Study Area boundary where the direct and indirect influence of other activities could overlap with Project-specific effects and cause cumulative effects on the environmental or socio-economic indicator. |
| *SARA* | *Species at Risk Act* |
| SCAT | Shoreline Clean-up Assessment Technique |
| SEP | Salmonid Enhancement Program |
| Stantec | Stantec Consulting Ltd. |
| Supplemental studies | studies to be conducted post submission of the application to confirm the effects assessment conclusions and gather site-specific information for the implementation of mitigation from the Project-specific environmental protection plans |
| TEH | total extractable hydrocarbons |
| TEK | Traditional Ecological Knowledge |
| TERMPOL | Marine Terminal Systems and Trans-shipment |
| TEX | Toluene, Ethylbenzene, Xylenes |
| the Project | the Trans Mountain Expansion Project |
| TMEP | Trans Mountain Expansion Project |
| TMPL system | Trans Mountain pipeline system |
| TOC | Total Organic Carbon |

| Definition/Acronym | Full Name |
|---|---|
| Trans Mountain | Trans Mountain Pipeline ULC |
| TSS | Total Suspended Solids |
| US | United States |
| USCG | United States Coast Guard |
| USEPA | United States Environmental Protection Agency |
| USNFWF | United States National Fish & Wildlife Foundation |
| VOC | Volatile Organic Compound |
| WCMRC | Western Canada Marine Response Corporation |
| WMT | Westridge Marine Terminal |
| YVR | Vancouver International airport |

# 1.0 INTRODUCTION

## 1.1 Project Overview

Trans Mountain Pipeline ULC (Trans Mountain) 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 Kinder Morgan Canada Inc. (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 Trans Mountain pipeline system (TMPL system).

The TMPL system commenced operations 60 years ago and now transports a range of crude oil and petroleum products from Western Canada to locations in central and southwestern British Columbia (BC), Washington State and offshore. The TMPL system currently supplies much of the crude oil and refined products used in BC. The TMPL system is operated and maintained by staff located at Trans Mountain‟s regional and local offices in Alberta (Edmonton, Edson, and Jasper) and BC (Clearwater, Kamloops, Hope, Abbotsford, and Burnaby).

The TMPL system has an operating capacity of approximately 47,690 $m^3$/d (300,000 bbl/d) using 23 active pump stations and 40 petroleum storage tanks. The expansion will increase the capacity to 141,500 $m^3$/d (890,000 bbl/d).

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.
- Three new berths at the Westridge Marine Terminal in Burnaby, BC, each capable of handling Aframax class vessels.

The expansion has been developed in response to requests for service from Western Canadian oil producers and West Coast refiners for increased pipeline capacity in support of growing oil production and access to growing West Coast and offshore markets. NEB decision RH-001-2012 reinforces market support for the expansion and provides Trans Mountain the necessary economic conditions to proceed with design, consultation, and regulatory applications.

Application is being made pursuant to Section 52 of the *National Energy Board Act* (*NEB Act*) for the proposed Trans Mountain Expansion Project (referred to as “TMEP” or “the 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 Certificate of Public Convenience and Necessity (CPCN) for construction and operation of the Project. Subject to the outcome of the NEB Hearing process, Trans Mountain plans to begin construction in 2016 and go into service in 2017.

Trans Mountain has embarked on an extensive program to engage Aboriginal communities and to consult with landowners, regulatory authorities, stakeholders, and the general public. Information on the Project is also available at www.transmountain.com.

While Trans Mountain does not own or operate the vessels calling at the Westridge Marine Terminal, it is responsible for ensuring the safety of the terminal operations. In addition to Trans Mountain‟s own screening process and terminal procedures, all vessels calling at Westridge must operate according to rules established by the International Maritime Organization, Transport Canada, the Pacific Pilotage Authority, and Port Metro Vancouver. Although Trans Mountain is not responsible for vessel operations, it is an active member in the maritime community and works with BC maritime agencies to promote best practices and facilitate improvements to ensure the safety and efficiency of tanker traffic in the Salish Sea. Trans Mountain is a member of the Western Canada Marine Response Corporation (WCMRC), and works closely with WCMRC and other members to ensure that WCMRC remains capable of responding to spills from vessels loading or unloading product or transporting it within their area of jurisdiction.

Currently, in a typical month, five vessels are loaded with heavy crude oil (diluted bitumen) or synthetic crude oil at the terminal. The expanded system will be capable of serving 34 Aframax class vessels per month, with actual demand driven by market conditions. The maximum size of vessels (Aframax class) served at the terminal will not change as part of the Project. Similarly, the future cargo will continue to be crude oil, primarily diluted bitumen or synthetic crude oil. Of the 141,500 $m^3$/d (890,000 bbl/d) capacity of the expanded system, up to 100,200 $m^3$/d (630,000 bbl/d) may be delivered to the Westridge Marine Terminal for shipment.

In addition to tanker traffic, the terminal typically loads three barges with oil per month and receives one or two barges of jet fuel per month for shipment on a separate pipeline system that serves Vancouver International Airport (YVR). Barge activity is not expected to change as a result of the expansion.

## 1.2 Context of this Preliminary Quantitative Ecological Risk Assessment

The evaluation of environmental effects arising from potential accidents and malfunctions resulting from the Project is required for the NEB Application. Section A.2.6 of the NEB Filing Manual outlines the requirements for the Effects Assessment and includes the following:

1. Describe the methods used to predict the effects of the Project on the biophysical and socio-economic elements, and the effects of the environment on the Project.
2. The application must also predict the effects associated with the proposed Project, including those that could be caused by construction, operations, decommissioning or abandonment, as well as accidents and malfunctions.

Additional application filing requirements related to the potential environmental and socio-economic effects of increased marine shipping activities were also outlined in correspondence from the NEB to Trans Mountain in a letter dated September 10, 2013, as presented below:

> *"The assessment of accidents and malfunctions related to the increase in marine shipping activities must include an assessment of potential accidents and malfunctions at the Terminal and at representative locations along the marine shipping routes. Selection of locations should be risk informed considering both probability and consequence. The assessment must include a description of:*
>
> - *measures to reduce the potential for accidents and malfunctions to occur, including an overview of relevant regulatory regimes;*
> - *credible worst case spill scenarios and smaller spill scenarios;*
> - *the fate and behaviour of any hydrocarbons that may be spilled;*
> - *potential environmental and socio-economic effects of credible worst case spill scenarios and of smaller spill scenarios, taking into account the season-specific behaviour, trajectory, and fate of hydrocarbons spilled, as well as the range of weather and marine conditions that could prevail during the spill event;*
> - *ecological and human health risk assessments for credible worst case spill scenarios and smaller spill scenarios, including justification of the methodologies used; and*
> - *preparedness and response planning and measures, including an overview of the relevant regulatory regimes.*
>
> *The assessment of accidents and malfunctions must also provide a description of the liability and compensation regime that would apply in the case of a spill."*

This Preliminary Quantitative Ecological Risk Assessment (PQERA) is intended to evaluate and report on the range of environmental effects from hypothetical spills that could potentially occur as a result of accidents during terminal loading operations. The nature of the hypothetical spills (location and release volume) evaluated is based on failure/risk analysis completed by Det Norske Veritas (DNV 2013). The report conclusions are based on the results of crude oil spill fate and transport modelling completed by EBA Engineering Consultants Ltd., (EBA 2013). The crude oil spill scenarios presented here consider both a credible worst case spill and a smaller spill, as well as season-specific behaviour, weather, marine conditions and trajectories.

This report presents the evaluation of effects to ecological resources resulting from loading spills originating at the Westridge Marine Terminal (WMT). The effects from spills at other locations along the marine transportation shipping lanes have been evaluated and are provided under separate cover.

## 1.3 Scope of the Preliminary Quantitative Ecological Risk Assessment

This PQERA presents an effects assessment consistent with the approach used for the Aleutian Islands Risk Assessment (AIRA, ERM 2011). The PQERA discusses the range of potential effects to various ecological resources by considering the probability of exposure to predicted surface oil slicks and affected aquatic and shoreline habitats within the study area. This interpretation is realized by overlaying GIS data layers containing information on biological resources, sensitive habitats and other areas of ecological importance with the results of stochastic oil spill modelling completed for each of four seasons including winter (January to March), spring (April to June), summer (July to September) and fall (October to December). Each set of stochastic modelling results represents 360 or more individual simulations for each season, and considers season specific behaviour (wind direct and speed, temperature, *etc.*), trajectories, and oil fate (refer to Section 5.2 for additional details on the stochastic modelling). Biological data sources used in the assessment are summarized in Section 4.6.7.

A Detailed Quantitative Ecological Risk Assessment (DQERA) for a credible worst case spill and a smaller spill for one selected spill location will be filed as supplemental information in early 2014. The DQERA will evaluate the toxicologically-induced changes in health of biological resources that might be exposed to chemicals of potential concern (COPC) from a spill of CLWB.

## 1.4 Objectives

This PQERA is designed to meet the requirements of Trans Mountain‟s application under Section 52 of the *NEB Act*, as outlined in the NEB Filing Manual (2013), and the other specified filing requirements outlined above.

The objectives of the PQERA are to:

- Evaluate the potential environmental effects of hypothetical spills of crude oil which is expected to be carried by the pipeline. In this case, Trans Mountain has selected Cold Lake Winter Blend (CLWB) as a representative diluted bitumen product for the purposes of the assessment of an accidental crude oil spill
- Evaluate a range of hypothetical spill scenarios including a credible worse case spill and smaller spills that could occur at the Westridge Marine Terminal during product loading
- Evaluate hypothetical spills under a range of weather and marine conditions that could prevail during the spill event, including season-specific behaviour, trajectories, and fate
- Support the Human Health Risk Assessment (HHRA) as required
- Advise the Environmental and Socio-Economic Assessment (ESA) document and support the NEB Application filing process.

## 1.5 Regulatory Standards

The NEB Filing Manual does not outline specific requirements or methodologies to be completed for the ERA to evaluate spills and malfunctions. Therefore, the general methodologies utilized in the PQERA follow the accepted guidance published by standards and regulatory authorities, including the Canadian Council of Ministers of Environment (*i.e.,* CCME 1996, 1997) and the United States Environmental Protection Agency (USEPA 1998).

The specific approach used for the evaluation of effects based on stochastic oil spill analysis is consistent with the methodology established in the AIRA (ERM 2011). This methodology was developed by the United States National Research Council (2008).

## 1.6 Organization of the ERA Report

This Marine Terminal Spills PQERA Technical Data Report is organized into sections as described in Table 1.1.

### TABLE 1.1 ORGANIZATION OF THE ECOLOGICAL RISK ASSESSMENT TECHNICAL REPORT

| Report Section | Content |
|---|---|
| Executive Summary | A non-technical summary of key findings to assist the reader in quickly understanding the most important aspects of this PQERA. |
| Section 1 – Introduction | An introductory section that provides an overview of the Project and describes the context, scope and objectives of the PQERA in the Environmental and Socio-economic Assessment (ESA) process. Also introduces regulatory standards used in the PQERA. |
| Section 2 – Consultation and Engagement | A description of the regulatory and stakeholder consultation and engagement process. |
| Section 3 – Ecological Risk Assessment Framework | A description of ERA framework and methods. |
| Section 4 – Problem Formulation | A description of various components related to problem formulation. Includes a description of the activities which are undertaken at Westridge Marine Terminal, the spatial boundaries of the assessment and the Regional Study Area, the environmental setting, identification of community-level resources being assessed, and the aboriginal traditional use of marine resources in the RSA. |
| Section 5 – Exposure and Hazard/Effects Assessments | An outline of the exposure and hazard/effects assessments including approach to determine exposure and effects of the spilled crude oil. |
| Section 6 – Risk Characterization Results – Credible Worst Case at Westridge Marine Terminal | The risk characterization step integrates the exposure and hazard/effects assessments to provide a conservative assessment of effects. |
| Section 7 – Qualitative Assessment of Smaller Spills | A qualitative evaluation of ecological effects resulting from smaller spills which could potentially occur during loading operations at the WMT. |
| Section 8 – Ecological Risk Assessment – Certainty and Confidence | A qualitative discussion of the implications of uncertainties and conservatism in the PQERA. |
| Section 9 – Summary and Conclusions | An outline of potential effects and recovery for community-level resources that were assessed. |
| Section 10 – Closure | A closure statement |
| Section 11 – References | A list of references cited throughout the PQERA. |

# 2.0 CONSULTATION AND ENGAGEMENT

Trans Mountain and its consultants have conducted a number of engagement activities to inform Aboriginal communities, stakeholders, the public and regulatory authorities about the approach to assessing potential environmental and socio-economic effects of the Project, and to seek input throughout the Project planning process.

## 2.1 Public Consultation, Aboriginal Engagement and Landowner Relations

Trans Mountain has implemented and continues to conduct open, extensive and thorough public consultation and Aboriginal engagement programs. These programs were designed to reflect the unique nature of the Project as well as the diverse and varied communities along the proposed pipeline and marine corridors. These programs were based on Aboriginal communities, landowner and stakeholder groups‟ interests and inputs, knowledge levels, time and preferred methods of engagement. In order to build relationships for the long-term, these programs were based on the principles of accountability, communication, local focus, mutual benefit, relationship building, respect, responsiveness, shared process, sustainability, timeliness, and transparency.

Feedback related to the Project that was raised through various Aboriginal engagement and public consultation activities including public open houses, ESA Workshops, Community Workshops and one-on-one meetings, is summarized below and was considered in the development of this technical report, and the description of effects of spills from loading accidents in Volume 7:

- effect of spills on land, water, fish and wildlife.

The full description of the public consultation, Aboriginal engagement and landowner relations programs are located in Volumes 3A, 3B and 3C, respectively. Section 3.0 of Volumes 5A and 5B summarizes the consultation and engagement activities that have focused on identifying and assessing potential issues and concerns related to accidental spills from loading accidents which may be affected by the construction and operation of the Project. Information collected through the public consultation and Aboriginal engagement programs for the Project was considered in the development of this technical report, and the assessment of spills from loading accidents in Volume 7.

## 2.2 Regulatory Consultation

Regulatory consultation with the applicable subject matter experts was conducted to present and discuss the proposed assessment methods and approaches for the various ERA studies. Consultation was completed in two phases with various expert groups including 1) consultation on the selection of ecological receptors for the ERA studies, and 2) consultation on the proposed oil spill fate modelling and assessment methods for assessing hypothetical spills.

Consultation on the selection of Key indicators for the ESA, and receptors for the ERA was completed in conjunction with the other ESA disciplines during a meeting held on April 16, 2013. The TMEP project team met with representatives from Environment Canada including members of the Canadian Wildlife Service (CWS) and the Environmental Assessment Office, as well as one external advisor to CWS. No specific comments or concerns were identified by the regulators during the consultation sessions, or through subsequent follow-up discussions.

# 3.0 ECOLOGICAL RISK ASSESSMENT FRAMEWORK

## 3.1 Overview

The primary focus of this PQERA was the evaluation of the potential effects to marine ecological receptors resulting from hypothetical accidental crude oil spills of a representative diluted bitumen (CLWB) during marine vessel loading. The assessment has been completed by overlaying GIS data layers containing information on biological resources, sensitive habitats and other areas of ecological importance with the results of seasonal stochastic crude oil spill modelling.

The PQERA was conducted according to accepted methodologies and guidance published by regulatory authorities, including the Canadian Council of Ministers of Environment (CCME 1996, 1997) and the United States Environmental Protection Agency (USEPA 1998), and in addition is patterned on an approach that was developed to support the Aleutian Islands Risk Assessment (ERM 2011).

The PQERA followed a standard protocol that is composed of the following steps:

- Problem formulation
- Exposure assessment
- Hazard assessment
- Risk characterization
- Discussion of certainty and confidence in the predictions
- Conclusions and recommendations.

The terminology and methodology of this framework followed that laid out by CCME (1996). The framework and methodology for the PQERA are described in Figure 3.1 and in the following sub-sections.

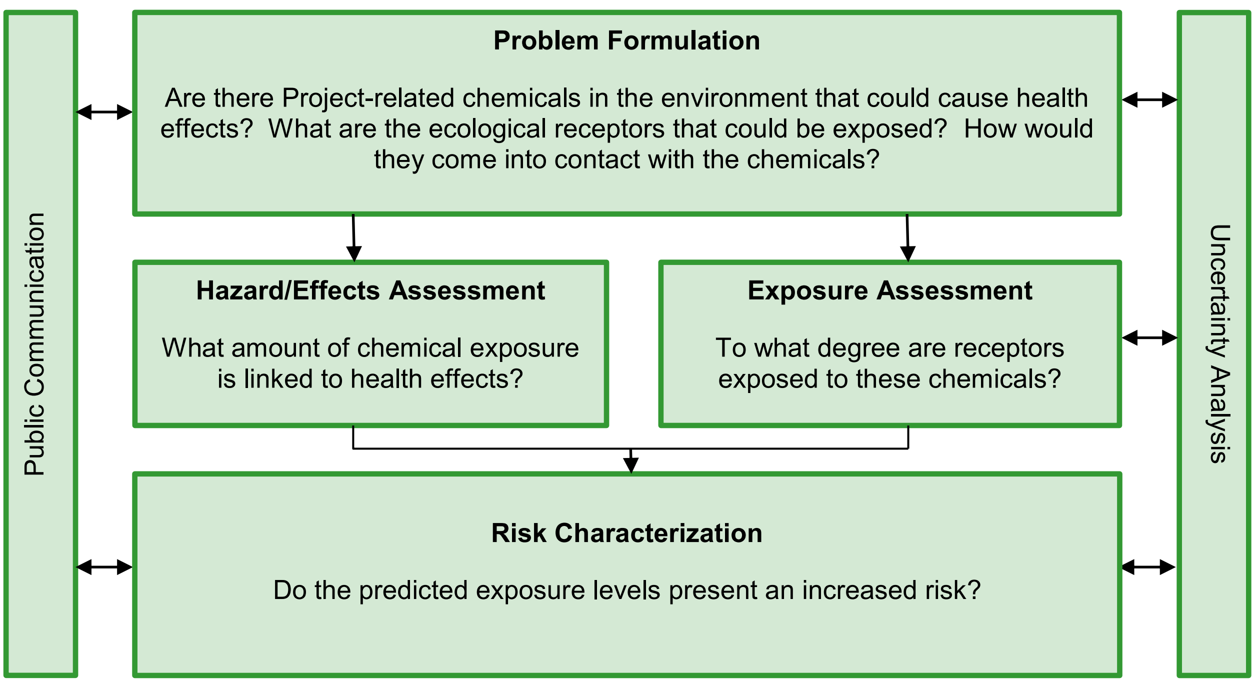


**FIGURE 3.1 CONCEPTUAL DIAGRAM OF THE PQERA FRAMEWORK**

## 3.2 Problem Formulation

The problem formulation stage is an information gathering and interpretation stage that focuses the study on areas of primary concern for the Project. Problem formulation defines the nature and scope of the work to be conducted, and enables practical boundaries to be placed on the overall scope of work, so the PQERA is directed at the key areas and issues of concern. The gathered data provides information regarding the general characteristics of the study area, the crude oil products being considered, possible release points and mechanisms for the crude oil, potential ecological receptors and any other specific areas or issues of concern to be addressed.

The key components of the problem formulation step include:

- Characterization of the geographic areas where the PQERA is being conducted
- Identification of representative crude oil products, and mechanisms of release to the environment
- Identification of exposure media and pathways
- Identification and characterization of representative ecological receptors.

The outcome of these components forms the basis of the PQERA.

## 3.3 Exposure Assessment

The purpose of the exposure assessment step is to evaluate data related to the crude oil product, ecological receptors and exposure pathways identified during the problem formulation phase. Using site-specific data and a series of conservative assumptions, the exposure assessment predicts the behaviour and distribution of crude oil in the environment, and the extent to which ecological receptors would be exposed via exposure scenarios and pathways identified in the problem formulation. The magnitude of exposure depends on the interaction(s) of a number of parameters, including:

- Extent of oiling in various environmental media following a hypothetical spill
- Physical-chemical characteristics of the crude oil, which affect environmental fate and transport and determine such factors as efficiency of absorption into the body and rate of metabolic breakdown or excretion
- Influence of site-specific environmental characteristics (*e.g.,* shoreline geology, sediment type, topography, hydrology, and hydrogeology on the crude oil‟s behaviour within environmental media)
- Physiological and behavioural characteristics of the ecological receptors which affect their exposure and susceptibility to crude oil exposure.

Separate exposure assessments are conducted for each hypothetical spill scenario. Exposure assessments result from stochastic crude oil spill modelling and are based on the properties of the representative hydrocarbons, and an assumed release volume for each scenario.

## 3.4 Hazard/Effects Assessment

The purpose of the hazard/effects assessment step is to identify the physical and/or toxic effects of spilled crude oil. The ecological effects of crude oil exposure depend on the amount of oiling and/or the amount taken into the body (the dose) and the duration of exposure (*i.e.,* the length of time the receptor is exposed). The toxicity of the oil is dependent on:

- Inherent properties of the oil that cause a biochemical or physiological effect
- Ability of the components of the oil to reach the site of action
- Unique sensitivities associated with the species being evaluated, its life-stage, and/or interactions with other environmental or physiological conditions.

This PQERA is based on stochastic modeling that provides information on how spilled crude oil would behave in the environment under a range of environmental conditions. Ecological receptors are assumed to be exposed to spilled crude oil if they occupy habitat where crude oil may be present. However, the stochastic modelling provides little information about the chemical characteristics of spilled crude oil, or concentrations of individual chemical constituents of the spilled crude oil in environmental media (*i.e.,* air, water, soil, sediment, or biological tissues). Although the acute effects of spilled crude oil can be predicted on the basis of direct exposure, the more subtle and chronic effects of spilled crude oil on ecological receptors will be addressed in a detailed quantitative ecological risk assessment to be submitted as a supplemental study in 2014.

## 3.5 Risk Characterization

The risk characterization step integrates the exposure and hazard/effects assessments with the biophysical characteristics of the marine environment to provide a conservative assessment of effects on each ecological receptor type. The potential negative effects of crude oil exposure are evaluated for four main ecological receptor group/habitat combinations including: shoreline and near shore habitats; marine mammals and supporting habitat; marine birds and supporting habitat; and marine fish and supporting habitat. Each of the four main receptor groups contains a variety of ecological receptors of differing sensitivity to crude oil exposure. The risk estimates are expressed in terms of the likely spatial extent, magnitude (or degree of injury), direction and reversibility of the environmental effects for each ecological receptor type. Potential risks are characterized through a comparison of the predicted exposures derived from applicable case studies (from the Exposure Assessment) to the exposure information detailed in the Hazard Assessment. The potential ecological consequence of crude oil exposure at any given location was considered to be defined by the overlap of the probability of crude oil presence, and the sensitivity of ecological habitat or receptors that may be present at that location. In the preliminary quantitative ERA, the assumption is that exposure may result in negative environmental effects and results are considered through probability ranges for exposure.

Accidents are evaluated using a slightly different approach than most other Project environmental effects, in the sense that environmental effects of construction or operation of the Project, and their duration, can usually be described with a high level of confidence. Accidents, on the other hand, may or may not occur, and serious accidents such as a marine oil spill are expected to have a very low probability of occurring. All of the residual environmental effects of an accident leading to a crude oil spill will be construed as being negative in aspect. The effects assessment framework used in risk characterization will therefore focus on the following aspects of the effects of accidents:

- Spatial Extent and Boundaries – oil spills do not fit within a conventional framework of the Project Footprint and Regional Study Area (RSA), as spilled oil could easily be transported a considerable distance. For this reason, the assessment of various oil spill scenarios will consider the spatial extent to which negative residual environmental effects could be expected to occur following a crude oil spill accident under a range of environmental conditions.
- Effect Magnitude – residual environmental effects will be considered in a qualitative manner, with rankings of Negligible, Low, Medium or High. Note that under the conditions of an oil spill, an environmental effect could be Negligible or Low in one area, but High in another nearby area; and that effects on one ecological receptor could be Low, while effects on another ecological receptor in the same or a nearby environment could be High. Effect magnitude definitions are as follows:
    - 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 organism)
    - 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 such as 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. In contrast to other Project environmental effects, which typically have defined duration (*e.g.,* one year of construction), the duration of an accident as an initiator of environmental effects may be very short, and accidents by definition are unlikely events.

Therefore, rather than focusing on the duration and frequency of accidents, the effects assessment will consider the reversibility, and in particular to the expected time to recovery for each ecological receptor in the event of exposure to spilled crude oil as a result of a loading arm breakage or leakage.

Limitations associated with the administrative boundaries and uncertainties of the risk assessment, in addition to conservative assumptions used in the modelling, are identified and discussed to provide perspective on the certainty and confidence that should be placed on the predictions.

## 3.6 Certainty and Confidence

This ERA step includes a qualitative assessment of the level of confidence that can be placed in the analysis and results. Risk assessments normally include elements of uncertainty, and these uncertainties are addressed by incorporating conservative assumptions (*i.e.,* assumptions that are likely to over-state rather than under-state the actual adversity of outcomes) into the analysis. Discussion of certainty and confidence in the analysis is provided in order to put these considerations into context, and to demonstrate that the conclusions are either not sensitive to key assumptions, or that the assumptions used are conservative. The assumptions and uncertainty associated with the PQERA are discussed in Section 8.

# 4.0 PROBLEM FORMULATION

## 4.1 Overview of Westridge Marine Terminal Operations

The following overview description of the Westridge Marine Terminal (WMT) operations is taken from the ESA Volume 4C Section 6.1.10.

The WMT is situated on the south shore of Burrard Inlet, in Vancouver Harbour. The existing facility performs two primary functions: loading crude oil onto tankers and barges for transportation to the US and elsewhere; and offloading jet fuel for onshore pipeline transport to Vancouver Airport.

The current terminal facilities include one (1) berth structure and associated mooring dolphins, articulated loading arms, facility control room and systems, fire suppression system and mobile equipment, and vapour destruction system. The expanded terminal proposed in the application will consist of terminal control room, three (3) vessel berth structures each capable of accommodating tankers up to approximately 120,000 deadweight tonnage (DWT), with associated mooring dolphins, articulated loading arms for each ship berth, a vapour handling system for each berth and fire suppression facilities.

Currently five tankers and three barges (*i.e.,* two barges outbound with crude oil shipments and one inbound with jet fuel) are typically handled each month at the WMT. It is expected that this will increase to the equivalent of 34 partially loaded Aframax tankers and three barges, an increase of about 30 vessels per month. Crude oil and jet fuel barge traffic is not expected to increase as a result of the Project.

Vessels calling at the WMT will follow procedures as recommended in the latest version of the International Safety Guide for Oil Tankers and Terminals (ISGOTT) and all other applicable rules and regulations. All vessels arriving at the terminal will be assisted by tugs during berthing operations. Once a tanker has been assisted to its assigned berth by the tugs, the vessel"s mooring lines will be secured by trained terminal personnel. A containment boom will also be deployed prior to, and throughout, all oil loading operations, including loading arm connection, cargo loading and disconnection procedures.

The vessel loading process at Westridge is a closed system, with oil loading via loading arms and displaced vapour being transmitted to onshore processing facilities via the vapour piping system. After loading operations are completed, the terminal personnel drain and disconnect the loading arms and vapour line in accordance with written terminal procedures. Once final departure procedures and documentation have been completed, Pilots then board the vessel, tugs are made fast, the gangway is removed, and the ship"s main propulsion and steering system are tested for operational readiness. In coordination with the ship's crew, the shore-side mooring crew will then release the mooring hooks as directed by the vessel master and mooring lines will be taken aboard the vessel, after which it will be ready for departure with the assistance of the tugs.

## 4.2 Spatial Boundaries of the PQERA

Spatial boundaries of the PQERA for crude oil spills originating from the WMT include the geographic extent where potential effects are expected to be measurable (*i.e.,* the modelling domain of for the stochastic crude oil spill model). The areas considered in the PQERA are identified as follows:

- Oil spill footprint: the area predicted to be directly affected by floating oil resulting from an individual release of crude oil at WMT; and
- Regional Study Area (RSA): The area of ecological relevance where effects could potentially result from spills. This area is effectively established by the physical limits of modelling domain for the stochastic crude oil spill modelling and includes the area of Vancouver Harbour, and Burrard Inlet east of the First Narrows, including Indian Arm and Port Moody Arm

Selection of the RSA boundaries considered the confined nature of this system of inlets and the fact that effects associated with spills originating at the Westridge Marine Terminal are not expected to extend westward beyond the mouth of English Bay.

The Regional Study Area for the PQERA is shown in Figure 4.1.


**FIGURE 4.1 REGIONAL STUDY AREA**

## 4.3 Hypothetical Oil Spill Scenarios

Det Norske Veritas (DNV) completed a marine transport Quantitative Risk Analysis (QRA) as part of the Marine Terminal Systems and Transshipment (TERMPOL) review process for the Trans Mountain Expansion Project. The QRA examined the probability of certain events occurring en route to the marine terminal or during marine terminal transhipment operations, and the likelihood of an event causing an uncontrolled release of crude oil.

In addition to the risk of various releases from ship based accidents, the QRA also examined the risk and probabilities of cargo transfer incidents at the Westridge Terminal to determine credible worse case (CWC) and smaller spill scenarios for evaluation in the PQERA. Risks from loading accidents included the following:

- Overfilling cargo tanks (*e.g.,* caused by technical failures or operator errors)
- Damage to loading arms/hoses or piping from external impacts (*e.g.,* caused by excessive vessel movements, mooring failure, operator errors, *etc.*)
- Leaks from loading arms/hoses or piping from internal damages (*e.g.,* caused by wear and tear, corrosion, fatigue, *etc.*).

The bases for frequencies of a release during the loading operations were accident statistics from Europe and are explained in detail in DNV 2013, “General Risk Analysis and Intended Methods of Reducing Risks” Technical Report Volume 8C. The highest failure frequencies were identified for two operations.

These were: 1) releases of crude oil resulting from defects in a loading arm; and 2) overfilling of a cargo tank.

The spill volume for a release during loading operations depends on the product transfer rate, spill detection time, and shut down time of the loading process and is calculated using the formula as follows:

*Volume of spill = Transfer rate * (Detection time + Emergency Shutdown Time)*

The credible worst case spill at the Westridge Terminal resulting from an incident during loading of a tanker was assessed, assuming a volume of 160 $m^3$. At 160 $m^3$, this spill is larger than the credible worst case spill resulting from a rupture of a loading arm. It is also substantially smaller than the over 1,500 $m^3$ capacity of the precautionary boom that will be deployed around each berth while any cargo transfer activities are taking place and it is reasonable to expect that the spill would be entirely contained within the boom. In addition, observed weak currents (Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project [Volume 8B]) at the Terminal support the full containment of the oil within the pre-deployed boom. However, as a conservative approach to this scenario, it was deemed that, for oil spill modelling purposes, 20% of the oil released would escape the containment boom (*i.e.,* 32 $m^3$). This condition was chosen to ensure a conservative approach to spill response requirements at the site and does not reflect Trans Mountain's expectation for performance of the precautionary boom which will be in place to fully contain such a release at the terminal. For information of the reader, the credible worst case oil spill volume resulting from this scenario has been calculated by DNV as 103 $m^3$ and deemed as a low probability event with likelihood of occurring once every 234 years (DNV 2013).

Two hypothetical oil spill scenarios were evaluated as part of this PQERA and are summarized in Table 4.1. These include scenarios representing two crude oil spill volumes: a credible worst case spill of 160 $m^3$ as a result of a large break in a loading arm; and a smaller volume of 10 $m^3$ as a result of a leaking in a loading arm for each four seasons (DNV 2013). The credible worst case oil spill during transfer operation has more recently been estimated to be 103 $m^3$ (see ection 9.2). However, the spill volume applied in the oil spill modeling for this PQERA is 160 $m^3$. The reason for the higher volume in the spill modeling is that it was conducted before the dock optimization and risk assessment were complete. The value of 160 $m^3$ is therefore conservative. Each hypothetical spill scenario was evaluated under a range of environmental conditions, including winter, spring, summer and fall.

**TABLE 4.1 SUMMARY OF HYPOTHETICAL OIL SPILL SCENARIOS FOR THE WESTRIDGE MARINE TERMINAL**

| Scenario | Season | Incident | Volume ($m^3$) | Product |
|---|---|---|---|---|
| 1 | Winter<br>Spring<br>Summer<br>Fall | Large break in loading arm (Credible Worst Case) | Total: 160<br>Released across boom: 32 (20%)<br>Retained by boom: 128 (80%) | Cold Lake Winter Blend |
| 2 | Winter<br>Spring<br>Summer<br>Fall | Leaking in loading arm | Total: 10<br>Released across boom: 0<br>Retained by boom: 10 (100%) | Cold Lake Winter Blend |

## 4.4 Selection of Representative Hydrocarbons

For the purposes of the various ERA studies, a sample of the representative diluted bitumen (*i.e.,* Cold Lake Winter Blend, abbreviated CLWB) was provided by Trans Mountain, and subjected to detailed physical and chemical analysis in order to gain an understanding of the particular hydrocarbon fractions present, as well as individual chemicals of potential concern (COPC) for the Project. CLWB was selected because it is already transported by Trans Mountain, and is expected to remain a major product transported by the new line. In addition, the diluent in CLWB is condensate (a light hydrocarbon mixture derived from natural gas liquids). As such the Cold Lake Winter Blend was considered to be a conservative choice for the ecological and human health risk assessments as the volatile and relatively water-soluble hydrocarbons associated with the condensate would present a higher level of risk as a result of inhalation of volatiles or exposure to dissolved hydrocarbons than would synthetic oil, which is also used as a diluent, but contains fewer volatile and less water soluble constituents.

### *4.4.1 Physical Properties of Representative Hydrocarbons*

The measured physical properties and chemical characteristics of fresh CLWB are provided in Tables 6.1 and 6.2 of the Stantec Pipeline Ecological Risk Assessment Technical Report – Volume 7. Additional information on the characteristics of weathering CLWB is provided by Witt O"Brien"s *et al.* (2013) Technical Report – Volume 8C. All transported hydrocarbons will meet Trans Mountain pipeline quality specifications as outlined in NEB Tariff No. 92 (KMC 2013).

## 4.5 Environmental Setting of Burrard Inlet

The following descriptions of the physical and biological setting of Burrard Inlet have been extracted with some modification from the Marine Resources – Westridge Marine Terminal Technical Report (Stantec 2013a) Volume 5C.

### *4.5.1 Physical Setting*

Burrard Inlet is a glacial fjord located on the south coast of British Columbia. It is bordered by the cities of Vancouver and Burnaby to the south and by North Vancouver and the North Shore Mountains (Coast Range) to the north. Burrard Inlet can be divided into three sub-areas: English Bay (comprising False Creek and the area between Point Grey, Point Atkinson, and the First Narrows); the Harbour (comprising the area between the First Narrows and Port Moody); and Indian Arm (from Belcarra and North Vancouver to the Indian River estuary). The Harbour area can be further divided into three sub-areas: the Central Harbour (between the First and Second Narrows); the Inner Harbour (extending from the Second Narrows to Barnet Marine Park); and Port Moody Arm (between Barnet Marine Park and Port Moody).

Burrard Inlet is approximately 50 km in length and ranges from 0.5 to 3 km in width. It includes over 11,000 ha of water and seabed, 190 km of shoreline, and a drainage basin of 98,000 ha (Stantec 2009). The maximum water depth in Burrard Inlet is approximately 220 m, which is found in the deep basin of Indian Arm. English Bay and the Harbour are much shallower, with typical water depths of 25 to 35 m and a maximum depth of about 65 m. The mean tidal range within Burrard Inlet is 3.3 m. Currents vary according to location, with the highest velocities occurring at locations where the inlet narrows, constricting water movement. Maximum currents at the First Narrows are on the order of 5.5 knots.

The main freshwater inputs into Burrard Inlet are from the Seymour River in the Inner Harbour (monthly mean discharges of 3.8 to 24.9 $m^3$/s) and the Capilano River, located just west of the First Narrows (5.7 to 42.8 $m^3$/s) (Nijman 1990). Other important sources of freshwater inflow include Lynn Creek, Mosquito Creek, and MacKay Creek in the Inner Harbour and Noons Creek in Port Moody Arm. Surface waters salinities in Burrard Inlet are strongly influenced by local and regional freshwater inputs, ranging from 20‰ to 25‰ during the winter to less than 10‰ during the summer (Nijman 1990). Low summer salinities are largely as a result of runoff from the Fraser River. In deeper waters of Burrard Inlet, salinities are typically 29‰ to 30‰ (Nijman 1990). Surface water temperatures vary seasonally, from as low as 5ºC in the winter to over 20ºC in the summer (Marine Resources – Westridge Marine Terminal Technical Report, Volume 5C).

### *4.5.2 Existing Water and Sediment Quality Conditions near the Westridge Terminal*

Information on existing water and sediment quality near the Westridge Terminal was obtained from the following sources:

- BCG Engineering Inc. 2006. Westridge Terminal Burnaby, British Columbia, Environmental & Geotechnical Study – Final Report prepared for Kinder Morgan. 16 pp + drawings and appendices. In Stantec Consulting Ltd. 2013a.
- British Columbia Ministry of Water, Land and Air Protection (BC MWLAP). 2004. Water Quality Objectives Attainment Monitoring in Burrard Inlet in 2002. Ministry of Water Land and Air Protection, Lower Mainland Region. July 2004.

- Stantec Consulting Ltd. 2010a. Environmental Impact Statement, Divisions B and D: Sewers, Foreshore, and Marine Environment – Westridge Hydrocarbon Accidental Release. Final Report. Prepared for Kinder Morgan Canada Inc. May 2010.
- Stantec Consulting Ltd. 2013b. Marine Sediment and Water Quality, Westridge Marine Terminal, Technical Report for the Trans Mountain Pipeline ULC Project. Preliminary Draft. Prepared for Kinder Morgan Canada Inc. October 2013.
- Stantec Consulting Ltd. 2012a. Long-term Monitoring Program – 2012 Report. Foreshore Environment. Westridge Hydrocarbon Accidental Release. Prepared for Trans Mountain Pipeline ULC. In Stantec Consulting Ltd. 2013a.
- Stantec Consulting Ltd. 2013c. Westridge Marine Terminal for the Trans Mountain Pipeline ULC Project, 2013 Sediment Quality Data Report. Prepared for Trans Mountain Pipeline ULC. September 2013.

#### *4.5.2.1 Existing Water Quality*

Water samples collected as part of the Marine Sediment and Water Quality Report (Stantec 2013b) and the Sediment Quality Data Report (Stantec 2013c) were collected at 1 m depth (shallow) and 1 m above the bottom (deep) on ebb and flow tides in four locations within 500 m of the terminal. Analytical results were all below British Columbia Ministry of Environment (BC MOE) Marine Water Quality Guidelines for the Protection of Aquatic Life and CCME Marine Water Quality Guidelines for the Protection of Aquatic Life, with the exception of zinc in shallow ebb tide water, which was slightly above the BC MOE guidelines.

Nutrients, total suspended solids and metal concentrations were higher in deep samples than in shallow samples. For surface samples, the highest salinity, nutrient and metal levels occurred at flood tide; lower concentrations at ebb tide suggest freshwater influence. For deep samples, metals tended to be higher at ebb than flood tide, but less markedly than for surface samples.

Literature/desktop review of available information shows that monthly monitoring of treated WMT stormwater for total extractable hydrocarbons (TEH) has met effluent discharge permit requirements of <5.0 mg/L in the 2010 and 2011 (most recent) annual monitoring reports and were less than detection limits (0.08 to 0.20 mg/L) in all monthly samples (Stantec 2013c).

Extractable petroleum hydrocarbon (EPH) and polycyclic aromatic hydrocarbon (PAH) levels in surface water were sampled at several locations one and two weeks after the July 2007 oil spill when a pipeline was ruptured by a backhoe conducting sewer work for the City of Burnaby. This ruptured pipeline resulted in oil entering Burrard Inlet via the storm drain system (Stantec 2010a). At all sample locations, EPH concentrations were below detection limits. Levels of PAH compounds were above detection limits in a few locations but did not exceed applicable water quality guidelines (Stantec 2010a).

For metals, data from the Water Quality Objectives Attainment Monitoring in Burrard Inlet in 2002 report (BC MWLAP 2004) showed that chromium and cobalt levels were below or marginally above detection limits in all samples collected, and copper, iron, lead, manganese and zinc levels were below British Columbia guidelines in all samples collected at the Shellburn location, which is the sample location closest to Westridge Terminal. At Shellburn, total suspended solids (TSS) ranged from below the detection limit (4 mg/L) in November to 22 mg/L in October (BC MWLAP 2004).

#### *4.5.2.2 Existing Sediment Quality*

Sediment samples collected as part of the Marine Sediment and Water Quality Report (Stantec 2013b) and Sediment Quality Data Report (Stantec 2013c) were collected at 29 locations within 500 m of Westridge Terminal, from varying depths to a maximum of 2 m; a total of 59 samples were analyzed.

Although there was spatial variability, surface sediment (top 7.5 cm) consisted on average of sand (61%) with some silt (30%) and clay (8.6%). Sediment collected using a corer (0 to 2 m depth) differed from surface samples with lower sand (39%) and higher silt (45%) and clay (16%) content. Total organic carbon (TOC) content, measured as %TOC, ranged from 0.36 to 2.9%, with an average of 1.95%.

All EPH and BTEX (benzene, toluene, ethylbenzene, xylenes) levels were below detection limits. Total non-alkylated PAH concentrations in surface and core samples (0 to 1 m depth) ranged from below the detection limit (0.20 mg/kg) to 3.66 mg/kg. Only one sample was above the *Disposal at Sea Regulations* screening criterion of 2.5 mg/kg. Concentrations of some individual PAH compounds exceeded the CCME interim sediment quality guideline (ISQG); however, those concentrations were below the probable effects level (PEL). Mean PAH levels were highest in the surface grab samples (1.47 mg/kg), intermediate in the 0 to 0.5 m cores (1.26 mg/kg) and lowest in the 0.5 to 1.0 m cores (0.39 mg/kg).

For metals, zinc and chromium concentrations were below the *Disposal at Sea Regulations* screening criteria and CCME ISQGs. Mercury exceeded the ISQG but not the Disposal at Sea screening criterion in 14 of 53 samples, and arsenic, cadmium, copper and lead exceeded both the screening criteria and ISQGs in several samples. Elevated levels of arsenic were noted at all depths sampled and throughout the sampling area, suggesting natural sediment conditions. In contrast, elevated levels of cadmium and lead occurred in core samples from 0 to 0.5 m depth only (not in surface grabs), suggesting anthropogenic sources unrelated to Westridge Terminal operations. Copper exceedances occurred at all depths and throughout the sampling area but were highest in core samples taken from 0 to 0.5 m depth, suggesting a combination of natural sediment and anthropogenic sources.

Concentrations of polychlorinated biphenyl (PCB) compounds were below detection limits, with the exception of PCB 1254, which was above its detection limit in six surface samples and ten core samples from the 0 to 0.5 m range. Total PCBs were marginally above the detection limit in the majority of these samples, but were above the *Disposal at Sea Regulations* screening level in one sample.

Literature/desktop review of available information indicates that concentrations of hydrocarbons and some metals in sediment have historically been elevated near Westridge Terminal. In samples collected prior to dredging activities in 2005 at the Terminal (BGC 2006 in Stantec 2013b), total non-alkylated PAH concentrations ranged from below detection limits to 130 mg/kg, and in 15 samples the concentrations were higher than the *Disposal at Sea Regulations* screening criterion (2.5 mg/kg). Concentrations were higher in the surface 0.6 m than in deeper sediment, and highest at the pier itself. BTEX and volatile petroleum hydrocarbons were not detected in 46 of 48 samples analyzed, and PCBs were not detected in 36 of 38 samples analyzed. There were no exceedances of the *Disposal at Sea Regulations* screening criterion for cadmium but there were 11 exceedances for mercury. Exceedances of total non-alkylated PAHs and metals were all below screening criteria after the dredge program in 2005 (BGC 2006 in Stantec 2013b).

The total non-alkylated PAH level in subtidal sediment collected from the Shellburn location as part of the Water Quality Objectives Attainment Monitoring in Burrard Inlet in 2002 was 1.0 mg/kg and total PCB was below the detection limit (BC MWLAP 2004). Subtidal sediment levels were above the *Disposal at Sea Regulations* screening criteria for arsenic, copper, and lead (BC MWLAP 2004).

Intertidal sediment sampling for PAHs conducted in 2007 following the accidental release of oil during the July 2007 pipeline rupture showed that total non-alkylated PAH levels were higher than the Burrard Inlet sediment quality guideline (1.68 mg/kg) and the *Disposal at Sea Regulations* screening criterion (2.5 mg/kg) at several locations near where released oil entered Burrard Inlet (Stantec 2010a). Following remediation in 2007 and 2008, total non-alkylated PAH levels were notably reduced, with no further exceedences of the *Disposal at Sea Regulations* screening criterion in 2010 or 2011; several individual PAH compounds had levels above Burrard Inlet sediment quality guidelines at two locations (Stantec 2012a in Stantec 2013b).

### 4.5.3 Effects Assessment and Recovery – July 2007 Spill near the Westridge Marine Terminal

In the 2007 case study near the WMT, the pipeline carrying crude oil between the Burnaby Terminal and the WMT was accidentally punctured by City of Burnaby workers while conducting sewer work. The incident resulted in the release of approximately 224,000 litres (224 $m^3$) of crude oil onto the ground surface, of which approximately 100,000 litres (100 $m^3$) entered the local storm drain system, and discharged into Burrard Inlet. In this case, subsequent response operations recovered all but an estimated 6,000 litres (6 $m^3$) of the spilled oil (Stantec 2010).

Surface water samples were collected at several locations one and two weeks after the incident. All sample results were below detection limits for extractable petroleum hydrocarbons (EPHs). In addition, while concentrations of PAHs were above detection limits at a few locations, none exceeded water quality guidelines which are protective of the marine environment. The follow-up monitoring and assessment report concluded that oil concentrations in the water column likely peaked soon after the release, but decreased to background levels within days (Stantec 2010).

Sediment tests indicated some areas with PAH concentrations above applicable guidelines. A comparison of PAH composition in sediment samples and released oil indicates that sediment in the Westridge area has likely been affected by the oil release, as well as by historic shipping activity and other sources of PAH. Sediment from sites further away (*e.g.,* Maplewood Flats, Deep Cove, Cates Park, Belcarra, Port Moody flats, Barnet Marine Park) also contained measurable PAHs, but their chemical fingerprint did not match that of the released oil.

A biophysical assessment of the affected marine areas, using Shoreline Clean-up Assessment Technique (SCAT) protocols, indicated effects in the intertidal area. Of the 50 km of shoreline assessed during SCAT surveys, approximately 15 km, east of Second Narrows, was affected by the accidental release. The most heavily affected area was 2.5 km of shoreline between the Shell Jetty Marine Terminal and Barnet Beach at Barnet Marine Park. This heavily oiled area was extensively remediated through removal of oiled seaweed (Fucus), agitation of soft sediments (sand, mud) and application of the shoreline treatment agent Corexit 9580 (a biodegradable cleanser that contains surfactant). As a result of the oil release and remediation, this area experienced habitat loss and death or removal of marine plants (primarily Fucus) as well as a likely loss of intertidal fauna such as starfish, barnacles and limpets. An analysis of mussels collected throughout the eastern part of the inlet indicated that only in the Westridge area was there an amount and distribution pattern (fingerprint) of PAHs that could be associated with the release.

Subtidal organisms may also have been affected by the release, but these effects appear to be limited and localized. Red rock crabs from the Westridge area showed elevated PAH levels and a similar pattern of PAH to the released oil. However, none of the Dungeness crabs sampled at Westridge or crabs of either species from Barnet Marine Park and Berry Point and elsewhere in the Inlet (Indian Arm and Port Moody Arm) showed evidence of having taken up oil from the release. There was no evidence for direct effects on fin-fish species.

Effects of the release were noted for some marine birds and mammals. Fifteen Canada geese, two gulls and one pelagic cormorant were captured as a result of oiling. All but two Canada geese were cleaned and released, one of the two not released was transferred to a different facility and the other was euthanized as a result of an injured eye. Effects on other species of marine birds were minimal, largely because overwintering birds had not yet returned from their northern breeding ranges. Three dead harbour seal pups were found in Burrard Inlet following the release, but cause of death could not be determined, and only one had signs of oil exposure. No other effects on marine mammals, including otters, were reported in Burrard Inlet.

## 4.6 Seasonal Distribution and Variability of Biological Resources in Burrard Inlet

This section describes the major biological resources present in Burrard inlet, in order to support the development of a consolidated set of Ecological Receptors for the ERA, in Section 5.3 of this report.

Burrard Inlet is a productive marine environment, supporting a diverse assemblage of algae, invertebrates, fish, marine mammals and birds. Over 100 taxa of invertebrates and over 75 species of fish have been documented to inhabit intertidal and subtidal habitats in Burrard Inlet (Renyard 1988, Hanrahan 1994, Richoux *et al.* 2006). Species diversity is strongly influenced by habitat type, with the highest diversity typically associated with rocky intertidal and shallow subtidal areas.

The biological features of Burrard Inlet and Indian Arm characterized throughout this report were based on a variety of information sources and databases. Table 4.2 lists the data sources and types of data used for each resource.

### TABLE 4.2 DATA SOURCES FOR BIOLOGICAL RESOURCE EVALUATION

| Resource / Receptor | Data Source | Data Type |
|---|---|---|
| ***Marine Fish and Supporting Habitat*** | | |
| Bathymetry | NOAA National Geophysics Data Centre | GIS Raster, converted to polygon |
| Herring Spawning Areas (Canada) | British Columbia Marine Conservation Analysis | GIS Raster, converted to polygon |
| Herring Spawning and Holding Areas (US) | Washington Department of Fish and Wildlife | GIS Polygon |
| Rock Fish Conservation Area (Canada) | British Columbia Land and Resources Data Warehouse | GIS Polygon |
| ***Marine Birds and Supporting Habitat*** | | |
| Important Bird Areas (Canada) | Canada Wildlife Services | GIS Polygon |
| Important Bird Areas (US) | Audubon Society | GIS Polygon |
| Shorebird nesting/breeding sites (Canada) | Bird Studies Canada | GIS Point |
| Shorebird nesting/breeding sites (US) | Washington Department of Fish and Wildlife | GIS Point |
| Migratory Bird Sanctuary (Canada) | Environment Canada | GIS Polygon |
| ***Marine Mammals and Supporting Habitat*** | | |
| Bathymetry | NOAA National Geophysics Data Centre | GIS Raster, converted to polygon |
| Northern and Southern Resident Killer whale critical habitat | Department of Fisheries and Oceans | GIS Polygon |
| Humpback whale proposed protected habitat for Humpback whale | Department of Fisheries and Oceans | GIS Polygon |
| Haulouts (Canada) | British Columbia Marine Conservation Analysis | GIS Point |
| Haulouts (US) | Washington Department of Fish and Wildlife | GIS Point |
| ***Shoreline and Near Shore Habitats*** | | |
| Classification | EBA, as adapted from Harper (2013) | GIS Polyline |
| Eel grass and kelp beds (Canada) | British Columbia Marine Conservation Analysis | GIS Polygon |
| Eel grass and kelp beds (US) | Washington Department of Natural Resources | GIS Polygon |
| ***Other Habitats*** | | |
| National Parks (Canada) | Government of British Columbia | GIS Polygon |
| Marine Protected Areas (Canada) | Department of Fisheries and Oceans | GIS Polygon |
| Marine Protected Areas (US) | NOAA | GIS Polygon |
| Aboriginal reserves (Canada) | Geogratis | GIS Polygon |
| Aboriginal reserves (US) | Washington Department of Transportation | GIS Polygon |
| Ecological Reserves (Canada) | Government of British Columbia | GIS Polygon |
| National Marine Conservation Areas (Canada) | Government of British Columbia | GIS Polygon |
| Provincial Parks (BC) | Government of British Columbia | GIS Polygon |
| National Wildlife Areas | Government of British Columbia | GIS Polygon |
| Sea Turtle Critical Habitat | NOAA Fisheries | GIS Polygon |

### *4.6.1 Shoreline and Intertidal Habitats and Resources*

The following descriptions of the habitat and fish community of Burrard Inlet have been extracted with some modification from the Marine Resources - Westridge Marine Terminal Technical Report (Stantec 2013a) Volume 5C.

The intertidal zone is defined as the area between the Highest High Water Mark (HHWM) line and Mean Lower Low Water (MLLW) line for spring tides (Williams 1993). Intertidal habitat is strongly influenced by a range of physical and biological factors including substrate type, slope, wave exposure, shore width, tidal range, salinity, light, temperature, and species assemblages (Burd *et al.* 2008, Howes *et al.* 1997, Levings *et al.* 1983; Williams 1993). Differences in the relative degree of influence among these factors can result in different species assemblages in similar intertidal habitats (Burd *et al.* 2008). Common intertidal species assemblages in British Columbia include marsh plants, seaweeds and other algae, eelgrass, invertebrates, and fish (Williams 1993).

British Columbia"s intertidal zone provides spawning, rearing, migration and foraging habitat for a diverse range of marine organisms including algae, invertebrates, and fish. Pacific salmon are known to use the intertidal zone of estuaries as rearing and migration habitat (Healey 1980; Levings and Thom 1994;

Levings and Jamieson 2001). Pacific salmon also feed on organisms that originate in seagrass and algae in the intertidal zone (Levings and Thom 1994, Levings and Jamieson 2001). Pacific herring (*Clupea harengus pallasi*) use intertidal seagrass and algae as spawning substrate for their eggs (Humphreys and Hourston 1978, Levings and Thom 1994). Surf smelt (*Hypomesus pretious*) and Pacific sand lance (*Ammodytes hexapterus*) spawn on intertidal sand and gravel substrates (Penttila 1997, 2002, Robards *et al.* 1999). Certain species of gunnels and sculpins use the low to mid intertidal zone for nesting and incubation (Hart 1973, Levings and Jamieson 2001). Larvae of Dungeness crabs and Manila clams settle in intertidal areas with shell, gravel, and eelgrass substrates (Burd *et al.* 2008).

The dominant species of algae in intertidal habitats throughout Burrard Inlet are rockweeds. With its gas filled bladders, rockweed becomes suspended in the water column when submerged, and provides a three dimensional matrix within which juvenile fish and invertebrates can forage and avoid predators. At low tide, rockweed provides refuge and protection against desiccation for many of the same organisms. Other common species of algae include sea lettuce (*Ulva* spp.), Turkish washcloth (*Mastocarpus papillatus*), sugar kelp (*Laminaria saccharina*) and five-ribbed kelp (*Costaria costata*) (Druehl and Hsiao 1977, Stantec 2012a). All of these species have been previously identified within the study area.

Eelgrass beds (*Zostera marina*) have been mapped in the vicinity of Maplewood Flats, and may occur at other locations in Burrard Inlet as well. Eelgrass beds are essential habitats for a number of economically, culturally and ecologically important species including juvenile salmon (*Oncorhynchus* spp.), Pacific herring (*Clupea pallasii*), rockfish (*Sebastes* spp.), and Dungeness crab (*Metacarcinus magister*) (Wilson and Atkinson 1995, Nelson and Waaland 1997).

Invertebrate surveys conducted throughout Burrard Inlet have identified over 100 taxa inhabiting a wide range of habitat types (Burd and Brinkhurst 1990, Richoux *et al.* 2006). Common intertidal species include blue mussel (*Mytilus edulis*), acorn barnacle, purple ochre stars (*Pisaster ochraceus*), snails (Littorina spp.), shore crabs (*Hemigrapsus* spp.) and limpets (*Lottia* spp.) (Foreshore 1996 in Haggarty 2001, Richoux et al. 2006, Stantec 2012a). Common subtidal species include Dungeness crab (*Cancer magister*), red rock crab (*Cancer productus*), anemones, tube worms, sea cucumbers, and shrimps (Foreshore 1996 in Haggarty 2001, Richoux *et al.* 2006, Stantec 2012a). In addition to these more conspicuous species, a large number of infaunal organisms (*i.e.,* those living beneath the seafloor) have been identified in Burrard Inlet. These include species from the following groups: polychaeta; oligochaeta; bivalvia; aplacophora; scaphopoda; isopoda; cumacea; decapoda; mysidacea; amphipoda; sipunculida; nemertean; holothuroidea; and ophiuroidea (Burd and Brinkhurst 1990, Richoux *et al.* 2006).

Since 2007, Stantec has conducted an annual survey of intertidal habitat and communities at six sites in Burrard Inlet, including the Westridge Marine Terminal, as part of a long-term monitoring program initiated after the accidental hydrocarbon release at the Westridge Terminal in July 2007. A total of 7 species of algae and 11 species of marine invertebrates were identified in the intertidal zone of Burrard Inlet between 2007 and 2012 (Stantec 2010a, b; 2011; 2012a, b). Rockweed, Turkish washcloth, and sea lettuce were the common macroalgae species observed, while barnacles (*Balanus glandula*), blue mussels, periwinkles and limpets were the most common invertebrate species. Richoux *et al.* (2006) identified a total of 103 taxa of invertebrates during a survey of 29 intertidal sites in Burrard Inlet.

### *4.6.2 Subtidal Habitat*

Subtidal habitat is strongly influenced by physical factors of the seabed including topography (macro relief), roughness (micro relief), sediment type and distribution, grain size and shape, patchiness, rock composition, and sediment thickness (Fader *et al.* 1998, Levings *et al.* 1983, Todd and Kostylev 2010). Oceanographic factors such as oxygen saturation, temperature variability, water stratification, and chlorophyll-a concentration also influence subtidal habitat (Todd and Kostylev 2010).

Shallow subtidal habitats (<20 m) cover an estimated 1,245 $km^2$ or 18% of the surface area of the Strait of Georgia (Levings *et al.* 1983). Sand and mud are the dominant substrate types in the Strait and represent an estimated 67% of the total subtidal habitat in the region (Levings *et al.* 1983). Subtidal habitats of Burrard Inlet are dominated by shallow (<30 m) mud substrates in inner portions of the Inlet, mid-depth (30 to 100 m) mud substrates in outer areas of the Inlet, and mid-depth silt/sand substrates in the vicinity of the First Narrows bridge and near the south side of the mouth of the Inlet (Burd *et al.* 2008, Burd 1990). Shallow and mid-depth mud substrates tend to be protected from wave exposure and are typically associated with low tidal currents (Burd *et al.* 2008). Information about marine sediment and water quality in Burrard Inlet and the Strait of Georgia is provided in the Westridge Marine Terminal Marine Sediment and Water Quality Technical Report.

Benthic substrates provide habitat for a diverse range of infauna, epifauna, and bottom-dwelling fish. Subtidal species assemblages in British Columbia may include algae and seaweeds, eelgrass, invertebrates and fish (Williams 1993). According to Levings and Thom (1994), studies of kelp beds in the southern Strait of Georgia have identified only two kelp beds in Burrard Inlet at Coal Harbour and Brockton Point.

Benthic communities in shallow to mid-depth soft substrates in the Strait of Georgia typically comprise bivalves, polychaetes, amphipods, bottom shrimp, gastropods, mud stars, brittle stars, heart urchins, spoon worms, and fish (Burd *et al.* 2008). Extensive bacterial and/or algal mats are common in these habitats as a result of the considerable particulate organic matter contained in soft substrates (Burd *et al.* 2008). Studies on macrobenthic infauna in Burrard Inlet indicate that the most abundant species include bivalves, gastropods, and polychaetes (Burd 1990). The abundance and species richness of macrobenthic infauna in Port Moody Arm appear to be more temporally variable and much lower relative to the rest of Burrard Inlet (Burd *et al.* 2008, Burd 1990).

Common subtidal invertebrate species include Dungeness crab (*Metacarcinus magister*), red rock crab (*Cancer productus*), anemones, tube worms, sea cucumbers, and shrimps (Foreshore 1996 in Haggerty 2001, Richoux *et al.* 2006, Stantec 2012a). In addition to these more conspicuous species, a large number of infaunal organisms (*i.e.,* those living beneath the seafloor) have been identified in Burrard Inlet. These include species from the following groups: *Polychaeta*; *Oligochaeta*; *Bivalvia*; *Aplacophora*; *Scaphopoda*; *Isopoda*; *Cumacea*; *Decapoda*; *Mysidacea*; *Amphipoda*; *Sipunculida*; *Nemertean*; *Holothuroidea*; and *Ophiuroidea* (Burd and Brinkhurst 1990, Richoux *et al.* 2006).

#### *4.6.2.1 Dungeness Crab*

Dungeness crab ranges from the Aleutian Islands in Alaska to Magdalena Bay, Mexico, and can be found at depths ranging from the intertidal, to 230 m (DFO 2012a, Fong and Gillespie 2008). They are usually found on sandy bottoms less than 50 m deep with moderate to strong current (DFO 2000).

Dungeness crabs grow periodically rather than continuously by molting, a process by which they produce a new shell and shed their old shell (DFO 2000, Fong and Gillespie 2008). The new shell quickly swells with water to a size 15% to 30% larger and remains soft for several weeks (DFO 2012a). The molting frequency depends on temperature, size, sex and sexual maturity (Fong and Gillespie 2008). Immature crabs may molt several times a year while mature crabs may molt once a year or every two years. Dungeness crabs reach sexual maturity at about 2 to 3 years of age which corresponds to 10 or 11 molts (Fong and Gillespie 2008). Males have a carapace width of approximately 116 mm at maturity, and females have a carapace width of approximately 100 mm at maturity (MacKay 1942, Fong and Gillespie 2008). In British Columbia, male Dungeness crabs reach a maximum size of 215 mm carapace width and a maximum weight of 2 kg, and have a lifespan of approximately 6 to 9 years (DFO 2000, DFO 2012a, Fong and Gillespie 2008).

Dungeness crabs mate immediately after the female molts and the fertilized eggs are carried on the underside of the female‟s abdomen. During its lifetime, a female Dungeness crab produces approximately three to five million eggs (MacKay 1942, Fong and Gillespie 2008). In British Columbia, mating occurs from April to September and hatching occurs from December to June, with a peak in March (MacKay 1942, Fong and Gillespie 2008). The larvae develop for 3 to 4 months and become dispersed by currents before settling on the bottom (DFO 2000).

The diet of a Dungeness crab depends on its life stage. Larvae feed offshore in the water column on zooplankton and phytoplankton; juveniles forage in littoral habitats for clams and mussels, small fish, molluscs, shrimp, and other crabs (DFO 2012a); and adult crabs feed on clams and mussels, crustaceans, worms, and fish (DFO 2012a).

Dungeness crabs have great social, cultural, and economic importance in British Columbia and are harvested by commercial, recreational, and Aboriginal fisheries (Fong and Gillespie 2008). As a result of the high natural variability in Dungeness crab populations caused by changing marine environmental conditions, it is difficult to obtain reliable abundance estimates from year to year (Fong and Gillespie 2008). All major Dungeness crab fishing areas in British Columbia are considered to be fully exploited and the demand and competition among the various fishing sectors is increasing (DFO 2000, Fong and Gillespie 2008). In 2010, 4,543 tonnes of Dungeness crab was landed by the commercial fishery in British Columbia with a value of $32.2 million (DFO 2012a). The 2010 landings marked the fourth consecutive year of harvest decline (DFO 2012a). In 2005, over 800,000 pounds of Dungeness crab was harvested in British Columbia"s recreational fishery, with 63% of this total harvested from the Strait of Georgia (DFO 2012a).

DFO maintains a database of Important Areas that are considered relevant to a species in terms of uniqueness, aggregation, and/or fitness (DFO 2013). DFO"s Important Areas for Dungeness crab in Burrard Inlet are shown in the Marine Resources – Westridge Marine Terminal Technical Report, (Stantec 2013a) Volume 5C. Several areas in eastern Burrard Inlet have been identified as Important Areas for Dungeness crab: this includes portions of the Inner Harbour, Port Moody Arm and Indian Arm (Jamieson and Levesque 2012a, b). The distribution, seasonal timing and conservation status for the Dungeness crab are summarized in Table 4.3.

**TABLE 4.3 DISTRIBUTION, SEASONAL TIMING AND CONSERVATION STATUS FOR DUNGENESS CRAB**

| Species | Relevant Distribution and Seasonal Timing | Conservation Status | | |
|---|---|---|---|---|
| | | *SARA* | BC | COSEWIC |
| Dungeness crab | Dungeness crabs mate immediately after the female moults and the fertilized eggs are carried on the underside of the female's abdomen. During its lifetime, a female Dungeness crab produces approximately three to five million eggs (MacKay 1942, Fong and Gillespie 2008). In British Columbia, mating occurs from April to September and hatching occurs from December to June, with a peak in March (MacKay 1942, Fong and Gillespie 2008). The larvae develop for 3 to 4 months and become dispersed by currents before settling on the bottom (DFO 2000). | No Status | No Status | No Status |

Source: Conservation Status (BC CDC 2013)

### *4.6.3 Marine Fish*

At least 75 species of fish are known to use Burrard Inlet (Renyard 1988, Hanrahan 1994). Common species found throughout the inlet include the shiner surfperch (*Cymatogaster aggregate*), starry flounder (*Platichthys stellatus*), English sole (*Pleuronectes vetulus*), rock sole (*Lepidospetta bilineata*), Dover sole (*Microstomus pacificus*) and staghorn sculpin (*Leptocottus armatus*) (Renyard 1988). Commercially important species include Pacific herring (*Culpea pallasii*), anchovy (*Engaulis mordax*), lingcod (*Ophiodon elongatus*), copper rockfish (*Sebastes caurinus*), quillback rockfish (*Sebastes maliger*) and kelp greenling (*Hexagrammos decagrammus*) (Renyard 1988). All five species of Pacific salmon, including chum (*Oncorhynchus keta*), chinook (*O. tshawytscha*), pink (*O. gorbuscha*), coho (*O. kisutch*), and sockeye (*O. nerka*) utilize near shore habitats in Burrard Inlet from spring through fall (Levy 1996, Macdonald and Chang 1993, Naito and Hwang 2000). Adult salmon have been observed to return to at least 17 streams in Burrard Inlet (Haggarty 2001, BC MOE 2013). Juvenile salmon migrating out of these streams are also expected to use near shore habitats within the study area for rearing and migration. Additional information on some of the marine fish species of Burrard Inlet is provided below.

#### *4.6.3.1 Pacific Salmon*

Pacific salmon belong to the family *Salmonidae*, which includes whitefishes, graylings, salmon, trout, and char. There are five species of Pacific salmon in Canada belonging to the genus *Oncorhynchus* including pink, chum, sockeye, coho, and Chinook; and in addition steelhead (rainbow) trout (*Oncorhynchus mykiss*) can be considered alongside the salmon species. The range of Pacific salmon includes the North Pacific Ocean, Bering Strait, southwestern Beaufort Sea, and surrounding freshwater rivers and streams (DFO 2012b). Pacific salmon occur in an estimated 1,300 to 1,500 rivers and streams in British Columbia and the Yukon (DFO 2012b). The most important rivers for Pacific Salmon in British Columbia include the Skeena River and Nass River in the north and the Fraser River in the south which together account for 75% of the salmon population in the province (DFO 2012b). The Fraser River system, which drains into the RSA, is considered the largest single salmon production system in the world (Northcote and Larkin 1988) and accounts for, on average, about 50% of salmon production in British Columbia (Henderson and Graham 1998). Burrard Inlet has been identified by DFO as an Important Area for Pacific salmon (Jamieson and Levesque 2012a, b) and 17 salmon-bearing rivers and streams draining into Burrard Inlet have been identified (BC MOE 2013). The location of the salmon-bearing rivers and streams in the RSA are shown in the Marine Resources - Westridge Marine Terminal Technical Report (Stantec 2013a), Volume 5C.

Pacific salmon are of great cultural and economic importance in British Columbia and all species are harvested in commercial, recreational, and Aboriginal fisheries. They are also ecologically important species because they support oceanic, estuarine, freshwater, and terrestrial food webs by providing nutrients to the ecosystem during their migration from the ocean to rivers and streams to spawn (DFO 2012b).

Nearly 10,000 salmon stocks have been identified in Canadian Pacific waters (DFO 2001). The vast number of stocks and the complex life cycles of Pacific salmon present a substantial assessment and management challenge (DFO 2012b). Fisheries for Pacific salmon are managed by DFO under the *Fisheries Act* and Canada's Policy for Conservation of Wild Pacific Salmon (Wild Salmon Policy). Under the Wild Salmon Policy, wild salmon populations are managed by conservation units that reflect their geographic and genetic diversity. Each year, DFO prepares a Southern BC Salmon Integrated Fisheries Management Plan (IFMP) to guide the management of the salmon fishery. The IFMP provides a context to the management of the Pacific salmon fishery and the interrelationships of all fishing sectors involved in the fishery (DFO 2012b). The IFMP outlines management objectives, access and allocation, decision guidelines, and management measures. DFO also administers the Salmonid Enhancement Program (SEP) which is comprised of over 300 projects involving hatcheries, fishways, spawning and rearing channels, and small classroom incubators (DFO 2012b).

Pacific salmon are anadromous, meaning that they spawn in fresh water but spend a good portion of their lives in marine waters, where they feed until maturity (DFO 2012b). The life span of Pacific salmon ranges from two years for pink salmon, to seven or eight years for sockeye, chinook, and chum salmon (DFO 2012b, DFO 2001). Depending on the species, salmon will spend one to seven years in marine waters before returning to their natal streams to spawn from spring to fall (DFO 2012b, DFO 2001). All Pacific salmon (but not steelhead) are semelparous, meaning that individual fish spawn once in their lifetime and then die.

Spawning female salmon seek out stream beds with gravel substrate to create a nest, known as a redd, where they deposit their eggs. Waiting male fertilizes the eggs by releasing a cloud of milt. The female then covers up the redd with gravel to protect it, constructs a second nest, and repeats the process until all of her eggs are deposited. After fertilization, eggs are buried in gravel substrate on the river/stream bed. The eggs hatch into alevins in mid-winter and emerge as fry in spring where they stay in freshwater streams and lakes for periods ranging from 1 week to 2 years, depending on species (DFO 2012b).

Pacific salmon are sensitive to changes in both marine and freshwater ecosystems (DFO 2012b). Fishing pressure and loss of habitat from human activities such as logging and agriculture are the key threats to Pacific salmon populations (COSEWIC 2006, 2003a, 2003b, 2002, DFO 2012b, 2001). Four populations of Pacific salmon have been designated as species of conservation concern by COSEWIC including one coho population, one chinook population, and two sockeye populations. No Pacific salmon populations are currently listed under *SARA*. DFO‟s 2012 salmon outlook identified a number of Pacific salmon stocks of conservation concern (DFO 2012b).

The physical characteristics, life histories, and spawning habits vary from species to species. This information is summarized below for each of the five Pacific salmon species. Pacific salmon generally return to their natal streams in the late summer early fall to December, with the exception of the Chinook salmon which tends to return earlier. Steelhead trout, in contrast, are spring spawners, but are noted for their highly variable life history. The distribution, seasonal timing and conservation status for the five Pacific salmon species and steelhead trout are summarized in Table 4.4. Additional details for each Pacific salmon species are presented in corresponding sub-sections below.

**TABLE 4.4 DISTRIBUTIONN, SEASONAL TIMING AND CONSERVATION STATUS FOR PACIFIC SALMON AND STEELHEAD TROUT**

| Species | Relevant Distribution and Seasonal Timing | Conservation Status | | |
|---|---|---|---|---|
| | | ***SARA*** | **BC** | **COSEWIC** |
| Pink salmon | Pink salmon are the least dependent on fresh water of all the Pacific salmon and trout species and they have the ability to spawn in the lower reaches of coastal streams that are tidally inundated (Holtby and Ciruna 2007). Pink salmon display a high fidelity to spawning in their native streams (Heard 1991, Hard *et al.* 1996), but larger populations of pink salmon may also colonize new habitat (Holtby and Ciruna 2007). Pink fry begin migrating to the sea in April and May where they remain for approximately 18 months before returning to their natal streams to spawn in September and October (DFO 2012b, DFO 2001, Hart 1973). | No Status | Yellow | No Status |
| Chum salmon | Chum fry emerge in spring and begin migrating to feeding grounds in the Pacific Ocean (DFO 2012b, DFO 2001). | No Status | Yellow | No Status |
| Sockeye salmon | Fry emerge in spring, rear in freshwater lakes for 1 to 3 years, and then migrate to the ocean for another 2 to 3 years before returning to their natal stream to spawn (DFO 2001, Hart 1973). | No Status | Yellow | Endangered |
| Coho salmon | Mature coho salmon migrate to their natal streams from October to December to spawn (DFO 2012b, DFO 2001). Juvenile coho remain in their spawning stream for 1 to 2 years before migrating to marine waters in the spring (DFO 2012b, DFO 2001). | No Status | Yellow | Endangered |
| Chinook salmon | Chinook salmon populations are categorized based on two major life-cycle types: stream and ocean (DFO 2001). Stream-type chinook typically spend 1 to 2 years in fresh water before migrating to marine waters, while ocean-type chinook typically spend no more than 90 days in fresh water before migrating to sea (DFO 2012b, DFO 2001).<br>Spawning times for chinook vary among stocks. They are often referred to as "spring salmon" because they spawn earlier than other Pacific salmon species. Chinook generally migrate upstream to the middle to upper regions of large rivers in British Columbia from the spring through fall to spawn (DFO 2012b, DFO 2001, Hart 1973). These upstream migrations can be as far as 1,500 km inland (DFO 2012b). The majority of chinook salmon in British Columbia come from the Fraser River watershed where spawning occurs from August to December (DFO 2001). Fry emerge in the spring. | No Status | Yellow | Threatened |
| Steelhead trout | The Fraser and other British Columbia rivers support anadromous stocks of rainbow trout known as steelhead. Run timing for steelhead is usually late summer in Juan de Fuca strait, although there are some spring-run populations. They typically spawn in the winter and spring. Juvenile fish may stay in fresh water from 1 to 3 years, often mixing with freshwater populations of rainbow trout before migrating to sea. Steelhead differ from other Pacific *Oncorhynchus* species in being able to spawn more than once, after returning to the sea. | No Status | Yellow | No Status |

Source: Conservation Status (BC CDC 2013)

## Pink Salmon

Pink salmon are the smallest and most abundant of the five species of Pacific salmon. Adult pink salmon weigh an average of 1 to 3 kg but can reach a maximum size of 76 cm in length and weigh up to 6.8 kg (DFO 2012b, DFO 2001, Lamb and Edgell 2010). Mature pink salmon are silver with bluish backs and large oval spots on their tail fin and back (DFO 2001; Lamb and Edgell 2010). Spawning pink salmon develop a pale grey back and a white to yellowish body (DFO 2001). Spawning males also develop a distinctive humped back and are sometimes referred to as “humpbacks” or “humpies”.

Pink salmon have a life span of only two years; most of which is spent feeding at sea (DFO 2012b, DFO 2001). Their diet consists primarily of plankton, euphausiids, coepods, amphipods, fish, and squid (DFO 2012b, Hart 1973). In North America, pink salmon demonstrate a fixed two-year life cycle where even-year fish and odd-year fish are completely reproductively isolated (DFO 2001, Heard 1991, Holtby and Ciruna 2007). As adults, pink salmon leave the ocean in the late summer and early fall and usually spawn in streams a short distance from the sea (DFO 2012b, Hart 1973, Holtby and Ciruna 2007). Pink salmon are the least dependent on fresh water of all the Pacific salmon and trout species and they have the ability to spawn in the lower reaches of coastal streams that are tidally inundated (Holtby and Ciruna 2007). Pink salmon display a high fidelity to spawning in their native streams (Heard 1991, Hard *et al.* 1996), but larger populations of pink salmon may also colonize new habitat (Holtby and Ciruna 2007). Pink fry begin migrating to the sea in April and May where they remain for approximately 18 months before returning to their natal streams to spawn in September and October (DFO 2012b, DFO 2001, Hart 1973).

The abundance of Pacific salmon populations is difficult to assess from year to year as a result of the random variability in annual survival rates (Grant and MacDonald 2012). In 2010, the abundance of Fraser pink salmon fry was estimated at 1 billion, which was the largest abundance of out-migrating fry on record and was more than double the long-term average of 376 million fry. While there was a high degree of uncertainty associated with the 2011 forecast, the estimated Fraser River pink salmon run size was between 9.2 million and 37.5 million fish (Grant and MacDonald 2012).

Even-year and odd-year pink salmon generally occur in equal abundance throughout British Columbia waters, but there are some geographic patterns in their relative abundance (Holtby and Ciruna 2007). Even-year pink salmon are either absent or rare in Puget Sound, southeast Vancouver Island, and the Fraser River, but are the dominant brood in Haida Gwaii (Holtby and Ciruna 2007). As a result of the dominance of odd-year pink salmon in the Fraser River system, there is relatively low abundance of pink salmon that return to the Fraser River in even numbered years (DFO 2012b). Pink salmon on British Columbia‟s south coast belong to a regional group whose range includes mainland portions around the Strait of Georgia and northeast Vancouver Island (Beacham *et al.* 1988, Holtby and Ciruna 2007). Odd-year pink salmon in Burrard Inlet are managed under the East Howe Sound-Burrard Inlet Conservation Unit (Holtby and Ciruna 2007).

Pink salmon populations in British Columbia are considered relatively stable and the 2012 salmon outlook did not identify any pink salmon stocks of conservation concern (DFO 2012b).

### Chum Salmon

Adult chum salmon can weigh up to 20 kg and measure more than 100 cm (DFO 2001, Lamb and Edgell 2010). Chum salmon are metallic blue and silver in colour and may have black speckling on their backs (DFO 2001). They also have dark tips on their pectoral, anal, and caudal fins (Hart 1973). Mature fish have reddish to purplish bars across the sides and dark edges on their fins (DFO 2001, Lamb and Edgell 2010).

Chum salmon have a maximum life span of eight years and their age at maturity ranges from three to five years (DFO 2012b). Chum fry emerge in spring and begin migrating to feeding grounds in the Pacific Ocean (DFO 2012b, DFO 2001). At sea, their diet consists primarily of plankton and crustaceans such as shrimp (DFO 2012b). After 2 to 7 years in the ocean, chum salmon return to their natal rivers to spawn in late fall and early winter (DFO 2012b, Hart 1973). Chum salmon prefer lower tributaries near the coast and rarely migrate more than 150 km inland to spawn (DFO 2012b).

Nearly 900 moderate-sized chum spawning streams have been identified in British Columbia (DFO 2001). Over 400 populations of chum salmon have been identified in the Johnstone Strait, Strait of Georgia, and Fraser River watersheds with the majority of production (85%) occurring in the Fraser River system

(DFO 1999, DFO 2001). These chum stocks are grouped into a single unit known as the Inner South Coast chum stock which spawn between September to January (DFO 2001).

The status of the Inner South Coast chum stock has varied over time. The stock declined sharply between the early 1950s and mid 1960s but had recovered by 1973 following closure of the chum fishery in 1965 and 1966 (DFO 1999). The stock declined again between 1974 and 1981, but recovered through the 1980s and 1990s following the implementation of new management strategies (DFO 1999). The 2012 salmon outlook did not identify any chum stocks of conservation concern (DFO 2012b).

### Sockeye Salmon

Sockeye salmon are the most commercially valuable of the five Pacific salmon species as a result of the superior quality of their flesh (DFO 2001). Sockeye can weigh up to 7 kg and reach a maximum length of 84 cm (DFO 2001, Hart 1973, Lamb and Edgell 2010). Adult sockeye are silver with blue-green backs with fine black specks on the dorsal surface and turn bright red when spawning (DFO 2001, Lamb and Edgell 2010).

Sockeye salmon have a lifespan of five to eight years (DFO 2001). Fry emerge in spring, rear in freshwater lakes for 1 to 3 years, and then migrate to the ocean for another 2 to 3 years before returning to their natal stream to spawn (DFO 2001, Hart 1973). Their diet consists primarily of plankton and crustaceans such as shrimp (DFO 2012b). Sockeye are preyed upon by seals, bears, and gulls during migration and spawning (Hart 1973). Major sockeye runs in British Columbia include watersheds drained by the Fraser, Skeena, and Nass rivers and those of Rivers and Smith Inlets (DFO 2001, Hart 1973). Some sockeye spawn in rivers and streams along the coast but most make long migrations upstream to and through inland lakes (Hart 1973). Fraser River sockeye typically mature and spawn at four years of age and have a four-year life cycle with a dominant year every four years (DFO 2001). During dominant years, the abundance of some population can be many times larger than that of other years (DFO 2012b). Historically, the Adams River sockeye has been the largest spawning population in the Fraser River watershed (DFO 2001).

Cultus Lake and Sakinaw Lake sockeye stocks were identified as stocks of conservation concern in the 2012 salmon outlook (DFO 2012b). Returns of these stocks are particularly low compared to historic levels and a number of management measures have been implemented to support rebuilding of these stocks. The Cultus and Sakinaw sockeye populations have been designated as Endangered by COSEWIC (2003a, b).

Fraser River sockeye stocks experienced a steady and profound decline between 1990 and 2009 (Cohen 2012). In 2009, the pre-season forecast was for a return of 11.4 million Fraser River sockeye but only 1.36 million fish returned (Cohen 2012). In 2010 and 2011, 29 million and 5 million sockeye returned to the Fraser River respectively (Cohen 2012). Following the dismal return in 2009, the federal government established the Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River, known as the „Cohen Commission‟ after the Commissioner Bruce Cohen, to investigate the causes of the decline. The final report of the Cohen Commission concluded that it was likely a combination of multiple Fraser River-specific and region-wide influences and stressors that contributed to the long-term decline of the Fraser River sockeye (Cohen 2012).

### Coho Salmon

Adult coho have silver sides, metallic blue backs, white gums, and irregular black spots on their back and the upper lobe of their tail fin (DFO 2001, Hart 1973, Lamb and Edgell 2010). Spawning males may develop bright red colouration on their sides, bright green on their backs and heads, and dark colouration on their bellies (DFO 2001). Coho salmon can weigh up to 18 kg and reach lengths of 108 cm (Lamb and Edgell 2010).

The age at maturity of coho salmon is typically three years (DFO 2012b). Juvenile coho remain in their spawning stream for 1 to 2 years before migrating to marine waters in the spring (DFO 2012b, DFO 2001). While at sea, coho remain in surface waters near the coast (DFO 2001). Many coho remain in the Strait of Georgia, but some migrate offshore up to 1,600 km into the Pacific Ocean (Hart 1973).

Their diet consists of plankton, small fish such as herring, and crustaceans such as shrimp (DFO 2012b, DFO 2001). Mature coho salmon migrate to their natal streams from October to December to spawn (DFO 2012b, DFO 2001). Coho primarily spawn in small streams, but some spawning takes place in large rivers (Hart 1973).

In the Strait of Georgia, coho are found in more than 350 streams including the lower Fraser River system (DFO 2001). The 2012 salmon outlook has identified the Interior Fraser River, Lower Fraser River, Strait of Georgia coho stocks as stocks of conservation concern (DFO 2012b). COSEWIC has designated the Interior Fraser coho population as Endangered (COSEWIC 2002). Poor marine survivals and impacts to freshwater habitat are ongoing concerns for these stocks.

## Chinook Salmon

Chinook salmon are the largest of the Pacific salmon species and can weigh up to 61 kg and reach lengths of 160 cm (Lamb and Edgell 2010). Chinook salmon are greenish blue to black, have black spots on their back, dorsal fin, and tail fin, and have black gums (Hart 1973, Lamb and Edgell 2010). Spawning fish have a darker colouration and a reddish hue around their fins and bellies (DFO 2001). Spawning males develop enlarged teeth and hooked snouts (DFO 2001).

Chinook salmon have a maximum life span of eight years and their age at maturity ranges from three to seven years (DFO 2012b). Chinook salmon populations are categorized based on two major life-cycle types: stream and ocean (DFO 2001). Stream-type chinook typically spend 1 to 2 years in fresh water before migrating to marine waters, while ocean-type chinook typically spend no more than 90 days in fresh water before migrating to sea (DFO 2012b, DFO 2001). Some chinook will travel up to 1,600 km into the Pacific Ocean where they tend to remain well below the surface (Hart 1973). Chinook salmon feed primarily on plankton, small fish such as herring, and crustaceans such as shrimp (DFO 2012b). Both stream and ocean types will then spend anywhere from 1 to 6 years in the ocean before returning to freshwater streams to spawn (DFO 2001). Most chinook return to spawn in their fourth or fifth year (Hart 1973).

pawning times for chinook vary among stocks. They are often referred to as “spring salmon” because they spawn earlier than other Pacific salmon species. Chinook generally migrate upstream to the middle to upper regions of large rivers in British Columbia from the spring through fall to spawn (DFO 2012b, DFO 2001, Hart 1973). These upstream migrations can be as far as 1,500 km inland (DFO 2012b). The majority of chinook salmon in British Columbia come from the Fraser River watershed where spawning occurs from August to December (DFO 2001). Fry emerge in the spring.

The 2012 salmon outlook has identified the Lower Strait of Georgia and Fraser River chinook stocks as stocks of conservation concern (DFO 2012b). Escapement of the Lower Strait of Georgia chinook stock is currently at low levels due in large part to poor marine survival (DFO 2012b). A number of the Fraser River chinook stocks have demonstrated poor survival rates and poor spawning escapements in recent years and are well below the long-term average (DFO 2012b). COSEWIC has designated the Okanagan chinook population as Threatened (COSEWIC 2006).

## Steelhead Trout

Steelhead are the anadromous form of rainbow trout (*Oncorhynchus mykiss*), belonging to the same genus as the five species of Pacific salmon, but displaying some important differences. Rainbow trout is the common name for a species that displays remarkable plasticity and adapatiblity. In general, this species is more adapted to the freshwater environment than the other species of its genus, and many populations are fully adapted to fresh water. Like many salmonids, however, it remains capable of anadromous life history, and steelhead populations are the result. Spawning usually occurs in spring (February through to June), or later depending upon water temperature and location. The eggs hatch in 3 to 4 weeks at temperatures of 10ºC to 15ºC, and the fry emerge from stream gravels approximately 2 to 3 weeks after hatching. In fresh water, the diet comprises drifting organisms, primarily aquatic insects and crustaceans. Anadromous strains typically spend 3 years in fresh water before migrating to the sea, and may undertake migrations of hundreds of kilometres. At sea for two or three years, steelhead occur throughout the North Pacific, but are most abundant in the Gulf of Alaska and the eastern part of the

North Pacific, occupying habitat with temperatures between 10ºC and 15ºC. While in the ocean, their diet is primarily small fish and crustaceans. Returning to freshwater through the summer and autumn, adult fish spawn in the spring, but differ from other Pacific salmon species in that they can survive spawning and return to the sea to feed, potentially spawning more than once. Most adult steelhead weigh between 2.5 and 5 kg; larger fish are likely to have spent more than one period at sea.

#### *4.6.3.2 Rockfish*

There are 102 species of rockfish belonging to the genus *Sebastes*, of which 36 species are known to occur in Canadian Pacific waters (COSEWIC 2009). Rockfish have long lifespans and are slow to mature. Rockfish eggs are fertilized internally and females provide nutrients to the developing embryos (COSEWIC 2009, DFO 2006; Hart 1973). Juveniles are born as larvae which undergo a pelagic phase before settling in benthic habitats (COSEWIC 2009). Rockfish populations may display episodic recruitment during periods of favourable environmental conditions every 15 to 20 years (COSEWIC 2009; Yamanaka and Lacko 2001).

The life history traits of rockfish such as their late age-at-maturity, slow growth, and episodic recruitment make them inherently vulnerable to human activities and overexploitation in fisheries (COSEWIC 2009). Rockfish are targeted in commercial, recreational, and Aboriginal fisheries in British Columbia. They are also caught incidentally in the hook and line fishery and as bycatch in the prawn trap, groundfish trawl, and shrimp trawl fisheries (DFO 2012c). A number of rockfish populations in British Columbia have been overfished and fishing is the primary threat to rockfish. There is a lack of information about the overall status of rockfish habitat in British Columbia, but their relatively deep subtidal habitat (14 to 143 m deep) remains largely unchanged since the last glaciation (COSEWIC 2009, DFO 2012c).

Eight species of rockfish that occur in Canadian Pacific waters have been identified as species of conservation concern by COSEWIC and three have been listed under *SARA*. The quillback rockfish has been designated as Special Concern by COSEWIC but is not currently listed under *SARA*. The copper rockfish has not been identified as a species of conservation concern.

In an effort to conserve inshore rockfish populations in Canadian Pacific waters, DFO (2002) developed a Rockfish Conservation Strategy. The strategy is focused on monitoring catch levels, reducing harvest levels, stock assessment, and the establishment of Rockfish Conservation Areas (RCAs). RCAs are areas where commercial and recreational fishing activities that negatively impact rockfish are prohibited year-round (DFO 2011). A total of 164 RCAs have been established in British Columbia to date, which together account for an estimated 30% of inshore rockfish habitat in the province (COSEWIC 2009).

Quillback rockfish (*S. maliger*) and copper rockfish (*S. caurinus*) are relatively common and prefer shallow water habitat in inlets. Therefore, these two species are among the most likely to be found in Burrard Inlet. The relevant distribution, seasonal timing and conservation status for these two rockfish species are summarized in Table 4.5. Additional species-specific details are presented below. The Marine Resources - Westridge Marine Terminal Technical Report (Stantec 2013a) Volume 5C shows the location of three RCAs in the RSA including Indian Arm – Crocker Island RCA; Indian Arm – Twin Islands RCA; and Eastern Burrard Inlet RCA. The WMT is located in proximity to the boundaries of the Eastern Burrard Inlet RCA, however, rockfish are not expected to be abundant in that general area, because the subtidal habitat is dominated by soft, muddy substrate rather than the hard substrate preferred by rockfish.

**TABLE 4.5 DISTRIBUTION, SEASONAL TIMING AND CONSERVATION STATUS FOR ROCKFISH**

| Species | Distribution and Seasonal Timing | Conservation Status | | |
|---|---|---|---|---|
| | | *SARA* | BC | COSEWIC |
| Quillback rockfish | Quillback rockfish mate from November to February and are born between March and July with a subsequent pelagic larval phase lasting 1 to 2 months (COSEWIC 2009). Quillback rockfish range from the Gulf of Alaska to southern California (COSEWIC 2009; Lamb and Edgell 2010). They occur in depths ranging from 16 to 182 m but are most common between 50 to 100 m (COSEWIC 2009, DFO 2012c, DFO 2006). | No Status | No Status | Threatened |
| Copper rockfish | Like the quillback, copper rockfish mate in the fall and are born in the spring with a subsequent pelagic larval phase lasting 1 to 2 months. Copper rockfish range from Baja California to the Gulf of Alaska (Hart 1973, Lamb and Edgell 2010). Copper rockfish are found from the subtidal to depths of 180 m but are most common in shallow waters less than 40 m deep (DFO 2006). | No Status | No Status | No Status |

Source: Conservation Status (BC CDC 2013)

## Quillback Rockfish

Quillback rockfish range from the Gulf of Alaska to southern California (COSEWIC 2009, Lamb and Edgell 2010). They have a distinctive high, spiny dorsal fin with deeply notched spines (COSEWIC 2009; Lamb and Edgell 2010). Adult fish are primarily brown with yellow or light tan toward the front of their body, dark fins, and a light coloured saddle patches extending into the dorsal fin (COSEWIC 2009, Hart 1973).

Quillback rockfish occur in depths ranging from 16 to 182 m but are most common between 50 to 100 m in depth (COSEWIC 2009, DFO 2012c, DFO 2006). This species prefers habitat with hard substrates such as rock reefs and ridges, steep relief, and high benthic complexity (COSEWIC 2009, DFO 2012c). They are often found in inlets near rocky reefs and in shallow rock piles (DFO 2006, Hart 1973). Quillback rockfish can live as long as 95 years in British Columbia and can reach lengths of 61 cm (COSEWIC 2009, DFO 2006, Hart 1973, Yamanaka and Lacko 2001). Approximately half of all fish will reach maturity at age 11 (COSEWIC 2009). Quillback rockfish mate from November to February and are born between March and July with a subsequent pelagic larval phase lasting 1 to 2 months (COSEWIC 2009). Larvae and juvenile rockfish are found in the water column at depths of <300 m where they are dispersed by oceanographic processes (COSEWIC 2009). At 6 to 9 months of age, juvenile rockfish will settle in benthic habitats where they feed on small invertebrates (COSEWIC 2009, DFO 2001c). The diet of adult rockfish consists of fish and invertebrates (COSEWIC 2009).

Visual surveys in the Strait of Georgia estimated the abundance of quillback rockfish to be 2.23 million individuals in the 527 $km^2$ survey area (COSEWIC 2009). Studies on quillback rockfish populations in British Columbia indicate they have declined 50% to 75% since the mid-1980s (DFO 2012c).

## Copper Rockfish

Copper rockfish range from Baja California to the Gulf of Alaska (Hart 1973, Lamb and Edgell 2010) and are found from the subtidal to depths of 180 m but are most common in shallow waters less than 40 m deep (DFO 2006). They prefer rocky habitats and kelp beds and are often found around pilings and jetties (DFO 2006, Lamb and Edgell 2010). Copper rockfish are known to prey on crab, squid, octopus, spiny dogfish, sand lance, herring, anchovy, surf perches, sculpins, greenlings, and other rockfishes (Alaska Marine Fisheries Center 2013, Lamb and Edgell 2010). The overall status of copper rockfish populations in British Columbia is unknown although they are relatively common on rocky reefs in shallow waters of the Strait of Georgia (Hart 1973).

Biological information about copper rockfish is limited (DFO 2001). Copper rockfish have olive brown to copper colouration with pink and yellow blotches, white undersides, and a clear, whitish, or pink lateral line (Hart 1973, Lamb and Edgell 2010). This species has a maximum life span of 45 to 50 years and can reach a length of 66 cm (DFO 2006, DFO 2001). Like the quillback, copper rockfish mate in the fall and are born in the spring with a subsequent pelagic larval phase lasting 1 to 2 months.

### *4.6.4 Marine Birds and Bird Habitat*

The following descriptions of the marine bird community of Burrard Inlet have been extracted with some modification from the Marine Birds, Westridge Marine Terminal Technical Report (Stantec 2013b) Volume 5C.

Burrard Inlet has been designated as an Important Bird Area (IBA020 - English Bay & Burrard Inlet) by BirdLife International, a partnership of Nature Canada and BC Nature (Bird Studies Canada and Nature Canada 2013, Birdlife International 2012). Approximately 110 of the 307 species recorded in the IBA throughout the year are marine birds and waterfowl. The area attracts tens of thousands of migratory birds along the Pacific Flyway, is globally important habitat for western grebes, Barrow"s goldeneye, and surf scoter, and is nationally important habitat for great blue herons (BIEAP 2002, Bird Studies Canada and Nature Canada 2013, BirdLife International 2012). Bird abundance in the inlet has been recorded at more than 24,000 birds during peak spring months (Breault and Watts 1996, BIEAP 2002). The marine areas of Central Harbour have the greatest abundance of waterbirds recorded here. The highest diversity of marine bird species is recorded near Port Moody, First Narrows and Second Narrows (Breault and Watts 1996).

Endangered or Threatened bird species known to use Burrard Inlet seasonally or year-round include the marbled murrelet, surf scoter, red-necked phalarope, western grebe, Clarke"s grebe, pelagic cormorant, double-crested cormorant, California gull, great blue heron and purple martin (BC CDC 2013, BIEAP 2002, Breault and Watts 1996).

Long term data sets compiled to characterize marine bird distribution and abundance in the study area indicated a total of 121 different waterbird species (813,647 individuals) recorded between 1962 and 2012. These data were derived from the following sources (NatureCounts 2013):

- British Columbia Breeding Bird Atlas (2008 – 2012)
- British Columbia Breeding Bird Atlas, Rare Occurrences (2008 – 2012)
- British Columbia Coastal Waterbird Surveys (1999 – 2012)
- eBird (1962 – 1963; 1966 – 1971; 1976 – 2012)
- Great Backyard Bird Count (1998 – 2012).

The British Columbia Breeding Bird Atlas documented 32 different species between 2008 and 2012. The greatest number of species was recorded by eBird (710,269 individuals; 118 species). Most observations were of mallard (23.3%), Canada goose (9.6%), northwestern crow (8.8%) and glaucous-winged gull (8.7%)

Of the 121 species recorded in the study area, 17 are designated as Blue (special concern) and four are designated as Red (endangered or threatened) under the *British Columbia Wildlife Act*. The red-listed species include black-crowned night heron (1 individual), Brandt"s cormorant (97 individuals), pelagic cormorant (10,196 individuals) and the western grebe (3,431 individuals). Marbled murrelets are protected under *SARA* and designated as Threatened. Only 25 marbled murrelets were recorded by eBird and no other survey recorded the presence of marbled murrelets in the study area.

A summary of the distribution, seasonal timing and conservation status for marine birds considered to be likely present around the WMT is presented in Table 4.6.

## TABLE 4.6 DISTRIBUTION AND SEASONAL TIMING FOR MARINE BIRDS

| Species | Distribution and Seasonal Timing | Conservation Status | | |
|---|---|---|---|---|
| | | ***SARA*** | **BC** | **COSEWIC** |
| Pelagic cormorant | There are two subspecies of pelagic cormorant which occur in this region: *Phalacrocorax pelagicus pelagicus* in winter (provincially Red-listed in British Columbia [BC CDC 2013]); and the resident *P. p. resplendens* which breeds from southern British Columbia northwards (Campbell *et al.* 1990a).<br>Pelagic cormorants prefer rocky coasts and sheltered habitat such as harbours and coves, and are rarely found far within inlets. Cliffs, reefs, unvegetated rocky islets and human-made structures, such as bridges and wharves, provide roosting habitat (Campbell *et al.* 1990a). Breeding colonies are located on rocky cliffs of islands or headlands, in caves, and on bridge pylons, towers, navigational beacons and other human-made structures (Campbell *et al.* 1990a). Within Haro Strait, they have been recorded on Mandarte, Great Chain Islands, Five Finger Island, Gabriola Island cliffs, Galiano Island cliffs, Hudson Rocks and Snake Island, North Pender Island cliffs, and Arbutus Island (Chatwin *et al.* 2002). Between 1955 and 2000, the number of pelagic cormorant nests within the Strait of Georgia declined by approximately 55% (Chatwin *et al.* 2002); however, in recent years populations have been stable (Crewe *et al.* 2012).<br>Pelagic cormorants are divers that select prey from the littoral-benthic zone and are bottom feeders of solitary fish and invertebrates that live in rocky areas (Hobson 1997, Campbell *et al.* 1990a, Ainley *et al.* 1981). | *P. p. pelagicus* | | |
| | | No Status | Red | No Status |
| | | *P. p. resplendens* | | |
| | | No Status | Yellow | No Status |
| Great blue heron | The great blue heron is widely distributed along the coast throughout the year, breeding mainly along southeastern Vancouver Island, the Southern Gulf Islands, the Fraser Lowlands, and east towards Hope (Campbell *et al.* 1990a). There are two subspecies of great blue heron in this region: *Ardea herodias Herodias*; and *A. h. fannini* (Vennesland 2004). It is primarily the *fannini* subspecies that breeds in the Strait of Georgia, with the *herodias* subspecies inhabiting the British Columbia interior (Vennesland 2004). Both subspecies are Blue-listed in British Columbia (BC CDC 2013), and the *fannini* subspecies is listed as a species of Special Concern under Schedule 1 of *SARA* (COSEWIC 2008). | *A. h. fannini* | | |
| | | Special Concern Schedule 1 | Blue | Special Concern |
| | | *A. h. herodias* | | |
| | | No Status | Blue | No Status |
| Barrow's goldeneyes | Barrow's goldeneyes are widely distributed along the British Columbia coast; less common in summer than in winter. Breeding occurs in the British Columbia interior with departure from winter ranges beginning in March. Wintering birds arrive on the coast in October (Campbell *et al.* 1990a). | No Status | Yellow | No Status |
| Bald eagle | The bald eagle is a widely distributed resident raptor present year round on the southwest coast (Campbell *et al.* 1990b). Within Burrard Inlet, the largest numbers of bald eagles are reported from Indian Arm with population spikes corresponding to peak fish runs and sightings of 75 individuals at once (Breault and Watts 1996). Bald eagles are culturally important to Aboriginal communities (Miller 1957).<br>Nesting occurs mostly in large old-growth or mature conifers primarily near lakes, large rivers, seashores, creeks, marshes or other bodies of water (Buehler 2000, Campbell *et al.* 1990b, Anthony *et al.* 1982, Keister 1981). There are several nest sites documented along the shores of Burrard Inlet and Indian Arm. | No Status | Yellow | Not At Risk |
| Glaucous-winged gulls | Glaucous-winged gulls are abundant and widespread along much of the Pacific coast maintaining a presence year round in a broad range of habitats (Hayward and Verbeek 2008, Campbell *et al.* 1990b). | No Status | Yellow | No Status |
| Spotted sandpiper | The spotted sandpiper is widespread along much of the coast from late spring to early fall. It breeds from northern Alaska southward through most of Canada, wintering from southwestern British Columbia to northern Chile (Campbell *et al.* 1990b). It is typically found in sparsely vegetated habitats near water but uses a variety of habitats including grasslands and forest. It inhabits the shorelines of virtually all waterways at all elevations, frequenting areas where small streams drain across tidal mud (Guiguet 1955). Other habitats include rain pools, sewage lagoons, and seaweed flotsam on sandy beaches (Campbell *et al.* 1990b). | No Status | Yellow | No Status |

**TABLE 4.6 DISTRIBUTION AND SEASONAL TIMING FOR MARINE BIRDS**

| Species | Distribution and Seasonal Timing | Conservation Status | | |
|---|---|---|---|---|
| | | *SARA* | BC | COSEWIC |
| Surf scoters | Surf scoters are medium-distance migrants that are widely distributed along the entire British Columbia coastline, especially during spring migration. The Strait of Georgia and the Burrard Inlet are particularly important winter and spring staging grounds. Southward migration from inland breeding areas occurs from late August to October (BC CDC 2013) and is usually at night (Butler and Savard 1985). Large aggregations occur from a few hundred to several thousand individuals.<br>Wintering surf scoters usually forage within 1 km of the shore (Vermeer 1981). Non-breeding habitat includes sheltered freshwater and marine bays, harbours and lagoons. At these sites, birds prefer shallow marine waters, less than 10 m deep, with substrates of pebbles and sand (Goudie *et al.* 1994, Campbell *et al.* 1990b). This species rarely uses estuaries except during migration (Campbell *et al.* 1990b; Savard *et al.*1998). Large numbers forage near steep shores of fjords where food resources (*e.g.,* mollusks) are abundant on submarine rocky walls (Vermeer 1981; Vermeer and Bourne 1984).<br>Surf scoters eat aquatic invertebrates on its breeding grounds and mollusks in spring, fall, and winter (Savard *et al.* 1998). | No Status | Blue | No Status |
| Pigeon guillemot | Pigeon guillemots are found along rocky coasts of the northern Pacific. Pigeon guillemots nest in burrows or rock cavities feeding near shore on fish and aquatic invertebrates (Ewins 1993). | No Status | Yellow | No Status |

Source: Conservation Status (BC CDC 2013)

### *4.6.5 Marine Mammals and Protected Habitat*

The following description of marine mammals in Burrard Inlet have been extracted with some modification from the Marine Resources - Westridge Marine Terminal Technical Report (Stantec 2013a) Volume 5C.

Marine mammal diversity and abundance in Burrard Inlet is generally considered low. The most abundant and commonly observed species by far is the harbour seal (*Phoca vitulina*), which is resident within the inlet and throughout the coastal waters of British Columbia. Over the years, there have been occasional but rare sightings of other marine mammal species such as Steller sea lion (Eum*etopias jubatus monteriensis*) and California sea lion (*Zalophus californianus*), northern fur seal (*Callorhinus ursinus*), and harbour porpoise (*Phocoena phocoena*) (Marine Mammal Research Unit 2012). Killer whale (*Orcinus orca*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), false killer whale (*Pseudorca crassidens*), grey whale (*Eschrichtius robustus*), humpback whale (*Megaptera novaeangliae*) and minke whale (*Balaenoptera acutorostrata*) have also made occasional appearances in Burrard Inlet or nearby waters (BC Cetacean Sightings Network 2013), although their use of this habitat is limited, and sightings are relatively uncommon.

#### *4.6.5.1 Harbour seal*

Harbour seals belong to the Family *Phocidae* (true seals) and are among the most widely distributed pinnipeds (*i.e.,* seal or sea lion) in the northern hemisphere. In Canada, they are found in Pacific, Atlantic, and Arctic waters. Harbour seals on the Pacific coast belong to a separate sub-species (Pacific harbour seal; subspecies *richardsi*). Their range in the northeast Pacific Ocean extends from Baja California north to Bristol Bay, Alaska and west through the Aleutian Islands (DFO 2010b).

Harbour seals use both aquatic and terrestrial environments and do not migrate but instead reside in British Columbia‟s coastal waters and inlets year-round (Baird 2001, Bigg 1981). They are likely the most commonly sighted marine mammal in British Columbia and prefer near shore habitats including sounds, inlets, straits, marinas and harbours, and have also been known to occur in river estuaries (Baird 2001). Terrestrial haulout sites, used for resting, mating, and pupping include isolated rocks or islets, sandbars, log booms, and recreational floats (Baird 2001).

As a true seal, harbour seals lack external ear flaps and have short flippers. Their coats vary in colour from light grey to dark brown or black with spots, rings, and blotches. Harbour seals average 0.8 m in length at birth and 1.5 m as adults; males are slightly larger than females (Baird 2001, Bigg 1981, McLaren 1993). Male and female harbour seals reach maturity at about 3 to 5 years of age (DFO 2010b). Harbour seals give birth to a single pup per year within a 1 to 2 month pupping season which varies geographically (Bigg 1981). In British Columbia, pups are born on land from mid-May to early-July in northern British Columbia, and from early-July to mid-August in southern British Columbia (DFO 2010b).

The diet of harbour seals varies between seasons, geographic areas, age, and habitat (Baird 2001). In the Strait of Georgia, their diet consists primarily of Pacific hake (*Merluccius productus*), Pacific herring, plainfin midshipman (*Porichthys notatus*), salmon, and lingcod (*Ophidon elogatus*) (Baird 2001, Olesiuk 1993).

Harbour seals in British Columbia were commercially harvested for pelts from 1879 to 1914 and 1962 to 1968 (Baird 2001, DFO 2010b). From 1914 to 1964, harbour seals were also harvested as part of a predator control program. DFO estimates that half a million seals were killed in British Columbia between the 1879 and 1968 (DFO 2010b). In 1970, harbour seals were legally protected by the Government of Canada under the Seal Protection Regulations. These regulations were later incorporated into the Marine Mammal Regulations in 1993 under the *Fisheries Act*. These regulations prohibit the unauthorized killing, hunting, and disturbance of harbour seals in Canada. Since these regulations came into effect, the Pacific coast population of harbour seals has returned to or exceeded historic levels. As such, they are not listed on *SARA* and were last designated by COSEWIC as Not at Risk in 1999 (COSEWIC 2011).

DFO has conducted aerial surveys of harbour seals in British Columbia since the early 1970s to determine abundance and distribution and to monitor population trends (DFO 2010b). As of 2009, approximately 82% of British Columbia"s 27,200 km coastline had been surveyed, with nearly 1,400 haulout sites identified. Data from these surveys indicate that the harbour seal population grew exponentially during the 1970s and 1980s at a rate of about 11.5% per year, before slowing in the 1990s (DFO 2010b). In 2008, the harbour seal population in British Columbia was estimated to be 105,000 individuals and appears to have stabilized (DFO 2010b). Highest densities were observed in the Strait of Georgia, with an average of 3.1 seals per kilometre of shoreline. DFO estimates that the British Columbia population represents about 29% of the 360,000 harbour seals estimated to inhabit the Northeast Pacific Ocean (DFO 2010b).

Harbour seals show high site fidelity (Baird 2001, DFO 2010b). They gather in groups as large as several hundred to several thousand individuals at haulout sites, but they are usually solitary or in small groups in the water and do not congregate to breed (Baird 2001, Bigg 1981). The mean haulout group size in the Strait of Georgia is 22 individuals (Baird 2001, Bigg 1981). Estimated seal densities in Burrard Inlet are moderate (BC Marine Conservation Analysis 2010) and seals may be observed year-round. Important Areas identified by DFO for harbour seals are in the Marine Resources - Westridge Marine Terminal Technical Report (Stantec 2013a) Volume 5C. The relevant distribution, seasonal timing and conservation status for harbor seals are summarized in Table 4.7.

### TABLE 4.7 DISTRIBUTION AND SEASONAL TIMING FOR HARBOUR SEAL

| Species | Relevant Distribution and Seasonal Timing | Conservation Status | | |
|---|---|---|---|---|
| | | *SARA* | BC | COSEWIC |
| Harbour seal | Estimated seal densities in and around Burrard Inlet are moderate (BC Marine Conservation Analysis 2010) and seals may be observed year-round. Harbour seals use both aquatic and terrestrial environments and do not migrate but instead reside in British Columbia's coastal waters and inlets year-round (Baird 2001, Bigg 1981). Male and female harbour seals reach maturity at about 3 to 5 years of age (DFO 2010b). Harbour seals give birth to a single pup per year within a 1 to 2 month pupping season which varies geographically (Baird 1981). In British Columbia, pups are born on land from mid-May to early-July in northern British Columbia, and from early-July to mid-August in southern British Columbia (DFO 2010b). | --- | Yellow | Not At Risk |

Source: Conservation Status (BC CDC 2013)

#### *4.6.5.2 Harbour Porpoise*

Harbour porpoises belong to the Family Phocoena and are generally recognized as the smallest cetacean species. In Canada they are found primarily over Pacific and Northwestern Atlantic continental shelves and divided into two populations: the Pacific Ocean population and the North Atlantic population. They can be found throughout British Columbia coastal waters (COSEWIC 2003c). Based on the available information, harbour porpoise do not migrate but instead reside in British Columbia‟s coastal waters and inlets (excluding deep water fjords) year-round (Baird and Guenther 1995). They prefer shallower waters (less than 200 m depth) and areas of lower current flow (COSEWIC 2003c).

Harbor porpoises are generally dark grey to black on the dorsal surface with white bellies. They average 0.8 to 0.9 m in length at birth and close to 2 m as adults; with females generally slightly larger than males (Baird and Guenther 1995, Read and Tolley 1997). The diet of harbour porpoises consists primarily of schooling fish. Stomach content studies of individuals from southern British Columbia indicate a diverse diet with common prey items such as market squid (*Loligo opalescens*), Pacific herring and Pacific hake (COSWEIC 2003c). Information on the reproduction of the Pacific Ocean population is mainly based on stranded animals with some inference from other populations. For example, mean age to sexual maturity has not been determined for the Pacific Ocean population, but is estimated to be three to four years for the North Atlantic population. In British Columbia, pups are born from May to September (COSEWIC 2003c). The relevant distribution, seasonal timing and conservation status for harbor porpoise is summarized in Table 4.8.

**TABLE 4.8 RELEVANT DISTRIBUTION AND SEASONAL TIMING FOR MARINE MAMMALS – HARBOUR PORPOISE**

| Species | Relevant Distribution and Seasonal Timing | Conservation Status | | |
|---|---|---|---|---|
| | | SARA | BC | COSEWIC |
| Harbour porpoise (Pacific Ocean population) | Based on the available information, harbour porpoise do not migrate but instead reside in British Columbia's coastal waters and inlets (excluding deep water fjords) year-round (Baird and Guenther 1995). They prefer shallower waters (less than 200 m depth) and areas of lower current flow (COSEWIC 2003c). In British Columbia, calves are born from May to September (COSEWIC 2003c). | Special Concern Schedule 1 | Blue | Special Concern |

Source: Conservation Status (BC CDC 2013)

## 4.7 Aboriginal Traditional Use of Marine Resources within Burrard Inlet

The following description of Aboriginal Traditional Use within the RSA has been extracted from the Marine Resources - Westridge Marine Terminal Technical Report (Stantec 2013a) Volume 5C, and Marine Birds - Westridge Marine Terminal Technical Report (Stantec 2013d) Volume 5C. Further information may also be obtained from the Marine Resources - Marine Transportation Technical Report Volume 8A.

Traditional marine resource harvesting remains an important activity for coastal Aboriginal communities, sometimes defined in terms of spiritual, emotional, mental and physical components (Gardner 2009). Coastal communities traditionally and actively managed the marine environment to maintain ecological integrity and to protect and preserve biodiversity; an example reported by Gardner (2009) described how “shellfish resources were managed by transplanting shellfish from one area to another, digging over beaches and modifying intertidal zones to increase clam and oyster growing grounds to increase production.” Marine resources are used culturally to highlight special events such as feasts while an extensive recorded vocabulary for sustainable management of marine resources demonstrates an historical understanding of the economic implications of marine subsistence, the food chain, the location and movement of food sources and currents (Gardner 2009).

Marine resources traditionally harvested within the study area include barnacles, butterclams, cockle clams, manila clams, horse clams, littleneck clams, Dungeness and red rock crab, giant red chiton, green and red sea urchin, mussels, oysters, northern abalone, octopus, prawns, sea cucumber and herring roe. Sandy, exposed shorelines were important habitats for harvesting clams, oysters and mussels, and eelgrass beds were locations for harvesting crabs (Jacques Whitford Ltd. 2006).

Aboriginal communities traditionally practiced duck, goose, grouse and waterfowl hunting as well as snaring of mudhen, mallard and crane (DFO and EC 2006). Duck species would be hunted by net and spear whereby nets would be baited and anchored underwater and then thrown over the flock in order to take a large number of ducks at a time (Suttles 2006). Duck species often hold cultural importance to coastal communities, and their feathers were used to insulate clothing (DFO and EC 2006, Suttles 2006).

# 5.0 EXPOSURE AND HAZARD/EFFECTS ASSESSMENTS

The effects assessment methodology presented in this section is based on an approach used for the Aleutian Islands Risk Assessment (AIRA, ERM 2011). The AIRA is an ongoing program being carried out on behalf of the US National Fish & Wildlife Foundation (NFWF), Coast Guard (USCG) and State of Alaska Department of Environmental Conservation (ADEC) to evaluate the likely characteristics and consequences of vessel accidents and spills in the Aleutian Islands. The specific methods used here are modified slightly, chiefly to reflect differences in the availability and format of data; and in addition to reflect the purpose of the present study, which is to support the NEB Application and the information needs and requirements of the NEB and *Canadian Environmental Assessment Act* (*CEA Act*).

Likelihood refers to a probabilistic assessment of some defined outcome having occurred or occurring in the future. In this report, when discussing the likelihood of certain outcomes, a set of associated meanings are as follows as defined by the International Panel on Climate Change (IPCC 2013) should be considered. The introduction of the terminology below it is not intended to restrictively apply the definitions to the associated probability values; rather it is intended to associate language with probability ranges in order to facilitate discussion more generally.

- Virtually certain — >99% probability of occurrence
- Very likely — 90 to 99% probability
- Likely — 66 to 90% probability
- About as likely as not — 33 to 66% probability
- Unlikely — 10 to 33% probability
- Very unlikely — 1 to 10% probability
- Exceptionally unlikely — <1% probability.

## 5.1 Effects Assessment Approach

The exposure and hazard/effects assessment steps involve considering first, what the probability of oiling would be for any given location within the RSA in the event of an accidental oil spill. This information was obtained from the stochastic modeling results at four levels of intensity. A low probability of oil exposure was assigned to areas having <10% probability. Areas having a probability of ≥10% but <50% were assigned a medium level of intensity. A high level of intensity was assigned to areas having a probability of oiling ≥50% but <90%, and a very high level of intensity was assigned to areas having a probability of oiling ≥90%. These exposure levels are illustrated for the winter, spring, summer and fall season stochastic modeling results.

The potential consequences in terms of negative environmental effects from crude oil exposure from each spill scenario are evaluated for four main ecological receptor group/habitat combinations including the following

- Shoreline and Near Shore Habitats
- Marine Fish and Supporting Habitat
- Marine Birds and Supporting Habitat
- Marine Mammals and Supporting Habitat.

These four ecological receptor groups are intended to broadly represent all of the marine resources of the RSA, as previously described, comprising ecological resources and supporting habitat, including water, sediment and air quality. Each of the four ecological receptor groups contains a variety of habitats and/or individual receptor types of differing sensitivity to crude oil exposure. The potential ecological consequences of crude oil exposure at any given location are considered to be defined by the overlap of the likelihood of crude oil presence in the event of an accidental spill, and the sensitivity of ecological habitat or receptors that may be present at that location.

The effects assessment considers both the probability of oiling, and the sensitivity of the ecological resources present. By superimposing the probability of oiling onto the ecological resource sensitivity maps, this overlap can be visualized, and using GIS tools, quantified. Depending upon the types of ecological resources, this quantification process can evaluate either 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, this analysis will focus on areas having medium, high or very high probability of oil exposure. The analysis is presented in tabular format, so that the amount of habitat exposed to different probabilities of oiling can be quantified, and then put into context by comparing this amount of habitat with the quantity of such habitat present within the RSA. This analysis is completed for ecological receptors having a range of biological sensitivity levels, for each season.

In addition to evaluating and ranking the intrinsic sensitivity to oiling or crude oil exposure of individual ecological receptors, receptor groups and/or the supporting habitat, where a receptor has status as an endangered species, this status will be considered as an additional factor when evaluating the importance of negative environmental effects caused by each hypothetical crude oil spill scenario. Likewise, the presence of provincial and national parks or other designated conservation areas represents an additional factor to consider (*i.e.,* societal values) on top of the intrinsic biological sensitivities.

An overview of the modelling framework and the presentation of results are provided in Sections 5.2 and 5.3. Details of the sensitivity ranking scheme for the various ecological receptor groups are provided in Section 5.4.

## 5.2 Marine Oil Spill Modelling Framework

Stochastic crude oil spill modelling simulations were completed by EBA (2013) to support this PQERA and to inform the oil spill response planning for the Project. The stochastic simulations were based on the hypothetical spill scenarios developed by DNV as outlined in Section 4.

Stochastic simulations were performed for a complete annual cycle to take into consideration seasonal variations in winds and currents, with hypothetical accidental releases of CLWB at the WMT being initiated every three hours throughout the year. All hypothetical spill simulations were allowed to run for up to 15 days, 360 or more stochastic runs being performed for each simulation. No consideration was given to possible mitigation, such as oil spill response activities, except in the context of biological recovery from harm caused by spilled oil. Details of the stochastic modelling completed by EBA are provided in the Modelling the Fate and Behaviour of Diluted Bitumen Spills in the Marine Environment, at Westridge Terminal and in the Lower Fraser River for the Trans Mountain Expansion Project - Technical Report – Volume 8C.

EBA provided a data package for the results of each spill scenario including wind speed and direction charts, probability contours for surface water oiling, probability contours for shoreline oiling, time to first contact and length of shoreline oiling, length of shoreline contacted per coastal class, amount of dissolved oil, mass balance results (including on-water and on-shore oiling, oil evaporated, dispersed, biodegraded, and dissolved), as well as average slick area and thickness. Table 5.1 provides a summary of each of the modelling outputs and how the data was utilized in the PQERA.

### TABLE 5.1 SUMMARY OF MODELLING OUTPUTS FOR EVALUATING EFFECTS

| Model Output | Description | Use for Evaluating Effects | Examples of Ecological Receptor Groups |
|---|---|---|---|
| Monthly wind speed and direction charts | Stick chart of daily wind speeds and direction for each month. | An aid to understanding differences between seasons. | n/a |
| Probability contours for overall surface water oiling | Probability of oil presence at a location at some point in time during the duration of a simulation, evaluated using 360 or more individual crude oil spill simulations per season. | Calculated total area of surface water oiling for each scenario according to probability ranges.<br>• 0 - <10<br>• 10 - <50<br>• 50 - <90<br>• 90 – 100 | Marine Fish and Supporting Habitat<br><br>Marine Birds and Supporting Habitat<br><br>Marine Mammals and Supporting Habitat |

### TABLE 5.1 SUMMARY OF MODELLING OUTPUTS FOR EVALUATING EFFECTS

| Model Output | Description | Use for Evaluating Effects | Examples of Ecological Receptor Groups |
|---|---|---|---|
| Probability contours for shoreline oiling (end of simulation) | Probability of oil contacting and adhering to a shoreline segment during the duration of a simulation, evaluated using approximately 360 or more individual crude oil spill simulations per season. | Calculated total length of shoreline oiling for each scenario according to probability ranges.<br>• 0 - <10<br>• 10 - <50<br>• 50 - <90<br>• 90 – 100 | Shoreline and near shore habitats |
| Time to first shoreline contact | Estimated time (in days) to first contact with the shoreline | An indicator of whether shorelines would be contacted by fresh or weathered crude oil. | n/a |
| Length of Shoreline Contacted | Estimated total length of shoreline contacted at the end of the simulation. | Limited use in the PQERA. To be considered in deterministic scenario evaluation. | Marine Birds and Supporting Habitat<br><br>Marine Mammals and Supporting Habitat |
| Length of Shoreline Contacted by Shoreline Type | Estimated length of shoreline contacted for each shoreline type. | Used to evaluate effects on shorelines of differing sensitivity to crude oil exposure. | Shoreline and Near Shore Habitats |
| Amount of dissolved oil | Daily amount of dissolved oil in $m^3$ over the duration of the spill | Limited use in the PQERA. To be considered in deterministic scenario evaluation. | Marine Fish and Supporting Habitat |
| Mass Balance | Estimated distribution of the crude oil in each environmental media (*e.g.,* water surface, water column, shoreline, evaporated) according to time elapsed from the hypothetical spill. | Considered and discussed in the PQERA. To be considered in detail for the deterministic scenario evaluation. | n/a |
| Slick area and thickness | Average daily slick area and thickness over the duration of the spill | Not used in the PQERA. To be considered in deterministic scenario evaluation. | n/a |

Selected oil spill modelling output files are provided in Appendix B for the 160 $m^3$ spill, and in Appendix C for the smaller 10 $m^3$ spill.

## 5.3 Sensitivity Ranking of Ecological Resources for Assessment

The following sections provide the definition of the four ecological receptor group/habitat combinations and the rationale for the corresponding sensitivity ranking scheme for each.

### *5.3.1 Shoreline and Near Shore Habitats*

Shoreline and near shore habitats are considered to include the intertidal or littoral zone, the area of the foreshore and seabed that is exposed at low tide, and submerged at high tide. Shoreline and near shore habitat types reflect their exposure to wind and wave action. Low-energy or protected shorelines found within the RSA 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 important because it provides a barrier that limits oil penetration of sub-surface sediment. In contrast, coarse (pebble, cobble or boulder) shorelines that are highly exposed to wind and wave action 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 typically found in subtidal areas with soft sediments, such as protected bays, inlets and lagoons.

Shoreline and near shore habitat characteristic data for the study area was available from existing coastal habitat mapping datasets. These are collectively referred to as the ShoreZone datasets and are managed by the Integrated Land Management Branch in British Columbia, and by the Department of Natural Resources in Washington State. The data were collected and compiled by Coastal & Ocean Resources, resulting in a single data layer for the study area that represented shoreline characteristics. The total length of shoreline in the modeling area is approximately 15,900 km, and this is represented by 172,000 individual shore segments. The shorelines of the RSA for the WMT represent a small portion of this larger dataset.

A total of thirteen different shore types were defined for the Project, based upon descriptive information available in the ShoreZone datasets. These were classified based on the degree of exposure (either low or high), and then by the upper intertidal substrate types. The selected attributes from the dataset considered by the spill modeling team are summarized in the following Table 5.2. The substrate types 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 were also considered to fall within the "shoreline and near shore" habitat, giving a total of fourteen different shoreline and near shore habitat types.

**TABLE 5.2 SHORE TYPES DEFINED FOR PROJECT**

| Exposure | Upper Intertidal Substrates | No | Code | Spill Shore Type |
|---|---|---|---|---|
| Low (VP, P, SP) | Rock | 1 | LE_R | Rock, low energy: assumed to be impermeable |
| | Rock with pebble, cobble veneer | 2 | LE_VR | Rock with veneer, low energy; a discontinuous veneer of pebble, cobble or boulder over rock |
| | Pebble veneer | 3 | LE_V | Pebble veneer over sand; a single layer of pebbles overlying sand, typical of low energy shorelines; stranded oil may attach to pebble but sand in subsurface limits penetration. |
| | Cobble or boulder veneer | 4 | LE_CV | Coarse veneer over sand; a single layer of cobbles or boulders overlying sand; sand limit subsurface penetration |
| | Sand or mud | 5 | LE_S | Sand or mud which typically has high water content and limits viscous oil penetration. |
| | Rip Rap | 6 | LE_RR | Course boulders or sometime concrete rubble that is commonly used as shore protection. |
| | Marsh | 7 | LE_M | Marsh |
| | Wood | 8 | LE_W | Wood bulkheads, generally assumed to be pilings and therefore somewhat porous. |
| | | | | |
| High (VE, E, SE) | Rock | 9 | HE_R | Impermeable rock surfaces; joint and fracture patterns may allow some oil retention |
| | Rock with coarse veneer | 10 | HE_VR | Boulder and cobble overlying bedrock creates potential for stranded oil retention |
| | Boulder, cobble beaches (also includes few rip-rap sections) | 11 | HE_C | Coarse boulder or cobble beaches assumed to have high penetration potential; may include coarse beaches associated with rock platforms; although high energy, penetration may result in lengthy persistence. |
| | Sand with pebble, cobble or boulder | 12 | HE_SG | Combinations of sand and various forms of gravel (pebble, cobble, boulder); and matrix is assumed to minimize penetration. |
| | Sand | 13 | HE_S | High energy sand beaches; sand will limit viscous oil penetration; sand is likely to be highly mobile so has the potential to bury stranded oil. |

Source: Methods of Estimating Shoreline Oil Retention - Harper (2013), Volume 8C.

The fourteen shoreline and near shore habitat types were assigned to four biological sensitivity factors (BSF), on a scale of BSF = 1 (low sensitivity) to BSF = 4 (very high sensitivity). While the BSF are somewhat correlated with the tendency for shoreline types to absorb or retain spilled crude oil, they are based primarily on a consideration of habitat complexity and the ability of the different habitat types to sustain biodiversity and productivity. In this sense, exposed bedrock or sand substrates are considered to be subject to high levels of natural disturbance and have relatively low levels of biodiversity and productivity, whereas sheltered rocky substrates, marsh, and eelgrass beds have high biodiversity and productivity.

Table 5.3 provides a summary of the shoreline and near shore habitat types, and the rationale supporting their assignment to BSF classes. Biological sensitivity factors assigned to the various shoreline and near shore habitats are shown in Figure A.1 in Appendix A.

**TABLE 5.3 SHORELINE AND NEAR SHORE HABITAT TYPES AND BIOLOGICAL SENSITIVITY FACTORS**

| Shoreline and Near Shore Habitat Type | Comments | Biological Sensitivity Factor |
|---|---|---|
| Low exposure, rock<br>Low exposure, sand<br>Low exposure, rip rap<br>Low exposure, wood bulkheads<br>High exposure, rock<br>High exposure, sand<br>High exposure, sand and gravel | • This is the least sensitive classification. A shoreline that has regular exposure to wave and tidal energy, no or low potential for subsurface oil penetration, and low oil retention.<br>• Because of the impermeable substrate and its exposure to waves, oil remains on the surface, thus allowing natural forces to remove the oil. Little or no clean-up is usually required.<br>• As a result of low habitat complexity, high exposure, or the artificial nature of some of the habitat types (*e.g.,* rip rap, bulkheads), biological sensitivity is considered to be low. | 1 |
| Low exposure, veneer over rock<br>Low exposure, pebble veneer over sand<br>High exposure, cobble/boulder veneer over rock<br>High exposure, cobble/boulder | • These shorelines comprise low-sloping, well compacted substrates, often with underlying fine-grained sediment which limit oil penetration.<br>• Biological sensitivity is generally reduced as a result of low complexity or high exposure. | 2 |
| Low exposure, cobble/boulder veneer over sand | • This shoreline has low exposure and higher complexity, giving greater opportunity for higher levels of biodiversity. Underlying fine-grained sediments limit oil penetration. | 3 |
| Low exposure, salt marsh<br>Low exposure, eelgrass | • These habitat types are considered to have the highest levels of complexity and productivity and to be important nursery and rearing areas for fish, in addition to being known to be highly sensitive to oil exposure. | 4 |

### *5.3.2 Marine Fish and Supporting Habitat*

Marine fish and supporting habitat are defined here as including marine fish, as well as marine invertebrates (*e.g.,* mollusks and crustaceans), but not mammals and birds which are addressed elsewhere. Acute effects of spilled crude oil on fish and marine invertebrates are rarely observed, except in situations where crude oil is confined and dispersed into shallow water, such as may occur if crude oil is driven onto a shoreline or into a confined bay.

Acute effects of hydrocarbon exposure on fish are generally caused by exposure to relatively soluble components of the crude oil. Monocyclic aromatic hydrocarbons (MAHs) such as benzene, toluene, ethylbenzene or xylenes (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 represent the timeframe when acute toxicity is most likely to occur.

Two major mechanisms of toxicity to 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 among the more sensitive to the narcosis mode of action, 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 the more sensitive to BSD.

As a result of the behaviour of crude oil spilled on water, the potential for toxicity to marine fish and supporting habitat is greatest in the surface water, where more soluble hydrocarbons can dissolve from the floating fresh crude oil, or from droplets that have been temporarily dispersed down in to the water column by wave action. The potential for acutely toxic concentrations of hydrocarbons to extend down into deep water is very low, as a result of the limited solubility of hydrocarbons, and the dilution that would accompany mixing into deep water.

Four BSF are defined for marine fish and supporting habitat, on a scale of BSF = 1 (low sensitivity) to BSF = 4 (very high sensitivity) as in Table 5.4. Marine fish and supporting habitat are assumed to comprise a wide variety of species, each of which has its own sensitivity to hydrocarbon exposure. For the non-polar narcosis mode of toxic action, it is usual to consider the toxicity of hydrocarbons to a sensitive species, defined as representing the 5"th 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, the sensitivity of the community becomes a function of the degree of exposure of the particular habitat to dissolved hydrocarbons. Therefore, the low end of the sensitivity scale is occupied by deep water habitat (BSF = 1), whereas the higher end of the sensitivity scale is occupied by shallow water habitat (BSF = 3). The highest biological sensitivity class is reserved for developing eggs and embryos in shallow water habitat represented here by herring spawning areas which are assigned to BSF = 4. Table 5.4 provides a summary of marine fish and supporting habitat, and the rationale supporting their assignment to BSF classes. Biological sensitivity factors assigned to the various habitats are shown in Figure A.2 in Appendix A.

**TABLE 5.4 BIOLOGICAL SENSITIVITY CLASSIFICATION FOR THE MARINE FISH AND SUPPORTING HABITAT**

| Marine Fish and Supporting Habitat | Comments | Biological Sensitivity Class |
|---|---|---|
| Water column and seabed (>30 m) | • All life stages of transient, pelagic or bottom fish species, including mollusks and crustaceans, found at depths >30 m. | 1 |
| Water column and seabed (>10 to <30 m) | • All life stages of transient, pelagic or bottom fish species, including mollusks and crustaceans, found at depths of 10 to 30 m | 2 |
| Water column and seabed (<10 m) | • All life stages of transient, pelagic or bottom fish species, including mollusks and crustaceans, found at depths of <10 m. | 3 |
| Herring Spawning Areas<br>Rockfish Conservation Areas<br>Eulachon Critical Habitat<br>Dungeness Crab Important Habitat<br>Salmon Streams and Important Areas | • Eggs, larvae, juveniles of Pacific herring or similar species, subject to developmental abnormalities such as BSD. | 4 |

### *5.3.3 Marine Birds and Supporting Habitat*

Seabirds are highly sensitive to spilled crude oil, due principally to the effects of oiling on feathers (*i.e.,* loss of insulative properties and buoyancy), as well as to ingestion of crude oil or contaminated food. In addition, birds that are gregarious are potentially at greater risk of population-level effects if crude oil affects 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). Many of these species can also be expected to be present within the RSA for the WMT.

The literature on the effects of spilled crude oil on birds is extensive. Table 5.5 provides a summary of the BSF classification for major groups or guilds of seabirds based on ERM (2011) and Williams *et al.* (1995). The classification scheme reflects guild membership, as is appropriate considering the similar lifestyle, behaviour, and exposure mechanisms that accompany the guilds. Biological sensitivity factors assigned to marine birds and supporting habitat in Burrard Inlet are shown in Figure A.3 in Appendix A

**TABLE 5.5 BIOLOGICAL SENSITIVITY FACTORS FOR MARINE BIRDS AND SUPPORTING HABITAT**

| Marine Birds and Supporting Habitat | Comments | Biological Sensitivity Factor |
|---|---|---|
| Waders and Shorebirds | • Species are not present in large numbers and are widely distributed.<br>• Shoreline dwelling species and waders have lower probability of oiling. | 1 |
| Gulls and Terns | • Gulls and terns tend not to be fully marine in their lifestyle, and in addition tend to be coastal in distribution. | 2 |
| Ducks and Cormorants | • Ducks and other waterfowl tend to be moderately sensitive to crude oil exposure, and may congregate.<br>• Cormorants also tend to be coastal in distribution. | 3 |
| Auks and Divers | • Auks tend to be highly reliant on the marine environment, often coming to shore only to breed.<br>• Auks are highly sensitive to crude oil exposure as well as being highly exposed in open water areas.<br>• Auks often form breeding colonies and may congregate on the water in feeding areas. | 4 |

### *5.3.4 Marine Mammals and Supporting Habitat*

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

- Terrestrial mammals, such as bears and moose, may at times frequent shoreline areas, depending upon the availability of food resources they may be seeking
- Pinnipeds, including harbour seal and potentially other species
- Cetaceans, including harbour porpoise, as well as occasional southern resident killer whale, humpback whale, and other species
- River otter, mink and occasional sea otter (sea otter are more common along the west coast of Vancouver Island, but the presence of occasional individuals in the study area cannot be discounted).

The different types of mammals will have differing levels of exposure to spilled crude oil, as well as having differential sensitivity if exposed. Aquatic mammals 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 crude 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 as a result of other exposure pathways or mechanisms.

Whales and seals may or may not avoid exposure to crude oil on the surface of the water. Inhalation of vapours is a potentially important exposure pathway during the early stages of an oil spill, as is potential ingestion of oil as a result of consuming oiled prey. Experience during the Exxon Valdez oil spill (EVOS) was equivocal (Exxon Valdez Oil Spill Trustee Council, EVOSTC 2013). While whales were observed swimming in areas close to the spill site, and were undoubtedly exposed to fumes from fresh oil, only circumstantial evidence links acute or chronic exposure to spilled oil with the disappearance of whales belonging to the AB (resident, fish-eating) and AT1 (transient, seal-eating) killer whale pods. Eight resident killer whale pods use Prince William Sound as part of their range, but of these, only the AB pod exhibited higher individual mortality rates following the EVOS. Members of this pod were also known to be subject to shooting by fishermen, as a result of conflicts associated with the longline fishery. Oil ingestion remains a potentially important exposure pathway, and fouling of baleen plates can have negative effects on baleen whales, although this would not be a problem for toothed whales. The potential for mortality of marine mammals as a result of acute exposure to hydrocarbon vapours will be considered quantitatively in the detailed quantitative ERA to be submitted as a supplemental study.

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

Table 5.6 provides a summary of the biological sensitivity factors applied to different types of marine mammals and supporting habitat that may be exposed to spilled crude oil. Biological sensitivity factors assigned to the various habitats are shown in Figure A.4 in Appendix A.

### TABLE 5.6 BIOLOGICAL SENSITIVITY CLASSIFICATION FOR MARINE MAMMALS AND SUPPORTING HABITAT

| Marine Mammals and Supporting Habitat | Comments | Biological Sensitivity Factor |
|---|---|---|
| Terrestrial Mammals | • Terrestrial wildlife species that might use the upper intertidal zone, or species migrating through the area. Examples would include bear, moose, fox or raccoon | 1 |
| Pinnipeds | • Pinnipeds include seals and sea lions. Seals such as the harbour seal would be common in Burrard Inlet. Sea lions would be most commonly observed along the marine transportation route. In addition to strictly marine habitat, sea lion haulouts are an important habitat feature. With their reliance on fat or blubber for insulation, seals are not as sensitive to external oiling as many sea birds or otters. | 2 |
| Whales | • A variety of toothed and baleen whales, including harbor porpoise, southern resident killer whale, humpback whale, and other whales. The southern resident killer whale population is considered to be endangered. Although not particularly sensitive to the thermal effects of oiling (as a result of the role of blubber as insulation rather than fur), whales may be sensitive to inhalation of hydrocarbon vapours, and baleen may be fouled by exposure to crude oil. | 3 |
| Otters | • Sea otters are unlikely to frequent the study area, except as occasional or transient animals, however, river otters are common in near shore areas, and around river mouths. Mink and otter would also be common along the coastline, foraging in the intertidal zone. It is assumed that otters could be found primarily in near shore areas, in water depths of 10 m or less. With their reliance on fur for insulation, otters are highly sensitive to crude oil exposure. | 4 |

The potential for terrestrial mammal species and otters to be present along shoreline areas that could potentially become oiled following a hypothetical oil spill is considered to be similar throughout the marine study area. Likewise, the potential for pinnipeds and cetaceans to be present is considered to be essentially uniform throughout the study area. For pinnipeds, haulout areas are also known to be important, and shoreline oiling in proximity to known haulout areas is considered to be potentially important in terms of pinniped exposure to oil.

The marine mammal knowledge base is derived from a review of relevant scientific literature, publications, and technical reports (*e.g.,* COSEWIC status reports and DFO"s Canadian cience Advisory Secretariat [CSAS] reports), as well as local and regional data (*e.g.,* BC Cetacean Sightings Network [BC CSN], BC Conservation Data Centre [BC CDC], British Columbia Marine Conservation Analysis [BC MCA]). The collection of information from these sources focused on marine mammal life history, broad habitat use, distribution, abundance, and effects of underwater noise.

# 6.0 RISK CHARACTERIZATION RESULTS – CREDIBLE WORST CASE AT WESTRIDGE MARINE TERMINAL

## 6.1 Summary of Stochastic Modelling Results

This section summarizes the evaluation of ecological effects resulting from a credible worst case spill which could potentially occur at the WMT during loading operations. The spill scenario considered here is based on the failure of a loading arm resulting in a release of 160 m$^3$ of CLWB. Taking into consideration the standard procedure of deploying containment boom around the ship prior to the start of loading, it was assumed that 80% of the spilled oil (132 m$^3$) would be retained within the boom, and 20% (28 m$^3$) would escape and disperse into Burrard Inlet, subject to seasonal weather and oceanographic conditions. Four seasonal conditions were modelled, representing winter, spring, summer and fall.

For the hypothetical 160 m$^3$ crude oil release considered for the WMT, while there is a high to very high probability of water surface oiling and/or shoreline oiling at the confluence of Indian Arm and Burrard Inlet, the probability of water surface oiling and/or shoreline oiling from a single individual crude oil spill to reach farther into Indian Arm and towards Port Moody, as well as west past Second Narrows is considered to be low. The overall results for each season were very similar, although some slight seasonal differences in the spill trajectories were identified, which are primarily as a result of variations in predominant current direction and speed, and/or predominant wind direction and speed.

### *6.1.1 Probability of Surface Oiling*

Table 6.1 provides a summary of the spatial extent of surface oiling (km$^2$) within the RSA for each season. Results are presented for each of three probability ranges (≥10%, ≥50% and ≥90%). The release location and probability contours for seasonal stochastic surface oiling are shown in Figures D.1 to D.4 in Appendix D.

Predictions indicate that between 14 and 17 km$^2$ of the water surface near the WMT has a high to very high probability (≥50%) of being exposed to oiling, with the greatest spatial extent (17 km$^2$) predicted during the spring season. The Regional Study Area (RSA) has a total water surface area of 115 km$^2$. As such, the stochastic results indicate that approximately 15% of the RSA has a high probability of being oiled based upon this hypothetical scenario.

**TABLE 6.1 AREA OF SURFACE OILING (BY PROBABILITY OF OILING)**

| 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 | 4 | 32 | 15 | 2.9 |
| | | Spring | 4.4 | 35 | 17 | 3.1 |
| | | Summer | 4.6 | 33 | 15 | 2.8 |
| | | Fall | 4 | 28 | 14 | 5.3 |

It is important to correctly understand the data presented in Table 6.1. The values presented under the column headed "Maximum Average Slick Area (km$^2$)" indicate, for the average simulated spill, the largest surface area of sea that was occupied by spilled oil at any given time step within the duration of the model 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. However, the oil slick is not static, it is moved around by tides and winds, so that the total area swept or affected by the moving oil slick is greater than the surface area of the slick at any given time. The values presented under the columns headed "Total Affected Surface Area (km$^2$)" indicate the probability, based on the stochastic oil spill model output, that particular grid squares in the marine oil spill model, each representing a unit of sea surface area, contained crude oil at the water surface during at least one time step within the duration of the model run. The three columns indicate the total area of sea surface swept by oil over the length of the oil spill simulation, at probability levels of ≥10%, ≥50% and ≥90%, respectively. It is important to understand that the areas presented in these columns of Table 6.1, and the same data as represented by contour outlines in Figures D.1 to D.4 do not represent the surface area of a single, continuous oil slick.

Mass balance results showed that, at the end of the stochastic simulations (15 days), escaped oil is no longer present on the water surface; approximately 90% of the escaped oil would strand on shoreline, with the highest amount in the fall with the rest undergoing weathering processes on the water surface. Mass balance results from the EBA modelling output for the 160 $m^3$ spill are presented in Appendix B.

### *6.1.2 Probability of Shoreline Oiling*

Table 6.2 provides a summary of the spatial extent of shoreline oiling within the RSA. Results indicate a high to very high probability (≥50%) of between 8.3 km and 11 km of shoreline oiling, with the greatest spatial extent of oiling occurring during summer conditions. The RSA includes approximately 200 km of shoreline, therefore overall it is predicted that only about 5% of the shoreline habitat within the RSA has a high to very high probability of being oiled in the unlikely event of an accidental oil spill. The average length of shoreline oiling for each seasonal condition ranged between 15 km and 19 km. These lengths are larger than the ≥50% probability value, but less than the length represented by the 10% probability of shoreline oiling.

**TABLE 6.2 LENGTH OF SHORELINE OILING (BY PROBABILITY OF OILING)**

| 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 160 $m^3$ | Winter | 15 | 33 | 8.3 | 0.9 |
| | | Spring | 17 | 38 | 8.6 | 1.3 |
| | | Summer | 19 | 35 | 11 | 0.7 |
| | | Fall | 15 | 30 | 8.7 | 1.5 |

## 6.2 Potential Environmental Effects to Shoreline and Near Shore Habitats

Of the 200 km of shoreline and near shore habitats in the RSA, 64% (128 km) is comprised of low and high exposures rock and sand, low exposure rip rap and wood bulkheads and high exposure sand and gravel and has been assigned a low biological sensitivity ranking (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 almost 24% (48 km) of the coastline and are assigned a biological sensitivity ranking of medium (BSF = 2). Approximately 10% (20 km) of the RSA has a high biological sensitivity ranking (BSF = 3) and includes low exposure cobble/boulder veneer over sand. The highest biological sensitivity ranking (BSF = 4) is generally limited to more sheltered embayments located in proximity to Port Moody and represents less than 2% (4 km) of the shoreline in the RSA. The overlays of shoreline oiling probability for each shoreline and near shore sensitivity class are summarized in Table 6.3.

Shorelines with a high to very high probability of oiling (≥50%) generally represent less than 10% of the available habitat belonging to that BSF within the RSA. The worst case effects are seen for shoreline with a high sensitivity rating, where between 4.8% (spring) and 17% (summer) of the available habitat may be affected.

Stochastic results indicate that shoreline and near shore habitat types with highest biological sensitivity factor (*i.e.,* 4) have a very low probability of being oiled, and that it is unlikely that any individual crude oil spill would result in oiling of these areas, which are located near Port Moody. Areas with high probability of oiling (≥50%) are limited to shoreline and near shore habitat types having biological sensitivity factors of 1 to 3, and are located in close proximity to the WMT. Areas of high probability of oiling (≥50%) represent only 3.7% to 4.5% of the total shoreline within the RSA assigned to BSF = 1; 3.8% to 5.5% of the total shoreline within the RSA assigned to BSF = 2; and 4.8% to 17% of the total shoreline within the RSA assigned to BSF = 3.

tochastic results also indicate areas with a high probability of oiling (≥50%) in proximity to the First Nation Reserves at Burrard Inlet 3 (Tsleil-Waututh First Nation) and Seymour Creek 2 (Squamish First Nation), both of which are located on the northern shoreline of Burrard Inlet. Contours indicating a high probability of oiling generally do not contact Provincial Parks, National Parks or Ecological Reserves, with the exception of the spring condition, when there is a high probability of surface water oiling extending to Racoon Island which is part of Indian Arm Provincial Park.

**TABLE 6.3 SUMMARY OF EFFECTS ANALYSIS FOR SHORELINE AND NEAR SHORE HABITATS, CREDIBLE WORST CASE SCENARIO**

| Season | Biological Sensitivity Factor | Shoreline Length in RSA (km) | Affected Shoreline and Near Shore Habitats (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 | 130 | 15 | 4.7 | 0.9 | 12 | 3.7 | 0.7 |
| | 2 | 47 | 11 | 1.8 | --- | 23 | 3.8 | --- |
| | 3 | 21 | 7.3 | 1.8 | --- | 34 | 8.5 | --- |
| | 4 | 3.7 | --- | --- | --- | --- | --- | --- |
| Spring | 1 | 130 | 18 | 5.0 | 1.3 | 14 | 4.0 | 1.0 |
| | 2 | 47 | 13 | 2.5 | --- | 27 | 5.5 | --- |
| | 3 | 21 | 7.3 | 1.0 | --- | 34 | 4.8 | --- |
| | 4 | 3.7 | --- | --- | --- | --- | --- | --- |
| Summer | 1 | 130 | 17 | 5.6 | 0.7 | 14 | 4.5 | 0.6 |
| | 2 | 47 | 11 | 1.3 | --- | 23 | 2.7 | --- |
| | 3 | 21 | 7.2 | 3.7 | --- | 34 | 17 | --- |
| | 4 | 3.7 | --- | --- | --- | --- | --- | --- |
| Fall | 1 | 130 | 14 | 5.2 | 1.2 | 11 | 4.1 | 1.0 |
| | 2 | 47 | 8.9 | 0.6 | --- | 19 | 1.3 | --- |
| | 3 | 21 | 7.3 | 2.9 | 0.3 | 34 | 14 | 1.3 |
| | 4 | 3.7 | --- | --- | --- | --- | --- | --- |

In summary, the PQERA indicates that the shoreline and near shore habitats would be affected by spilled oil following the credible worst case oil spill event at the WMT. This is based upon the assumption of a 160 $m^3$ oil spill, of which 80% is retained by a boom placed around the vessel being loaded. The affected areas generally represent a small fraction of total amount of shoreline belonging to each shoreline and near shore habitats sensitivity class within the RSA. The area with the highest probability of oiling and negative effects is located near the confluence of Indian Arm and Burrard Inlet. Although salt marsh and eelgrass habitats are considered to be highly sensitive to crude oil exposure, these habitats have a very low probability of oiling. Shoreline and near shore habitats classes with low exposure cobble/boulder veneer over sand would be most affected.

Very little of the potentially affected shoreline and near shore habitats in Burrard Inlet is of a type that would tend to sequester spilled crude oil. It is expected that shoreline clean-up and assessment techniques (SCAT) would be applied to the spilled crude oil that reached shorelines 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.

## 6.3 Potential Environmental Effects to Marine Fish and Supporting Habitat

The RSA comprises approximately 115 $km^2$ of habitat for marine fish and supporting habitat and includes habitats and species representing all four of the BSF classifications. Habitats classified by BSF = 1 (low) to BSF = 3 (high) are based on water depth, and are deemed to be exclusive with no overlap in area. However, BSF = 4 (very high) is based on critical habitats and 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 40% of the RSA (46 km$^2$). Areas represented by BSF = 2 (water depths between 10 and 30 m deemed to have medium sensitivity), and areas with BSF = 3 (water depths less than 10 m, deemed to have high sensitivity) represent approximately 30% (34.5 km$^2$) and 26.5% (30.5 km$^2$) of the RSA, respectively. Critical habitats for herring, rockfish and Dungeness crab are combined as BSF = 4 (very high), and overlap with other areas. Overall the BSF = 4 areas represent approximately 15% (34.5 km$^2$) of the RSA. The overlay of water surface oiling probability onto the marine fish and supporting habitat sensitivity classes is shown in Table 6.4.

Results indicate that areas with a high to very high (≥50%) probability of oiling represent 6.4% to 11% of the total area with water depths >30 m, 22% to 24% of the total area with water depths between 10 m and 30 m (BSF = 2), 11% to 13% of the total area with depths <10 m (BSF = 3) and 19% to 21% of the important habitat for rockfish and crab with the highest values typically encountered in the spring.

**TABLE 6.4 SUMMARY OF EFFECTS ANALYSIS FOR MARINE FISH AND SUPPORTING HABITAT, CREDIBLE WORST CASE SCENARIO**

| Season | Biological Sensitivity Factor | 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 | 49 | 11 | 3.8 | 0.2 | 22 | 7.6 | 0.4 |
| | 2 | 35 | 12 | 7.8 | 2.2 | 35 | 22 | 6.3 |
| | 3 | 30 | 9.0 | 3.4 | 0.5 | 29 | 11 | 1.7 |
| | 4 | 18 | 7.6 | 3.3 | 1.2 | 43 | 19 | 7.0 |
| Spring | 1 | 49 | 12 | 5.2 | 0.1 | 25 | 11 | 0.2 |
| | 2 | 35 | 12 | 8.3 | 2.4 | 36 | 24 | 6.7 |
| | 3 | 30 | 9.9 | 3.9 | 0.6 | 32 | 13 | 2.1 |
| | 4 | 18 | 8.3 | 3.7 | 0.6 | 47 | 21 | 3.5 |
| Summer | 1 | 49 | 11 | 3.2 | 0.3 | 22 | 6.4 | 0.7 |
| | 2 | 35 | 14 | 8.5 | 2.1 | 40 | 24 | 6.0 |
| | 3 | 30 | 7.6 | 3.3 | 0.4 | 25 | 11 | 1.3 |
| | 4 | 18 | 6.5 | 3.3 | 1.4 | 37 | 19 | 7.8 |
| Fall | 1 | 49 | 9.2 | 3.2 | 1.6 | 19 | 6.4 | 3.3 |
| | 2 | 35 | 13 | 8.1 | 2.9 | 36 | 23 | 8.3 |
| | 3 | 30 | 6.7 | 3.2 | 0.8 | 22 | 11 | 2.5 |
| | 4 | 18 | 6.0 | 3.3 | 2.1 | 34 | 19 | 12 |

Of a total of 49 km$^2$ of deep water habitat in the RSA (with a low BSF ranking), between 3.2 and 5.2 km$^2$ has a high or very high (≥50%) probability of oil exposure, representing between 6.4% and 11% of this habitat type within the RSA. Given the limited fetch of Burrard Inlet, and the low potential for oil droplets to become dispersed in the water column, it is very unlikely that fish would be harmed by exposure to crude oil in this habitat type.

Of a total of 35 km$^2$ of intermediate depth habitat in the RSA (with a medium BSF ranking), between 7.8 and 8.5 km$^2$ has a high or very high (≥50%) probability of oil exposure, representing approximately 22 to 24% of this habitat type within the RSA. Given the limited fetch of Burrard Inlet, and the low potential for oil droplets to become dispersed in the water column, it is very unlikely that fish would be harmed by exposure to crude oil in this habitat type.

Of a total of 30 km$^2$ of shallow water habitat in the RSA (with a high BSF ranking), between 3.2 and 3.9 km$^2$ has a high or very high (≥50%) probability of oil exposure, representing between 11 and 13% of this habitat type within the RSA. Given the limited fetch of Burrard Inlet, and the low potential for oil droplets to become dispersed in the water column, it is unlikely that fish would be harmed by exposure to crude oil in this habitat type, however, in circumstances where crude oil is driven into 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 18 $km^2$ of critical fish habitat in the RSA (with a very high sensitivity BSF = 4), between 3.3 and 3.7 $km^2$ has a high or very high (≥50%) probability of oil exposure, representing between 19% and 21% of this habitat type within the RSA. Given the limited fetch of Burrard Inlet, and the low potential for oil droplets to become dispersed in the water column, it is unlikely that fish would be harmed by exposure to crude oil in this habitat type. However, where such 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 polycyclic aromatic hydrocarbons in the crude 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 occurred at a time when strong winds caused the oil to be driven into shallow water that could be spawning or nursery areas for herring or crab.

In summary, the PQERA indicates that marine fish and supporting habitat would be affected by spilled oil following the credible worst case oil spill event at the WMT. This is based upon the assumption of a 160 $m^3$ oil spill, of which 80% is retained by a boom placed around the vessel being loaded. The affected areas can represent a substantial fraction (up to 25%) of total amount of some of the habitat types evaluated, however, the potential for negative effects is generally low, as a result of the limited fetch of Burrard Inlet, and the low potential for dissolved hydrocarbon concentrations in water to reach thresholds that would cause mortality of fish or other aquatic life. This potential 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 as a result of narcosis, or could cause abnormalities in developing embryos if spawn was present. The area with the highest probability of effects is located near the confluence of Indian Arm and Burrard Inlet. Critical habitats and spawning areas as well as developing eggs and embryos in shallow water habitat located in proximity to the WMT would be most affected.

As a result of the limited spatial extent of potential effects of spilled oil on marine fish and supporting habitat, and the generally low potential for the credible worst case scenario to cause acute lethality to fish, recovery of marine fish and supporting habitat would be rapid. Even under a worst-case outcome event where a localized fish kill might be observed, it is expected that the lost biological productivity would be compensated for by natural processes within one to two years.

## 6.4 Potential Environmental Effects to Marine Birds and Supporting Habitat

For marine birds and supporting habitat, the entire regional study area (representing an area 115 $km^2$, including all of English Bay, Vancouver Harbour and Burrard Inlet) has been assigned to BSF = 4 (very high) as a result of its designation as an important bird area (IBA). The IBA designation is specific to western grebe and Barrow‟s goldeneye, which winter in the area. Other notable bird species present in the area include colonies of pigeon guillemot, pelagic cormorant and glaucous-winged gull, as well as many other recorded bird species.

Stochastic results identify areas of medium, high and very high probability of oiling for shorelines and the water surface that overlap the distribution of marine birds and supporting habitat. Although these areas demonstrate some seasonal variation, the extent of these areas is generally similar. Results (Table 6.5) indicate that less than 15% of the water surface within the IBA (BSF = 4) has a high or very high probability (≥50%) of being swept by an oil slick following the credible worst case spill. The areas with a very high probability of oiling (90% or higher) are located in close proximity to the terminal and generally extend less than 2 km away from it.

### TABLE 6.5 SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS AND SUPPORTING HABITAT, CREDIBLE WORST CASE SCENARIO

| Season | Biological Sensitivity Factor | 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 | --- | --- | --- | --- | --- | --- | --- |
| | 2 | --- | --- | --- | --- | --- | --- | --- |
| | 3 | --- | --- | --- | --- | --- | --- | --- |
| | 4 | 115 | 32 | 15 | 2.9 | 28 | 13 | 2.6 |
| Spring | 1 | --- | --- | --- | --- | --- | --- | --- |
| | 2 | --- | --- | --- | --- | --- | --- | --- |
| | 3 | --- | --- | --- | --- | --- | --- | --- |
| | 4 | 115 | 35 | 17 | 3.1 | 30 | 15 | 2.7 |
| Summer | 1 | --- | --- | --- | --- | --- | --- | --- |
| | 2 | --- | --- | --- | --- | --- | --- | --- |
| | 3 | --- | --- | --- | --- | --- | --- | --- |
| | 4 | 115 | 33 | 15 | 2.8 | 28 | 13 | 2.5 |
| Fall | 1 | --- | --- | --- | --- | --- | --- | --- |
| | 2 | --- | --- | --- | --- | --- | --- | --- |
| | 3 | --- | --- | --- | --- | --- | --- | --- |
| | 4 | 115 | 28 | 14 | 5.3 | 25 | 13 | 4.6 |

The presence of seabirds and shorebirds is strongly seasonal, and each season will offer different species that could be negatively affected by spilled oil. Whereas there are relatively few nesting colonies, perhaps due in part to the largely urban characteristic of much of the shoreline, migrating birds will visit the area in spring and fall, and the mild winters support populations of waterfowl and other birds.

Burrard Inlet contains habitat for glaucous-winged gull, pelagic cormorant and surf scoter; however, it should be noted that the areas with high or very high probability of oiling (50% or higher) are generally located away from these bird colonies. Exceptions include two colonies of glaucous-winged gull and one colony of pelagic cormorant. The glaucous-winged gull is present year round in the IBA, and is not a species of management concern. However, one subspecies of pelagic cormorant which is present in this region, (*Phalacrocorax pelagicus pelagicus*) is provincially Red-listed and is present in the winter. The other pelagic cormorant species (*P. p. resplendens*) is considered a year round resident. (Campbell *et al.* 1990a). Surf scoters are widely distributed along the British Columbia coastline, especially during spring migration and Burrard Inlet is a particularly important staging ground in the winter and spring.

In summary the PQERA indicates that marine birds and supporting habitat would be affected by the CWC spill, however, the affected area would be small in comparison to the total available supporting habitat present within Burrard Inlet. Less than 15% of the IBA would have a high or very high probability of oiling. The area with the highest probability of oiling is located at the confluence of Indian Arm and Burrard Inlet. Bird colonies located in proximity to the WMT would be most affected.

There is clearly potential for oiling and mortality of seabirds following an accidental spill of crude oil at the WMT. 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, and the ability of oil spill responders to capture and treat oiled birds. The present analysis has evaluated the spreading and fate of spilled oil that escapes from the containment boom without consideration of any further mitigation. Under this pessimistic scenario, modeling showed that less than 15% of the area of the Burrard Inlet IBA would be swept by crude oil at some time during the 15 day period following the spill. Taking into consideration the oil spill recovery and wildlife protection actions that would follow an accidental oil spill, it remains likely that birds would be harmed, but it is also likely that the numbers would be small. At the population level, the lost individuals would likely be compensated for by natural processes within one to two years.

### 6.5 Potential Environmental Effects to Marine Mammals and Supporting Habitat

Several categories of mammals, and their supporting habitats were considered in the PQERA. Terrestrial mammals that may frequent the shoreline were assigned a BSF = 1 (low). The potential for terrestrial mammal exposure to oil was evaluated on the basis of the length of oiled shoreline (km), and that length as a percentage of the total shoreline in the RSA. Pinnipeds and whales, which rely on blubber for insulation and are generally somewhat tolerant of oil exposure were assigned BSF = 2 (medium), and BSF = 3 (high), respectively. It was assumed that pinnipeds (principally harbour seal in the vicinity of the WMT) would occupy marine habitat generally less than 30 m in depth. Conversely, it was assumed that whales (principally harbour porpoise in the vicinity of the WMT) would occupy marine habitat generally greater than 10 m in depth. Furred marine mammals (*e.g.,* otters) that are particularly susceptible to hypothermia and ingestion of crude oil as a result of grooming activity following exposure were assigned a BSF = 4 (very high). It was assumed that these mammals would generally occupy habitat less than 10 m in depth. The overlays of habitat oiling probability for each of the marine mammals and supporting habitat sensitivity classes are summarized in Table 6.6.

For terrestrial mammals (*e.g.,* bears, moose, raccoons, *etc.*, BSF = 1) potential exposure is determined by the 8.3 to 11 km of shoreline that is predicted to have a high or very high probability of oiling. This represents about 5% of the available shoreline habitat. 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 population level effect.

For pinnipeds such as harbour seal (BSF = 2), between 11 and 12 $km^2$ of habitat is estimated to be exposed to surface oil at some time during the 15 day simulations. This represents between 17% and 19% of the available habitat. Therefore there is a relatively high probability of exposure for harbour seal inhabiting Burrard Inlet in the unlikely event of an accidental crude oil spill. Some level of negative effect would be expected for animals exposed to crude oil, but 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 the harbour porpoise (BSF = 3), between 11 and 14 $km^2$ of habitat is estimated to be exposed to surface oil at some time during the 15 day simulations. This represents between 13% and 16% of the available habitat. Therefore there is a relatively high probability of exposure for harbour porpoise inhabiting Burrard Inlet in the unlikely event of an accidental crude oil spill. Some level of negative effect would be expected for animals exposed to crude oil, but the effects would not likely be lethal, except in the case of weaker animals such as calves or older and diseased animals.

For furred marine mammals such as the river otter (BSF = 4), between 3.2 and 3.9 $km^2$ of habitat is estimated to be exposed to surface oil at some time during the 15 day simulations. This represents between 11% and 13% of the available habitat. Therefore there is a relatively high probability of exposure for some of the otters inhabiting Burrard Inlet in the unlikely event of an accidental crude oil spill. Some level of negative effect would be expected for animals exposed to crude 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 crude oil ingested through grooming the fur would have the potential to cause death. The overlay of oiling probability onto the marine mammals and supporting habitat sensitivity factors is shown in Table 6.6.

**TABLE 6.6 SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS AND SUPPORTING HABITAT, CREDIBLE WORST CASE SCENARIO**

| Season | Biological Sensitivity Factor | Area or Length in RSA ($km^2$ or km*) | Affected Surface Water (by Surface Water Oiling Probabilities) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Area or Length According to Sensitivity Factor ($km^2$ or km | | | Percent Area According to Sensitivity Factor (%) | | |
| | | | Medium (≥10%) | High (≥50%) | Very High (≥90%) | Medium (≥10%) | High (≥50%) | Very High (≥90%) |
| Winter | 1* | 200* | 33* | 8.3* | 0.92* | 17 | 4.2 | 0.46 |
| | 2 | 66 | 21 | 11 | 2.7 | 33 | 17 | 4.2 |
| | 3 | 84 | 23 | 12 | 2.4 | 28 | 14 | 2.9 |
| | 4 | 30 | 9.0 | 3.4 | 0.52 | 29 | 11 | 1.7 |
| Spring | 1* | 200* | 38* | 8.6* | 1.3* | 19 | 4.3 | 0.65 |
| | 2 | 66 | 22 | 12 | 3.0 | 34 | 19 | 4.6 |
| | 3 | 84 | 25 | 14 | 2.4 | 29 | 16 | 2.9 |
| | 4 | 30 | 9.9 | 3.9 | 0.63 | 32 | 13 | 2.1 |
| Summer | 1* | 200* | 35* | 11* | 0.74* | 18 | 5.4 | 0.38 |
| | 2 | 66 | 22 | 12 | 2.5 | 33 | 18 | 3.8 |
| | 3 | 84 | 25 | 12 | 2.4 | 30 | 14 | 2.9 |
| | 4 | 30 | 7.6 | 3.3 | 0.41 | 25 | 11 | 1.3 |
| Fall | 1* | 200* | 30* | 8.7* | 1.5* | 15 | 4.4 | 0.76 |
| | 2 | 66 | 19 | 11 | 3.7 | 29 | 17 | 5.6 |
| | 3 | 84 | 22 | 11 | 4.6 | 26 | 13 | 5.4 |
| | 4 | 30 | 6.7 | 3.2 | 0.77 | 22 | 11 | 2.5 |

NOTE: * For terrestrial mammals (BSF = 1), environmental effects are estimated as length (km) of shoreline subject to oiling, rather than the area ($km^2$) of affected habitat.

In summary, the PQERA indicates that marine mammals and supporting habitat would be affected, however the affected areas would be modest in comparison to the overall habitat present within Burrard Inlet. Less than 20% of the RSA would have a high or very high probability of oiling. The area with the highest probability of oiling is located at the confluence of Indian Arm and Burrard Inlet. Marine mammals and supporting habitat located in proximity to the WMT would be most affected.

There is clearly potential for oiling of marine mammals and supporting habitat following an accidental spill of crude oil at the WMT. 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. The present analysis has evaluated the spreading and fate of spilled oil that escapes from the containment boom without consideration of any further mitigation. Under this pessimistic scenario, modeling showed that less than 20% of the available marine mammal habitat within the RSA would be swept by crude oil at some time during the 15 day period following the spill. Taking into consideration the oil spill recovery and wildlife protection actions that would follow an accidental oil spill, it remains likely that some animals would be harmed, but it is also likely that the numbers would be small. Animals like otter would be most at risk, with lower potential for mortality of harbour porpoise and harbour seals. Exposure of other whales and pinnipeds is quite unlikely as a result of their low occupancy in Burrard Inlet. At the population level, lost individuals would likely be compensated for by natural processes within one to two years.

## 6.6 Risk Characterization Summary for a Credible Worst Case Spill

A credible worst case spill involving the release of 160 $m^3$ of CLWB from the WMT would potentially cause negative environmental effects on shoreline and near shore habitats, marine fish, marine birds and marine mammals, as well as their supporting habitat, within the RSA. However, the affected areas would be modest in consideration of all available habitat within the RSA. Based on the stochastic simulations for this scenario, areas with highest probability of oiling are located around the WMT and near the confluence of Indian Arm and Burrard Inlet. Acute lethality of fish is an unlikely scenario, although damage to oiled shoreline and intertidal communities is likely, although localized. There is potential for mortality of seabirds, but numbers are likely to be low. There is a low potential for mortality to terrestrial mammals exposed to oil on shorelines, and also a low potential for mortality of seals or porpoises. A higher potential exists for mortality of otters. While negative environmental effects are likely to occur within a portion of Burrard Inlet, most of the negative environmental effects would be expected to be reversible within one to two years.

This conclusion is supported by the results of samples collected after a crude oil release which occurred near the WMT in July, 2007 (Stantec 2010a). That accident, which was due to third-party damage to a pipeline resulted in approximately 100 $m^3$ of CLWB entering Burrard Inlet near the WMT. Surface water samples were collected at several locations one and two weeks after the incident. All sample results were below detection limits for extractable petroleum hydrocarbons (EPHs). In addition, while concentrations of PAHs were above detection limits at a few locations, none exceeded water quality guidelines which are protective of the marine environment. The follow-up monitoring and assessment report concluded that oil concentrations in the water column likely peaked soon after the release, but decreased to background levels within days (Stantec 2010a). Sediment tests indicated some areas with PAH concentrations above applicable guidelines. A comparison of PAH composition in sediment samples and released oil indicates that sediment in the Westridge area has likely been affected by the oil release, as well as by historic shipping activity and other sources of PAH. Sediment from sites further away (*e.g.,* Maplewood Flats, Deep Cove, Cates Park, Belcarra, Port Moody flats, Barnet Marine Park) also contained measurable PAHs, but their chemical fingerprint did not match that of the released oil.

Approximately 15 km of shoreline east of Second Narrows was affected by the accidental release (Stantec 2010a). The most heavily affected area was 2.5 km of shoreline between the Shell Jetty Marine Terminal and Barnet Beach at Barnet Marine Park. This heavily oiled area was extensively remediated through removal of oiled seaweed (Fucus), agitation of soft sediments (sand, mud) and application of the shoreline treatment agent Corexit 9580 (a biodegradable cleanser that contains surfactant). As a result of the oil release and remediation, this area experienced habitat loss and death or removal of marine plants (primarily Fucus) as well as a likely loss of intertidal fauna such as starfish, barnacles and limpets. An analysis of mussels collected throughout the eastern part of the inlet indicated that only in the Westridge area was there an amount and distribution pattern (fingerprint) of PAHs that could be associated with the release. Subtidal organisms may also have been affected by the release, but these effects appear to be limited and localized. Red rock crabs from the Westridge area showed elevated PAH levels and a similar pattern of PAH to the released oil. However, none of the Dungeness crabs sampled at Westridge or crabs of either species from Barnet Marine Park and Berry Point and elsewhere in the Inlet (Indian Arm and Port Moody Arm) showed evidence of having taken up oil from the release. There was no evidence for direct effects on fin-fish species.

Effects of the release were noted for some marine birds and mammals (Stantec 2010b). Fifteen Canada geese, two gulls and one pelagic cormorant were captured due to oiling. All but two Canada geese were cleaned and released, one of the two not released was transferred to a different facility and the other was euthanized due to an injured eye. Effects on other species of marine birds were minimal, largely because overwintering birds had not yet returned from their northern breeding ranges. Three dead harbour seal pups were found in Burrard Inlet following the release, but cause of death could not be determined, and only one had signs of oil exposure. No other effects on marine mammals, including otters, were reported in Burrard Inlet.

# 7.0 QUALITATIVE ASSESSMENT OF SMALLER SPILLS

This section summarizes the evaluation of environmental effects to ecological receptors resulting from smaller spills which could potentially occur at the WMT during loading operations. The spill scenario considered here was developed by DNV (2013), and is summarized as leak from a loading arm resulting in a release of 10 $m^3$ of CLWB. Based on the standard procedure of deploying containment boom around the ship prior to the start of loading, as well as the smaller spill volume, this scenario considered that the spilled oil would be completely retained within the boom, and would not spread across the water surface outside of the boom, or impinge directly on the adjacent shoreline.

While stochastic simulations for all four seasons were completed, no oil spill trajectory was modelled as the spilled crude oil would remain within the containment boom. Standard operating procedures in place at the terminal would result in immediate shut-down of transfer operations, and implementation of spill response plans including immediate recovery of the oil using pre-deployed equipment, and this mitigation was also considered when evaluating potential environmental effects from smaller spills. Based on existing spill response plans, recovery operations for such smaller spills would be expected to be complete within a few days.

## 7.1 Summary of Stochastic Modelling Results

The stochastic modelling for smaller spills was completed over a 5-day tracking period, and did not consider any mitigation or recovery of the spilled oil other than its effective containment within the pre-deployed boom. Results of the seasonal stochastic simulations were very similar with only small differences related to seasonal variations in temperature, predominant current direction and speed and/or predominant wind direction and speed.

Mass balance results showed that approximately 22% to 23% of the oil would evaporate, with the highest amount in the fall and lowest amount in winter, approximately 2% would dissolve and 3% would biodegrade, leaving approximately 72% to 73% on the water surface inside the boom after 5 days, with the highest amount in summer and lowest amount in the fall. However, in reality the spilled crude oil would be expected to be recovered from the boom within this time frame. Mass balance results from the EBA modelling output for the 10 $m^3$ spill are presented in Appendix C.

Given that the oil spill fate modelling results were similar across all seasons, results are discussed in the context of the summer spill scenario only. The environmental effects of the smaller spills in other seasons (*i.e.,* winter, spring and fall) are expected to be qualitatively similar to those in the summer season.

## 7.2 Oil Fate and Potential Effects on Shoreline and Near Shore Habitats

After being released to the water surface, some of the more water-soluble constituents of the crude oil would dissolve into the water column. These constituents are also relatively volatile, and there is a limited window of time when the spilled oil is relatively unweathered so that these constituents are available. Approximately 22% of the oil evaporates and disperses in the atmosphere. Less than 2% of the crude oil dissolves into the water column. The protected nature of Burrard Inlet, and the additional protection afforded by the pre-deployed boom would limit the effects of wind or waves on the spilled oil, so that the dispersion of oil droplets beneath the slick is highly unlikely. This limitation also strongly limits the dissolution of the more water-soluble constituents, such as BTEX and light PAHs.

Any dissolved hydrocarbons resulting from the spill would be quickly diluted by the surrounding marine water. Tidal action would ensure that the hydrocarbons dissolving into the water did not have an opportunity to reach saturation, and would also help to dilute the dissolved hydrocarbons, resulting in only a short-term negative effect on water quality. It is highly unlikely that dissolved hydrocarbon concentrations would be sufficiently high for long enough to cause acute lethality to fish or other aquatic life.

Sedimentation of oil can occur when dispersed oil enters the water column, if it combines with suspended particulate matter, and settles to the bottom. Testing carried out in support of the Project showed that CLWB did not sink by itself after ten days exposure on brackish water (Witt O'Brien *et al.* 2013). Oil spill modeling indicated that negligible amounts of oil would become suspended as droplets in the water column, as a result of the sheltered nature of Burrard Inlet and the relatively viscous characteristic of the oil. Very little suspended sediment is present in the waters of Burrard Inlet. Taking these factors into consideration, formation of OMA and sinking of oil is an unlikely scenario. Therefore, it is unlikely that a smaller spill of CLWB would have a substantial negative effect on sediment quality.

## 7.3 Potential Effects to Marine Fish and Supporting Habitat

Because hydrocarbons are hydrophobic, they partition strongly between water and living organisms. Uptake of hydrocarbons from water by living organisms is regulated primarily by equilibrium exchange processes between water and lipids, and occurs primarily across permeable or vascular surfaces such as gills or egg membranes. Once inside the organism, hydrocarbons become part of the generalized lipid pool where they can disrupt cellular and tissue function (French McCay 2009).

While short-term (acute) exposure to dissolved hydrocarbons in the water column could potentially be lethal to aquatic biota (*e.g.,* fish, invertebrates, aquatic vegetation), as a result of the relatively small spill volume, and short duration of exposure, lethality is not expected as an outcome of the smaller spill, which remains confined within the containment boom. Sub-lethal effects to aquatic receptors would not be persistent at population levels, and recovery would be expected to occur quickly.

## 7.4 Potential Effects to Marine Birds or Marine Mammals and Supporting Habitat

Because the spilled oil would be completely retained within the containment boom, it would not come into contact with the adjacent shoreline, and thus there would be no exposure of terrestrial mammals. Acute environmental effects of an oil spill on birds and aquatic mammals could however result either from direct contact with floating oil within the boom, or through inhalation of vapours by an individual animal (*e.g.,* birds, or aquatic mammals surfacing in an oil slick).

Direct oiling of wildlife can result in decreased survival and reproductive success through a number of mechanisms, including loss of waterproofing and insulating characteristics of feathers or fur, toxicity from transfer of oil from feathers to eggs during incubation, absorption through the skin, ingestion of toxins via grooming or feeding, and reduced mobility (USNRC 2003; French McCay 2009). However, given the relatively small amount of spilled oil, and the level of human activity that the oil spill response would quickly engender, the probability of a direct encounter between birds or mammals and floating oil would be low.

While volatile components of the oil (*e.g.,* BTEX) can concentrate vapours on the surface of an oil slick as they evaporate into the surrounding air and potentially create narcotic effects on wildlife, these vapours would likely be dispersed quickly.

Therefore, although individual birds or mammals may be exposed to the direct effects of oiling or inhalation of vapours, the effects would not be expected to be lethal, or to persist at the population level.

## 7.5 Risk Characterization Summary for a Smaller Spill

In summary, a hypothetical release of 10 $m^3$ of CLWB at the Westridge terminal during loading operations would not likely affect shoreline habitat or sediment quality, but would result in a short-term and localized effect on water quality. Acute lethality to aquatic biota is not likely to result. Birds and mammals in direct contact with the oil at the water surface could also be affected. However, as a result of the presence of the containment boom, and the expected recovery of the oil within a few days, ecological effects would not be persistent at population levels. Therefore, the environmental effects on marine ecological receptors of a smaller spill of crude oil at the WMT, which remains confined within the containment boom, are expected to be Negligible.

# 8.0 CERTAINTY AND CONFIDENCE

Administrative boundaries and uncertainties are inherent to many aspects of predicting risks to ecological receptors. The extent of these boundaries is dictated by the availability and quality of information, as well as the variability associated with many of the exposure processes and factors being considered. When conducting 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 PQERA, prediction confidence is based on the following factors:

- Environmental fate modeling
- Selection of marine ecological receptors and derivation/assignment of biological sensitivity factors
- Exposure and hazard assessment.

## 8.1 Environmental fate Modelling

Models used in the stochastic oil spill modelling have been developed over many years to include as much information as possible to simulate the fate and effects of oil spills in a realistic manner. However, there are limits to the complexity of processes that can be modelled, as well as gaps in knowledge regarding the environment that is affected, and the behaviour of specific organisms and ecosystems.

In the unlikely 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. Thus, the results presented here are a function of the scenarios simulated and the accuracy of the input data used. The goal of this study is 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 scenarios. The model inputs are designed to provide representative conditions to inform such an analysis. Thus, the modelling is used to provide quantitative guidance in the analysis of the scenarios considered in the ERA.

The outcomes of the oil spill stochastic simulations are consistent with the behaviour and fate of crude oil that was accidentally released to Burrard Inlet in 2007.

## 8.2 Biological Sensitivity Factors

Biological sensitivity factors were established through consideration of marine biota receptors with anticipated exposure to the oil with particular attention to species believed to be sensitive to disturbance, and which act as indicators of overall environmental health. For each receptor category, four biological sensitivity classes were defined on a scale of 1 (low sensitivity) to 4 (very high sensitivity). For shoreline and near shore habitats, biological sensitivity factors were based on consideration of habitat complexity and ability of different habitat types to sustain high levels of biodiversity and productivity, as well as the way in which spilled crude oil would interact with and persist on such habitat. For marine fish and supporting habitat, 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 mammals and their habitats, the classification scheme considers lifestyle, behaviour, and exposure mechanisms, and in particular the role of fur or feathers in providing thermal insulation for warm-blooded animals in a cold environment. These factors are well understood in terms of their importance to the sensitivity of different types of wildlife when exposed to spilled oil.

## 8.3 Exposure and Hazard Assessment

Ecological receptors were assumed to be exposed to spilled crude oil to the extent that their habitat overlapped with three probability boundaries for oil presence on water, or oiling of shorelines (*i.e.,* ≥10%; ≥50% and ≥90% probability of oiling). It is conservatively assumed that any contact between a marine ecological receptor and crude oil is potentially harmful, regardless of the amount of oil present, or the duration of the exposure. This approach is likely to overstate, rather than understate the potential consequences of spilled crude oil.

## 8.4 Recovery Assessment

The recovery assessment was carried out with primary consideration being given to the recovery of ecological receptors following the EVOS of 1989. 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 a defining 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 learned 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, including shoreline and near shore habitats, marine fish and supporting habitat, marine birds and supporting habitat, and marine mammals and supporting habitat, recovery predictions and time to recovery are based upon relevant real-world experience, and are accorded a high level of confidence.

# 9.0 SUMMARY AND CONCLUSIONS

This PQERA indicates that while shoreline and near shore habitats within Burrard Inlet could be negatively affected by crude oil in the event of an accidental spill during loading operations at the WMT, the magnitude of such effects would largely depend upon the quantity of crude oil that escaped from the containment boom within which such operations are carried out. Crude oil that remains confined within the containment boom would not have the potential to harm shoreline and near shore habitats, and would be unlikely to cause mortality of fish, marine birds or marine mammals. Contained crude oil would also be amenable to recovery operations.

Crude oil that escaped from such confinement would have much greater potential to cause harm to shoreline and near shore habitats, shallow-water fish habitats, and marine birds and mammals. The extent to which such negative effects would be realized (*i.e.,* effect magnitude), and the length of time required for biological recovery to occur, would depend upon the quantity of such fugitive oil, as well as seasonal factors influencing weather, and biological resources. These and other factors are summarized by ecological receptor type in the following sections.

## 9.1 Potential Effects and Recovery of Shoreline and Near Shore Habitats

While shoreline and near shore habitats within Burrard Inlet could be affected by crude oil that escaped from confinement under the CWC scenario, the affected areas generally represent a small fraction of the total amount of shoreline within the RSA belonging to each shoreline and near shore habitats sensitivity class. For the CWC scenario, the maximum spatial extent of affected shorelines with high to very high probability of oiling is 4.5% of the available habitat within the RSA assigned to BSF = 1; 5.5% of the available habitat within the RSA assigned to BSF = 2; and 17% of the available habitat within the RSA assigned to BSF = 3. Shoreline types with highest biological sensitivity factor (BSF = 4) have a very low probability of being oiled, and it is unlikely that any individual crude oil spill would result in oiling of these areas, which are located near Port Moody. In the context of effect magnitude, any crude oil spill that entered habitat for fish or migratory birds would be a violation of federal and/or provincial regulations respecting such habitat, and would be assigned an effect magnitude rating of “High”.

Results also indicate areas with a high probability of oiling in proximity to the First Nation Reserves at Burrard Inlet 3 (Tsleil-Waututh First Nation) and Seymour Creek 2 (Squamish First Nation), both of which are located on the northern shoreline of Burrard Inlet. Contours indicating a high probability of oiling generally do not contact Provincial Parks, National Parks or Ecological Reserves, with the exception of the spring condition, when there is a high probability of surface water oiling extending to Racoon Island which is part of Indian Arm Provincial Park.

Very little of the potentially affected shoreline habitat in Burrard Inlet is of a type that would tend to sequester spilled crude oil. It is expected that shoreline clean-up and assessment techniques (SCAT) would be applied to spilled crude oil that reached shorelines 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, as was the case for an accidental spill of CLWB that entered Burrard Inlet in 2007.

## 9.2 Potential Effects and Recovery of Marine Fish and Supporting Habitat

Fish habitat within Burrard Inlet would be negatively affected by any crude oil spill to the marine environment at the WMT. For the CWC scenario, the areas affected by spilled crude oil that escaped from confinement represent a spatial extent less than 25% of the total amount of each habitat type available within the RSA. The maximum spatial extent of affected fish habitat with high to very high probability of oiling is 11% of the available habitat within the RSA assigned to BSF = 1; 24% of the available habitat within the RSA assigned to BSF = 2; 13% of the available habitat within the RSA assigned to BSF = 3; and 21% of the available habitat within the RSA assigned to BSF = 4, which includes important habitat for rockfish and crab.

As noted for shoreline and near shore habitats, any spill of crude oil to the water surface would be a violation of federal and/or provincial regulations respecting such habitat for fish, and would therefore be assigned an effect magnitude rating of “High”. However, the potential for negative effects to marine fish and supporting habitat is generally low, due to the limited fetch of Burrard Inlet, and the low potential for dissolved hydrocarbon concentrations in water to reach thresholds that would cause mortality of fish or other aquatic life. This potential would be greatest in shallow water areas under weather conditions causing spilled oil to be driven into shallow areas with wave action, leading to localized high concentrations of dissolved hydrocarbons and hydrocarbon droplets in the water column. This could result in the death of fish as a result of narcosis, or could cause abnormalities in developing embryos if spawn was present. The area with the highest probability of negative effects is located near the confluence of Indian Arm and Burrard Inlet. Critical habitats and spawning areas as well as developing eggs and embryos in shallow water habitat located in proximity to the WMT would be most likely to be affected.

Due to the limited spatial extent of potential effects of spilled oil on fish and fish habitat, and the generally low potential for the credible worst case scenario to cause acute lethality to fish, recovery of marine fish and fish habitat would be rapid. Even under a worst-case outcome event where a localized fish kill might be observed, it is expected that the lost biological productivity would be compensated for by natural processes within one to two years.

## 9.3 Potential Effects and Recovery of Marine Birds and Supporting Habitat

Marine bird habitat would be negatively affected by any crude oil spill to the marine environment at the WMT. For marine birds and supporting habitat, the entire regional study area (representing an area 115 $km^2$, including all of English Bay, Vancouver Harbour and Burrard Inlet) has been assigned to BSF = 4 (very high) due to its designation as an important bird area (IBA). Any spill of crude oil to the water surface would be a violation of federal regulations respecting such habitat for migratory birds, and potentially federal and/or provincial regulations regarding species at risk, and would therefore be assigned an effect magnitude rating of “High”. Any spill of crude oil that resulted in the death of a migratory bird would also be assigned an effect magnitude of “High”.

For the CWC scenario the maximum spatial extent of affected bird habitat with high to very high probability of oiling is less than 15% of the available habitat within the RSA. The areas with a very high probability of oiling (90% or higher) are located in close proximity to the terminal and generally extend less than 2 km away from it. As such, bird colonies located in proximity to the WMT would be most likely affected.

There is potential for oiling and mortality of seabirds following any accidental spill of crude oil at the WMT. 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, and the ability of oil spill responders to capture and treat oiled birds. Taking into consideration the oil spill recovery and wildlife protection actions that would follow an accidental oil spill, it remains likely that birds would be harmed, but it is also likely that the numbers would be small. At the population level, the lost individuals would likely be compensated for by natural processes within one to two years.

## 9.4 Potential Effects and Recovery of Marine Mammals and Supporting Habitat

Marine mammal habitat within Burrard Inlet would be negatively affected by any crude oil spill to the marine environment at the WMT. As noted for marine birds and supporting habitat, any spill of crude oil to the water surface could potentially violate federal and/or provincial regulations regarding species at risk, and would therefore be assigned an effect magnitude rating of “High”. Likewise, any spill of crude oil that resulted in the death of a marine mammal would be assigned an effect magnitude of “High”.

For the CWC scenario the maximum spatial extent of affected marine mammals and supporting habitat with high to very high probability of oiling is about 5% of the available habitat within the RSA assigned to BSF = 1; 19% of the available habitat within the RSA assigned to BSF = 2; 16% of the available habitat within the RSA assigned to BSF = 3; and 3% of the available habitat within the RSA assigned to BSF = 4. Marine mammals and supporting habitat present in the vicinity of the WMT would be most likely to be affected.

There is potential for oiling of marine mammals following an accidental spill of crude oil at the WMT. 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. Taking into consideration the oil spill recovery and wildlife protection actions that would follow an accidental oil spill, it remains likely that some animals would be harmed, but it is also likely that the numbers would be small. Animals like otters would be most at risk, with lower potential for mortality of harbour porpoise and harbour seals. Exposure of other whales and pinnipeds is unlikely due to the low frequency of their presence in Burrard Inlet. At the population level, lost individuals would likely be compensated for by natural processes within one to two years.

## 10.0 CLOSURE

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## Appendix A Biological Sensitivity Factor Figures


Stantec

km
0 1.5 3 4.5 6
ALL LOCATIONS APPROXIMATE

| MAP NUMBER 123110494_064 | | PAGE SHEET 1 OF 1 |
|---|---|---|
| DATE Nov 2013 | TERA REF. REF | REVISION A |
| SCALE 1:200,000 | PAGE SIZE 8.5 x 11 | DISCIPLINE ERA |
| DRAWN HW | CHECKED AS, PM | DESIGN MS, HW |

★ Westridge Marine Terminal
Regional Study Area Boundary
Land of British Columbia
Waterbody

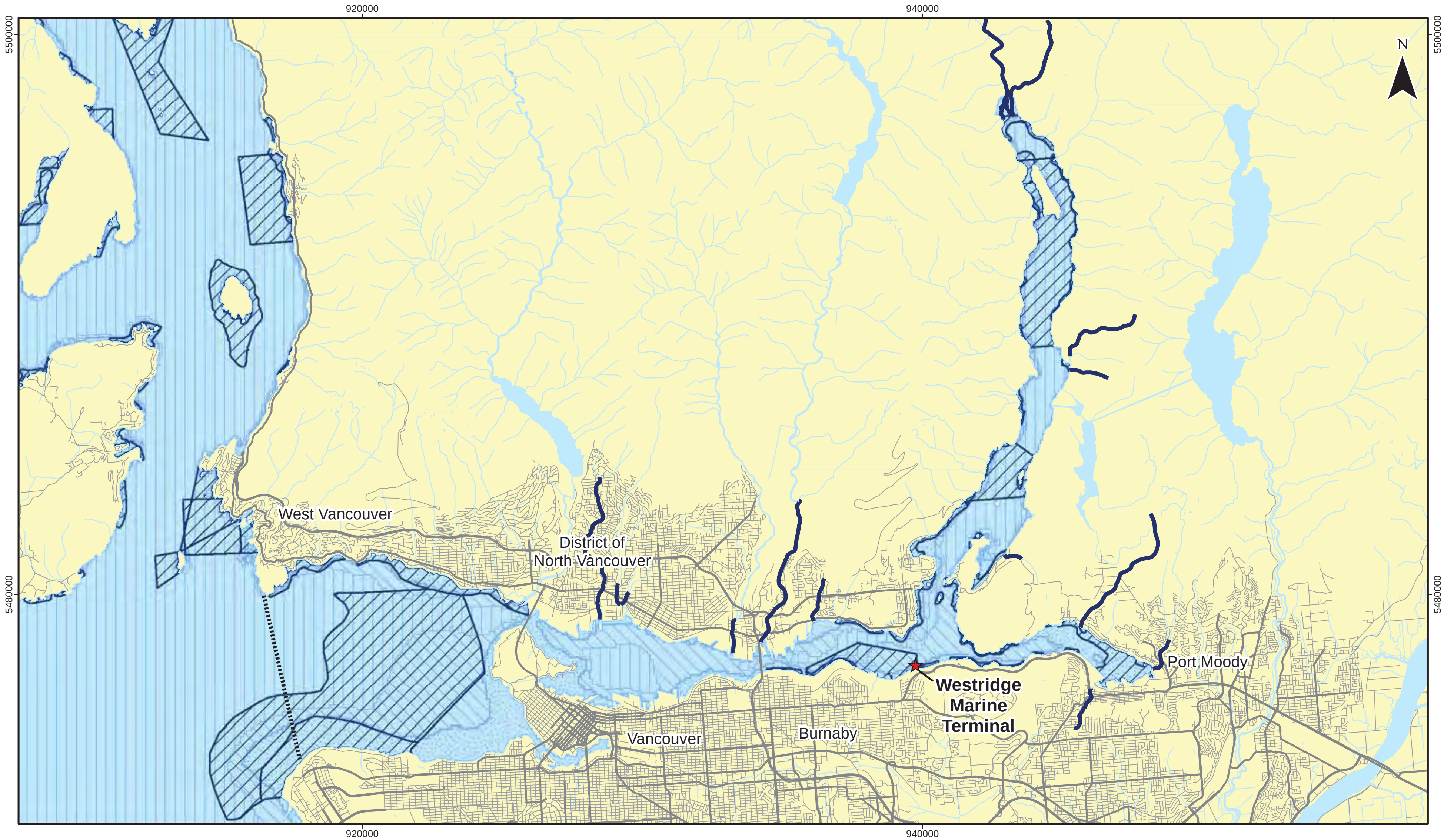
Protected Area
Aboriginal Reserve

Biological Risk Factor - Shoreline
1 Low
2 Medium
3 High
4 Very High

TRANS MOUNTAIN

FIGURE: A.1

BIOLOGICAL SENSITIVITY FACTORS FOR NEAR SHORE HABITATS




Stantec

km
0 1.5 3 4.5 6

ALL LOCATIONS APPROXIMATE

| MAP NUMBER 123110494_062 | | PAGE SHEET 1 OF 1 |
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| SCALE 1:200,000 | PAGE SIZE 8.5 x 11 | DISCIPLINE ERA |
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★ Westridge Marine Terminal

Regional Study Area Boundary

Land of British Columbia

Waterbody

Salmon-bearing Streams

Biological Risk Factor - Fish

1 Low

2 Medium

3 High

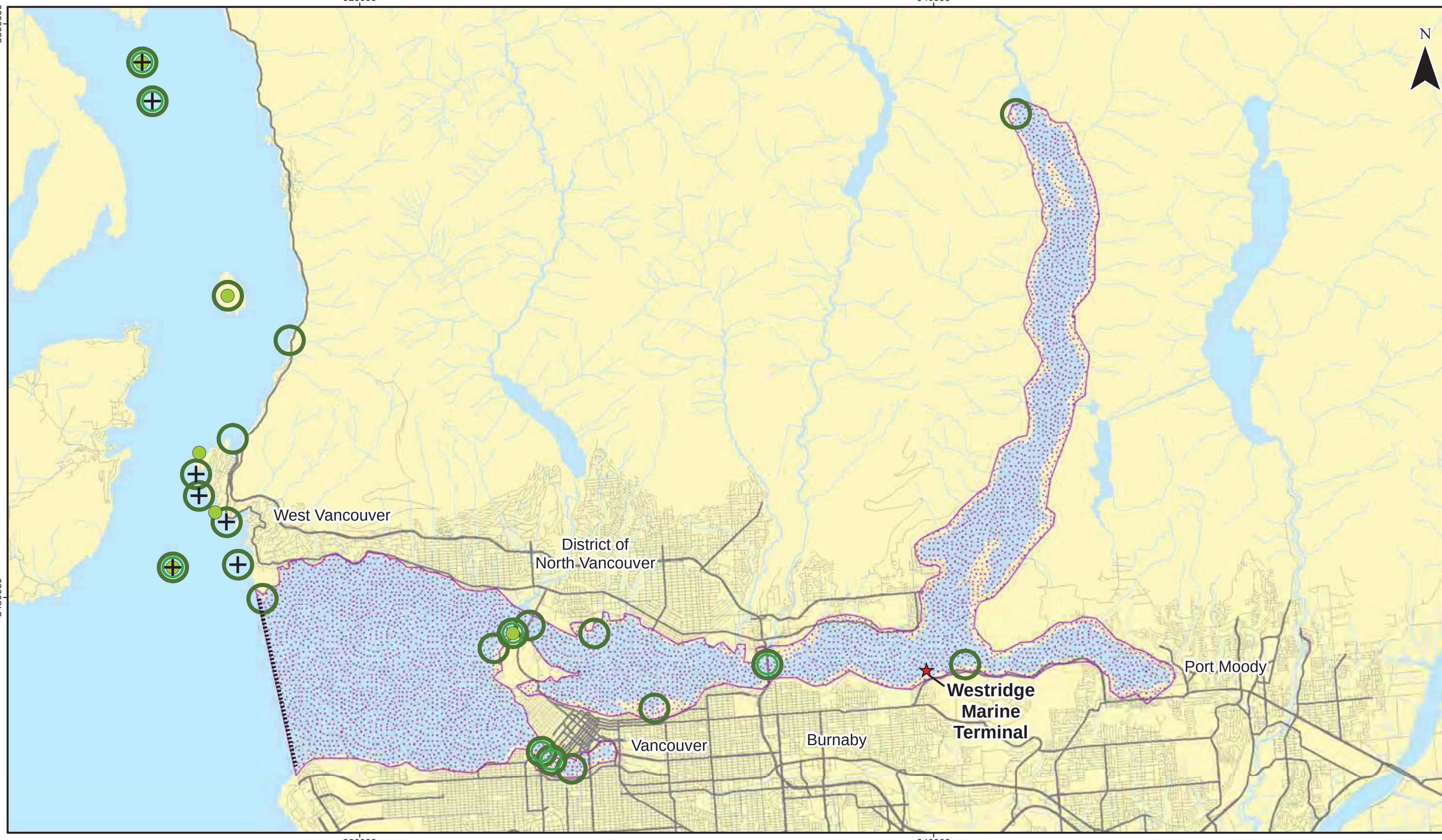
4 Very High



TRANS MOUNTAIN

FIGURE: A.2

**BIOLOGICAL SENSITIVITY FACTORS FOR FISH AND FISH HABITAT**




Stantec

0 1.5 3 4.5 6 km

ALL LOCATIONS APPROXIMATE

| | | |
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| MAP NUMBER 123110494_063 | | PAGE SHEET 1 OF 1 |
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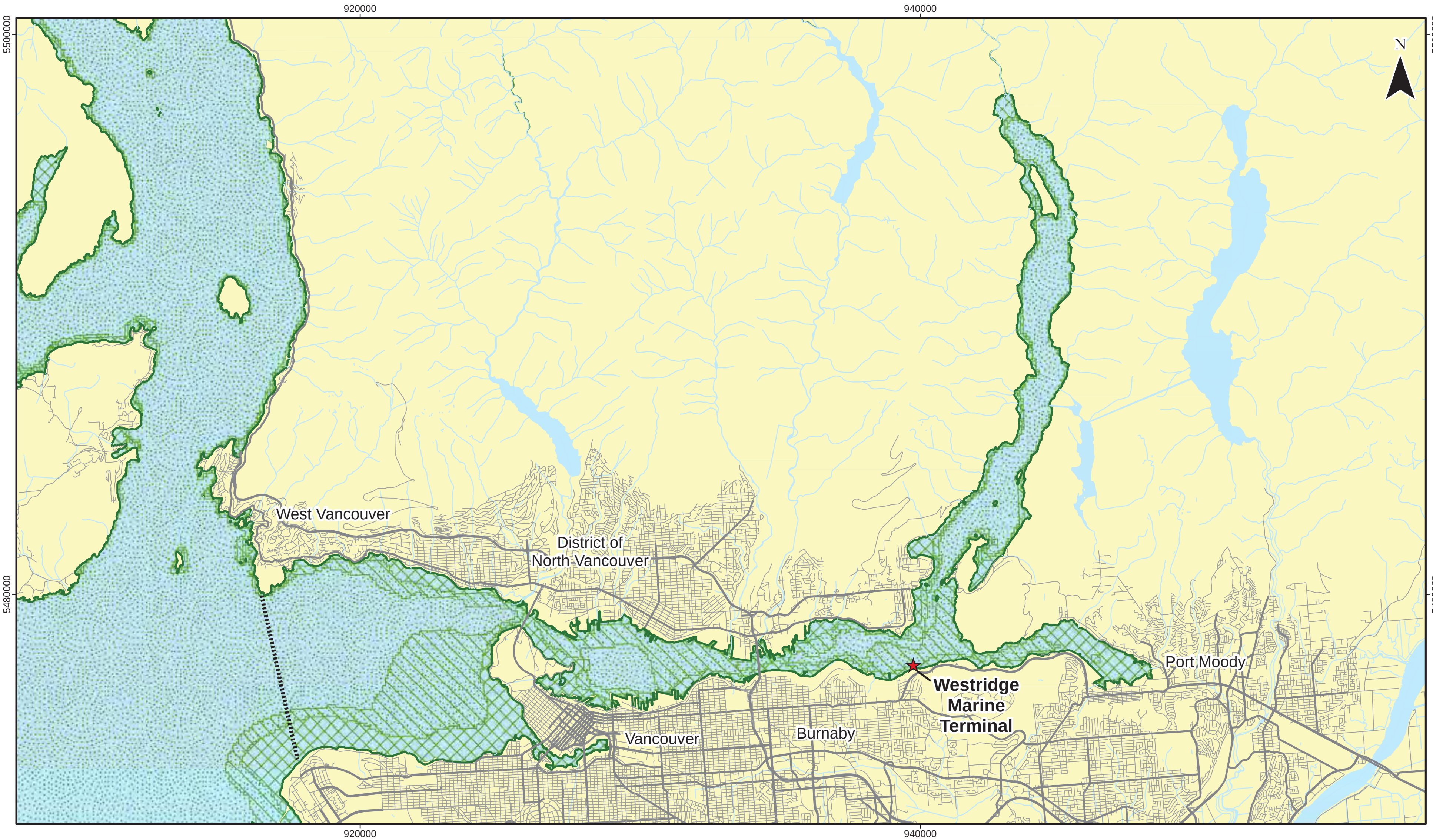
- Westridge Marine Terminal
- Regional Study Area Boundary
- Land of British Columbia
- Waterbody
- Black Oystercatcher Breeding Areas
- Pigeon Guillemot Colony
- Pelagic Cormorant Colony
- Glaucous-winged Gull Colony
- Important Bird Area



TRANS MOUNTAIN

FIGURE: A.3

**BIOLOGICAL SENSITIVITY FACTORS FOR MARINE BIRDS AND BIRD HABITAT**




Stantec

km
0 1.5 3 4.5 6
ALL LOCATIONS APPROXIMATE

| | | |
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| MAP NUMBER 123110494_065 | | PAGE SHEET 1 OF 1 |
| DATE Nov 2013 | TERA REF. REF | REVISION A |
| SCALE 1:200,000 | PAGE SIZE 8.5 x 11 | DISCIPLINE ERA |
| DRAWN HW | CHECKED AS, PM | DESIGN MS, HW |

★ Westridge Marine Terminal
Regional Study Area Boundary
Land of British Columbia
Waterbody

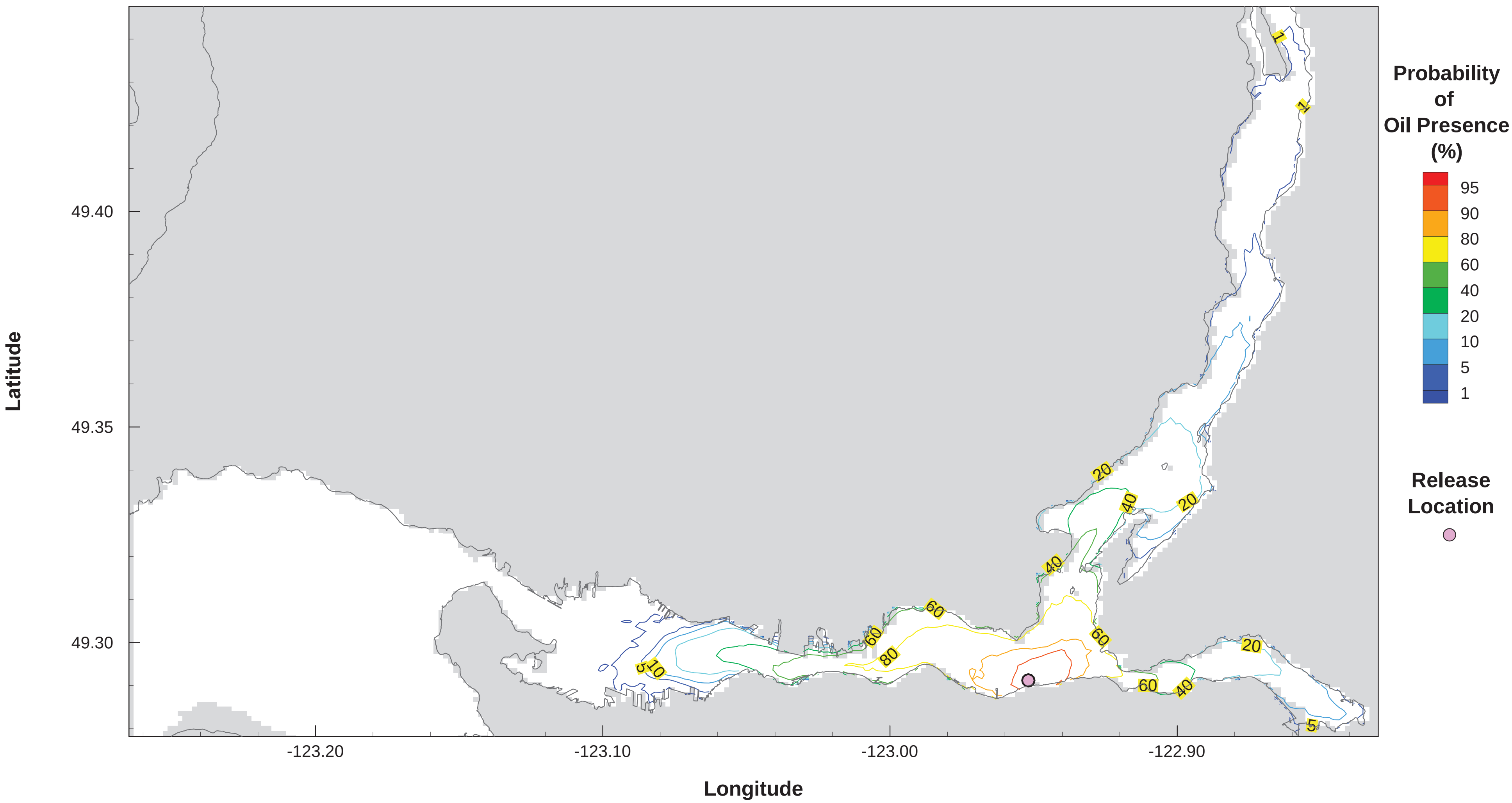
Biological Risk Factor - Mammals
1 Low
2 Medium
3 High
4 Very High

TRANS MOUNTAIN

**FIGURE: A.4**

**BIOLOGICAL SENSITIVITY FACTORS FOR MARINE AND TERRESTRIAL MAMMALS**

# Appendix B Output from EBA (EBA 2013) Credible Worst Case (CWC) 160 $m^3$ Spill




## NOTES

- Statistical results based on independent spills occuring every 3 hours from January 01 00:00 to March 31 23:00, for a total of 728 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

STATUS
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## TRANS MOUNTAIN OIL SPILL STUDY

### Stochastic Simulation Winter 2012, Site A Probability of Oil Presence

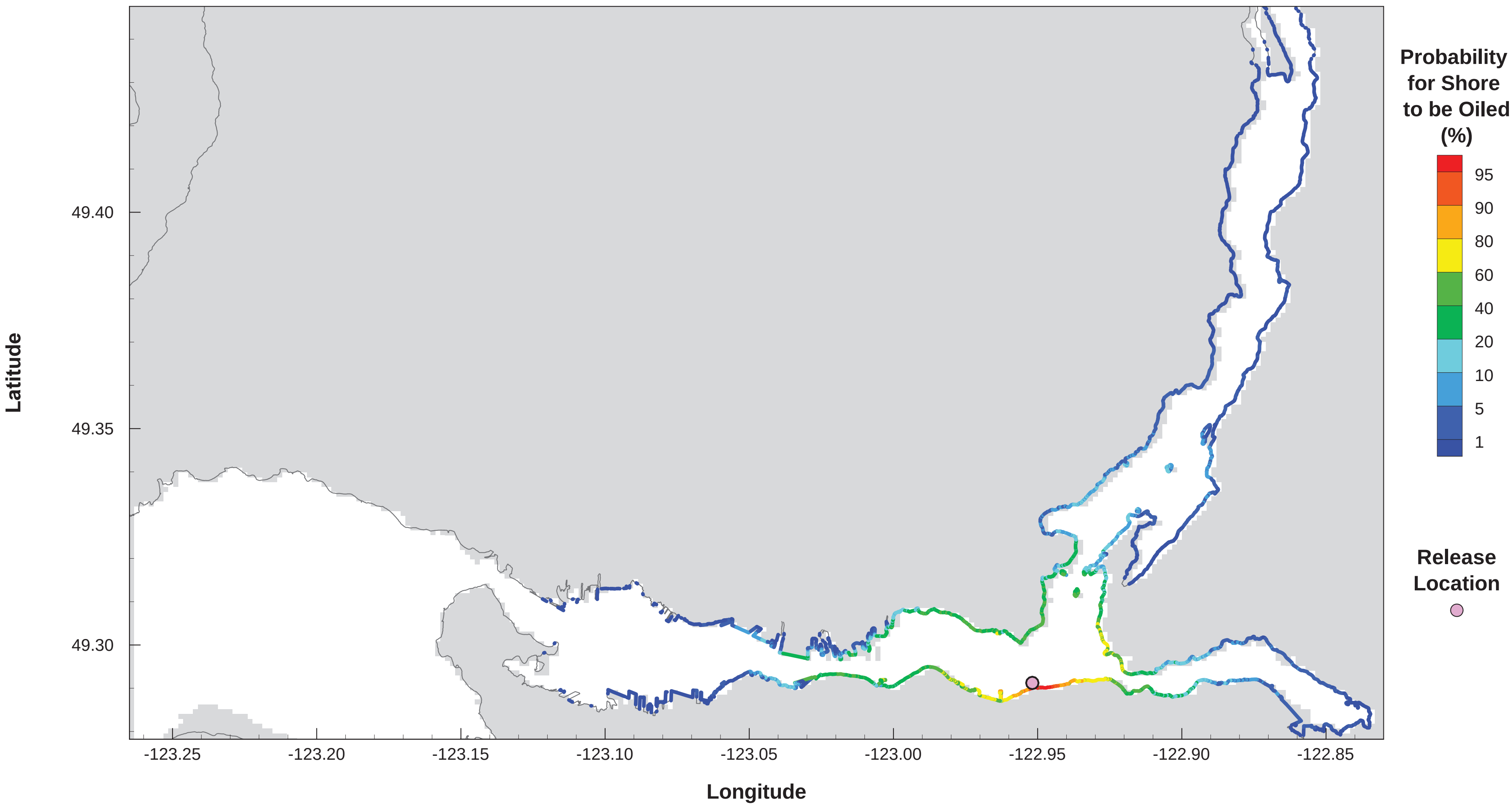
| PROJECT NO. | DWN | CKD | APVD | REV |
|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 |

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 21, 2013 |

Figure A.1-3

V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\510-Stochastic_Westridge\Results_Winter2012\Tecplot\03-stochastic_map_lines.lay

26 Aug 2013 11:04:15




## NOTES

- Statistical results based on independent spills occuring every 3 hours from January 01 00:00 to March 31 23:00, for a total of 728 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

STATUS
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## TRANS MOUNTAIN OIL SPILL STUDY

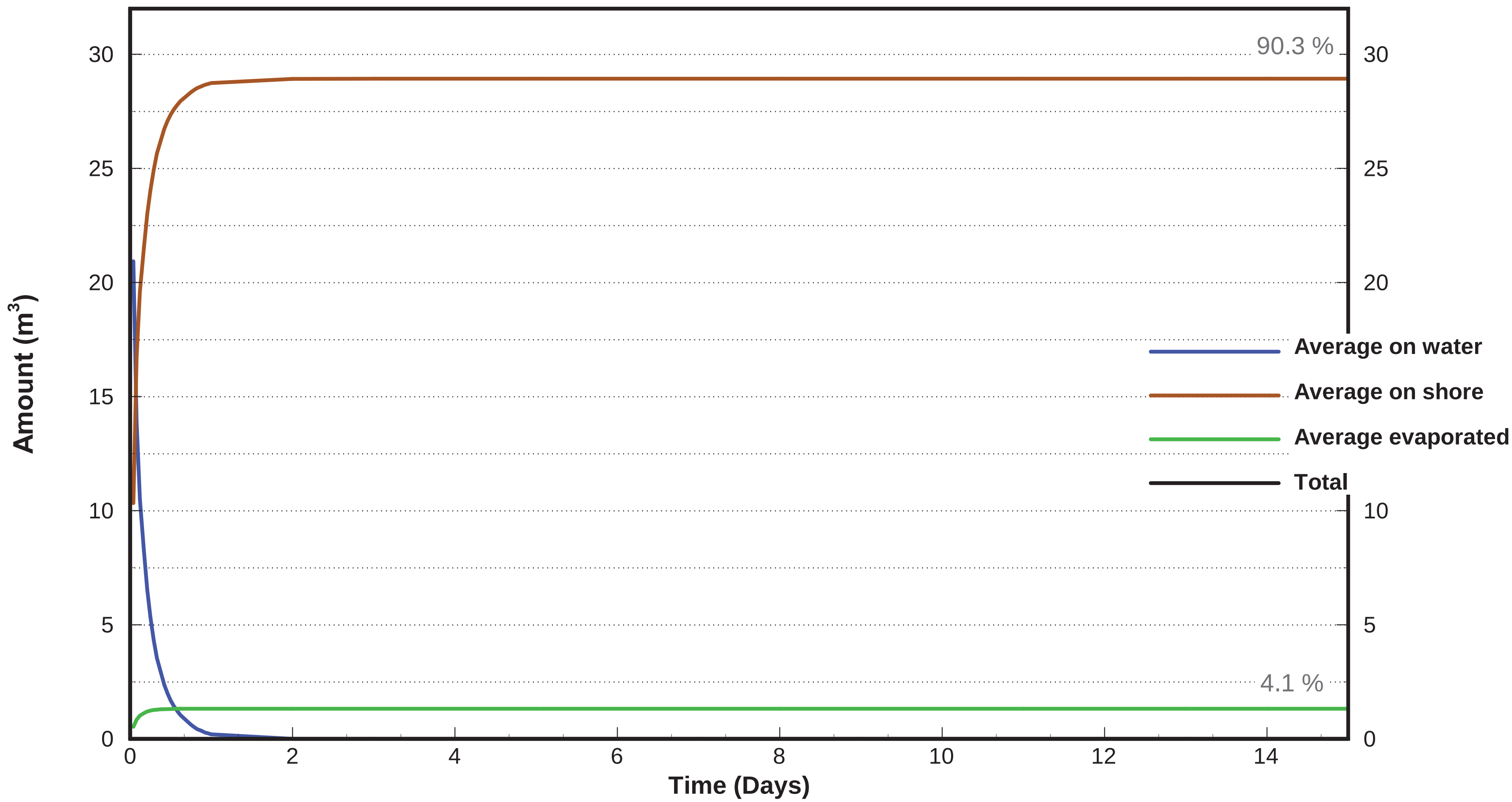
### Stochastic Simulation Winter 2012, Site A Shoreline Oiled Probability

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 21, 2013 |

**Figure A.1-4**

V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\510-Stochastic_Westridge\Results_Winter2012\Tecplot\04-shore_prob.lay 26 Aug 2013 11:04:01




## NOTES

- Statistical results based on independent spills occuring every 3 hours from January 01 00:00 to March 31 23:00, for a total of 728 independant spills.
- Tracking time for each spill was a maximum of 15 days.
- The major components of the mass balance are shown above.

STATUS
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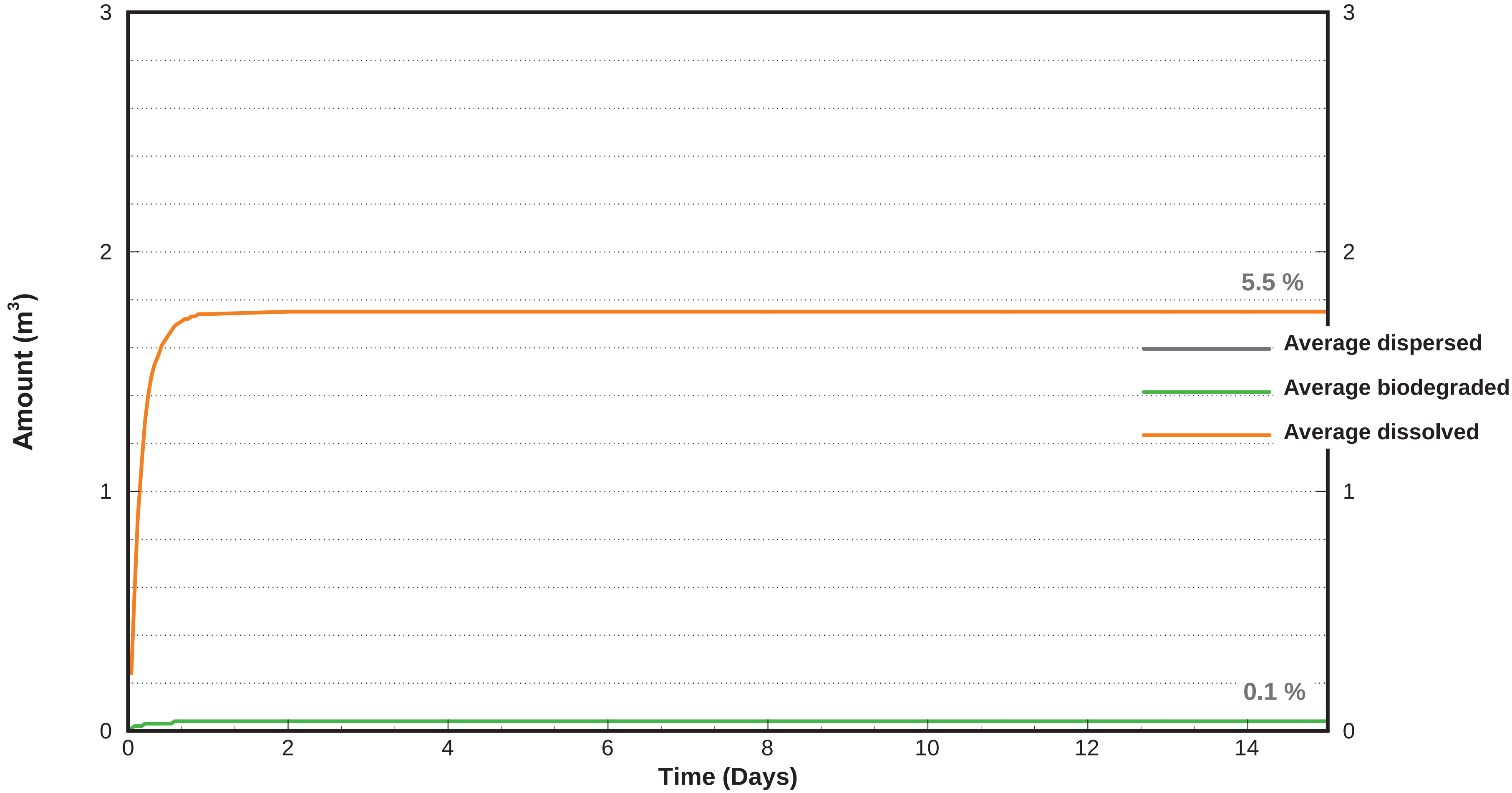
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Winter 2012, Site A**
**Major Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 22, 2013 |

**Figure A.1-9**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from January 01 00:00 to March 31 23:00, for a total of 728 independant spills.
- Tracking time for each spill was a maximum of 15 days.
- The minor components of the mass balance are shown above.

STATUS
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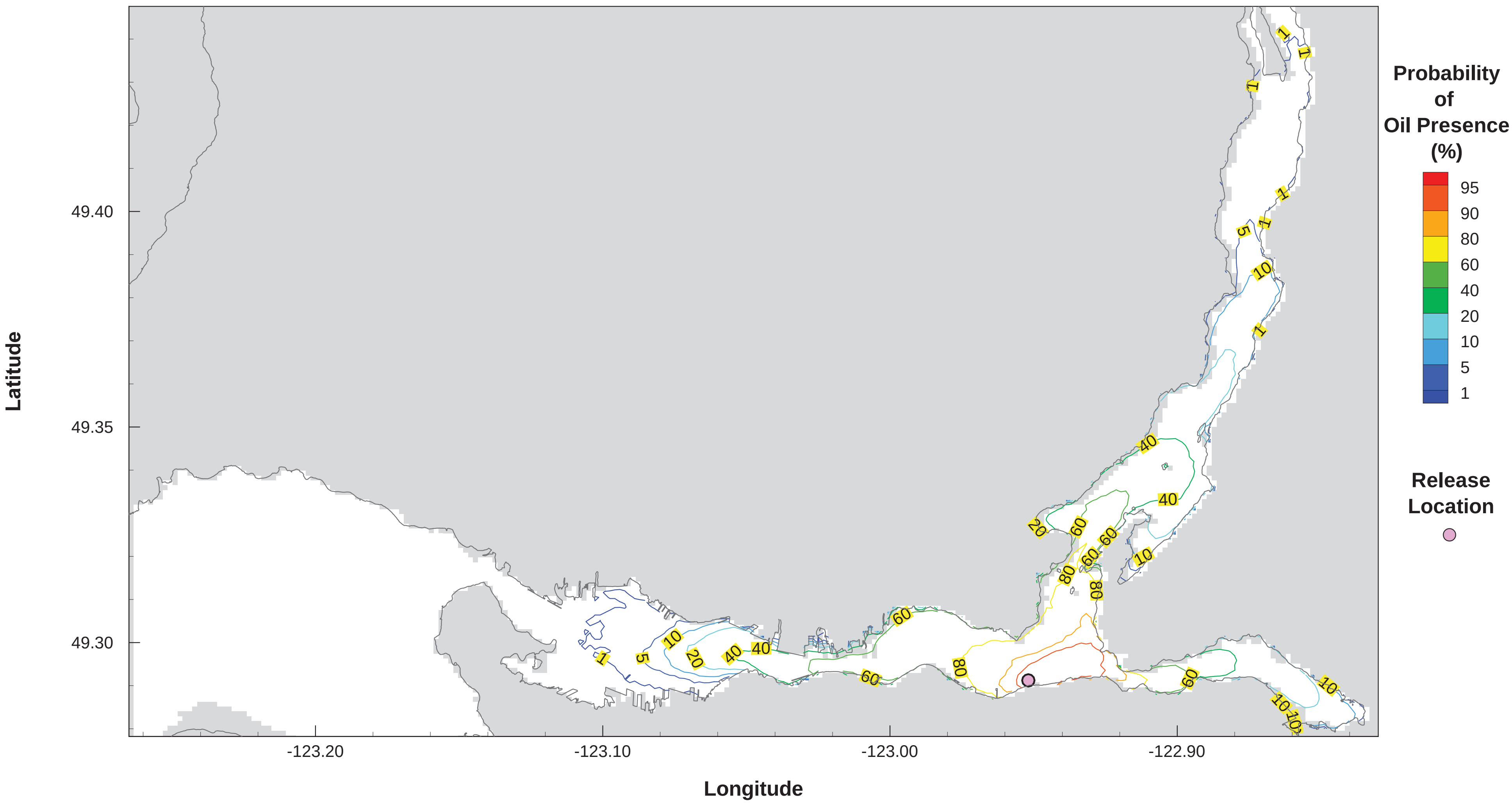
## TRANS MOUNTAIN OIL SPILL STUDY

### Stochastic Simulation
### Winter 2012, Site A
### Minor Components of the Mass Balance

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 22, 2013 |

**Figure A.1-10**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from April 01 00:00 to June 30 23:00, for a total of 728 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 m$^3$ release was modelled, corresponding to a 160 m$^3$ operational spill at berth with 20%, i.e. 32 m$^3$ distribution across the spill boom.

STATUS
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# TRANS MOUNTAIN OIL SPILL STUDY

## Stochastic Simulation Spring 2012, Site A Probability of Oil Presence

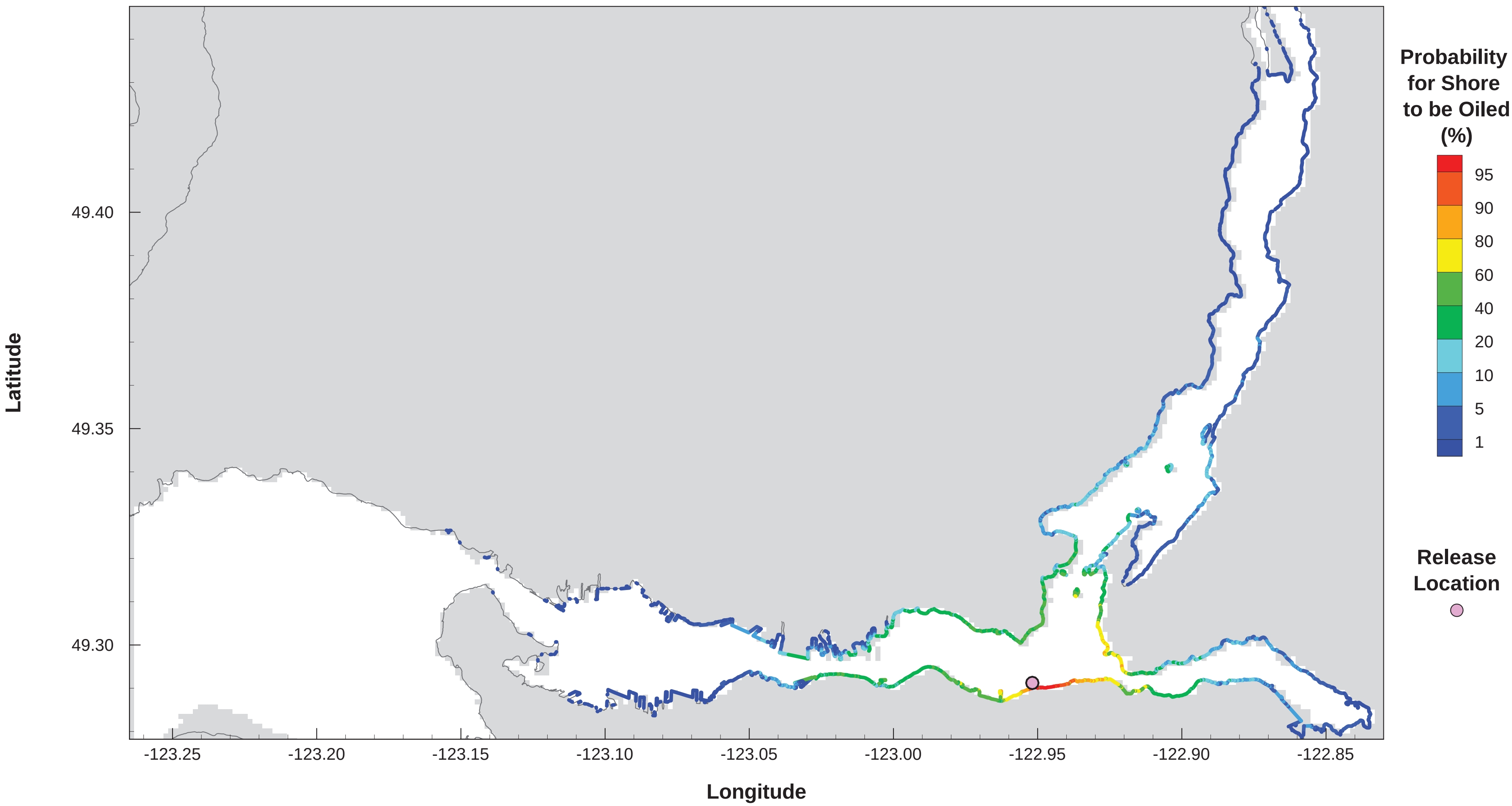
| PROJECT NO. | DWN | CKD | APVD | REV |
|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 |

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 21, 2013 |

Figure A.2-3

V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\510-Stochastic_Westridge\Results_Spring2012\Tecplot\03-stochastic_map_lines.lay

26 Aug 2013 11:44:41




## NOTES

- Statistical results based on independent spills occuring every 3 hours from April 01 00:00 to June 30 23:00, for a total of 728 independant spills.

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

- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.

- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

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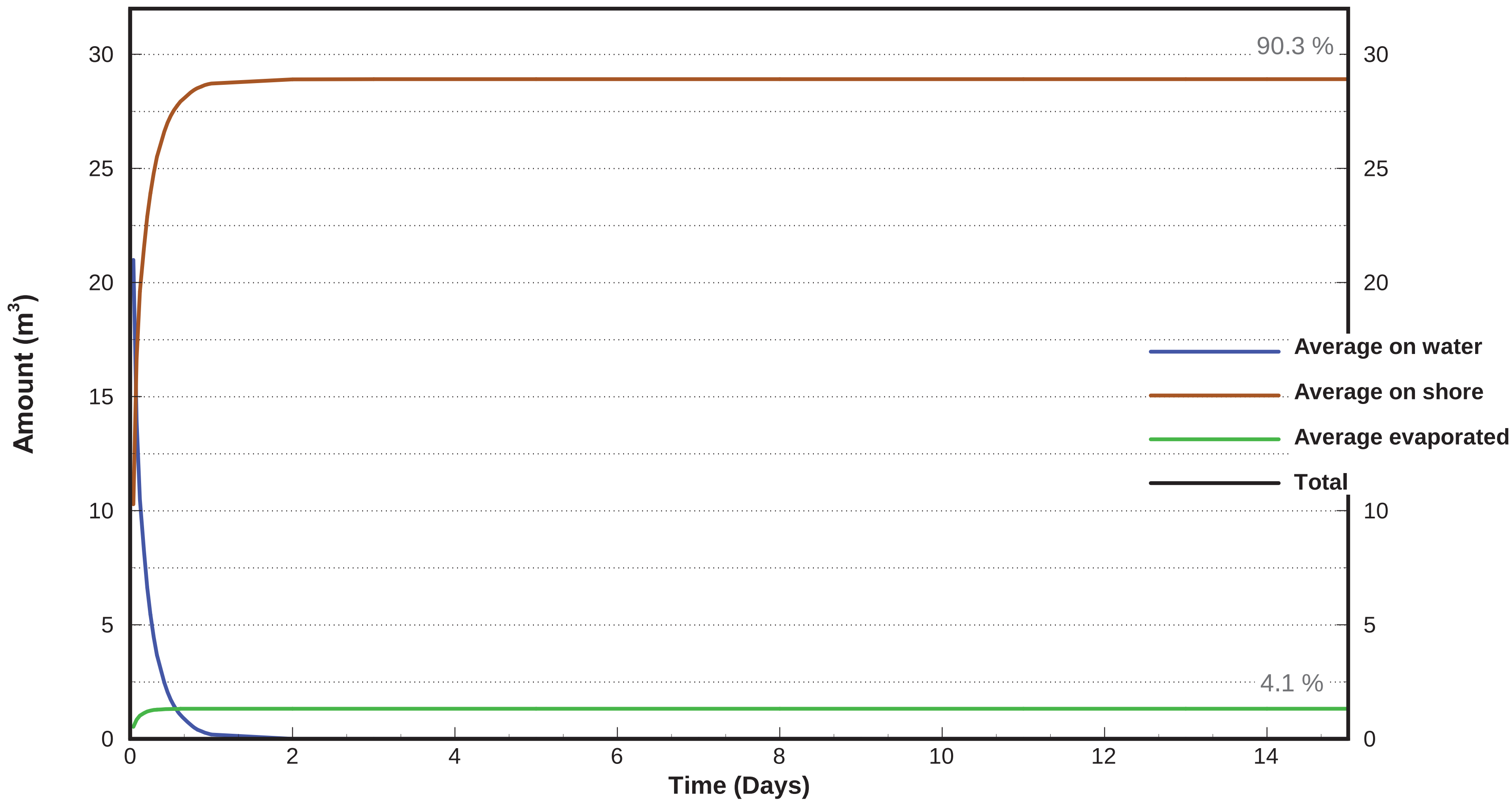
## TRANS MOUNTAIN OIL SPILL STUDY

### Stochastic Simulation Spring 2012, Site A Shoreline Oiled Probability

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 21, 2013 |

**Figure A.2-4**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from April 01 00:00 to June 30 23:00, for a total of 728 independant spills.

- Tracking time for each spill was a maximum of 15 days.

- The major components of the mass balance are shown above.

STATUS
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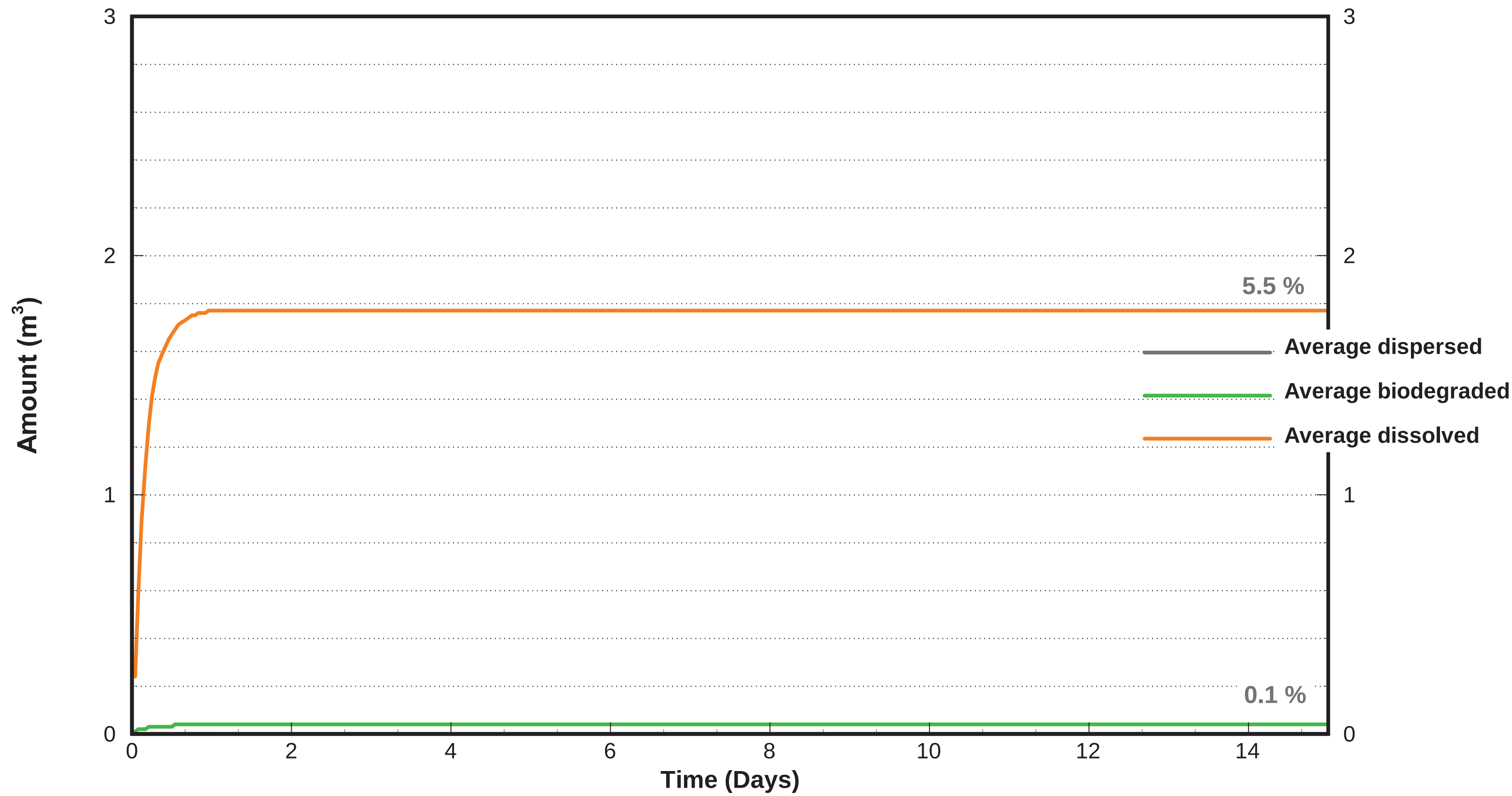
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Spring 2012, Site A**
**Major Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 22, 2013 |

**Figure A.2-9**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from April 01 00:00 to June 30 23:00, for a total of 728 independant spills.
- Tracking time for each spill was a maximum of 15 days.
- The minor components of the mass balance are shown above.

STATUS
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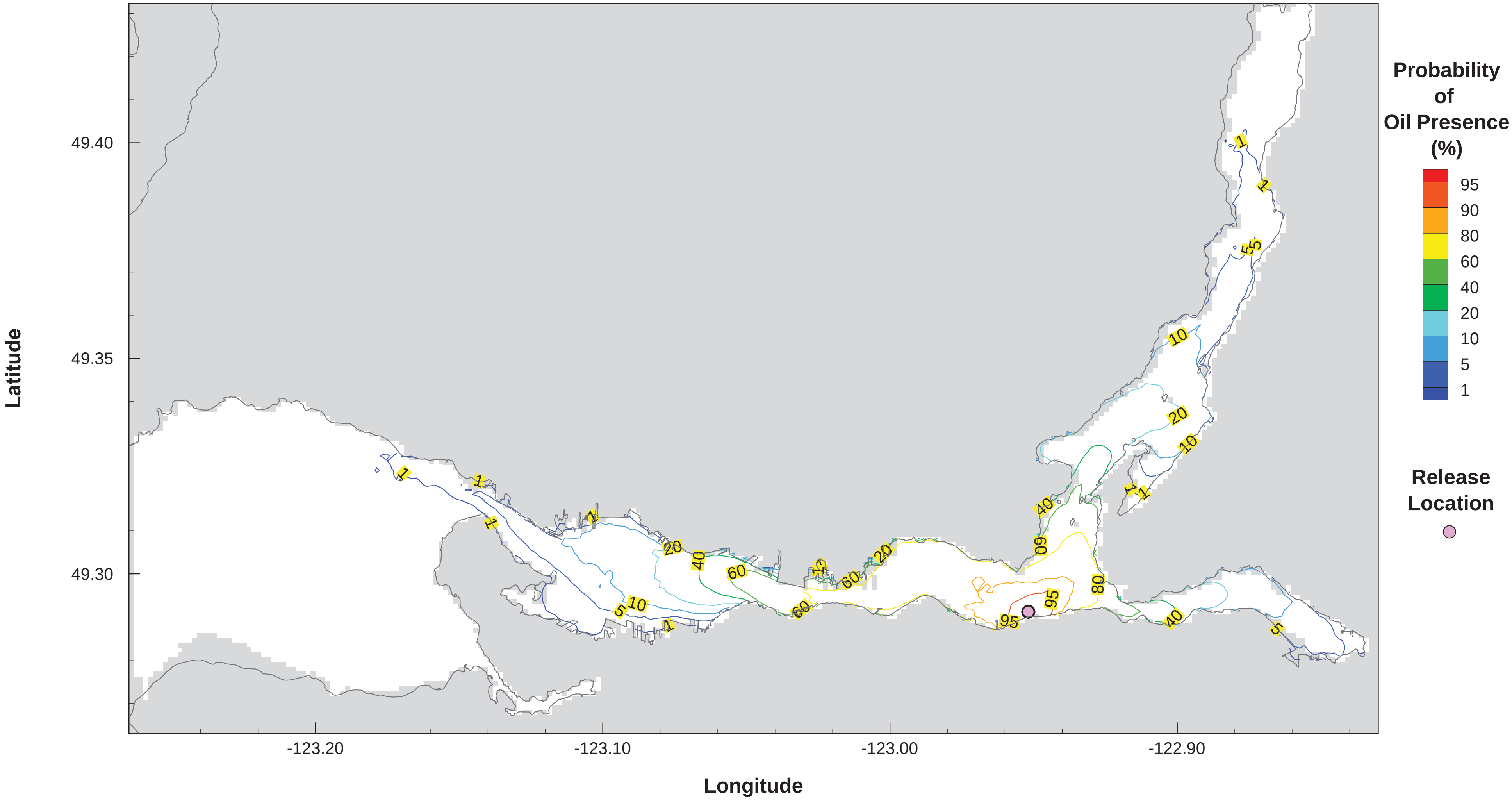
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Spring 2012, Site A**
**Minor Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 22, 2013 |

**Figure A.2-10**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from July 01 00:00 to September 30 23:00, for a total of 736 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

STATUS
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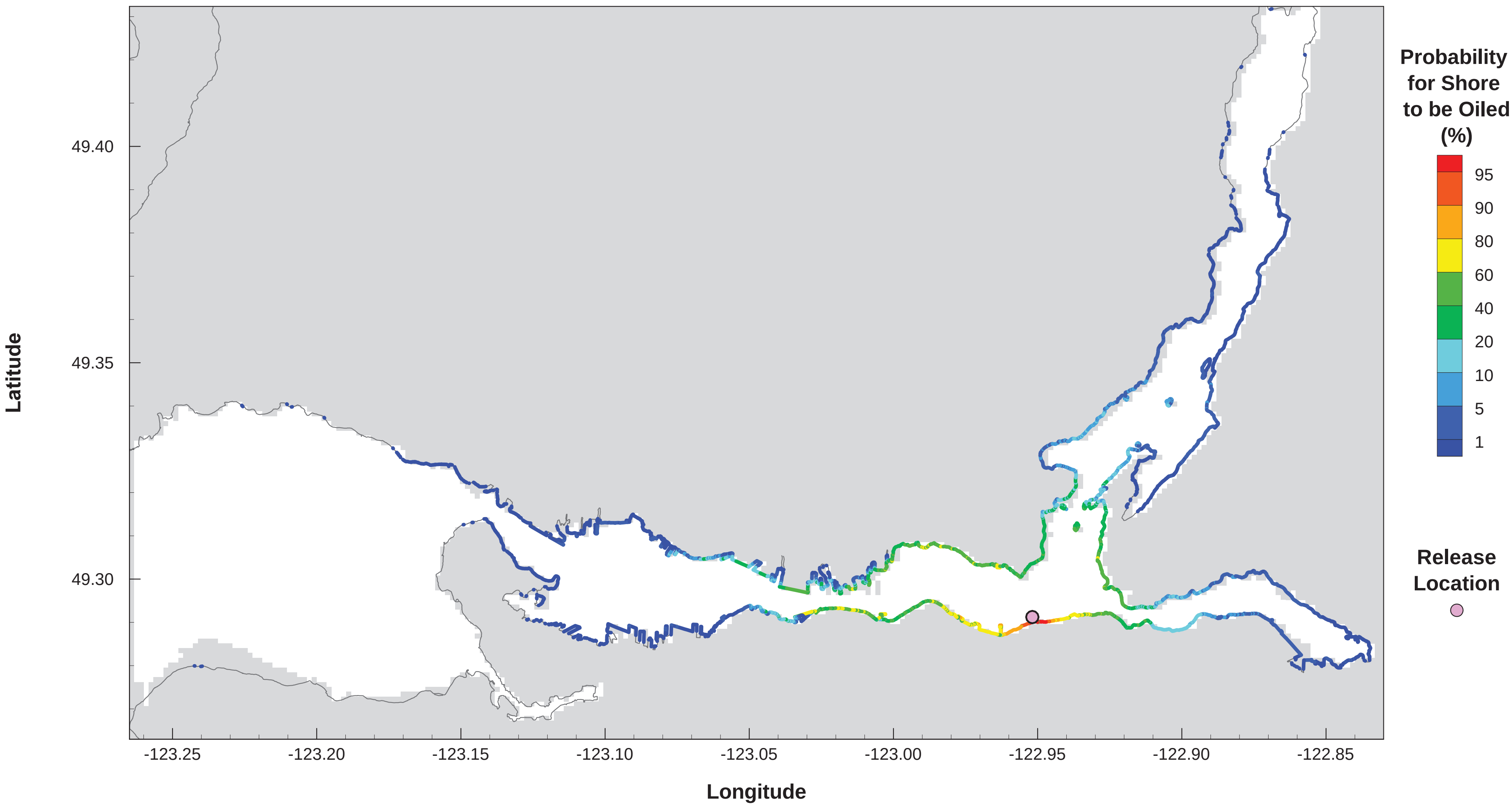
# TRANS MOUNTAIN OIL SPILL STUDY

## Stochastic Simulation Summer 2012, Site A Probability of Oil Presence

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 16, 2013 |

Figure A.3-3




## NOTES

- Statistical results based on independent spills occuring every 3 hours from July 01 00:00 to September 30 23:00 for a total of 736 independant spills.

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

- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.

- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

STATUS
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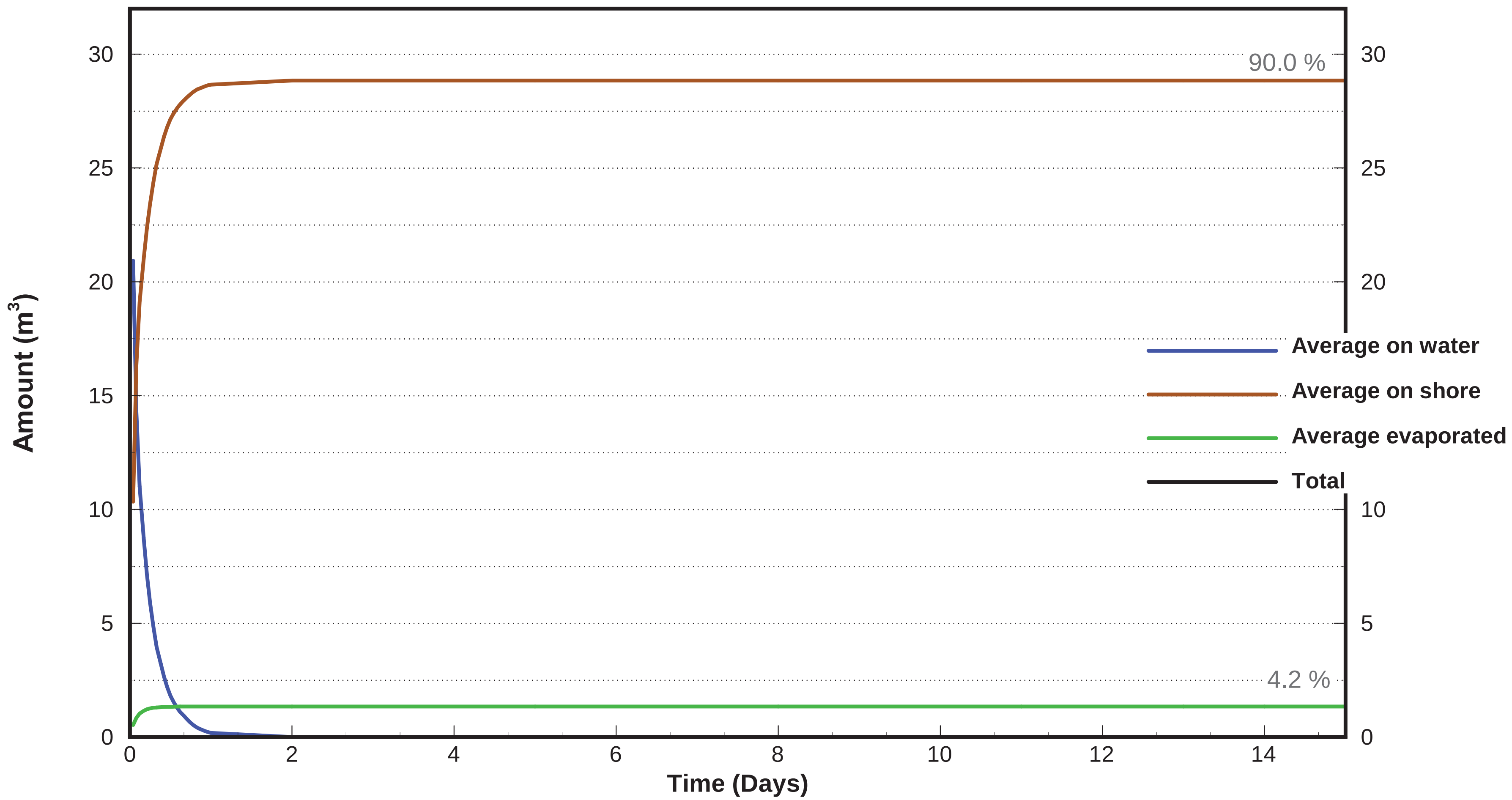
## TRANS MOUNTAIN OIL SPILL STUDY

### Stochastic Simulation Summer 2012, Site A Shoreline Oiled Probability

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 16, 2013 |

**Figure A.3-4**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from July 01 00:00 to September 30 23:00, for a total of 736 independant spills.
- Tracking time for each spill was a maximum of 15 days.
- The major components of the mass balance are shown above.

STATUS
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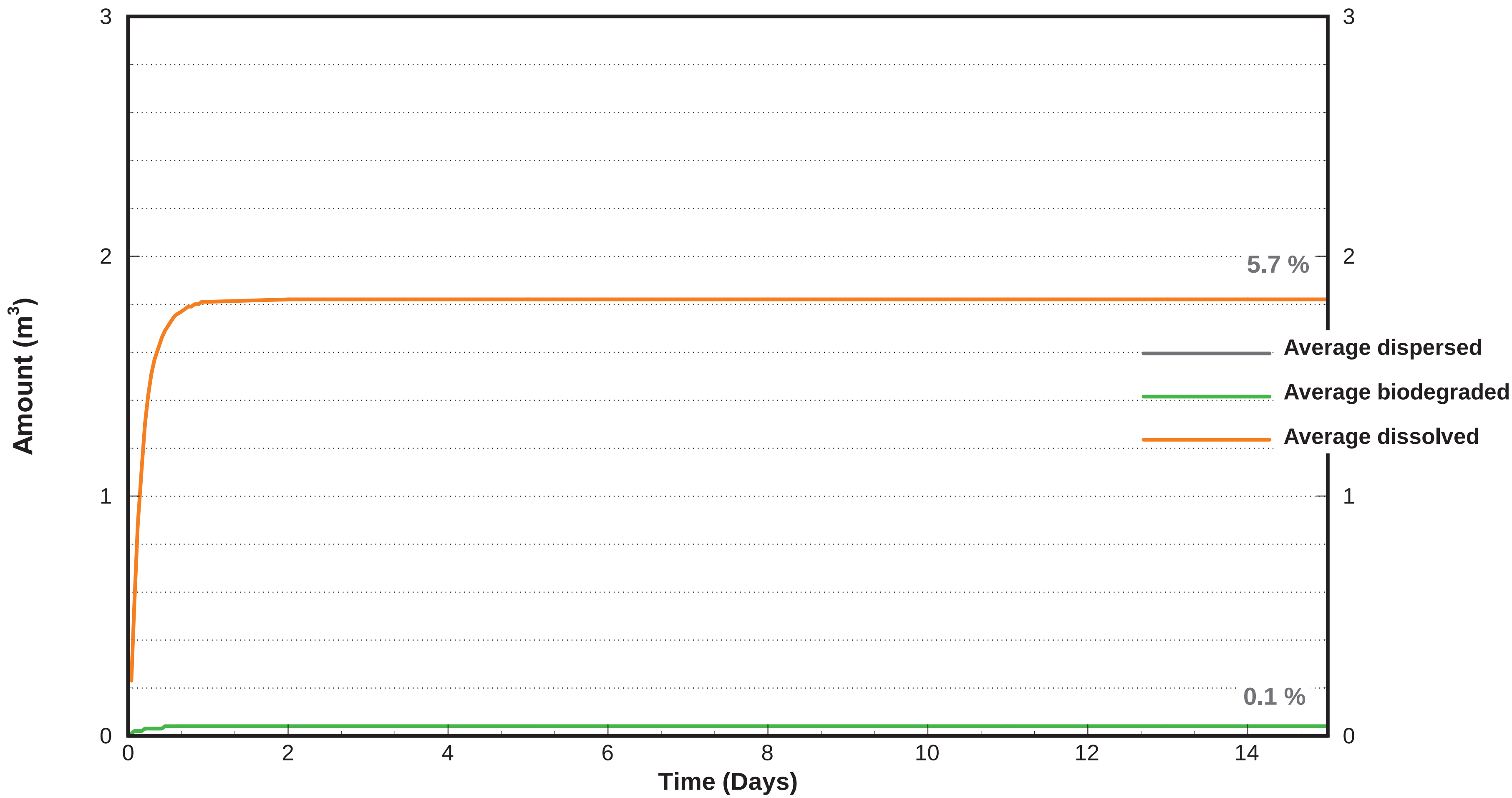
# TRANS MOUNTAIN OIL SPILL STUDY

## Stochastic Simulation
## Summer 2012, Site A
## Major Components of the Mass Balance

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 16, 2013 |

**Figure A.3-9**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from July 01 00:00 to September 30 23:00, for a total of 736 independant spills.
- Tracking time for each spill was a maximum of 15 days.
- The minor components of the mass balance are shown above.

STATUS
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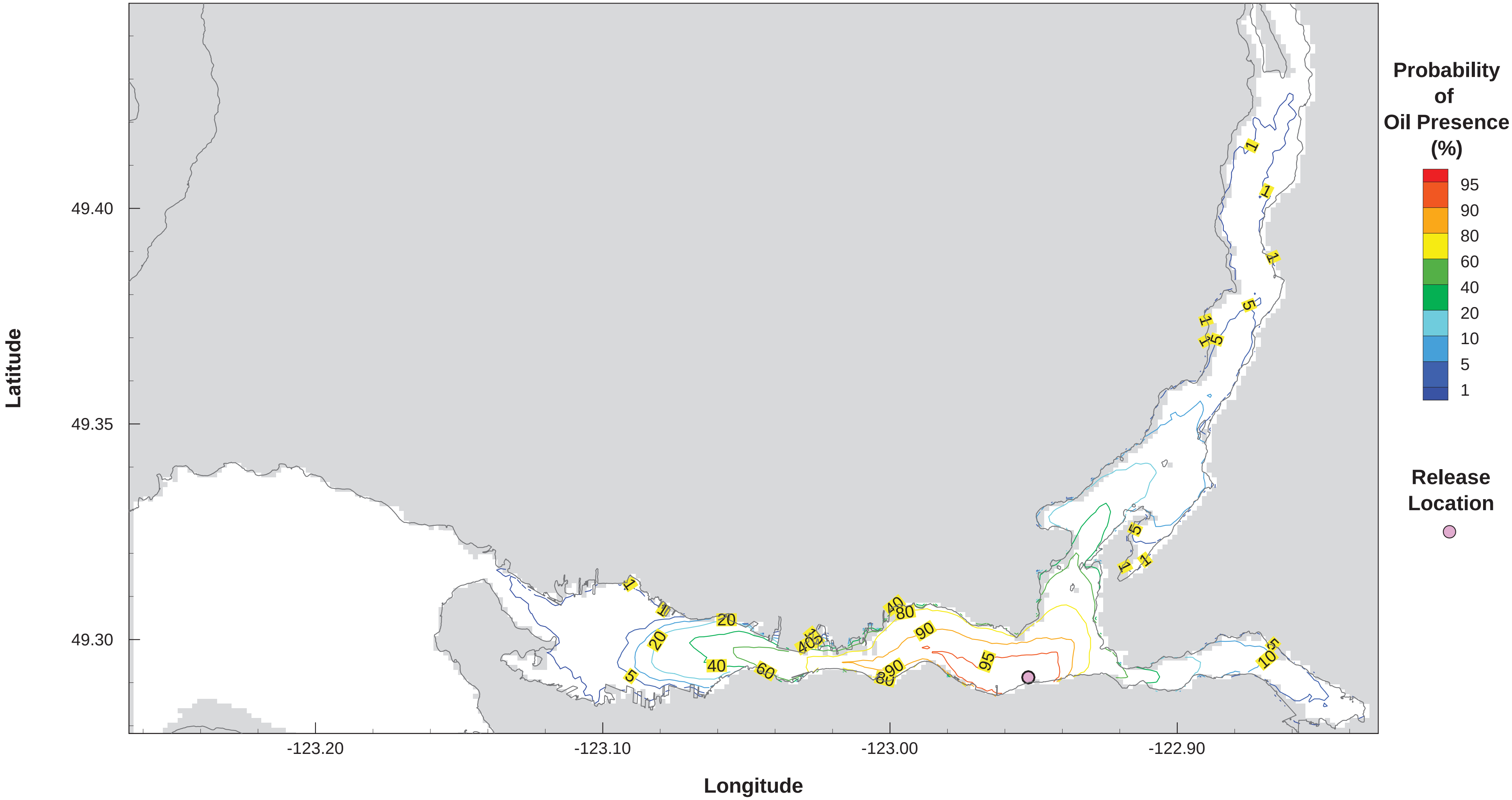
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Summer 2012, Site A**
**Minor Components of the Mass Balance**

| PROJECT NO. | DWN | CKD | APVD | REV | |
|---|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 | **Figure A.3-10** |
| OFFICE | DATE | | | | |
| EBA-VANC | October 16, 2013 | | | | |




## NOTES

- Statistical results based on independent spills occuring every 3 hours from October 01 01:00 to December 31 23:00, for a total of 728 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

STATUS
ISSUED FOR REVIEW

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# TRANS MOUNTAIN OIL SPILL STUDY

## Stochastic Simulation
## Fall 2011, Site A
## Probability of Oil Presence

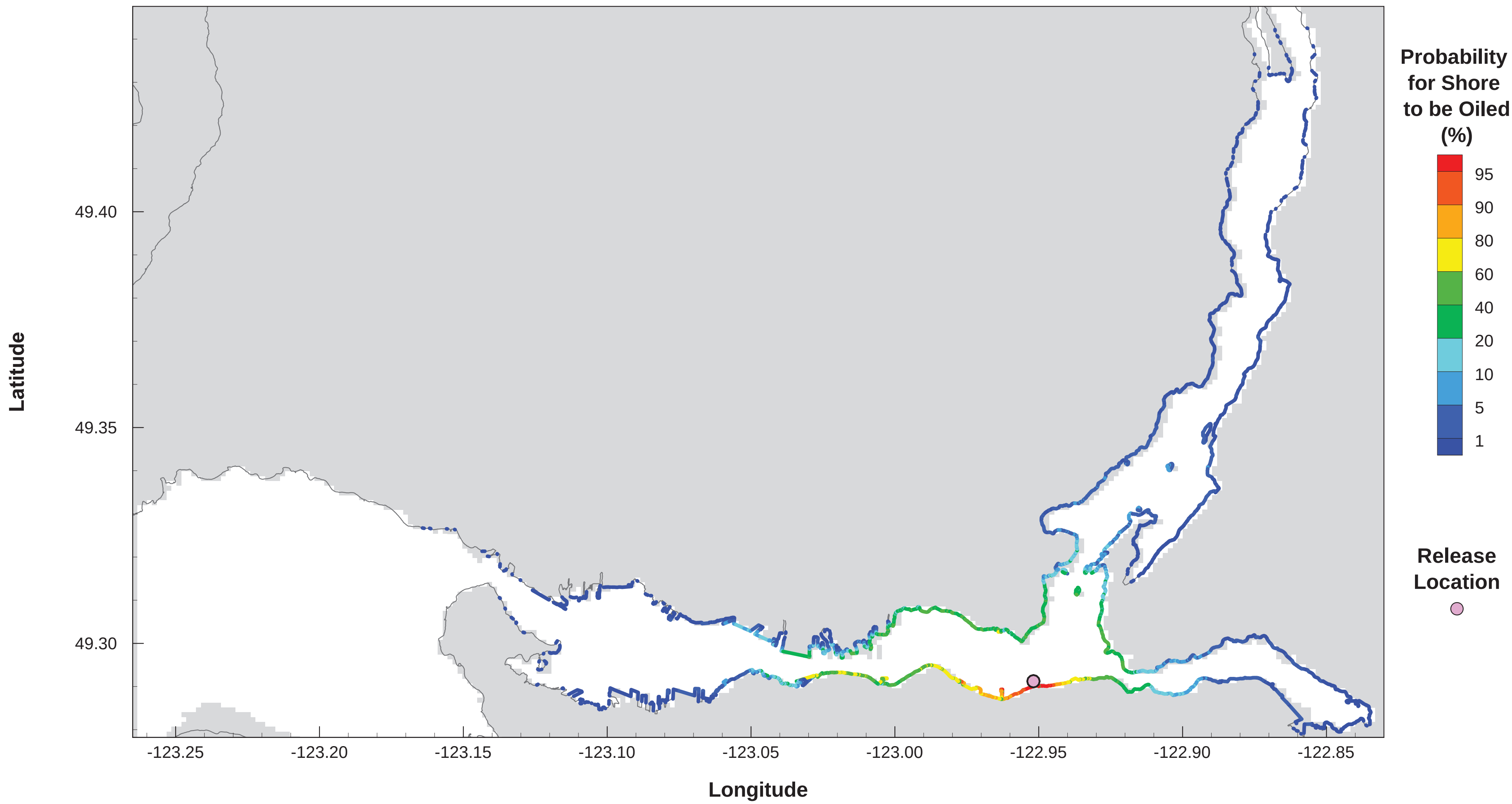
| PROJECT NO. | DWN | CKD | APVD | REV |
|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 |

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 21, 2013 |

**Figure A.4-3**

V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\510-Stochastic_Westridge\Results_Fall2011\Tecplot\03-stochastic_map_lines.lay

26 Aug 2013 13:54:19




## NOTES

- Statistical results based on independent spills occuring every 3 hours from October 01 01:00 to December 31 23:00, for a total of 728 independant spills.

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

- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.

- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

STATUS
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## TRANS MOUNTAIN OIL SPILL STUDY

### Stochastic Simulation
### Fall 2011, Site A
### Shoreline Oiled Probability

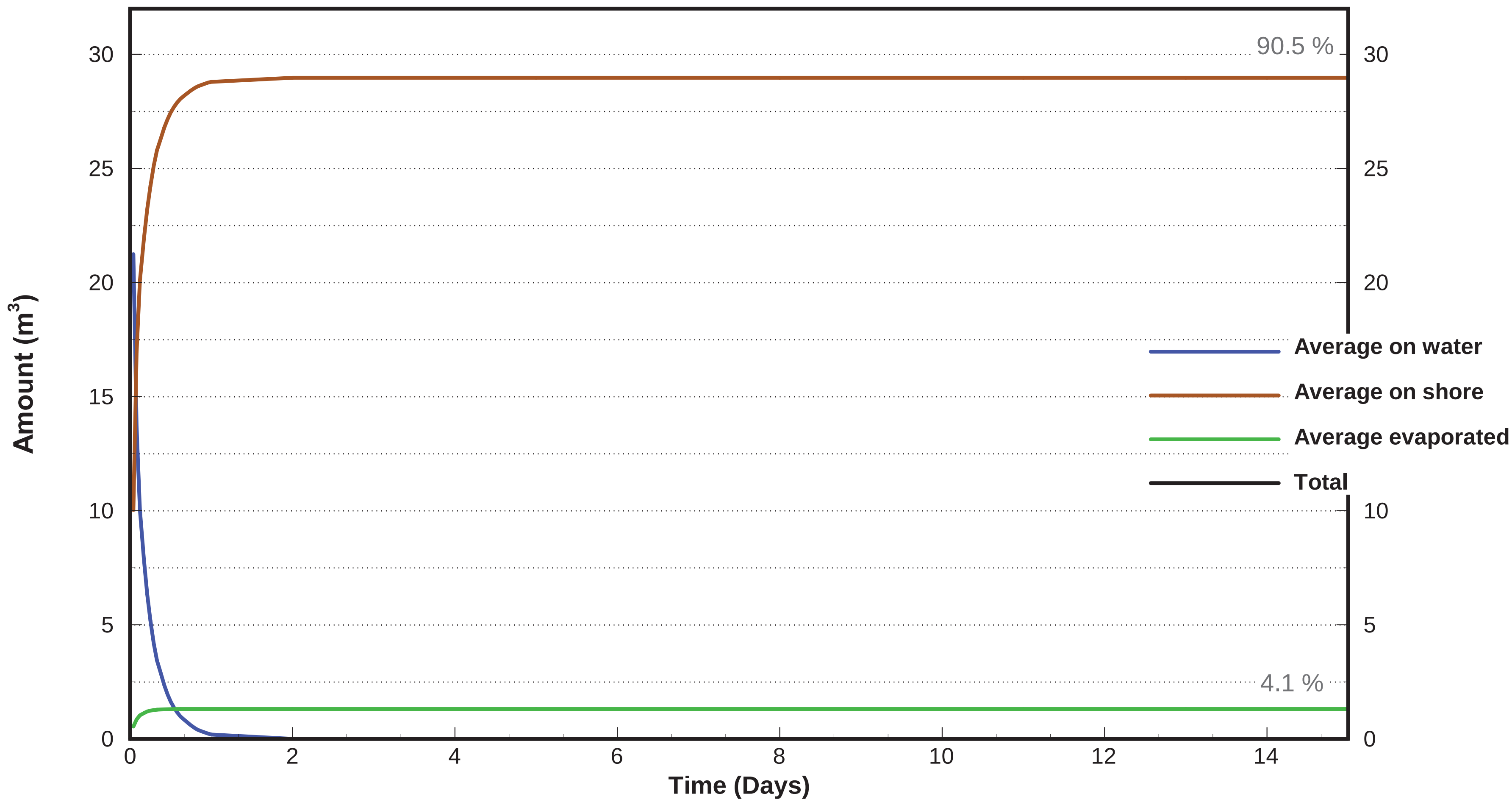
| PROJECT NO. | DWN | CKD | APVD | REV |
|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 |

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 21, 2013 |

**Figure A.4-4**

V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\510-Stochastic_Westridge\Results_Fall2011\Tecplot\04-shore_prob.lay

26 Aug 2013 13:54:04




## NOTES

- Statistical results based on independent spills occuring every 3 hours from October 01 01:00 to December 31 23:00, for a total of 728 independant spills.
- Tracking time for each spill was a maximum of 15 days.
- The major components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

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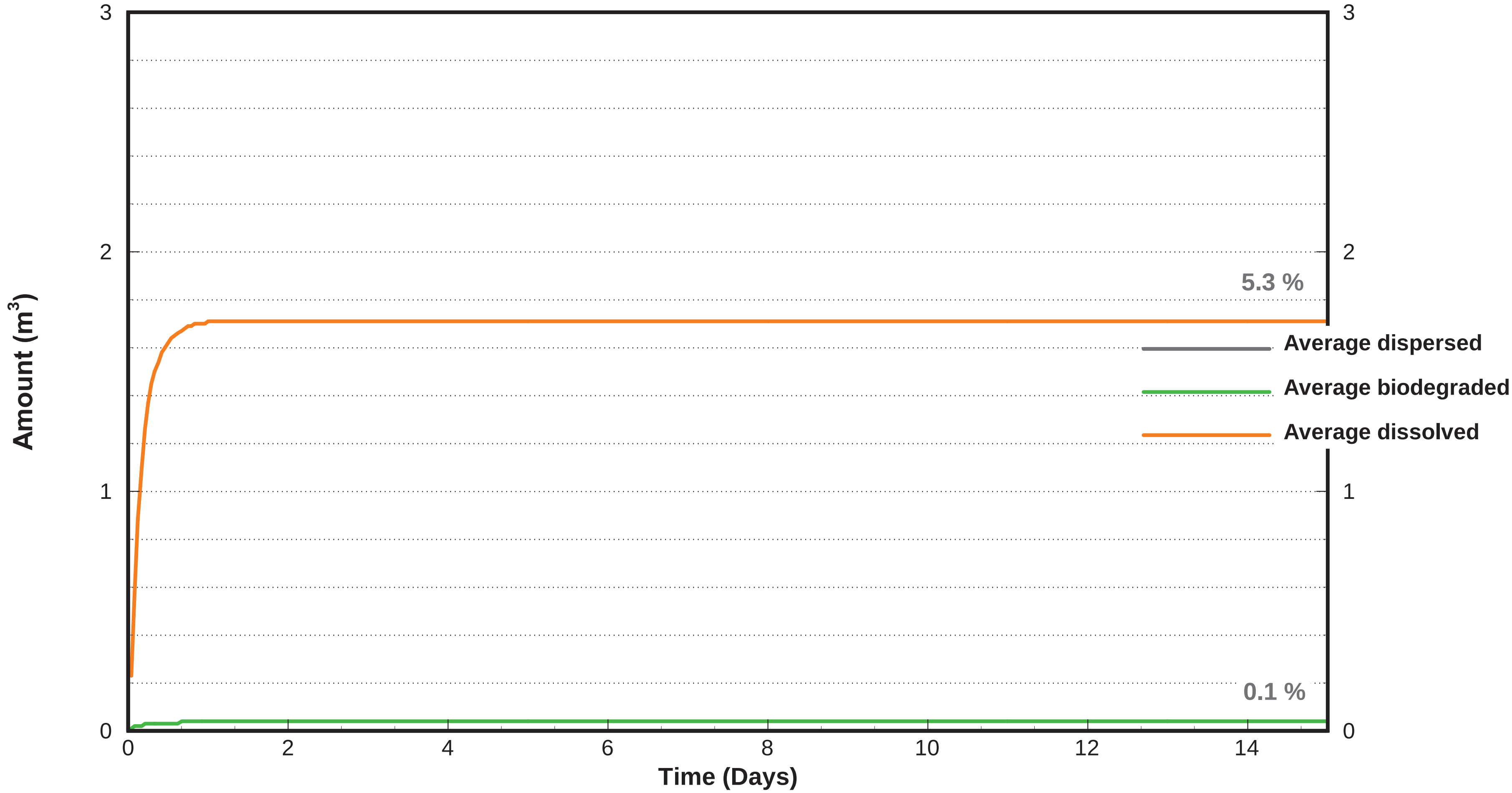
# TRANS MOUNTAIN OIL SPILL STUDY

## Stochastic Simulation
## Fall 2011, Site A
## Major Components of the Mass Balance

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 22, 2013 |

**Figure A.4-9**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from October 01 01:00 to December 31 23:00, for a total of 728 independant spills.
- Tracking time for each spill was a maximum of 15 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

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## TRANS MOUNTAIN OIL SPILL STUDY

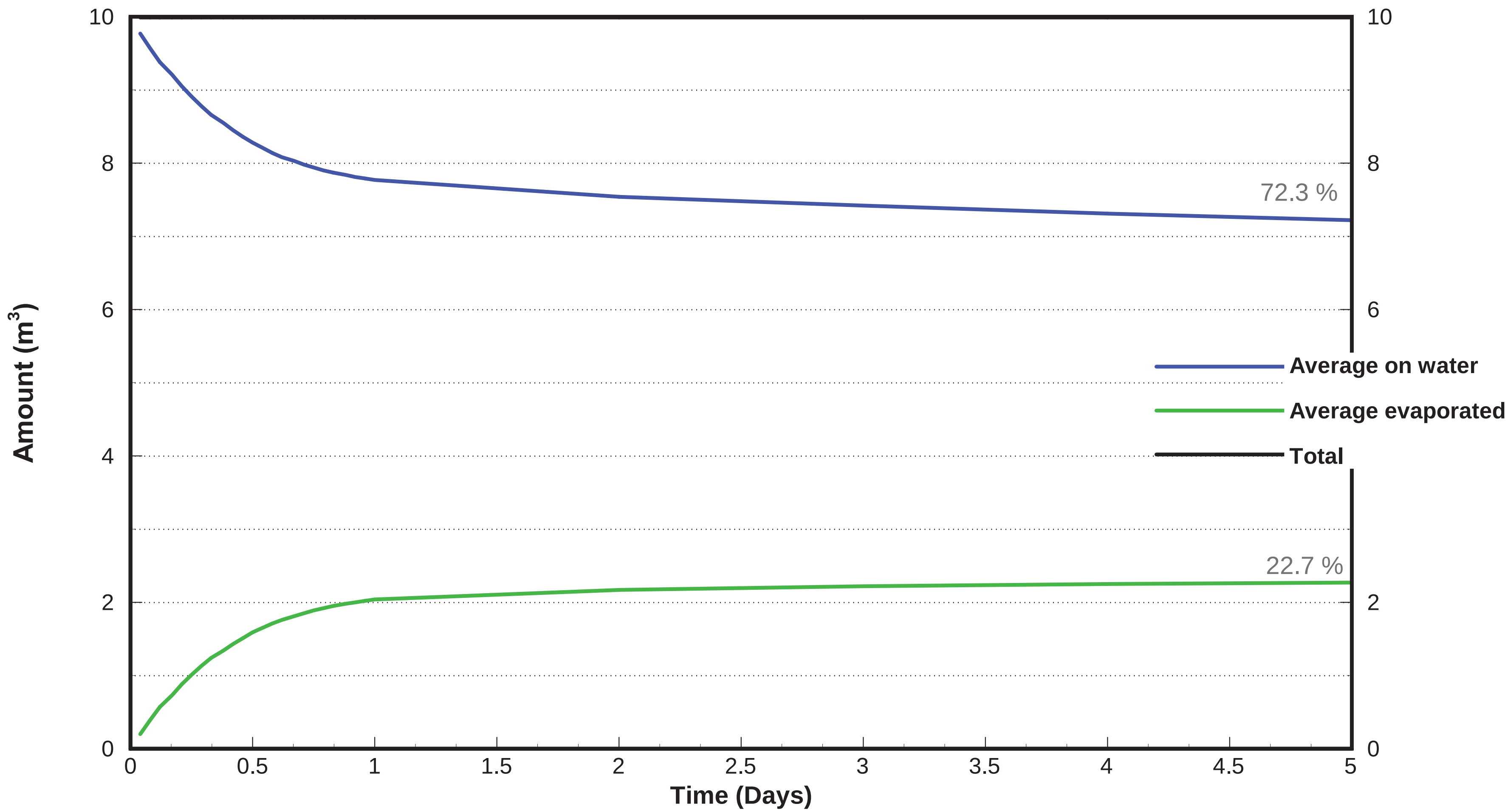
**Stochastic Simulation**
**Fall 2011, Site A**
**Minor Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | August 22, 2013 |

**Figure A.4-10**

# Appendix C Output from EBA (EBA 2013) 10 $m^3$ Smaller Spills




## NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00.
- Tracking time for each spill was 5 days.
- The major components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

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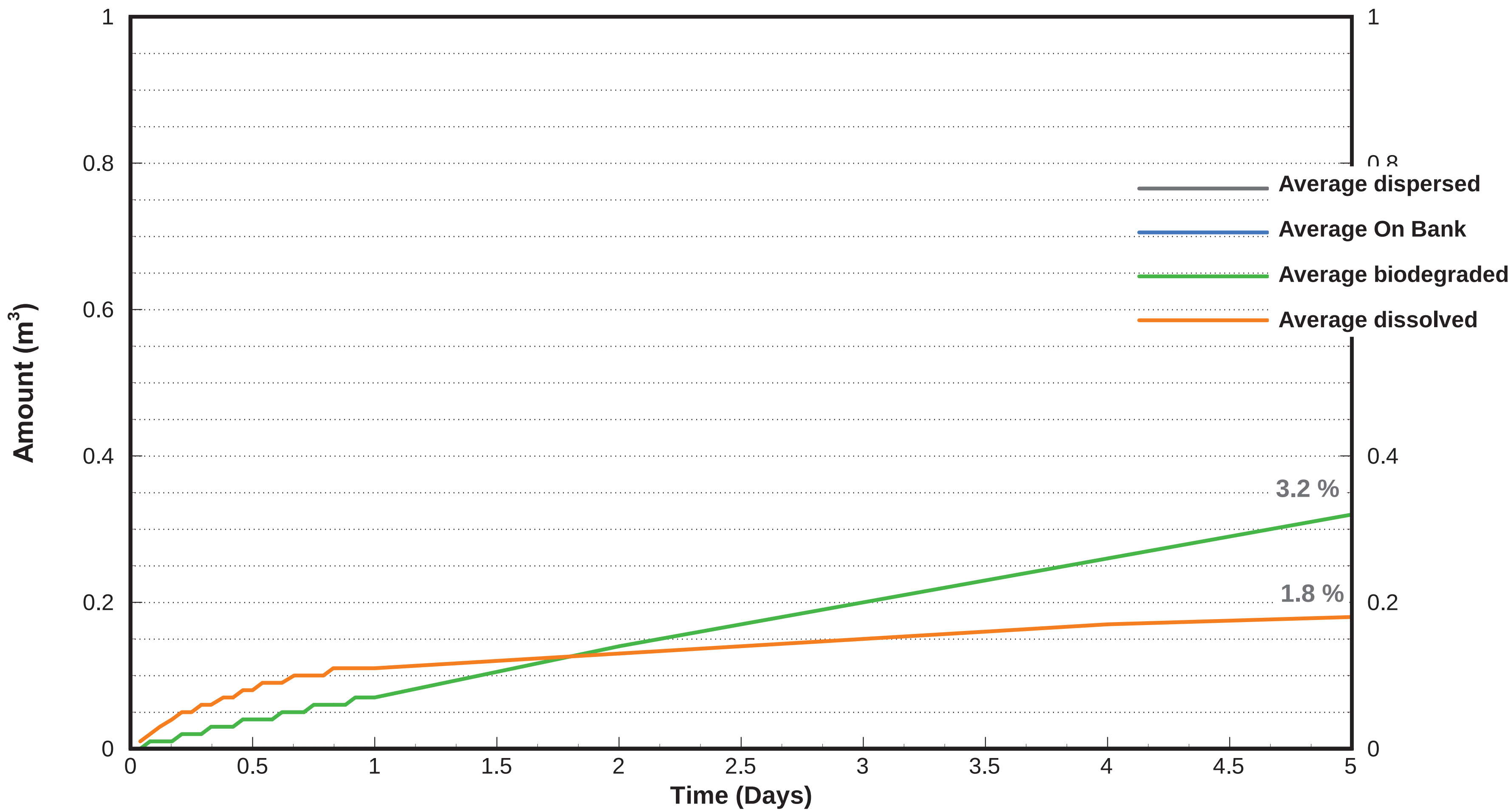
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Winter 2012, Site A (10 $m^3$)**
**Major Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 23, 2013 |

**Figure A.1-2**




## NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00.
- Tracking time for each spill was 5 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

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## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Winter 2012, Site A (10 m$^3$)**
**Minor Components of the Mass Balance**

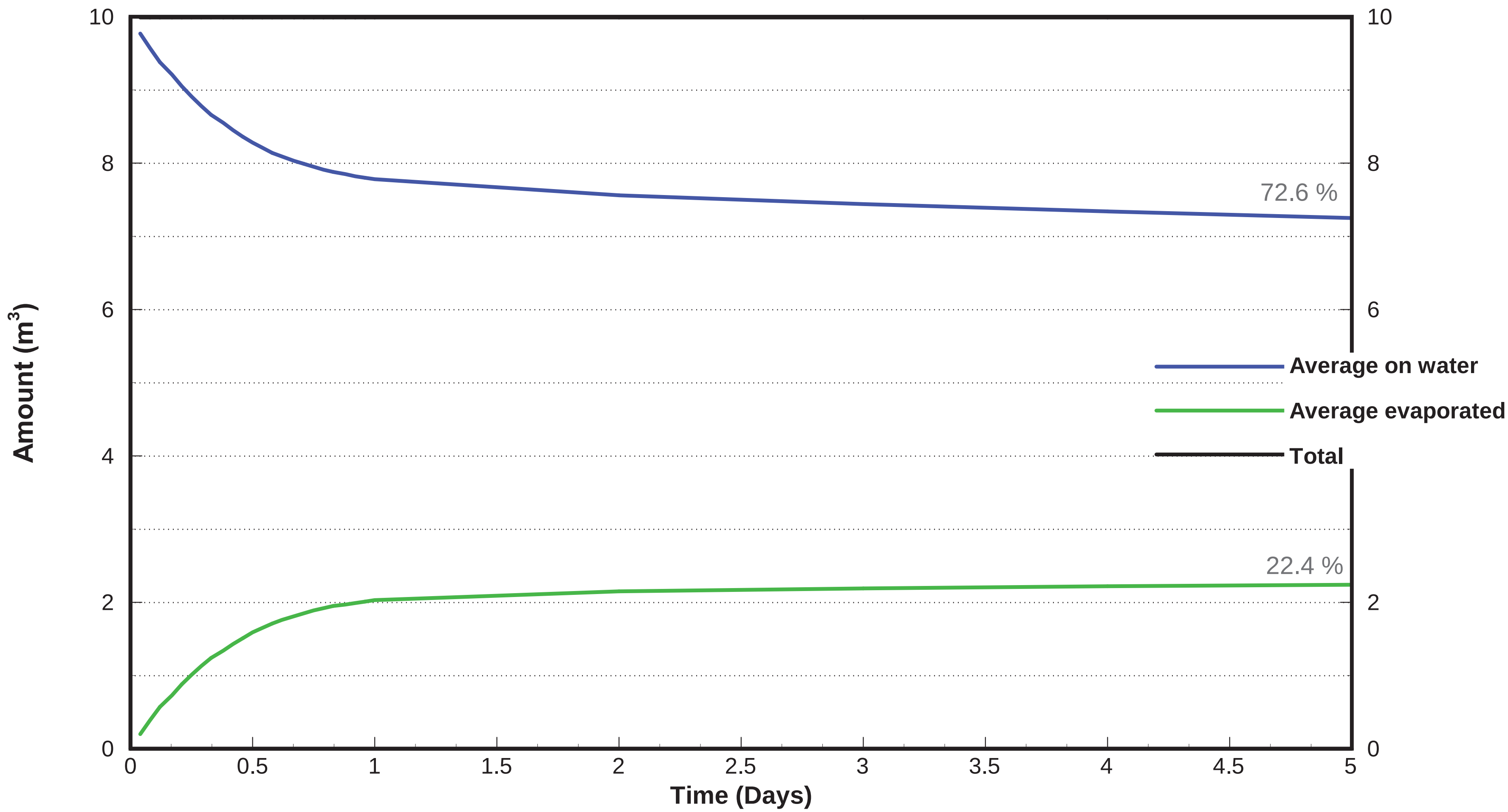
| PROJECT NO. | DWN | CKD | APVD | REV |
|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 |

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 23, 2013 |

**Figure A.1-3**

T:\TMEP\working\AH\02-SPILLCALC\512-Stochastic_Westridge_10m3_Boom\Results_Winter\Tecplot\09-statistics_MB_2.lay

21 Oct 2013 15:20:29




## NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00.
- Tracking time for each spill was 5 days.
- The major components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

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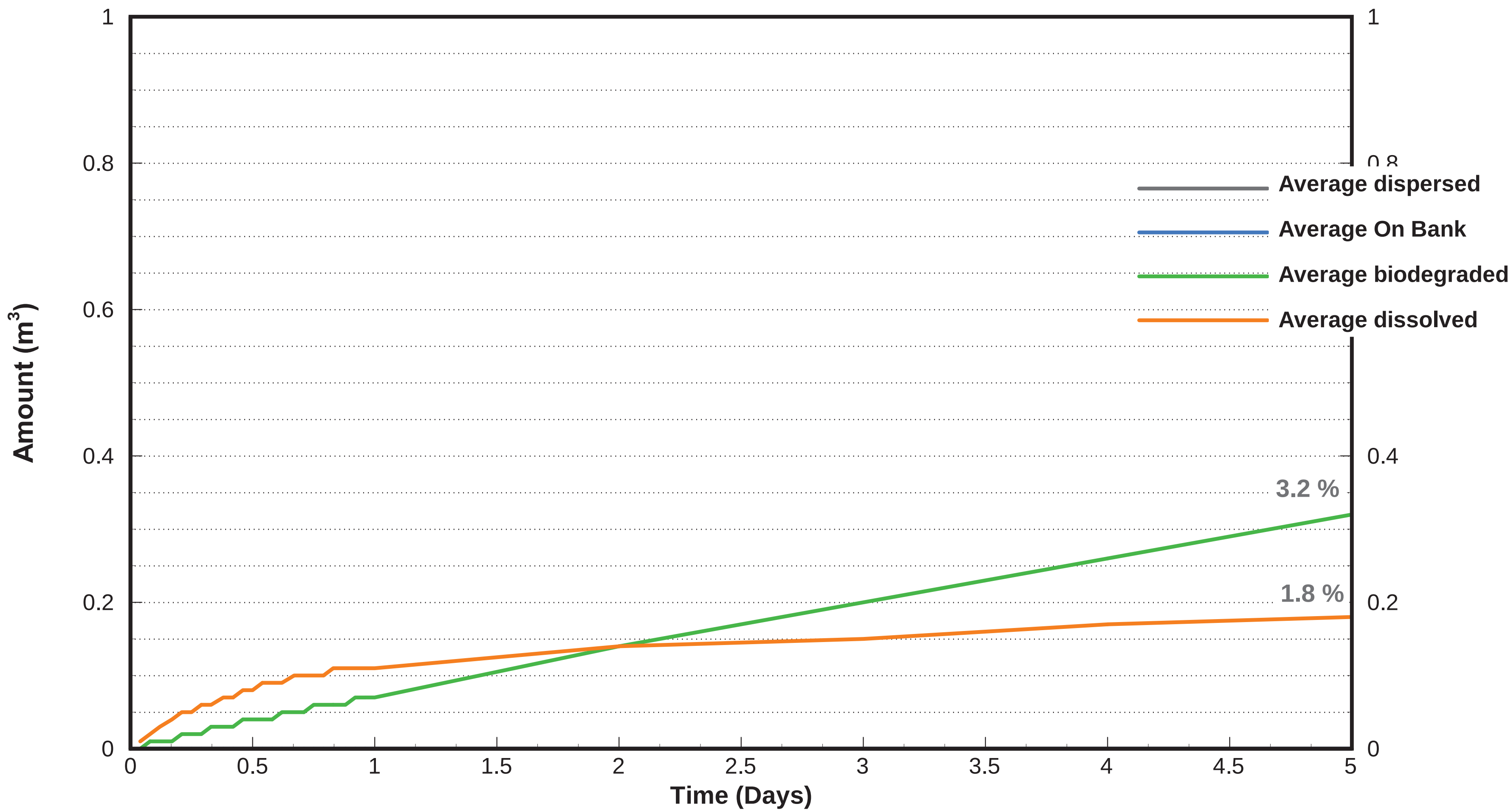
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Spring 2012, Site A (10 $m^3$)**
**Major Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 23, 2013 |

**Figure A.2-2**




## NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00.
- Tracking time for each spill was 5 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

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## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Spring 2012, Site A (10 $m^3$)**
**Minor Components of the Mass Balance**

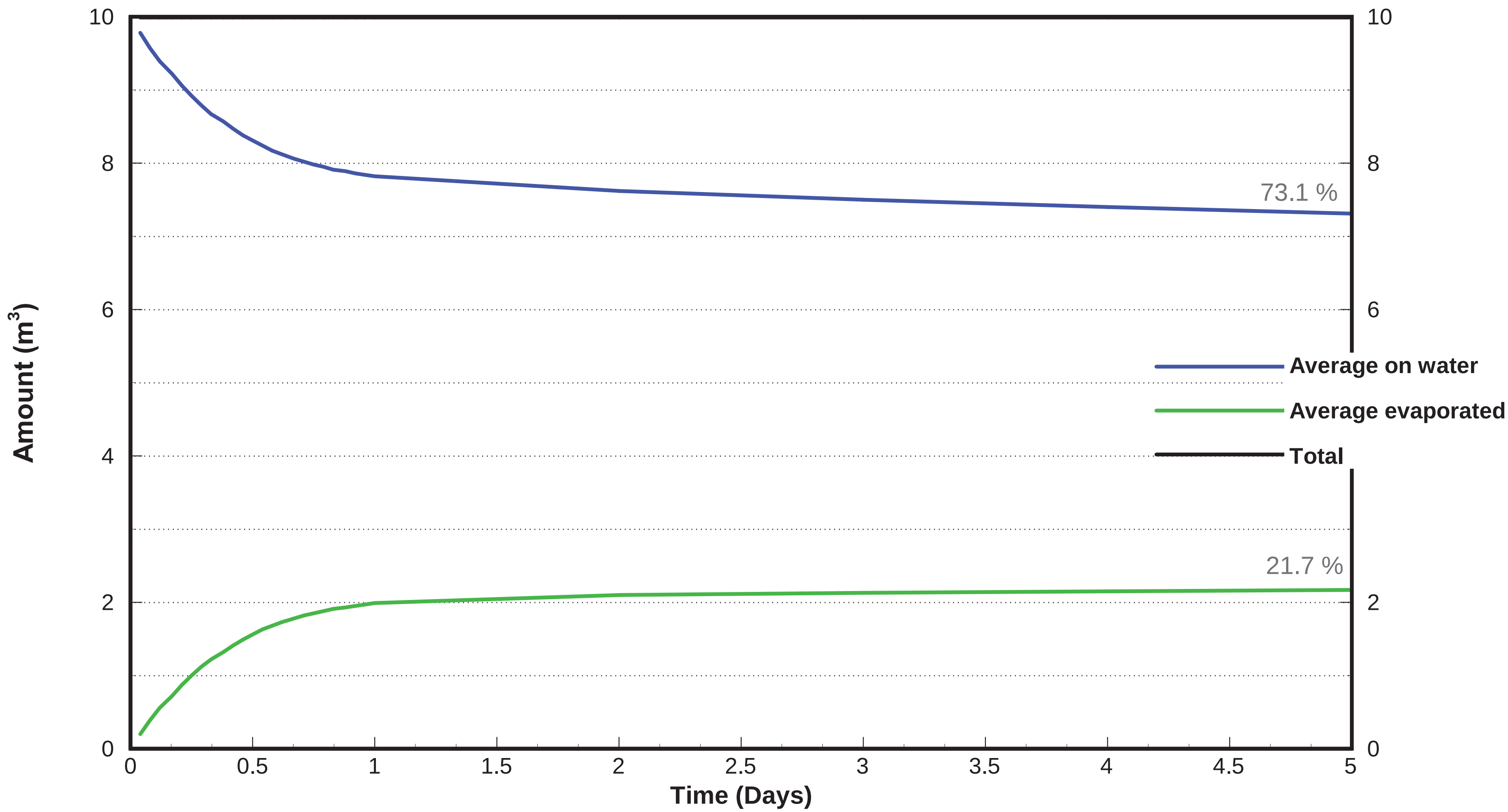
| PROJECT NO. | DWN | CKD | APVD | REV |
|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 |

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 23, 2013 |

**Figure A.2-3**

T:\TMEP\working\AH\02-SPILLCALC\512-Stochastic_Westridge_10m3_Boom\Results_Spring\Tecplot\09-statistics_MB_2.lay

21 Oct 2013 15:30:04




## 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 5 days.
- The major components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

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## TRANS MOUNTAIN OIL SPILL STUDY

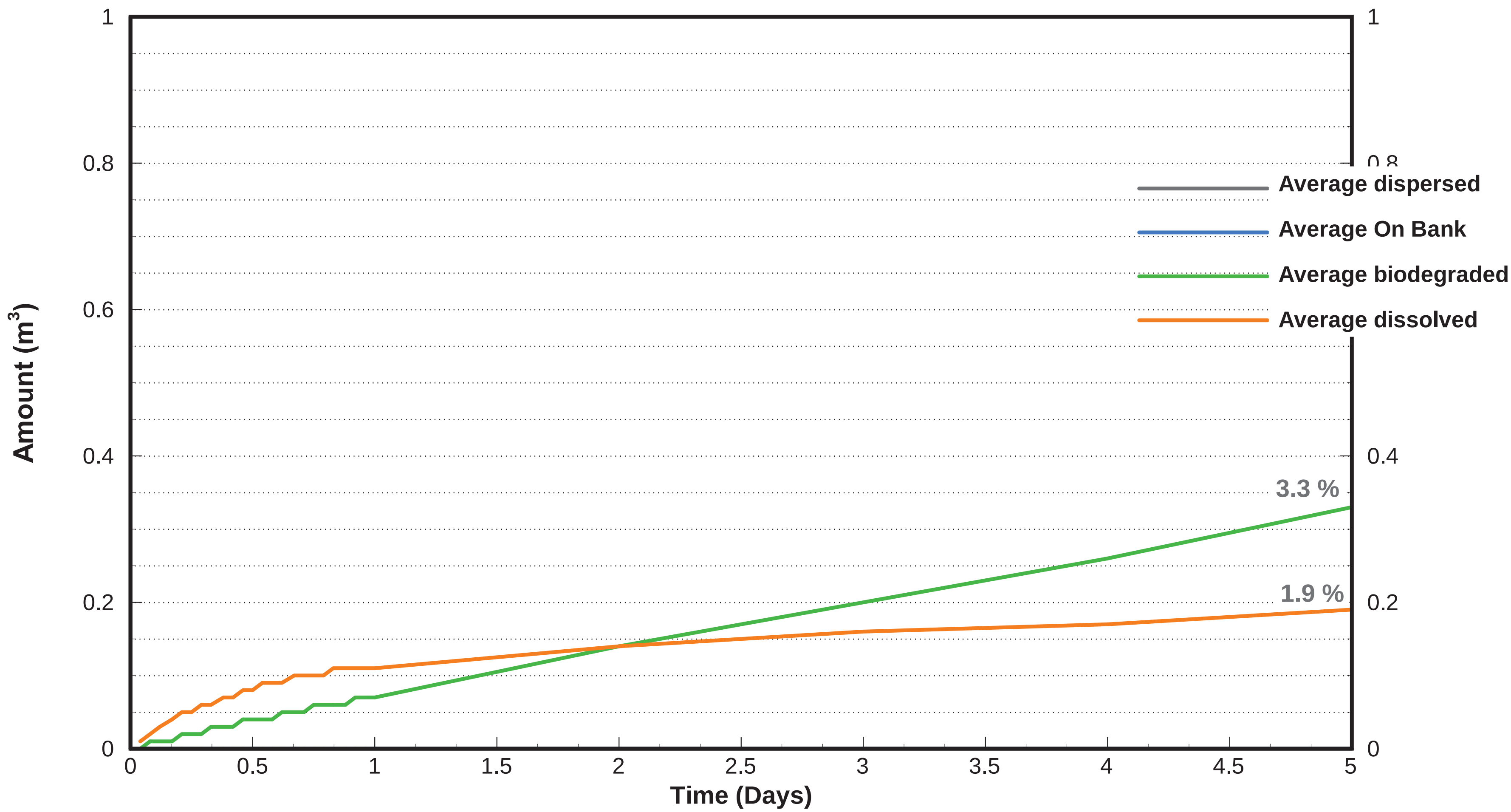
**Stochastic Simulation**
**Summer 2012, Site A (10 $m^3$)**
**Major Components of the Mass Balance**

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

| OFFICE | DATE |
| --- | --- |
| EBA-VANC | October 23, 2013 |

**Figure A.3-2**

T:\TMEP\working\AH\02-SPILLCALC\512-Stochastic_Westridge_10m3_Boom\Results_Summer\Tecplot\08-statistics_MB_1.lay 21 Oct 2013 15:26:55




## 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 5 days.
- The minor components of the mass balance are shown above.

STATUS
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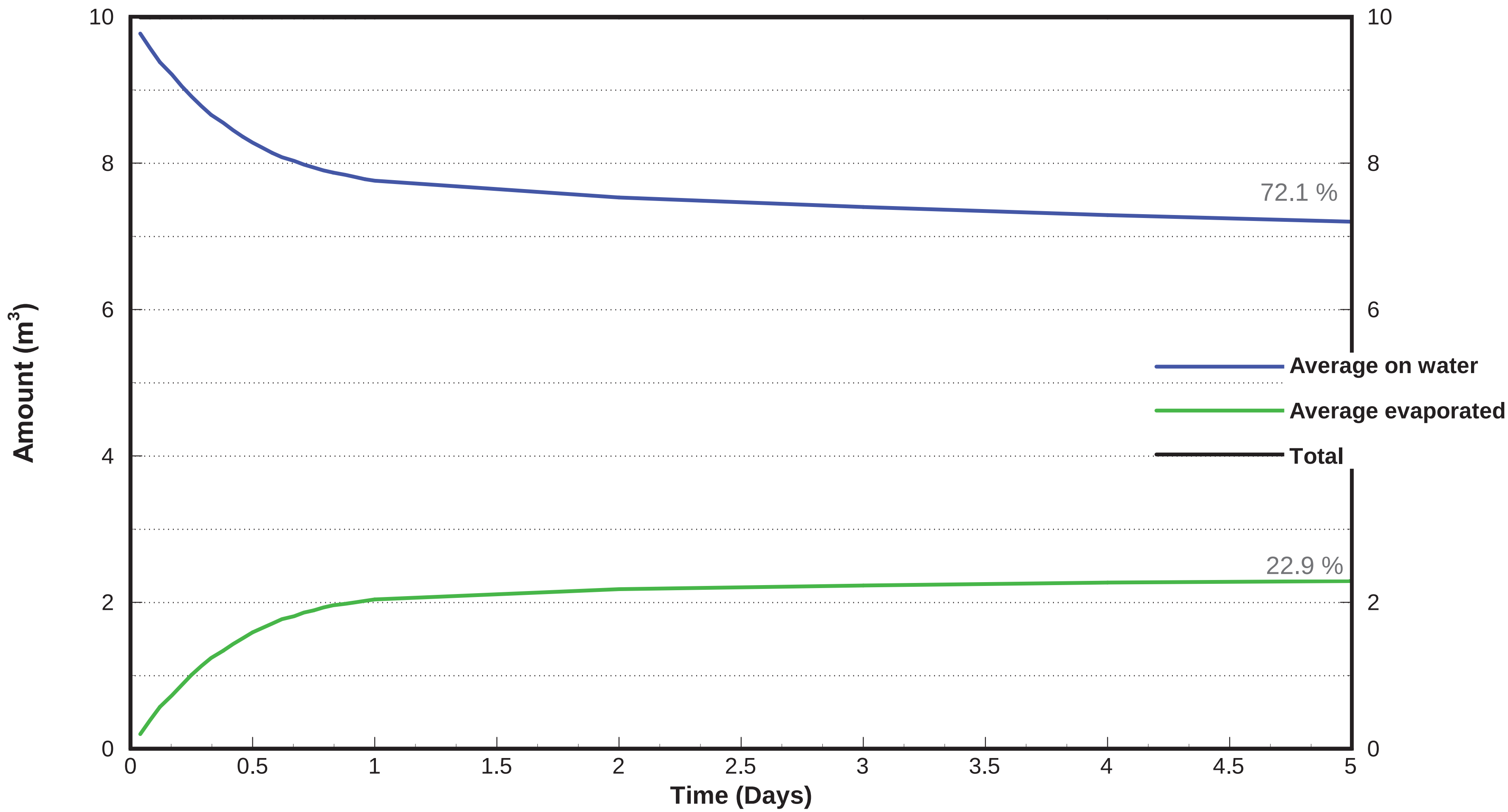
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Summer 2012, Site A (10 $m^3$)**
**Minor Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 23, 2013 |

**Figure A.3-3**




## NOTES

- Statistical results based on independent spills occuring every 6 hours from October 01 00:00 to December 31 23:00.
- Tracking time for each spill was 5 days.
- The major components of the mass balance are shown above.

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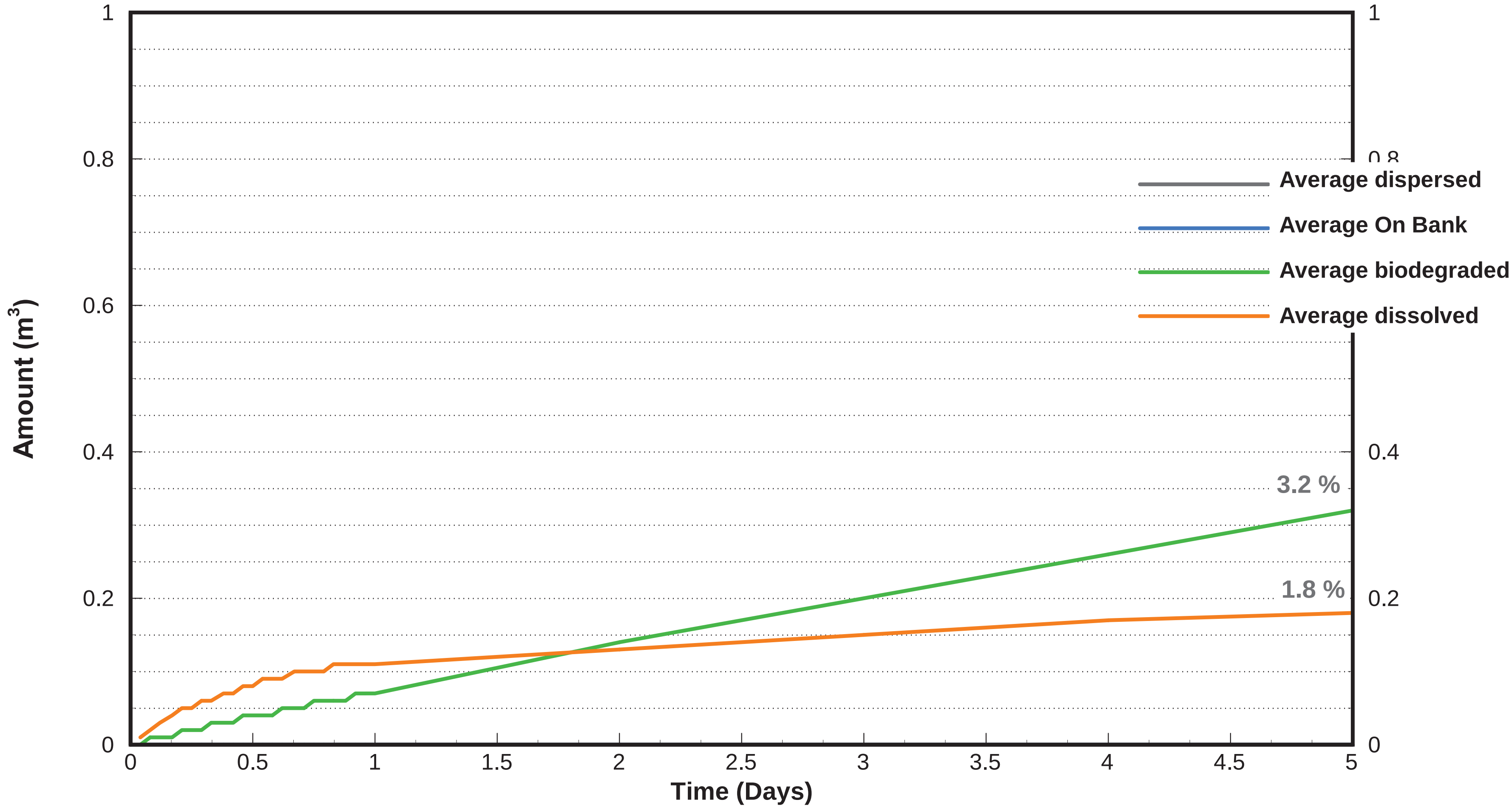
## TRANS MOUNTAIN OIL SPILL STUDY

**Stochastic Simulation**
**Fall 2011, Site A (10 $m^3$)**
**Major Components of the Mass Balance**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | October 23, 2013 |

**Figure A.4-2**




## NOTES

- Statistical results based on independent spills occuring every 6 hours from October 01 00:00 to December 31 23:00.
- Tracking time for each spill was 5 days.
- The minor components of the mass balance are shown above.

STATUS
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# TRANS MOUNTAIN OIL SPILL STUDY

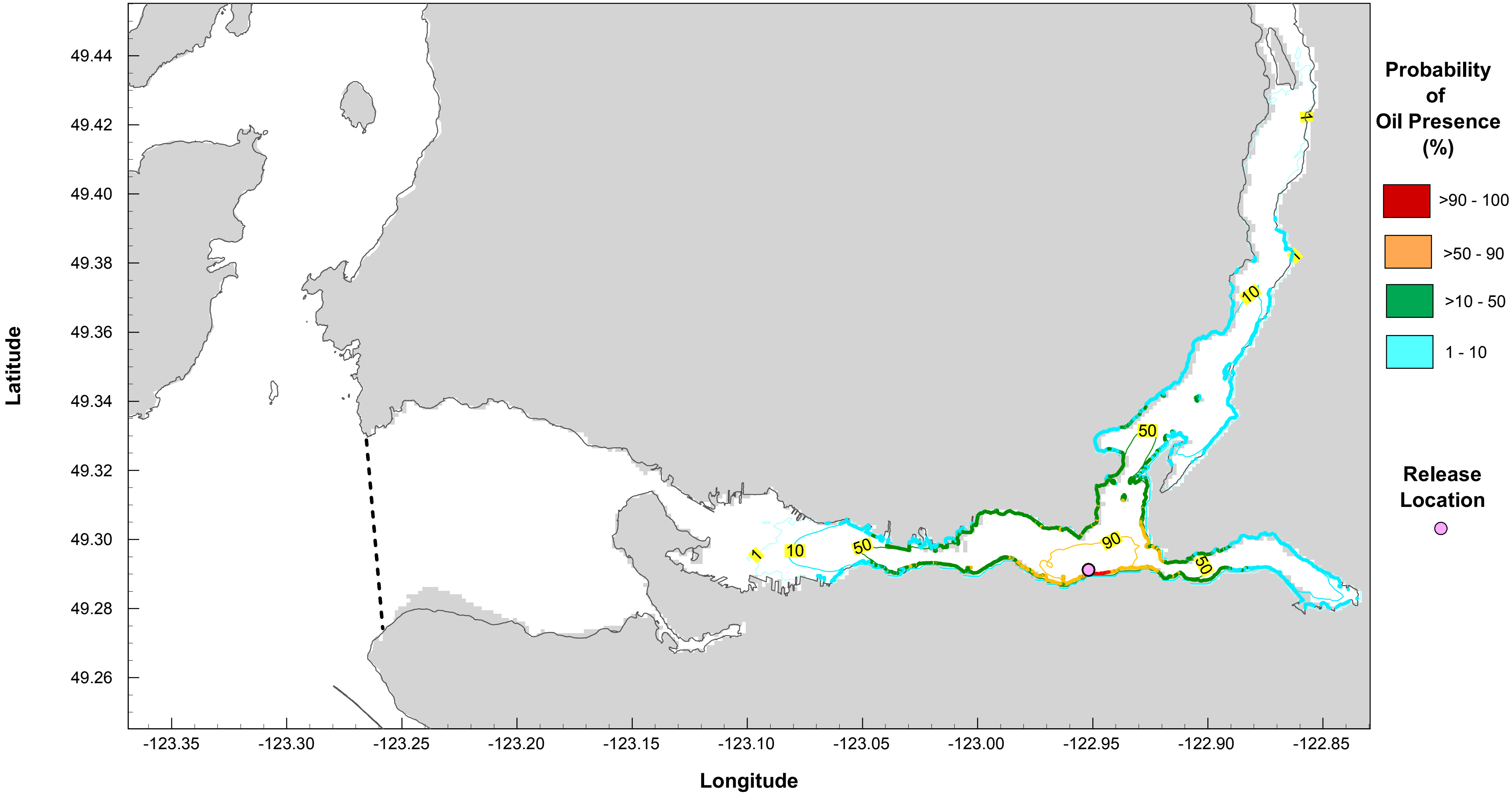
## Stochastic Simulation
## Fall 2011, Site A (10 $m^3$)
## Minor Components of the Mass Balance

| PROJECT NO. | DWN | CKD | APVD | REV | Figure A.4-3 |
|---|---|---|---|---|---|
| V13203022 | AH | JAS | - | 0 | |
| OFFICE | DATE | | | | |
| EBA-VANC | October 23, 2013 | | | | |

T:\TMEP\working\AH\02-SPILLCALC\512-Stochastic_Westridge_10m3_Boom\Results_Fall\Tecplot\09-statistics_MB_2.lay

21 Oct 2013 15:33:39

# Appendix D Probability of Surface and Shoreline Oiling for a 160 m$^3$ Spill




## NOTES

- Statistical results based on independent spills occuring every 3 hours from January 01 00:00 to March 31 23:00, for a total of 728 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or water surface.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

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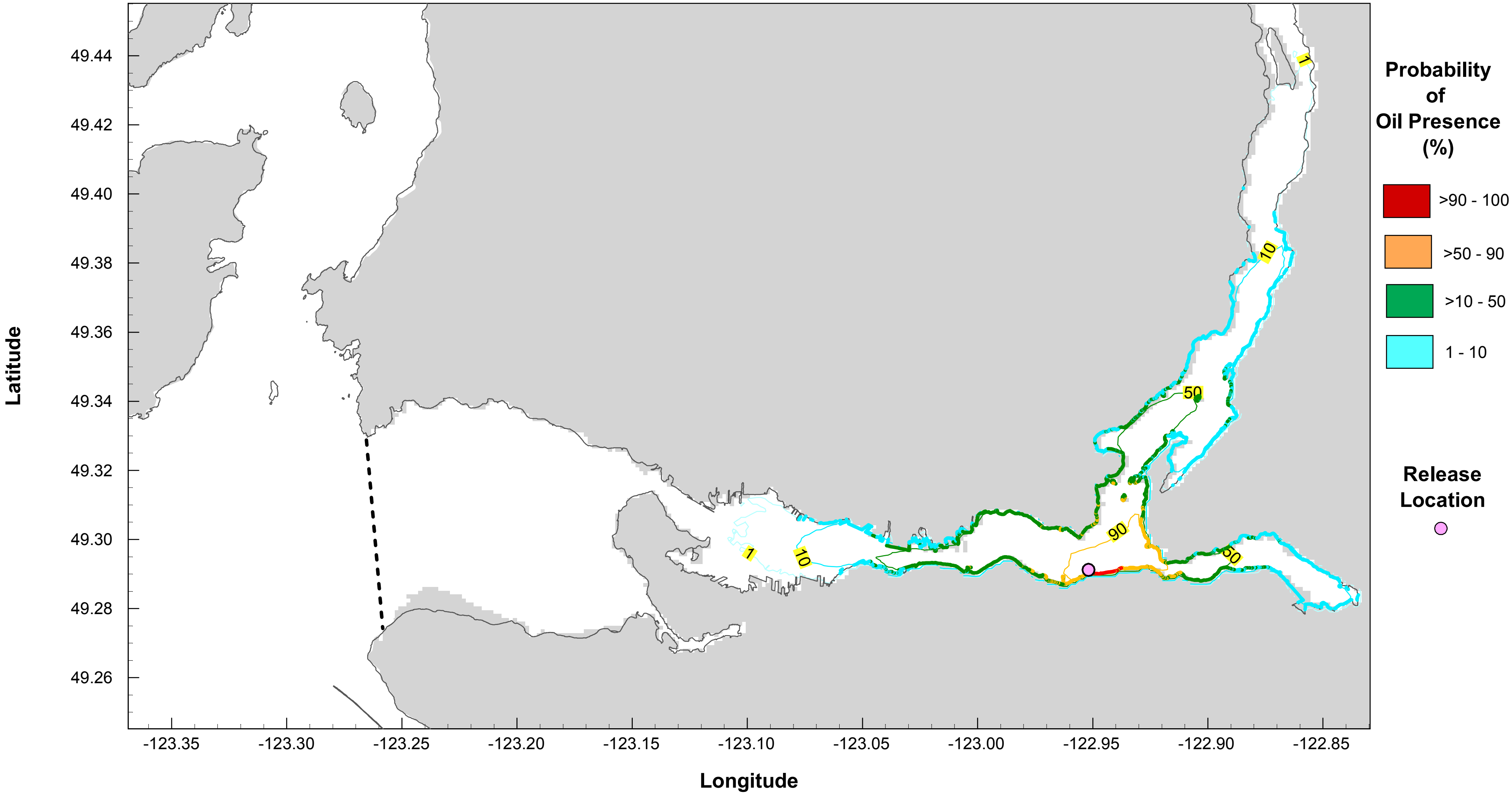
## TRANS MOUNTAIN OIL SPILL STUDY

**Probability of Oiling**
**Westridge Terminal Stochastic Simulation**
**160 $m^3$ Spill Winter Season**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | December 9, 2013 |

**Figure D.1**




## NOTES

- Statistical results based on independent spills occuring every 3 hours from April 1 00:00 to June 30 23:00, for a total of 728 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or water surface.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 $m^3$ release was modelled, corresponding to a 160 $m^3$ operational spill at berth with 20%, i.e. 32 $m^3$ distribution across the spill boom.

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## TRANS MOUNTAIN OIL SPILL STUDY

**Probability of Oiling**
**Westridge Terminal Stochastic Simulation**
**160 $m^3$ Spill Spring Season**

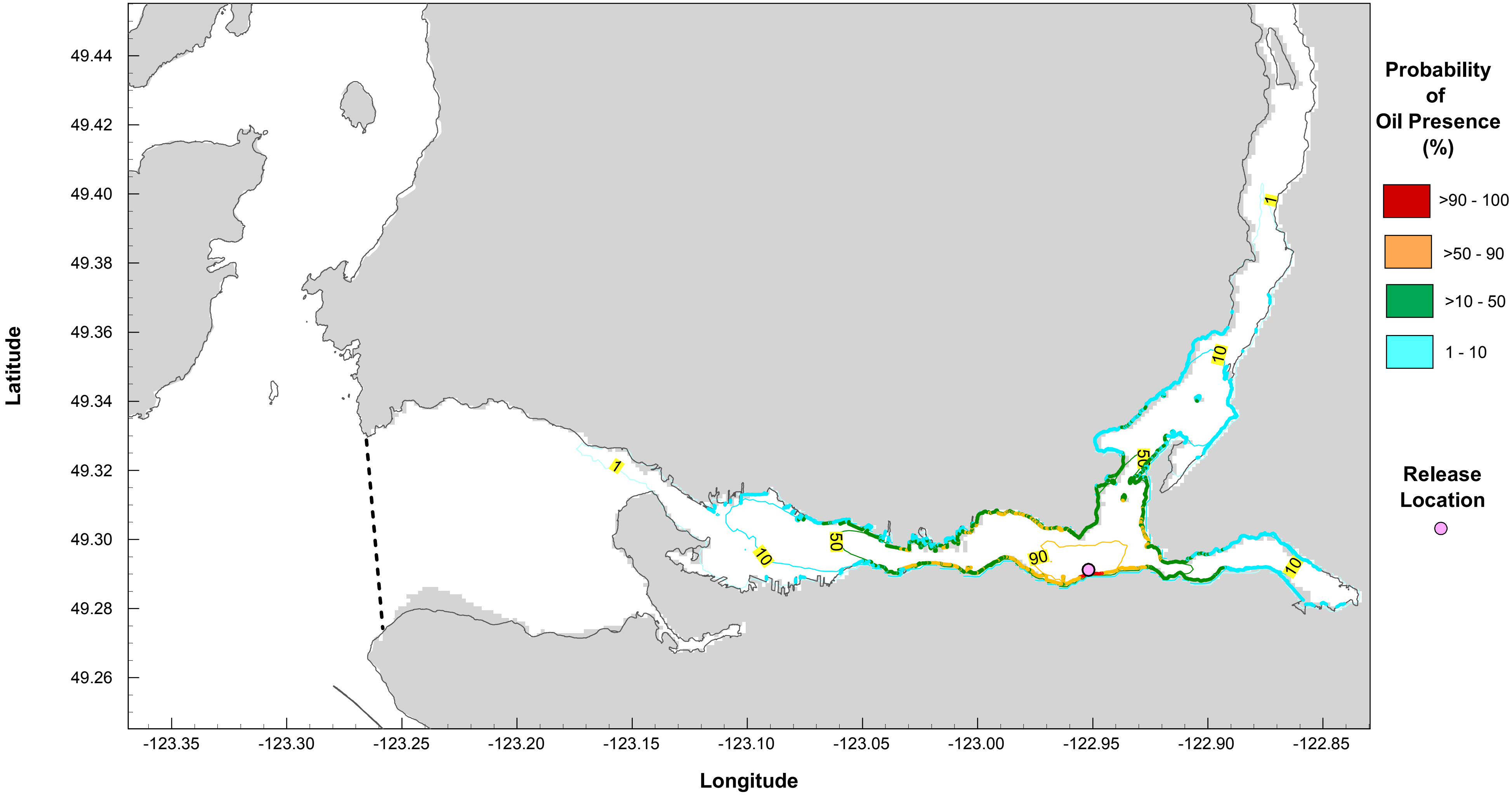
| PROJECT NO. | DWN | CKD | APVD | REV |
|---|---|---|---|---|
| V13203022 | AH | JAS | MS | 0 |

| OFFICE | DATE |
|---|---|
| EBA-VANC | December 9, 2013 |

**Figure D.2**

V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\510-Stochastic_Westridge\Results_Spring2012\Tecplot\03-stochastic_map_lines_4Stantec.lay

09 Dec 2013 09:04:35




## NOTES

- Statistical results based on independent spills occuring every 3 hours from July 1 00:00 to September 30 23:00, for a total of 736 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or water surface.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 m$^3$ release was modelled, corresponding to a 160 m$^3$ operational spill at berth with 20%, i.e. 32 m$^3$ distribution across the spill boom.

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## TRANS MOUNTAIN OIL SPILL STUDY

**Probability of Oiling**
**Westridge Terminal Stochastic Simulation**
**160 m$^3$ Spill Summer Season**

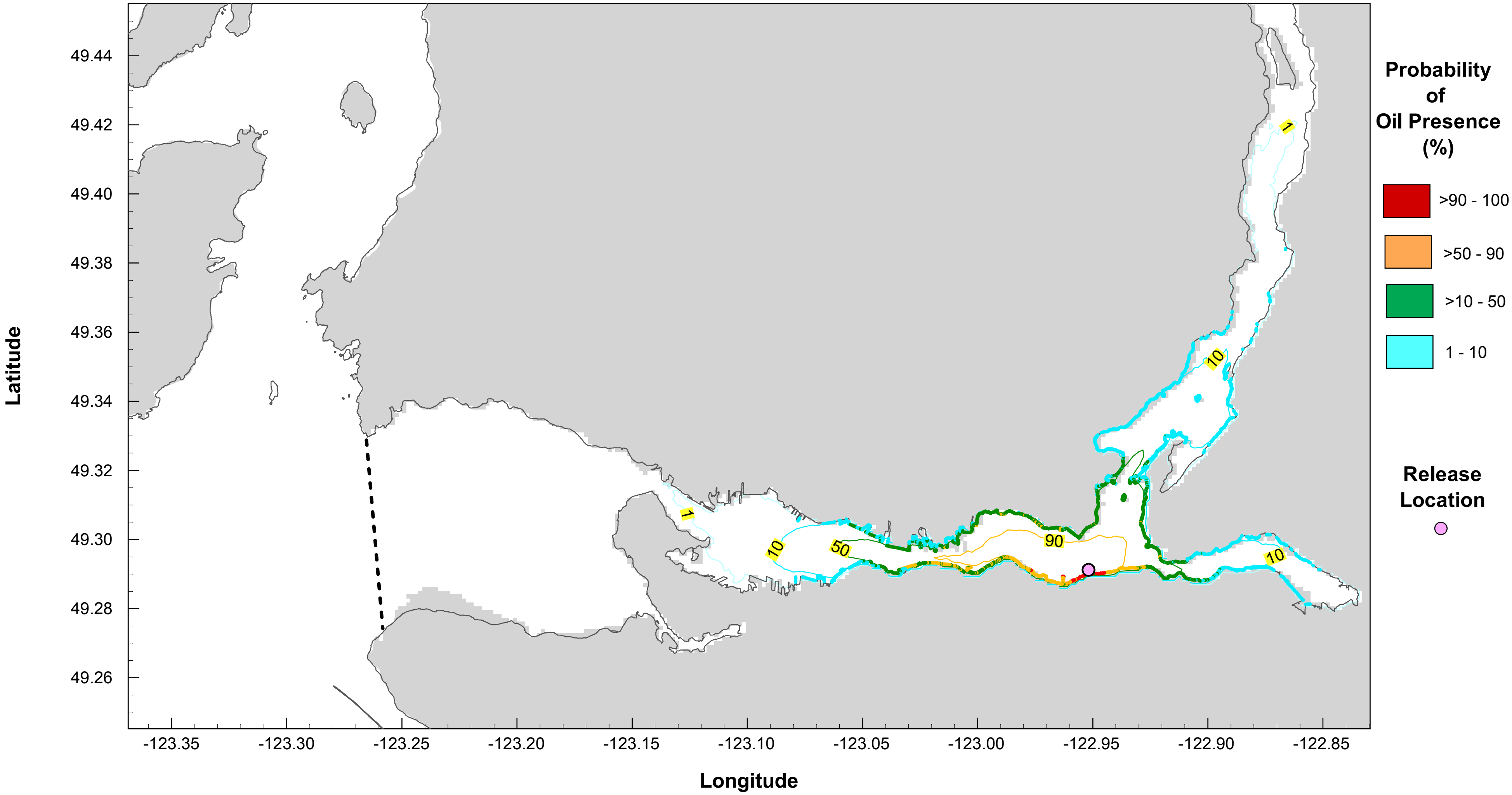
| PROJECT NO. | DWN | CKD | APVD | REV |
| --- | --- | --- | --- | --- |
| V13203022 | AH | JAS | MS | 0 |

| OFFICE | DATE |
| --- | --- |
| EBA-VANC | December 9, 2013 |

**Figure D.3**

V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\510-Stochastic_Westridge\Results_Summer2012\Tecplot\03-stochastic_map_lines_4Stantec.lay

09 Dec 2013 09:16:04




## NOTES

- Statistical results based on independent spills occuring every 3 hours from October 1 00:00 to December 31 23:00, for a total of 736 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location on shoreline or water surface.
- Spills were tracked until no oil left on water. Tracking time for each spill varied, based on the duration of oil on water.
- A 32 m$^3$ release was modelled, corresponding to a 160 m$^3$ operational spill at berth with 20%, i.e. 32 m$^3$ distribution across the spill boom.

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## TRANS MOUNTAIN OIL SPILL STUDY

**Probability of Oiling**
**Westridge Terminal Stochastic Simulation**
**160 m$^3$ Spill Fall Season**

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

| OFFICE | DATE |
|---|---|
| EBA-VANC | December 9, 2013 |

**Figure D.4**