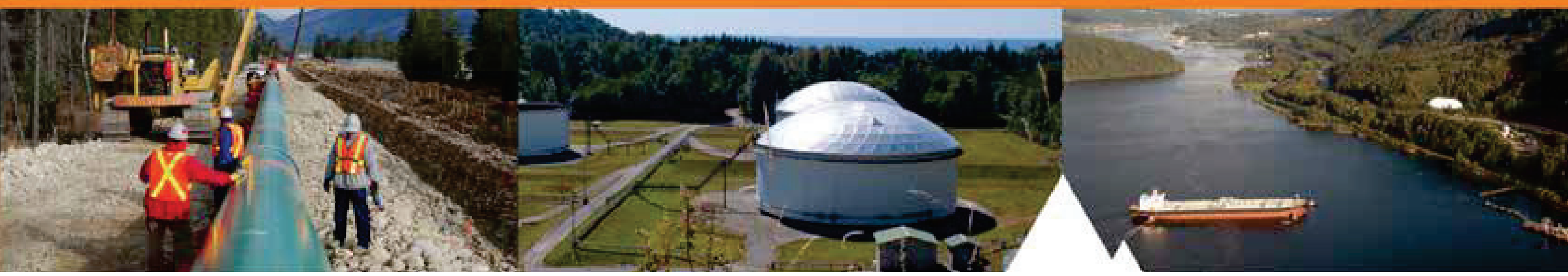
TRANSMOUNTAIN

CELEBRATING 60 YEARS OF SERVICE 1953 to 2013

Trans Mountain Pipeline ULC



Trans Mountain Expansion Project

An Application Pursuant to Section 52 of the National Energy Board Act

December 2013

Volume 7 Risk Assessment & Management of Pipeline & Facility Spills

KINDER MORGAN CANADA

NATIONAL ENERGY BOARD

IN THE MATTER OF

the *National Energy Board Act*,
R.S.C. 1985, c. N-7, as amended, ("*NEB Act*")
and the Regulations made thereunder;

AND IN THE MATTER OF

the *Canadian Environmental Assessment Act, 2012*,
S.C. 2012, c. 37, as amended,
and the Regulations made thereunder;

AND IN THE MATTER OF

an application by Trans Mountain Pipeline ULC
as General Partner of Trans Mountain Pipeline L.P.
(collectively "Trans Mountain")
for a Certificate of Public Convenience and Necessity and
other related approvals pursuant to Part III of the *NEB Act*

APPLICATION BY TRANS MOUNTAIN FOR APPROVAL OF THE TRANS MOUNTAIN EXPANSION PROJECT

December 2013

To: The Secretary
The National Energy Board
444 — 7th Avenue SW
Calgary, AB T2P 0X8

Trans Mountain Expansion Project
Application Pursuant to Section 52 of the *National Energy Board Act*

Guide to the Application

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Transmittal - Letter to the National Energy Board	
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Volume 3A	Public Consultation
Volume 3B	Aboriginal Engagement
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Section 4.0	Emergency Preparedness and Response
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ABBREVIATIONS AND ACRONYMS

This table lists the abbreviations and acronyms used in this volume of the application.

Term	Meaning
∑ BTEX	total BTEX (sum of concentration of each of constituents)
AB	Alberta
AHS	Albian Heavy Synthetic
AMP	Administrative Monetary Penalties
ANS	Alaska North Slope
API	American Petroleum Institute
AWB	Access Western Blend
bbl/d	barrels per day
BC	British Columbia
BC MOE	British Columbia Ministry of Environment
BCERMS	British Columbia Emergency Response Management System Standards
BSD	blue sac disease
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAPP	Canadian Association of Petroleum Producers
CC	Control Centre
CCME	Canadian Council of Ministers of the Environment
CCO	Control Centre Operator
CL	Cold Lake
CLB	Cold Lake Blend
CLWB	Cold Lake Winter Blend
COPC	chemical of potential concern
CPCN	Certificate of Public Convenience and Necessity
CSA	Canadian Standards Association
CSR	Contaminated Sites Regulation
cSt	centistokes
CST	Crisis Support Team
dilbit	diluted bitumen
dilsynbit	diluted synthetic bitumen
DNV	Det Norske Veritas
EHS	Environment, Health and Safety
ERA	Ecological Risk Assessment
ERL	Emergency Response Line
ERL+	Emergency Response Line Plus
ERP	Emergency Response Plan
FIMP	Facility Integrity Management Program
ft.	feet
gal	gallons
GIS	geographic information system
HCA	High Consequence Area
HHRA	Human Health Risk Assessment
IBA	Important Bird Area
ICS	Incident Command System
ILI	in-line inspection
IMP	Integrity Management Program
IMT	Incident Management Team
IOPCF	International Oil Pollution Compensation Fund

Term	Meaning
ISLMS	Integrated Safety and Loss Management System
KMC	Kinder Morgan Canada Inc.
KMP	Kinder Morgan Energy Partners, L.P.
MEAA	Mutual Emergency Assistance Agreement
MIACC	Major Industrial Accidents Council of Canada
mN/m	milliNewton/metre
mPas	milliPascal-second
NDT	Non-destructive Testing
NEB	National Energy Board
NEB Act	*National Energy Board Act*
NIIMS	National Interagency Incident Management System
NR	not relevant
NRC	Natural Resources Canada
OMA	oil-mineral (or particulate) aggregates
OPR	Onshore Pipeline Regulations
OSCAR	Oil Spill Containment and Recovery
PAH	polycyclic aromatic hydrocarbons
PHMSA	Pipeline and Hazardous Materials Safety Administration
ppt	parts per thousand
RK	Reference Kilometre
RSA	Regional Study Area
SCADA	Supervisory Control and Data Acquisition
SCAT	Shoreline Cleanup Assessment Technique
SCB	Statoil Cheecham Blend
SHB	Surmont Heavy Blend
synbit	synthetic bitumen
the Program	the Kinder Morgan Canada Emergency Management Program
the Project	Trans Mountain Expansion Project
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain Pipeline
TMPL system	Trans Mountain Pipeline system
TPAH	total polycyclic aromatic hydrocarbons
TPH	total petroleum hydrocarbon
Trans Mountain	Trans Mountain Pipeline ULC
US	United States
VAFFC	Vancouver Airport Fuel Facilities Corporation
VOC	volatile organic compound
WCMRC	Western Canada Marine Spill Response Corporation
WCSS	Western Canada Spill Services

NEB FILING MANUAL CHECKLIST

CHAPTER 3 – COMMON INFORMATION REQUIREMENTS

Filing #	Filing Requirement	In Application? References	Not in Application? Explanation
3.1 Action Sought by Applicant			
1.	Requirements of s.15 of the Rules.	Volume 1 Section 1.1	---
3.2 Application or Project Purpose			
1.	Purpose of the proposed project.	Volume 2 Section 1.1	---
3.4 Consultation		Volumes 3A, 3B, 3C; Volumes 5A, 5B Section 3; Volume 8A Section 3	--
3.4.1 Principles and Goals of Consultation			
1.	The corporate policy or vision.	Volume 3A Section 1.2.1 Volume 3B Section 1.2.1	--
2.	The principles and goals of consultation for the project.	Volume 3A Section 1.2.2 Volume 3B Section 1.2.2 Volume 5A Section 3.2.1 Volume 5B Section 3.2.1	--
3.	A copy of the Aboriginal protocol and copies of policies and principles for collecting traditional use information, if available.	Volume 3B Section 1.3.5	--
3.4.2 Design of Consultation Program			
1.	The design of the consultation program and the factors that influenced the design.	Volume 3A Section 1.3 Volume 3B Section 1.3 Volume 5A Section 3.1.1, 3.2.2 Volume 5B Section 3.1.1, 3.2.2	--
3.4.3 Implementing a Consultation Program			
1.	The outcomes of the consultation program for the project.	Volume 3A Section 1.7 Volume 3B Section 1.5 Table 1.5.1 Volume 5A Section 3.1.5, 3.2.4 Volume 5B Section 3.1.5, 3.2.4	--
3.4.4 Justification for Not Undertaking a Consultation Program			
2.	The application provides justification for why the applicant has determined that a consultation program is not required for the project.	N/A	N/A
3.5 Notification of Commercial Third Parties			
1.	Confirm that third parties were notified.	Volume 2 Section 3.2.2	--
2.	Details regarding the concerns of third parties.	Volume 2 Section 3.2.2	--
3.	List the self-identified interested third parties and confirm they have been notified.	N/A	N/A
4.	If notification of third parties is considered unnecessary, an explanation to this effect.	N/A	N/A

CHAPTER 4 – SECTIONS 4.1 AND 4.2: COMMON REQUIREMENTS FOR PHYSICAL PROJECTS

Filing #	Filing Requirement	In Application? References	Not in Application? Explanation
4.1 Description of the Project			--
1.	The project components, activities and related undertakings.	Volume 2 Section 2.0; Volume 4A	--
2.	The project location and criteria used to determine the route or site.	Volume 2 Section 4.0; Volume 4A	--
3.	How and when the project will be carried out.	Volume 2 Section 2.3; Volume 4B Section 2.0	--
4.	Description of any facilities, to be constructed by others, required to accommodate the proposed facilities.	N/A	N/A
5.	An estimate of the total capital costs and incremental operating costs, and changes to abandonment cost estimates.	Volume 2 Section 2.9	--
6.	The expected in-service date.	Volume 2 Section 1.1; Volume 4B Section 2.1	--
4.2 Economic Feasibility, Alternatives and Justification			
4.2.1 Economic Feasibility			
1.	Describe the economic feasibility of the project.	Volume 2 Section 3.5	--
4.2.2 Alternatives			
1.	Describe the need for the project, other economically-feasible alternatives to the project examined, along with the rationale for selecting the applied for project over these other possible options.	Volume 2 Section .3.0; Volume 8A Section 2.2	--
2.	Describe and justify the selection of the proposed route and site including a comparison of the options evaluated using appropriate selection criteria.	Volume 2 Section 4.0; Volume 8A Section 2.2	--
3.	Describe the rationale for the chosen design and construction methods. Where appropriate, describe any alternative designs and methods evaluated and explain why these other options were eliminated.	Volume 2 Section 4.0; Volume 8A Section 2.2	--
4.2.3 Justification			
1.	Provide a justification for the proposed project	Volume 2 Section 3.4	--

GUIDE A – A.1 ENGINEERING

Filing #	Filing Requirement	In Application? References	Not in Application? Explanation
A.1.1 Engineering Design Details			
1.	Fluid type and chemical composition.	Volume 4A Section 3.1.1	--
2.	Line pipe specifications.	Volume 4A Section 3.2.8	--
3.	Pigging facilities specifications.	Volume 4A Section 3.3.1, 3.3.2	--
4.	Compressor or pump facilities specifications.	Volume 4A Section 3.4	--
5.	Pressure regulating or metering facilities specifications.	Volume 4A Section 3.5	--
6.	Liquid tank specifications, or other commodity storage facilities.	Volume 4A Section 3.4	--
7.	New control system facilities specifications.	Volume 4A Section 3.3	--
8.	Gas processing, sulphur or LNG plant facilities specifications.	N/A	N/A
9.	Technical description of other facilities not mentioned above.	N/A	N/A
10.	Building dimensions and uses.	Volume 4A Section 3.3, 3.4, 3.5	--
11.	If project is a new system that is a critical source of energy supply, a description of the impact to the new system capabilities following loss of critical component.	N/A	N/A
A.1.2 Engineering Design Principles			
1.	Confirmation project activities will follow the requirements of the latest version of CSA Z662.	Volume 4A Section 2.2	--
2.	Provide a statement indicating which Annex is being used and for what purpose	Volume 4A Section 2.3	--
3.	Statement confirming compliance with OPR or PPR.	Volume 4A Section 2.1	--
4.	Listing of all primary codes and standards, including version and date of issue.	Volume 4A Section 2, Table 5.1.1	--
5.	Confirmation that the project will comply with company manuals and confirm manuals comply with OPR/PPR and codes and standards.	Volume 4A Section 2.6, Table 5.1.2	--
6.	Any portion of the project a non-hydrocarbon commodity pipeline system? Provide a QA program to ensure the materials are appropriate for their intended service.	N/A – all hydrocarbons	N/A
7.	If facility subject to conditions not addressed in CSA Z662: • Written statement by qualified professional engineer • Description of the designs and measures required to safeguard the pipeline	Volume 4A Section 2.9	--
8.	If directional drilling involved: • Preliminary feasibility report • Description of the contingency plan	Volume 4A Section 2.12	--
9.	If the proposed project involves the reuse of materials, provide an engineering assessment in accordance with CSA Z662 that indicates its suitability for the intended service.	Volume 4A, Section 2.7	--
10.	If new materials are involved, provide material supply chain information, in tabular format.	Volume 4A Section 2.7	
11.	If reuse of material is involved, provide an engineering assessment in accordance with CSA Z662 that indicates its suitability for the intended service.	Volume 4A, Section 2.7	--
A.1.3 Onshore Pipeline Regulations			
1.	Designs, specifications programs, manuals, procedures, measures or plans for which no standard is set out in the OPR or PPR.	--	Existing standards will be followed
2.	A quality assurance program if project non-routine or incorporates unique challenges due to geographical location.	--	No unique challenges
3.	If welding performed on a liquid-filled pipeline that has a carbon equivalent of 0.50% or greater and is a permanent installation: • Welding specifications and procedures • Results of procedure qualification tests	--	Welding on liquid filled pipe will not be conducted

GUIDE A – A.2 ENVIRONMENTAL AND SOCIO-ECONOMIC ASSESSMENT

The following table identifies where information requested in the National Energy Board (NEB) Filing Manual Guide A – A.2 Environmental and Socio-economic Assessment checklist may be found in the various volumes of the Application for the Trans Mountain Expansion Project.

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
A.2.5 Description of the Environmental and Socio-Economic Setting				
1.	Identify and describe the current biophysical and socio-economic setting of each element (*i.e.*, baseline information) in the area where the project is to be carried out.	Volume 5A: ESA - Biophysical · Sections 5.0 and 6.0 Volume 5B: ESA - Socio-Economic · Sections 5.0 and 6.0 Volume 5C: ESA - Biophysical Technical Reports Volume 5D: ESA - Socio-Economic Technical Reports	Volume 8A: Marine Transportation · Section 4.2 Volume 8B: Technical Reports	---
2.	Describe which biophysical or socio-economic elements in the study area are of ecological, economic, or human importance and require more detailed analysis taking into account the results of consultation (see Table A-1 for examples). Where circumstances require more detailed information in an ESA see: i. Table A-2 – Filing Requirements for Biophysical Elements; or ii. Table A-3 – Filing Requirements for Socio-economic Elements.	Volume 5A: ESA - Biophysical · Sections 5.0 and 6.0 Volume 5B: ESA - Socio-Economic · Sections 5.0 and 6.0 Volume 5C: ESA - Biophysical Technical Reports Volume 5D: ESA - Socio-Economic Technical Reports	Volume 8A: Marine Transportation · Section 4.2 Volume 8B: Technical Reports	---
3.	Provide supporting evidence (*e.g.*, references to scientific literature, field studies, local and traditional knowledge, previous environmental assessment and monitoring reports) for: · information and data collected; · analysis completed; · conclusions reached; and · the extent of professional judgment or experience relied upon in meeting these information requirements, and the rationale for that extent of reliance.	Volume 5A: ESA - Biophysical · Sections 5.0 and 6.0 Volume 5B: ESA - Socio-Economic · Sections 5.0 and 6.0 Volume 5C: ESA - Biophysical Technical Reports Volume 5D: ESA - Socio-Economic Technical Reports	Volume 8A: Marine Transportation · Section 4.2 Volume 8B: Technical Reports	---
4.	Describe and substantiate the methods used for any surveys, such as those pertaining to wildlife, fisheries, plants, species at risk or species of special status, soils, heritage resources or traditional land use, and for establishing the baseline setting for the atmospheric and acoustic environment.	Volume 5A: ESA - Biophysical · Sections 5.0 and 6.0 Volume 5B: ESA - Socio-Economic · Sections 5.0 and 6.0 Volume 5C: ESA - Biophysical Technical Reports Volume 5D: ESA - Socio-Economic Technical Reports	Volume 8A: Marine Transportation · Section 4.2 Volume 8B: Technical Reports	---
5.	Applicants must consult with other expert federal, provincial or territorial departments and other relevant authorities on requirements for baseline information and methods.	Volume 5A: ESA - Biophysical · Sections 3.0, 5.0 and 6.0 Volume 5B: ESA - Socio-Economic · Sections 3.0, 5.0 and 6.0 Volume 5C: ESA - Biophysical Technical Reports Volume 5D: ESA - Socio-Economic Technical Reports	Volume 8A: Marine Transportation · Sections 3.0 and 4.2 Volume 8B: Technical Reports	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
A.2.6 Effects Assessment				
Identification and Analysis of Effects				
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 (*i.e.*, changes to the Project caused by the environment).	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0 Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0 · Technical Reports	Volume 8A: Marine Transportation · Sections 4.3, 5.5 and 5.6	---
2.	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. Also include effects the environment could have on the project. For those biophysical and socio-economic elements or their valued components that require further analysis (see Table A-1), provide the detailed information outlined in Tables A-2 and A-3.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0 Volume 5C: ESA - Biophysical Technical Reports Volume 5D: ESA - Socio-Economic Technical Reports Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0 · Technical Reports	Volume 8A: Marine Transportation · Sections 4.3, 5.6 and 5.7 Volume 8B: Technical Reports	---
Mitigation Measures for Effects				
1.	Describe the standard and project specific mitigation measures and their adequacy for addressing the project effects, or clearly reference specific sections of company manuals that provide mitigation measures. Ensure that referenced manuals are current and filed with the NEB.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0 Volume 5C: ESA - Biophysical Technical Reports Volume 5D: ESA - Socio-Economic Technical Reports Volume 6B: Pipeline Environmental Protection Plan (EPP) Volume 6C: Facilities EPP Volume 6D: Westridge Marine Terminal EPP Volume 6E: Environmental Alignment Sheets Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 2.0, 3.0, 4.0, 6.0, 7.0, and 8.0 · Technical Reports	Volume 8A: Marine Transportation · Sections 4.3, 5.1, 5.3, 5.6 and 5.7 Volume 8B: Technical Reports	---
2.	Ensure that commitments about mitigative measures will be communicated to field staff for implementation through an Environmental Protection Plan.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0 Volume 6A: Environmental Compliance Volume 6B: Pipeline EPP Volume 6C: Facilities EPP Volume 6D: Westridge Marine Terminal EPP Volume 6E: Environmental Alignment Sheets Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 2.0, 3.0, 4.0, 6.0, 7.0 and 8.0	Volume 8A: Marine Transportation · Sections 4.3, 5.1, 5.3, 5.6 and 5.7	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
3.	Describe plans and measures to address potential effects of accidents and malfunctions during construction and operation of the project.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0 Volume 6B: Pipeline EPP Volume 6C: Facilities EPP Volume 6D: Westridge Marine Terminal EPP Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 2.0, 4.0, 6.0, 7.0 and 8.0	Volume 8A: Marine Transportation · Sections 4.3, 5.1, 5.3, 5.6 and 5.7	---
Evaluation of Significance				
1.	After taking into account any appropriate mitigation measures, identify any remaining residual effects from the project.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0	Volume 8A: Marine Transportation · Section 4.3	---
2.	Describe the methods and criteria used to determine the significance of remaining adverse effects, including defining the point at which any particular effect on a valued component is considered "significant".	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0	Volume 8A: Marine Transportation · Section 4.3	---
3.	Evaluate significance of residual adverse environmental and socio-economic effects against the defined criteria.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0	Volume 8A: Marine Transportation · Section 4.3	---
4.	Evaluate the likelihood of significant, residual adverse environmental and socio-economic effects occurring and substantiate the conclusions made.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0	Volume 8A: Marine Transportation · Section 4.3	---
A.2.7 Cumulative Effects Assessment				
Scoping and Analysis of Cumulative Effects				
1.	Identify the valued components for which residual effects are predicted, and describe and justify the methods used to predict any residual results.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
2.	For each valued component where residual effects have been identified, describe and justify the spatial and temporal boundaries used to assess the potential cumulative effects.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
3.	Identify other physical works or activities that have been or will be carried out within the identified spatial and temporal boundaries for the cumulative effects assessment.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
4.	Identify whether the effects of those physical works or activities that have been or will be carried out would be likely to produce effects on the valued components within the identified spatial and temporal boundaries.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
5.	Where other physical works or activities may affect the valued components for which residual effects from the applicant's proposed project are predicted, continue the cumulative effects assessment, as follows: · consider the various components, phases and activities associated with the applicant's project that could interact with other physical work or activities; · provide a description of the extent of the cumulative effects on valued components; and · where professional knowledge or experience is cited, explain the extent to which professional knowledge or experience was relied upon and justify how the resulting conclusions or decisions were reached.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
Mitigation Measures for Cumulative Effects				
1.	Describe the general and specific mitigation measures, beyond project-specific mitigation already considered, that are technically and economically feasible to address any cumulative effects.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
Applicant's Evaluation of Significance of Cumulative Effects				
1.	After taking into account any appropriate mitigation measures for cumulative effects, identify any remaining residual cumulative effects.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
2.	Describe the methods and criteria used to determine the significance of remaining adverse cumulative effects, including defining the point at which each identified cumulative effect on a valued component is considered "significant".	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
3.	Evaluate the significance of adverse residual cumulative effects against the defined criteria.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
4.	Evaluate the likelihood of significant, residual adverse cumulative environmental and socio-economic effects occurring and substantiate the conclusions made.	Volume 5A: ESA - Biophysical · Section 8.0 Volume 5B: ESA - Socio-Economic · Section 8.0	Volume 8A: Marine Transportation · Section 4.4	---
A.2.8 Inspection, Monitoring and Follow-up				
1.	Describe inspection plans to ensure compliance with biophysical and socio-economic commitments, consistent with Sections 48, 53 and 54 of the *NEB Onshore Pipeline Regulations (OPR)*.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0 Volume 6A: Environmental Compliance Volume 6B: Pipeline EPP Volume 6C: Facilities EPP Volume 6D: Westridge Marine Terminal EPP	Volume 8A: Marine Transportation · Section 4.3	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
2.	Describe the surveillance and monitoring program for the protection of the pipeline, the public and the environment, as required by Section 39 of the *NEB OPR*.	Volume 5A: ESA - Biophysical · Section 7.0 Volume 5B: ESA - Socio-Economic · Section 7.0 Volume 6A: Environmental Compliance Volume 6B: Pipeline EPP Volume 6C: Facilities EPP Volume 6D: Westridge Marine Terminal EPP	Volume 8A: Marine Transportation · Section 4.3	---
3.	Consider any particular elements in the Application that are of greater concern and evaluate the need for a more in-depth monitoring program for those elements.	Volume 5A: ESA - Biophysical · Sections 9.0 and 10.0 Volume 5B: ESA - Socio-Economic · Sections 9.0 and 10.0 Volume 6A: Environmental Compliance Volume 6B: Pipeline EPP (Socio-Economic Management Plan of Appendix C)	Volume 8A: Marine Transportation · Section 4.5	---
4.	For *Canadian Environmental Assessment (CEA) Act, 2012* designated projects, identify which elements and monitoring procedures would constitute follow-up under the *CEA Act, 2012*.	Volume 5A: ESA - Biophysical · Section 10.0 Volume 5B: ESA - Socio-economic · Section 10.0	N/A	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
Table A-1 Circumstances and Interactions Requiring Detailed Biophysical and Socio-Economic Information				
Physical and meteorological environment		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0 and 7.0	N/A	---
Soil and soil productivity		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Soil Assessment Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 5.3, 6.0 and 7.0	N/A	---
Water quality and quantity (onshore and marine)		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Groundwater Technical Report · Fisheries (Alberta) Technical Report · Fisheries (British Columbia) Technical Report · Wetland Evaluation Technical Report · Marine Sediment and Water Quality – Westridge Marine Terminal Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Section 7.0 · Quality Ecological Risk Assessment of Pipeline Spills Technical Report	Volume 8A: Marine Transportation · Sections 4.2, 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Ecological Risk Assessment of Marine Transportation Spills Technical Report	---
Air emissions (onshore and marine)		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Marine Air Quality and Greenhouse Gas – Marine Transportation Technical Report · Air Quality and Greenhouse Gas Emissions Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Section 7.0	Volume 8A: Marine Transportation · Sections 4.2, 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Marine Air Quality and Greenhouse Gas Emissions	---
Greenhouse gas emissions (onshore and marine)		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0 and 7.0 Volume 5C: ESA - Biophysical Technical Reports · Air Quality and Greenhouse Gas Emissions Technical Report	Volume 8A: Marine Transportation · Sections 4.2 and 4.3 Volume 8B: Technical Reports · Marine Air Quality and Greenhouse Gas Emissions	---
Acoustic environment (onshore and marine)		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0, and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Acoustic Environment Technical Report	Volume 8A: Marine Transportation · Sections 4.2, 4.3 and 4.4 Volume 8B: Technical Reports · Marine Noise (Atmospheric)	---
Fish and fish habitat (onshore and marine), including any fish habitat compensation required		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Fisheries (Alberta) Technical Report · Fisheries (British Columbia) Technical Report · Marine Resources - Westridge Marine Terminal Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0 · Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report	Volume 8A: Marine Transportation · Sections 4.2, 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Marine Resources – Marine Transportation Technical Report · Ecological Risk Assessment of Westridge Marine Terminal Spills	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
Wetlands		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Wetland Evaluation Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 7.0 and 8.0 · Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report	N/A	---
Vegetation		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Vegetation Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 7.0 and 8.0 · Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report	N/A	---
Wildlife and wildlife habitat (onshore and marine)		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Wildlife and Wildlife Habitat Technical Report · Wildlife Modeling and Species Accounts Report · Marine Resources –Westridge Marine Terminal Technical Report · Marine Birds – Westridge Marine Terminal Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0 · Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report	Volume 8A: Marine Transportation · Sections 4.2. 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Marine Resources – Marine Transportation Technical Report · Marine Birds – Marine Transportation Technical Report · Ecological Risk Assessment of Westridge Marine Terminal Spills	---
Species at Risk or Species of Special Status and related habitat (onshore and marine)		Volume 5A: ESA - Biophysical · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C: ESA - Biophysical Technical Reports · Fisheries (Alberta) Technical Report · Fisheries (British Columbia) Technical Report · Vegetation Technical Report · Wildlife and Wildlife Habitat Technical Report · Wildlife Modeling and Species Accounts Report · Marine Resources –Westridge Marine Terminal Technical Report · Marine Birds – Westridge Marine Terminal Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0 · Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report	Volume 8A: Marine Transportation · Sections 4.2. 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Marine Resources – Marine Transportation Technical Report · Marine Birds – Marine Transportation Technical Report · Marine Transportation Spills Ecological Risk Assessment Technical Report	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
Human occupancy and resource use (onshore and marine)		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D: ESA - Socio-Economic Technical Reports · Socio-Economic Technical Report · Managed Forest Areas Technical Report · Agricultural Assessment Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0	Volume 8A: Marine Transportation · Sections 4.2, 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Marine Commercial, Recreational and Tourism Use – Marine Transportation Technical Report	---
Heritage resources		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0 and 7.0 Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Section 6.3.3	N/A	---
Navigation and navigation safety		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0 and 7.0 Volume 5D: ESA - Socio-Economic Technical Reports · Socio-Economic Technical Report	Volume 8A: Marine Transportation · Section 5.2	---
Traditional land and resource use		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D: ESA - Socio-Economic Technical Reports · Traditional Land and Resource Use Report · Pipeline and Facilities Human Health Risk Assessment Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 7.0, 8.0 and 9.0 · Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report	Volume 8A: Marine Transportation · Sections 4.2, 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Traditional Marine Use Report for Marine Transportation · Marine Transportation Human Health Risk Assessment Technical Report	---
Social and cultural well-being		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D: ESA - Socio-Economic Technical Reports · Socio-Economic Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0	N/A	---
Human health and aesthetics		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D: ESA - Socio-Economic Technical Reports · Socio-Economic Technical Report · Community Health Technical Report · Viewshed Modelling Analysis Technical Report · Pipeline and Facilities Human Health Risk Assessment Technical Report Volume 7 Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0 · Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report	Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Qualitative Human Health Risk Assessment of Westridge Marine Terminal Technical Report Volume 8A: Marine Transportation · Sections 4.2, 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Marine Transportation Human Health Risk Assessment Technical Report · Marine Transportation Spills Human Health Risk Assessment Technical Report	---

Filing #	Filing Requirement	In Application? References	Applicable Marine Transportation Elements	Not in Application? Explanation
Infrastructure and services		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D: ESA - Socio-Economic Technical Reports · Socio-Economic Technical Report · Community Health Technical Report Volume 7: Risk Assessment and Management of Pipeline and Facility Spills · Sections 6.0, 7.0 and 8.0	Volume 8A: Marine Transportation · Sections 4.2, 4.3, 4.4, 5.6 and 5.7 Volume 8B: Technical Reports · Marine Commercial, Recreational and Tourism Use – Marine Transportation Technical Report	---
Employment and economy		Volume 5B: ESA - Socio-Economic · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D: ESA - Socio-Economic Technical Reports · Socio-Economic Technical Report · Worker Expenditures Analysis Technical Report	N/A	---

GUIDE A – A.3 ECONOMICS

Filing #	Filing Requirement	In Application? References	Not in Application? Explanation
A.3.1 Supply			
1.	A description of each commodity.	Volume 2 Section 3.1.1	--
2.	A discussion of all potential supply sources.	Volume 2 Section 3.3.2	--
3.	Forecast of productive capacity over the economic life of the facility.	Volume 2 Sections 3.3.1, 3.4.1	
4.	For pipelines with contracted capacity, a discussion of the contractual arrangements underpinning supply.	Volume 2 Section 3.3.2	--
A.3.2 Transportation Matters			
Pipeline Capacity			
1.	In the case of expansion provide: • Pipeline capacity before and after and size of increment • Justification that size of expansion is appropriate	Volume 2 Sections 1.1, 2.1, 3.5	--
2.	In case of new pipeline, justification that size of expansion is appropriate given available supply.	N/A – expansion	N/A
Throughput			
1.	For pipelines with contracted capacity, information on contractual arrangements.	Volume 2 Section 3.2.1	--
2.	For non-contract carrier pipelines, forecast of annual throughput volumes by commodity type, receipt location and delivery destination over facility life.	N/A	N/A
3.	If project results in an increase in throughput: • theoretical and sustainable capabilities of the existing and proposed facilities versus the forecasted requirements • flow formulae and flow calculations used to determine the capabilities of the proposed facilities and the underlying assumptions and parameters	Volume 2 Section 3.1	--
4.	If more than one type of commodity transported, a discussion pertaining to segregation of commodities including potential contamination issues or cost impacts.	N/A	N/A
A.3.3 Markets			
1.	Provide an analysis of the market in which each commodity is expected to be used or consumed.	Volume 2 Section 3.4.2	--
2.	Provide a discussion of the physical capability of upstream and downstream facilities to accept the incremental volumes that would be received and delivered.	Volume 2 Section 3.4.2	--
A.3.4 Financing			
1.	Evidence that the applicant has the ability to finance the proposed facilities.	Volume 2 Section 3.2.2	--
2.	Estimated toll impact for the first full year that facilities are expected to be in service.	Volume 2 Section 3.2.1	--
3.	Confirmation that shippers have been apprised of the project and toll impact, their concerns and plans to address them.	Volume 2 Section 3.2.1	--
4.	Additional toll details for applications with significant toll impacts.	Volume 2 Section 3.2.1	
A.3.5 Non-NEB Regulatory Approvals			
1.	Confirm that all non-NEB regulatory approvals required to allow the applicant to meet its construction schedule, planned in-service date and to allow the facilities to be used and useful are or will be in place.	Volume 2 Section 1.5	--
2.	If any of the approvals referred to in #1 may be delayed, describe the status of those approval(s) and provide an estimation of when the approval is anticipated.	Volume 2 Section 1.5	--

GUIDE A – A.4 LANDS INFORMATION

Filing #	Filing Requirement	In Application? References	Not in Application? Explanation
A.4.1 Land Areas			
1.	• Width of right-of-way and locations of any changes to width • Locations and dimensions of known temporary work space and drawings of typical dimensions • Locations and dimensions of any new lands for facilities	Volume 2 Section 5.2	--
A.4.2 Land Rights			
1.	The type of lands rights proposed to be acquired for the project.	Volume 2 Section 5.3	--
2.	The relative proportions of land ownership along the route of the project.	Volume 2 Section 5.3.2	--
3.	Any existing land rights that will be required for the project.	Volume 2 Section 5.4	--
A.4.3 Lands Acquisition Process			
1.	The process for acquiring lands.	Volume 2 Section 5.4.1, 5.4.2	--
2.	The timing of acquisition and current status.	Volume 2 Section 5.4.3	--
3.	The status of service of section 87(1) notices.	Volume 2 Section 5.4.4	--
A.4.4 Land Acquisition Agreements			
1.	A sample copy of each form of agreement proposed to be used pursuant to section 86(2) of the NEB Act.	Volume 2 Section 5.4.2	--
2.	A sample copy of any proposed fee simple, work space, access or other land agreement.	Volume 2 Section 5.5.2	--
A.4.5 Section 87 Notices			
1.	A sample copy of the notice proposed to be served on all landowners pursuant to section 87(1) of the NEB Act.	Volume 2 Section 5.4.4, Appendix D	--
2.	Confirmation that all notices include a copy of Pipeline Regulation in Canada: A Guide for Landowners and the Public.	Volume 2 Section 5.4.4	--
A.4.6 Section 58 Application to Address a Complaint			
1.	The details of the complaint and describe how the proposed work will address the complaint.	N/A	N/A

CONCORDANCE TABLE WITH THE *CEA ACT, 2012*

CEA Act, 2012 Requirement	Section in *CEA Act, 2012*	Application Volume and Section
The environmental effects of the designated project, including:		
the environmental effects of malfunctions or accidents that may occur in connection with the designated project;	s.19.1(a)	Volume 5A ESA - Biophysical: · Section 7.0 Volume 5B ESA - Socio-economic: · Section 7.0 Volume 7 Risk Assessment and Management of Pipeline and Facility Spills Volume 8A Marine Transportation: · Sections 4.3 and 5.0
any cumulative environmental effects that are likely to result from the designated project in combination with other physical activities that have been or will be carried out;	s.19.1(a)	Volume 5A ESA - Biophysical: · Section 8.0 Volume 5B ESA - Socio-economic: · Section 8.0 Volume 8A Marine Transportation: · Section 4.4
the significance of the effects referred to in paragraph (a);	s.19.1(b)	Volume 5A ESA - Biophysical: · Sections 7.0 and 8.0 Volume 5B ESA - Socio-economic: · Sections 7.0 and 8.0 Volume 8A Marine Transportation: · Sections 4.3 and 4.4
comments from the public – or, with respect to a designated project that requires that a certificate be issued in accordance with an order made under section 54 of the *National Energy Board Act*, any interested party – that are received in accordance with this *act*;	s.19.1(c)	Volume 3A Public Consultation Volume 3B Aboriginal Engagement Volume 3C Landowner Relations Volume 5A ESA - Biophysical: · Section 3.0 Volume 5B ESA - Socio-economic: · Section 3.0 Volume 8A Marine Transportation: · Section 3.0
mitigation measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the designated project;	s.19.1(d)	Volume 5A ESA - Biophysical: · Sections 7.0 and 8.0 Volume 5B ESA - Socio-economic: · Sections 7.0 and 8.0 Volume 5C ESA – Biophysical Technical Reports Volume 5D ESA - Socio-economic Technical Reports Volume 6B Pipeline Environmental Protection Plan Volume 6C Facilities Environmental Protection Plan Volume 6D Westridge Marine Terminal Environmental Protection Plan Volume 6E Environmental Alignment Sheets Volume 8A Marine Transportation: · Sections 4.3, 4.4 and 5.0 Volume 8B Technical Reports
the requirements of the follow-up program in respect of the designated project;	s.19.1(e)	Volume 5A ESA - Biophysical: · Section 10.0 Volume 5B ESA - Socio-economic: · Section 10.0
the purpose of the designated project;	s.19.1(f)	Volume 5A ESA - Biophysical: · Section 2.0 Volume 5B ESA - Socio-economic: · Section 2.0 Volume 8A Marine Transportation: · Section 1.1

CEA Act, 2012 Requirement	Section in *CEA Act, 2012*	Application Volume and Section
alternative means of carrying out the designated project that are technically and economically feasible and the environmental effects of any such alterative means;	s.19.1(g)	Volume 5A ESA - Biophysical: · Sections 2.0 and 4.0 Volume 5B ESA - Socio-economic: · Sections 2.0 and 4.0 Volume 8A Marine Transportation: · Section 2.2
any change to the designated project that may be caused by the environment;	s.19.1(h)	Volume 5A ESA - Biophysical: · Section 7.10 Volume 8A Marine Transportation: · Section 4.3
the results of any relevant study conducted by a committee established under section 73 or 74; and	s.19.1(i)	N/A
any other matter relevant to the environmental assessment that the responsible authority, or, – if the environmental assessment is referred to a review panel – the Minister, requires to be taken into account.	s.19.1(j)	Volume 8A Marine Transportation Volume 8B Technical Reports Volume 8C TERMPOL Reports These volumes take into consideration the *Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project* (September 10, 2013) (NEB 2013)
The environmental assessment of a designated project may take into account community knowledge and Aboriginal traditional knowledge.	s 19.3	Volume 5A ESA - Biophysical: · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5B ESA - Socio-economic: · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C ESA - Biophysical Technical Reports Volume 5D ESA - Socio-economic Technical Reports Volume 8A Marine Transportation: · Sections 4.2, 4.3 and 4.4 Volume 8B Technical Reports
Subsection 5(1) of *CEA Act, 2012* defines environmental effects as a change that may be caused to the following components of the environment that are within the legislative authority of Parliament:		
fish as defined in section 2 of the *Fisheries Act* and fish habitat as defined in subsection 34(1) of that *Act*;	s.5(1)(a)(i)	Volume 5A ESA - Biophysical: · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C ESA - Biophysical Technical Reports Volume 8A Marine Transportation: · Sections 4.2, 4.3, 4.4 and 5.0 Volume 8B Technical Reports
aquatic species as defined in subsection 2(1) of the *Species at Risk Act;*	s.5(1)(a)(ii)	Volume 5A ESA - Biophysical: · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C ESA - Biophysical Technical Reports Volume 8A Marine Transportation: · Sections 4.2, 4.3, 4.4 and 5.0 Volume 8B Technical Reports
migratory birds as defined in subsection 2(1) of the *Migratory Birds Convention Act, 1994*, and	s.5(1)(a)(iii)	Volume 5A ESA - Biophysical: · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5C ESA - Biophysical Technical Reports Volume 8A Marine Transportation: · Sections 4.2, 4.3, 4.4 and 5.0 Volume 8B Technical Reports
any other component of the environment that is set out in Schedule 2.	s.5(1)(a)(iv)	N/A
Subsection 5(1) of the *CEA Act, 2012* defines environmental effects as (b) a change that may be caused to the environment that would occur		
on federal lands,	s.5(1)(b)(i)	Volume 5A ESA - Biophysical: · Section 7.0 Volume 5B ESA - Socio-economic: · Section 7.0
in a province other than the one in which the *act* or thing is done or where the physical activity, the designated project or the project is being carried out, or	s.5(1)(b)(ii)	N/A No changes are anticipated in provinces other than Alberta and BC in relation to the ESA.

CEA Act, 2012 Requirement	Section in *CEA Act, 2012*	Application Volume and Section
outside Canada.	s.5(1)(b)(iii)	Volume 8A Marine Transportation: · Sections 4.3, 4.4 and 5.0
Subsection 5(1) of the *CEA Act, 2012* defines environmental effects as (c) with respect to aboriginal peoples, an effect occurring in Canada of any change that may be caused to the environment on:		
health and socio-economic conditions;	s.5(1)(c)(i)	Volume 5B ESA - Socio-economic: · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D ESA - Socio-economic Technical Reports Volume 8A Marine Transportation: · Sections 4.3 and 4.4 Volume 8B Technical Reports
physical and cultural heritage;	s.5(1)(c)(ii)	Volume 5B ESA - Socio-economic: · Sections 5.0, 6.0 and 7.0
the current use of lands and resources for traditional purposes; or	s.5(1)(c)(iii)	Volume 5B ESA - Socio-economic: · Sections 5.0, 6.0, 7.0 and 8.0 Volume 5D ESA - Socio-economic Technical Reports Volume 8A Marine Transportation: · Sections 4.3 and 4.4 Volume 8B Technical Reports
any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.	s.5(1)(c)(iv)	Volume 5B ESA - Socio-economic: · Sections 5.0, 6.0 and 7.0

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 2015/2016 and go into service in 2017.

Trans Mountain has embarked on an extensive program to engage Aboriginal communities and to consult with landowners, government agencies (*e.g.*, regulators and municipalities), stakeholders, and the general public. Information on the Project is also available at www.transmountain.com.

1.2 Purpose and Scope of Volume 7

Trans Mountain is making application to the NEB under Section 52 of the *NEB Act*, for a CPCN for the TMEP. Volume 7 provides a comprehensive overview of risk assessment and management of pipeline and facility spills. The volume includes all information required by the NEB Filing Manual (NEB 2013), NEB Onshore Pipeline Regulations (OPR) (NEB 1999) and Canadian Standards Association (CSA) Z662-11 - Oil and Gas Pipeline Systems (CSA 2011), as illustrated in the preceding concordance table, page 7-xxii.

Volume 7 provides a comprehensive overview of the measures to prevent oil spills, risks related to oil spills, emergency response in the event of a spill, fate and behaviour of spills in both fresh and brackish water, the ecological and human health risks associated with a spill for both terrestrial and a Westridge marine spill, and a detailed assessment of KMC's financial capacity to respond to a spill.

This document and the systems and processes described herein are specific to the risks associated with the proposed pipeline and expanded Westridge Terminal operations. Marine transportation risks, emergency response, crude oil fate and behaviour, and ecological and human health risks are included in Volume 8A.

2.0 MEASURES TO PREVENT AND MITIGATE OIL SPILLS

Kinder Morgan Canada considers the prevention of spills to be its' primary goal and will employ the necessary management systems and resources to ensure that this goal is achieved on the TMEP. The measures available to prevent and mitigate spills from new pipelines and facilities will depend on the nature of the threat and the associated consequences of a spill. Many of the prevention and mitigation measures considered have been identified in other parts of this application: engineering designs that eliminate or minimize integrity threats are detailed in Volume 4A, construction and quality assurance practices that will ensure the integrity of the pipeline and facilities through to commissioning in Volume 4B, and ongoing Integrity Management Programs (IMPs) that will be applied once the pipeline and facilities are operational in Volume 4C.

Spill prevention and mitigation measures are embedded throughout the full project lifecycle and start with risk assessment of preliminary engineering designs at the earliest stages of the project. Formalized risk assessments are conducted as documented in Section 3.0, as part of the design process, which allows for early identification of all applicable hazards and suitable control measures supplemental to code-based design.

The KMC IMPs for both pipelines and Facility Integrity Management Program (FIMP) for facilities will confirm the ongoing operational reliability of all system components including the pipeline, pump stations, valve and launcher/receiver assemblies, tank terminals, and the expanded marine terminal. The IMPs will contribute to ensuring compliance with applicable regulatory requirements.

2.1 Pipeline

Safety of the TMEP pipelines will be assured by proper engineering design, material specification and selection and systematically applied quality assurance and quality management programs along with the consistent application of KMC's pipeline IMP.

Design decisions that will contribute to spill prevention and mitigation include:

- pipe material to maximize fracture initiation resistance;
- pipe wall thickness, depth of cover, or mechanical protection to minimize the risk of damage from external forces;
- route selection that avoids geotechnical hazards;
- communication systems and instrumentation that allow for state-of-the-art control, monitoring, and leak detection;
- detailed hydraulic analyses that establish operating limits and protective device settings to ensure overpressure prevention; and
- selection of valve locations to reduce potential spill volumes in High Consequence Areas (HCAs).

Key aspects of the pipeline IMP that will help ensure long-term spill prevention and mitigation include:

- annual risk assessments following start-up of TMEP with recommendations focusing on operational improvement and incremental risk reduction;
- in-line inspection (ILI) runs to assess for pipe movement and the presence of metal loss, mechanical damage, cracking and material defects;
- ensuring that threats such as unstable soils and low depth of cover at water crossings are identified, monitored and remediated as necessary as part of the Natural Hazard Program;
- continued implementation of the Pipeline Protection Program, with a primary focus on preventing pipeline damage from ground disturbance activities;
- verification of the effective functioning of the cathodic protection system through annual test lead surveys and close interval pipe to soil surveys completed every five years;
- completing pipeline repairs in accordance with technical code requirements and KMC standards;
- identification, assessment and management of newly identified hazards;
- implementing system upgrades and technological improvements through the sustaining capital program; and
- continuous improvement through tracking of performance indicators and showing measurable risk reduction.

2.2 Facilities

The safety of TMEP facilities will be assured through proper engineering design, material specification and selection, and consistent application of KMC's FIMP. Facilities in this respect are defined as all operational elements that are not covered by the pipeline IMP, and this includes all pumping stations, terminals, launcher/receivers, and remote valve sites.

Terminal and pump station expansions will be designed to minimize environmental impacts during construction and operations. Numerous control measures are utilized to prevent or mitigate a product release and/or fire. Design control measures generally include:

- emergency shut down systems that isolate a facility in the event of a spill or fire;
- piping overpressure protection through Supervisory Control and Data Acquisition (SCADA) monitoring and control, critical valve interlock logic in the Programmable Logic Controller, automated shut down systems, and pressure relief systems;
- cathodic protection and durable coating systems to ensure corrosion prevention;

- electrical design in accordance with hazardous area classifications;
- storage tank overfill protection, including redundant high-high level detection instrumentation connected to motor operated tank valves;
- secondary containment equipped with hydrocarbon detection for all storage tanks;
- process area (pump rooms, valve manifolds, meter banks, etc.) equipped with containment and hydrocarbon detection;
- impermeable liner and leak detection systems under tank bottoms;
- pump seal leak detection system and containment connected to sump tank;
- double wall non-metallic underground sump tanks equipped with level monitoring and overfill protection;
- leak detection for double wall sump tank interstitial space;
- sump tank vents and access openings are located high enough to prevent spillage during equipment drain down;
- combustible gas detection instrumentation inside pump rooms;
- fire detection and suppression equipment, including fire water and foam systems for storage tanks; and
- site fencing, access control and security systems to prevent unauthorized access.

Key aspects of the FIMP that will help ensure long-term spill/fire prevention and mitigation include:

- risk assessments every three years following start-up of the new system with recommendations focusing on reducing overall risk;
- internal and/or external inspection and condition monitoring of all terminal piping;
- tank inspections as per American Petroleum Institute (API) 653, including periodic wall thickness, base settlement, and coating assessment;
- winterization of storage tank roof drain and water draw systems;
- Safe Work and Hot Work Permit procedures strictly enforced;
- routine facility inspections by operations personnel following detailed procedures;
- facility modification request procedure (*i.e.,* management of change);

- comprehensive incident history tracking and analysis, including leaks, security incidents, near misses, significant equipment malfunctions, and process upset conditions;
- valve inspection and testing programs;
- inspection program for the marine structures;
- flange integrity program;
- electrical substation breaker thermal inspections;
- inspection and maintenance program for site water handling systems and oil detection systems;
- pipeline repairs in accordance with technical code requirements and KMC standards;
- identification, assessment and management of newly identified hazards;
- implementing system upgrades and technological improvements through the sustaining capital program; and
- continuous improvement through tracking of performance indicators and showing measurable risk reduction.

In addition to the above, all terminals will be staffed sites and will undergo required monitoring and preventive maintenance so that the facilities meet all applicable regulations, codes, standards and specifications as well as KMC's standards, specifications, and recommended practices.

2.2.1 Westridge Marine Terminal

The safety of TMEP Westridge Marine Terminal will be assured through proper engineering design, material specification and selection, and consistent application of KMC's FIMP.

The Westridge expansion will be designed to minimize environmental impacts during construction and operations. Numerous control measures are utilized to prevent or mitigate a product release and/or fire. Design and operations control measures will include:

- The dock shall be constructed incorporating appropriate design, specifications and material selection, and construction elements consistent with marine structures of this type.
- The dock and vessel mooring components shall be designed fit for purpose and shall be managed through the FIMP.
- Boom will be deployed around a tanker before loading arms are connected.
- Ability to immediately deploy emergency response equipment and boom in the event of a spill, with additional boom available at the dock.

- Detailed Operating procedures for product loading and unloading. Operations procedures focused on safety and environmental protection.
- Assignment of a loading master to the tankers who shall be available to the vessel throughout her stay at the terminal and be the first point of contact between the vessel's crew and the terminal. The loading master has the authority to stop cargo transfer in case of any safety matter that remains unresolved.
- Containment at the loading arms area of the dock.
- Tanker loading stops and loading arms are disconnected if wind speeds exceed acceptable limits.
- Tanker loading stops if a mooring line fails and loading arms may be disconnected if there is failure of multiple mooring lines.
- Product is drained from the loading arms before disconnection from the tanker.
- Inspection and pressure rating check of hoses and hard arms at scheduled intervals and checked prior to use.
- Emergency stop buttons near the loading connection with ability for the vessel to initiate immediate cessation of cargo loading.
- In case of a fire, adequate number of fire and foam monitors at each berth capable of reaching the cargo deck area of the tanker. Water supply for the fire and foam system shall be adequate with independent power source available for ensuring continuous supply.

Control measures related to tanker berthing and de-berthing activities are included in Volume 8A, Section 1.0.

3.0 OIL SPILL RISK ASSESSMENTS

Guidance on the application of risk assessment to pipeline systems including pipelines, pump stations and terminals is provided in Annex B of CSA Z662-11. As detailed in that guidance, risk assessment forms a component of the broader process of risk management and includes the steps of identifying risk, risk analysis (hazard identification, frequency analysis, consequence analysis, risk estimation), risk evaluation (risk significance and options) and risk response.

Oil spill risk is a function of the frequency of an event leading to a loss of containment and release of product and the consequences of that release, should such an event occur. For pipelines a release has the potential to impact the natural or human environment. Inside facilities (*i.e.,* pump stations and terminals), where historically, most releases have occurred, spilled product is contained and there are normally minimal external consequences.

Risk based design is an iterative process, where the risk associated with a preliminary design is reviewed and an evaluation is made as to whether risk objectives are met. If they are, then the associated design and operating conditions are established as the basis of the finalized design. Otherwise, pipeline system components (*e.g.,* pipeline segments) that are deemed unacceptably high in risk are identified, and appropriate mitigation strategies are developed until risk objectives are met.

Using a risk-based design approach enables the pipeline and facilities design teams to identify primary drivers of risk, and to mitigate the risk to be as low as reasonably practical (OPR) (NEB 1999). For TMEP, risk based design will be primarily used to develop a basis for identifying and mitigating principal threats such as natural hazards (*e.g.,* geotechnical, hydrological and seismic), and external threats (such as third-party damage). It will also be used to highlight the principal factors that contribute to those threats and associated consequences and pre-emptively (*i.e.,* at the design stage, rather than during operations), develop strategies to reduce risk resulting from identified threats and associated consequences.

3.1 Pipeline

3.1.1 Oil Spill Risk Assessment Overview

The risk assessment method being used for the pipeline is best characterized as a semi-quantitative risk assessment in which quantitative estimates of failure frequency (expressed in units of failures/km-year), are combined with qualitative estimates of consequence values. The final result will be a relative ranking of risk for all segments along the pipeline.

Failure frequencies are either determined by reliability methods or through reference to relevant industry statistics. For geohazards, the availability of temporal data related to individual hazards is often scarce, necessitating subjectivity and expert judgment.

Consequence areas are identified and a sensitivity ranking assigned. The outflow volume at any point along the pipeline is modeled as a worst-case spill volume from a full-bore rupture associated with the pipeline alignment and valve configuration. Once spill volumes along the pipeline are determined, a spill trajectory model is used to determine the overland and downstream pathways of spills. A geographic information system (GIS) is used to identify HCAs intersected by the spill pathways, and a scoring model is used to assign consequence scores.

The consequence scores and frequencies are then combined to produce a final risk value.

Figure 3.1.1 shows the spill risk assessment process.

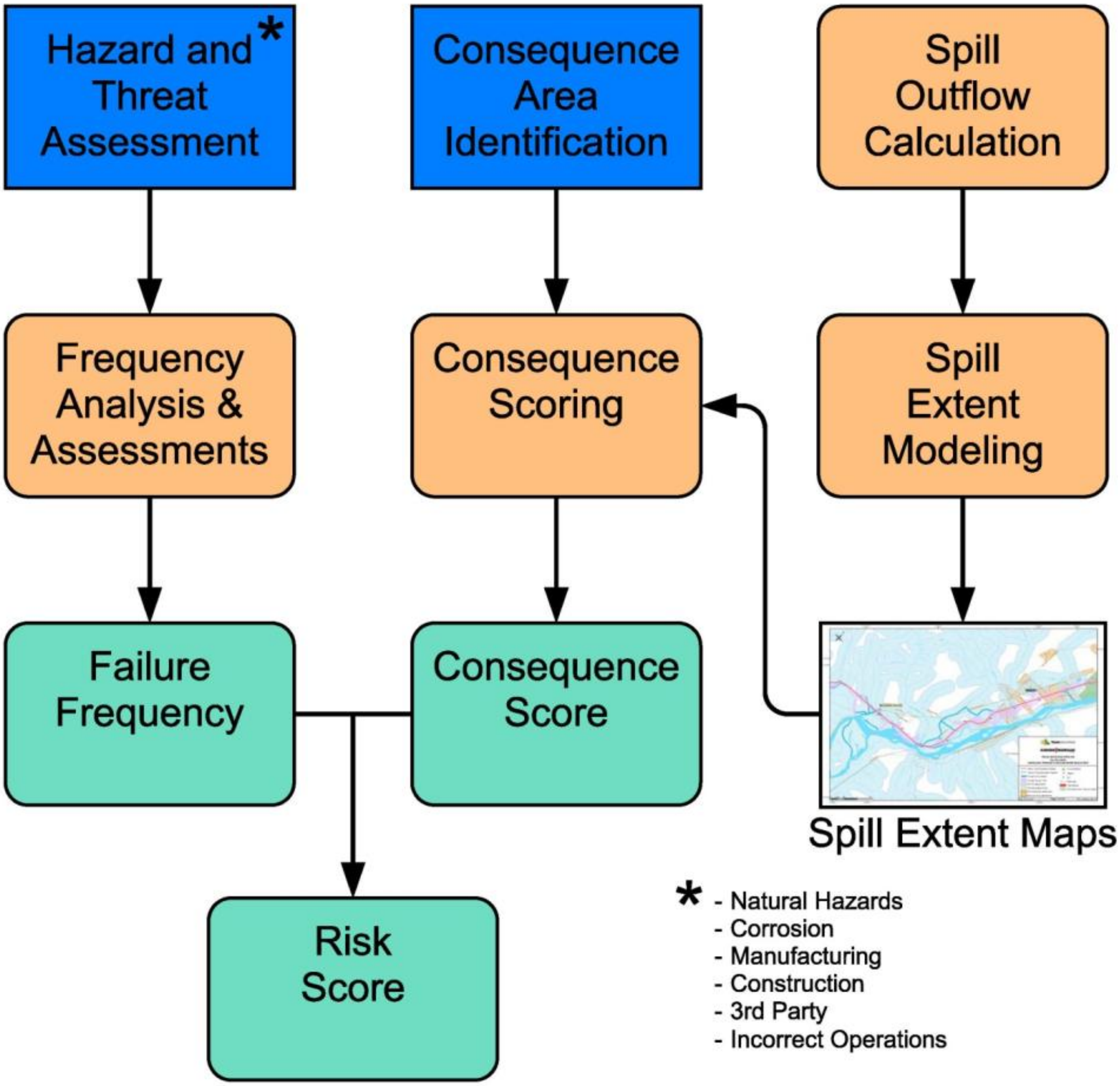

Figure 3.1.1 Spill Risk Assessment Process

The risk-based design process is iterative. Based on the results, additional measures can be implemented in the design to either reduce the probability (frequency) of failure or to reduce the consequences for areas of higher risk. An example of a measure to reduce consequences would be the relocation of a valve to reduce potential outflow in an HCA; an example of a measure to reduce the probability of failure would be extra depth of cover to reduce the potential for third-party damage.

3.1.2 Hazard Identification and Threat Assessment

In the context of a risk assessment, a hazard is defined as a condition with the potential for causing an undesired consequence. In this case, hazards are defined as any threat that might cause a loss of containment. These threats are identified in a process that reviews the attributes for all potential threats to a pipeline system in consideration of the materials, design, construction and operational variables that are associated with the pipeline system. Through this review, the relevance and severity of each threat is then assessed in the context of the operating environment for the pipeline being reviewed.

A threat assessment has been completed, based on the preliminary design and routing information (Appendix A, Threat Assessment Report). As part of the threat assessment, the threat attributes were each considered in terms of their relevance as well as data availability. Specific data sets are required in order to employ a reliability approach for failure likelihood estimation, and the availability and type of data that are available dictate the specific approach that can be adopted. Therefore, the other primary goal of a threat assessment was to establish approaches for estimating failure likelihood based on the availability, quality, and completeness of the data attributes for each threat.

As part of preliminary engineering, a detailed inventory of specific geohazards along the TMEP corridor has been developed through desktop-based terrain mapping followed by ground reconnaissance (Volume 4A, Appendix H, Terrain Mapping and Geohazard Inventory Report). A seismic assessment was also undertaken (Volume 4A, Appendix J, Seismic Assessment Desktop Study Report).

As a result of the assessments completed, the following threats were considered as principal threats to the TMEP:

- corrosion (internal and external);
- manufacturing defects;
- construction defects;
- third-party damage;
- incorrect operations; and
- geohazards (geotechnical, hydrotechnical and seismic).

The threat assessment and principle threats considered are specific to the pipeline and will be included in the risk based design. Risk assessment for facilities will be in accordance with Section 3.2.

3.1.3 Failure Frequency Estimating – Pipeline Construction, Operations and Third-party Damage

There are two basic approaches for making quantitative estimates of failure likelihood. One method is to base the estimate on industry incident statistics such as NEB or Pipeline and Hazardous Materials Safety Administration (PHMSA) databases, and the other is to base the estimate on a reliability methods approach. Where possible, a reliability approach to estimating failure frequency is used.

A challenge in making quantitative estimates of failure frequency for a new pipeline is that industry failure statistics are not directly applicable to modern pipeline designs, materials, and operating (*i.e.*, assessment) practices. A review of industry failure statistics suggests that the majority of pipeline failures occur on pipelines that were installed in the 1970s or earlier, prior to the availability of current standards and technology, such as high-toughness steels, 100 per cent non-destructive testing (NDT) of all welds, piggable pipeline systems in combination with application of ILI technologies, and high-performance coating systems. Because of the advent of these and other technologies, sole reliance on historical based industry failure statistics is not a suitable basis for estimating future failure rates. Another disadvantage of using industry failure databases as the basis of a quantitative risk assessment is that they do not address unique site-specific threats, such as geotechnical hazards.

The pipeline industry has moved towards a reliability methods approach as a tool for managing risk and reliability, and pipeline industry research organizations such as the Pipeline Research Council International and the European Pipeline Research Group have spent much time and resources in the past several years in developing reliability-based models for various threats. Reliability models employ limit state functions for the specific damage mechanism of interest in which the load variables and resistance variables are characterized in terms of probability density functions. This enables the use of reliability modeling techniques to characterize the probability of incurring a failure on a pipeline.

In the pipeline industry, reliability models exist for the primary threats, including third-party damage, internal corrosion and external corrosion. Natural hazards, including geotechnical, hydrological, and seismic threats can be characterized in terms of expected magnitude and associated frequency of occurrence, thereby enabling pipeline reliability to be established for each hazard.

The basis of every reliability model is a limit state model that describes the failure conditions for the mechanism being considered. At least one of the input variables to the limit state model must be characterized as a probability density function. A reliability approach is not possible for threats where these limit state models and probability density functions are not available.

For threats where limit state models are not available the only alternative is to employ industry failure statistics, incorporating analytical measures to account for differences in materials, design and operations that are characteristic of modern pipelines.

PHMSA data are used as the basis for assessment of manufacturing, construction and incorrect operations threats. It is based on a large database of pipeline failures, including both leaks and ruptures, and is derived from the many kilometers of United States (US) regulated pipelines. As such, the failure incident data is statistically relevant. Furthermore, the PHMSA incident failure database contains information specific to each incident that provides the ability to determine the relevancy of the data to the pipeline being modeled and enables conclusions to be drawn relative to issues such as the magnitude of release for associated threats, and the underlying causes of failure.

The TMEP threat assessment (Appendix A, Threat Assessment Report) provides additional details of the methods employed to estimate the frequency for each threat.

3.1.3.1 External Corrosion

A reliability approach leverages existing analogue ILI datasets along with the specific design details (diameter, wall thickness, grade, and operating pressure) of the TMEP pipeline. The reliability analysis models how pipeline materials and design responds to an anticipated degradation process factoring in tool measurement error and anticipated corrosion growth rates.

The analogue datasets used are representative (or slightly conservative) relative to the expected external corrosion performance of the TMEP pipeline. In this way, the reliability parameters of external corrosion feature incident rate, external corrosion feature size distribution, and external corrosion growth rate that are obtained from the analogue ILI datasets can be employed, knowing that the reliability data that they impart are representative, or conservative.

The final results of the reliability analysis will show that an ILI re-assessment program can be designed in a way that will be adequate to control failure frequency for corrosion features to levels that are below the sensitivity and resolution of the analysis.

3.1.3.2 Internal Corrosion

The corrosivity analysis contained in the Threat Assessment Report shows that the product stream in conjunction with the operating and flow characteristics should render the pipe wall in an oil-wet (*i.e.,* non-corrosive) condition, although ongoing monitoring with a view to implementing appropriate mitigation strategies will be undertaken in the course of TMEP's operations and IMPs.

A significant amount of operating experience with heavy oil pipelines (diluted bitumen [dilbit] and synthetic bitumen [synbit]) has been reported, and is available in the public record. A review of this evidence has been undertaken to provide guidance in establishing estimates of the corrosivity of the product stream, and how that corrosivity will reflect on failure likelihood due to internal corrosion.

Available evidence supports that dilbit (or synbit) are no more corrosive than other conventional heavy crude oils (Alberta Innovates - Comparison of the Corrosivity of Dilbit and Conventional Crudes-2011, National Academy of Science – Effects of Diluted Bitumen on Crude Oil Transmission Pipelines – 2013, Penspen Integrity – Dilbit Corrosivity – 2013). With basic sediments and water limited to 0.5 per cent, water and solids should be readily entrained within a turbulent flow regime. This will ensure that the pipe wall remains oil-wet (*i.e.*, a non-corrosive condition) and flow conditions will prevent the deposition of solids. Nevertheless, the corrosion performance of this pipeline will be monitored through regular ILIs, and mitigation measures, such as cleaning and inhibition, will be employed if necessary.

Under such circumstances, an ILI re-assessment program can be designed in such a way that it will be adequate to control failure frequency to levels that are below the sensitivity and resolution of the analysis.

3.1.3.3 Manufacturing Defects

Kinder Morgan Canada's pipe procurement program specifies rigorous controls to ensure the quality of line pipe to be supplied to the TMEP project. Category II pipe, with requirements for fracture toughness and fracture appearance will be specified for this project. Apart from pipe purchase specifications that exceed the requirements of CSA Z662-11, controls will be implemented that include supplier pre-qualification practices that focus on technical and quality criteria, as well as 100 per cent third-party pipe mill quality surveillance that conforms to a test plan that is defined during the material requisition process. With these controls in place, the threat of manufacturing defects will not be a significant contributor to overall risk for the TMEP pipeline.

The threat of manufacturing defects does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters.

An upper bound estimate of failure frequency attributed to this threat based on industry operating experience has been obtained through an analysis of the PHMSA hazardous liquids transmission pipeline incident database. This estimate was derived from sorting the incident data such that it reflects onshore, large-diameter (≥ 24”) pipelines installed since 1980. Based on this evaluation, the resultant full-bore rupture frequency attributed to this threat is estimated at 2.0×10^{-05} failures/km-year.

3.1.3.4 Construction Defects

Kinder Morgan Canada’s construction practices and Quality Management Plan will specify rigorous controls to ensure the quality of the pipeline installation that will be used in the construction of the TMEP pipeline, including welding processes. In addition, rigorous quality checks will be employed, including 100 per cent NDT using phased array ultrasonics and/or x-ray inspection, as well as 100 per cent inspection with a caliper tool after installation to ensure that the pipeline is free of dents, buckles, and excessive out-of-round conditions. Tight controls imposed on line pipe carbon equivalent as well as the use of a mechanized low hydrogen welding process in which procedural variables are tightly controlled will be effective in managing the likelihood of weld cracking, or other systemic welding-related defects, and verified through NDT. As a final test, the pipeline segments will be hydrostatically tested to prove the integrity of the pipeline segments prior to Application for Leave to Open and operation of the pipeline.

An upper bound estimate of failure frequency attributed to this threat based on industry operating experience has been obtained through an analysis of the PHMSA hazardous liquids transmission pipeline incident database. This estimate was derived from the incident data such that it reflects onshore, large-diameter (≥ 24”) pipelines installed since 1980. Based on this evaluation, the resultant full-bore rupture frequency attributed to this threat is estimated at 9.8×10^{-06} failures/km-year.

3.1.3.5 Third-party Damage

All pipelines experience some level of threat due to third-party damage, the magnitude of this threat being a function of the effectiveness of damage prevention measures, adjacent land use, depth of cover, material properties and pipeline design. Although damage prevention measures can help to minimize this threat, the risk of third-party damage can never be fully neutralized.

A reliability model is available that considers all the parameters of damage prevention measures, adjacent land use, depth of cover, material properties and pipeline design, and this model will be used for the TMEP pipeline (Chen and Nessim 1999). The reliability approach employs a fault tree model to estimate hit frequency, and a separate stochastic model to predict probability of failure, given a hit.

Initial runs of the model based on preliminary routes and hydraulic parameters indicate that the average value for the frequency of this threat over the pipeline is in the order of 5.1×10^{-6} failures/km-year.

The threat of third party damage will be subject to risk based design with the identification of mitigation measures as the detailed design progresses. Consideration will include depth of burial, added wall thickness, pipe material properties, or additional mechanical protection for specific higher risk areas. Detail of this work is being completed to better inform and validate the risk assessment.

3.1.3.6 Incorrect Operations

All pipelines experience some level of threat due to incorrect operations, the magnitude of this threat being a function of the effectiveness of the system design, operations, and maintenance practices and procedures. Management systems, properly employed, can be effective in reducing the threat through documentation, training, measurement, and corrective actions. Although design, operations and maintenance practices as well as Management systems can help to offset this threat, incorrect operations can never be fully neutralized.

The threat of incorrect operations does not lend itself to failure likelihood estimation using a reliability approach. Reflecting this fact, an estimate of full-bore rupture frequency has been obtained through an analysis of the PHMSA hazardous liquids transmission pipeline incident database. This estimate was derived from the incident data such that it reflects onshore, large-diameter (≥ 24”) pipelines installed since 1980. This estimate was further refined based on an evaluation of KMC’s operating procedures. Based on this evaluation, the resultant full-bore rupture frequency attributed to incorrect operations is estimated at 4.4×10^{-06} failures/km-year.

3.1.4 Failure Frequency Estimating – Geohazards

For the TMEP geohazard assessment, factors related to frequency and vulnerability will be evaluated using expert judgment and applied in a probabilistic framework. The frequency of the geohazard event will be determined using an order of magnitude approach for each of the sites in the geohazard inventory, unless specific return interval data is available. For an element’s vulnerability, the spatial relationship between the hazard and element will be assessed, including the hazard’s magnitude, its proximity to the hazard, whether its distribution is continuous over the area of the geohazard (*e.g.,* for a pipeline) or isolated (*e.g.,* for a valve or structure), and whether the element is buried or on surface.

For each geohazard site, a set of descriptive attributes will be assigned, and an initial hazard ranking determined. For the initial phase, the assessment will show a range of hazard values. In the absence of any risk control measures, some of these will be acceptable (low likelihoods of geohazards causing pipeline failure), and will require no further action. Some may be marginally acceptable (moderate likelihood of geohazard causing pipeline failure), and others will be unacceptable (high likelihood of geohazards causing pipeline failure); together, these moderate and higher hazard level sites are considered the significant hazards.

Only those significant hazards that have the potential to result in a loss of containment will be incorporated into the calculations of oil spill risk.

For each of the significant hazards there will likely exist several technically feasible risk control options (*e.g.,* avoidance, protection, stabilization, monitoring), applicable at different phases of the project (*e.g.,* routing, design, construction, and operation). The choice of mitigation measure to be employed will be finalized during detailed design.

From the geohazard inventory, the North Thompson and Coquihalla regions have a higher potential for higher likelihood geohazards including landslides and debris flows as the proposed pipeline corridor tends to pass through more mountainous terrain through these regions. Likewise, towards the west of the Coquihalla and extending through the Lower Mainland, the spatial frequency of geohazards that could be triggered by earthquakes increases due to higher predicted peak ground acceleration values towards the Pacific coast.

It should be noted that there are many geohazards that will have an effect on the right-of-way, but only a small subset that would have the potential to affect pipe or structural integrity to the point where there is a loss of containment. Over the last 60 years, the existing TMPL pipeline has operated in a corridor where statistically few significant geohazard events have occurred. Through data gathered from the Natural Hazard Management Program along the existing line over the last 20 years, on average one to two moderate sized debris flow events occur each year over the entire pipeline length and similarly an average of less than one landslide per year has been recorded. Over the 60 year history only a handful of these hazards have been of significant size to require intervention such as mitigation. Hydrotechnical hazards, such as from flooding and scour at river or stream crossings, remain present, but with appropriate design (such as through adopting the 1:200 year flood event to determine the necessary depth of cover, plus implementation of an ongoing inspection program), the impact of these hazards can be mitigated and the risk reduced.

For the Northern Gateway pipeline route, a route traversing similar mountainous terrain and river valleys across northern BC, the results of the geohazard assessment indicated mitigated frequency values for events leading to a loss of containment typically ranged from 1×10^{-10} to 1×10^{-4} events per year. Given the similarity in routes and historical observations along the TMPL pipeline corridor, a similar range of geohazard frequency values can be expected across the TMEP project.

3.1.5 High Consequence Area Identification

As part of KMC's ongoing operations risk management program, HCAs along the existing pipeline corridor have been previously identified and mapped. The reference to HCAs is an adaption of the US Department of Transportation Pipeline safety regulations (PHMSA) which use the concept of HCAs to identify specific locales and areas where a release could have the most significant adverse consequences.

Portions of the new pipeline will be located in areas which, if a release were to occur, would have elevated consequences due to land use or location with respect to water bodies such as rivers, streams and lakes. These are defined as HCAs. HCAs include the following:

- national, provincial or regional parks;
- watercourses, and in particular those deemed to be sensitive due to the presence of fish habitat or fish populations;
- high population area that contains 50,000 or more people and has a population density of at least 1,000 people per square mile;
- other populated areas that contains a concentrated population, such as an incorporated or unincorporated city, town, village, or other designated residential or commercial area;
- First Nation lands;
- an area which contains drinking water sources or an aquifer that could be impacted by a release; and
- other environmentally sensitive areas, such as ecological reserves.

For the purposes of the spill risk assessment the HCAs have been given a relative sensitivity ranking. This sensitivity ranking is based on the inherent value of a consequence area as well as the difficulty of containment and restoration. For example, a high value fish-bearing watercourse would have a higher relative sensitivity ranking than a non-populated land.

3.1.6 Spill Outflow Modelling

For the purpose of the oil spill risk assessment a worst case full-bore rupture scenario was used, even though experience has indicated this to be a low likelihood event. In this scenario it is assumed that immediately after failure product is released through an opening equivalent to the internal diameter of the pipeline.

The volume outflow calculation is based on the release prior to pump shut-down and valve closure plus the volume of product remaining in the pipeline that would drain out due to gravity.

A time interval of ten minutes has been used for the release prior to pump shut-down. During this interval, Operations personnel will be verifying the validity of the low pressure SCADA alarm and all pump stations will still be operating. As ten minutes is a worst case duration for a partial line break or moderate leak where it is not immediately obvious that the pipeline has experienced a failure, the use of a ten minute time interval for a readily identifiable catastrophic rupture is conservative since a trained Control Centre Operator (CCO) will recognize the event immediately. After the pumps are shutdown, the Main Line Block Valves located upstream and downstream of the leak site are closed which will take five minutes from the time of activation to full valve closure. At some locations, check valves will be employed at river crossings which will provide an immediate shutoff and prevention of backwards flow from downstream sections of the pipeline.

Following shutdown and isolation, there is a period of draindown where the remaining product in the isolated pipeline segment is released over time. The topographic profile determines the amount and rate of release as some product may continue to be trapped inside the line.

Assumptions used in the model include:

- maximum design throughput of 90,370 m^3/day (568,420 bbl/d);
- product released through an opening in the bottom of the pipe equivalent to the internal diameter;
- preliminary valve locations that will be finalized during detailed engineering; and
- conservative assumptions of times to system shutdown and valve closure, based on assumptions for recognition, shutdown and isolation of pipeline segments.

Outflow volumes are calculated on a 25 m interval along the length of the pipeline. The results are contained in Appendix B, Oil Spill Outflow Model Results.

3.1.7 Spill Extent Mapping

Hypothetical spills were simulated along the route using the OilMAP land model to determine the overland and downstream pathways using the input volumes from the outflow model. Using the largest volume within each kilometre segment, the spill extent pathways from the model were mapped at 1:25,000.

This map series can be found in Appendix C, Overland and Stream Flow Modeling of Potential Full-Bore Rupture. Details of the methodology and assumptions of the spill extent mapping are in the report in Appendix D, Simulations of Hypothetical Oil Spills from the Trans Mountain Expansion Project Pipeline – P1 V6 Route.

As discussed in the Applied Science Associates report, there are number of simplifying and conservative assumptions that result in the spill path trajectories being significantly longer and thus more conservative than can be reasonably expected in a real spill situation:

- Water transport velocity is based on basin hydrology, not specific measurements. A maximum mean monthly discharge is used for each watercourse.
- The digital elevation model used is necessarily coarse and only approximates topography that would slow or catch oil. Features such as roads or railway tracks that would impede or re-direct oil flow are not always captured in the model at this scale.
- There is an arbitrary time frame for the model (12 hours) that does not reflect mitigation through a spill control response.
- The model does not take into account any braiding, debris, backwater, log jams or other impediments to waterborne travel but simply assumes a straight channel. The only product entrainment is along the simulated banks.

Nevertheless the results are accurate enough to determine where a potential release could intersect a consequence area within the proposed pipeline corridor and provide an approximate volume of oil at the point of intersection.

3.1.8 Consequence Scoring

A consequence algorithm provides a prioritized ranking of the consequences of failure. The aggregated consequence score of a spill path is a function of the oil volume and number and sensitivity ranking of HCAs (see Section 3.1.5) that are crossed by the spill path.

A GIS model is used to determine whether or not a spill intersects an HCA. If there is an intersection, the resultant consequence score is a function of:

- the number of HCAs intersected by a single spill extent;
- the sensitivity ranking of intersected HCAs; and
- the predicted spill volume at its intersect with the HCA.

The highest consequences come from a large volume spill that intersects multiple HCAs areas with high sensitivity rankings. Lowest non-zero consequences come from a single spill plume intersecting a low sensitivity HCA. Scores in the middle arise from combinations of the above scenarios.

3.1.9 Risk Scoring

The risk scoring algorithm combines the quantitative frequency of failure with the qualitative consequence score to produce a semi-quantitative measure of risk for each one kilometre pipeline segment.

This approach to risk scoring enables:

- the evaluation of the efficacy of the application of site-specific or systemic risk-reduction measures; and
- a comparison of the risks from segment to segment and to determine which segments have the highest relative risk.

The semi-quantitative risk scoring will be used to inform and guide the detailed design of the TMEP pipeline. As indicated risk based design is an iterative process, where the risk associated with a preliminary design is reviewed and an evaluation is made as to whether risk objectives are met. If they are, then the associated design and operating conditions are established as the basis of the finalized design. Otherwise, pipeline system components (*e.g.,* pipeline segments) that are deemed high in risk are identified, and appropriate mitigation strategies are developed until risk objectives are met.

3.1.10 Reactivated Sections

Risk assessments will also be conducted as part of detailed design for the two NPS 24 segments to be reactivated as part of Line 1 as well as the NPS 30 segment between Darfield and Black Pines that will be included as part of Line 2. The risk assessments will be completed following the general approach as outlined above for the new pipeline.

3.2 Facilities

Facilities proposed as part of the TMEP include remote block valve sites, pump stations and terminals, including the Westridge Marine Terminal. The risk assessments planned for these facilities will match those that are done for existing facilities. Key elements of the risk assessment methodology are described below and the results will be completed as part of detailed design.

3.2.1 Facility Qualitative Risk Assessment

The Facility Qualitative Risk Assessment Procedure is an element of the Trans Mountain FIMP. The intent of the procedure is to examine facility components to identify high risk elements or scenarios within the facility. The process includes a review of control measures to prevent or minimize the impact from hazards and documentation of control measures that require inspection, testing, maintenance and tracking through the company maintenance management system. All identified facility integrity control measures are tagged in the maintenance management system to ensure the measures are tracked by way of compliance reporting. The maintenance management system is used to confirm that the measures are appropriately implemented, operated, tested and maintained to ensure functionality of the facility.

The procedure provides a structured process to review integrity hazards at a facility and to qualitatively assess the risk of the hazards. The procedure also identifies prevention, detection and protection measures used to control hazards. Prevention measures reduce the likelihood of a product release, whereas detection or protection measures reduce the consequence or impact of a release.

Prevention control measures can prevent the occurrence of a release. An example of a prevention control measure is a high level switch on a tank that is configured to provide an alarm to indicate that the tank has exceeded its high operating limit. An added prevention control measure is to have a second high-high level switch that will provide an additional alarm and automatically close the tank inlet valve.

Detection control measures can potentially reduce the impact of a release by either reducing the spill volume through early intervention or by early initiation of emergency response measures. An example of a detection control measure is a hydrocarbon detector in a surface water drainage system from an operational area. Detection measures can include instrumentation as well as manual inspections.

Protection control measures can reduce the impact of a release by controlling the affected area (*e.g.,* tank dykes, tank dyke linings, controlled drainage from operating areas). Emergency response is not considered a protection measure.

The qualitative risk assessment will determine the likelihood of a facility release or facility fire for each category and each hazard based on the assumption that in the absence of preventive measures the risk of release from an identified hazard is assumed to be high. For each valid and independent preventive measure, the probability of release will be reduced by one level. To be considered valid, a preventive measure must be properly installed, maintained and tested on an ongoing basis, and evidence of this must be documented in the maintenance management program.

The consequence of a facility release or fire will be determined for each category and each hazard based on the assumption that in the absence of consequence reduction measures the consequence will be assumed to be high. For each valid and independent consequence reduction measure the consequence level will be reduced by one. Consequence reduction measures are generally in the form of containment or leak detection for release mitigation, and in the form of fire-fighting measures, containment, or fire detection for fires. To be considered valid, a consequence reduction measure must be properly installed, maintained and tested on an ongoing basis, and evidence of this must be documented in the maintenance management system.

The current list of hazards and scenarios that are considered along with potential prevention and consequence reduction measures are included as Appendix E, Facility Integrity Hazards Listings.

3.2.2 Secondary Containment and Tank Fire Risk Assessments

With regards to the risk of tank fires and fires resulting from a product release within a containment area, determination of level of risk is made with reference to the Major Industrial Accidents Council of Canada (MIACC) criteria. Specific requirements for each jurisdiction, in terms of acceptable levels of risk may vary, but the MIACC criteria are broadly accepted.

The risk assessment begins with identification of hazards or concerns. This step relies on regulations and company direction to determine what is considered a hazard. Possible scenarios are fire and explosion risks from flammable materials, boil over from an internal tank fire, and toxic smoke plumes. Since a product release is the most likely event to occur, the realistic worst case scenario is a fire and/or explosion of flammable material. Even though a boil over scenario is not considered likely, this hazard is considered for emergency planning purposes. In addition, because the product in the storage tanks may contain trace amounts of sulphur, the hazard of human exposure is also considered for emergency planning purposes.

The next step in the assessment is to examine each hazard for the consequence (potential impact on nearby areas) and the probability of occurrence. Following the assessment, the risks can be determined. It should be noted that the risk determination does not include emergency planning or other forms of mitigation. The assessment provides a conservative worst case situation and emergency plans can be developed once the worst case is identified. The risk assessment process generally involves the following activities:

- reviewing the sources of risk including project design and facility operations, and which would include a review of petroleum properties and hazards, release containment and fire protection capability;
- developing a list of potential hazards or concerns to consider in the risk assessment;
- characterizing the potential to cause harm (*i.e.,* consequence analysis) to the public outside the facility property lines by modeling fire and explosion events for flammable materials, and identification of impacts;
- modeling potential toxic vapour plumes including air dispersion for the products identified and identification of impacts;
- characterizing the probability of an incident occurring (*i.e.,* likelihood of a release and/or fire);
- determining the acceptable level of risk for hazards/concerns; and
- conducting a Hazard and Operability Study.

Design criteria, leak detection and containment systems, fire detection and suppression systems, operations management, and emergency response planning will be utilized to minimize risks.

4.0 EMERGENCY PREPAREDNESS AND RESPONSE

4.1 General

Kinder Morgan Canada has a mature Emergency Management Program (the Program), which is based on a combination of regulatory compliance, operational need, industry best practice, and lessons learned through regular exercises and actual incidents. The Program is embedded within the management system framework provided by the Integrated Loss Management System and the Environment, Health and Safety (EHS) Management System. Key elements of the Program include long-standing regularly reviewed Emergency Response Plans (ERPs), response equipment, and regular desktop training and field deployment exercises, which contribute to a highly trained response staff and response readiness within the organization.

Regulatory compliance and enforcement of the Program for the existing pipeline and proposed TMEP is provided through multiple federal jurisdictions and cooperation with provincial regulators:

- the NEB enforces the OPR and is responsible for monitoring and auditing Emergency Management Program requirements for the pipelines and associated facilities, including the Westridge dock; and
- Transport Canada enforces the *Canada Shipping Act* and monitors water based facilities and marine transportation.

In addition to the regulatory requirements the Program has been established based on the guidance provided by existing standards:

- CAN/CSA-Z731-03 - Emergency Preparedness and Response (CSA 2003);
- BC Emergency Response Management System Standards (BCERMS) 1001 and 1002 (BCERMS 2000);
- BC Guidelines for Industrial Emergency Response Plans (BC Ministry of Environment [MOE] 2002); and
- Alberta Energy Regulator - Guide 71 - Emergency Preparedness and Response Requirements for the Upstream Petroleum Industry (formerly the Energy and Utilities Board).

In compliance with requirements and recognized best practices KMC has developed an integrated approach to emergency management, which includes:

- a documented EHS Management System;
- a comprehensive Emergency Management Program, which includes:
  - emergency vulnerability identification;
  - goals, objectives and targets;
  - Incident Command System (ICS) guide;
  - ERPs;

- control point manuals;
- field guide manuals;
- training/exercise program;
- post incident evaluations; and
- continuing education and consultation with first responders, municipalities and the public adjacent to the pipeline.

4.2 Management Systems

4.2.1 Integrated Safety and Loss Management System

The *NEB Act* provides the NEB with the authority to make regulations governing pipeline design, construction, operation, and abandonment for the protection of people, property, and the environment.

Pursuant to the OPR, a company must have a management system that outlines the policies, processes and procedures for the planning and execution of the core business of the organization in a manner that provides for the protection of people, property, and the environment. The management system must also apply to the key program areas for which companies are responsible; safety, pipeline integrity, security, emergency management, and environmental protection. These programs must each follow management system processes to anticipate, prevent, manage, and mitigate conditions that have the potential to harm people, property or the environment throughout the lifecycle of the pipeline.

The KMC Integrated Safety and Loss Management System (ISLMS) has been developed in response to the 2013 amendments to the OPR, and applies to all activities involving the design, construction, operation, and abandonment of the pipeline system. The Program falls under the EHS department and associated EHS Management System, with the current system in place since 2008. The Program has been developed and is regularly updated in accordance with the EHS Management System.

Figure 4.2.1 illustrates the KMC ISLMS, EHS Management System and the Emergency Management Program.

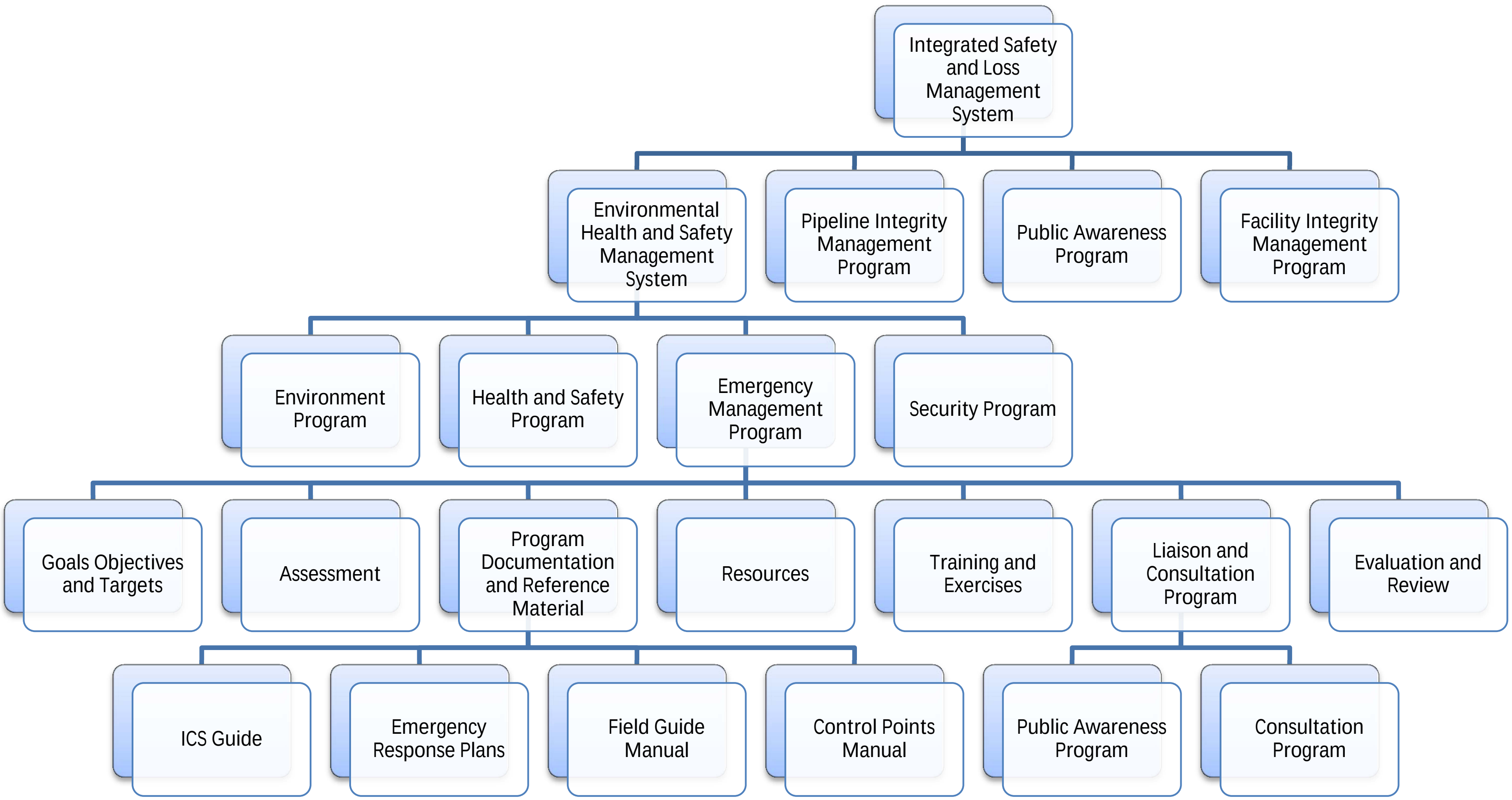

Figure 4.2.1 KMC ISLMS, EHS Management System, and the Emergency Management Program

4.2.2 EHS Management System

Kinder Morgan Canada's current EHS Management System was initially developed in 2008 drawing from three management systems: CSA Z1000-06 – Occupational Health and Safety Management (CSA 2006), International Organization for Standardization (ISO) 14001 Standards - Environmental Management (ISO 2004), and OHSAS 18001 - Occupational Health and Safety Management Systems – Requirements (British Standards Institution 2007). Previous to the current system, KMC had individual management systems for Emergency Response, Security, Safety, and Environment, which were integrated into the current EHS Management System. With the NEB's amendment of the OPR in 2013, KMC's EHS Management System was updated to adhere to the specific requirements as defined in Section 6 of the OPR. The three management system frameworks are periodically consulted for comparison and general information.

The EHS Management System describes how the company operates in a way that minimizes risk to its employees, contractors, the public and the environment. The management system structure emphasizes the importance of EHS impact prevention and continuous performance improvement, rather than reaction and management of loss occurrences. The EHS Management System is divided into the five primary sections described below.

4.2.2.1 Policy and Commitment

The EHS Policy (Figure 4.2.2) is the overarching statement that the EHS Management System and all EHS Programs have been developed in accordance with. The policy statement appears in all ERPs.

Environment, Health and Safety Policy

Every employee is expected to share Kinder Morgan's commitment to pursue the goal of not harming people, protecting the environment, using material and energy efficiently and promoting best practices, thereby earning the confidence of customers, security holders and society at large, being a good neighbor and contributing to sustainable development. Kinder Morgan's policy is to comply with all health, safety, security and environmental laws, rules and regulations, not just because it is legally required but also because we believe it is the responsible way to conduct our business. Kinder Morgan has systems in place that prepare for emergencies and procedures that coordinate our response plans with emergency response organizations in the communities where we operate. Kinder Morgan has a systematic approach to health, safety, security and environmental management designed to ensure compliance with the law, to train employees to be aware of and meet their responsibility for protection of health, safety and the environment, and to achieve continuous performance improvement. In addition to the Kinder Morgan commitment, contractors are required and joint ventures under Kinder Morgan's operational control are expected to apply this policy. Employees, supervisors or operational managers who knowingly engage in or condone environmental health or safety violations are subject to disciplinary action including suspension or termination.

Ian D. Anderson

President

Kinder Morgan Canada

A Member of the Kinder Morgan Group of Companies

Figure 4.2.2 Kinder Morgan Canada Environment, Health and Safety Policy

4.2.2.2 *Planning*

Kinder Morgan Canada has established, implemented, and maintains a procedure to achieve the following:

- establishment of objectives and targets, including designation of responsibility and means, and time-frame by which they will be achieved;
- proactively monitor changes in applicable regulation and legal requirements;
- determine if/how the regulatory or legal requirements apply to its aspects/hazards/threats;
- periodically evaluate compliance with these requirements and resolve any nonconformity; and
- communicate relevant requirements to responsible personnel within the company.

4.2.2.3 *Implementation*

Kinder Morgan Canada has established, implemented, and maintains a procedure to achieve the following:

- communicate information specific to the EHS Policy and implementation plan to all levels in the company; and
- identify training needs associated with its operations and programs, provide training or take other action to meet these needs, and evaluate the effectiveness of the training. Employees are made aware of:
    - their roles and responsibilities, and importance in achieving conformity with the EHS Policy and procedures, and to the requirements of the EHS Management System;
    - the environmental health and safety consequences of their work and the benefits of improved personal performance;
    - training requirements associated with emergency preparedness and response; and
    - potential consequences of departure from specified procedures.

4.2.2.4 *Checking and Corrective Action*

Kinder Morgan Canada has established procedures to monitor and measure performance on a regular basis. These checking and corrective actions include:

- both qualitative and quantitative measures, appropriate to the needs of the organization;
- monitoring such that the objectives and targets identified in the policy and planning activities are met;

- monitoring the effectiveness of the controls put in place with measures that validate the performance of the system; and
- reporting and investigating incidents to identify root cause(s) and ensure that any preventative and corrective actions are fully implemented.

4.2.2.5 Management Review

Senior management shall review the EHS Management System at regular planned intervals to ensure its continued suitability, adequacy, and effectiveness. The review shall include decisions and actions specific to:

- the need for changes to the organizations policy, objectives and targets;
- improvements in effectiveness;
- the extent to which objectives and targets have been met; and
- recommendations for improvement and time-lines for implementation.

4.3 Emergency Management Program

The Emergency Management Program is central to KMC's response to an emergency. The Program provides the key elements of a skilled and trained workforce, strategically located spill response equipment and resources, and pre-defined tactics for expedient and effective response to a pipeline emergency. The ICS is used to provide a structured and consistent approach to management of the pipeline emergency and provides seamless integration with third parties through a Unified Command structure. The Emergency Management Program has been developed and enhanced through a combination of learnings from table-top and field deployment spill exercises, and through experience gained through response to live spills, such as the third party strike on the Westridge pipeline in 2007.

The Emergency Management Program is subject to audit through the NEB, with findings addressed internally through a Corrective Action Plan.

4.3.1 Incident Command System

The ICS system was developed in the 1970's in California by the FIRESCOPE program to approach the problem of managing rapidly moving fires, with requirement for coordination over multi-jurisdictions. In 1980, the FIRESCOPE program made the transition into the national program called the National Interagency Incident Management System (NIIMS). At the time, ICS became the backbone of a broader system for all US federal agencies with wild land fire management responsibilities. Today law enforcement, fire departments and municipalities use a form of ICS in their incident management system.

The ICS is a management system designed to enable effective, efficient incident management through integration of facilities, equipment, personnel, procedures and communications within a common organizational structure. ICS provides a standard format, with the purpose of enabling incident managers to identify the key concerns associated with the incident—often under urgent conditions—without sacrificing attention to any component of the response. It represents organizational "best practices" and, as an element of the Command and Management Component of NIIMS, has become the standard for emergency management. The ICS was also designed to be flexible in application to size of incident, to enable rapid integration of agencies and personnel into a common management structure, and is intended to minimize duplication of effort.

The NEB uses ICS for emergency response management through participation in Unified Command, as well as integration of staff within the response structure. The Province of BC employs ICS for provincial emergency programs, and the Province of Alberta (AB) is currently developing similar standards as is the Canadian Coast Guard.

KMC was an early adopter of the ICS to manage emergency response, with introduction of the system in the early 1990s. The ICS structure outlines clear roles and responsibilities with respect to emergency response and includes a unified command structure for co-ordination with the multiple levels of government; federal, provincial, municipal, and Aboriginal communities, along the pipeline. Figure 4.3.1 provides the organizational structure employed within the ICS framework.

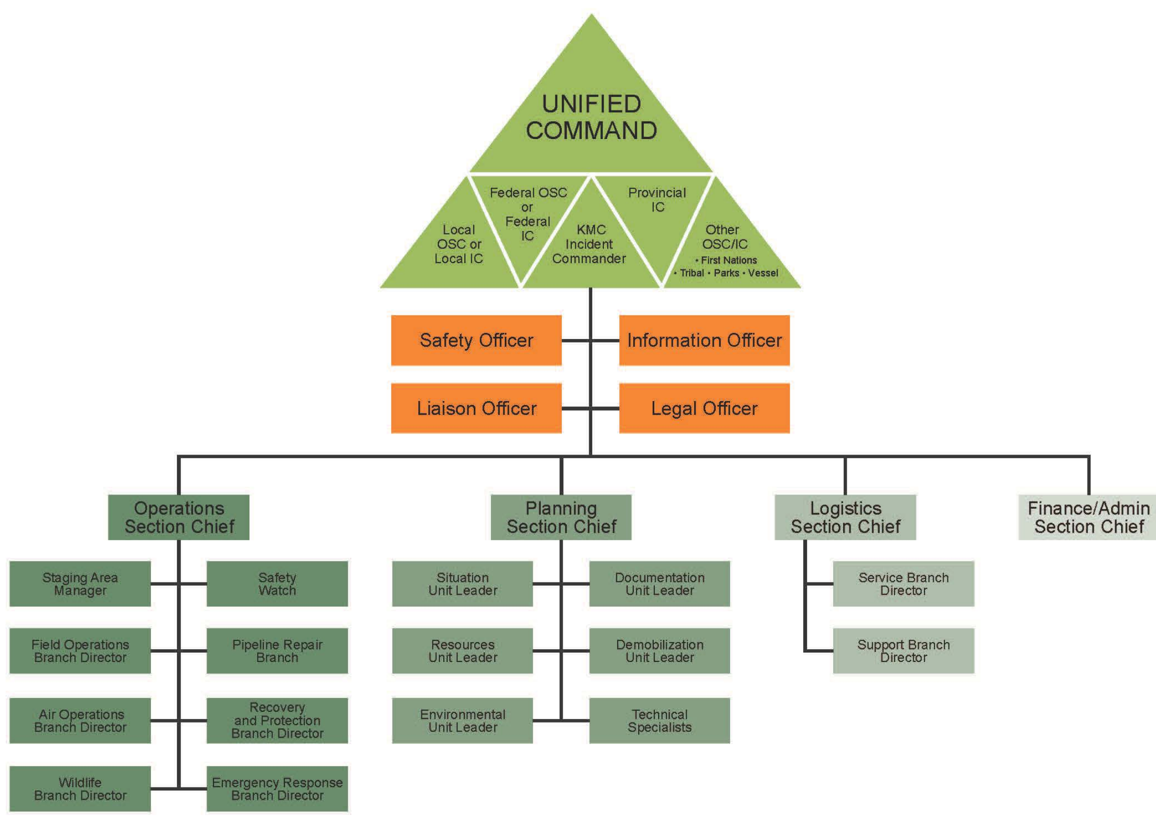

Figure 4.3.1 Organizational Structure Employed within the ICS Framework

The KMC Emergency Management Program and response organization is based on a three-tiered response structure (Table 4.3.1). Incidents are identified and categorized into one of the three tiers. Each Tier is managed by an escalating degree of management seniority and authority, and assistance from outside the initial response organization. The standardization of the ICS Structure and Incident Management Process provides the flexibility to tailor the size of the response organization to the specifics of the incident and allows for rapid adjustments as an incident evolves. Where appropriate, the KMC Incident Commander will invite the participation of federal, provincial, First Nations, and local agencies to form a Unified Command.

TABLE 4.3.1

THREE-TIERED RESPONSE STRUCTURE

Level	Definition	Examples
1	The Company has the capability to manage and control a Level I emergency using company resources available within the area. The District Supervisor will assume the Incident Commander position.	· Oil spills confined to company property (pipeline station, terminal, or scraper trap) · Public, contractor, or employee safety not endangered · Public property not endangered · Local response handled by District personnel · Notification may not be required to regulatory authorities · Little or no media interest
2	The Company has the capability to manage and control a Level II emergency using company resources and expertise, with some assistance from local contractors. The Region Director or designate may assume the Incident Commander position.	· Oil has migrated beyond company property (pipeline station, terminal, or scraper trap) but not into a waterway · Emergency services may be required (*e.g.*, fire, police, ambulance) · Public, contractor, or employee safety and/or property may be endangered · Notification required to regulatory authorities · May use a unified command organizational structure in the emergency · Local media interest
3	The Company may request assistance from other Industry, Municipal, or State Agency personnel to support the response to the incident. The Region Director will assume the Incident Commander position.	· Major emergency condition such as: - uncontrolled leak - spill on a watercourse - large fire at an operating facility or office building - fatality or serious injury to an employee, contractor, or the public - spill of hazardous substances · Major off-site environmental impact has occurred · Public, contractor, or employee safety and/ or property is endangered · Emergency services are required (*e.g.*, police, fire, ambulance) · Notification required to regulatory authorities · Use of a Unified Command organizational structure in the emergency, as required, to facilitate coordination of company, government and other agency response to the emergency. · Local, Provincial/State, and/or National Media interest.

The Initial notification of a pipeline spill activates the ICS team. All spills, regardless of size, are reported immediately to the Control Centre (CC). A notification procedure is then initiated which includes:

- contact of the terminal supervisor, or district supervisor to verify and assess the situation;
- determine the response level; and

- initiate the notification of company and external personnel and agencies.

Upon being notified of the incident, the CC Supervisor will issue an Emergency Response Line (ERL) or Emergency Response Line Plus (ERL+) for incidents that require an escalated response (additional staff and senior management call in). The ERL system is an online tool that delivers an automated group text message to designated KMC personnel when notification of an emergency or non-emergency event is required. The CCO fills in the Emergency Condition Report and issues an ERL/ERL+ call. Once received, the mandatory call in personnel will participate in a conference call to determine next actions, and the Incident Management Team (IMT) personnel that need further contact/mobilization. The mandatory callers are as follows:

- regional director, affected area; and
- the following people are contacted at the discretion of the regional director:
  - pipeline protection supervisor, affected area;
  - director, external relations;
  - scheduler, shipper services, affected area;
  - director, central region and CC;
  - director, technical services;
  - field representative/district supervisor;
  - EHS, regional contact;
  - director, EHS (Calgary);
  - legal representative; and
  - manager, emergency response and security.

If the online system is not operational the CCO will begin a manual call down of the above individuals and request they join the conference call. If the conferencing telephone lines are not operational the flow of information will occur via individual telephone calls until an alternate conferencing solution is available.

The following positions may be assigned depending on the severity of the incident:

- Incident Commander;
- Safety Officer;
- Information Officer;
- Liaison Officer;
- Legal Officer;
- Operations Section Chief;

- Planning Section Chief;
- Logistics Section Chief; and
- Finance/Administration Section Chief.

A trained and experienced **Incident Commander** is designated early in the process to provide a repeatable, consistent approach to managing the response and to make sure that all responders are being directed by a single, responsible individual. Depending on the level of the incident and required response, the organization is developed with the assignment of section chiefs designated for the roles of operations, planning, logistics and finance. Depending on the incident level, a Unified Command may be established with representatives of government agencies (may include Aboriginal, federal, provincial or local) though the structure supports Unified Command at all levels, if needed.

Other functions assigned early in the response are command staff positions including **Safety Officer, Liaison Officer** and **Information Officer**. The safety officer or the initial responder to the spill will take immediate actions to ensure the safety of the public and workers in the area of the spill, and will establish the initial health and safety plan for the site and identify potential hazards. The safety officer will develop hazard mitigation plans so that the response team can undertake incident response to the spill in a safe and effective manner. The section chiefs are responsible for assigning roles and responsibilities within each of their functional areas with the organization within each section scalable, depending on the spill categorization or tier.

The liaison officer makes sure that all necessary external groups are contacted, made aware of the issues and kept up to date as the incident develops. This role of ongoing communication and regular updates is an important part of the success of any emergency response. KMC's goal is to provide full and timely notification to regulatory bodies, Aboriginal communities, and other key stakeholders such as affected municipalities and first responders.

The information officer will be the primary contact for all external communications including the public and the media. This position must establish contact and set up a communication plan to ensure that these parties have the necessary information about the incident. This includes establishing a media relations centre and providing regular media updates.

The **Operations Section Chief** is primarily responsible for spill containment and recovery, and is responsible for all tactical assignments. This includes all contractors or other agencies that supply tactical resources in response to the incident. These might include representatives from the fire department, the police, the ambulance service as well as response organizations. The operations section chief assigns detailed duties and responsibilities for individuals in the operations section. The operations section may also consist of numerous (functional) groups and branches or divisions, depending on the geographical extent of the spill.

The **Planning Section Chief** is responsible for the gathering of incident intelligence and the development of Incident Action Plans. This includes the tracking of incident information and resources, and the ongoing documentation of the incident. The planning section chief is responsible for tracking of current incident information as well as planning for the next operational period. The planning section serves as a coordinating role with the planning section chief responsible for leading the tactics and planning meetings critical to the development of the Incident Action Plan. Technical specialists (*i.e.*, fire or oil spill specialists) will be assigned to the planning section.

The **Logistics Section Chief** is responsible for providing support to the incident, including all incident facilities (including the incident command post). The logistics section will also source all required resources, including personnel and equipment, accommodations, food and supplies.

The **Finance and Administration Section Chief** is responsible for all financial aspects of the response, including assisting in establishing contracts with suppliers, and setting up systems to monitor time and costs.

Once the emergency phase of the incident is over, the incident commander and/or Unified Command will stand down the IMT and ensure that all post-incident activities are completed. This includes transitioning of the response to the continued post-emergency phase, coordination of an incident debrief and lessons learned, and ensuring that all incident documentation is completed. The incident will transition to a project management structure with activities focused on repair of any pipeline or facility assets and remediation of impacted sites.

4.4 Emergency Response Manuals and Reference Material

Emergency Response Plans (ERPs) are available for the TMPL (including pump stations), terminals (Edmonton, Kamloops, Sumas, Burnaby) and the Westridge Terminal. These plans detail prescriptive procedures, activities, and check-lists to ensure consistent response to an incident across the pipeline with the common objective of protecting public and company personnel, the environment, and company and public property. The ERPs are utilized in coordination with the Control Point and Field Guide manuals which provide complementary information specific to the spill location including predetermined control points and response tactics.

The current ERP for TMPL provides a generic response to a spill for any location along the pipeline, whereas the ERPs for Terminals/Tank Farms and for Westridge Marine Terminal are location-specific. All plans have a common structure and format and address key elements. These include:

- responder health and safety;
- internal and external notifications;
- spill/site assessments;
- spill containment and recovery;
- protection of sensitive areas; and
- multiple hazards.

Each of the plans also includes detailed information on the ICS, includes the Environmental Health and Safety Policy, regulatory background, and documents the approach to training and exercises. The plans provide comprehensive information and are a ready resource to a safe, consistent, and timely response to an emergency or spill. All ERPs also address general requirements for non-spill incidents such as security, explosions, and fires, and include a detailed air monitoring plan that is applied in the event of a spill.

The emergency response Field Guides are supplementary to the ERPs and are intended as a single source reference readily available in vehicles assigned to operations personnel. The field guides provide reference information consistent with the ERPs, and include detailed route maps complete with control points and facility plot plans for Trans Mountain operational assets.

Other reference material available to supplement the response to an emergency includes a detailed Control Point Manual, ICS guide, shoreline clean-up and assessment technique procedures manual (marine and freshwater), and facility fire-fighting plans.

These plans are regularly exercised and tested, and have been used in actual incidents. Where required, the plans are updated based on lessons learned from incidents and training exercises.

The Corporate Crisis Support Plan

The broader Kinder Morgan (KM) organization maintains a Crisis Support Plan which establishes a framework and procedures for all KM business units for accessing additional resources and other support for field operations during an operating crisis. The Crisis Support Plan is an extension of local ERPs and is designed to build upon and integrate with the local plan to form an integrated KM corporate response.

The crisis support plan is implemented by the KM Crisis Support Team (CST). The functions of the CST are as follows:

- support the field incident command to protect life, property, and the environment;
- support operations in safely returning facilities back to service;
- provide a focal point for specific activities such as business continuation, major media response and investor relations activities; and
- assist in providing for humanitarian needs.

The CST may be formally convened to respond to incidents by decision of the incident commander or business unit management.

4.5 Spill Response Resources

Kinder Morgan Canada maintains a network of response resources which includes internal and external equipment and personnel.

4.5.1 Internal Response Equipment

There are seven Oil Spill Containment and Recovery (OSCAR) response units placed strategically along the existing TMPL route, at a spacing of approximately two to three hours of road driving distance apart. All units are equipped to a standard level, which includes a minimum of 750 ft. of containment boom, skimmers, sorbents, pumps, temporary storage, tools and personal protective gear; however, some units have extra specialized equipment to meet the specific needs of the local area. To maintain a base level of readiness, the units are inventoried and restocked annually and when needed following deployment for a spill exercise or in response to a spill. After any event or training with the equipment, a needs assessment is done on the unit to identify if there are newer technologies or additional equipment that would be useful in the in the low likelihood event of a real incident. Table 4.5.1 indicates the general location of the equipment and a basic overview of the equipment at each location.

TABLE 4.5.1

LOCATION OF INTERNAL RESPONSE EQUIPMENT

Location	Type of Equipment
Burnaby, BC	Response Boat (one anchored at Westridge, one on trailer) OSCAR Trailers with a total of 2,050 ft. of containment boom, skimmers, sorbents, pumps, temporary storage, tools, personal protective gear, 10,500 gal of foam, fire-fighting trailer and foam cannon
Hope, BC	Response Boat OSCAR Trailer with a total of 750 ft. of containment boom, skimmers, sorbents, pumps, temporary storage, tools, personal protective gear.
Kamloops, BC	Response Boat OSCAR Trailer with a total of 5,250 ft. of containment boom, skimmers, sorbents, pumps, temporary storage, tools, personal protective gear, cold weather equipment, 2,100 gal of foam, fire-fighting equipment.
Blue River, BC	Response Boat OSCAR Trailer with a total of 1,200 ft. of containment boom, skimmers, sorbents, pumps, temporary storage, tools, personal protective gear, and ice response equipment.
Jasper, AB	Response Boat OSCAR Trailer with a total of 900 ft. of containment boom, skimmers, sorbents, pumps, temporary storage, tools, personal protective gear, and ice response equipment. This unit is rated for helicopter deployment.
Stony Plain, AB	Response Boat OSCAR Trailer with a total of 1,200 ft. of containment boom, skimmers, sorbents, pumps, temporary storage, tools, personal protective gear, and ice response equipment.
Edmonton, AB	Sorbents, pumps, temporary storage, tools personal protective gear, cold weather response equipment, 15,000 gal of foam, fire-fighting trailer and foam cannon.

In addition to the mobile units, all facilities and operations vehicles are equipped with standard spill kits for response to minor spills.

4.5.2 External Response Equipment and Personnel

KMC belongs to a number of response organizations and participates in mutual aid exercises to supplement the company's self-reliant response capability. There are two main spill response organizations from which KMC, as a shareholder and member, can source equipment and manpower as outlined in the mutual aid agreements.

Transport Canada-certified Western Canada Marine Spill Response Corporation (WCMRC) is based in Burnaby, BC, and locates a response vessel at KMC's Westridge Marine Terminal for rapid deployment. KMC is a founding shareholder and member of WCMRC and sits on the Board of Directors. WCMRC's mandate is to ensure there is a state of preparedness in place and to mitigate the impact when an oil spill occurs. This includes the protection of wildlife, economic and environmental sensitivities, and the safety of both the responders and the public. http://wcmrc.com/.

The second major, established response organization is Western Canada Spill Services (WCSS), of which KMC is a shareholder and sits on the Board of Directors. The mandate of the WCSS is to ensure the provision of cost-effective, integrated, emergency response capabilities and to continually improve and communicate to their customers, stakeholders and regulators all aspects of their business. This includes planning, preparedness / response, and research and development for the petroleum industry. To ensure that industry is capable of safe, effective oil spill response, WCSS focuses its efforts on communication initiatives with government and stakeholders, research and development, contingency planning, equipment readiness and training to ensure skilled personnel are prepared to react quickly and thoroughly. http://www.wcss.ab.ca/. Although the scope of WCSS is generally limited to Alberta and north east BC cooperative areas, WCSS has confirmed that it is capable of and willing to deploy resources into BC and has done so in the past.

In addition to WCMRC and WCSS, KMC has contracts and master services agreements with a number of response contractors to supply equipment and/or personnel during an emergency. KMC works with Quantum Murray, 3Si Risk Strategies, Lions Gate Risk Management Group, PHH Arc Environmental, Golder and Associates, Tervita, TERA Environmental Consultants, and Witt O'Brien's during emergencies and in training to ensure a smooth working relationship in the event of an actual incident.

4.6 Training and Exercise Programs

KMC has a rigorous training and response exercise program that ranges from detailed equipment deployment drills to full ICS management and organization training and deployment. Training is provided to operations and head office staff, and at locations along the pipeline.

4.6.1 Training

The goal is to ensure that employees receive the training necessary to protect themselves, the public, the local community and the environment during a spill or emergency. Training is provided to enable employees to perform their designated emergency responsibilities. Formal training is reinforced by a program of regular hands on emergency response exercises. For specific training or exercises, efforts are made to coordinate with regulators and external emergency agencies.

There are several types of training available to KMC employees for emergency response. At a minimum, all employees who could be involved in emergency response will receive ICS level 100 training, which provides a general overview of the ICS, structure, procedures, processes, and standard forms. The IMT members receive increased detail and complexity of ICS training depending on their role following the widely recognized training format of ICS-200, ICS-300 and ICS-400 level. The level of training is commensurate with the anticipated roles and responsibilities of personnel, with efforts to cross-train key personnel for ICS Leadership roles such as incident commander, deputy incident commander, and the section chief roles.

Field operations personnel receive Incident Safe Approach training and some employees will receive Hazardous Waste Operations and Emergency Response training if they are expected to respond to incidents in Washington State. Employees also receive training on the Emergency Management Program and all of the plan elements.

Training records are the responsibility of the operations training coordinator and are maintained at the Sherwood Park office.

4.6.2 Exercises

The objective of response exercises is to practice the knowledge and skills received in training, identify areas of future training priority, identify areas to improve current emergency procedures or equipment, engage with local response communities, and to share exercise learnings to ensure a smooth response in the event of an incident. KMC conducts, on average, 20 to 25 training, table-top, and deployment exercises at locations along the pipeline each year. Many of the exercises involve Aboriginal communities, regulatory agencies, stakeholders, and contracted emergency response support companies.

KMC personnel at company facilities such as terminals and tanks farms will participate in exercises each year that are relevant to their site specific operations. At a minimum, each terminal or tank farm will participate in a fire response exercise using tactical equipment and interact with the local first response organization. Additionally, personnel at each terminal/tank farm will participate in a security exercise each year. These exercises will involve the local operating group only and may be tactical or a table-top or the scenario may be combined into one exercise.

The IMT will participate in one Level 3 (all resources deployed) exercise per year. The location of the IMT exercise will change from year to year and will be rotated throughout the communities in which KMC operates. The IMT exercise will test different areas of the plan and scenarios each year. The IMT is the same for the TMPL ERP, Terminal ERP and Westridge Terminal ERP, with the intent that the IMT will be trained/exercised annually, regardless of the ERP used for the actual exercise.

Both table-top and deployment exercises are often preceded by a full day training refresher which may include ICS, tactics and equipment specifics. Local response organizations and government agencies are invited to participate in both table-top exercises and field deployments.

Incident debriefs are conducted after every exercise and every actual emergency response deployment.

4.7 Community Awareness and Emergency Preparedness

KMC's Public Awareness Program is an integral component of the organization's Damage Prevention Program. Public awareness serves to alert the public to the presence of pipelines in the community as well as provide safety and damage prevention messaging to those who live or work near KMC's assets in Canada, or who may be called upon to respond in the event of a pipeline emergency. The program includes two main subprograms: (1) Continuing Education, and (2) Consultation. This program is conducted in English with documents translated into other languages as deemed necessary; for example, the *Working near Pipelines* brochure is translated into Punjabi, Korean, Tagalog, and Chinese Traditional.

4.7.1 Continuing Education Program

The baseline contact for emergency responders, including provincial emergency programs in communities where the Trans Mountain pipeline operates, is direct mail once every three years. The direct mail campaign addresses:

- how to participate in KMC's emergency response drills, table-top exercises, or equipment deployments;
- how to notify KMC in the event of a suspected pipeline emergency;
- where to get information on oil characteristics and recommended equipment for responding to a pipeline emergency; and
- information about KMC's ERPs specific to their local municipality, county, or regional district.

In addition to the baseline contact information, continuing education is provided through Community Awareness and Emergency Response presentations. The community training programs are delivered by KMC operations staff in consultation with other training providers, as required. In addition to table-top exercises and joint field deployment exercises, other topics presented and discussed include:

- the pipeline route(s);
- the types of petroleum products transported;
- how pipelines are identified by above ground signage;
- pipeline safety features;
- petroleum product hazard awareness;
- KMC and first responder emergency response procedures and respective roles and responsibilities;
- firefighting equipment; and
- KMC emergency response exercises.

Other continuing education training includes fire equipment training, storage tank courses, deployment exercises, ICS training, table-top exercises and participation in events as requested by outside stakeholders. These sessions focus on the overall response structure used by KMC, hazards associated with the pipeline operation and petroleum products transported, and many safety and general interest topics, as well as serve as a forum for information exchange.

4.7.2 Consultation Program

When conducting a major update to an ERP, KMC makes contact with agencies that could reasonably be expected to participate in an incident response for input on the procedures used during a response. In years where a major update is not being conducted on an ERP, KMC verifies the contact information for responding agencies. In any year, consultation may occur by email, telephone or through direct meetings.

In addition to the formal review of roles and contact information, KMC invites outside responding agencies to participate in training, deployment and table-top exercises to determine the working relationships of the organizations. During these events, further refinements to ERPs occur due to changes in real world conditions and processes. KMC also participates in external agency trainings and table-top exercises to further develop the working relationships with local authorities and integration of the emergency operations centres.

4.8 Planning and Improvements

Kinder Morgan Canada acknowledges that, despite the substantial measures in place through the existing Emergency Management Program, and the spill mitigation measures that will be incorporated in the risk based design, the Emergency Management Program will be comprehensively reviewed and modified to address the needs of TMEP. The proposed expansion coincides with a heightened public awareness of hazards associated with transportation of petroleum products.

As described, KMC's ISLMS and EHS Management System provide a structured framework for management and continuous improvement to the Emergency Management Program. The ICS also provides the management structure for emergency response which will govern internal organizational response and provides for a unified command structure to incorporate external agencies. It is anticipated that the management systems currently employed are effective and flexible in the overall management of an emergency and that fundamental changes to the management systems will not be required.

Not surprisingly, Trans Mountain's Aboriginal engagement, stakeholder consultation and landowner relations programs identified pipeline safety and emergency response as two of the top concerns specific to the TMEP. These outreach efforts included direct meetings with federal, provincial, and municipal governments, Aboriginal communities, targeted workshops with emergency managers and first responders, and Public Information Sessions along the pipeline and in adjoining marine communities. These consultation efforts served to highlight and reinforce the need for enhancements and/or improvements to the program, including ongoing communication of existing emergency response programs. In particular, the Province of BC has described five minimum requirements that it deems necessary before supporting heavy oil pipeline projects in BC. Items 2 and 3 of these minimum requirements are specific to emergency response for the marine and terrestrial environments, respectively:

- Requirement 2 - World-leading marine oil spill response, prevention and recovery systems for BC's coastline and ocean to manage and mitigate the risks and costs of heavy oil pipelines and shipments; and
- Requirement 3 - World-leading practices for land oil spill prevention, response and recovery systems to manage and mitigate the risks and costs of heavy oil pipelines.

Although regulation of marine transportation is not specifically within the jurisdiction of the NEB, the environmental and socio-economic effects of increased marine traffic is considered in Volume 8A in accordance with NEB direction. That includes the potential effects of accidents or malfunctions that may occur. Much of this material is relevant to requirement 2.

The preceding and subsequent discussion of measures to prevent oil spills and to enhance KMC's existing emergency preparedness programs is relevant to requirement #3 above.

4.8.1 External Emergency Management Plans and Improvements

In addition to KMC's internal review to enhance the Emergency Management Program (Section 4.8.2 below and elsewhere) external reviews by the BC and Canadian governments are currently also in progress. To the extent possible, KMC is either participating in or providing input to these reviews; either directly or through the Canadian Energy Pipeline Association.

4.8.1.1 BC Land Based Spill Preparedness and Response Initiative

Requirement 3 states: "World-leading practices for land oil spill prevention, response and recovery systems to manage and mitigate the risks and costs of heavy oil pipelines".

In November 2012, the BC Ministry of Environment released the Land Based Spill Preparedness and Response in British Columbia Policy Intentions Paper for Consultation (BC MOE 2012). The paper offered stakeholders the opportunity to comment on information provided on three aspects of land based spill preparedness and response:

- world leading regime for land based spill preparedness and response;
- effective and efficient rules for restoration of the environment following a spill; and
- effective government oversight and coordination of industry spill response.

It also introduced a 5-phase process to implement a proposed industry funded option for strengthening BC's spill preparedness and response policies and capacity.

KMC has taken a leadership role and engaged early in the land based spill initiative consultation process by submitting comments in response to the intentions paper. The company also participated as a contributor to the response prepared by the Canadian Energy Pipeline Association.

To further this initiative, the government developed a working group with various industry associations and held an initial meeting in Vancouver March 13 2013. KMC represented the Canadian Energy Pipeline Association in this working group and presented at the Land Based Spill Preparedness and Response Symposium, March 25 to 27. Following the symposium, BC MOE initiated the formation of three work groups and an advisory committee to develop elements of a world leading response regime. The advisory committee included a member representing the Tsawwassen First Nation. KMC personnel represented the Canadian Energy Pipeline Association on the advisory committee and two of the three work groups, and the Canadian Energy Pipeline Association had a representative on Work group 1. The work groups focused on the following areas:

- **Work group 1** - spill prevention and preparedness;
- **Work group 2** - spill response standards; and
- **Work group 3** - environment and natural resource recovery.

The work groups discussed numerous items at a conceptual level, focusing on gaps, the need for policy that aligns with other jurisdictions, and with the objective of avoiding duplication. Through discussion and a high level overview, a number of items were identified as being important elements of a world class response program with recognition that the details specific to each of the elements would be developed during the implementation phase. The following are some of the key considerations discussed:

- **Response Organization** - The working group discussed single entity or multiple organizations options as well as alternatives that would allow industry to meet the requirements individually or companies to opt out if they can demonstrate sufficient response capacity. The use of response contractors, existing spill response cooperatives WCSS and WCMRC, and potential for Aboriginal equipment and responders was discussed.
- **Oversight/Advisory Committee** - This committee would provide a method for input from municipalities, Aboriginal communities and industry which would contribute to the continuous improvement of the program. No firm recommendation on this topic emerged from the groups.

- **Geographic Response Plans** - These plans include information that is specific to a waterway or area and could include environmental sensitivities, control points, equipment and resources, etc.
- **Responder Training** - The group discussed implementation of a training program that would teach responders how to safely respond to a release. Response exercises could also be a required component of the training program.
- **Response Time** - Mandatory response times were proposed. Considerable concern was voiced at both the work group and advisory committee level as response time can depend on variables including weather and other hazards. Mandatory response capacity was discussed as being a more favourable requirement.
- **Sampling Requirements** - This would require mandatory sampling beginning at the start of a spill response and potentially continuing into the restoration period.
- **Spill Reporting** - Discussions focused on enhancing current spill reporting requirements to include update reports as well as a written report 30 days following a release.
- **Natural Resource Recovery** - Discussion focused on how to determine the restoration work required following spill response and remediation. Formula to determine impact and research models for recovery were discussed. Another option considered would allow for a contribution to a habitat fund in certain cases where it would achieve a more favourable result.

In addition to the above elements, all work groups discussed measures which could be implemented to improve community preparedness. Various industry or company programs are currently in place with potential improvement through a coordinated provincial effort.

A funding program has been proposed to implement improvements to spill response in BC. The province has introduced several possible requirements for consideration and has formed an additional work group (Work group 4) to engage in a review of funding and governance. The proposed funding program has broader implications than heavy oil projects as it encompasses bulk transportation of hazardous materials such as chemicals and hydrocarbons. The following topics have been identified as being within the scope of the proposed funding discussions:

- contingency funding for spill response and environmental and natural resource recovery;
- funding to establish a strategic advisory body;
- funding for spill preparedness and response activities;
- funding to administer BC MOE’s Environmental Emergency Program; and
- compensation for loss of public use of the enjoyment of the environment and natural resources.

The Canadian Energy Pipeline Association is represented on Work group 4, and will represent member companies with regard to proposed funding issues. KMC will continue to work with the Canadian Energy Pipeline Association in the consideration of the proposed program.

It is anticipated that the Province of BC will introduce legislation in 2014 that will formalize the discussions and requirements for land based spill preparedness and response.

4.8.1.2 Federal Government

Government of Canada's Commitment to Pipeline Safety

The Government of Canada is committed to protecting both the safety of Canadians and the environment, as outlined in its statements on Strengthening Canada's Pipeline Safety Regime (Natural Resources Canada [NRC] 2013). The Government of Canada has strong environmental laws and standards, robust pipeline safety regulations, and has an experienced regulator for pipelines in the NEB. The Government is committed to the 'polluter pay' principle and responsible management of risks under its plan for Responsible Resource Development. Specifically in 2013, the Government of Canada updated and or introduced the following regulations:

- the NEB's OPR, reinforcing the need for commitments to safety focused on protecting the public, workers and the environment;
- completed regulations to enable the NEB to issue Administrative Monetary Penalties (AMP) for companies that violate the *NEB Act*; and
- proposed legislation that further strengthens incident prevention and ensures the appropriate response in the low likelihood event of a spill.

Kinder Morgan Canada has responded positively to each of the new and/or proposed regulations by reinforcing our commitment to protecting the safety of Canadians, our employees and the environment. Each of the above regulations has impact to key areas of operations to KMC and the TMPL system. Our programs will continue to evolve as regulations develop enabling us to strengthen our systems in accordance with initiatives by the Government of Canada.

Recently Amended Onshore Pipeline Regulations

On April 10, 2013, the Government of Canada updated the NEB's OPR. These amendments reinforced the need for commitment to safety and a culture of safety focused on protecting the public, workers, and the environment. These updated regulations require:

- senior company leadership to be accountable for building a safety culture and supporting management systems. KMC has appointed a senior officer who is accountable to ensure that the company's management system and programs are in compliance;
- development and implementation of a security program. KMC has a mature security program that anticipates, prevents, manages and mitigates conditions that could adversely affect people, property or the environment; and
- development and implementation of an emergency management program focused on emergency-preparedness and response requirements. KMC has a

mature and robust emergency management program for the TMPL which is based on a management system that ensures continuous improvement.

National Energy Board's Administrative Monetary Penalties

The Government has now completed the regulations to enable the NEB to issue AMPs for companies that violate the *NEB Act*. These new regulations came into force on July 3, 2013.

Strengthening Canada's Pipeline Safety System

While Canada's regulatory and environmental record with respect to onshore federal pipelines is strong, the government is working to update and expand legislation to ensure that Canada remains world leading. These changes will help to further strengthen incident prevention and ensure the appropriate response in the low likelihood event of a spill. KMC supports the federal government initiatives to ensure the safety of Canadians and the environment. Some of the highlights of the proposed legislation are as follows.

- Require pipeline operators to maintain minimum financial capacity to respond to leaks, spills, and ruptures. The Government intends to propose regulations that will require companies operating major crude oil pipelines to have a minimum of $1 billion in financial capacity to respond to emergencies. Trans Mountain has always operated under the principle of polluter pay and is supportive of this principle being enshrined in regulation. Trans Mountain currently has $750 million of spill liability insurance. In the event that a new financial capacity standard is required (*i.e.,* $1 billion), Trans Mountain will meet that standard.

- Provide clarity on the restricted safety zone areas along pipelines, helping to reduce the potential for third party damage and increase safety. Restricted zones are established around pipelines, where ground disturbance is restricted prior to contacting the pipeline operator; the Government will work with the provinces to align the federal and provincial restricted zones. KMC supports the development of provincial and federal guidelines that protect the right-of-way for pipelines; therefore, ensuring the continued safe operation of the Trans Mountain Pipeline system.

- Clarify that the powers of the NEB and its officers have the power to conduct audits and enable enforcement for all parts of the *NEB Act*. For example, the NEB will be provided with enhanced legal powers to compel pipeline company officers to provide information requested by the Board. KMC has always operated in a transparent manner, and provides the NEB with all requested information.

- Clarify that, even after a pipeline is abandoned in place without being removed, the NEB continues to have jurisdiction over the abandoned pipeline, and can take steps to prevent, mitigate, and remediate any post-abandonment impacts, and that pipeline operators remain responsible for any costs and damages from an abandoned pipeline, so long as the pipeline remains in the ground.

- Improve transparency by ensuring company's emergency and environmental plans are easily available to the public. These emergency and environmental plans spell out exactly what a company will do, and the sequence of actions, in the low likelihood event of a pipeline spill. KMC is willing to provide copies of the emergency response and any other plan that describes what the company does in the event of a spill, upon request by any member of the public that has an interest in the operations of Trans Mountain Pipeline.

4.8.1.3 *Industry Initiatives*

Improvements to the Emergency Management Program will consider internal capacity, including equipment, resources, and training programs. Additional capacity enhancement is available through mutual aid agreements or cooperative relationships that are currently available or in progress.

Canadian Energy Pipeline Association Mutual Emergency Assistance Agreement

KMC has been a firm proponent of the Canadian Energy Pipeline Association initiative to develop a Mutual Emergency Assistance Agreement (MEAA) amongst all members. The MEAA was announced November 20, 2013, and is effective January 1, 2014, with KMC a signatory to the agreement. Canadian Energy Pipeline Association member companies include Access Pipeline Inc., Alliance Pipeline Ltd., ATCO Pipelines, Enbridge Pipelines Inc., Inter Pipeline Ltd., Kinder Morgan Canada, Pembina Pipeline Corporation, Plains Midstream Canada ULC, Spectra Energy Transmission, TransCanada PipeLines Limited, TransGas Limited and Trans-Northern Pipelines Inc.

The MEAA between the Canadian Energy Pipeline Association member companies will strengthen the existing emergency response process. The agreement will formalize an already existing practice whereby member companies can share resources during an emergency.

During an emergency situation, the Canadian Energy Pipeline Association member companies can call upon each other to share additional human resources, equipment, and tools that can increase each individual company's existing emergency response capabilities. The agreement will facilitate an even quicker response to protecting people, the environment, and property.

Western Canada Spill Services

Trans Mountain is a member of the WCSS, a Western Canada based spill cooperative that provides spill preparedness and response support services in Alberta, northeast BC and part of Saskatchewan. The cooperatives maintain spill contingency plans and strategically placed OSCAR units that are available to all member companies in the operating areas. They hold annual training exercises and provide educational funding for their membership.

To supplement internal response capability, KMC has initiated discussion with WCSS to extend the geographical reach of WCSS's mandate to encompass the Trans Mountain pipeline fully from Edmonton, AB, to Burnaby, BC. The initial discussion has been positive and Trans Mountain will continue to work with WCSS to develop a formalized agreement and understanding of available equipment and resourcing capacity. As Trans Mountain is a long standing member of WCSS, integration of resources and equipment is available within the existing Emergency Management Program.

Western Canada Marine Response Corporation

Trans Mountain is a founding member of the Western Canada Marine Response Corporation (WCMRC), the Transport Canada-certified marine spill response organization with a mandate to respond to spills in navigable waters on the BC coastline. WCMRC's mandate is to ensure there is a state of preparedness in place and to mitigate the impact when an oil spill occurs.

As described in Volume 8A, Trans Mountain has been working collaboratively with WCMRC to effect enhancement of the emergency preparedness and response capacity.

WCMRC's current mandate includes response to a spill in the marine environment at the Westridge Marine Terminal. The Westridge Marine Terminal also serves as a base for a WCMRC response vessel, which enables rapid response in the event of a spill. For the Westridge delivery line release in 2007, WCMRC was instrumental in the response and high recovery rate of oil achieved.

4.8.2 Emergency Response Plans and Improvements

4.8.2.1 Emergency Response Plan Review and Update

As part of regular maintenance, a review and update of all current KMC ERPs, and the ICS Guide was completed in 2013. The existing plans and guides will be used as the foundation for the development of enhanced plans and guides for the Project. These updated plans for the pipeline and facilities will reflect the added scope of the project, increased volumes, new or updated control points due to routing, and updates to new response equipment and bases if required. The updated plans will also reflect the recent Canadian Energy Pipeline Association MEAA, finalized plans with WCSS, and any new additions as a result of the BC Land based spill initiative. The underlying basis for the review will include performance standards for estimated response time and response capacity.

The detailed review will be developed collaboratively with stakeholders over the next two years. Consultation to date has indicated a strong interest in pipeline safety and emergency response, and plans include continued engagement with emergency planners and first responders to solicit input to planning efforts and to enhance understandings of pipeline hazards, emergency readiness, and roles and responsibilities in the event of a spill.

Finalized ERPs and supporting documents will be completed in advance of commissioning and operation of the Project.

4.8.2.2 Equipment Review and Availability

A comprehensive review of existing response equipment and locations is planned. This review will examine the existing equipment available internally within KMC, as well as potential locations for supplemental equipment available through mutual aid partners including WCSS and Canadian Energy Pipeline Association partners. The review will also include consideration of equipment availability through Aboriginal communities and local governments. The review will include:

- determining if the existing Trans Mountain OSCAR Units have sufficient equipment and capacity for the expanded system;
- evaluating the current locations of all equipment caches in the context of strategic deployment;
- reviewing inventory, and evaluating equipment and human resources available through both formal and informal mutual aid programs; and
- cataloging all existing resources and defining future needs.

This scope of the review will include facilities (pump stations and terminals), pipelines and appurtenances, and Westridge Marine Terminal. Although the specific details may change, planning completed to date based on conceptual designs for Westridge Terminal include:

- The Westridge Marine Terminal will require additional equipment located in close proximity to the expanded berthing facilities. It is anticipated that this equipment will be situated either at the existing WCMRC operations facility in Burnaby, BC, approximately 2 km west of the Westridge Marine Terminal, or at the utility dock. This may include an approximate 250 tonne oil spill response capacity including boom and skimmer to deal with dock-side spills.

- The equipment stationed at Westridge Marine Terminal is backed up by an OSCAR trailer located at the Burnaby Terminal. The Burnaby OSCAR unit will continue to be staged at this location following TMEP.

- Two rapid deployment boom reels are anticipated on-shore at the eastern and western limits of the Westridge Marine Terminal shoreline. This boom would allow for isolation of all three berths and the two nearby municipal storm water outfalls. This booming capability would be in addition to the current booming practice that occurs with each individual vessel berthed at the dock.

4.8.2.3 Aboriginal Integration

Consultation with Aboriginal communities has indicated an interest in participation in emergency response planning and programs with some communities already participating in emergency response exercises and training. The integration of Aboriginal communities provides opportunity for reduced response time in some locations and additional workforce to respond to a spill. Participation of Aboriginal communities in emergency planning and response also aligns with the principles outline in the BC Land based spill initiative.

Trans Mountain will continue to engage with Aboriginal communities with the objective of enhancing the current ERP. Consideration will include location of communities along the pipeline, community capacity, and resource needs to develop intermediate response equipment locations, as well as training and exercise requirements to more fully integrate these communities into Trans Mountain’s program.

Final determination of Aboriginal community participation and roles and responsibilities will be established through formal agreements between KMC and the communities.

4.8.2.4 Training and Exercises

Based on the planned updates and improvements associated with TMEP, Trans Mountain will coordinate training and exercises to provide a smooth integration of the added resources and capacity, and changes from the current ERPs and guides. This training program will include both desktop and classroom training to enable integration to the ICS used by Trans Mountain for the management of spills, as well as exercises that focus on tactical response. The planned training will include participation of multiple levels of government, mutual aid organizations, and Aboriginal communities formalized through agreements with Trans Mountain.

An Emergency Response Training Plan will be developed, which outlines the training program, participants, content, and exercise locations, with the intent of providing field deployment exercises that will cover the geographical extent of the pipeline, and align with Trans Mountain operating districts. The plan will include training and exercise requirements specific to the entire scope of TMEP and the existing TMPL.

4.8.2.5 Spill Response Tactics

Standard spill response tactics are included in the ERPs, together with location specific tactics addressed in the Control Points Manual. Methods employed are generally targeted at meeting the overarching objectives of protecting the public and company personnel, protection of environmental sensitive resources, and protection of public and company property. The tactics include control of the spill source, and containment and recovery. For spills into watercourses, tactics generally include boom deployment for containment and to protect sensitive resources as well as the use of recovery equipment such as skimmers and vacuum trucks.

The results of the fate and behaviour studies for diluted bitumen indicate that a prompt response can reduce the consequences of a spill. While this factor is important in all incident responses, weathering of the diluted bitumen combined with specific environmental conditions can increase the potential of some portion of the oil becoming submerged, reducing the effectiveness of a conventional spill response.

Tactics and equipment deployed on an oil spill depend on many factors. To be effective Trans Mountain can select from a wide variety of tactics and currently have staff trained in their use; primarily mechanical methods for containment, protection and recovery including the use of booms and skimmers. In addition to mechanical methods there are two other spill mitigation tactics that merit discussion; (1) the use of dispersants, and (2) in situ burning. Experience has proven that dispersants and burning are tactics that are effective in responding to a spill, but that they have to be applied early in the response as their effectiveness diminishes over time.

Either method requires approval from regulatory agencies before it can be used in a site-specific situation, and past experience has indicated that the approval process timing can be delayed. Because of the importance of prompt deployment Trans Mountain recommends that it would be prudent to have pre-approval or protocols established for these less-than-conventional tactics. Trans Mountain intends to meet with various provincial and federal regulatory and response organizations to investigate the conditions under which pre-authorization might be obtained. This will be approached in a collaborative fashion with the NEB, Environment Canada, Alberta Support and Emergency Response Team, BC MOE Environmental Emergencies Program, appropriate First Nations and local governments.

Pre-approval of these non-conventional tactics would expedite the decision making process, reduce the recovery time substantially and allow remediation work to begin earlier than if a purely mechanical recovery was utilized.

4.8.2.5.1 Dispersants

Dispersants are a group of chemicals designed to be sprayed onto oil slicks to accelerate the process of natural dispersion. When used appropriately, dispersants can be an effective method of response to an oil spill. They are capable of rapidly removing large amounts of certain oil types from the sea surface by transferring it into the water column. Significant environmental benefits can be achieved, particularly when other at-sea response techniques are limited by weather conditions or the availability of resources. In certain situations, dispersants may provide the only means of removing significant quantities of surface oil quickly, thereby minimizing or preventing damage to important sensitive resources. Their use is intended to minimize the environmental impact caused by floating oil, for example to birds or before the oil may hit sensitive shorelines. However, in common with all spill response options, the use of dispersants has limitations and its use should be carefully planned and controlled.

4.8.2.5.2 In-Situ Burning

Burning is proposed by Trans Mountain as an alternative tactic to provide a rapid means to remove oil in the event of a spill from the pipeline or terminal operations. In situ burning is the oldest technique applied to oil spills and is also one of the techniques that has been explored in scientific depth. The successful use of in situ burning on the Deepwater Horizon spill in the Gulf of Mexico drew attention to the technique and illustrated the effectiveness of burning when properly applied.

Advantages of in situ burning include rapid removal of oil from the water surface, requirement for less equipment and labour than many other techniques, significant reduction in the amount of material requiring disposal, significant removal of volatile oil components, and may be the only solution possible, such as for oil-in-ice situations and wetlands.

Disadvantages of in-situ burning include creation of a smoke plume, residues of the burn may have to be removed, oil must be a sufficient thickness to burn quantitatively; and therefore, may require containment, and danger of the fire spreading to other combustible materials. Potential human health impacts may result from smoke plume and particulate generation so may not be suitable where public exposure will result.

Similar to dispersants, the decision on whether or not to use burning rather than other response options will need to take into account the site-specific conditions at the spill location, and balance the conflicting priorities for protecting different resources from pollution damage. On occasion the benefit gained by using burning including its rapid application will offer the better alternative for protecting public and environmental interests.

For additional information on application of dispersants and in situ burning see Appendix F, Special Tactics for Spill Response.

5.0 FATE AND BEHAVIOUR OF A HYDROCARBON RELEASE

5.1 Properties and Weathering of Liquid Hydrocarbons

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

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

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

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

The oil properties and behaviour of diluted bitumen are of particular interest to spill modellers, transportation and handling operators, environmental scientists, and spill responders. Although dilbit has been transported via pipeline for the past 30 years and their general properties are similar to other heavy oils, the specific characteristics and behaviours of these oils as they weather have been the subject of a limited number of published studies. On balance, oil fate, behaviour and spill response issues associated with heavy oils have been the focus of numerous reports (Ansell *et al.* 2001; BMT Cordah 2009; Brown *et al*. 1997; CRRC 2007, Lee *et al*. 1992; Michel *et al*. 1995, 2006; NRC 1999). Laboratory and mesoscale weathering experiments done in the recent past have shown dilbits to have physical properties very much aligned with a range of intermediate fuel oils and other heavy crude oils, depending on the state of weathering. Trans Mountain undertook its own mesoscale weathering experiment in support of the Project and this is described in detail in Section 5.2.8 and in Volume 8A, Section 5.4.

Oil properties provide information about their potential behaviour and fate in the environment and the potential environmental effects if a release were to occur. Medium to heavy crude oils and dilbits undergo very similar changes when released to similar settings. This section describes the general physical and chemical properties of oils that will continue to be transported on the expanded TMPL system, compares these properties to other crude oils, and discusses the changes in these properties as the oil weathers.

5.1.1 Hydrocarbon Properties Relevant to the Trans Mountain Expansion Project

The primary type of hydrocarbon to be transported in Line 2 is diluted bitumen (*i.e.*, both dilbit and synbit). The physical and chemical properties can be used to predict the fate of diluted bitumen in various environments (*e.g.*, marine, terrestrial and freshwater). Sources of information on oil properties for these oils are available in published literature and via the CAPP sponsored website www.crudemonitor.ca.

5.1.1.1 Oil Physical Properties for Proposed Expansion

To ensure pipeline transportability, tariffs approved by the NEB specify that the density of crude oil shipments is not to exceed 940 kg/m^3 at a reference temperature of 15°C and that viscosity not exceed 350 cSt, when measured at the posted pipeline operating temperature (Table 5.1.1). To meet these specifications, bitumen is diluted into either dilbit or synbit (Table 5.1.2).

TABLE 5.1.1

TRANS MOUNTAIN PIPE LINE REFERENCE TEMPERATURES

1. Petroleum tendered for transport on the Trans Mountain Pipeline System, will not be accepted by the Carrier if the viscosity exceeds 350 cSt at the Reference Temperature listed below.
2. The reference temperature limit on viscosity will be applied as of 07:00am on the first day of application, specified below.
3. Density is not to exceed 940 kg/m^3 at 15^0C.

Time Period	Reference Temperature (^{0}C)
January 1 – 15	8.0
January 16 – 31	7.5
February 1 – 15	7.5
February 16 – 28	7.5
March 1 - 15	7.5
March 16 – 31	7.5
April 1 – 15	7.5
April 16 – 30	8.5
May 1 – 15	9.5
May 16 – 31	11.5
June 1 – 15	13.0
June 16 – 30	15.0
July 1 – 15	16.0
July 16 – 31	17.0
August 1 – 15	18.0
August 16 - 31	18.5
September 1 – 15	18.5
September 16 – 30	17.0
October 1 – 15	15.5
October 16 – 31	14.0
November 1 - 15	12.5
November 16 – 30	10.5
December 1 – 15	9.5
December 16 – 31	8.5

Table 5.1.2 presents typical blending ratios for synbit and dilbit, though the actual blend ratios will vary depending on actual bitumen and blend component properties, as well as reference temperature.

TABLE 5.1.2

EXAMPLE BLENDING RATIOS, DENSITY AND VISCOSITY LEVELS FOR SYNBIT AND DILBIT

Blend Component	Volume Percent	Density (kg/lm^3)	Viscosity (cSt at 15°C)
Synbit			
Bitumen	51.7	1,010	760,000
Synthetic crude oil	48.3	865	5.9
Total	100	940	128
Dilbit			
Bitumen	74.6	1,010	760,000
Condensate	25.4	720	0.6
Total	100	936	350

Source: Illustrative blending ratios presented by R. Segato, Suncor Energy, October 23, 2012 to US National Academy of Sciences, on behalf of CAPP (CAPP 2013b)
Actual blend ratios will be adjusted on a seasonal basis.

Table 5.1.3 summarizes the density ranges typical of the five streams that are representative of the majority of the anticipated throughput for Line 2.

TABLE 5.1.3

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

	Access Western Blend (AWB)	Cold Lake (CL)	Statoil Cheecham Blend (SCB)	Surmont Heavy Blend (SHB)	Albian Heavy Synthetic (AHS)
Density (kg/m^3)	923.6 ± 5.3	928.0 ± 5.2	928.1 ± 5.2	931.9 ± 6.1	933.2 ± 6.8
Gravity (° API)	21.6 ± 0.9	20.9 ± 0.9	20.8 ± 0.9	20.2 ± 1.0	20.0 ± 1.1

Source: Crudemonitor.ca.

Note: Format is: Average ± std. deviation.

Diluted Bitumen falls into an oil group classification (US Environmental Protection Agency and US Coast Guard) noted as Group 3 hydrocarbons. That is, the specific gravity of the dilbit is equal to or greater than 0.85 and less than 0.95. Table 5.1.4 provides a point of comparison between the physical properties of dilbits and those of other crude and fuel oils with ranges of specific gravities that overlap with the Group 3 category. Dilbits and these other commodities have been transported throughout the world and the general behaviour of these oils are quite comparable with respect to fate and weathering, and spill countermeasures.

TABLE 5.1.4

RANGES OF PROPERTIES FOR GROUP 3 AND 4 OILS (HEAVY CRUDE AND DILBIT RANGE HIGHLIGHTED)

Property	Units	Light Crude	Heavy Crude	Intermediate Fuel Oil	Bunker C	Crude Oil Emulsion
Specific Gravity		780 to 880	880 to 1,000	940 to 990	960 to 1,040	950 to 1,000
API Gravity		30 to 50	10 to 30	10 to 20	5 to 15	10 to 15
Viscosity	mPas at 15°C	5 to 50	50 to 50,000	1,000 to 15,000	10,000 to 50,000	20,000 to 100,000
Flash Point	15°C	-30 to 30	-30 to 60	80 to 100	> 100	> 80
Solubility in Water	ppm	10 to 50	5 to 30	10 to 30	1 to 5	-
Pour Point	°C	-40 to 30	-40 to 30	-10 to 10	5 to 20	> 50
Interfacial Tension	mN/m at 15°C	10 to 30	15 to 30	25 to 30	25 to 35	NR
Distillation Fractions (% distilled at)	100°C	2% to 15%	1% to 10%	-	-	NR
	200°C	15% to 40%	2% to 25%	2% to 5%	2% to 5%	NR
	300°C	30% to 60%	15% to 45%	15% to 25%	5% to 15%	NR
	400°C	45% to 85%	25% to 75%	30% to 40%	15% to 25%	NR
	residual	15% to 55%	25% to 75%	60% to 70%	75% to 80%	NR

Source: Modified from Fingas (2001).

Note: NR = not relevant.
mPas = milliPascal-second.
mN/m = milliNewton/metre.

5.1.1.2 Oil Chemical Properties for Proposed Expansion

When assessing the potential fate and behaviour of pipeline releases it is important to determine the state of the three phases of the oil. The first consideration is the vapour phase, that is, what volatile compounds are present and are likely to be released into the atmosphere during weathering. This is typically characterized by determining the volatile or light end components as summarized in Table 5.1.5. The second consideration is analyzing the compounds that would become soluble in water and may have toxic effects on aquatic life. These compounds fall into two general groups: benzene, toluene, ethylbenzene, and xylenes (BTEX), and polycyclic aromatic hydrocarbons (PAH). Results of the BTEX crude oil analyses are summarized in Table 5.1.6. PAHs comprise a relatively small amount of the total oil and are < 30 mg/kg for dilbit.

TABLE 5.1.5

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

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

Source: Crudemonitor.ca

Note: Format is: Average ± std. dev.

TABLE 5.1.6

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

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

Source: Crudemonitor.ca

Note: Format is: Average ± std. dev.

5.2 Weathering Processes

Hydrocarbons released into the environment, including both land and water, undergo changes in physical and chemical properties due to the natural weathering processes of evaporation, emulsification, natural dispersion, dissolution, oxidation, interaction with particulates, and biodegradation. Physical and chemical changes occur immediately and rapidly upon release. Although these processes usually act simultaneously, their relative importance varies with time and determines the hydrocarbon fate and behaviour. The rate of change in oil properties due to weathering is dependent on a number of factors including spreading (or containment) and environmental variables such as temperature, currents, turbulence, winds, and sediments. Key processes in oil weathering are described in the following sections in order of their effect on the mass balance of the oil (Fingas 2011).

5.2.1 Evaporation

Evaporation begins immediately upon release of the oil. The rate and percent evaporation is dependent on the oil composition, available surface area for evaporation (*i.e.*, spreading), and conditions of the receiving environment, such as wind, turbulence, and temperature of oil, water and air. The lighter hydrocarbon components, containing from 1 to 12 carbon atoms (C_1 to C_{12}), will generally evaporate within the first 12 hours of exposure. Some of the more toxic components of the oil (BTEX) fall into this range and therefore, the toxicity of the vapour plume dramatically reduces within a matter of hours.

5.2.2 Emulsification

Emulsification is the formation of a water-in-oil mix. Emulsions may be stable, in which case incorporated water will remain within the mix, to very unstable in which incorporated water is quickly lost from the mix. Stable emulsions, such as a chocolate mousse can contain 20 per cent to 80 per cent water. Water turbulence and wind speeds greater than 5 cm/s are generally regarded as necessary conditions for formation of stable oil-in-water emulsions. Stability of the emulsion usually increases with decreasing temperature. Emulsions can slow other weathering processes, particularly evaporation and natural dispersion, leading to greater persistence of the hydrocarbon. Stable emulsions may slow biodegradation because of the higher resulting viscosity of the mix, which reduces nutrient exchange.

5.2.3 Natural Dispersion

Natural dispersion is the transformation of the bulk oil, under the influence of turbulence, into finely divided droplets below the water surface. Larger droplets have sufficient buoyancy to rejoin the bulk oil. Smaller droplets that do not coalesce but remain suspended in the water column have an increased total surface area relative to the equivalent bulk volume, which speeds the process of biodegradation. Light crude oils, which do not form stable oil-in-water emulsions, have a higher rate of natural dispersion than hydrocarbons that form stable oil-in-water emulsions.

5.2.4 Dissolution

Dissolution of oil into water takes place early in the release. Most hydrocarbons are not highly soluble in water although the lower molecular weight aromatics, such as BTEX components, may be accommodated in the water column. Given that the more soluble fractions are light end hydrocarbons, this process is limited to the initial stages of weathering. In terms of total mass balance; however, this mechanism is considered a very minor component of weathering.

5.2.5 Oxidation

Oxidation or, more specifically, photo-oxidation is the reaction of hydrocarbons with oxygen in the presence of sunlight. Degradation of oil by photo-oxidation is not a major component of weathering, but it can affect emulsification. Over extended timeframes, aggregates referred to as tar balls may form as a result of these reactions.

5.2.6 Biodegradation

Biodegradation is the bio-chemical breakdown of oil by bacteria, yeast, and fungi that are able to metabolise the hydrocarbons. The process occurs at the oil/water interface and is dependent on the abundance of the organisms, availability of oxygen and nutrients, water temperature and the hydrocarbon composition. It is a relatively slow process, but can remove large volumes of hydrocarbon over time.

5.2.7 Interaction with Particulates

Interaction with particulate matter is the process whereby particles of sediment or organic matter adhere to oil droplets. The combination of sediment adhered to oil droplets may result in an oil-mineral (or particulate) aggregates (OMA) with densities greater than the surrounding water in which case the combination can become dense enough to submerge unless turbulence maintains the OMA in suspension. Waters laden with suspended solids, such as along a shoreline with breaking waves and sand or along rivers with high concentrations of suspended sand and silt, provide favourable conditions for OMA formation. OMA, much like natural dispersion, creates larger surface areas for adhered hydrocarbons, which can enhance the biodegradation potential of that portion of oil. Reduced flow and turbulence may allow the submerged oil and particulate combination to settle and sink. Oil-particulate matter that sinks will tend to collect in low points and areas of reduced bottom current or flow.

Evaporation, water-in-oil emulsification, natural dispersion, and dissolution are most important during the early stages of a spill. Interactions with particulates, photo-oxidation, and biodegradation are slower, longer term processes that determine the ultimate fate of the hydrocarbons.

5.2.8 Weathering Behaviour of Access Western Blend and Cold Lake Winter Blend

Although several detailed studies have been completed that characterize the fate and behaviour of heavy crude oils from Alberta oil sands, the majority of testing has been laboratory and bench-scale tests. Trans Mountain undertook testing, A study of Fate and Behaviour of Diluted Bitumen Oils on Marine Water, Dilbit Experiments, Gainford, Alberta (the Gainford Study) (Volume 8C, TR 8C-12, S7), to expand upon this knowledge through larger, mesoscale tests of diluted bitumen in brackish water. Larger tank tests allowed for simulated wave and current conditions that may be more typical of the marine setting of Burrard Inlet, the export point for dilbit from the TMPL. Induced wave and wind energy on the mesoscale test tanks provide a mechanism to assess shifts in weathering rates as weathering energy increases. Increased energy from wind and waves in a marine setting can be analogous to the increased energy in freshwater system in which increased current speeds and turbulence result in faster weathering rates.

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

Weathering processes result in changes to the physical and chemical properties of the remaining oil. For the two dilbits tested, the most significant changes noted from the 10-day weathering events, in terms of oil fate and behaviour, were in density (key factor in floating versus non-floating weathered oil), viscosity (key factor in weathered oil penetration into pore spaces and affects pump ability to recover spilled oil), water uptake and emulsification (affects density, viscosity, and potentially oil recovery systems), and chemistry (light ends). Both AWB and CLWB dilbits exhibit water uptake within the weathered oil matrix, although not as a stable, uniform emulsion but rather as a mechanically mixed and unstable oil-water combination. Water content analyses, conducted following procedures for whole oil, showed no systematic uptake or pattern for either oil during the weathering process. Given the unstable character of water-in-oil, sampling and sample processing may result in very different oil-water mixtures at the time of analyses; hence, no conclusions are drawn for those tests other than to note that the maximum water contents measured, above 40 percent, were noted in samples from three tanks with moderate and mild agitation and after 1 to 3 days of weathering. Visual observations of the surface of the oil in the various tanks showed that a crust or armouring formed as the oil weathered. There also was little evidence of small droplets (natural dispersion) into the water column. Instead, the oil tended to form relatively continuous floating patches on the tank surface. In the end, the behaviour of both products proved to be no different than what might be expected of other conventional heavy crudes when exposed to similar conditions.

5.2.8.1 Physical Properties of Weathered Access Western Blend Dilbit

Density increases during weathering were more pronounced with moderate agitation; whereas, oil under static conditions and mild agitation had comparable change (Figure 5.2.1). In all cases, absolute densities (at 15°C) reached or slightly exceeded 1,000 kg/m^3 (freshwater equivalent), but only after 8 to 10 days of weathering. The increase in AWB pour point and in viscosity as it weathered was pronounced in the first 48 hours, with the latter ranging from 108 to over 60,000 cSt within that timeframe (Figure 5.2.1 and 5.2.2). Loss of a portion of lighter hydrocarbons combined with water inclusion into oil, much as may occur with most heavy crudes, are key factors defining the weathered oil properties.

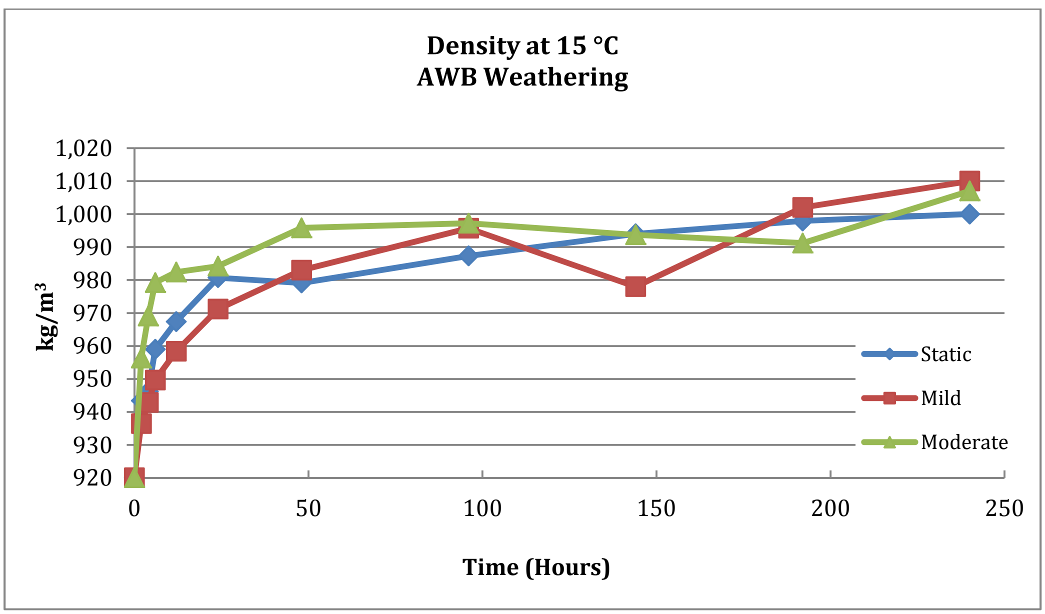

Figure 5.2.1 AWB - Absolute Density

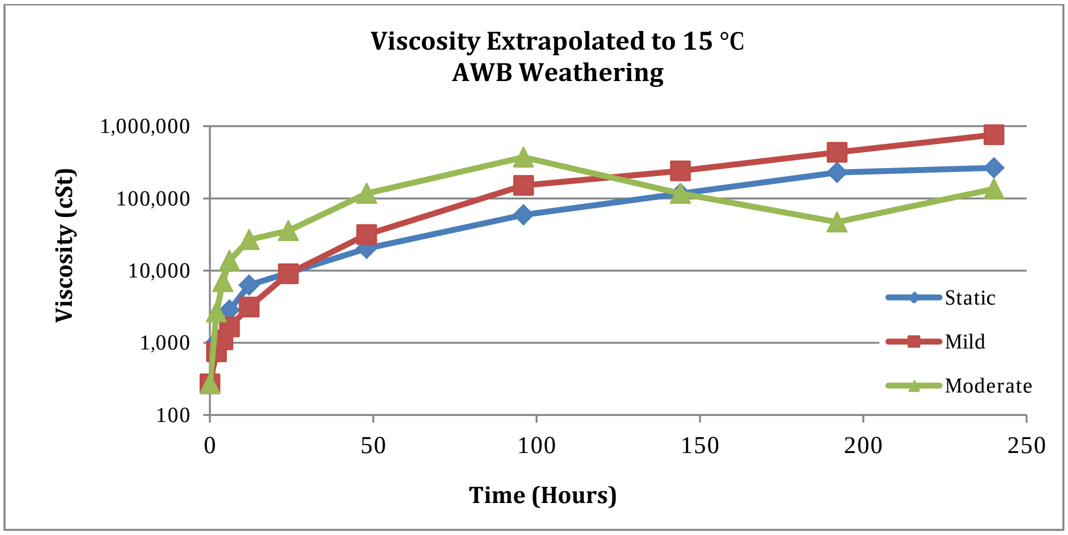

Figure 5.2.2 AWB Viscosities

5.2.8.2 Physical Properties of Weathered Cold Lake Winter Blend Dilbit

The density increase in weathered CLWB was more pronounced in in the first 24 hours under moderate agitation (Figure 5.2.3), but oils in static and mild agitation tanks achieved similar densities after that time. In all cases, absolute densities (at 15°C) never exceeded 1,000 (freshwater equivalent) with the exception of a single measurement at 8 days for the CLWB oil under moderate agitation. Viscosities increased to over 10,000 cSt within the first 48 hours, although increases in viscosity were much less pronounced in the static tank (Figures 5.2.3 and 5.2.4)

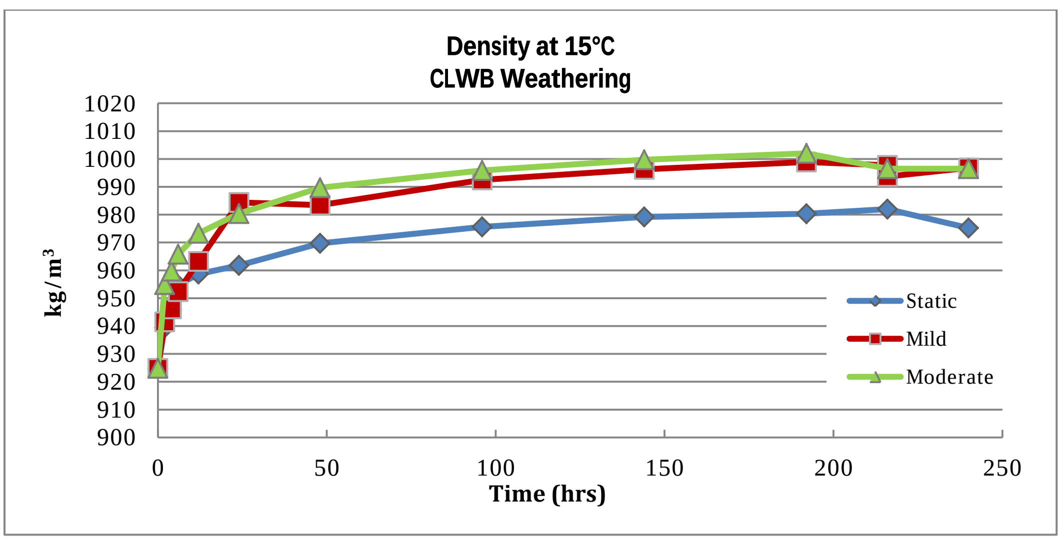

Figure 5.2.3 CLWB - Absolute Density

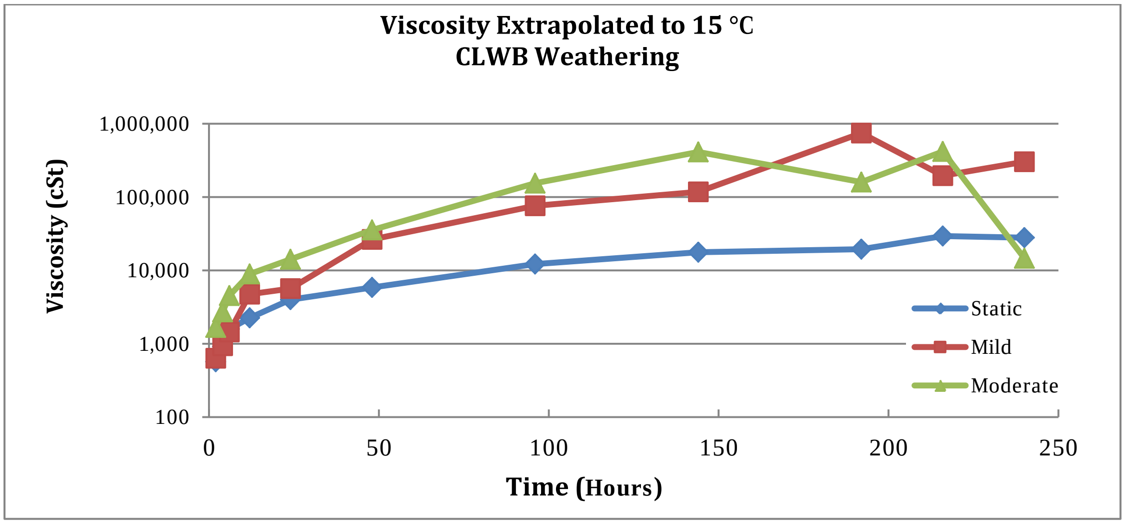

Figure 5.2.4 CLWB Viscosities

5.2.8.3 Chemical Properties of Weathered Access Western Blend and Cold Lake Winter Blend Dilbit

Oil chemistry, including C_1 to C_{30} and PAH analyses, were analyzed to characterize the originating (fresh oil) dilbit, and to assess hydrocarbon content and degradation patterns. Figures 5.2.5 and 5.2.6 show PAH data for weathered and fresh AWB oil samples. Figures 5.2.7 and 5.2.8 shows relative weight concentration of C_1 through C_{30} compounds in fresh and weathered AWB and CLWB dilbits, respectively, and compares changes in these compounds with different levels of induced turbulence (see Gainford Study and attachments for full details).

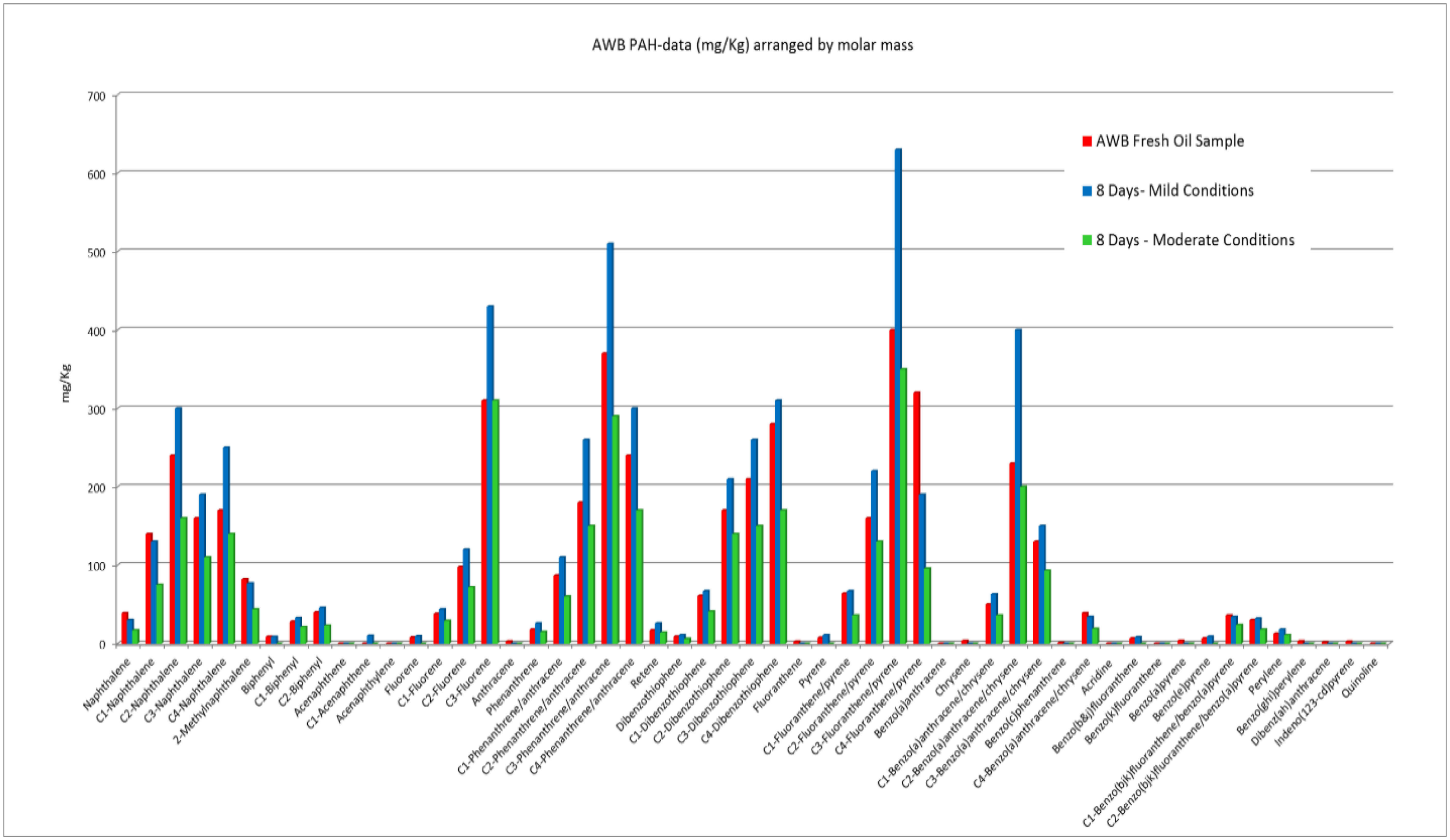

Figure 5.2.5 Oil Chemistry Data – AWB Dilbit

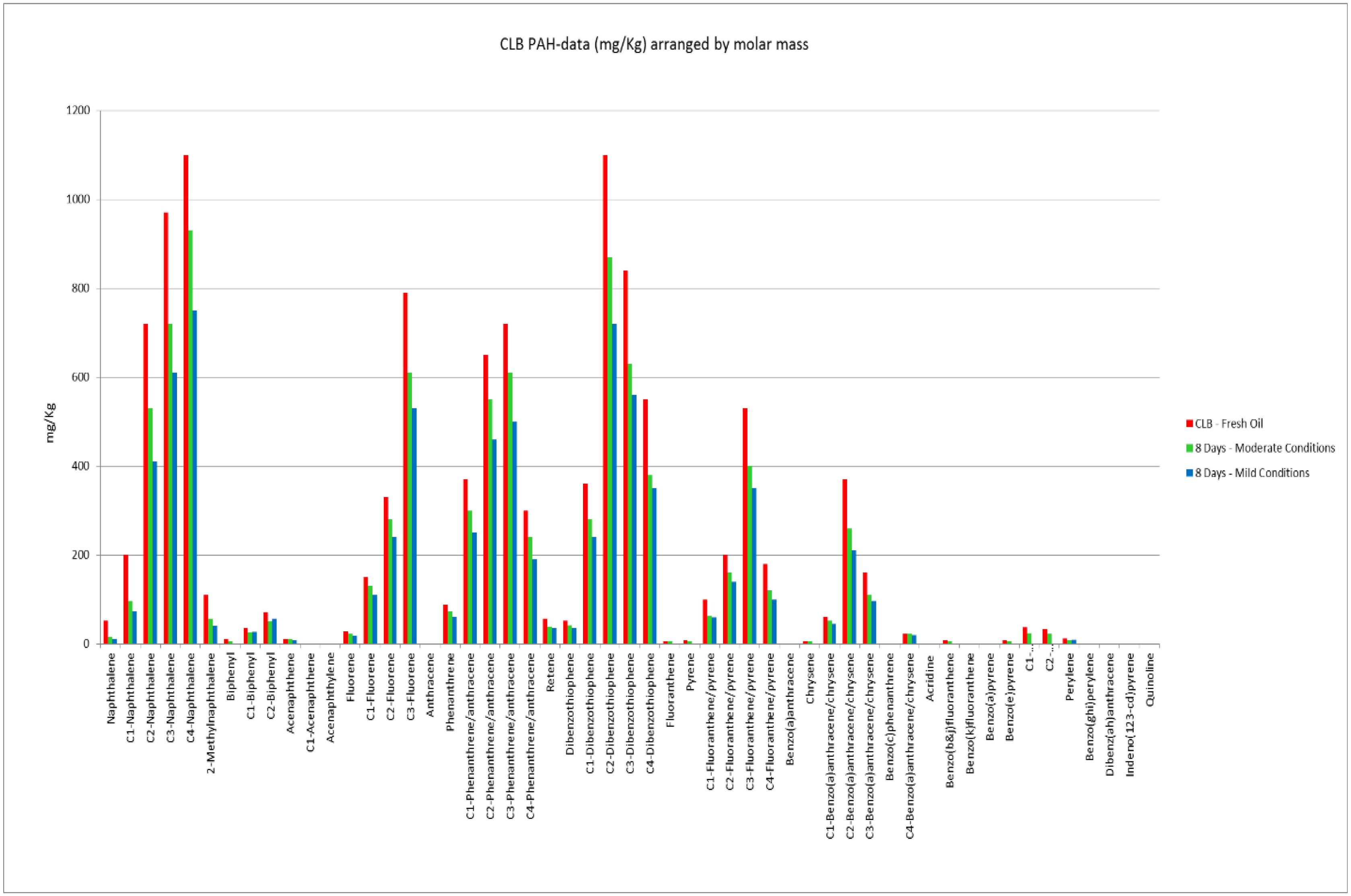

Figure 5.2.6 Oil Chemistry Data – CLWB Dilbit

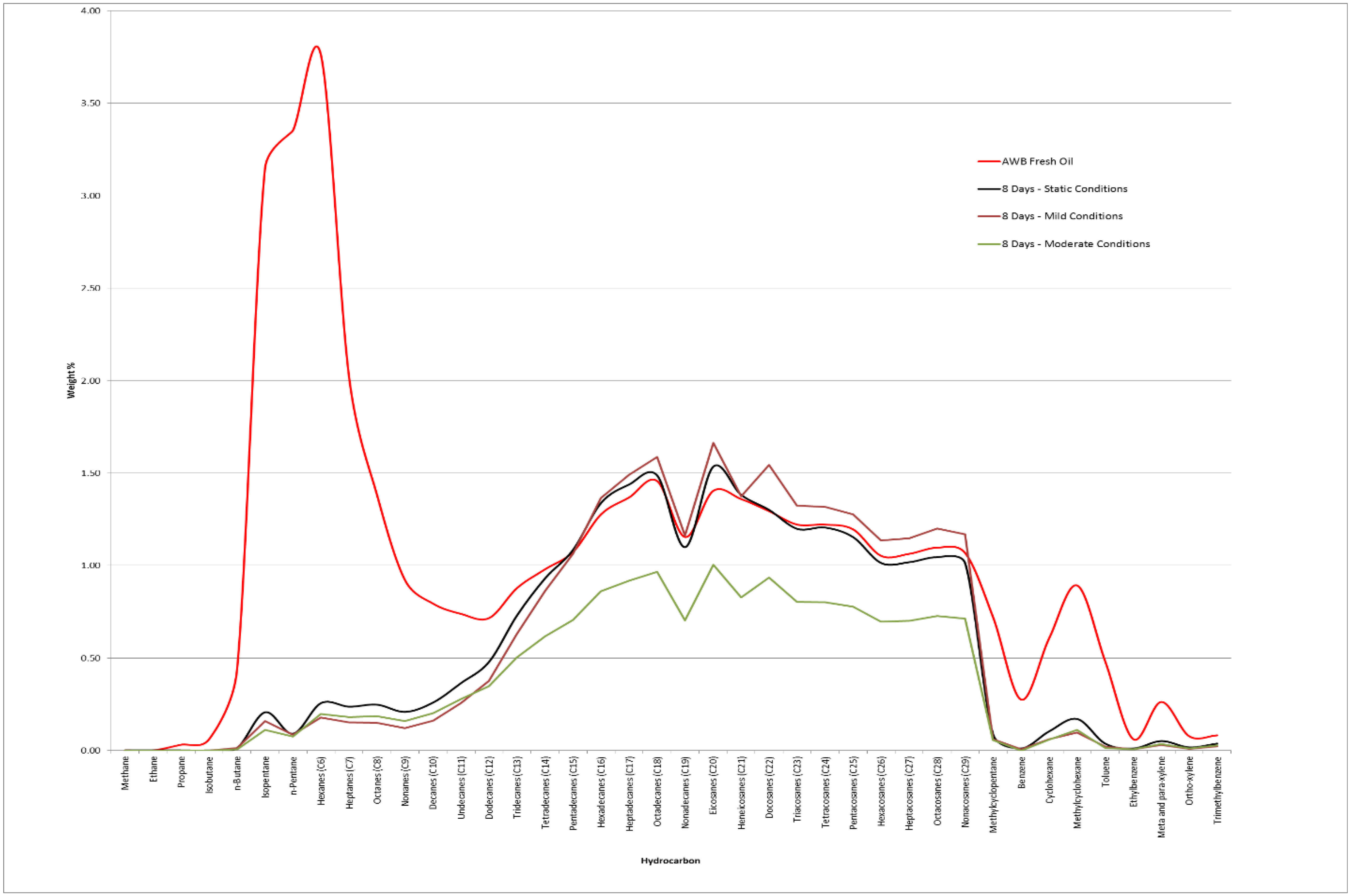

Figure 5.2.7 Light Ends (C_1 – C_{30}) AWB Dilbit

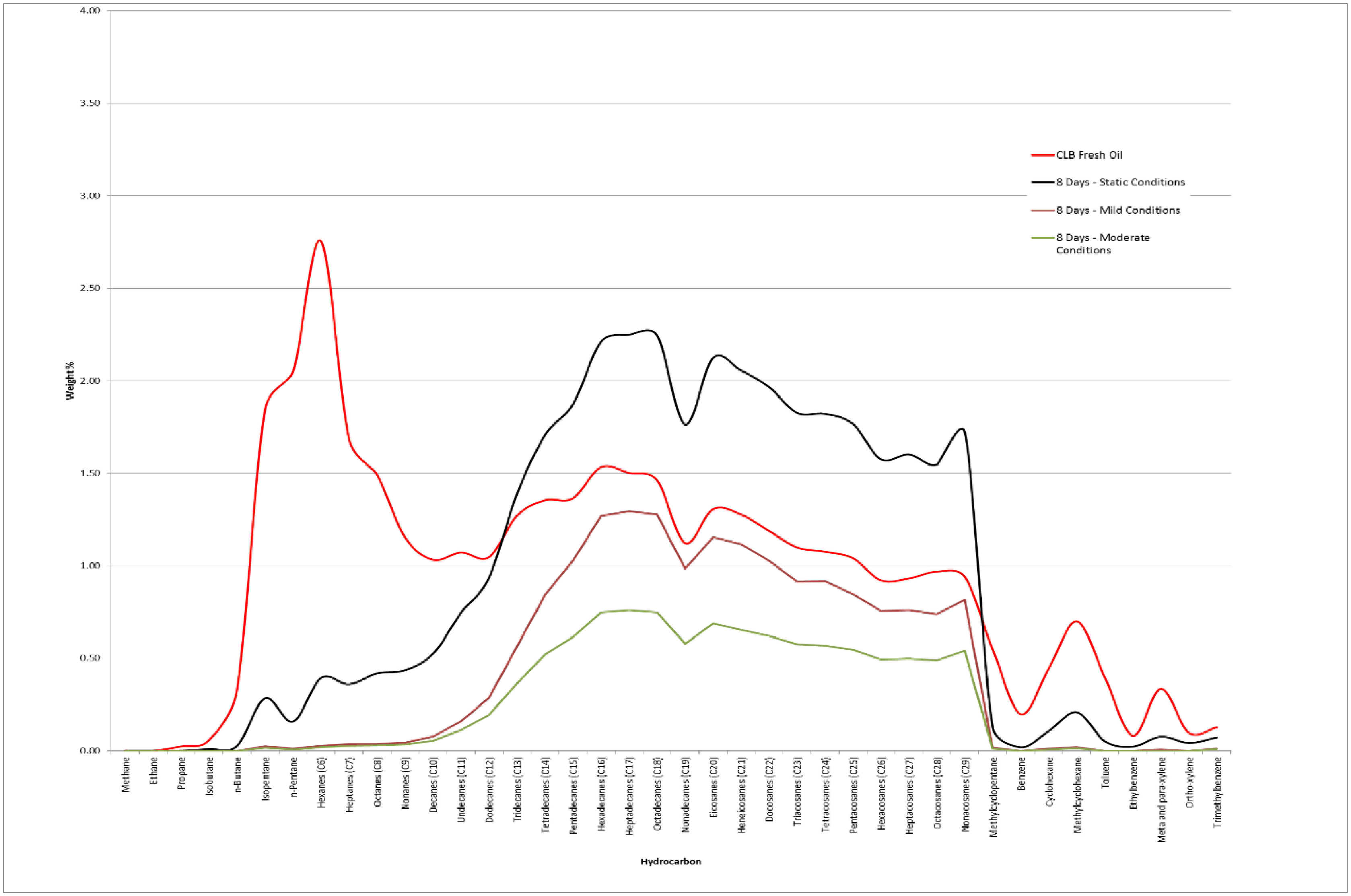

Figure 5.2.8 Light Ends (C_1 – C_{30}) CLWB Dilbit

5.2.8.4 Oil Distribution in the Water Column

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

5.2.8.5 Total Petroleum Hydrocarbon the Water Column

Total petroleum hydrocarbon measured in the water columns of the AWB and CLWB dilbit tanks were in nearly all cases below detection thresholds (< 2 mg/L) with the exception of tanks with moderate agitation (S3 - AWB and S9A - CLWB). The highest TPH values measured were 120 mg/L at 1 m below the water surface from the CLWB dilbit and 60 mg/L at 50 cm below the water surface for AWB (Figure 5.2.9). By approximately 12 hours, all TPH values, regardless of depth in the water column or oil type, were near 10 mg/L in the tanks with moderate agitation. This pattern demonstrates that the lower molecular weight fractions of TPH tend to be more soluble in water and weather (*i.e.*, volatilize) faster.

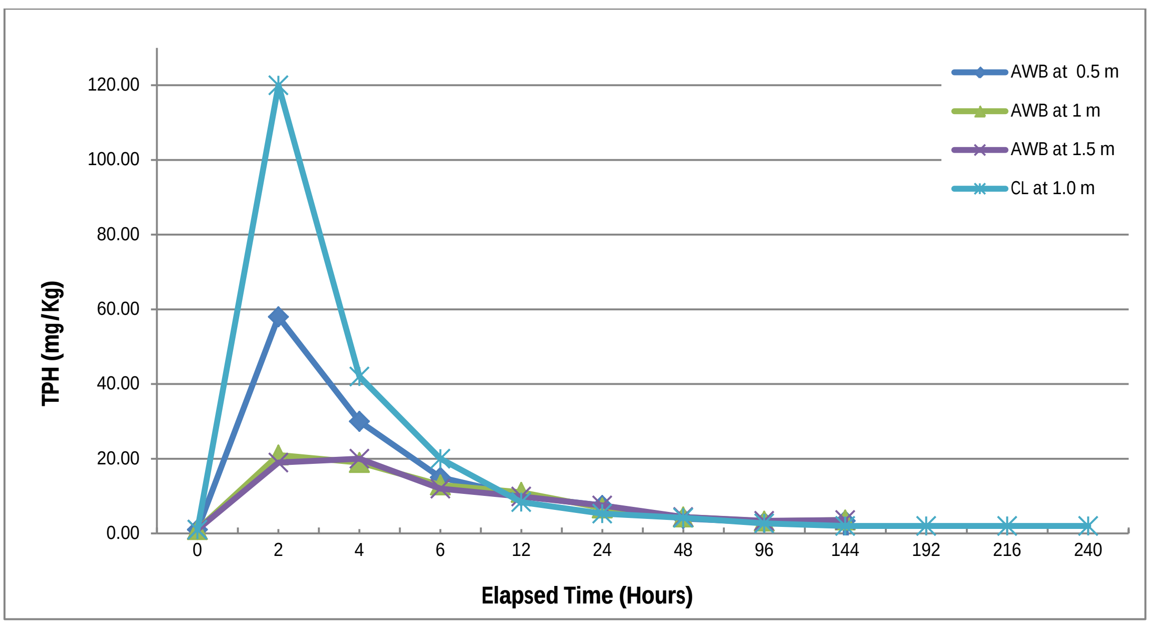

Figure 5.2.9 TPH in Water Column Samples - AWB and CLWB Weathering under Moderate Conditions

5.2.8.6 Benzene, Toluene, Ethyl Benzene, and Xylenes in the Water Column

Benzene, toluene, ethyl benzene, and xylenes, commonly referenced as BTEX, are the volatile single-ringed aromatic compounds found in crude oils. The behaviour of the four compounds is somewhat similar when released to the environment and therefore they are usually considered as a group. Most crude oils contain BTEX usually from about 0.5 per cent up to 5 per cent or more. The CLWB and AWB contain approximately 1 per cent BTEX in the fresh oil samples, consistent with other crude oils. Gasoline can contain up to 40 per cent BTEX. BTEX compounds are volatile and rapidly volatilize producing a net loss of BTEX compounds.

Single-ringed aromatics are also soluble in water at low ppm levels and readily partition out of the heavy crude. In the study of both CLWB and AWB, the BTEX compounds partitioned into the water column evenly at all depths examined (Figure 5.2.10 and Figure 5.2.11), but behaved somewhat differently overall under different wind and wave conditions. The BTEX in both oils behaved very similarly. In the AWB static tests, dissolution of BTEX in the water column increased at 12 to 24 hours with maximum concentrations reaching approximately 900 µg/L total BTEX (∑ BTEX) at approximately 6 days (Figure 5.2.10). There was little evidence of a net loss of BTEX in the static water leading up to 10 days.

In mild wind and wave conditions, BTEX began to partition into the water column immediately reaching maximum ∑ BTEX concentrations of 1,200 µg/L (CLWB) to 1,500 µg/L (AWB) in 48 hours (Figure 5.2.10 and Figure 5.2.11). Net loss of BTEX to volatilization was apparent at 48 hours with water concentrations dropping to less than 200 µg/L by 8 days.

In moderate wind and wave conditions, CLWB ∑ BTEX reached 3,000 µg/L almost immediately followed by a net loss to < 100 µg/L in 4 days (Figure 5.2.11). The AWB ∑ BTEX reached maximum concentrations of approximately 1,700 µg/L after four hours followed by a slightly slower net loss to < 200 µg/L after 4 days. It is possible that the CLWB tanks located outdoors resulted in more rapid net loss of BTEX compounds. The higher maximum concentration of BTEX in CLWB dilbit could have been the result of confinement within a smaller tank.

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

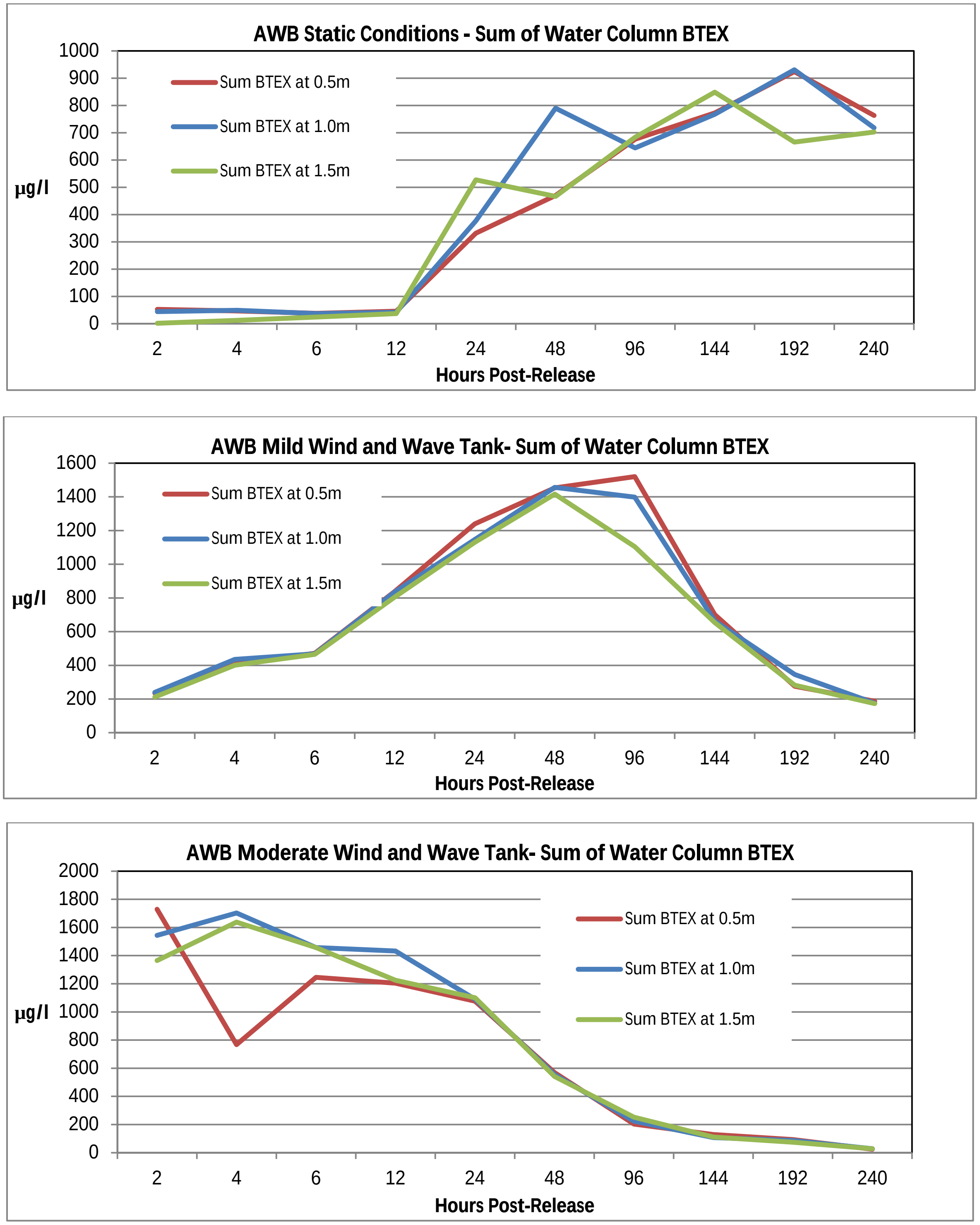

Figure 5.2.10 BTEX in Water Column Samples – AWB Tanks

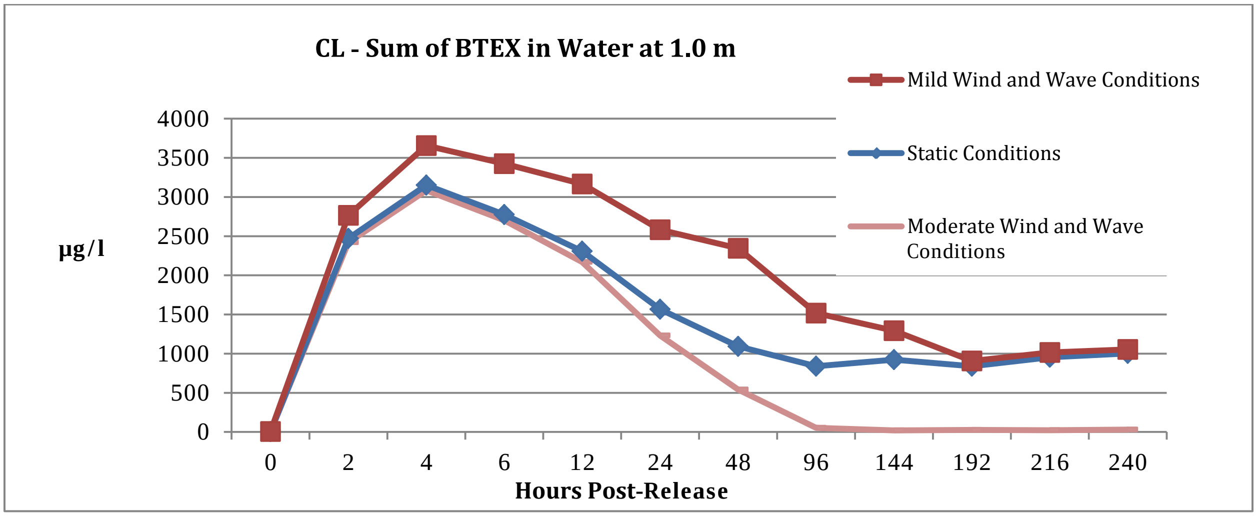

Figure 5.2.11 BTEX in Water Column Samples – CLWB Tanks

5.2.9 Comparison of Cold Lake Winter Blend and Other Oils

Table 5.2.1 provides a summary comparison of the changes in key physical properties of representative oils through evaporative loss of lighter-end hydrocarbons. Table 5.2.2 summarizes example changes in oil chemistry. Although general perceptions may conceive of dilbits as being very different types of oil from other commodities transported via pipelines and tankers, the fact is that these crude oils have been transported for years (Line 1) and their general physical and chemical properties are not significantly different than heavy crude oils. As such, their fate and behaviour (if spilled) in the environment would be quite similar to Group 3 oils.

TABLE 5.2.1

CHANGES IN PHYSICAL PROPERTIES OF REPRESENTATIVE OILS THROUGH EVAPORATIVE LOSS

	Weathering (weight (%)	API	Water (vol (%)	Flash Point (°C)	Density (g/mL) @at0/15		Pour Point (°C)	Dynamic Viscosity (cP) at 0/15		Adhesion (g/m²)	Surface Tension (mN/m) @ 0/15		Oil/Brine (33 ppt) Interfacial Tension (mN/m) at 0/15		Oil Freshwater Interfacial Tension (mN/m) at 0/15		Emulsion Formation: Visual Stability	Emulsion Formation: Complex Modulus (Pa)	Emulsion Formation: Emulsion Water Content (%)	Reference
					0°C/1°C*	15°C		0°C/1°C*	15°C		0°C	15°C	0°C	15°C	0°C	15°C	15°C/14°C*			
Alaska North Slope (ANS) Crude Oil	0	30.89	< 0.1	< -8	0.877	0.8663	-32	23.2	11.5	20	27.3	26.4	22.5	20.2	26.7	23.6	Unstable			1
	10		< 0.1	19	0.9054	0.894	-20	76.7	31.8	35	29.8	28.4	25.3	23.1	28.1	25.5	Unstable			1
	22.5		< 0.1	75	0.9303	0.9189	-9	614	152	38	31.2	30.4	26.8	24.2	30.8	27.7	Unstable			1
	30.5		< 0.1	115	0.9457	0.934	-6	4,230	614.7	40	33.1	31.8	30.1	25.6	33.2	30.2	Mesostable	155	72.9	1
Fuel Oil #5	0	11.5	3.1	94	1.0034	0.9883	-19	18,600	1,410	34	NM	NM	NM	NM	NM	NM	Stable	1,590	78.3	1
	7.2		< 0.1	136	1.016	1.0032	-3	72,000	4,530	47	NM	NM	NM	NM	NM	NM	Stable	2,490	72.8	1
Heavy Fuel Oil	0	11.47	0.1	111	1.0015	0.9888	-1	241,000	22,800	100	NM	NM	NM	NM	NM	NM	Entrained	752	57.7	1
	2.5		< 0.1	133	1.0101	0.9988	11	3600,000	149,000	240	NM	NM	NM	NM	NM	NM	Entrained	984	24.1	1
CLWB	0	21.4^{+}	0.9	-4.5	0.948*	0.936	< -24	1,363*	368					23.2			Mesostable*		53	2/3
	14.3	14.3^{+}		4	0.987*	0.977	-15	57,548*	9,227					24.7			Unstable*		0	2/3
	17	12.1^{+}		4	0.990*	0.981	-12	98,625*	14,486					> 27			Unstable*		0	2/3
	23^{+}	10.2	33.4	56		0.9986	9													3

Sources: SL Ross 2010, Wang. *et al.* 2003.
The Gainford Study (Volume 8C, TR 8C-12, S7).

Notes: NM = Not measured
mN/m = milliNewton/metre.

TABLE 5.2.2

CHANGES IN OIL CHEMISTRY OF REPRESENTATIVE OILS THROUGH EVAPORATIVE LOSS

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

Source: SL Ross, 2010, Wang *et al.* 2003.

The Gainford Study (Volume 8C, TR 8C-12, S7).

5.3 Fate of Hydrocarbon Releases

Based on recognized measures of risk there will be a low likelihood potential for release of oil from the pipeline. Pipeline design considerations, construction practices, operating procedures, and effective maintenance will ensure that the likelihood is reduced to as low a level as practical. Based on historical spill records for both modern and older pipelines, it is more likely that releases will occur within the property boundaries of facilities, with embedded monitoring and containment systems, and much lower potential consequences. If however, there is an oil spill, the fate of the released oil depends on multiple factors, including the oil properties, in the case of TMEP likely diluted bitumen, ambient and environmental conditions, and the effectiveness of the spill response. The fate of oil releases and factors that affect the released oil are discussed further in the following subsections.

Given that the pipeline is buried, a fundamental aspect of a release is that the initial receiving environment is the trench fill around the pipeline. Hydrocarbons would tend to fill pore spaces in the fill provided adequate relative permeability of the soil with respect to the released oil. As the soils surrounding the release point become saturated, oil would tend to flow to adjoining media along the trench fill and following general surface and subsurface topography. If soils are saturated, oil may become evident on the ground surface and extend downward to an impermeable layer or groundwater.

5.3.1 Release to Land

A hydrocarbon release to land will tend to move downslope, sink downward under gravity, and spread horizontally on the surface and in the subsurface. When the mobile oil encounters an impermeable soil structure (bedrock or the water table), downward movement halts and the oil will spread laterally, mostly through capillary forces, or down the slope of the more impermable layer. Eventually oil will stop moving and be trapped in the soil; however, even when immobilized, the oil will continue to lose mass through water (dissolution) and vapour (evaporation) phases and through biodegradation. The natural rate of depletion through these processes becomes progressively slower with time as the remaining hydrocarbons are increasingly more complex components that resist weathering.

The rate and extent of movement is influenced by various factors, including:

- properties of the hydrocarbon, such as density and viscosity;
- type and properties of the receiving substrate;
- temperature; and
- soil saturation.

On land surfaces, oil will move downslope as long as it is above its pour point, the lowest temperature at which oil becomes semi solid and loses its flow characteristics. After the initial period when the dynamic and static pressures from the spill site subside and the oil has spread out, hydrocarbon movement tends to slow. Oil in or on soil may move downward under gravity and spread horizontally in the subsurface as a result of capillary forces. If the oil encounters an impermeable or semi-permeable soil structure (*e.g.,* bedrock, impermeable or frozen soil, water table), downward movement would halt or slow, and the oil would spread laterally. Eventually the oil would stop moving and remain in local surface pools, be absorbed by vegetation and the litter layer, and be trapped in the void spaces within the soil structure. Natural terrain roughness creates locations where oil may pool. Snow acts as a sorbent for oil and may retain in excess of 40 per cent of its volume in crude oil (Allen 1991). However, even when immobilized, hydrocarbons would remain subject to physical weathering and microbial biodegradation.

Estimates of CLWB penetration and retention in different substrates, based on extrapolated results of tests with intermediate fuel oil and Bunker C oil, is provided in the report Coastal and Ocean Resources, 2013 (8C, TR 8C-12, S11). Given initial viscosties of CLWB dilbit of less than 350 cSt at 15°C, the fresh material has higher penetration potential into substrate. Once the oil weathers to viscosities near 10,000 cSt, the penetration and retention potential is likely to resemble that of a bunker oil. Table 5.3.1 (Harper and Kory 1995) provides estimates of potential penetration and retention of dilbit in different substrate materials and for two general ambient energy conditions.

TABLE 5.3.1

INITIAL DILBIT RETENTION ESTIMATES

Setting	Substrate	Penetration* (cm)	Concentration (L/m^3)	Thickness (cm)	Volume in Sediment (L/m^2)	Volume in Surface Layer (L/m^2)	Total Volume (L/m^2)
Low Energy	Rock	0	0	0.5	0	5	5
	Rock w pebble, cobble veneer	1	100	0.5	1	5	6
	Pebble veneer	2	200	0.5	4	5	9
	Cobble or boulder veneer	10	100	0.5	10	5	15
	Sand or mud	1	300	0.5	3	5	15
	Rip Rap	30	100	0.5	30	5	35
	Marsh	1	300	1	3	10	13
	Wood	2	300	0.5	6	5	11
High Energy	Rock	0	0	0.5	0	5	5
	Rock with coarse veneer	20	200	0.5	40	5	45
	Boulder, cobble beaches (also includes few rip-rap sections)	30	200	0.5	60	5	65
	Sand w pebble, cobble or boulder	1	300	0.5	3	5	8
	Sand	1	300	0.5	3	5	8

Source: Coastal and Ocean Resources, 2013 (8C, TR 8C-12, S11)

Note: *The estimates assume that: (1) weathered dilbit will have < 1 cm of penetration in sands, < 5 cm in pebbles and < 10 cm in cobbles (Harper and Kory 1995); (2) retention of 300 L/m^3 for sand, 200 L/m^3 for pebble and 100 L/m^3 for cobbles (Harper and Kory 1995); and (3) a layer of weathered oil above the sediments of 1 cm for rock, sand, pebbles and cobbles.

5.3.2 Release to Water

Major factors influencing the behaviour of spilled oil to water include size of spill relative to receiving waterbody (*e.g.*, limited versus unlimited spreading), ambient temperatures (water and air), salinity, flow (turbulent, laminar, static), wind and wave energy, and materials in the waterbody such as vegetation, suspended sediment loads, organic matter, snow/ice, etc. Transport, spreading and evaporation are the more significant processes in the early stages of oil fate on water.

Weathering processes are similar for hydrocarbons in freshwater and marine environments, with some differences in the rate and extent at which the processes occur, given the differences in physical, chemical and hydrodynamics of the receiving environments. For example, the reduced density difference between weathered oil in freshwater compared to seawater can lead to more overwashed, submerged or sunken oil. The Gainford Study, however, showed that both AWB and CLWB dilbits maintained densities of less than 1 at least for up to eight days. Although oil may weather faster in an uncontained setting relative to the tank setting, the initial spill can be expected to float except in cases where the hydrodynamics of the receiving water are such that the oil becomes entrained through turbulent flow.

Oil released to water will be transported by that medium. Factors influencing transport include current speeds, size and form of the freshwater body, and potentially wind in calmer water settings (lakes, wetlands). As oils are transported within the water body, portions may adhere to substrate or vegetation and become stranded along shorelines (river and stream banks). To a limited degree, some residue may be retained within coarse stream or river bed substrates, as summarized in Table 5.3.1 (above). Changes in water level within freshwater, or tidal, systems may flood or inundate areas where hydrocarbons had stranded and refloat a portion of that material. Alternatively, falling water levels, or tides, may strand hydrocarbons along higher water lines or in overbank areas following flood events.

As oils are transported, normal weathering processes continue to change the character of the oil. The rate of spreading, dissolution and dispersion of oil would be less in the low turbulence environments of ponds and lakes compared to the Burrard Inlet or an estuary setting, but higher in highly turbulent rivers, where the oil would also move downstream and spread laterally. Ice formation in freshwater bodies would affect how the oil is partitioned and would have implications for cleanup strategies and persistence of the oil. Dilbit spilled under ice can be expected to have lower evaporation (and weathering) rates. Inland waters along the pipeline route tend to contain higher nutrient levels compared with seawater, which may enhance the rate of microbial degradation of hydrocarbon.

Understanding the behaviour of dilbit spilled to water is available from lab to mesoscale testing in tanks and from observations made following actual spills (Westridge and Marshall spills). The most significant observations are that the behaviour of dilbits tested or spilled are consistent with Group 3 and 4 crude oils: they float on water until oil densities change, through weathering and/or sediment uptake. As with most crude oils, dilbits may gradually overwash, become suspended in the water column, or sink depending on the degree of weathering and formation of OMAs. The Marshall spill, into Talmadge Creek and Kalamazoo River, resulted in oil transport down river with most oil remaining on the water surface. A portion of oil, mixed with river bank and/or suspended sediment, and did submerge and in places sank. Some of the dilsynbit from the Westridge delivery line release (AHS) reached the surface waters of Burrard Inlet where it was collected and cleaned from shorelines. Based on the rapid response, the dilsynbit was readily recoverable using conventional spill recovery equipment including booms and skimmers with a high percentage of recovered oil estimated to be greater than 90per cent. No submerged or sunken oil was noted during that incident.

5.3.3 Pipeline Spill Scenarios

In order to understand the fate and behaviour of spilled oil, representative scenarios (Section 7.0) have been selected and analyzed to assess potential effects. Key factors that may influence oil transport, fate and behaviour are listed in Table 5.3.2.

TABLE 5.3.2

EXAMPLE SCENARIOS USED TO DESCRIBE POTENTIAL FATE AND EFFECTS OF ACCIDENTAL RELEASES IN THIS APPLICATION

V6 Reference Kilometre (RK)*	Credible Worst Case Spill Volume (m^3)*	Receiving Environment	Key Factors in Oil Fate and Behaviour
309.0	2,700	Land/Water, Trail Creek, Athabasca River	Winter (snow/ice), ground saturation and soil permeability, local topography of streams, water levels in streams and rivers, currents/turbulence, suspended sediment loads, mixed sand-gravel bed and banks.
766.0	1,400	Land/Water, North Thompson River	Winter (snow/ice), ground saturation and soil permeability, vegetation, local topography and structures (road), water level of river, currents/turbulence, suspended sediment loads, mixed sand-gravel bed and banks.
1,072.8	1,300	Land/Water, Creek, Fraser River	Winter (snow/ice), ground saturation and soil permeability, local topography of streams, water levels in creeks and rivers, confined channel leading to braided river, turbulent flow, suspended sediment loads, mixed coarse sediment bed and banks.
1,167.5	1,250	Land/Water, Fraser River, Surrey	Ground saturation and soil permeability, local topography and manmade structures, suspended sediment loads, Fraser River estuary, seasonal flow and daily tides and salinity; variable composition bed and banks.

Note: *RK rounded to nearest 0.1; Spill volume rounded to nearest 50 m^3

6.0 POTENTIAL EFFECTS OF PIPELINE RELEASES

The NEB Filing Manual (2013) requires an Environmental and Socio-Economic Assessment to assess the environmental, socio-economic, and health effects of potential accidents and malfunctions. Although TMPL's 60-year operating history and the risk assessment provided in Section 3.1 demonstrate that the probability of a large pipeline spill is low, Aboriginal groups and the public-at-large consulted about this Project were concerned about catastrophic spills - those that are least likely but of highest consequence.

This section discusses potential environmental and socio-economic effects of credible worst case and smaller oil spills (accidental releases) from the pipeline and Westridge Marine Terminal. The spill effects methodology and discussion provided here and in Volume 8A for marine transportation differs from that adopted for routine pipeline, facility and tanker activities because spills represent low-probability, unpredictable events (see Section 3.1 for pipelines). Rather than estimating potential residual effects and significance for each element and indicator discussed for routine activities, spill evaluations identify the potential consequences of credible worst case spills using a structured risk assessment approach:

- This section (Section 6.0) provides a qualitative evaluation of potential environmental and socio-economic consequences based on evidence from past oil spills or documented in scientific reports and studies. This discussion considers a wide range of spill volumes (small to large) and locations throughout the proposed pipeline corridor. While it focuses on documented effects, it does not explicitly consider the way that emergency response approaches described in Section 4.0 could reduce these potential effects.

- More in-depth assessments of pipeline credible worst case oil spill scenarios are provided in Section 7.0 to supplement the qualitative evaluation of pipeline and facility spill effects provided in Section 6.0. The four representative scenarios evaluated for ecological effects all assume that accidental releases of CLWB (the representative oil described in Section 5.1), reach water bodies, as this represents the worst case for environmental effects. The general fate of oil in each scenario is described. A qualitative Ecological Risk Assessment (ERA) then assesses potential effects for a variety of aquatic and terrestrial ecological receptors based on the conservative assumption that initial response and clean-up of these hypothetical worst-case events would be limited.

- More detailed assessments of credible worst case and smaller spill scenarios at the Westridge Marine Terminal are provided in Section 8.0 to supplement the qualitative evaluation of pipeline and facility spill effects provided in Section 6.0. The potential ecological and human health effects of this representative scenario assume that CLWB is released during tanker loading. The general fate of oil is described for this scenario. A qualitative ERA then assesses potential effects for a variety of marine ecological receptors. Finally, a qualitative Human Health Risk Assessment (HHRA) assesses the prospect for people's health to be affected by a spill, including sub-populations known to show heightened sensitivity to chemical exposures, such as young children, the elderly and people with compromised health.

A more focused and detailed ERA and HHRA for the hypothetical Westridge Marine Terminal spill scenario described in Section 8.0 will be completed and submitted to the NEB in early 2014. These quantitative evaluations will verify conclusions provided in Sections 6.0, 7.0, and 8.0 and provide additional information to inform potential mitigation and emergency response actions.

6.1 Transport and Fate

Oils and refined petroleum products are complex mixtures of hydrocarbon compounds derived from naturally occurring geological formations. As described earlier in Section 5.2, when these compounds are released into the environment, various weathering processes work to break down the hydrocarbons into primarily carbon dioxide and water. Immediately following release, volatile hydrocarbons quickly (*i.e.,* on a time scale of minutes to days, depending upon the volatility of the compound and the environmental conditions) evaporate into the atmosphere, leaving heavier components of the oil mixture behind. As the oil weathers, its density and viscosity tend to increase. On a slower time scale (*i.e.,* days to weeks or longer), sunlight and microorganisms degrade hydrocarbons through photo-oxidation and biodegradation, which results in the gradual breakdown of larger molecules into smaller and simpler molecules that are themselves generally more amenable to further weathering. The general transport and fate of pipeline spills to land and water is described above in Sections 5.3.1 and 5.3.2.

Pipeline burial typically slows the spread of oil from a spill site. Depending on the rate of discharge from the pipeline (*e.g.,* a pin-hole leak versus a full-bore rupture) and the oil properties (*e.g.,* viscosity and pour point), oil may be forced to the surface through the pore spaces in soil. Frozen ground may limit the movement of oil from the spill site, and snow cover, if present, can also help to absorb or limit the spread of oil. In Burrard Inlet, if a spill were to occur during tanker loading, oil movement will be contained or reduced by the presence of a boom placed around each loading tanker prior to beginning any oil loading activities. Regardless, when a spill is detected, emergency response actions will be undertaken to reduce the effects on people and the environment. Containment, recovery, and clean-up actions undertaken would be specific to the affected receiving environment and include consideration of local sensitivities such as human health, public safety, priority ecosystem values, weather, and other site-specific considerations (Section 4.0).

6.2 Environmental Effects

Previous studies of oil spills in similar environments provide a basis for evaluating the fate, transport and effects of hypothetical pipeline spills of diluted bitumen resulting from the Project. Trans Mountain conducted a literature review to identify and acquire information on simulated and actual oil spills in the freshwater environment (estuarine environments are discussed in Sections 6.2.4 and 8.0 and marine environments in Volume 8A). From the scientific literature in peer-reviewed journals, government reports and technical documents, case studies of oil spills were selected using the following set of criteria:

- releases occurred in an onshore or freshwater environment;
- releases were located in a cold temperate zone or subarctic location; and
- spilled oil had similar physical and chemical properties to the hydrocarbons that will be transported by the Project.

Table 6.2.1 summarizes the case studies evaluated in the ERA. While it was not possible to match all three of the desired criteria for each case study, each case study was considered to have relevance to the Project (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

TABLE 6.2.1

CASE STUDIES CONSIDERED FOR ENVIRONMENTAL EFFECTS OF OIL SPILLS

Oil Spill	Location	Year	Spill Source	Oil Type	Volume (m^3)
Kalamazoo River	Michigan, US	2010	Pipeline Full-bore Rupture	Diluted Bitumen	3,200
Wabamun Lake	Alberta, Canada	2005	Rail Accident	Bunker “C”	712
East Walker River	California/Nevada, US	2000	Truck Accident	Bunker “C”	14
Pine River	BC, Canada	2000	Pipeline Full-bore Rupture	Light Crude	985
Yellowstone River	Montana, US	2011	Pipeline Full-bore Rupture	Light Crude	240
OSSA II	Bolivia, South America	2000	Pipeline Full-bore Rupture	Mixed Crude	4,611
DM932	Louisiana, US	2008	Barge Accident	Bunker “C”	1,070
Westridge	Burnaby, BC	2007	Pipeline Third Party Damage	Heavy Synthetic Crude	224

6.2.1 Air

Greatest effects on air quality occur immediately following an oil spill as a result of evaporation of volatile (light end) hydrocarbons. As noted in Section 5.2.1, light end components of C_1 to C_{12} will generally evaporate within the first 48 hours of exposure, with highest concentrations during the first 12 hours. Some of the most toxic components of the oil (benzene, toluene, ethylbenzene, xylenes or BTEX) fall into this range. Ground-level hydrocarbon concentrations would be highest in the immediate vicinity of an oil spill and would be dramatically reduced within a matter of hours, but elevated concentrations in air could continue for days to weeks depending on spill volume, oil characteristics, and spill environment. Exposure through secondary pathways also could occur if released hydrocarbons ‘fall-out’ or deposit from the air onto the ground and enter the ‘food chain’. When discussing ecological and human health effects, the potential effects associated with short-term and long-term exposure to hydrocarbons are referred to as acute and chronic effects, respectively. Human health effects that could occur following hydrocarbon evaporation, dispersion and inhalation are discussed in Section 6.3.2. Trans Mountain will conduct air quality modeling for specific spill scenarios to predict ground-level hydrocarbon concentrations for the Westridge Marine Terminal spill scenario and support quantitative ERA and HHRA studies to be submitted in early 2014 to verify conclusions and inform potential mitigation and emergency response planning.

6.2.2 Land and Upland Areas

The general transport and fate of pipeline spills to land and water is described above in Section 5.3.1. Effects on soil, soil invertebrates, upland vegetation and terrestrial wildlife could occur as a result of a spill that remains on land or upland areas. Near topographic high points, the portion of the total spill volume that results from the drain down of the line would be considerably less than what would occur near the bottom of a slope.

6.2.2.1 Soil and Groundwater

Hydrocarbon exposure to soil could result in soil contamination because of changes in physical, chemical and biological properties that could lead to deterioration of surface soil. After the initial period when the dynamic and static pressures from the spill site subside and the oil has spread out, hydrocarbon movement tends to slow. Oil in or on soil may move downward under gravity and spread horizontally in the subsurface as a result of capillary forces. If the oil encounters an impermeable or semi-permeable soil structure (*e.g.,* bedrock, impermeable or frozen soil, water table), downward movement would halt or slow, and the oil would spread laterally. Eventually the oil would stop moving and remain in local surface pools, be absorbed by vegetation and the litter layer, and be trapped in the void spaces within the soil structure. However, even when immobilized, hydrocarbons would remain subject to physical weathering and microbial biodegradation.

In Canada, clean-up criteria emphasize exposure pathways based on direct contact between contaminated soils and both plant roots and soil invertebrates. This emphasis is based on the need to preserve the principal ecological functions performed by the soil and the low bioaccumulation rates of petroleum hydrocarbons that would tend to limit exposure to birds and mammals. The Canada-Wide Standard for Petroleum Hydrocarbons in Soil (Canadian Council of Ministers of the Environment [CCME] 2008) provides benchmark values for the protection of plants and soil invertebrates exposed to hydrocarbons. Additional information on soil effects and response strategies is provided in the discussion of economic effects on agriculture and forestry in Section 6.3.1.

Without treatment or physical removal, oil would be a long-term source of groundwater contamination if it contacted the water table. For this reason, spill response efforts aim to reduce potential for groundwater contamination by removing pooled oil and affected surface materials as quickly as possible, and as deeply as needed to remove contamination so that aquifers are not affected. Residents of the Fraser River valley noted the importance of aquifers that provide domestic and community water sources. During detailed engineering, Trans Mountain will complete a pipeline risk assessment and evaluate the need for additional mitigation measures (*e.g.*, valve spacing, deeper burial or thicker-walled pipe) to reduce threats and associated risk to aquifers.

6.2.2.2 Upland Vegetation

Direct contact of vegetation with spilled oil could result in physical smothering, habitat modification and toxicity to shoreline and riparian vegetation, which could lead to ecosystem changes, including loss of overall diversity, rare species and rare ecological communities. In addition, response and remediation activities can disrupt habitat and provide an opportunity for invasion by non-native or weedy species.

Oiling of vegetation is expected to result in the death of annual plants, as well as the death of contacted foliage of perennials, shrubs and trees. Where contact is only with the stems of plants, particularly trees and shrubs, effects are usually minimal. Areas subject to heavy oiling may require aggressive remedial actions, so that all habitat is initially destroyed, then reconstructed and seeded with appropriate native seed mixes. Outside of these areas, recovery is usually allowed to proceed via natural attenuation following appropriate oil spill clean-up procedures to remove the most visible oiling. Annual plant communities typically recover from moderate oiling within 1 or 2 years while forest communities could require longer than 10 years.

6.2.2.3 Soil Invertebrates

Oil retained in soil, shorelines and floodplains may result in effects to soil invertebrates by:

- physically smothering organisms;
- exposing them to acute or chronic toxicity; and
- altering habitat.

Clean-up activities can also affect soil invertebrates. Following the 2010 spill of diluted bitumen into Talmadge Creek and the Kalamazoo River, oil and affected soils were excavated from the source area and along riverbanks and replaced with clean organic soils (Enbridge 2011).

The recovery time of soil invertebrate populations would be similar to the recovery time for upland and riparian vegetation. Oil spills have the potential to chronically affect soil invertebrates through soil contamination; however, remediation measures, including the removal of oiled soils, would promote recovery, whereby soil invertebrate populations would recolonize from neighbouring areas not affected by the spill.

6.2.2.4 Terrestrial Wildlife

The acute effects of oil spills on terrestrial wildlife result from direct contact with unweathered or slightly weathered oil, as well as ingestion or inhalation of hydrocarbons hours to weeks following an oil spill event. Chronic effects of oil spills on terrestrial wildlife include effects resulting from longer term (*i.e.,* weeks to months) exposure to chemical constituents of the spilled oil (such as PAH), which result from ingestion of contaminated surface water, soil, plants, or animal food types. Because petroleum hydrocarbons do not biomagnify up food chains (Environment Canada and Health Canada 2011), consumption of plants or other animals does not tend to constitute the major component of exposure to petroleum hydrocarbons for wildlife. Instead, toxic effects in birds, mammals, reptiles and adult amphibians primarily result from direct ingestion (*e.g.,* from grooming and preening of oiled feathers and fur, or ingestion of contaminated water, soil or sediment).

Oiling of wildlife can result in decreased survival and reproductive success through a number of different mechanisms, including loss of waterproofing and insulating characteristics of feathers or fur; toxicity resulting from the transfer of oil from feathers to eggs during incubation or shoreline oiling of reptile eggs; toxicity through the skin; ingestion of toxins via grooming or feeding; and reduced mobility (French McCay 2009, NRC 2003). Animals oiled above a threshold lethal dose would presumably die, given the remoteness of the areas considered, and the low probability that timely capture and rehabilitation would be possible. The likelihood of an encounter with oil would be different for each wildlife type depending on its behaviour. Scavengers and wildlife that obtain part of their diet from the oiled area would have the highest probability of becoming oiled. Evidence from the case studies indicates that few dead birds and mammals are usually found following inland oil spills. Among inland bird species, waterfowl appear to be the most sensitive because they are exposed to ponded oil or oil on water surfaces. Evidence from the Kalamazoo River case study indicate that amphibians and reptiles (particularly turtles) may be more likely to be exposed to spilled oil; however, most oiled reptiles captured after the Kalamazoo River spill recovered and were subsequently released alive (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3 Lakes, Rivers, and Streams

The general transport and fate of pipeline spills to water is described above in Section 5.3.2. Biological effects of oil spills to freshwater environments vary widely in relation to the characteristics of spilled oil, the physical dimensions and other characteristics of the receiving waterbodies, season, and other factors. If relatively fresh oil reaches water, oil spreads over the water surface forming an oil slick. Volatile hydrocarbons quickly evaporate into the atmosphere, and some of the lighter water-soluble components that would otherwise evaporate may dissolve in the water, resulting in concentrations that may be toxic to aquatic organisms. As oil is transported downstream, it can become stranded on shorelines and riparian vegetation, retained in the water column as droplets, or retained within coarse bed substrates. The rate of spreading, dissolution and dispersion of hydrocarbons would be slower in the low-turbulence environments of ponds and lakes compared to the Burrard Inlet or an estuary setting, but faster in highly turbulent rivers, where the hydrocarbon would also move downstream and spread laterally. As noted previously in Section 5.3, winter conditions change spill transport, fate and clean-up strategies.

The pipeline corridor crosses 474 defined watercourses and also passes close to important lakes and watercourses, such as Wabamun and Kamloops Lakes and the Athabasca, North Thompson and Fraser Rivers. Lakes or large reservoirs can act as retention basins for spilled oil and can retain a high percentage of spilled oil on their surface. The following summaries of potential oil spill effects on water quality, sediment quality, aquatic invertebrates, aquatic vegetation, shoreline and riparian vegetation and wetlands, fish and wildlife are drawn from a review of freshwater spill incidents (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3.1 Water Quality

After an oil spill in the aquatic environment, oil dispersed into the water column from the water surface has three general fates: 1) hydrocarbons dissolve or are entrained in the water column to be diluted and degraded by microbial action; 2) droplets dispersed by waves or turbulent conditions may coalesce into larger droplets and float back to the water surface; or 3) dispersed oil droplets may accumulate suspended particulate matter in the water column, becoming submerged oil.

As summarized below, and described in more detail in the Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1), the evidence shows that hydrocarbon concentrations in affected waterbodies are often high immediately following a spill and that water quality typically recovers within days to weeks following an oil spill into inland waters.

Within two months of the Kalamazoo River diluted bitumen spill, thousands of surface water samples had been collected and analyzed. The majority of these samples showed non-detectable concentrations of hydrocarbon constituents within five months after the spill, although two samples collected one year after the spill (May to August 2011) had benzo(a)pyrene concentrations above guidelines. Following the Wabamun Lake Bunker “C” oil spill, monitoring found few indications of hydrocarbon contamination in the lake water column within six weeks (Anderson 2006). Water quality monitoring conducted following the Bunker “C” oil spill into the East Walker River initially found total polycyclic aromatic hydrocarbons (TPAH) concentrations that were greater than fish embryo toxicity thresholds; however, within five months, dissolved TPAH in the water column had decreased to near background concentrations (Higgins 2002). Surface water samples showed that water quality had returned to pre-spill conditions within three weeks following the Pine River light oil spill (de Pennart *et al.* 2004). As expected, surface water samples collected in the days following the Yellowstone River light crude spill showed no petroleum-related compounds in the water column given the high flow conditions and rapid initial weathering of the oil (US EPA 2011a). Operators of downstream public drinking water systems, which drew water from the river, were notified of the spill; however, monitoring and testing of the water supply systems did not identify any exceedance of drinking water standards (US EPA 2011b). Modelling conducted for the Enbridge Northern Gateway Project found that after the acute phase of a spill (days to two weeks), hydrocarbon concentrations in river water rapidly declined so that they would not be expected to cause acute or chronic effects to aquatic biota (Stantec *et al.* 2012).

6.2.3.2 Sediment Quality

Once dispersed in the water column, oil droplets may accumulate enough suspended particulate matter to become as dense as or denser than water, and settle out of the water column onto the riverbed, usually in low-energy areas of silty sediment. Contaminated sediments have the potential to adversely affect water quality in sediment pore water, which can affect benthic invertebrates, rooted aquatic plants and developing fish eggs. Oil can also re-contaminate the water if the sediment is disturbed.

As summarized below, and described in more detail in the Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1), the evidence shows that oil can persist in silty aquatic sediments when deposited in slow-moving areas of water. Physical recovery of such oil is usually the preferred response option. Formation of OMA can increase the density of oil droplets in the water, increasing the fraction that becomes submerged; however, OMA formation is not usually a major process in inland oil spills because of limiting low salinity values, limiting suspended sediment concentrations, or both. OMA formation also has potential benefits as it maintains the dispersed characteristic of affected oil and enhances rates of biodegradation. Relatively little oil appears to become entrained into riverbed gravels, and such oil remains subject to weathering as water passes through the gravels, so that recovery of lightly or moderately oiled substrates will occur over a period of weeks to months.

Weathering of the oil released in the Kalamazoo River diluted bitumen spill resulted in sedimentation of a portion of the released oil in both Talmadge Creek and the Kalamazoo River. In Talmadge Creek, an extensive sediment recovery program removed most if not all of the oil (Enbridge 2013). In the Kalamazoo River, as the unrecovered oil was transported downstream in the water column, a portion of it incorporated suspended sediments. This oil became part of the river bedload and was transported toward geomorphological traps in the riverbed, such as silt deposits near in-stream dams (Enbridge 2013). Removal of the recoverable portion was ordered, principally in relation to the headponds of the Ceresco and Morrow dams. Removal of the remainder was considered likely to result in substantial further damage to the river, so it was to be left in place and monitored (US EPA 2013).

Following the release of Bunker “C” oil into Wabamun Lake, the released oil formed tar balls and other aggregates that tended to accumulate in reed beds instead of incorporating into the lakebed sediment (Anderson 2006). Measured TPAH sediment concentrations increased substantially three months after the East Walker River Bunker “C” oil spill; a phenomenon that was attributed to warming water temperatures and increasing mobilization of the Bunker “C” type oil, which solidified at low temperatures. However, five months after the spill TPAH sediment concentrations were generally below levels of concern (Higgins 2002). Most of the unrecovered oil from the Pine River light oil spill was considered likely to be located in river sediments or trapped in woody debris dams within the river, and while sediment hydrocarbon concentrations decreased over the next two years, they were still detectable in river sediments (de Pennart *et al.* 2004). The high flow conditions and rapid initial weathering experienced during the Yellowstone River light crude spill resulted in sediment hydrocarbon concentrations below detection limits or applicable standards (Montana Department of Environmental Quality 2013). Modelling results for the Enbridge Northern Gateway Project showed that in the absence of containment and recovery, hydrocarbon concentrations in sediment vary greatly as a function of distance from the release; river size (small or low-gradient rivers generally experience greater oil sedimentation than larger or high-gradient rivers); sediment characteristics (high organic content and fine-grained sediments trap and retain more hydrocarbons); and oil type (diluted bitumen and synthetic oil were both predicted to have the potential to load heavily to sediments) (Stantec *et al.* 2012).

6.2.3.3 Aquatic Invertebrates

Aquatic invertebrates exhibit a broad range of sensitivity to hydrocarbon exposure. Sensitive species such as stoneflies, mayflies and caddisflies would be expected to respond to dissolved hydrocarbon exposure at levels similar to sensitive fish species, while other invertebrates are expected to be more tolerant. The case studies show that although benthic invertebrate community biomass and diversity are affected by oil spills, they recover quickly. A study of unionid clams in the Kalamazoo River also provided evidence of mortality associated with both the oil spill and recovery efforts, although the clam communities did not appear to be extirpated by the spill. With the exception of a few long-lived species such as bivalves, most benthic invertebrates have annual life cycles and are well adapted for population recovery following natural or anthropogenic losses, typically recovering within one or two years. Examples are provided by the Kalamazoo, Pine, and East Walker river oil spills in the Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1).

6.2.3.4 Aquatic Vegetation

Hydrocarbons have the potential to affect aquatic vegetation by:

- physically smothering plants;
- exposing plants to acute or chronic toxicity; and
- altering habitat.

Where they occur, floating aquatic plants would be killed if contacted by an oil slick. Submerged aquatic plants would be less vulnerable, as they would be exposed primarily to dissolved hydrocarbons and are not considered likely to fall within the most sensitive groups of aquatic biota to such exposure. Emergent aquatic plants would generally be quite tolerant of moderate exposure to floating oil (such that a portion of the stem was oiled). Slow-moving rivers with soft sediments, as well as backwaters and riparian wetland areas, are all high-value habitats for aquatic plants, and such plants are important as habitat and as a source of food for many wildlife species. Other river types, however, may support very limited aquatic plant populations. For example, rivers draining mountainous areas in western Canada, where snow and glacial melt water dominates flow patterns, typically fall into this second group and are typically less productive. High water levels and flow rates during the summer months may cause erosion and scour in gravel/cobble riverbeds, which would damage delicate aquatic plant tissues. High turbidity levels also limit light penetration into the water column, further limiting the habitat quality for aquatic plants. As a result, aquatic plants are not expected to be an important part of the ecological structure of most of the larger rivers crossed or paralleled by the proposed pipeline corridor (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3.5 Shoreline and Riparian Vegetation and Wetlands

Shoreline and riparian vegetation are expected to be affected only in cases where rivers are in flood condition at the time of an oil spill, such that the riparian areas are overwashed by oil. Oiling of vegetation is expected to result in the death of annual plants, as well as the death of contacted foliage of perennials, shrubs and trees. Where contact is only with the stems of plants, particularly trees and shrubs, effects are usually minimal. Areas subject to heavy oiling, such as the initial overland flow path from a spill site to the aquatic environment, may require aggressive remedial actions so that all habitat is initially destroyed, then reconstructed and seeded with appropriate native seed mixes. Outside of these areas, recovery is usually allowed to proceed via natural attenuation following appropriate oil spill clean-up procedures to remove the most visible oiling. Annual plant communities typically recover from moderate oiling within one or two years. The Kalamazoo River diluted bitumen spill provides a good example (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3.6 Fish, Fish Eggs and Larvae

A hydrocarbon spill into a waterbody has a high potential to affect fish, fish eggs and larvae. Hydrocarbons may have lethal and non-lethal effects on aquatic biota, depending on the sensitivity of the species or life stage exposed, and the degree and duration of exposure. Hydrocarbons have the potential to affect fish species and the habitat upon which they depend, by:

- altering essential habitat;
- physically smothering organisms; and
- exposing fish to acute or chronic toxicity.

Three primary mechanisms of toxicity have been identified for fish and fish eggs exposed to hydrocarbons:

- Non-polar narcosis, whereby reversible exposure to and accumulation of hydrocarbons from the water column causes interference with intracellular functioning at a target lipid site, potentially causing death if a critical hydrocarbon concentration is exceeded in the target lipid. Salmonid fish are sensitive to the narcosis pathway, and small fish are more sensitive than large fish.
- Blue sac disease (BSD), whereby exposure to 3- and 4-ring PAH compounds results in a syndrome of cardiac, craniofacial, and/or spinal deformity and death in developing embryos. Sensitivity to BSD is greatest in newly fertilized eggs, and decreases with the hardening of the egg membrane, and with increasing developmental stage. Embryos of salmon species are among those more sensitive to BSD. Studies that have used oiled gravel packed into columns to generate dissolved PAHs for toxicity studies typically find that the weathering process results in a rapid depletion of water soluble PAHs, so that the potential for toxic effects on fish, fish eggs or embryos persists for only a few months.
- Phototoxicity occurs when PAHs present in biological tissues are exposed to natural light including ultraviolet light, and a resulting reaction enhances the toxicity of PAHs in the

tissues, potentially causing mortality or other harm to fish and other aquatic organisms. Although the potential for photo-enhancement of PAH toxicity exists and has been demonstrated in laboratory studies, it is not considered to be of sufficient importance in the natural environment to merit special consideration.

Few, if any, of the case studies provide direct evidence for effects on fish eggs in spawning gravels. Mortality of adult fish, however, is commonly but not always observed in association with inland oil spills. Factors that affect the probability of fish kills include: oil type (*i.e.,* the availability of more water-soluble constituents of the oil, and density and viscosity relationships that facilitate or impede the formation of oil droplets); the turbulence of the receiving environment (which helps to determine the extent to which oil droplets form and accelerate the dissolution of light hydrocarbons into the water); and the volume of water flowing in the receiving environment, relative to the volume of spilled oil (which may limit the maximum dissolved hydrocarbon concentration that can be achieved). High levels of fish mortality were observed in the Pine River spill case study, where a light oil was spilled into a relatively small, turbulent river. Some mortality was also observed in the East Walker and Kalamazoo River spills, although effects of flow regulation and cold winter weather were also implicated at the East Walker River.

Case study evidence shows that effects on fish, fish eggs and larvae are limited to the period of a few days to a few years after a release, depending on the factors noted in the previous paragraph, among others. Water concentrations are likely to decrease below effects thresholds within days to weeks after a spill and relatively little oil appears to become entrained into riverbed gravels, where it would remain subject to weathering so that recovery would occur over a period of weeks to months. In contrast, oil can persist for long periods of time in silty sediments when deposited in slow-moving areas of water. Although the uneven distribution of hydrocarbons in sediment could result in some areas where effects on developing fish eggs could occur, it is equally likely that areas with lower deposition would remain unaffected. As a result of natural weathering processes, concentrations of TPAH would decline to concentrations below effects thresholds. The most likely outcome, depending upon the type of oil spilled and the characteristics of the receiving environment, is that a portion of the reproductive capacity of a single year-class of fish could be lost, but that recovery would occur in subsequent years (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3.7 Wildlife

6.2.3.7.1 In-water Amphibians

Little information is provided by the case studies with respect to amphibians. However, it is assumed that in-water amphibians, such as eggs, juveniles or adults, will have sensitivity similar to that exhibited by sensitive fish and benthic invertebrate species (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3.7.2 Reptiles and Air-breathing Amphibians

Oil spills in the freshwater environment can result in lethal and sub-lethal effects to reptiles and air-breathing amphibians (*i.e.,* adult frogs, toads and salamanders). These effects can result from dermal exposure, chronic exposure from ingestion of contaminated food, and external oiling of reptile and salamander eggs by oil stranded on floodplains. Reptiles and air-breathing amphibians may also experience habitat loss and a decline in food availability through decreased prey abundance resulting from contamination.

Case study evidence suggests that reptiles (particularly turtles) and air-breathing amphibians are moderately to highly exposed to oiling following oil spills. However, although amphibians are presumed to be highly sensitive as a result of having permeable and delicate epidermal tissue, the epidermis of reptiles is impermeable, and in the case of turtles, largely armoured. Therefore, turtles would appear to have generally lower sensitivity to oil exposure than many birds or mammals. In the event of harm, recovery of amphibian populations would be fairly rapid (*i.e.,* one or two breeding cycles) because of their high reproductive potential. On the other hand, turtles tend to be long lived and have lower reproductive potential, so recovery from serious harm at the population level could take longer; potentially five years or more (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3.7.3 Birds

Oil spills to the freshwater environment can result in lethal and sub-lethal effects to birds. These effects can result from contamination of feathers (which reduces thermoregulatory capacity), inhalation of volatile organic compounds (VOCs), dermal exposure, ingestion of hydrocarbons during preening, chronic exposure from ingestion of contaminated food, and external oiling of bird eggs through contact with oily residues on the feathers of parent birds. Birds may also experience habitat loss and a decline in food availability through decreased prey abundance resulting from contamination.

Case study evidence indicates that few birds are usually found following inland oil spills; from tens to a few hundred mortalities occur in most cases, although the actual numbers are likely to be higher because the probability of finding all dead birds is low. Among inland bird species, waterfowl appear to be the most sensitive because of their high level of exposure to oil slicks on the surface of the water. Wading birds, shorebirds and birds that live around the water generally have lower exposure, although some birds such as dippers, which bob in and out of the water to take invertebrates, tadpoles and small fish, may be an exception. As was observed for grebes following the Wabamun Lake Bunker "C" oil spill, affected populations of wading birds and shorebirds may appear to rebound quickly because of immigration of birds from other unaffected areas.

The evidence from case studies also suggests that a wide variety of bird species would be exposed to oiling following a large oil spill into a river. While many birds would likely die undetected, experience based on various oil spill response operations suggests that waterfowl are among the most exposed birds, and that many bird species (such as wading birds and raptors) are less exposed and can tolerate light to moderate oiling without becoming incapacitated. Population recovery could take up to five years, depending upon the extent of the injuries, and the reproductive capacity of the affected population (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.3.7.4 Mammals

Oil spills to the freshwater environment can result in lethal and sub-lethal effects to terrestrial and semi-aquatic mammals. These effects can result from oiling of fur (which reduces thermoregulatory capacity), inhalation of VOCs, dermal exposure, ingestion of hydrocarbons during preening, and chronic exposure from ingestion of contaminated food. Mammals may also experience habitat loss and a decline in food availability through decreased prey abundance.

The evidence from case studies indicates that relatively few mammals are usually found dead following inland oil spills with tens, rather than hundreds, typically found. In part, this reflects the generally low sensitivity or exposure of many mammalian wildlife species. However, it may also reflect the low probability of finding all dead animals. The species most likely to be affected are those that actively swim in water (*e.g.,* muskrat, beaver, mink and otter), as opposed to those that occasionally visit streams and rivers or occupy riparian habitat (*e.g.,* bears, raccoons or ungulates). Mortality tends to be associated with the acute phase of the spill and may be caused by loss of insulative function in oiled fur, leading to hypothermia; or to ingestion of oil while trying to clean the fur, leading to haemorrhaging of the digestive tract; or to a combination of such stressors. Individuals and populations of smaller semi-aquatic mammal species (*e.g.,* muskrat, beaver, otter and mink) would be more likely to experience adverse effects. Population recovery could take up to five years, depending upon the extent of the injuries, and the reproductive capacity of the affected population (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

6.2.4 Burrard Inlet

Marine resources in Burrard Inlet could be affected by hydrocarbon spills at the Westridge Marine Terminal and nearby Project facilities that drain into this estuary.

An onshore pipeline spill in 2007 that resulted from third-party damage to the existing Trans Mountain Pipeline in Burnaby reached the Westridge Marine Terminal and Burrard Inlet via storm drains. This release provides directly applicable information about the fate, transport and effects of spills of heavy crude oil. As a result of the third-party damage to the existing Trans Mountain pipeline, approximately 100 m^3 of heavy crude oil reached Burrard Inlet, of which approximately 5.6 m^3 was not recovered. The spill affected 15 km of shoreline east of Second Narrows, concentrated in the area around and between the storm drain outfalls, from the Shell jetty (1 km west of the Westridge Marine Terminal jetty) to the western end of Barnet beach in Barnet Marine Park.

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. 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.

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 Cleanup 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

Marine Terminal 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 have been 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, including resident and juvenile salmon. PAH were not detected in starry flounder collected from Westridge and Barnet Marine Park.

Effects of the release were noted for some marine birds and mammals. Effects on marine birds were minimal, largely because overwintering birds had not yet returned from northern breeding ranges. Wildlife specialists captured 15 Canada geese, 2 gulls and 1 pelagic cormorant that were oiled; all but 2 Canada geese were cleaned and released. Three dead harbour seal pups were found following the incident but cause of death could not be determined and only one had signs of oiling. No other effects on marine mammals, including otters, were reported in Burrard Inlet.

Following clean up, recovery endpoints were established and a long-term monitoring program was initiated. As of 2012, recovery endpoints for water quality, intertidal sediment, intertidal vegetation and crab tissue PAH concentrations were achieved. Monitoring of mussel tissue PAH concentrations continues in the Westridge area, as results are confounded by additional PAH sources in this area.

Potential acute and chronic ecological effects of a hypothetical spill to Burrard Inlet during tanker loading at the Westridge Marine Terminal are discussed in Section 8.3.

6.3 Socio-economic Effects

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

- distance from human settlements;
- size and population density of nearby human settlements (*e.g.*, rural versus urban areas);
- particular patterns of land and resource use in the vicinity (*e.g.*, residential, commercial, agricultural, recreational, traditional); and
- key economic activities and sectors in areas that may be reached by the spill, in particular the presence of resource-based economic activities (*e.g.*, tourism, agriculture or subsistence farming, commercial fisheries, hunting/trapping, traditional livelihoods).

This section provides a summary of how credible worst case and smaller pipeline hydrocarbon spills can affect the health, economy and general well-being of communities along and downstream of the proposed pipeline corridor. Where applicable, it considers issues identified by Aboriginal communities, residents, land users, service providers and regulatory authorities. Because the location and extent of a spill cannot be predicted, precise socio-economic effects cannot be predicted. As such, this summary references past pipeline spills and other relevant incidents as examples of documented effects. Although there is considerable literature concerning the effects of hydrocarbon spills on the human environment, most is related to large, open-water marine releases. However, a growing body of literature shows that both positive and adverse effects can occur, influenced by the spill volume, location, nature of the resources affected, the extent of traditional and non-traditional activities in the area, and the duration of clean-up and recovery. The complexity of predicting socio-economic effects is a function of numerous factors including:

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

6.3.1 Economy

Pipeline spills can have both positive and negative effects on local and regional economies, both in the short and long term. Spill response and clean-up creates business and employment opportunities for affected communities, regions, and clean-up service providers. This demand for services and personnel can also directly or indirectly affect businesses and resource-dependant livelihoods. The net overall effect depends on the size and extent of a spill, the associated demand for clean-up services and personnel, the capacity of local and regional businesses to meet this demand, the willingness of local businesses and residents to pursue response opportunities, the extent of business and livelihoods adversely affected (directly or indirectly) by the spill, and the duration and extent of spill response and clean-up activities. Evidence from past incidents shows that economic activities would be affected if a large spill were to directly affect an HCA such as a community or water body. The magnitude of effects resulting from a small spill on land would be smaller.

6.3.1.1 Potential Economic Effects on Agriculture and Forestry

The pipeline industry and regulators have developed standardized approaches to avoid or minimize the long-term effects of land-based spills on landowners and resource tenure holders. Hydrocarbon exposure to soil could result in soil contamination because of changes in physical, chemical and biological properties that could lead to deterioration of surface soil. During spill response and remediation activities, efforts are made to avoid impacts by restricting movement of livestock and planting or harvesting in the affected area. Emergency response activities themselves can have secondary effects such as admixing, compaction and rutting, erosion and loss, and changes in moisture of soil, although the overall goal of response activities is to minimize adverse effects.

The NEB has published a *Remediation Process Guide* (NEB 2011) to aid companies in the event of a spill. Upon detection, the company must report the spill to the NEB and all applicable regulators (*e.g.,* the Transportation Safety Board and provincial or territorial authorities). The company is then required to complete an Environmental Site Assessment and, if remediation is required, a Remedial Action Plan. The most stringent clean-up criteria must be used for remediation of soil and groundwater (*i.e.,* the lower of provincial, territorial, or other limits developed by the CCME), and the site is considered clean once the NEB approves the Remediation Closure Report, which demonstrates that all applicable standards have been met. Although the Project will be regulated by the NEB, the involvement of other regulators, including provincial and municipal regulatory authorities, may be required depending on the applicable provincial and municipal legislation and regulatory requirements, circumstances of the spill and site location. For example, in BC, schedules contained in the Contaminated Sites Regulation (CSR) define the numerical standards for soil, water, vapour, and sediment that are used to determine if a site is contaminated. Following that determination, a site owner/operator has the option of either cleaning up to the numerical standards listed in the Schedules or cleaning up to risk-based (site-specific) standards (BC MOE 2009).

Soils along the pipeline route include agricultural soils and a range of non-agricultural soils, including wetlands and river sediments. Regardless of soil type, hydrocarbons in mineral or organic soil could affect vegetation and soil productivity. In non-agricultural areas, changes in soil quality related to contamination are assessed by comparison with CCME regulatory guidelines for hydrocarbons in soil and requirements for soil remediation, based on land use (CCME 2008). As noted above, appropriate provincial criteria may also apply. On agricultural land, or most types of non-agricultural land, hydrocarbons are adsorbed by soil or spread into the environment. The amount of adsorption or spreading is influenced by:

- the physical state of the soil (including texture and bulk density);
- the soil's cation exchange capacity;
- the soil's organic matter content; and
- the depth to restricting layers.

Clean-up and remediation is designed to return the affected area to baseline soil capability or quality. Prior agricultural or other land use can be restored in the short to medium term. Residual contaminated soils can be remediated in five years offsite, although the timeline varies based on the type of remediation, soil type, moisture content, level of soil contamination and other factors (Bailey and McGill 2001).

Contamination of water sources may require farmers to bring water in from out of the area to irrigate crops or to water livestock. Livestock may also come into contact with contaminated water, if waterbodies pass through pastoral land where they are grazing. The extent of these effects would depend on several factors, including volume, product and length of exposure.

In the event of effects on business or landowners, Trans Mountain will make initial mitigation efforts to contain the hydrocarbon release, followed by clean-up and restoration of the site. Landowners and businesses will be compensated for impacts directly resulting from a hydrocarbon release.

6.3.1.2 Potential Effects on Tourism/Recreation Industry

The pipeline corridor passes through or directly adjacent to several protected areas with management focused on recreation, including fishing, hunting, camping and hiking. During stakeholder meetings, some attendees expressed concern over the potential of a pipeline spill affecting tourism in these areas. For example, in Wabamun, attendees at stakeholder meetings indicated a strong connection in the local community between tourism and the quality of lake water.

Recreation areas and provincial parks along the proposed pipeline corridor include Wabamun Lake, Blue River Black Spruce Park, Finn Creek Park, North Thompson River Park, Lac Du Bois Grasslands Park, McQueen Creek Ecological Reserve, Coquihalla Summit Recreation Area, Coquihalla River Park, and Coquihalla Canyon Park. Recreationalists also use public lands along the corridor. A pipeline spill could affect the tourism/recreation industry both by directly disrupting the activities of tourists and recreationalists and by causing economic effects to recreation or tourism-based businesses.

In the event of a spill, recreational fishing, boating, and camping may be restricted or prohibited at the source site and downstream. These restrictions would typically apply during the active clean-up period, but could extend until affected resources are stable or recovered. As examples, an angling closure was implemented on the Pine River following the Pine River spill (BC MOE 2000a). Also, following a hydrocarbon spill into the Red Deer River, all sport fisheries in the river and tributaries upstream of the affected area were changed from restricted harvest to catch and release (*i.e.*, no harvest). This restriction has been in place for two years and will remain until monitoring information is sufficient to determine the status of sport fish populations in the affected area.

There may be a minor disruption to hunting activities in a spill and response area or other areas accessible only through this area. However, hunting in areas beyond the affected location would not be affected. There would be a minor disruption of trapping activities if a spill occurred in winter, the main season for trapping activities, and there were active trap lines in the area. Emergency response activities could result in further disturbance of furbearers in the areas immediately around response sites as a result of noise and traffic and thus reduced trapping success.

6.3.1.3 Potential Effects on Property

Pipeline spills can potentially damage homes, business/commercial establishments and infrastructure, resulting in costs for individuals and lost income for affected neighbourhood businesses. Municipalities may also incur infrastructure repair and replacement costs.

For example, third-party damage to the existing Trans Mountain Pipeline in Burnaby (the Westridge delivery line release) resulted in a release of approximately 1,100 m^3 of heavy crude oil with effects on surrounding properties (Transportation Safety Board of Canada 2007). Fifty homes and properties as well as a section of the Barnet Highway were affected. The crude oil seeped into the surrounding soil, storm drains, and sewer lines, and residential properties required restoration. KMC (along with the responsible parties and their insurers) spent millions cleaning up the spill, remediating the environment, and compensating those who suffered property damage as a result of the third-party strike to the pipeline. The Wabamun Lake Bunker “C” oil spill also caused property damage and about 20 people were evacuated from the area (Transportation Safety Board of Canada 2005). CN released a statement on October 18, 2005 that estimated the railroad's financial obligation for spill clean up to be $28 million, with remaining costs covered by insurance.

6.3.2 Human Health

Stakeholders at various community meetings and the Fraser Health Authority and Vancouver Coastal Health Authority expressed an interest in understanding the potential human health effects that could result following a spill in an urban environment. Urban areas are considered sensitive for human health effects because of their high population density and likely presence of sensitive individuals (*i.e.,* infants and young children, the elderly, pregnant women, and individuals with compromised health).

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

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

When discussing human health effects, the potential effects associated with short-term and long-term exposure to hydrocarbons are referred to as acute and chronic effects, respectively. In the event of a spill, the Trans Mountain ERP will be activated (see Section 4.0) and municipal, provincial and federal authorities responsible for the protection of public health will be notified. Evacuation of affected areas will occur if health and safety of the public is threatened and this will limit opportunities for short-term exposure to hydrocarbon vapours and potential for acute effects. Involvement of local, provincial and federal public health officials will also ensure that controls to limit long-term exposure and chronic effects potential will be implemented if warranted. Examples of such controls include closure of recreational or commercial fisheries, beach closures, the issuance of drinking water or food consumption advisories, and forced evacuation. This will limit long-term exposure from all pathways, including: inhalation; ingesting contaminated food, plants, or animals; drinking from a contaminated source; or incidental skin contact with hydrocarbons. The following case study findings are relevant. Based on monitoring results, a drinking water advisory was issued following the Pine River light oil spill (BC MOE 2000b) but no drinking water standards were exceeded by the Yellowstone River light oil spill (US EPA 2011c). A precautionary fish consumption advisory was issued following the Yellowstone River light oil spill although subsequent monitoring did not detect any petroleum hydrocarbon constituents in fish tissue and only traces of hydrocarbons in fish organs (Montana Fish, Wildlife and Parks 2011a,b). A fish consumption advisory was not considered to be necessary following the Kalamazoo River diluted bitumen spill based on monitoring results (Michigan Department of Community Health 2013).

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

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

Recent hydrocarbon releases in the lower mainland urban area from the Trans Mountain pipeline system provide evidence of health effects from actual incidents. Heavy crude oil from the 2007 Westridge Line third-party damage spill reached the residential neighbourhood via air dispersion and deposition and overland flow onto surrounding roads. Oil also travelled through the storm drain system and entered Burrard Inlet through two submerged storm sewer outfalls. The immediate area was evacuated to minimize exposure to hydrocarbon vapours and potential for acute effects. Between 2007 and 2008 Trans Mountain completed a remedial program that involved the excavation of contaminated soils in excess of the BC CSR Numerical Soil Standards. Subsequently an HHRA was conducted to determine the potential for residual soil contamination, as well as associated contamination present in groundwater and soil vapour, to pose a risk to human health.

The HHRA commissioned by KMC in 2010 following spill clean-up concluded that there were no long-term or chronic risks to human health (SLR Consulting (Canada) Ltd. 2010). This HHRA evaluated conditions of potential exposure pathways (soil, groundwater, soil vapour, ambient air, indoor air, grass, garden and fruit trees, hard surfaces, food fish, and beaches) and considered potential health risks to residents, park users, and fishers and health receptors. Pathways considered were inhalation, ingestion, and dermal contact.

A HHRA was also completed by KMC in 2009 following a release of oil at the Burnaby Terminal (SLR Consulting (Canada) Ltd. 2009). Spilled oil was retained onsite in the tank area and surface water retention pond but volatile hydrocarbons were released to the atmosphere. This HHRA evaluated potential health risks to residents and park users via inhalation of BTEX and H_2S and concluded that there were no acute risks to human health during the release.

6.3.3 Community Well-being

There is great diversity in the communities and regions that interact with the Project. Pipeline spills may adversely affect community well-being by affecting cultural and heritage resources, traditional lands, culture, and practices, and psychological well-being.

6.3.3.1 Cultural and Heritage Resources

Heritage resources could be affected by a spill in a number of ways. Product released from the pipe could interfere with the ability to interpret, date and analyze artefacts and preserved organic remains. Hydrocarbons can contaminate culturally modified trees (important both to the scientific and aboriginal community). Clean-up activities can disturb soils and contamination, removal or mixing of the artefacts and fossils and strata without scientific recording may result in permanent loss of critical information. In the case of a larger or more deeply buried site with high or moderate heritage value, the effects may be greater compared with smaller sites.

The shores of waterbodies are generally thought to have high potential for undiscovered historic and pre-contact archaeological sites of high and moderate heritage value. Paleontological resources at or below the high water mark downstream from a spill are most vulnerable.

6.3.3.2 Aboriginal Culture

The pipeline route will traverse the traditional territories of Aboriginal groups in Alberta and BC, as well as areas used to hunt, gather, and connect to the land. Accidental spills could affect traditional lands, culture, and practices by causing short to medium-term disruption to trail systems, waterways, landmarks and gathering areas or sites within or downstream of the spill area. Credible worst case and smaller spills could also result in mandated or voluntary interruption of subsistence trapping, hunting and gathering activities as a result of real or perceived changes in the quality of berries, medicinal plants, fish, and wildlife. A spill could also damage or affect use of spiritual and burial sites and sacred landscapes. Evidence from other spills demonstrates that Aboriginal peoples who depend on subsistence trapping, hunting and gathering activities will experience adverse effects if the resources that support their culture and lifestyle are affected (Palinkas et al. 1992, 1993; Gill et al. 2012).

6.3.3.3 Local Infrastructure and Services

In the event of a large spill, demands are likely to be placed on local, municipal, regional and independent emergency responders (fire, police, ambulance, disaster agencies), hospitals, clinics, social service and relief organizations, and local, municipal, regional and federal government officials and staff. For example, Medical Officers of Health for Vancouver and Fraser Valley received many inquiries following the Trans Mountain Pipeline Westridge delivery line release and Lower Mainland emergency responders expressed concern about demands that could be placed on them should a spill occur. Actual effects would depend on the size and nature of a spill, the number of people potentially affected and the availability of proper equipment and trained personnel. The engagement and training activities described in Sections 4.5 and 4.7 will confirm roles, responsibilities and the availability of trained personnel, response equipment, and services along the proposed pipeline corridor.

6.3.3.4 Psychological Effects

Stakeholder engagement activities conducted for the Project indicate that in almost every geographic region people are currently concerned about the effects an oil spill would have on human and environmental health. In the event of a spill, it is likely that this concern would evolve into stress and anxiety among some residents.

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

Regardless of the actual exposure, the possibility of exposure and the perception that contamination has occurred may be sufficient to cause anxiety or psychological effects in some people (Aguilera et al. 2010). Following the Trans Mountain pipeline Westridge heavy oil spill, 250 residents left their homes for a short period as a precautionary measure (Transportation Safety Board of Canada 2007). Anecdotal evidence also suggests that there were increases in medical service use as a result of the Trans Mountain Sumas tank farm spill.

Evidence from past incidents indicates that psychological effects would be most likely in the event of a large spill that reaches an HCA, such as a community, large waterbody, Indian Reserve or National Park (see Section 6.3.3) and that individuals and groups who would be at greatest risk of adverse effects include:

- those involved in the clean-up efforts;
- those who already have chronic physical or mental illness;
- those whose jobs and livelihoods are directly affected by the spill, including family members; and
- Aboriginal groups who participate in subsistence hunting and gathering and whose families rely on subsistence foods to support healthy diets.

7.0 HYPOTHETICAL PIPELINE SPILL SCENARIOS

This section provides more in-depth assessments of pipeline credible worst case oil spill scenarios to supplement the qualitative evaluation of pipeline and facility spill effects provided in Section 6.0. The four representative scenarios described below all assume that accidental releases of CLWB (the representative crude oil described in Section 5.1), reach waterbodies, as this is considered to be the worst case for environmental effects. The general fate of oil in each scenario is described. A qualitative ERA then assesses potential effects for a variety of aquatic and terrestrial ecological receptors.

Credible worst case scenario locations described in Section 7.1 were selected solely to provide worst case ecological consequences, independent of the hazard or threat of an incident at the selected locations. These scenario evaluations are used to illustrate the types of effects that might be observed as a result of a large spill, however unlikely. More importantly, information from the scenario evaluations will be important in planned undertakings to fully evaluate the existing ERPs and develop necessary amendments to further minimize the risk of environmental and socio-economic effects described here.

7.1 Pipeline Release Reaching Waterbodies

7.1.1 Release Scenarios

No hypothetical scenario can represent all potential environmental and socio-economic outcomes, but scenario-based hydrocarbon spill evaluations can provide decision makers and resource managers with a clearer understanding of potential effects pathways, the range of potential outcomes, vulnerable resources, and spill preparedness and response priorities and capabilities. Although TMPL's operating history and the risk assessment overview provided in Section 3.1 demonstrate that the probability of a large pipeline spill is low, Aboriginal groups and the public-at-large consulted about this Project were concerned about catastrophic spills - those that are least likely but of highest consequence. To address this concern, four worst case pipeline spill scenarios were identified, using CLWB as a representative crude oil (see Section 5.1).

The Upper Athabasca, North Thompson, and Lower Fraser Rivers were identified as appropriate areas for credible worst case scenario evaluations because they:

- reflect the range of waterbody and ecological conditions encountered by the pipeline corridor, when considered together;
- provide conditions whereby large spill volumes could credibly enter a watercourse and be carried downriver for some distance;
- include areas of expressed concern for spills by Aboriginal groups and the general public; and
- support evaluation of potential effects to environmentally sensitive resources (*e.g.*, salmon spawning grounds and shorebird feeding areas).

Four specific locations were selected where the pipeline corridor was near each river and a large spill could be expected to reach the river via overland flow or smaller tributaries. Trans Mountain commissioned an independent outflow analysis based on preliminary valve spacing to quantify the oil volume that would be released in the event of an incident. Modeling assumed a full-bore rupture with hole on the bottom of the pipe, which provided worst-case outflows for the purpose of the ERA; predicted outflows for the four locations were used. All outflow was assumed to reach the river and be available for transport downstream, except where noted in the scenario evaluations. Calculated volumes and other information on the pipeline spill scenario locations assumed for the ERA is summarized in Table 7.1.1. Subsequent Quantitative Risk Assessment full-bore volume rupture estimates show slightly different predicted release volumes. The ERA has not been modified to reflect this refinement as the ecological consequences described below are still valid.

Lake scenarios were excluded as a credible worst case scenario because lake systems generally provide a low energy environment which will ultimately reduce oil transport and increase recovery potential; and substantial information is currently available on the effects of heavy oil spills into lakes (*e.g.*, Wabamun Lake). Similarly, land scenarios were not specifically considered because past incidents demonstrate that their potential effects are generally more restricted in time and space than those from spills that reach flowing waterbodies (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]).

TABLE 7.1.1

PIPELINE SPILL SCENARIO LOCATIONS

Pipeline Location (RK)	Credible Worst Case Spill Volume (m^3)[1]	Smaller Spill Volume (65% of Credible Worst Case) (m^3)	Notes
309.0	2,700	1755	Athabasca River Scenario Location: approximately 10 km east of Hinton at a forest site approximately 200 m from the Athabasca River. Inland river system in Alberta: water supply, coldwater and coolwater fisheries and wildlife habitat for communities and Aboriginal groups.
766.0	1,400	910	North Thompson River Scenario Location: approximately 3 km north of Darfield at partially cleared lands approximately 100 m from the North Thompson River. Inland river system in BC: water supply, coldwater fisheries, and wildlife habitat for communities and Aboriginal groups.
1,072.8	1,300	845	Fraser River Near Hope Scenario Location: forested stream crossing site in west Chilliwack upstream from Trans-Canada Highway approximately 600 m from Vedder Canal, a Fraser River tributary. Coastal river system: water supply, coldwater fisheries, and wildlife habitat for communities, Aboriginal groups, recreation, and agriculture.
1,167.5	1,250	812.5	Fraser River and Delta Near Port Mann Bridge Scenario Location: approximately 500 m west of Port Mann Bridge at an industrial site on the south bank approximately 400 m from the Fraser River. Coastal river system and estuary: coldwater fisheries, shorebird habitat, and wildlife habitat for communities, Aboriginal groups, recreation, agriculture, and the commercial sector.

Note: 1 Volume rounded to nearest 50 m^3

7.1.1.1 Spill Scenario ERA Methods

The pipeline spill ERA (Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report [TR 7-1]) evaluates potential acute and chronic environmental effects to aquatic organisms and wildlife over the range of watercourses and flow conditions traversed by the Project. The qualitative ERA focuses on different groups of ecological receptors that might be exposed to spilled oil as a result of their habitats and life cycles as it is neither practical nor necessary to individually assess every receptor that may potentially be affected by a hypothetical spill (Table 7.1.1). ERA methods are described in detail in Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1). The key objectives of the ERA are to:

- Make predictions about the fate and transport of hypothetical releases of diluted bitumen into representative freshwater environments along the proposed pipeline corridor under a range of flow conditions.
- Assess the ecological effects that could result from hypothetical pipeline releases of diluted bitumen to the freshwater environments along the proposed pipeline corridor.
- Assess long-term recovery of the freshwater environment after a hypothetical spill of diluted bitumen resulting from the Project.

The environmental effects of a spill at the scenario locations described below are representative of the environmental effects that could result from a large oil spill at almost any location along the proposed pipeline corridor. In that context, the ecological receptors considered in the ERA are treated generically. They are not intended to be an exact representation of the species present at the hypothetical spill location; rather, they are representative of species that could be affected by an accidental oil spill affecting a watercourse or watercourses in Alberta or BC.

7.1.1.1.1 Ecological Receptors

The ecological receptors assessed in the ERA are shown in Table 7.1.2 and described in more detail below and in Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1).

The pipeline spill ERA evaluated emergent and submerged aquatic vegetation as a community. While individual species will vary in their sensitivity to hydrocarbon exposure, community metrics such as biomass, species richness and species diversity are indicators of environmental effects and recovery.

The aquatic invertebrate community provides many important links in aquatic and terrestrial food webs, as well as providing a substantial food resource for many fish, amphibian, and bird species. The ERA evaluated aquatic invertebrates as a community. While individual species will vary in their sensitivity to hydrocarbon exposure, community metrics such as biomass, species richness and species diversity are commonly used indicators of environmental effect and recovery.

For the qualitative ERA, fish were evaluated as an assemblage, represented by a generic salmonid species. Salmonids are among the more sensitive species to hydrocarbon exposure, and critical portions of their life cycle occur in fresh water. They are also among the species of highest management and public concern in both Alberta and BC.

The ERA assumed that in-water amphibians may be present within the spill area as they spend all or some of their life cycle in or around freshwater streams and rivers. Amphibian eggs and larvae are the most sensitive life stages, and these life stages were evaluated (along with fish eggs, embryos, and larvae) because of a general lack of toxicological information on the effects of low-level hydrocarbon exposure on amphibian eggs, embryos and adults.

The soil invertebrate community provides many important links in the terrestrial food web, particularly the processing of detritus, as well as providing a substantial food resource for many amphibians, reptiles, mammals and birds. Soil invertebrates were treated as a community for the ERA. While individual species will vary in their sensitivity to hydrocarbon exposure, community metrics such as biomass, species richness and species diversity are indicators of environmental effects and recovery.

TABLE 7.1.2

ECOLOGICAL RECEPTORS ASSESSED IN THE ERA

Aquatic Biota	Terrestrial Biota
Aquatic Vegetation Aquatic Invertebrates Fish and Fish Eggs and Larvae In-water Amphibians	Soil Invertebrates Shoreline Vegetation Reptiles and Air-breathing Amphibians Birds Mammals

Along most river reaches, shoreline vegetation consists of a mixture of forest trees, shrubs and sedges, with potential for emergent, floating or submerged aquatic plants including both vascular and non-vascular plants and fungi in the riparian and aquatic environments. Locally, however, agricultural or urbanized land may extend to the river edge. Depending upon the particular river and reach, the riparian zone may be narrow and confined by steep valley walls, or may represent an extensive zone of high biological richness and diversity, inundated seasonally or, less frequently, by high river flows. Shoreline and riparian vegetation was treated as a community for the ERA.

Reptiles such as turtles and snakes and amphibians such as toads are likely present in the rivers and streams or in nearby terrestrial habitat along portions of the pipeline route. The most likely interaction in the event of a spill would be with the Western painted turtle in riparian habitat or backwater ponds of portions of the Thompson and lower Fraser River drainages. This species was selected as the ERA indicator for reptiles and air-breathing amphibians.

A wide range of bird species inhabit the pipeline corridor, including a number of songbirds, raptor species, waterfowl, and waterbirds. The ERA evaluated individual species as indicators of effects on birds generally. Indicator species, selected for their tendency to occupy habitat and use resources associated with rivers and streams, were:

- bald eagle;
- Canada goose;
- great blue heron;
- mallard;

- spotted sandpiper; and
- tree swallow.

Much of the proposed pipeline corridor is surrounded by forested land that supports a wide range of mammal species. The ERA evaluated individual species as indicators of effects on mammals generally. Indicator species selected for their tendency to occupy habitat and use resources associated with rivers and streams were:

- grizzly bear;
- moose;
- muskrat; and
- river otter.

7.1.1.1.2 Exposure Pathways

An exposure pathway describes the movement of a COPC from a source to an eventual point of contact or intake (exposure) by an ecological receptor. Table 7.1.3 provides a summary of potential exposure pathways for the Project resulting from hypothetical pipeline spills of diluted bitumen into the freshwater environment.

TABLE 7.1.3

POTENTIAL EXPOSURE PATHWAYS RESULTING FROM HYPOTHETICAL PIPELINE SPILLS INTO THE FRESHWATER ENVIRONMENT

Source	Exposure Pathways	Exposure Pathways Carried Forward?	Justification
Oiled upland soils and vegetation	· Direct contact · Ingestion · Inhalation of vapours	No	The area of upland soil affected by overland flow is expected to be very small and isolated in comparison with the area of aquatic and riparian habitat that is potentially affected. Further, the ERA assumed upland soil will be remediated to Provincial Standards that are protective of all exposure pathways and receptors. Therefore, there will be no residual effects on receptors and this exposure pathway is not carried forward in the ERA.
Oiled shoreline or riparian soils and vegetation	· Direct contact · Ingestion · Inhalation of vapours	Yes	ERA expects shorelines will become oiled if downstream transport of oil slicks results in shoreline stranding. Such stranding becomes more likely to occur and to account for more oil mass if a spill occurs during a high flow event and receding flows allow oil to become trapped over a broad riparian zone. Ecological receptors may directly contact or ingest oiled soils. Although ecological receptors may inhale hydrocarbon vapours, dilution in the outdoor air is expected to result in negligible effects; therefore, the vapour inhalation pathway will not be carried forward in the ERA.
Accumulation of hydrocarbon COPCs by terrestrial plants, soil invertebrates, reptiles, air-breathing amphibians, mammals and birds	· Ingestion of shoreline plants · Ingestion of terrestrial invertebrates · Ingestion of reptiles/air-breathing amphibians · Ingestion of bird/mammal prey	Yes	Following shoreline oiling, soil invertebrates, reptiles, air-breathing amphibians, mammals and birds may accumulate hydrocarbon COPCs as a result of ingesting contaminated plant, invertebrate or animal foods.

TABLE 7.1.3

POTENTIAL EXPOSURE PATHWAYS RESULTING FROM HYPOTHETICAL PIPELINE SPILLS INTO THE FRESHWATER ENVIRONMENT (continued)

Source	Exposure Pathways	Exposure Pathways Carried Forward?	Justification
River water	· Direct contact · Ingestion · Inhalation of vapours	Yes	River water will become contaminated with floating, dispersed, overwashed or dissolved hydrocarbon COPCs if spilled oil enters the aquatic environment. Ecological receptors may come into direct contact with or be exposed to oil or oily water, or may ingest contaminated water. Although ecological receptors may inhale hydrocarbon vapours at the water surface, dilution in the outdoor air is expected to result in negligible effects; therefore, the vapour inhalation pathway will not be carried forward in the ERA.
River sediment	· Direct contact · Ingestion · Direct contact with pore water	Yes	Some river sediments may become contaminated by trapping droplets or globules of dispersed or overwashed oil, by adsorbing dissolved oil, or if oil becomes mixed with denser materials such as sand, gravel or suspended sediment, resulting in the physical submergence of oil. Ecological receptors may come into direct contact with oil in sediment, or may ingest contaminated sediments. In addition, ecological receptors such as fish eggs and embryos or benthic invertebrates may be exposed to sediment pore water that contains dissolved hydrocarbon COPCs.
Accumulation of hydrocarbon COPCs by aquatic plants, aquatic invertebrates, in-water amphibians, fish, mammals and birds	· Ingestion of aquatic plants · Ingestion of benthic invertebrates · Ingestion of in-water amphibians · Ingestion of fish	Yes	Following release of oil to a river, aquatic invertebrates, in-water amphibians, fish, mammals and birds may accumulate hydrocarbon COPCs as a result of ingesting contaminated plant, invertebrate or animal foods.

Acute (short-term) effects of oil spills are evaluated assuming the conservative assumption of no mitigation. While evidence from past spills demonstrates that effective oil spill response efforts like those described in Section 4.0 can be implemented, this conservative assumption reflects the fact that spills could occur at remote locations, and that negative environmental effects could occur within 24 hours of a large oil spill occurring. Chronic effects of oil spills are evaluated assuming that SCAT and other remedial measures would be applied in the days and weeks following a spill, and until additional efforts would cause more harm than good, based on net environmental benefit analysis. The ERA also assumes that remedial efforts remove most visible oil from shorelines and riparian zone soils, although a residual hydrocarbon loading on soils of up to 1 kg/m^2 might be expected. The chronic assessments also assume that submerged oil, if any, is not recovered from the riverbed.

Qualitative ERA conclusions are expressed in terms of the spatial extent of effects and time to recovery of the environmental effects for each ecological receptor (considering the beneficial effects of potential mitigation such as oil spill recovery and restoration efforts). Qualitative magnitude (or degree of injury) ratings were based on the following definitions:

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

7.1.2 Scenario 1: Athabasca River near Hinton, Alberta, RK 309.0

The hypothetical full bore rupture spill scenario involves a release of 2,700 m^3 of CLWB at RK 309.0. The spilled oil would flow overland a short distance before entering Trail Creek, a tributary to the Athabasca River. Trail Creek is a first-order (headwater) watercourse that does not provide fish habitat in its upper reaches, but likely does support fish in its lower reaches prior to entering the Athabasca River. Wetted width of the Athabasca River at this location is 100 to 300 m, with gentle meander and cobble-gravel banks and bed. Flows are strongly seasonal, ranging from approximately 500 m^3/s in June (during freshet), to 32.5 m^3/s at low flow in March.

This spill scenario was evaluated with reference to four case studies described in the Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1): the Kalamazoo River spill, since that oil spill involved a similar form of diluted bitumen; the Yellowstone River oil spill, as that river has similar gradients to the Athabasca River near Hinton; the modeling conducted by the Enbridge Northern Gateway Project for the Athabasca River near Whitecourt, Alberta, as this was a nearby reach of the Athabasca River, with very similar characteristics; and the modeling conducted by the Enbridge Northern Gateway Project for the Morice River, as that river also has similar overall gradients to the Athabasca River.

The ERA scenario evaluation did not consider the probability of occurrence of the spill nor the various design, engineering, maintenance, inspection and other preventative programs that Trans Mountain will have in place to reduce the likelihood of spills occurring, the details of which can be found in Section 2.0. Rather, this evaluation assessment was performed based on the premise that the spill had occurred despite these preventative programs. In addition, the evaluation did not consider the full application of emergency response approaches and spill response resources described in Section 4.0, a conservative, and unrealistic, assumption based on evidence from past spills.

Three environmental conditions were considered for this spill scenario:

- Winter conditions between December and March, with ice cover on the river and snow cover on the land. Air temperatures were assumed to be below the freezing mark, and the river flow in the low range (50 m^3/s or less).
- Summer conditions between June and August, with air temperatures in the warm range (15 to 25ºC). The river was assumed to be in freshet, with flow greater than 500 m^3/s.
- Spring or fall conditions between April and June or September and November. The river flow was assumed to be in a moderate range, at around 200 m^3/s, and the air temperatures cool, between 0 and 15ºC.

The following summary of oil spill fate and effects for these three conditions is based on Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1).

7.1.2.1 Winter Conditions

7.1.2.1.1 Assumed Fate

Under winter conditions, overland flow of the oil is slowed, and some of the oil is absorbed into the snowpack in the Trail Creek gully bottom. Following local terrain, oil would reach Trail Creek, and then follow the thalweg of the tributary down to the Athabasca River. Water flow in Trail Creek is negligible because of its small size during winter conditions. The low temperatures also help to limit the flow of CLWB as its viscosity increases as it cools. Although the gully bottom containing Trail Creek is heavily oiled, only a small amount of the CLWB is assumed to reach the Athabasca River. This spreads out on the ice, but the density of the oil is less than that of water and the increased viscosity minimizes volumes that would penetrate cracks in the ice, and down-river transport of the CLWB is negligible. Under these circumstances, the environmental effects of spilled oil may be minimized because most of the oil is recoverable.

7.1.2.1.2 Potential Effects

Table 7.1.4 summarizes the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group for the Athabasca River spill scenario during winter. During the winter season, most migratory birds would be at their wintering grounds, so acute effects on raptors, waterfowl, wading and shorebirds would be limited. Some mammals such as bears would be hibernating, although others such as moose, muskrat and river otter remain active year-round. Because of the limited spatial extent of physical oiling, effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation, would likewise be limited in spatial extent. However, oil spill recovery effects on the overland flow path and affected areas of the unnamed tributary would be substantial, likely requiring extensive excavation causing destruction of affected habitat, followed by reconstruction and restoration of habitat. Depending upon the receptor group affected, this process of restoration and recovery could take anywhere from 18 months to 5 years.

Oil spill recovery efforts would still result in environmental effects along the overland flow path, and in Trail Creek, but effects on the Athabasca River would be reduced or avoided. Many of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* migratory birds). The spatial extent of oil spill effects would therefore be limited to the overland flow path and the lower portion of Trail Creek, on the order of several hundred metres, where primary environmental effects would be associated with oil spill recovery efforts. Recovery of the terrestrial environment and Trail Creek would take approximately 18 months to 5 years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer

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TABLE 7.1.4

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent of Effects	Effect Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Aquatic vegetation is not contacted by spilled oil.	Low. Aquatic vegetation is not actively growing at the time of the spill, and ice cover prevents contact between the spilled oil and aquatic vegetation. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek.	Spilled CLWB is prevented from entering, or is recovered from the frozen river surface, without materially affecting aquatic vegetation.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of Trail Creek and the river. Effects on the benthic community of the tributary are substantial, affecting the entire tributary as a result of oil spill recovery activities. Effects on the benthic community of the river are Low, because most of the spilled oil is recovered.	High although localized in Trail Creek. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek. Low in the Athabasca River.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the benthic invertebrate community begins about 18 months after the spill, and is effectively complete after 30 months. Recovery of the benthic community in the Athabasca River is complete within 6 months of the spill.
Fish and Fish Eggs	Few fish are present in the tributary, because of winter low flow conditions. Fish are present in the river, and salmonid eggs may be present in pockets of suitable habitat in the river bed downstream from the oil spill location. However, effects on fish and fish eggs are Low, because most of the spilled oil is recovered.	Low, because the fish habitat present in Trail Creek is minimal during the winter because of low flow conditions, and very little oil contacts the river water. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins about 18 months after the spill, and is effectively complete after 30 months. Recovery of fish habitat in the Athabasca River is complete within 6 months of the spill.
In-water Amphibians	Juvenile amphibians are not present in the winter season. Adult amphibians may be overwintering in the sediments of Trail Creek, which is wholly affected, or in low energy areas of the Athabasca River, which is minimally affected.	Low, because overwintering amphibians will be buried in stream sediments, and are unlikely to be directly contacted by the spilled oil. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 18 months after the spill, and is effectively complete after 30 months. Recovery of amphibian habitat in the Athabasca River is complete within 6 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River, but annual plants are not present except as seeds, and perennial plants, shrubs and trees are in a dormant state. Little if any shoreline habitat of the Athabasca River is affected.	Low, because the plants are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near Trail Creek.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River, but soil invertebrates are in a dormant state. Little if any shoreline habitat of the Athabasca River is affected.	Low, because the soil invertebrates are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near Trail Creek.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	Not likely to be directly affected as they hibernate during winter.	Low, because the probability of a grizzly bear den being located within the overland flow path or proximal to Trail Creek is small. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Moose	Potentially affected but localized, as Trail Creek could provide sheltering habitat during cold periods. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range and oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Muskrat	Potentially affected but localized, as the lower reaches of Trail Creek could provide suitable habitat, and muskrat remain active through the winter. However, effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting Trail Creek. Disturbance caused by oil spill recovery activities would also eliminate their habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
River Otter	Potentially affected but localized, as otters remain active through the winter. Most otter habitat would be present around openings in the river ice, where access to fish is present. Effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near Trail Creek or its confluence with the Athabasca River. Disturbance caused by oil spill recovery activities would also eliminate their habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.

TABLE 7.1.4

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA (continued)

Athabasca River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent of Effects	**Effect Magnitude**	**Time to Recovery**
Birds			
Bald Eagle	Not likely to be affected as the winter range is generally south of the pipeline right of way in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Not likely to be affected as the winter range is generally south of the pipeline right of way in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Not likely to be affected as the winter range is generally south of the pipeline right of way in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	Not likely to be affected as the winter range is generally south of the pipeline right of way in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Not likely to be affected as the winter range is generally south of the pipeline right of way in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Not likely to be affected as the winter range is generally south of the pipeline right of way in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Western painted turtle range is not likely to extend to the Athabasca River. Adult amphibians could potentially be overwintering in the sediments of Trail Creek, which is wholly affected, or in quiescent areas of the Athabasca River, which is minimally affected.	Low, because overwintering amphibians will be buried in stream sediments, and are unlikely to be directly contacted by the spilled oil. However, disturbance caused by oil spill recovery activities would also eliminate their habitat.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 18 months after the spill, and is effectively complete after about five years. Recovery of habitat in the Athabasca River is complete within 6 months.

7.1.2.2 Summer Conditions

7.1.2.2.1 Assumed Fate

Under summer conditions, the spilled CLWB flows overland to the Trail Creek gully, resulting in oiled ground-level vegetation, some adsorption of oil on vegetation and the soil litter layer, and some penetration to soil. Most of the spilled CLWB, however, enters Trail Creek and flows rapidly towards the Athabasca River. The short-term loading of oil to Trail Creek is large (approximately 2,500 m^3 over several hours), in comparison with the water flow rate (<0.1 m^3/s), and so the aquatic habitat in the tributary is severely affected, and oil overflows the banks of the tributary causing oiling of the riparian habitat. About half of the spilled oil reaches the Athabasca River, which is at or near flood stage, entering on the south shoreline, and is advected downstream by the quickly moving water. Because the oil is unweathered and has low viscosity and density less than that of the water, it spreads across the water surface and is susceptible to entrainment in the water column because of turbulent flow conditions. Floating oil is trapped along shorelines, particularly where river flow is above the banks and vegetation is flooded. Unweathered oil that is entrained into the water column in the early stages enhances the dissolution of BTEX and other light-end hydrocarbons into the water column. Over time, much of the entrained oil re-surfaces, although some has to potential to interact with suspended sediment to become neutrally buoyant or denser than the water, resulting in submergence.

As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of this oil becomes submerged in low-energy areas such as eddy zones behind islands and in backwaters. Although the water of the Athabasca River is somewhat turbid, the suspended sediment load is not particularly high and the water has no appreciable salinity; thus OMA formation is not a dominant factor in the fate of the spilled oil. Most of the spilled and stranded oil has weathered, largely because of evaporation along the shoreline and in riparian zones within 35 to 50 km of the spill location. A small amount of oil is advected farther downstream as dissolved and entrained oil droplets, or as OMA that moves with bedload until being deposited in quiescent areas, potentially up to 100 km downstream.

7.1.2.2.2 Potential Effects

Table 7.1.5 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group for the Athabasca River spill scenario during summer. Effect magnitude on the overland flow path and riparian areas of Trail Creek is high but localized, and is addressed by physical remediation and reseeding of affected areas. Effects on aquatic receptors, including vegetation, invertebrates, fish and amphibians, are high but localized in Trail Creek, and generally moderate to low in the Athabasca River. Medium-magnitude effects are observed within the first 10 km downstream from Trail Creek, and low magnitude effects are observed between 10 and 35 to 50 km downstream. Most oil becomes stranded along shorelines and in riparian areas where vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flow path and along Trail Creek, but medium to low along the Athabasca River because of the patchy distribution of the oil. Whereas the overland flow path and Trail Creek are subject to intensive oil spill clean-up which is initially destructive to habitat, riparian areas along the Athabasca River are likely to be remediated with less intrusive methods and a greater emphasis on natural attenuation of spilled oil residues at low levels. Environmental effects on mammal populations are greatest for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 50 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears and moose, effects are expected to be moderate, and may arise from disturbance of habitat, as well as from oiling of fur or ingestion of oil. For birds, guilds such as ducks and geese are considered to be most exposed to spilled oil, and effects on these species could be high (including mortality) to moderate, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience moderate effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 7.1.5

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Aquatic Receptors			
Aquatic Vegetation	Submerged, floating and emergent aquatic vegetation in Trail Creek is likely to be killed by the flow of oil at the time of the spill, or by oil spill recovery efforts following the spill. Very little aquatic vegetation is present in the Athabasca River because of the high summer flows and cobble-gravel nature of most of the river bed. Effects are therefore likely to be limited to Trail Creek.	High in Trail Creek, as a result of clean-up activities which would result in the physical destruction, and then reconstruction of aquatic habitat. Low in the Athabasca River, because of the scarcity of aquatic vegetation generally.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the aquatic plant community begins about 12 months after the spill, and is effectively complete after 5 years. Recovery of the aquatic plant community in the Athabasca River is complete within one year of the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of Trail Creek and the river. Effects on the benthic community of the creek are substantial, affecting the entire creek as a result of oil spill recovery activities. Effects on the benthic community of the river range from moderate, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations near the confluence with the tributary, to Low, in downstream areas.	High in Trail Creek, with direct effects of oiling and hydrocarbon exposure as well as oil spill recovery activities resulting in the physical destruction, and then reconstruction of aquatic habitat in the creek. Medium to Low in the Athabasca River, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the benthic invertebrate community begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of the benthic community in the river is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer to recover fully.
Fish and Fish Eggs	The lower reaches of Trail Creek may provide rearing habitat for various fish species, and such fish would likely be killed as a result of high dissolved hydrocarbon concentrations at the time of the spill. Turbulent flow in the Athabasca River further enhances dispersion and dissolution of hydrocarbons in the reaches below the confluence, so that fish mortality is likely within 10 km of the spill location, but unlikely with increasing distance.	High in Trail Creek, because of the confined nature of the habitat and the lack of dilution water, as well as the physical effects of oil spill clean-up on fish habitat in the tributary. Medium in the first 10 km of the river, and Low in more distant reaches, because of the rapid weathering of oil. The high summer flow of the river also provides abundant dilution water, which limits the dissolved concentrations.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of fish habitat in the Athabasca River is complete within 12 months of the spill.
In-water Amphibians	Both adult and juvenile amphibians are likely present in Trail Creek during the summer season, and could be killed. Adult amphibians in shoreline habitat as well as in quiescent areas of the Athabasca River could be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration, likely within the first 10 km, but potentially up to 35 to 50 km downstream.	High in Trail Creek, which likely provides good breeding and rearing habitat for amphibians. High in shoreline habitat of the Athabasca River within 10 km of the spill site, and Medium in areas up to 35 to 50 km downstream, because of the more patchy spatial distribution of stranded oil, and decreased dissolved hydrocarbon concentrations.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of amphibian habitat in the Athabasca River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Similar effects are observed in the riparian areas of the Athabasca River, where high river flows cause flooding and terrestrial vegetation is contacted by oil.	High on the overland flow path and in Trail Creek, as a result of direct effects of oil on vegetation, and as a result of oil spill recovery efforts which result in physical destruction of habitat. Medium to Low in the riparian areas of the Athabasca River, because of the patchy distribution of oil, and with increasing distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the Athabasca River requires about two years, once visible oil has been recovered.
Soil Invertebrates	Soils are oiled along the overland flow path to Trail Creek, and along the creek to the river. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Effects on soil invertebrates are lower in riparian zones of the Athabasca River, in part because of the patchy nature of deposition. The heaviest oiling is noted in the first 10 km downstream from the spill location, but some oiling of riparian areas is observed as far as 35 to 50 km downstream.	High on the overland flow path and in Trail Creek, as a result of direct effects of oil on soil invertebrates, and as a result of oil spill recovery efforts which result in physical destruction of habitat. Medium to Low in the riparian areas of the Athabasca River, because of the patchy distribution of oil, and with increasing distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the Athabasca River requires about two years, once visible oil has been recovered.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 35 to 50 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by bears.

TABLE 7.1.5

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA (continued)

Athabasca River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Moose	Oiling of individual moose could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 35 to 50 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil with vegetation or as a result of grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by moose.
Muskrat	Any muskrat present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Muskrat present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 35 to 50 km.	Effects on muskrat would be High, including mortality of individuals inhabiting Trail Creek and up to 35 to 50 km downstream in the river. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Muskrat populations recover as a result of re-colonization of affected areas from adjacent unaffected areas, likely within 5 years.
River Otter	Any otters present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Otters present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 35 to 50 km.	Effects on otter would be High, including mortality of individuals inhabiting Trail Creek and up to 35 to 50 km downstream in the river. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Otter populations recover as a result of re-colonization of affected areas from adjacent unaffected areas, likely within 5 to 10 years.
Birds			
Bald Eagle	Bald eagle would be present during summer, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 35 to 50 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 35 to 50 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 35 to 50 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 35 to 50 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 35 to 50 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 35 to 50 km from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult amphibians could be present in Trail Creek, or in riparian habitat or backwater areas along the Athabasca River. Such animals could be exposed to spilled oil for a distance of up to 35 to 50 km from the spill location.	High to Medium. Amphibians present in Trail Creek could be smothered by spilled oil or die from exposure to volatile hydrocarbons. Amphibians along the shoreline of the Athabasca River would be less exposed, and effect magnitude would decline with decreasing exposure. The risk of acute lethality would be greatest in the first 10 km downstream from Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 24 months. Recovery of habitat in the Athabasca River is complete within 12 months of the spill.

7.1.2.3 Spring or Fall Conditions

7.1.2.3.1 Assumed Fate

With spring and fall conditions, the spilled CLWB flows overland to the Trail Creek gully, resulting in oiled ground-level vegetation, some absorption of oil on vegetation and the soil litter layer, and some penetration into soil. Most of the spilled CLWB, however, enters Trail Creek and flows rapidly towards the Athabasca River. The short-term loading of oil to Trail Creek is large (approximately 2,500 m^3 over a period of several hours), in comparison with the water flow rate (<0.1 m^3/s), and so the aquatic habitat in the tributary is severely affected, and oil overflows the banks of the tributary, causing oiling of the riparian habitat. Most of the spilled oil reaches the Athabasca River which is flowing normally, within its banks. The oil enters the river on the south shoreline, and is advected downstream by the moving water. Because the oil is unweathered and has low viscosity and density less than that of the water, it spreads across the water surface. Floating oil is trapped along shorelines, particularly on gravel and cobble exposures, but does not penetrate these deeply because of the shallow slope of the shorelines and the presence of the water table at or near the surface. The river flow is slower and less turbulent than under summer conditions, and owing to the cooler temperatures the turbulence of the river flow is less likely to entrain droplets of the oil in the water. As a result the concentrations of BTEX and other light-end hydrocarbons in the water column are lower, but the surface slick tends to be thicker. As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of the oil becomes submerged in low energy areas such as eddy zones behind islands and in backwaters. Although the water of the Athabasca River is somewhat turbid, the suspended sediment load is not particularly high, little oil is entrained in the water column, and the water has no appreciable salinity; thus OMA formation is not a dominant factor in the fate of the spilled oil. Most of the spilled oil has weathered, largely as a result of evaporation or has been stranded along the shoreline within 25 km of the spill location. A small amount of oil is advected farther downstream.

7.1.2.3.2 Potential Effects

Table 7.1.6 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group from the Athabasca River spill scenario during spring or fall. Effect magnitude on the overland flow path and riparian areas of Trail Creek is high but localized, and is addressed by physical remediation and reseeding of affected areas. Effects on aquatic receptors, including vegetation, invertebrates, fish and amphibians, are high but localized in Trail Creek, and generally moderate to low in the Athabasca River. Medium effects are observed within the first 10 km downstream from Trail Creek, and low-magnitude effects are observed between 10 and 25 km downstream. Most of the oil becomes stranded along shorelines, but there is little contact with riparian areas because of the moderate water level in the river. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flow path and along Trail Creek, but low along the Athabasca River as a result of the low level of exposure. The overland flow path and Trail Creek are subject to intensive oil spill clean-up which is initially destructive to habitat. Environmental effects on mammal populations are greatest for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 25 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears and moose, effects are expected to be moderate, and may arise from disturbance of habitat, as well as from oiling of fur or ingestion of oil. For birds, guilds such as ducks and geese are most exposed to spilled oil, and effects on these species could be high (including mortality) to moderate, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience moderate effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the spring and fall could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 7.1.6

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Spring and Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Aquatic Receptors			
Aquatic Vegetation	Submerged, floating and emergent aquatic vegetation in Trail Creek is likely to be killed by the flow of oil at the time of the spill, or by subsequent oil spill recovery efforts. Very little aquatic vegetation is present in the Athabasca River, because of the high summer flows and cobble-gravel nature of most of the river bed. Effects are therefore likely to be limited to Trail Creek.	High in the creek, because clean-up activities would result in the physical destruction and subsequent reconstruction of aquatic habitat. Low in the Athabasca River, because of the general scarcity of aquatic vegetation.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the aquatic plant community begins about 12 months after the spill, and is effectively complete after 5 years. Recovery of the aquatic plant community in the Athabasca River is complete within one year of the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of Trail Creek and the river. Effects on the benthic community of the tributary are substantial, affecting the entire creek as a result of oil spill recovery activities. Effects on the benthic community of the river range from moderate, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations near the confluence with the creek, to Low, in downstream areas.	High in Trail Creek, with direct effects of oiling and hydrocarbon exposure as well as oil spill recovery activities resulting in the physical destruction, and then reconstruction of aquatic habitat in the creek. Medium to Low in the Athabasca River, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the benthic invertebrate community begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of the benthic community in the river is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer.
Fish and Fish Eggs	The lower reaches of Trail Creek may provide spawning habitat for various fish species, with most species spawning either in the spring or the fall. Such fish, and their eggs and larvae, would likely be killed as a result of high dissolved hydrocarbon concentrations during the spill. Flow in the Athabasca River is less turbulent than in the summer, but the lower flow also reduces the dilution potential. Fish mortality, as well as effects on eggs in spawning habitat, is likely to occur within 10 km of the spill location.	High in Trail Creek, because of the confined nature of the habitat and the lack of dilution water, as well as the physical effects of oil spill clean-up on fish habitat in the tributary. Moderate in the first 10 km of the Athabasca River, and Low in more distant reaches of the river, because of weathering of oil which causes more water soluble fractions to evaporate.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of fish habitat in the Athabasca River is complete within 12 months of the spill.
In-water Amphibians	Both adult amphibians and their eggs or larvae are likely present in Trail Creek during the spring season, and would be killed. Adults and juveniles could be present in the fall. Amphibians in shoreline habitat, as well as in quiescent areas of the Athabasca River, could be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration.	High in Trail Creek, which likely provides good breeding and rearing habitat for amphibians. Moderate in shoreline habitat of the Athabasca River within 10 km of the spill site, and Low in areas between 10 and 25 km downstream, because of the limited contact of oil with riparian habitat.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of amphibian habitat in the Athabasca River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Lesser effects are observed in the riparian areas of the river, because flow is within the banks, and oil contact with the riparian areas is minimal.	High along the overland flow path and in Trail Creek, because of direct effects of oil on vegetation, and because of oil spill recovery efforts which result in physical destruction of habitat. Low in the riparian areas of the Athabasca River, because of minimal contact between spilled oil and riparian habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the shoreline areas of the Athabasca River requires about one year, once visible oil has been recovered.
Soil Invertebrates	Soils are oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Lesser effects are observed in the riparian areas of the Athabasca River, because flow is within the banks of the river, and oil contact with the riparian areas is minimal.	High along the overland flow path and in Trail Creek, because of direct effects of oil on soil invertebrates, and because of oil spill recovery efforts which result in physical destruction of habitat. Low in the riparian areas of the Athabasca River, because of minimal contact between spilled oil and riparian habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the shoreline areas of the Athabasca River requires about one years, once visible oil has been recovered.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during spring or fall is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by bears.
Moose	Oiling of individual moose could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during spring or fall is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by moose.

TABLE 7.1.6

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA (continued)

Athabasca River, Spring and Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Muskrat	Any muskrat present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Muskrat present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 25 km.	Effects on muskrat would be High, including mortality of individuals inhabiting Trail Creek and up to 25 km downstream. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Muskrat populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
River Otter	Any otters present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Otters present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 25 km.	Effects on otter would be High, including mortality of individuals inhabiting Trail Creek and up to 25 km downstream. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Otter populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
Birds			
Bald Eagle	Bald eagle would be present during spring and fall, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs during the spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. Oiled birds could also transfer oil to eggs during the spring, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs during the spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs during the spring, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs during the spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 25 km from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult amphibians could be present in Trail Creek, or in riparian habitat or backwater areas along the Athabasca River. Such animals could be exposed to spilled oil for a distance of up to 25 km from the spill location.	High to Medium. Amphibians present in Trail Creek could be smothered by spilled oil, or die from exposure to volatile hydrocarbons. Amphibians along the shorelines of the Athabasca River would be less exposed, and effect magnitude would decline with decreasing exposure. The risk of mortality would be greatest in the first 10 km downstream from Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 24 months. Recovery of habitat in the Athabasca River is complete within 12 months of the spill.

7.1.3 Scenario 2: North Thompson River near Darfield, British Columbia, RK 766.0

The hypothetical full bore rupture spill scenario involves a release of 1,400 m^3 of CLWB at RK 766.0. Like the Athabasca River, the North Thompson River has a flow regime driven by glacial meltwater, with a strong mid-summer freshet. However, the North Thompson River experiences considerably higher summer flows than the Athabasca River, while having lower average gradient. The hypothetical spill location is within approximately 120 m of the river bank, just west and upslope of the Yellowhead Highway. Overland flow would cause oil to move towards the highway and potentially along a roadside ditch until encountering a culvert that would allow passage beneath the highway. Emerging on the east side of the highway, the oil would follow local drainage pathways to the river. Some hold-up of spilled oil in pools and low areas between the spill site and the river is possible, but most of the spilled oil (*i.e.*, 1,000 m^3 or greater) is assumed to reach the river. The North Thompson River at this location is approximately 300 m wide in unconstrained channel areas, although the hypothetical spill location is near the downstream end of a large island that causes the river to divide. Scour marks on the island and on nearby riparian habitat indicate that flood flows can extend over the island and a considerable distance across the valley. Flows are strongly seasonal, ranging from approximately 1,300 m^3/s in June (during freshet, with peak flow potentially up to 2,000 m^3/s) to low flows between December and March that are potentially less than 100 m^3/s.

This spill scenario was evaluated with reference to three case studies described in the Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1): the Kalamazoo River spill, since that oil spill involved a similar form of diluted bitumen, and the gradient of the Kalamazoo River is most similar to that of the North Thompson River; the Yellowstone River oil spill; and the modeling conducted by Enbridge Northern Gateway Project for the Morice and Athabasca Rivers.

The ERA scenario evaluation did not consider the probability of occurrence of the spill nor the various design, engineering, maintenance, inspection and other preventative programs that Trans Mountain will have in place to reduce the likelihood of spills occurring, the details of which can be found in Section 2.0. Rather, this evaluation assessment was performed based on the premise that the spill had occurred despite these preventative programs. In addition, the evaluation did not consider the full application of emergency response approaches and spill response resources described in Section 4.0, a conservative, and unrealistic, assumption based on evidence from past spills.

Three environmental conditions were considered for this spill example:

- Winter conditions between December and March, with ice cover on the river and snow cover on the land. Air temperatures were assumed to be below freezing, and the river flow in the low range (100 m^3/s or less).
- Summer conditions between June and August, with air temperatures of 15 to 25ºC. The river was assumed to be in freshet, with flow greater than 1,250 m^3/s.
- Spring or fall conditions between April and June or September and November. The river flow was assumed to be moderate, at around 500 m^3/s, with cool air temperatures between 0 and 15ºC.

The following summary of oil spill fate and effects for these three conditions is based on Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1).

7.1.3.1 Winter Conditions

7.1.3.1.1 Assumed Fate

For the North Thompson River in winter, because of generally milder winter conditions, snow and ice conditions are less reliable than those at the Athabasca River. However, conditions are still likely to be such that overland flow of the oil is slowed, and some of the oil is absorbed into the snowpack. Following local terrain, oil would reach the roadside ditch on the west side of the Yellowhead Highway, then move along the ditch until encountering a culvert. Emerging on the east side of the highway, the oil would follow local drainages to the river. Most of the spilled CLWB (approximately 1,000 m^3) reaches the North Thompson River and spreads out on the ice. Although the North Thompson River can be ice covered for several months of the year, it responds quickly to snow melt or rain events, and the ice cover may not be reliable. Open water patches in the ice allow some of the oil to become entrained in the river, and it moves downstream beneath the ice but still floats as its density is initially around 940 kg/m^3. Owing to the winter conditions, many of the ecological receptors that could potentially be exposed are absent or dormant. Under these circumstances, the environmental effects of spilled oil may be minimized.

7.1.3.1.2 Potential Effects

Table 7.1.7 summarizes the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by the North Thompson River spill scenario during the winter. Many of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* migratory birds), although some birds such as the bald eagle may be present through the winter where open water occurs. During the winter season, most migratory birds would be at their wintering grounds, so acute effects on raptors, waterfowl, wading and shorebirds are likely to be limited. Similarly, some mammals such as bears would be hibernating, although others such as moose, muskrat and river otter remain active year-round. Because of the limited spatial extent of physical oiling, effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would likewise be limited in spatial extent. However, oil spill recovery effects on the overland flow path would be substantial, likely requiring extensive excavation causing destruction of affected habitat, followed by reconstruction and restoration of the terrestrial habitat. Depending upon the receptor group, this process of restoration and recovery could take anywhere from 18 months to 5 years.

Oil spill recovery efforts would still result in environmental effects along the overland flow path, but effects on the North Thompson River would be reduced. The spatial extent of high-magnitude oil spill effects would therefore be limited to the overland flow path, where the primary environmental effects would be those associated with oil spill recovery efforts. Oil spill effect magnitudes for aquatic receptors in the North Thompson River would be low to medium, depending upon how much oil entered the river. Effect magnitudes on shoreline and riparian vegetation and soil invertebrates would be low, due partly to winter dormancy, and particularly to the low level of exposure given low winter water levels. Effect magnitudes for mammals and birds would generally be low as a result of lack of exposure for migratory birds or hibernating mammals, but also to the low level of exposure within the North Thompson River. Recovery of the terrestrial environment would take approximately 18 months to 5 years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer.

TABLE 7.1.7

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BC

North Thompson River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Aquatic vegetation is not contacted by spilled oil.	Low. Aquatic vegetation is not actively growing at the time of the spill, and ice cover prevents contact between the spilled oil and aquatic vegetation.	Spilled CLWB is prevented from entering, or is recovered from the river surface, without materially affecting aquatic vegetation.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the river. Effects on the benthic community of the river are Low, because most of the spilled oil is recovered.	Low, although localized areas of Medium effect magnitude may be present.	Recovery of the benthic community in the North Thompson River is complete within 6 months of the spill.
Fish and Fish Eggs	Fish are present in the river, and salmonid eggs may be present in pockets of suitable habitat in the river bed downstream from the oil spill location. However, effects on fish and fish eggs are Low, because most of the spilled oil is recovered.	Low, because very little oil contacts the river water.	Recovery of fish habitat in the North Thompson River is complete within 6 months of the spill.
In-water Amphibians	Juvenile amphibians are not present in the winter season. Adult amphibians are unlikely to be wintering in the river sediments, although presence of individuals in protected locations is possible.	Low, because overwintering amphibians will be buried in sediments in protected locations, and are unlikely to be directly contacted by the spilled oil.	Recovery of amphibian habitat in the North Thompson River is complete within 6 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the North Thompson River, but annual plants are not present except as seeds, and perennial plants, shrubs and trees are in a dormant state. Little if any shoreline habitat of the North Thompson River is affected.	Low, because plants are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat along the overland flow path and in some limited shoreline areas.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to the North Thompson River, but soil invertebrates are in a dormant state. Little if any shoreline habitat of the North Thompson River is affected.	Low, because the soil invertebrates are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat along the overland flow path and in some limited shoreline areas.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	Not likely to be directly affected as they hibernate during winter.	Low, because the probability of a grizzly bear den being located within the overland flow path is very small. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Moose	Potentially affected. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, and oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Muskrat	Potentially affected, as muskrat remain active through the winter. However, effects on more than a few individual animals are unlikely.	Low, because muskrat populations will be limited along the main stem of the North Thompson River, with occupancy mainly in protected areas such as tributaries where exposure to oil is unlikely.	Recovery of this habitat is complete within 6 months of the spill.
River Otter	Potentially affected, as otters remain active through the winter. Most otter habitat would be present around openings in the river ice, where access to fish is present. Effects on more than a few individual animals are unlikely.	Low, because populations will be limited along the main stem of the North Thompson River, with occupancy mainly in protected areas such as tributary mouths with open water, where exposure to oil is unlikely.	Recovery of this habitat is complete within 6 months of the spill.
Birds			
Bald Eagle	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC, although individual birds may overwinter in areas with open water.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 7.1.7

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BC (continued)

North Thompson River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Spotted Sandpiper	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Western painted turtle habitat extends into the North Thompson River. Adult turtles and amphibians could potentially be overwintering in the sediments of protected areas such as backwaters and tributaries, but these will be minimally affected.	Low, because overwintering turtles and amphibians will be buried in stream or pool and pond sediments, and are unlikely to be directly contacted by the spilled oil.	Recovery of turtle habitat in the North Thompson River is complete within 6 months of the spill.

7.1.3.2 Summer Conditions

7.1.3.2.1 Assumed Fate

During summer, the spilled CLWB flows overland to the west side of the Yellowhead Highway, moves along the ditch until encountering a culvert, and emerges on the east side of the highway. The oil then follows local drainages to the North Thompson River. Some oil is held up in low areas, or absorbed onto vegetation and the soil litter layer, and some penetrates or is absorbed by soil. Most (approximately 1,300 m^3) of the spilled CLWB is likely to reach the North Thompson River over a period of several hours. The river is at or near flood stage, and as the oil enters on the western shoreline it is advected downstream by the quickly moving water. Because the oil is unweathered, and has low viscosity and density less than that of the water, it spreads across the water surface. Oil is trapped along shorelines, and in particular where river flow is above the banks and vegetation is flooded. Because of the high water, however, the river flow is turbulent, and in the early stages of the spill the turbulence of the river flow is sufficient to entrain droplets of the oil in the water, enhancing the dissolution of BTEX and other light-end hydrocarbons into the water column, although much of this oil also re-surfaces. As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of the oil becomes submerged in low-energy areas such as eddy zones behind islands and in backwaters. Although the water of the North Thompson River is somewhat turbid, the suspended sediment load is not particularly high and the water has no appreciable salinity; thus OMA formation is not a significant factor in the fate of the spilled oil. Most of the spilled oil has weathered, largely as a result of evaporation, or has been stranded along the shoreline and in riparian zones within 60 km of the spill location. A small amount of oil is advected farther downstream primarily as submerged oil, and some traces of oil are subsequently found in silty sediment deposits at the upstream end of Kamloops Lake, below the confluence of the North and South Thompson rivers.

Table 7.1.8 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by the North Thompson River spill scenario during the summer. Effect magnitude on the overland flow path is high but localized, and is addressed by physical remediation and reseeding of affected areas. Effects on aquatic receptors, including vegetation, aquatic invertebrates, fish and amphibians are generally medium to low, except for amphibians which may be affected in breeding habitats riparian to the river, if these areas are subject to heavy oiling. High turbulence in the river water tends to increase the dissolution of hydrocarbons into the river water, but the high flow rate of the river provides dilution, and widespread mortality of fish in the North Thompson River is unlikely. Much of the spilled oil becomes stranded along shorelines, and in riparian areas where vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flow path, but medium to low along the North Thompson River because of the patchy distribution of deposited oil. Whereas the overland flow path is subject to intensive oil spill clean-up which is initially destructive to habitat, areas riparian to the river are expected to be remediated with less intrusive methods, and a greater emphasis on natural attenuation of spilled oil residues at low levels. Environmental effects on mammal populations are high for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 60 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur or ingestion of oil. For birds, guilds such as ducks and geese are most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend for up to 60 km downstream. Other species such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 7.1.8

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BC

North Thompson River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Aquatic Receptors			
Aquatic Vegetation	Very little aquatic vegetation is present in the North Thompson River, because of the high summer flows, turbid water, and cobble-gravel nature of most of the river bed.	Low, because of the general scarcity of aquatic vegetation.	Not Applicable
Aquatic Invertebrates	Turbulent flow in the North Thompson River enhances dispersion and dissolution of hydrocarbons so effects on aquatic invertebrates are likely within 10 km of the spill location. Effects range from Medium, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations near spill location, to Low in downstream areas.	Medium to low, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected, but these are localized, and tend to be silty sediments, rather than gravel/cobble areas.	Recovery of the benthic community is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer to recover fully.
Fish and Fish Eggs	Turbulent flow in the North Thompson River enhances dispersion and dissolution of hydrocarbons so that fish mortality is likely within 10 km of the spill location. However, as the oil spreads across the surface of the river, and the dissolved hydrocarbons are diluted by the full flow of the river, lethal exposures to fish become unlikely.	Medium in the first 10 km of the river, and Low in more distant reaches of the river, as a result of the rapid weathering of oil which causes more water soluble fractions to evaporate. The high summer flow of the North Thompson River also provides abundant dilution water, which limits the dissolved concentrations in the river.	Recovery of fish habitat in the North Thompson River is complete within 12 months of the spill; the fish community is restored by immigration from nearby unaffected areas and tributaries.
In-water Amphibians	Adult amphibians in shoreline habitat as well as in quiescent areas of the North Thompson River would be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration. Effects are most likely within 10 km of the spill site, but remain possible up to 60 km from the spill site.	High in shoreline habitat of the North Thompson River within 10 km of the spill site, and Medium in areas up to 60 km downstream, as a result of the more patchy spatial distribution of stranded oil, and decreased dissolved hydrocarbon concentrations.	Recovery of amphibian habitat in the North Thompson River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the North Thompson River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Similar effects are observed in the riparian areas of the river, where high river flows cause flooding and terrestrial vegetation is contacted by oil.	High along the overland flow path, but Medium to Low in the riparian areas of the North Thompson River, as a result of the patchy distribution of oil, and decreasing with distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the North Thompson River requires about two years, once visible oil has been recovered.
Soil Invertebrates	Soils are oiled along the overland flow path to the river. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Effects on soil invertebrates are lower in riparian zones of the North Thompson River, in part because of the patchy nature of deposition. The heaviest oiling is noted in the first 10 km downstream from the spill location, but some oiling of riparian areas is observed as far as 60 km downstream.	Medium to Low in the riparian areas of the North Thompson River, as a result of the patchy distribution of oil, and with increasing distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the North Thompson River requires about two years, once visible oil has been recovered.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage along the shoreline of the North Thompson River up to 60 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. Recovery of river riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by bears.
Moose	Oiling of individual moose could occur if they forage along the shoreline of the North Thompson River up to 60 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. Recovery of river riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by moose.
Muskrat	Muskrat present in the North Thompson River are also likely to become oiled and die throughout the affected reach of up to 60 km.	Effects on muskrat would be High, including mortality of individuals up to 60 km downstream.	Recovery of river and riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Muskrat populations recover as a result of recolonization of affected areas from adjacent unaffected areas.

TABLE 7.1.8

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BC (continued)

North Thompson River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
River Otter	Otters present in the North Thompson River are likely to become oiled and die, throughout the affected reach of up to 60 km.	Effects on otter would be High, including mortality of individuals up to 60 km downstream.	Recovery of river and riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Otter populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
Birds			
Bald Eagle	Bald eagle would be present during summer, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 60 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult turtles and amphibians could be present in riparian habitat or backwater areas along the North Thompson River. Such animals could be exposed to spilled oil for a distance of up to 60 km from the spill location.	High to Medium. Effect magnitude would decline with distance downstream and decreasing exposure. The risk of acute lethality would be greatest in the first 10 km downstream from spill location.	Recovery of turtle habitat in the North Thompson River is complete within 12 months of the spill.

7.1.3.3 Spring or Fall Conditions

7.1.3.3.1 Assumed Fate

With spring or fall conditions, the spilled CLWB flows overland to the west side of the Yellowhead Highway, moves along the ditch until encountering a culvert, and emerges on the east side of the highway. The oil then follows local drainages to the North Thompson River. Some oil is held up in low areas, or absorbed onto vegetation and the soil litter layer, and some penetrates or is absorbed by soil. Most (approximately 1,300 m^3) of the spilled CLWB is likely to reach the North Thompson River over a period of several hours. For the North Thompson River in spring and fall, flow in the river is at an intermediate level, typically rising in the spring because of the onset of freshet, or falling in the fall, as freshet recedes. Most of the spilled oil reaches and is advected downstream in the North Thompson River which is flowing normally, and confined within its banks. Because the oil is unweathered, and has low viscosity and density less than that of the water, it spreads across the water surface. Floating oil is trapped along shorelines, particularly on gravel and cobble exposures, but does not penetrate these deeply because of the shallow slope of the shorelines and the presence of the water table at or near the surface. Because of the low gradient of the river and the moderate water flow, the turbulence in the river is rarely sufficient to entrain droplets of the oil in the water. As a result the concentrations of BTEX and other light-end hydrocarbons in the water column are lower, but the surface slick tends to be thicker. As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of the oil becomes submerged in low energy areas such as eddy zones behind islands and in backwaters. Although the water of the North Thompson River is somewhat turbid, the suspended sediment load is not particularly high and the water has no appreciable salinity; thus OMA formation is not a dominant factor in the fate of the spilled oil. Most of the spilled oil has weathered, largely as a result of evaporation, or has been stranded along the shoreline and in riparian zones within 25 km of the spill location. A small amount of oil is advected farther downstream primarily as submerged oil, but does not extend to the confluence of the South and North Thompson rivers.

7.1.3.3.2 Potential Effects

Table 7.1.9 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by the North Thompson River spill scenario during spring or fall conditions. Effect magnitude on the overland flow path is high but localized, and is addressed by physical remediation and re-seeding of affected areas. Effects on aquatic receptors, including aquatic vegetation, invertebrates, fish and amphibians, are generally medium to low in the North Thompson River, except for effects on amphibians in spring, which could be high if oil enters habitat where amphibian eggs or larvae are present. Moderate effects are observed within the first 10 km downstream, and low magnitude effects are observed between 10 and 25 km downstream. Most of the oil becomes stranded along shorelines, but there is little contact with riparian areas because of the moderate water level in the river. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flow path, but low along the North Thompson River because of the low level of exposure. The overland flow path is subject to intensive oil spill clean-up which is initially destructive to habitat. Environmental effects on mammal populations are greatest for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 25 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur or ingestion of oil. For birds, guilds such as ducks and geese are most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the spring and fall could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 7.1.9

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BC

North Thompson River, Spring and Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Very little aquatic vegetation is present in the North Thompson River, as a result of the high summer flows, turbid water, and cobble-gravel nature of most of the river bed.	Low, as a result of the scarcity of aquatic vegetation generally.	Not Applicable
Aquatic Invertebrates	Spring and fall flows in the North Thompson River are less turbulent than in summer, limiting the dispersion and dissolution of hydrocarbons in the reaches below the spill site, so that most aquatic invertebrate mortality is limited to areas within the first 5 km. Effects on the benthic community range from Medium, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations within 5 km of the spill location, to Low, in downstream areas.	Medium to low, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected, but these are localized, and tend to be silty sediments, rather than gravel/cobble areas.	Recovery of the benthic community is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer to recover fully.
Fish and Fish Eggs	Spring and fall flows in the North Thompson River are less turbulent than in summer, limiting the dispersion and dissolution of hydrocarbons in the reaches below the spill site, so that most fish mortality is limited to areas within the first 5 km. As the oil spreads across the surface of the river, and the dissolved hydrocarbons are diluted by the full flow of the river, lethal exposures to fish become less likely.	Medium in the first 5 km of the river, and Low in more distant reaches of the river, as a result of the rapid weathering of oil which causes more water soluble fractions to evaporate. The North Thompson River provides abundant dilution water, which limits the dissolved concentrations in the river.	Recovery of fish habitat in the North Thompson River is complete within 12 months of the spill; the fish community is restored by immigration from nearby unaffected areas and tributaries.
In-water Amphibians	Adult amphibians or amphibian eggs and larvae (in spring) in shoreline habitat as well as in quiescent areas of the North Thompson River would be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration. This would be most likely within 10 km of the spill site, although effects could be observed up to 25 km downstream.	High in shoreline habitat of the North Thompson River within 10 km of the spill site, and Medium in areas up to 25 km downstream, as a result of the more patchy spatial distribution of stranded oil, and decreased dissolved hydrocarbon concentrations.	Recovery of amphibian habitat in the North Thompson River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the North Thompson River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Riparian areas of the river are not affected, as the river is flowing within its normal banks.	High on the overland flow path, as a result of aggressive clean-up activities on land, but Low to unaffected in riparian areas of the North Thompson River.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Riparian areas along the river are essentially unaffected.
Soil Invertebrates	Soils are oiled along the overland flow path to the river. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Riparian areas of the river are not affected, as the river is flowing within its normal banks.	High on the overland flow path, as a result of aggressive clean-up activities on land, but Low to unaffected in riparian areas of the North Thompson River.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Riparian areas along the river are essentially unaffected.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage along the shoreline of the North Thompson River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. River riparian habitat is minimally affected. Oil spill response activities focusing on shoreline areas could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by bears.
Moose	Oiling of individual moose could occur if they forage along the shoreline of the North Thompson River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. River riparian habitat is minimally affected. Oil spill response activities focusing on shoreline areas could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by moose.
Muskrat	Muskrat present in the North Thompson River are likely to become oiled and die, throughout the affected reach of up to 25 km.	Effects on muskrat would be substantial, including mortality of individuals up to 25 km downstream.	Recovery of shoreline habitat begins about 12 months after the spill, and is effectively complete after 2 years. Muskrat populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
River Otter	Otters present in the North Thompson River are likely to become oiled and die, throughout the affected reach of up to 25 km.	Effects on otter would be substantial, including mortality of individuals up to 25 km downstream.	Recovery of shoreline habitat begins about 12 months after the spill, and is effectively complete after 2 years. Otter populations recover as a result of recolonization of affected areas from adjacent unaffected areas.

TABLE 7.1.9

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BC (continued)

North Thompson River, Spring and Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Birds			
Bald Eagle	Bald eagle would be present during spring and fall, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil on shoreline habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard Duck	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in shoreline habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 25 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Turtles and adult amphibians could be present in shoreline habitat or backwater areas along the North Thompson River. Such animals could be exposed to spilled oil for a distance of up to 25 km from the spill location.	High to Medium. Turtles and adult amphibians along the shorelines of the river would be less exposed, and effect magnitude would decline, with distance downstream. The risk of mortality would be greatest in the first 10 km downstream from spill location.	Recovery of turtle and amphibian habitat in the North Thompson River is complete within 12 months of the spill.

7.1.4 Scenario 3: Fraser River near Hope, British Columbia, RK 1,072.8

The hypothetical full bore rupture spill scenario involves a release of 1,300 m^3 of CLWB at RK 1072.8. The hypothetical spill location is on the east side of the Fraser River, approximately 25 km southwest of Hope and 6 km east of Agassiz, BC. At this location, the Fraser River is a large river entering the coastal lowlands, but still occupies a broad valley with mountains on either side. The river is wide, having a main channel width of approximately 350 m, but is meandering and braided, with large islands and gravel bars that are overwashed during periods of high flow. Flow remains strongly seasonal, with freshet in June driven by meltwater in the mountainous terrain to the east and north, tailing off until the end of the year. Low flows are observed in January, February and March, as snow accumulates in the mountains. The water of the lower Fraser River has high turbidity. Winter low-flow periods measured at Hope have monthly mean flows of 500 to 2,000 m^3/s. Peak flow in June averages almost 7,000 m^3/s, with a maximum recorded monthly mean discharge of 10,800 m^3/s.

The hypothetical spill location is just east of the eastbound lane of Highway 1, on a slope adjacent to a gully, approximately 500 m from a small side channel of the Fraser River. Oil emerging from the ground would flow downhill into the gully. The gully is the lower portion of a watercourse originating on the mountain side to the east of the highway and river. Water flows in the gully are highly variable, driven by local precipitation and snowmelt events, and the boulder/cobble substrates clearly show that episodic high flow rates are common. Because of the steep gradient and flashy nature of flows, the watercourse in the gully is not likely to provide fish habitat. The gully passes beneath the two divided lanes of Highway 1, and outwashes to a small side channel of the Fraser River. At low water levels, this channel is stranded, although water remains in pools. Moving downstream, the side channel remains confined to the shoreline for a distance of approximately 6.1 km before emerging from the protection of an island and complex of gravel bars to enter the main stem of the river, approximately 1.5 km upstream from the Agassiz Rosedale (Highway 9) Bridge. From this point, oil could spread across the width of the Fraser River, and would be transported downstream with the flowing water.

This spill scenario was evaluated with reference to four case studies described in the Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1): the Kalamazoo River spill, since that oil spill involved a similar form of diluted bitumen, and the gradient of the Kalamazoo River is most similar to that of the lower Fraser River; the Yellowstone River oil spill; the DM 932 oil spill; the Wabamun Lake Bunker “C” oil spill; and the modeling conducted by Enbridge Northern Gateway Project for the Athabasca River near Whitecourt, Alberta.

The ERA scenario evaluation did not consider the probability of occurrence of the spill nor the various design, engineering, maintenance, inspection and other preventative programs that Trans Mountain will have in place to reduce the likelihood of spills occurring, the details of which can be found in Section 2.0. Rather, this evaluation assessment was performed based on the premise that the spill had occurred despite these preventative programs. In addition, the evaluation did not consider the full application of emergency response approaches and spill response resources described in Section 4.0, a conservative, and unrealistic, assumption based on evidence from past spills.

Three environmental conditions were considered for this spill example:

- A winter condition between December and March. Air temperatures are assumed to be around the freezing mark, but snow cover is not guaranteed, and the river is ice-free. The river flow is in a low range (around 2,000 m^3/s).

- A summer condition between June and August, with air temperatures 15 to 25°C. The river is in freshet, with flow greater than 6,000 m^3/s, and potentially approaching 12,000 m^3/s.

- A spring or fall condition between April and June, or September and November. The river flow is in a moderate range, at around 5,000 m^3/s, and the air temperatures are cool, between 0 and 15°C.

The following summary of oil spill fate and effects for these three conditions is based on Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1).

7.1.4.1 Winter Conditions

7.1.4.1.1 Assumed Fate

Under winter conditions at this low elevation (no more than 50 masl), it is unlikely that sufficient (if any) snowpack would be present to influence the behaviour of the spilled CLWB. Owing to the frequently wet winter weather, it is likely that water is flowing rapidly down the gully towards the Fraser River. Due to these factors, virtually all (1,250 m^3) of the spilled CLWB reaches the side channel of the Fraser River within a few hours of the rupture event. Although the river stage is low, and waters of the Fraser River are not actively flowing in this portion of the river channel, the flow of water from the gully and other similar tributaries acts to transport spilled oil farther downstream towards the main channel 6.1 km distant.

Frequent contact with sand and gravel bars acts to hold up some of the spilled oil, and it is possible that emergency responders could trap and recover much of the spilled oil before it entered the main channel of the Fraser River, which is ice free. Failing this, oil entering the main channel, now somewhat weathered, would be advected downstream initially following the left (south) bank of the river, before emerging and dispersing across the river channel between 4 and 7 km downstream of the Agassiz Rosedale Bridge. The river is at low flow, and has a low gradient, so the currents are weak and have low turbulence. Floating oil or slicks may be carried 30 to 50 km downstream from the point where it entered the main river channel, and globules or tar balls may be recovered up to 100 km downstream.

The spilled oil floats until it strands on gravel or sand bars, or other shorelines. As it weathers, it becomes more viscous and thicker, but is stranded before its density approaches or exceeds that of the water. Little oil is entrained in the water column as a result of the low turbulence. Although the river has relatively high turbidity, turbidity is at a seasonally low level because of low water flow. There is no appreciable salinity to the water, so OMA formation is limited by the low levels of suspended oil droplets, low suspended sediment concentration, and absence of salinity. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand and gravel particles as the oil weathers, so that the weathered oil-mineral mixture may become submerged if it is subsequently overwashed before it can be recovered. Owing to the winter conditions, many of the ecological receptors that could potentially be exposed are absent or dormant.

7.1.4.1.2 Potential Effects

Table 7.1.10 summarizes the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by the Fraser River near Hope spill scenario during winter. Most migratory birds would be at their wintering grounds, although it is likely that bald eagles and some waterfowl may be overwintering in the area, particularly in sheltered habitat like the side channel. Similarly, some mammals such as bears would be hibernating, although others such as moose, muskrat and river otter remain active year-round. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would likewise be limited in spatial extent. The gully does not provide fish habitat. The side channel of the Fraser River would provide fish habitat, and it is likely that acute toxicity to fish would be observed, considering the large volume of spilled CLWB and the small amount of water present or flowing in the side channel. The main stem of the Fraser River, however, is not likely to experience fish kills as a result of the large volume of flowing water, the low turbulence and limited potential for oil droplet formation, and the partially weathered condition of the oil by the time it reaches the main channel. Oil spill recovery effects on the side channel of the Fraser River would be substantial. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to 5 years.

For the Fraser River in winter, it is assumed that both the side channel and the main river channel will be ice free but that a considerable portion of the oil is retained in the side channel of the river, and does not reach the main channel. Oil spill recovery efforts would result in environmental effects along the overland flow path, and in the 6 km side channel to the Fraser River. Some of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* some migratory birds), although birds such as bald eagle and potentially some waterfowl could be present through the winter because of the ice free conditions. High-magnitude oil spill effects would therefore occur along the overland flow path, where environmental effects associated with oil spill recovery efforts would follow the oil spill effects, in the gully leading to the river, and in the side channel of the Fraser River where heavy oiling of the water surface and shorelines would occur as a result of the small dimensions of the channel. Oil spill effect magnitudes for aquatic receptors in the side channel would be high to medium, taking into consideration both oil effects and oil spill recovery effects. Effect magnitudes on shoreline and riparian vegetation and soil invertebrates would be low, partly because of winter dormancy, and particularly because of the low level of exposure given low winter water levels. Effect magnitudes for mammals and birds would generally be low because of lack of exposure for migratory birds or hibernating mammals; however, higher effect magnitudes would be seen for semi-aquatic mammals in the side channel and Fraser River as a result of oiling of fur. Higher effect magnitudes could also be seen for wintering birds such as ducks, depending upon the numbers present. Recovery of the terrestrial environment would take approximately 18 months to 5 years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer.

TABLE 7.1.10

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE FRASER RIVER NEAR HOPE, BC

Fraser River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	The small side channel of the Fraser River is assumed to be ice-free, but river water levels are low. The aquatic habitat is mostly small interconnecting pools, with flow provided mainly from tributaries. The side channel, extending some 6 km before entering the main Fraser River, supports some aquatic vegetation, but this is senescent in winter.	High. Aquatic vegetation is not actively growing at the time of the spill. However, oil spill recovery activities result in damage to, and then reconstruction of aquatic habitat in the side channel.	Oil spill recovery efforts in the side channel result in extensive disturbance of this habitat, but erosion and deposition of sediment during and after the summer high flow period effectively restore this habitat, so that effects persist for 6 to 18 months.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the side channel and the main Fraser River. Effects on the benthic community of the side channel (6 km) are substantial, affecting the entire channel as a result of initial toxicity as well as oil spill recovery activities. Effects on the benthic community of the main Fraser River are Low, because most of the spilled oil is recovered.	High although localized in the side channel. However, oil spill recovery activities result in damage to, and then reconstruction of aquatic habitat in the gully and side channel. Low in the main Fraser River, because of the partially weathered nature of the oil, and large size of the river.	The gully and side channel are heavily disturbed by clean-up activities in the first months following the oil spill. Recovery of the benthic invertebrate community begins between 6 and 18 months after the spill, and is effectively complete after 30 months. Recovery of the benthic community in the main Fraser River channel is complete within 6 months of the spill.
Fish and Fish Eggs	Few fish are present in the side channel, because of winter low flow conditions; however such fish, or eggs, would likely be killed throughout the 6 km reach. Fish are present in the main Fraser River. It is not a major migratory period for salmon or eulachon, although steelhead could be migrating up the river during the winter period. Mortality of fish in the main Fraser River is unlikely because of weathering of the oil and the large volume of water flowing in the river.	High although localized in the side channel. However, oil spill recovery activities result in damage to, and then reconstruction of aquatic habitat in the side channel.	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins between 6 and 18 months after the spill, and is effectively complete after 30 months. Recovery of fish habitat in the main Fraser River is complete within 6 months of the spill.
In-water Amphibians	Juvenile amphibians are not present in the winter season. Adult amphibians may be overwintering in the sediments of the side channel, which is wholly affected, or in quiescent areas of the main Fraser River where they are minimally affected.	Medium, because overwintering amphibians will be buried in stream sediments, and are unlikely to be directly contacted by the spilled oil. Oil spill recovery efforts, however, would result in damage to and then reconstruction of habitat in the side channel.	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins between 6 and 18 months after the spill, and is effectively complete after 30 months. Recovery of fish habitat in the main Fraser River is complete within 6 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path, in the gully leading to the side channel, and potentially in places along the side channel to the main Fraser River, but annual plants are not present except as seeds. Perennial plants, shrubs and trees are in a dormant state. Little if any shoreline habitat of the Fraser River is affected because of low winter water levels.	High along the overland flow path, but Low elsewhere because the plants are in a dormant state at the time of the spill, and water levels are low during the winter. However, oil spill recovery activities result in damage to and then reconstruction of terrestrial habitat near the spill location.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path, in the gully leading to the side channel, and potentially in places along the side channel to the Fraser River. Little if any shoreline habitat of the main Fraser River is affected because of low winter water levels.	High along the overland flow path, but Low elsewhere even though soil invertebrates may remain active during the mild winter conditions. Water levels are low during the winter, so contact with riparian areas of the river is minimal. Oil spill recovery activities result in damage to and then reconstruction of terrestrial habitat near the spill location.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons), some of which may be winter-active in the lower mainland of BC, even if grizzly bear are not present. A small number of individual animals might come into contact with spilled oil in the overland flow path, the gully, the side channel, or stranded along shorelines of the main Fraser River channel.	Low, because mild winter conditions reduce the probability that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Moose	Moose or other ungulates are potentially affected, as the gully and forested riparian areas of the side channel and river could provide sheltering habitat during cold periods. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.

TABLE 7.1.10

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE FRASER RIVER NEAR HOPE, BC (continued)

Fraser River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Muskrat	Muskrat are potentially affected, as the side channel could provide suitable habitat, and muskrat remain active through the winter. However, effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
River Otter	Otters are potentially affected, as they remain active through the winter. Effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Birds			
Bald Eagle	Winter range of bald eagle could extend to the hypothetical spill location. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick.	Low. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard Duck	Not likely to be affected as the winter range is generally south of the pipeline right of way in BC.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Not likely to be affected as the winter range is south of the pipeline right of way in BC.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Not likely to be affected as the winter range is south of the pipeline right of way in BC.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. A variety of amphibian species could be present in the side channel. Pools in the side channel could provide overwintering habitat for both turtles and amphibians, but these would be dormant and likely buried in sediments under winter conditions.	Low, because overwintering turtles and amphibians will be buried in sediments of the side channel, and are unlikely to be directly contacted by the spilled oil. Oil spill recovery activities, however, have the potential to disturb and possibly kill these animals.	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of turtle and amphibian habitat begins about 18 months after the spill, and is effectively complete after 30 months.

7.1.4.2 Summer Conditions

7.1.4.2.1 Assumed Fate

With summer conditions, it is assumed that water flow in the gully is low, and that as the oil moves down the gully, it displaces and overflows the water, causing accumulation and penetration of oil into the boulder and cobble outwash materials. This process results in some hold-up of oil that could otherwise reach the Fraser River. As a result, approximately 1,200 m^3 of CLWB reaches the river, which is in flood condition. Water is flowing freely along the side channel, and most of the sand and gravel bars are submerged. The oil is rapidly transported to the confluence with the main river channel, and is swept downstream with oil and sheens being observed as far as 100 km downriver, approaching the greater Vancouver area.

Because the river is flowing at a high stage, flows frequently wash over islands or riparian areas, with oil contacting vegetation and shoreline soils. Air and water temperatures are relatively warm, so the oil weathers quickly. The side channel is relatively calm, but turbulent flow is encountered as the oil enters the main river channel, and some oil is entrained into the water column, locally enhancing concentrations of dissolved hydrocarbons at this point. The viscosity of the oil increases as it weathers, so most of the oil remains on the surface in patchy slicks and sheens until it strands on shorelines, often coating vegetation.

The river is turbulent and has high turbidity at this time of year. The turbulent flow tends to entrain oil droplets into the water column in the upper reaches of the spill-affected area, but there is no appreciable salinity to the water, so OMA formation is limited. Most of the oil becomes stranded on shorelines and vegetation, so as water levels drop, this oil remains stranded and little remains in the river bed as submerged oil. The presence of residual oil in riparian areas leads to exposure for ecological receptors occupying terrestrial and shoreline habitat.

7.1.4.2.2 Potential Effects

Table 7.1.11 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by the Fraser River near Hope spill scenario during summer. In summer conditions, the oil is rapidly advected as much as 100 km downstream, with oil becoming stranded on shorelines and coating shoreline vegetation. During the summer season, most migratory birds would be present and breeding. Similarly, mammals such as bears, moose, muskrat and river otter would be present and active. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation, would likewise be limited in spatial extent. The gully does not provide fish habitat. The side channel of the Fraser River would provide fish habitat, and it is possible that fish mortality might be observed in the side channel. The main stem of the Fraser River, however, is not likely to experience fish kills because of the large volume of flowing water, notwithstanding the turbulence and potential for oil droplet formation. Oil spill recovery effects would be greatest on riparian and shoreline habitat. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to 5 years.

For the Fraser River in summer, flow in the river is peaking because of snow melt in its mountain headwaters. Most of the spilled oil reaches the side channel, and is advected downstream to the confluence with the main Fraser River. Effect magnitude on the overland flow path and in the gully leading to the side channel is high but localized, and is addressed by physical remediation and reseeding of affected areas. Effects on aquatic receptors are variable. Effects on aquatic vegetation are of low magnitude as the spilled oil largely floats on the surface of the side channel, so vegetation has little direct exposure. Similarly effects on benthic invertebrates are generally low. There is potential for effects on fish and amphibians in the side channel that would result from expected high dissolved hydrocarbon concentrations. Much of the spilled oil becomes stranded along shorelines and in riparian areas where vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flow path and along the side channel, becoming medium to low along the main Fraser River channel up to 100 km downstream because of the patchy distribution of the oil. Whereas the overland flow path is subject to intensive oil spill clean-up which is initially destructive to habitat, the ERA assumes that riparian areas along the Fraser River will be remediated with less intrusive methods, and a greater emphasis will be placed on natural attenuation of spilled oil residues at low levels. Environmental effects on mammal populations are high for semi-aquatic species such as muskrat, beaver, otter and mink in the side channel, and it is assumed that some of these animals could also be sufficiently oiled to cause death in areas downstream in the main Fraser River channel. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur or ingestion of oil. For birds, guilds such as ducks and geese are most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend for up to 100 km downstream. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 7.1.11

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER NEAR HOPE, BC

Fraser River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	The side channel of the Fraser River is flooded with water from the main river, and islands, sandbars, and some riparian habitat are inundated. Aquatic vegetation in the side channel has little exposure to floating oil, and generally low sensitivity to dissolved hydrocarbon constituents. Little of the oil sinks in this area.	Low. Aquatic vegetation is not directly exposed to the spilled oil, and oil spill recovery activities focus on riparian habitat, where oil has stranded.	Spilled CLWB enters the side channel of the Fraser River, moving along it quite rapidly because of the high river flow. Oil spill recovery efforts result in little disturbance of this habitat. Recovery is generally complete within 6 months.
Aquatic Invertebrates	The side channel of the Fraser River is flooded with water from the main river, and islands, sandbars, and some riparian habitat are inundated. Aquatic invertebrates in the side channel have little exposure to floating oil, and exhibit a range of sensitivity to dissolved hydrocarbon constituents. Little of the oil sinks in this area. Some sensitive species are locally affected.	Low. Aquatic invertebrates are not directly exposed to the spilled oil, and oil spill recovery activities focus on riparian habitat, where oil has stranded.	Spilled CLWB enters the side channel of the Fraser River, moving along it quite rapidly because of the high river flow. Oil spill recovery efforts result in little disturbance of this habitat. Recovery is generally complete within 6 months.
Fish and Fish Eggs	Fish, including potentially inward migrating salmon, could be present in the side channel. Eulachon are not likely to use spawning habitat this far up the Fraser River. Mortality of fish is possible in the side channel, because of its small dimensions and turbulent flow, with unweathered CLWB forming droplets in suspension in the river water. The same process will continue in the main Fraser River, but mortality of fish here is unlikely because of the high flow rate, and progressive weathering of the oil.	High although fish mortality is localized in the side channel.	Acutely lethal conditions persist for only about one day. Oil spill recovery efforts result in little disturbance of this aquatic habitat. Recovery is generally complete within 6 months.
In-water Amphibians	Amphibians may be spawning or juvenile amphibians may be present, but likely in protected areas not exposed to the high river flows. Turtles may be present and may be breeding, but also in more protected areas. Direct mortality is unlikely for turtles, although some limited mortality of amphibians in the side channel, or riparian areas of the main Fraser River is possible.	Low to Medium, because amphibians and turtles are likely to occupy protected areas, not exposed to the main flow of the Fraser River.	Spilled CLWB enters the side channel of the Fraser River, moving along it quite rapidly because of the high river flow. Oil spill recovery efforts result in little disturbance of this habitat. Recovery is generally complete within 6 months.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the gully and side channel, and in riparian areas of the side channel and main Fraser River. Annual plants contacted by the spilled oil are likely to be killed. Leaves of perennial plants, shrubs and trees will also be killed, but these plants are likely to survive and regenerate. Effects extend throughout the riparian areas of the side channel, and where oil accumulates in riparian areas of the main Fraser River, up to 100 km downstream.	High. The combination of direct contact with spilled oil, as well as oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near the spill location. Effects on riparian habitat are patchy, but can extend up to 100 km downstream.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to the side channel, and in riparian areas of the side channel and main Fraser River. Soil invertebrate communities may be affected by residual hydrocarbon concentrations. Effects extend throughout the riparian areas of the side channel, and where oil accumulates in riparian areas of the main Fraser River, up to 100 km downstream.	Medium, because residual hydrocarbon concentrations in soil are generally patchy, and recolonization from adjacent minimally affected areas proceeds rapidly.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivore/carnivores (such as raccoons). A small number of individual animals might come into contact with spilled oil in the overland flow path, the gully, the side channel, or stranded along shorelines of the main Fraser River channel.	Low, because partially oiled animals would not be likely to die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Moose	Moose or other ungulates are potentially affected, as the gully and forested riparian areas of the river could provide sheltering and feeding habitat. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.

TABLE 7.1.11

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER NEAR HOPE, BC (continued)

Fraser River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Muskrat	Muskrat are potentially affected, as the side channel could provide suitable habitat. Muskrat in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur, and mortality is possible.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about five years.
River Otter	River otter are potentially affected, as the side channel could provide suitable habitat. Otters in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur, and mortality is possible.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Birds			
Bald Eagle	Bald eagle would be present during summer, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 100 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil on shoreline habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard Duck	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 100 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in shoreline habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 100 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult turtles and amphibians could be present in riparian habitat or backwater areas along the Fraser River. Such animals could be exposed to spilled oil for a distance of up to 100 km from the spill location.	High to Medium. Turtles and amphibians along the shorelines of the river would be less exposed, and effect magnitude would decline with distance downstream and decreasing exposure. The risk of mortality would be greatest in the first 6 km (*i.e.,* the side channel).	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of turtle and amphibian habitat begins about 18 months after the spill, and is effectively complete after 30 months.

7.1.4.3 Spring or Fall Conditions

7.1.4.3.1 Assumed Fate

With spring and fall conditions, it is assumed that water flows down the gully, and that the spilled oil quickly moves down the gully, displacing water and overflowing on the boulder and cobble substrates, with some accumulation and penetration of oil into the outwash materials. This process results in some hold-up of oil that could otherwise reach the Fraser River. Approximately 1,200 m^3 of CLWB reaches the river, which is flowing normally within its banks at 2,000 to 4,000 m^3/s. Some river water is flowing slowly along the side channel, but most of the sand and gravel bars remain visible. The oil flows along the side channel to the confluence with the main river channel, and is subsequently transported downstream with oil and sheens being observed as far as 60 km downriver, approaching the greater Vancouver area.

As the river is at moderate flow, the river banks, islands and gravel bars provide abundant solid substrate that oil can adhere to. Oiling, however, is principally confined to sand and gravel shorelines, and little riparian habitat is oiled. Flow in the side channel is relatively calm, but more turbulent flow is encountered as the oil enters the main river channel and some oil is entrained into the water column, locally enhancing concentrations of dissolved hydrocarbons at this point. The viscosity of the oil increases as it weathers, so most of the oil remains on the surface in patchy slicks and sheens until it strands on shorelines.

The river has moderate turbulence and turbidity at this time of year. The turbulent flow tends to entrain some droplets of relatively unweathered oil into the water column in the upper reaches of the spill-affected area, but there is no appreciable salinity to the water, so OMA formation is limited. Most of the oil becomes stranded on shorelines. In the springtime, water levels tend to be steadily rising, so some of this oil may re-float, and some (if it has mixed with sand and gravel) may remain submerged. In the fall, water levels tend to be steadily falling, so stranded oil will generally remain stranded and exposed to weathering on the shoreline through the winter months. This results in different exposure pathways for ecological receptors in spring and fall.

7.1.4.3.2 Potential Effects

Table 7.1.12 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by the Fraser River near Hope spill scenario during spring or fall. Because of the river flow condition, the oil is advected as much as 60 km downstream, with much of the oil becoming stranded on shorelines and gravel bars. During the spring and fall seasons, many migratory birds would be present. Similarly, mammals such as bears, moose, muskrat and river otter would be present and active. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation, would likewise be limited in spatial extent. The gully does not provide fish habitat. The side channel of the Fraser River would provide fish habitat, and it is possible that fish mortality might be observed in the side channel. The main stem of the Fraser River, however, is not likely to experience fish kills as a result of the large volume of flowing water, notwithstanding the turbulence and potential for oil droplet formation. Oil spill recovery effects would be greatest on shoreline habitat. The potential for submerged oil is greatest in spring, as weathered oil that has contacted sand and gravel may be remobilized with rising waters and transported downriver as part of the bedload. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to 5 years.

Effect magnitude on the overland flow path and in the gully leading to the side channel is high but localized, and is addressed by physical remediation and reseeding of affected areas. Effects on aquatic receptors, including aquatic vegetation, invertebrates, fish and amphibians, are generally medium to low in the side channel, and low in the Fraser River, except for effects on amphibians in spring, which could be high if oil enters habitat where amphibian eggs or larvae are present. Effects farther downstream in the main Fraser River are generally low because of increasing dilution and dispersion of the oil. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flow path, but low along the Fraser River because of the low level of exposure. The overland flow path is subject to intensive oil spill clean-up which is initially destructive to habitat. Environmental effects on mammal populations are greatest for semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 60 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur or ingestion of oil. For birds, guilds such as ducks and geese are most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the spring and fall could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 7.1.12

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER NEAR HOPE, BC

Fraser River, Spring or Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Aquatic Receptors			
Aquatic Vegetation	The side channel of the Fraser River is somewhat isolated from the main Fraser River because of intermediate water levels. Islands and sandbars are present and visible. Little if any riparian habitat is inundated. Aquatic vegetation in the side channel has little exposure to floating oil, and generally low sensitivity to dissolved hydrocarbon constituents. Little of the oil sinks in this area.	Medium. Some aquatic vegetation is contacted by the spilled oil. Oil spill recovery efforts in the side channel result in damage to the habitat. Oil exiting the side channel to enter the main channel is carried up to 60 km downstream, but little aquatic plant habitat is present in the main channel.	Spilled CLWB enters the side channel of the Fraser River, moving along it and entering the main channel. Because more of the oil is retained in the side channel, more habitat disturbance results from recovery efforts. Recovery is generally complete within 12 to 24 months.
Aquatic Invertebrates	The side channel of the Fraser River is somewhat isolated from the main Fraser River because of intermediate water levels. Islands and sandbars are present and visible. Little if any riparian habitat is inundated. Aquatic invertebrates in the side channel have moderate exposure to dissolved hydrocarbon constituents. Little of the oil sinks in this area.	Medium. Some aquatic invertebrates are killed by exposure to dissolved hydrocarbons in the side channel. Oil spill recovery efforts in the side channel result in damage to the habitat. Oil exiting the side channel to enter the main channel is carried up to 60 km downstream, but flow in the river is such that acute toxicity to aquatic invertebrates is unlikely. Some oil sinks and is deposited to sediment in areas of low flow and silty sediment. This aquatic invertebrate habitat remains compromised.	Spilled CLWB enters the side channel of the Fraser River, moving along it and entering the main channel. Because more of the oil is retained in the side channel, more habitat disturbance results from recovery efforts. Efforts to recover sunken oil from backwater areas of silty sediments take longer, but the natural flow regime of the river tends to periodically erode and re-suspend sediment in these areas. Recovery is generally complete within 12 to 24 months.
Fish and Fish Eggs	Fish, including potentially inward migrating salmon in the fall, could be present in the side channel. Eulachon are not likely to use spring spawning habitat this far up the Fraser River. Mortality of fish is possible in the side channel, because of its small dimensions, but flow characteristics have low turbulence, so droplet formation is limited. Flow is more turbulent in the main Fraser River, but the oil is somewhat weathered by the time it leaves the side channel, and the flow volume is still large, limiting the potential for fish mortality.	Medium, and localized in the side channel.	Acutely lethal conditions persist for only about one day. Oil spill recovery efforts result in disturbance of this aquatic habitat. Recovery is generally complete within 12 to 24 months.
In-water Amphibians	Amphibians may be spawning in the spring, but likely in protected areas not exposed to the high summer river flows. Turtles may be present and may be breeding, but also in more protected areas. Direct mortality is unlikely for turtles, although some limited mortality of amphibians in the side channel, or riparian areas of the main Fraser River is possible.	Low to Medium, because amphibians and turtles are likely to occupy protected areas, not exposed to the main flow of the Fraser River.	Spilled CLWB enters the side channel of the Fraser River, moving along it with river flow. Oil spill recovery efforts result in disturbance of this habitat. Recovery is generally complete within 12 to 24 months.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Some shoreline and riparian vegetation is oiled along the overland flow path to the side channel, but little riparian habitat along the side channel or main Fraser River is contacted by oil, because of intermediate water levels. Annual plants contacted by the spilled oil are likely to be killed. Leaves of perennial plants, shrubs and trees will also be killed, but these plants are likely to survive and regenerate. Effects are largely confined to the overland flow path and the area where the oil enters the side channel.	Low. The combination of direct contact with spilled oil, as well as oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near the spill location. Effects on riparian habitat of the side channel and main Fraser River are minimal.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to the side channel. Riparian areas of the side channel and main Fraser River are minimally affected.	Low. The combination of direct contact with spilled oil, as well as oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near the spill location. Effects on riparian habitat of the side channel and main Fraser River are minimal.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivore/carnivores (such as raccoons). A small number of individual animals might come into contact with spilled oil in the overland flow path, the gully, the side channel, or stranded along shorelines of the main Fraser River channel.	Low, because partially oiled animals would not be likely to die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Moose	Moose or other ungulates are potentially affected, as the gully and forested riparian areas of the river could provide sheltering and feeding habitat. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.

TABLE 7.1.12

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER NEAR HOPE, BC (CONTINUED)

Fraser River, Spring or Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Muskrat	Muskrat are potentially affected, as the side channel could provide suitable habitat. Muskrat in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur up to 60 km downstream, and mortality is possible.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
River Otter	River otter are potentially affected, as the side channel could provide suitable habitat. Otters in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur up to 60 km downstream, and mortality is possible.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Birds			
Bald Eagle	Bald eagle would be present during spring and fall, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oil in slicks or stranded on shorelines up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil on shoreline habitat. Oiled birds could also transfer oil to eggs in spring, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oil in slicks or stranded on shorelines up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs in spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard Duck	Nesting mallards or other waterfowl could be exposed to oil in slicks or stranded on shorelines up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in shoreline habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality in spring. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oil stranded on shorelines up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs in spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 60 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult turtles and amphibians could be present in riparian habitat or backwater areas along the Fraser River. Such animals could be exposed to spilled oil for a distance of up to 60 km from the spill location.	High to Medium. Turtles and amphibians along the shorelines of the river would be less exposed, and effect magnitude would decline with distance downstream and decreasing exposure. The risk of mortality would be greatest in the first 6 km (*i.e.,* the side channel).	Spilled CLWB enters the side channel of the Fraser River, moving along it and entering the main channel. Because more of the oil is retained in the side channel, more habitat disturbance results from recovery efforts. Recovery is generally complete within 12 to 24 months.

7.1.5 Scenario 4: Fraser River and Delta near Port Mann Bridge, British Columbia, RK 1,167.5

The hypothetical full bore rupture spill scenario on the bank of the Fraser River near the Port Mann Bridge (RK 1,167.5) was established as 1,250 m^3 of CLWB for the purpose of detailed spill modeling and the pipeline ERA. Subsequent spill outflow modelling volume estimates show slightly different predicted release volumes. The ERA has not been modified to reflect this refinement as the ecological consequences described below are still valid.

The hypothetical spill location is adjacent to railway yards on the south side of the Fraser River, a short distance downstream from the Port Mann Bridge. At this location, the pipeline is within a few hundred metres of the river, and it is likely that culverts and other drainage systems would rapidly transport most of the spilled oil from the spill location to the river. For this reason, there was assumed to be no hold-up of spilled oil on land, although it is possible that by blocking such culverts or ditches as an early emergency response action, a considerable amount of oil could be prevented from reaching the water. The Fraser River at this location is about 450 m wide, with a gentle meander and a sand bed. Shorelines are highly developed with wharves, pilings, log booms and rip-rap. Flows are strongly seasonal, ranging from approximately 7,000 to 12,000 m^3/s in June (during freshet), to 2,000 m^3/s or lower during winter.

Owing to the complex nature of interactions between spilled oil and water, suspended sediment, and hydrology as the Fraser River enters the delta, this spill example is supported by stochastic oil spill fate and transport modeling (Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project [Volume 8C, TR 8C-12, S9]). In addition, the evaluation is supported by reference to two case studies described in the Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1): the Kalamazoo River oil spill, since that oil spill involved a similar form of diluted bitumen; and the DM 932 spill in the lower Mississippi River, since that involved a heavy oil, and a large river/estuary system with high suspended sediment load. Consideration was also given to information that was developed during the Gainford experimental study (see Gainford Study in Volume 8C, TR 8C-12, S7) and as part of the proposed Vancouver Airport Fuel Delivery Project (Vancouver Airport Fuel Facilities Corporation [VAFFC] 2012a).

Three environmental conditions were considered for this spill example:

- A winter condition between December and March. Air temperatures are assumed to be around the freezing mark, but snow cover is not guaranteed, and the river is ice-free. The river flow is in a low range (around 2,000 m^3/s).
- A summer condition between June and August, with air temperatures 15 to 25°C. The river is in freshet, with flow greater than 6,000 m^3/s, and potentially approaching 12,000 m^3/s.
- A spring or fall condition between April and June, or September and November. The river flow is in a moderate range, at around 5,000 m^3/s, and the air temperatures are cool, between 0 and 15°C.

The ERA scenario evaluation did not consider the probability of occurrence of the spill nor the various design, engineering, maintenance, inspection and other preventative programs that Trans Mountain will have in place to reduce the likelihood of spills occurring, the details of which can be found in Section 2.0. Rather, this evaluation assessment was performed based on the premise that the spill had occurred despite these preventative programs. In addition, the evaluation did not consider the full application of emergency response approaches and spill response resources described in Section 4.0, a conservative, and unrealistic, assumption based on evidence from past spills.

7.1.5.1 Ecological Receptors

The ecological receptors considered for the other three hypothetical spill locations were also evaluated for this scenario, considering the potential for a oil spill to affect the Fraser River Delta. However, the potential for finding freshwater turtles and amphibians decreases as the river water becomes brackish. Two species of sea turtle (Pacific green turtle and Pacific leatherback turtle) are reported from BC waters, but reproduce in more southerly areas, and would have a very low probability of being encountered in the Fraser River Delta. Based on regulatory consultation carried out for the Project, as well as consideration of concerns raised during the Vancouver Airport Fuel Delivery Project (Environment Canada 2012, VAFFC 2012a,b) two additional ecological receptors relevant to the Fraser River estuary were evaluated for this scenario: biofilm and Western sandpiper. These receptors are described briefly below; additional information is provided in Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1).

Biofilm (also sometimes referred to as microphytobenthos) is the name given to an assemblage of algal cells, rotifers, protozoans, bacteria and detritus found as a thin layer on the surface of mudflats. The thin, biofilm layer is easily disturbed, although it may potentially help to stabilize the sediment surface from gentle wave action. The biofilm and underlying mud also support benthic invertebrate species such as polychaete worms and small crustaceans.

The Western sandpiper is a small shorebird that nests on tundra in eastern Siberia and Alaska, and summers in the southern US. During spring migration, Roberts Bank can host over one million Western sandpiper over a 15 day period. During this stopover, the sandpipers feed heavily on biofilm (Kuwae *et al.* 2008). While Western sandpiper can be found throughout the mudflat areas of Sturgeon and Roberts Banks and Boundary Bay, an area south of Brunswick Point appears to be particularly important as a congregating and feeding area (VAFFC 2012a).

7.1.5.2 Winter Conditions

7.1.5.2.1 Assumed Fate

Predicted fate during winter conditions is described in Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S9) for the months of November, December, January, February and March. In winter conditions, at this low elevation and proximity to the ocean, it is unlikely that snowpack would be present to influence the behaviour of the spilled CLWB. It is assumed that culverts and ditching are present close to the pipeline, and that this drainage system quickly conveys virtually all of the spilled oil directly to the river over a period of several hours. Although the river stage is low, transit times for the spilled oil to reach the delta are short, on the order of one to two days, depending upon the tidal state at the time of the spill.

Frequent contact with shorelines strands some of the spilled oil, and it is possible that emergency responders could collect and recover some of the spilled oil, particularly in the main channel, before it reaches the mouth of the Fraser River. Failing this, oil entering the main channel is advected downstream. Most of the spilled oil remains within the main river channel, although a small amount enters the north channel but generally strands within a short distance.

The probability of oil presence on the surface of the river exceeds 90 per cent between the Port Mann Bridge and a point downstream of Annacis Island. There is approximately a 50 per cent probability of oil on the surface of the water reaching the islands and marshes near Port Guichon, and about a 5 to 10 per cent probability of oil on the surface of the water exiting the mouth of the river into the Strait of Georgia. This represents a small amount of spilled oil, and the probability of oil stranding on Roberts Bank or other mudflats is low. As with other seasonal simulations, oil leaving via the main river channel tends to be swept out into the Strait of Georgia, and little if any strands in the immediate vicinity of the Delta.

The probability of shoreline oiling is high (generally 60 to 100 per cent between the Port Mann Bridge and the upstream end of Annacis Island, and 60 to 90 per cent along the west and south shorelines of Annacis Island), although lower on the south shoreline of the Fraser River in this area. Lower probability of shoreline oiling (20 to 60 per cent) generally prevails between the middle of Annacis Island and the George Massey Tunnel. Beyond the George Massey Tunnel, the probability of shoreline oiling falls and is generally less than 10 per cent, with most occurring along the main river channel. Some oil is also entrained into the river channels around the islands and marshes near Ladner and Port Guichon, but the probability of oil stranding in these areas is relatively low.

Mass balance plots provided in Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1) show that most of the spilled oil (>80 per cent) strands along river shorelines within three days of spill initiation. By this time, about 11 per cent of the oil has evaporated, and <5 per cent remains on the surface of the water. Small amounts of the oil (generally <1 per cent) have become submerged, undergone biodegradation, or dissolved into the water. Formation of OMA and dispersion of oil into the water are not predicted to occur to any meaningful extent (each representing <0.1 per cent of the spilled oil).

Weathering CLWB is not likely to achieve a density greater than that of brackish water within 10 days of being spilled (see Gainford Study in Volume 8C, TR 8C-12, S7). The spilled oil therefore floats until it strands on shorelines. As it weathers, it becomes more viscous and thicker, but strands before its density approaches or exceeds that of the water. Little oil is entrained in the water column due to the viscosity of the oil and the relatively low turbulence of the river flow. Turbidity is at a seasonally low level due to low water flow. The water is brackish, so OMA formation is limited primarily by the low levels of suspended oil droplets, and low suspended sediment concentrations. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand particles as the oil weathers, so that the weathered oil-sand mixture may become submerged if it is subsequently eroded or flooded before it can be recovered. Owing to winter conditions, many of the ecological receptors that could potentially be exposed are absent, or dormant.

7.1.5.2.2 Potential Effects

Table 7.1.13 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group for the Fraser River and Delta Port Mann spill scenario during winter. River level may substantially alter the characteristics of exposed shorelines. At low river flows, little shoreline vegetation or rip-rap would be exposed to flowing water or oil, and most of the exposed shoreline would be sandy or muddy. The lower river reaches and Delta have a greater amount of fringing marsh, with relatively less artificial shoreline. Oil spill recovery effects on the main channel of the Fraser River and in marsh areas near Ladner and Port Guichon would likely be substantial. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to five years.

Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would be limited in spatial extent. The Fraser River provides fish habitat and is a major migration route for Pacific salmon, but winter conditions are not the primary season for such migrations. The main stem of the Fraser River is not likely to experience fish kills due to the large volume of flowing water, the low turbulence and limited potential for oil droplet formation, as indicated by the very small fraction of the spilled CLWB predicted to become dissolved in the water.

Effect magnitudes on shoreline and riparian vegetation and soil invertebrates would be low, due to low water levels and lack of oiling of riparian habitats, as well as to winter dormancy. Some of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* some migratory birds), although birds such as bald eagle and waterfowl could be present around the river through the winter due to the ice free conditions. The Delta is also an important wintering area for large numbers of birds, including raptors, waterfowl, and many shorebirds, particularly in sheltered habitat areas like side channels and wetlands. It is less likely that large mammals (such as bear or moose) would be present in this predominantly urban landscape, however, other wildlife species such as raccoon, fox, deer, otter and muskrat would be present and active year-round. Effect magnitudes for mammals and birds would generally be low to medium due to lack of exposure for migratory birds or hibernating mammals. However, higher effect magnitudes would be seen for semi-aquatic mammals in the Fraser River due to oiling of fur. Higher effect magnitudes could also be seen for wintering birds such as ducks, depending upon the numbers present. Recovery of the various ecological receptors from oil spill effects would take approximately 12 months to five years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer.

TABLE 7.1.13

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC

Fraser River Delta, Winter Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	**Effect Magnitude**	**Time to Recovery**
Aquatic Receptors			
Biofilm	Biofilm of variable quality will be present wherever sediments are exposed and remain moist at low tide, along the Fraser River channels and on the Banks and mudflats, but particularly in more protected areas and on more stable substrates. Biofilm will not be present on the river bed, generally, as a result of poor light penetration and the shifting sand nature of the river bed. The probability of shoreline oiling in the river is greatest along the south shore between the Port Mann Bridge and Annacis Island, becoming medium in the vicinity of the island, medium to low between the downstream end of Annacis Island and the George Massey Tunnel, and low downstream of the George Massey Tunnel. Sturgeon Bank, Roberts Bank, and the mudflats of Boundary Bay are not significantly exposed to oiling.	Variable, with a High effect magnitude in areas along the river shorelines where oiling is heavy; becoming Low downstream of the George Massey tunnel, and Negligible on the Banks and Boundary Bay.	Short. Biofilm has been observed to re-form within 24 hours following removal from mudflats (VAFFC 2012a), and it is likely that once shoreline clean-up has taken place, biofilm will readily regenerate.
Aquatic Vegetation	Aquatic vegetation is not expected to be a significant component in the main stem of the river, and will be senescent during the winter months in wetland areas that would otherwise be more productive.	Medium to Low. Aquatic vegetation is not actively growing at the time of the spill. However, oil spill recovery activities may result in some damage to oiled shorelines in the lower part of the river. The probability of shoreline oiling decreases substantially below the George Massey Tunnel.	Oil spill recovery efforts along the river channel and in wetland areas result in some disturbance of this habitat, but erosion and deposition of sediment during and after the summer high flow period effectively restore this habitat, so that effects persist for 6 to 18 months.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the main Fraser River, and in wetland and side-channel areas. Effects on the benthic community are low, however, as a result of the small amount of spilled hydrocarbon that becomes dissolved in the river water, and the large river flow.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the benthic community are minor, and rapidly reversible.
Fish and Fish Eggs	Fish are present in the main Fraser River, but it is not a major migratory period for salmon or eulachon, although steelhead could be migrating up the river during the winter period. Mortality of fish in the main Fraser River is unlikely as a result of the large volume of water flowing in the river and the low probability of oil droplet formation.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the fish community are minor, and rapidly reversible.
In-water Amphibians	Juvenile amphibians are not present in winter conditions. Adult amphibians may be overwintering in the sediments of the protected areas in the upstream portion of the river, but are minimally affected. The presence of amphibians becomes less likely as the river becomes more brackish, downstream.	Low, as a result of the low numbers expected to be present in this habitat, and the overwintering dormancy of any animals that may be present.	Short. Effects on amphibians are minor, and rapidly reversible.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	The overland flowpath comprises industrial lands, ditches and culverts. Little if any shoreline riparian habitat of the Fraser River is affected, as a result of low winter water flow rates. Water levels in the Delta and on the Banks remain within normal tidal ranges, so shoreline vegetation is not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low for shoreline communities along the river and in the Delta, as a result of lack of exposure to oiling.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils or vegetation communities of the river and Delta.
Soil Invertebrates	The overland flowpath comprises industrial lands, ditches and culverts. Little if any shoreline habitat of the Fraser River is affected, as a result of low winter water flow rates. Water levels in the Delta and on the Banks remain within normal tidal ranges, so shoreline soil invertebrate communities are not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low for shoreline communities along the river and in the Delta, as a result of lack of exposure to oiling.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils or invertebrate communities of the river and Delta.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons and foxes), some of which may be winter-active in the lower mainland of BC, even if grizzly bear are not present. A small number of individual animals might come into contact with spilled oil in the overland flowpath, or stranded along shorelines of the Fraser River and Delta.	Low, because mild winter conditions reduce the probability that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils or invertebrate communities of the river and Delta.
Moose	It is unlikely that moose would be exposed, but other ungulates such as deer could use habitat along the river or in the Delta. Effects of external oiling on more than a few individual animals are unlikely.	Low, because soil spill clean-up activities will largely be confined to SCAT, and disturbance of habitat where deer or other ungulates are present is likely to be short-term and intermittent.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils and terrestrial habitats of the river and Delta.

TABLE 7.1.13

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC (continued)

Fraser River Delta, Winter Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	Effect Magnitude	Time to Recovery
Muskrat	Muskrat are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the main Fraser River channel or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual muskrat causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
River Otter	Otters are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy habitat in the main Fraser River channel, or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual otters causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
Birds			
Bald Eagle	Bald eagle, as well as many other raptors, are present year-round. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel.	Low. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	The Fraser River Delta provides important wintering habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel. Geese are likely to spend much of their time foraging in farmland on Westham Island and near Ladner.	Generally Low, as a result of low level of exposure, although individual birds could die if more heavily oiled.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	The Fraser River Delta provides important wintering habitat for herons. Individual birds could become oiled while foraging in shallow water or along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel. Herons also utilize terrestrial habitat and often hunt for voles in farmland during winter.	Generally Low, as a result of low level of exposure, although individual birds could die if more heavily oiled.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	The Fraser River Delta provides important wintering habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel. Ducks and swans generally would have greater exposure to oil than geese, as a result of their more aquatic habits.	Generally Medium to High. Oil presence on the water surface and stranded along shorelines is most likely in the main river channel, and Low elsewhere, including side channels and sloughs, and in the more marine environment of Roberts and Sturgeon Banks. Individuals and groups of birds could die (giving a High effect magnitude) if heavily oiled in the main river channel. Mortality is less likely elsewhere as a result of lower exposure.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Not likely to be affected as the winter range is south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Western Sandpiper	Not likely to be affected as the winter range is south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	Not Applicable as a result of low probability of shoreline oiling in the Banks.
Tree Swallow	Not likely to be affected as the winter range is south of the pipeline right of way in BC.	Low, as a result of lack of exposure.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the Western painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. The presence of turtles and amphibians becomes less likely as the waters of the estuary become more brackish.	Low, as a result of lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

7.1.5.3 Summer Conditions

7.1.5.3.1 Assumed Fate

Predicted fate during winter conditions is described in Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S9) for the months of May, June and July. Spill summary information is presented in Appendix B. In summer conditions, it is assumed that the river is at or near peak flow. It is assumed that culverts and ditching are present close to the pipeline, and that this drainage system quickly conveys virtually all of the spilled oil directly to the river over a period of several hours. Transit times for the spilled oil to reach the river mouth are short, on the order of one day, and tidal state is less important in summer than in winter, due to the high water level and flow rate which overwhelm the tidal influence.

Frequent contact with shorelines strands some of the spilled oil, but most of the oil would be advected rapidly downstream. Less of the oil is stranded along shorelines than under winter conditions, and more remains on the water surface, having been discharged into the Strait of Georgia. As in winter, most of the spilled oil is transported along the main river channel. Very little enters the north channel, and this oil generally strands within a short distance. More oil, however, is transported into side channels near Ladner and Port Guichon, and most of this oil is likely to become stranded in the side channels, wetlands and sloughs.

The probability of oil presence on the surface of the river exceeds 90 per cent between the Port Mann Bridge and a point downstream of the George Massey Tunnel. From there to the mouth of the river, the probability of oil on the surface is between 60 and 80 per cent. There is about a 40 per cent probability of oil on the surface of the water entering the side channels and marshes near Ladner and Port Guichon. Oil that reaches the mouth of the river is discharged into the Strait of Georgia with considerable momentum, so it is likely to disperse to the north or south in the Strait and does not have a high probability of directly affecting the Sturgeon or Roberts Banks. It is more likely that this oil will affect shorelines on the opposite side of the Strait.

The probability of shoreline oiling is high (generally 60 to 100 per cent along the south shore of the river between the Port Mann Bridge and the upstream end of Annacis Island), becoming moderate (40 to 60 per cent along the west and south shorelines of Annacis Island, and along the north shoreline of the Fraser River from the lower end of Annacis Island to the George Massey Tunnel). Moderate probability of shoreline oiling (20 to 40 per cent) generally prevails along the balance of the main channel, and low probability of oiling (<10 per cent) prevails in the side channels and wetlands near Ladner and Port Guichon. There is low probability of oiling shorelines along the Sturgeon and Roberts Banks, although some oiling occurs around Point Roberts.

Mass balance plots provided in Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1) show that less of the spilled oil (<60 per cent) is likely to strand along river shorelines than during the winter. About 10 per cent of the oil evaporates, and about 30 per cent may remain on the surface of the water. Small amounts of the oil (generally <1 per cent) also become submerged, undergo biodegradation, or dissolve into the water. Formation of OMA and dispersion of oil into the water are not predicted to occur to any meaningful extent (each representing <0.1 per cent of the spilled oil).

Weathering CLWB is not likely to achieve a density greater than that of brackish water within 10 days of being spilled (see Gainford Study in Volume 8C, TR 8C-12, S7). The spilled oil therefore floats until it strands on shorelines. As it weathers, it becomes more viscous and thicker, but mostly strands before its density approaches or exceeds that of the water. Little oil is entrained in the water column due to the viscosity of the oil and the relatively low turbulence of the river flow. Although the river has relatively high turbidity due to the high flow rate, and the water is brackish, OMA formation remains low due to the low abundance of suspended oil droplets. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand particles as the oil weathers, so that the weathered oil-sand mixture may become submerged if it is subsequently eroded or flooded before it can be recovered. In addition, there is a potential for reed beds and salt marsh vegetation to trap floating or submerged oil being transported in the river if it enters wetland habitats.

7.1.5.3.2 Potential Effects

Table 7.1.14 summarizes the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group for the Fraser River and Delta Port Mann spill scenario during summer. River level may substantially alter the characteristics of exposed shorelines. At high water levels, oil may enter and become trapped by rip-rap, or contact flooded riparian vegetation. The lower river reaches and Delta have a greater amount of fringing marsh, with relatively less artificial shoreline. Oil spill recovery efforts would likely result in environmental effects along the overland flowpath, but as these areas are industrial lands the effects on ecological receptors are minimal.

Effects on aquatic receptors are variable. Effects on aquatic vegetation are of medium magnitude as the spilled oil largely floats on the surface of the water, and oil that enters salt marsh or reed bed areas may become trapped there. Although the physical effects of this oil on the vegetation may be low to medium, oil spill recovery effects may be equally damaging to the vegetation, as well as affecting habitat utilization by wildlife species. Effects on fish and fish habitat, as well as benthic invertebrates would be low and limited in spatial extent. The Fraser River and Delta provide important fish habitat and the river is a major migration route for Pacific salmon, and some of these fish would be moving through the river during summer. The river is also an important migratory route for Eulachon in spring, with spawning occurring in the river between Chilliwack and Mission. Late spawning adults or fry could be moving down the river in summer. The main stem of the Fraser River, however, is not likely to experience fish kills due to the large volume of flowing water, the low turbulence and limited potential for dissolved hydrocarbons and oil droplet formation, as indicated by the very small fraction of the spilled CLWB predicted to be dissolved in water. There is also low potential for effects on amphibians and reptiles, due to the limited distribution of turtles, and expected decline in habitat quality as the river becomes more brackish.

A considerable amount of the spilled oil becomes stranded along shorelines, and riparian vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are low on the overland flowpath, due to the industrial nature of the land, becoming medium to high along the main Fraser River channel, and medium in the Delta as the probability of shoreline oiling decreases. Fraser River riparian areas are likely to be remediated with relatively non-intrusive methods, and an emphasis on natural attenuation of spilled oil residues at low levels. Oil spill recovery effects on the main channel of the Fraser River, and in marsh areas near Port Guichon, would likely be substantial. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 12 months to five years.

During summer conditions, most migrating birds (*e.g.,* Western sandpiper) would already be at their summer breeding grounds farther north, although the Delta is noted as high quality habitat for raptors, waterfowl, and shorebirds. Guilds such as ducks and geese are considered to be most exposed and sensitive to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend along the entire river channel, as well as affecting portions of the Delta. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level. Some of the spilled oil would be swept into the Strait of Georgia, and could affect other seabirds, such as alcids, on summer feeding grounds.

Environmental effects on mammal populations are potentially high for truly aquatic species such as muskrat, beaver, otter and mink, and it is assumed that some of these animals could be sufficiently oiled to cause death. For mammals that are larger or that are less adapted to the aquatic environment, such as raccoons fox and deer, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of oil.

TABLE 7.1.14

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC

Fraser River Delta, Summer Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	**Effect Magnitude**	**Reversibility and Time to Recovery**
Aquatic Receptors			
Biofilm	Biofilm of variable quality will be present wherever sediments are exposed and remain moist at low tide, along the Fraser River channels and on the Banks and mudflats, but particularly in more protected areas and on more stable substrates. Biofilm will not be present on the river bed, generally, as a result of poor light penetration and the shifting sand nature of the river bed. In summer, with the river in freshet, the probability is high that oil will reach the river mouth and be discharged into the Strait of Georgia within 1 day of the spill. In the Strait, the oil is forced in a jet towards the open water and disperses, with very low probability (around 1%) of oil occurring on the water surface or stranding at Sturgeon or Roberts Banks. It is more likely that oil will disperse to the north and south in the Strait of Georgia, or cross the strait and strand along the shorelines of Gabriola, Valdes and Galiano Islands, although such oiling would be light and spatially discontinuous. The probability of shoreline oiling in the river is greatest along the south shore between the Port Mann Bridge and Annacis Island, becoming medium in the vicinity of the island, and medium to low between the downstream end of Annacis Island and the mouth of the river.	Variable, with a High effect magnitude in areas along the river shorelines where oiling is heavy; becoming Medium downstream of the George Massey tunnel, including areas of wetland near Ladner, Low along the shorelines of the Gulf Islands, and Negligible on Sturgeon and Roberts Banks and in Boundary Bay.	Short. Biofilm has been observed to re-form within 24 hours following removal from mudflats (VAFFC 2012a), and it is likely that once shoreline clean-up has taken place, biofilm will readily regenerate.
Aquatic Vegetation	Aquatic vegetation is not expected to be a significant component in the main stem of the river. Wetland vegetation will be actively growing during the summer, and both floating and emergent vegetation may be exposed to oiling while the river is in freshet. Effects are likely to occur in the wetlands near Ladner.	Medium to High. Emergent aquatic vegetation is likely to survive low to moderate oiling of stems. However, reed beds and salt marsh are likely to trap and retain floating oil. Oil spill recovery activities may result in damage to these areas in the lower part of the river.	Oil spill recovery efforts along the river channel and in wetland areas result in some disturbance of this habitat, but most of the aquatic vegetation regenerates from buried root systems, so that recovery is essentially complete in the year following the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the main Fraser River, and in wetland and side-channel areas. Effects on the benthic community are low, however, as a result of the small amount of spilled hydrocarbon that becomes dissolved in the river water, and the large river flow.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the benthic community are minor, and rapidly reversible.
Fish and Fish Eggs	Fish are present in the main Fraser River. Some salmonids may be migrating through the river, and late spawning eulachon or juvenile eulachon may be out-migrating. Mortality of fish in the Fraser River or Delta is unlikely as a result of the large volume of water flowing in the river, and the low level of entrainment of oil droplets into the water column.	Low in the Fraser River and Delta, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the fish community are minor, and rapidly reversible.
In-water Amphibians	Juvenile and adult amphibians may be present in the upstream portion of the river, but are minimally affected. The presence of amphibians becomes less likely as the river becomes more brackish, downstream.	Low, as a result of the low numbers expected to be present in the affected habitat.	Short. Effects on amphibians are minor, and rapidly reversible.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	The overland flowpath comprises industrial lands, ditches and culverts. High water levels caused by freshet result in oil entering and stranding in shoreline riparian habitat of the Fraser River. Water levels in the Delta are also high, causing flooding of marshlands with some oil stranding. Water levels on the Banks remain within normal tidal ranges, and oiling is minimal, so shoreline vegetation there is not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. High to Medium for shoreline riparian habitat along the river, with greater effect magnitude on the south side of the river, between the spill location and the upstream end of Annacis Island. Medium to Low for shoreline communities farther downstream and in the Delta, as a result of lower exposure to oiling. Low to Negligible on near the Sturgeon and Roberts Banks, and Negligible along shorelines of Gabriola, Valdes and Galiano Islands, and near Point Roberts, as oil that initially dispersed in the Strait of Georgia becomes stranded in the upper intertidal zone.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Recovery efforts in riparian areas that were moderately to heavily oiled cause some damage to annual vegetation, but this regenerates in subsequent years.
Soil Invertebrates	The overland flowpath comprises industrial lands, ditches and culverts. High water levels caused by freshet result in oil entering and stranding in shoreline riparian habitat of the Fraser River. Water levels in the Delta are also high, causing flooding of marshlands with some oil stranding. Water levels on the Banks remain within normal tidal ranges, and oiling is minimal, so shoreline vegetation there is not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. High to Medium for shoreline riparian habitat along the river, with greater effect magnitude on the south side of the river, between the spill location and the upstream end of Annacis Island. Medium to Low for shoreline communities farther downstream and in the Delta, as a result of lower exposure to oiling. Low to Negligible on near the Sturgeon and Roberts Banks, and Negligible along shorelines of Gabriola, Valdes and Galiano Islands, and near Point Roberts, as oil that initially dispersed in the Strait of Georgia becomes stranded in the upper intertidal zone.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Riparian areas that were moderately to heavily oiled may experience some harm to soil invertebrate communities, but these recover in subsequent years after clean-up.

TABLE 7.1.14

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC (continued)

Fraser River Delta, Summer Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	Effect Magnitude	Reversibility and Time to Recovery
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons and foxes), some of which will be present in the lower mainland of BC, even if bears are not present. A small number of individual animals might come into contact with spilled oil in the overland flowpath, or stranded along shorelines of the Fraser River and Delta.	Low, because it is unlikely that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled riparian areas could cause disturbance of habitat use for several months.
Moose	It is unlikely that moose would be exposed, but other ungulates such as deer could use habitat along the river or in the Delta. Effects of external oiling on more than a few individual animals are unlikely.	Low, because soil spill clean-up activities will largely be confined to SCAT, and disturbance of habitat where deer or other ungulates are present is likely to be short-term and intermittent.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled riparian areas could cause disturbance of habitat use for several months.
Muskrat	Muskrat are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the main Fraser River channel or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual muskrat causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
River Otter	Otters are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy habitat in the main Fraser River channel, or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual otters causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
Birds			
Bald Eagle	Bald eagle, as well as many other raptors, are present year-round. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Low to Medium. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Geese are likely to nest close to water, and could be exposed to oil on the surface of the water, or stranded along shorelines.	Generally Low to Medium, depending on the level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	The Fraser River Delta provides important foraging habitat for herons. Individual birds could become oiled while foraging in shallow water or along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Generally Low to Medium, as a result of low level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Ducks and swans generally would have greater exposure to oil than geese, as a result of their more aquatic habits.	Generally Medium to High, as individual birds could die if more heavily oiled. Oil presence on the water surface and stranded along shorelines is most likely in the main river channel, and lower elsewhere, including side channels and sloughs, and in the more marine environment of Roberts and Sturgeon Banks. Individuals and groups of birds could die if heavily oiled in the main river channel. Mortality is less likely elsewhere as a result of lower exposure. Oiling also extends out onto the Strait of Georgia, although it is patchy and discontinuous. This could result in negative effects including mortality to sea ducks, cormorants, and alcids. Disturbance caused by oil spill recovery activities could temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 7.1.14

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC (continued)

Fraser River Delta, Summer Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	**Effect Magnitude**	**Reversibility and Time to Recovery**
Spotted Sandpiper	Shorebirds like the spotted sandpiper are likely to be present along the Fraser River channel, and throughout the Delta and Banks. They have a lower level of sensitivity to oiling than more aquatic birds such as ducks. Effects are likely to be related to the intensity of shoreline oiling, where there are shoreline types and/or adjacent upland habitats that are utilized by these birds.	Medium to low, depending upon the level of exposure. Exposure will be greatest along the main channel of the Fraser River, where mortality could occur in heavily oiled sections, and in the parts of the Delta. Negligible exposure is expected on Sturgeon and Roberts Banks, although low levels of exposure could be present on the shorelines of Gabriola, Valdes and Galiano Islands, as well as towards Point Roberts. Disturbance caused by oil spill recovery activities could temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Western Sandpiper	Not likely to be affected as they would be occupying summer breeding grounds far north of the Fraser River Delta.	Low, as a result of lack of exposure.	Not Applicable.
Tree Swallow	Tree swallows could be breeding along the Fraser River and around the Delta, and could be exposed to oil while dipping to the water. Direct mortality is unlikely, but oil could be transferred to eggs, causing mortality of developing embryos. Spatial extent is determined by the presence of oil on the water surface, principally affecting the main Fraser River channel for a period of several days.	Low to Medium, depending upon the level of exposure. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the Western painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. The presence of turtles and amphibians becomes less likely as the waters of the estuary become more brackish.	Low, as a result of low numbers present and lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

7.1.5.4 Spring or Fall Conditions

7.1.5.4.1 Assumed Fate

Predicted fate during winter conditions is described in Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S9) for the months of April, August and September. In spring and fall conditions, it is assumed that the river is on the rising or falling limbs of its peak, not at peak flow. It is assumed that culverts and ditching are present close to the pipeline, and that this drainage system quickly conveys virtually all of the spilled oil directly to the river over a period of several hours. Although the river stage is intermediate, transit times for the spilled oil to reach the river mouth are short, on the order of one or two days. The river is not flooding into riparian habitats, and is somewhat tidal, with flow reversal on high tides, as far upstream as the Port Mann Bridge.

Frequent contact with shorelines strands some of the spilled oil, but most of the oil would be rapidly advected downstream. Less of the oil is stranded along shorelines than under winter conditions, and some remains on the water surface, having been discharged into the Strait of Georgia. As in winter and summer, most of the spilled oil is transported along the main river channel. Very little enters the north channel, and this oil generally strands within a short distance. Some oil, however, is transported into side channels near Ladner and Port Guichon, and may become stranded in the side channels, wetlands and sloughs.

The probability of oil presence on the surface of the river exceeds 90 per cent between the Port Mann Bridge and a point approaching the George Massey Tunnel. From the George Massey Tunnel to the mouth of the river, the probability of oil on the surface is between 60 and 80 per cent. There is about a 40 per cent probability of oil on the surface of the water entering the side channels and marshes near Ladner and Port Guichon. Oil that reaches the mouth of the river is discharged into the Strait of Georgia with considerable momentum, so that it is likely to disperse to the north or south in the Strait and does not have a high probability of directly affecting the Sturgeon or Roberts Banks. It is more likely that this oil will affect shorelines on Gabriola, Valdes and Galiano Islands, or at Point Roberts.

The probability of shoreline oiling is high (generally 60 to 100 per cent along the south shore of the river between the Port Mann Bridge and the upstream end of Annacis Island), becoming moderate (40 to 60 per cent along the west and south shorelines of Annacis Island, and along the north shoreline of the Fraser River from the lower end of Annacis Island to the George Massey Tunnel). Moderate probability of shoreline oiling (20 to 40 per cent) generally prevails along the balance of the main channel, and low probability of oiling (<10 per cent) prevails in the side channels and wetlands near Ladner and Port Guichon. As in summer, a considerable amount of the spilled oil is transported into the Strait of Georgia, where it disperses. Some of this oil subsequently strands along the shorelines of Gabriola, Valdes and Galiano Islands, or at Point Roberts, but very little strands on Sturgeon or Roberts Bank, or in Boundary Bay.

Mass balance plots provided in Qualitative Ecological Risk Assessment of Pipeline Spills Technical Report (TR 7-1) show that more of the spilled oil (about 70 per cent) is likely to strand along river shorelines than during the summer. About 10 per cent of the oil evaporates, and about 20 per cent may remain on the surface of the water. Small amounts of the oil (generally <1 per cent) also become submerged, undergo biodegradation, or dissolve into the water. Formation of OMA and dispersion of oil into the water are not predicted to occur to any meaningful extent (each representing <0.1 per cent of the spilled oil).

Weathering CLWB is not likely to achieve a density greater than that of brackish water within 10 days of being spilled (see Gainford Study in Volume 8C, TR 8C-12, S7). The spilled oil therefore floats until it strands on shorelines. As it weathers, it becomes more viscous and thicker, but mostly strands before its density approaches or exceeds that of the water. Little oil is entrained in the water column due to the viscosity of the oil and the relatively low turbulence of the river flow. Although the river has relatively high turbidity, due to the flow rate, and the water is brackish, OMA formation remains low due to the low abundance of suspended oil droplets. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand particles as the oil weathers, so that the weathered oil-sand mixture may become submerged if it is subsequently eroded or flooded before it can be recovered, as could easily occur in the springtime. In addition, there is a potential for reed beds and salt marsh vegetation to trap floating or submerged oil being transported in the river if it enters wetland habitats.

7.1.5.4.2 Potential Effects

Table 7.1.15 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group for the Fraser River and Delta Port Mann spill scenario during spring or fall conditions. Effect magnitude on the overland flowpath is low, due to the industrialized nature of the land. At high water levels, oil may enter and become trapped by rip-rap, or contact flooded riparian vegetation. The lower river reaches and Delta have a greater amount of fringing marsh, with relatively less artificial shoreline. Oil spill recovery effects on the main channel of the Fraser River, and in marsh areas near Port Guichon, would likely be substantial, leading to physical habitat disturbance. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 12 months to five years.

Effects on aquatic receptors are variable. Effects on aquatic vegetation are of medium magnitude as the spilled oil largely floats on the surface of the water, and oil that enters salt marsh or reed bed areas may become trapped there. Although the physical effects of this oil on the vegetation may be low to medium, oil spill recovery effects may be equally damaging to the vegetation, as well as affecting habitat utilization by wildlife species. The Fraser River and Delta provide important fish habitat and the river is a major migration route for Pacific salmon, and some of these fish would be moving through the river during spring and fall. The river is also an important migratory route for Eulachon in spring, with spawning occurring in the river between Chilliwack and Mission. Effects on benthic invertebrates and fish are generally low however as the main stem of the Fraser River is not likely to experience fish kills due to the large volume of flowing water, the low turbulence and limited potential for oil droplet formation, as indicated by the very small fraction of the spilled CLWB that becomes dissolved in the water. There is also low potential for effects on amphibians and reptiles, due to the limited distribution of turtles, and expected decline in habitat quality as the river becomes more brackish.

A considerable amount of the spilled oil becomes stranded along shorelines, but not in riparian areas, so effects on terrestrial plants and soil invertebrates are negligible. Environmental effects on mammal populations are potentially high for truly aquatic species such as muskrat, beaver, otter and mink, and it is assumed that some of these animals could be sufficiently oiled to cause death. For mammals that are larger or that are less adapted to the aquatic environment, such as raccoon, fox and deer, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of oil.

During spring and fall conditions, migrating birds (*e.g.,* Western sandpiper) could be present, depending upon the exact timing of their migrations. The Delta is noted as high quality habitat for raptors, waterfowl, and shorebirds, and it is assumed that a large number of species would be present either as resident or migrating species. Guilds such as ducks and geese are considered to be most exposed and sensitive to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend along the entire river channel, as well as affecting portions of the Delta. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times could be as short as 12 months for some receptors, or up to five years where effects occur at the population level. Some of the spilled oil would be swept into the Strait of Georgia, and could affect other seabirds, such as alcids.

Particular consideration was given in this scenario to Western sandpiper, which use the Sturgeon and Roberts Banks as a stopover and feeding area during spring and fall migrations. For short periods of time, hundreds of thousands of birds may congregate on the banks, feeding on biofilm and benthic invertebrates present in the mudflats. Oil fate modeling (Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S9) shows that the probability of oiling on Sturgeon and Roberts Banks is very low, either because the oil becomes stranded and does not exit from the Delta during periods of low flow, or because it is carried through and away from the Delta and into the Strait of Georgia by the momentum of the freshwater jet created by the Fraser River during periods of moderate or high flow. Once in the Strait of Georgia, the oil will continue to weather and disperse, and stranding does occur on the shorelines of Gabriola, Valdes and Galiano Islands and Point Roberts, but at low probability and intensity. The biofilm itself is not likely to be materially affected if weathered oil becomes stranded, and recovers quickly from disturbance. Therefore, biofilm and Western sandpiper are unlikely to be significantly affected in the event of a pipeline oil spill that results in oil entering the Fraser River near the Port Mann Bridge and any effects are likely to be reversible.

TABLE 7.1.15

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC

Fraser River Delta, Spring or Fall Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Duration
Aquatic Receptors			
Biofilm	Biofilm of variable quality will be present wherever sediments are exposed and remain moist at low tide, along the Fraser River channels and on the Banks and mudflats, but particularly in more protected areas and on more stable substrates. Biofilm will not be present on the river bed, generally, as a result of poor light penetration and the shifting sand nature of the river bed. In spring and fall, with the river at about average annual flow rate, the probability is high that oil will reach the river mouth and be discharged into the Strait of Georgia within 1 or 2 days of the spill. In the Strait, the oil is forced in a jet towards the open water and disperses, with very low probability (around 1%) of oil occurring on the water surface or stranding at Sturgeon or Roberts Banks. It is more likely that oil will disperse to the north and south in the Strait of Georgia, or cross the strait and strand along the shorelines of Gabriola, Valdes or Galiano Islands, although such oiling would be light and spatially discontinuous. The probability of shoreline oiling in the river is greatest along the south shore between the Port Mann Bridge and Annacis Island, becoming medium in the vicinity of the island, and medium to low between the downstream end of Annacis Island and the mouth of the river.	Variable, with a High effect magnitude in areas along the river shorelines where oiling is heavy; becoming Medium downstream of the George Massey tunnel, including areas of wetland near Ladner, Low along the shorelines of the Gulf Islands, and Negligible on Sturgeon and Roberts Banks and in Boundary Bay.	Short. Biofilm has been observed to re-form within 24 hours following removal from mudflats (VAFFC 2012a), and it is likely that once shoreline clean-up has taken place, biofilm will readily regenerate.
Aquatic Vegetation	Aquatic vegetation is not expected to be a significant component in the main stem of the river. Wetland vegetation will be actively growing during the spring, becoming senescent in fall. Both floating and emergent vegetation will be exposed to oiling. Effects are likely to occur in the wetlands near Ladner.	Medium to High. Emergent aquatic vegetation is likely to survive low to moderate oiling of stems. However, reed beds and salt marsh are likely to trap and retain floating oil. Oil spill recovery activities may result in damage to these areas in the lower part of the river.	Oil spill recovery efforts along the river channel and in wetland areas result in some disturbance of this habitat, but most of the aquatic vegetation regenerates from buried root systems, so that recovery is essentially complete in the year following the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the main Fraser River, and in wetland and side-channel areas. Effects on the benthic community are low, however, as a result of the small amount of spilled hydrocarbon that becomes dissolved in the river water, and the large river flow.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the benthic community are minor, and rapidly reversible.
Fish and Fish Eggs	Fish are present in the main Fraser River. Some salmonids may be migrating through the river, and eulachon may be entering the river to spawn in spring. Mortality of fish in the Fraser River or Delta is unlikely as a result of the large volume of water flowing in the river, and the low level of entrainment of oil droplets into the water column.	Low in the Fraser River and Delta, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the fish community are minor, and rapidly reversible.
In-water Amphibians	Juvenile and adult amphibians may be present in the upstream portion of the river, but are minimally affected. The presence of amphibians becomes less likely as the river becomes more brackish, downstream.	Low, as a result of the low numbers expected to be present in this habitat.	Short. Effects on amphibians are minor, and rapidly reversible.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	The overland flowpath comprises industrial lands, ditches and culverts. Moderate water levels do not cause oil to enter or strand in riparian habitat.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low in riparian habitat of the river and Delta as a result of lack of oil entering or stranding in such habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors.
Soil Invertebrates	The overland flowpath comprises industrial lands, ditches and culverts. Moderate water levels do not cause oil to enter or strand in riparian habitat.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low in riparian habitat of the river and Delta as a result of lack of oil entering or stranding in such habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons and foxes), some of which will be present in the lower mainland of BC, even if bears are not present. A small number of individual animals might come into contact with spilled oil in the overland flowpath, or stranded along shorelines of the Fraser River and Delta.	Low, because it is unlikely that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled shoreline areas could cause disturbance of habitat use for several months.
Moose	It is unlikely that moose would be exposed, but other ungulates such as deer could use habitat along the river or in the Delta. Effects of external oiling on more than a few individual animals are unlikely.	Low, because clean-up activities will largely be confined to SCAT, and disturbance of habitat where deer or other ungulates are present is likely to be short-term and intermittent.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled shoreline areas could cause disturbance of habitat use for several months.

TABLE 7.1.15

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC (continued)

Fraser River Delta, Spring or Fall Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Duration**
Muskrat	Muskrat are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the main Fraser River channel or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual muskrat causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
River Otter	Otters are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy habitat in the main Fraser River channel, or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual otters causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
Birds			
Bald Eagle	Bald eagle, as well as many other raptors, are present year-round. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Low to Medium. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Geese are likely to nest close to water, and could be exposed to oil in the surface of the water, or stranded along shorelines.	Generally Low to Medium, depending on the level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	The Fraser River Delta provides important foraging habitat for herons. Individual birds could become oiled while foraging in shallow water or along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Generally Low to Medium, as a result of low level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Ducks and swans generally would have greater exposure to oil than geese, as a result of their more aquatic habits.	Generally Medium to High, as individual birds could die if more heavily oiled. Oil presence on the water surface and stranded along shorelines is most likely in the main river channel, and lower elsewhere, including side channels and sloughs, and in the more marine environment of Roberts and Sturgeon Banks. Individuals and groups of birds could die if heavily oiled in the main river channel. Mortality is less likely elsewhere as a result of lower exposure. Oiling also extends out onto the Strait of Georgia, although it is patchy and discontinuous. This could result in negative effects including mortality to sea ducks, cormorants, and alcids. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Shorebirds like the spotted sandpiper are likely to be present along the Fraser River channel, and throughout the Delta and Banks. They have a lower level of sensitivity to oiling than more aquatic birds such as ducks. Effects are likely to be related to the intensity of shoreline oiling, where there are shoreline types and/or adjacent upland habitats that are utilized by these birds.	Medium to Low, depending upon the level of exposure. Exposure will be greatest along the main channel of the Fraser River, where mortality could occur in heavily oiled sections, and in the parts of the Delta. Negligible exposure is expected on Sturgeon and Roberts Banks, although low levels of exposure could be present on the shorelines of Gabriola, Valdes and Galiano Islands, as well as towards Point Roberts. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 7.1.15

LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BC (continued)

Fraser River Delta, Spring or Fall Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Duration
Western Sandpiper	Western sandpiper arrive at the Fraser River Delta in large numbers while migrating in spring and fall, feeding heavily on biofilm and benthic invertebrates on Roberts and Sturgeon Banks, and in Boundary Bay. These areas are predicted to have a very low level of exposure to floating or stranded crude oil.	Low, as a result of low level of exposure.	Six months or less
Tree Swallow	Tree swallows could be breeding along the Fraser River and around the Delta, and could be exposed to oil while dipping to the water. Direct mortality is unlikely, but oil could be transferred to eggs, causing mortality of developing embryos. Spatial extent is determined by the presence of oil on the water surface, principally affecting the main Fraser River channel for a period of several days.	Low to Medium, depending upon the level of exposure. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the Western painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. The presence of turtles and amphibians becomes less likely as the waters of the estuary become more brackish.	Low, as a result of low numbers present and lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

8.0 HYPOTHETICAL SCENARIO: WESTRIDGE MARINE TERMINAL RELEASE REACHING BURRARD INLET

8.1 Scenario Rationale

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 8C, TR 8C-12, S9]) 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 per cent 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 Det Norske Veritas (DNV) as 103 m^3 and deemed as a low probability event with likelihood of occurring once every 234 years.

EBA (a Tetra Tech company) completed stochastic oil spill modeling for the simulated credible worst case spill of CLWB at the berth (Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project [Volume 8C, TR 8C-12, S9]). CLWB was used as the representative oil for spill modeling for reasons described in Section 5.1. For the ERA and HHRA, approximately 720 independent model simulations were completed for each of four seasons: winter (January–March), spring (April–June), summer (July–September) and fall (October–December). Each independent simulation run relied upon weather, currents and tide data drawn from the relevant season for 2011 and 2012, beginning with data starting three hours after the previous run. The movement and mass balance (distribution of total hydrocarbon between water, shore and air) of oil was tracked over 15 days. The set of approximately 2,900 independent simulations covers the expected transport and fate of spilled oil over the course of a full year of weather and tidal observations, and in this sense the modeling data set is as realistic as possible. Environmental conditions in 2011 and 2012 were analyzed and compared to a 30-year wind record: the selected period (October 2011–September 2012) was confirmed to be representative of wind speeds and wind directions.

One of the 2,900 independent simulations was selected for more comprehensive deterministic modeling in order to compute the fate of individual oil components in the water column and in the air in addition to on the water surface. The objective of the selection process was to identify a representative scenario that was credible, while tending to be worst case from both ecological and human health perspectives. Selection of one of the stochastic simulations for deterministic oil spill modeling proceeded step-wise, as outlined below.

First, consideration was given to the four seasons that were modeled stochastically. Selection focused on the summer season as warmer water and air temperatures facilitate more rapid dissolution and volatilization of lighter hydrocarbons into water or air, respectively. At the same time, generally lower wind speeds result in less wave action (hence, less vertical mixing of the water column and higher concentrations of dissolved hydrocarbons in the surface water layer), as well as less dilution of vapours in air. These summer season conditions represent the credible worst case because increased hydrocarbon concentrations in water and air would increase exposure to people and organisms relative to colder ambient conditions. In addition, people and a wider variety of organisms are more likely to be in close proximity to a spill at the Westridge Marine Terminal during the summer months.

Second, consideration was given to the predicted length of shoreline oiled, as oil spill effects on shorelines are among the more obvious and profound environmental effects of spills (both with respect to people and organisms). The median length of shoreline oiled was identified as a selection criterion in order to balance: 1) the need to address potential hazards to aquatic organisms, which are primarily driven by the amount of oil remaining in water; 2) the need to address potential hazards to terrestrial organisms, which are primarily driven by the length of shoreline oiled; and 3) the need to address the potential hazards that might be presented to people in boats and on shore from chemical exposures associated with an oil spill to the Burrard Inlet.

To this end, the median length of shoreline oiled as a result of the spill was determined based on the 736 summer stochastic simulations. The specific simulations resulting in a length of oiled shoreline corresponding to this median value were then identified and examined. Twenty simulations meeting this criterion were identified. The following additional criteria were then factored into the selection of the single simulation to be used for deterministic oil spill modeling:

- the maximum thickness of the oil modelled on water during the simulation;
- the time elapsed to first contact with the shoreline;
- the exposure duration for the oil on water; and
- the distribution of total hydrocarbon between water, shore and air (*i.e.*, the mass balance).

Thus, as the third step of the selection process, each of the 20 stochastic simulations was ranked (high, moderate or low) according to how well the final four selection criteria were satisfied. Higher weighting was given to those simulations that demonstrated greater thickness of the oil reaching the shoreline, shorter time to first contact with the shoreline, longer exposure time on water, and higher percentage of hydrocarbon in air. On this basis, the list was narrowed to two of the simulations.

As the final step of the selection process, visual examination of the outputs for these two simulations and the outputs for the summer season stochastic modeling show that one represented the simulation with a higher probability of occurrence. In other words, the movement of the oil slick in this simulation was more typical of the movement of the oil slick modelled in the 720 summer simulations. As such, this simulation based on the weather, current and tidal patterns from this hypothetical run was selected as the credible worst case scenario and was selected as the basis for the more detailed deterministic modelling. These data inputs were used in the deterministic model for the prediction of potential health risks for people and organisms as a result of a 160 m^3 spill at the Westridge Marine Terminal, in which 128 m^3 of spilled oil were contained within the boom around the tanker and 32 m^3 escaped into Burrard Inlet.

In addition to this credible worst case scenario, ecological and human health effects of a smaller release of 10 m^3 were also evaluated, consistent with the NEB's letter of September 10, 2013 Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of

Increased Marine Shipping Activities, Trans Mountain Expansion Project. This smaller release was assumed to result from a loading arm leak, and be totally contained within the boom placed around all tankers during loading operations (General Risk Analysis and Intended Methods of Reducing Risks, Volume 8C, TR 8C-12, TERMPOL 3.15).

8.2 Transport and Fate

Trans Mountain commissioned a number of studies as part of an iterative risk assessment process to properly evaluate the location and severity of threats to increased shipping of oils, including diluted bitumen oils by tanker from the Westridge Marine Terminal in Burnaby. These included the quantitative risk assessment conducted by DNV (General Risk Analysis and Intended Methods of Reducing Risks, Volume 8C, TR 8C-12, TERMPOL 3.15), research and tests of representative diluted bitumen oil to better understand the characteristics of this type of oil (see Gainford Study in Volume 8C, TR 8C-12, S7), and modelling to predict transport and fate of oil released from hypothetical spill scenarios by EBA (Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S9).

Stochastic oil spill fate modelling simulations for the credible worst case scenario were performed for a complete annual cycle including winter (January to March), spring (April to June), summer (July to September), and fall (October to December) to take into consideration seasonal variations in winds and currents. To be conservative, no consideration was given to possible mitigation, such as oil spill response activities. Outputs of the stochastic modeling included: 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. Additional details of the stochastic modelling completed by EBA are provided in Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project (Volume 8C, TR 8C-12, S9).

8.2.1 Unmitigated Credible Worst Case Spill

Credible worst case spill scenario modeling predictions indicate that oil released from the Westridge Marine Terminal would affect areas of Burrard Inlet and Indian Arm, particularly in close proximity to the spill location. Some slight seasonal differences in the spill trajectories were identified, primarily due to variations in predominant current direction and speed or predominant wind direction and speed (Figures 8.2.1 through 8.2.4). While the modelling results provide probability bands for each seasonal simulation, it is important to differentiate between where spilled oil could go, based upon the suite of stochastic simulations and where spilled oil would go under the specific set of circumstances that would occur for a single actual oil spill event. Therefore, the probability contours derived from the stochastic modelling must not be interpreted as an indicator of the likely spreading of the oil from a single spill. In this case, the 10 per cent probability contour indicates that oil was predicted to be presented at a location at some time over the course of the stochastic simulation period in 10 per cent of the simulations. This represents a low probability of oil presence, and in fact is an indicator that oil would probably not reach that location, not that it would probably be oiled. The maximum area of a surface oil slick resulting from an individual spill would be much smaller, likely somewhat larger than the ≥90 per cent probability contour, but much less than the surface area represented by the ≥50 per cent contour.

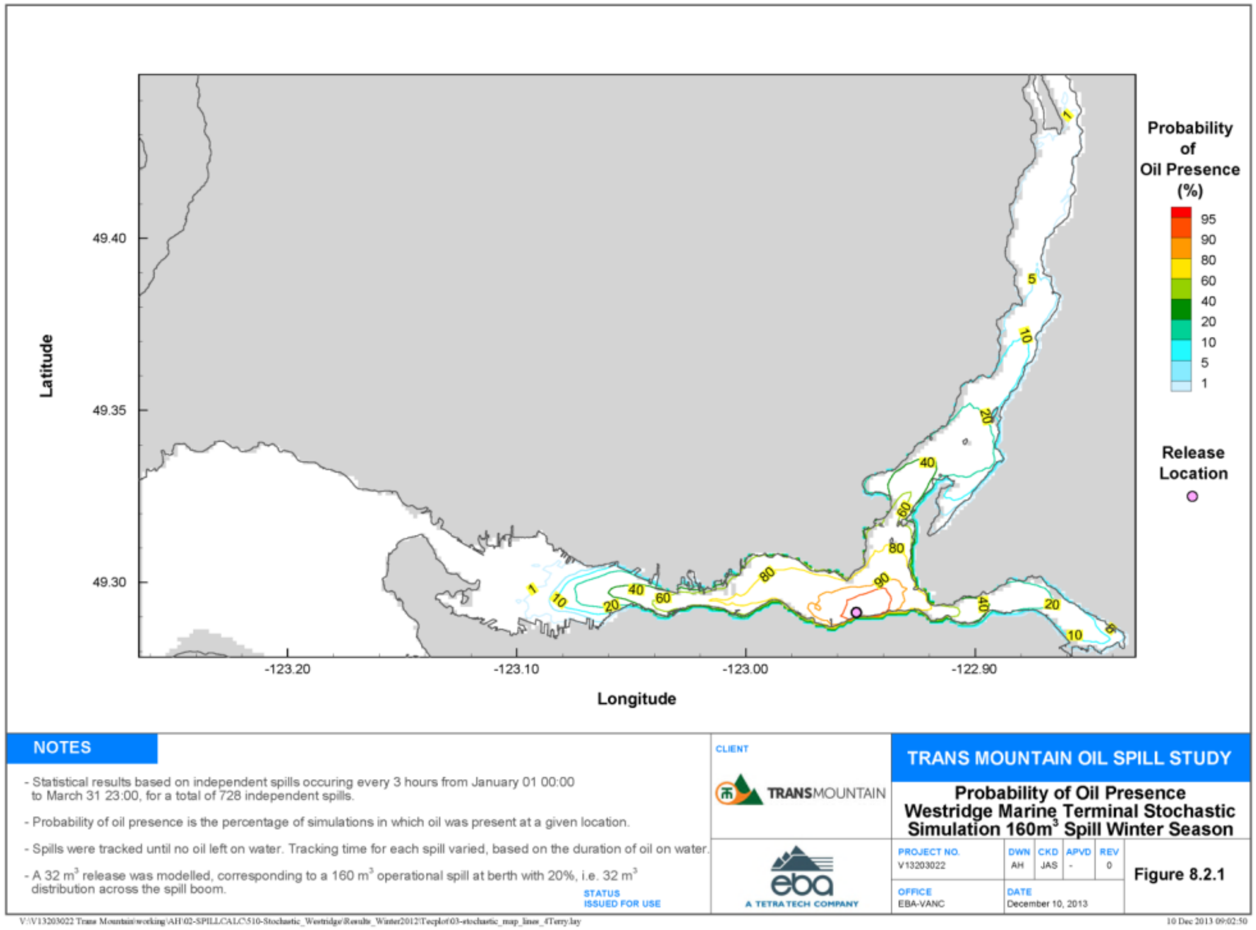

Figure 8.2.1 Probability of Oil Presence – Westridge Marine Terminal Stochastic Simulation 160 m^3 Spill Winter Season

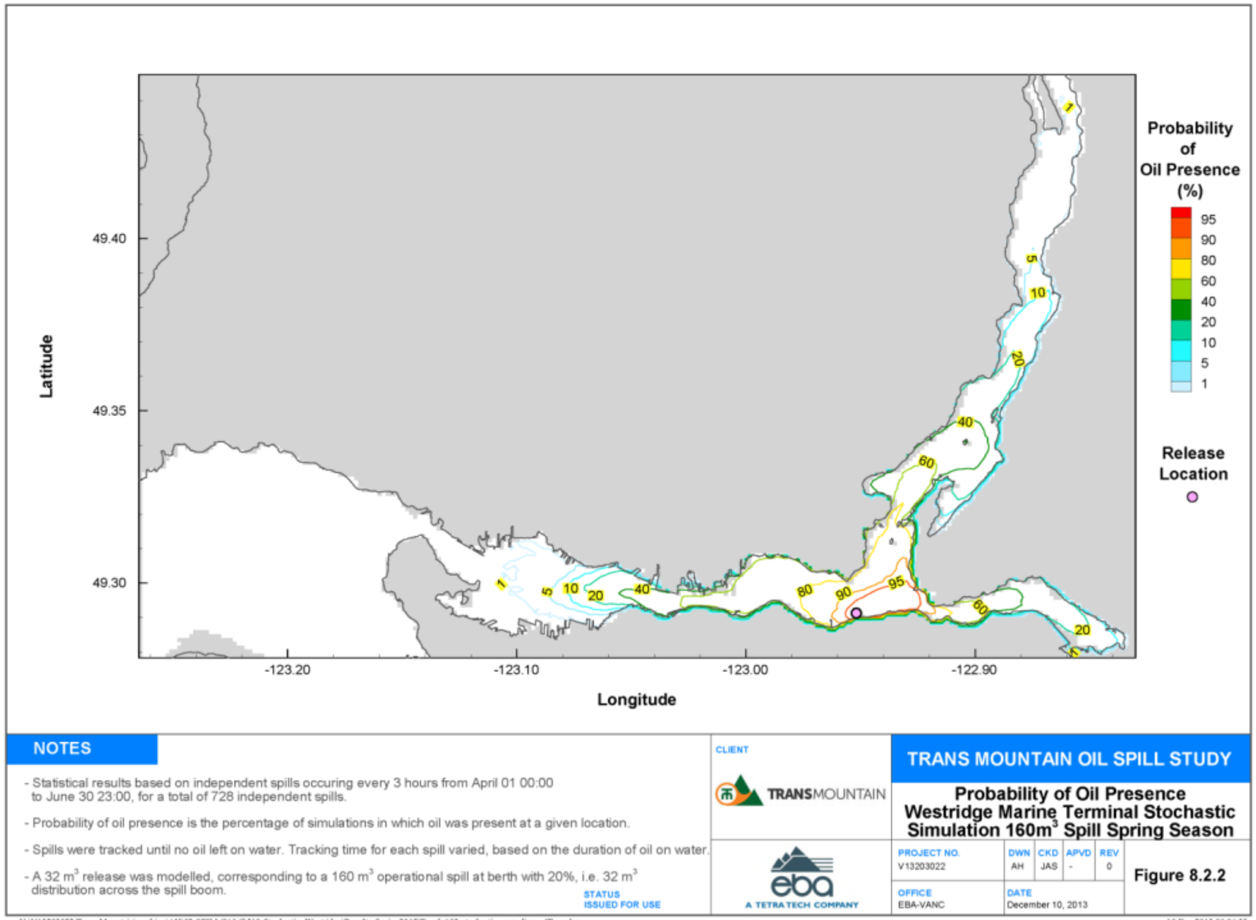

Figure 8.2.2 Probability of Oil Presence – Westridge Marine Terminal Stochastic Simulation 160 m^3 Spill Spring Season

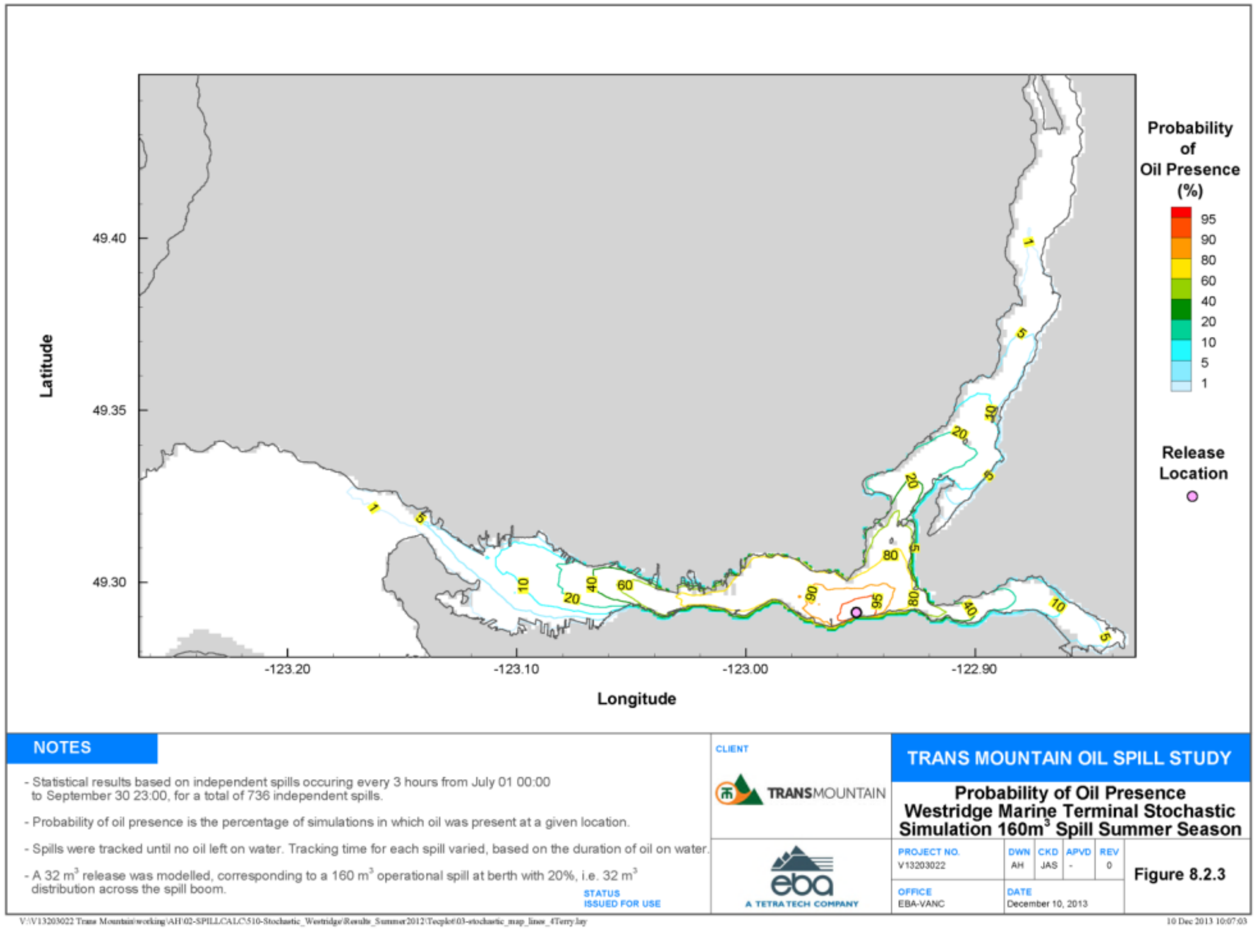

Figure 8.2.3 Probability of Oil Presence – Westridge Marine Terminal Stochastic Simulation 160 m^3 Spill Summer Season

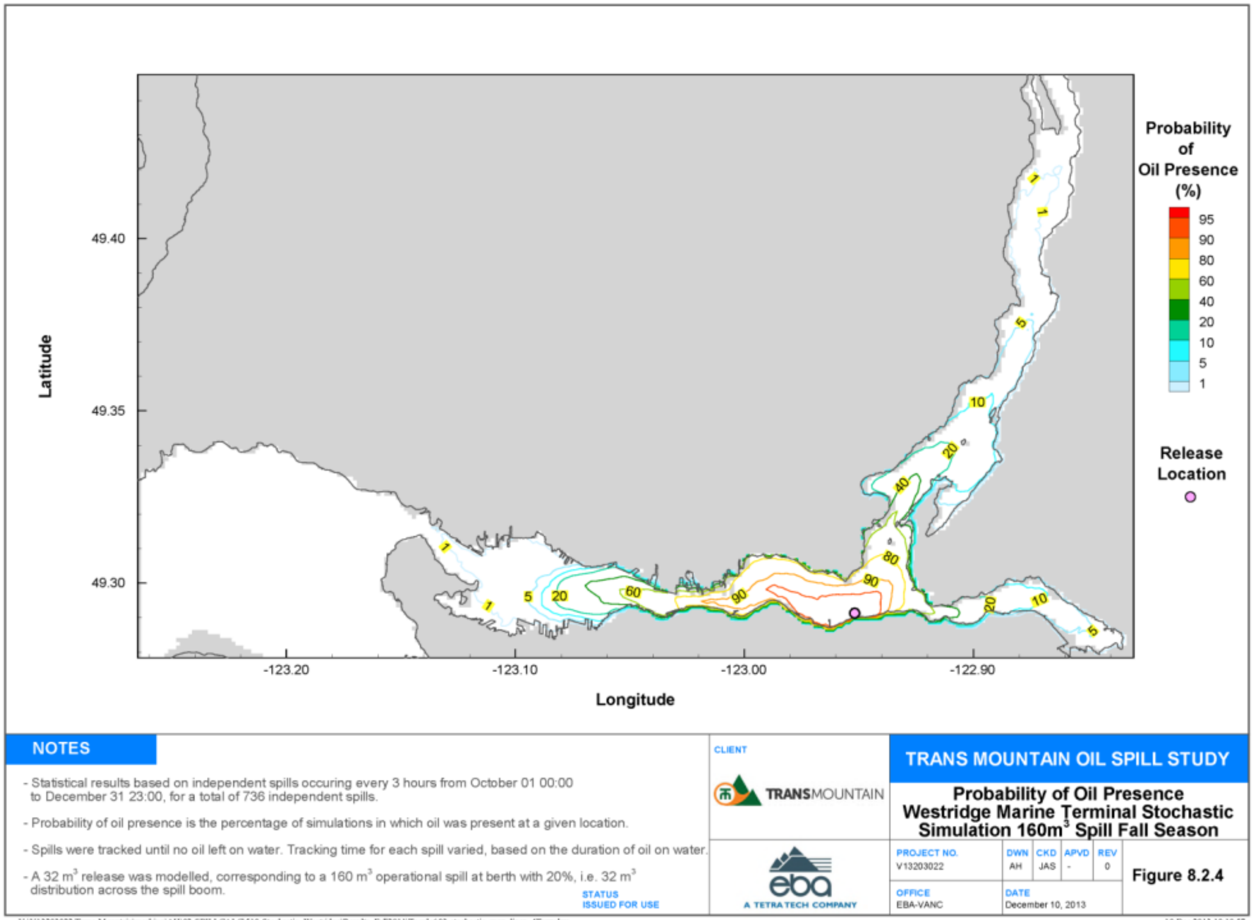

Figure 8.2.4 Probability of Oiling – Westridge Marine Terminal Stochastic Simulation 160 m³ Spill Fall Season

For the hypothetical credible worst case scenario, most of the oil is predicted to appear as sheen after 24 hours, and oil is totally gone within 24 hours in some simulations. There is a high probability of water surface oiling and/or shoreline oiling at the confluence of Indian Arm and Burrard Inlet. However, there is a low probability of water surface oiling and/or shoreline oiling from a single individual oil spill farther into Indian Arm and towards Port Moody, as well as west past Second Narrows.

Predictions indicate a medium probability (≥50 per cent) that between 14 and 17 km^2 of the water surface near Westridge Marine Terminal would be oiled, with maximum (17 km^2) predicted during the spring season. The Marine Resources Regional Study Area (RSA) includes a total area of 115 km^2. As such, the stochastic results suggest that approximately 15 per cent of the RSA has a medium probability of being oiled from this spill scenario. However, the average maximum surface slick area for a single oil spill is less than the medium probability contour, ranging from 4.0 to 4.6 km^2, with maximum predicted for the summer season. These average maximum areas are somewhat larger than the 90 per cent probability contour, but are smaller than the ≥50 per cent medium probability contour.

Shoreline oiling predictions indicate that between 8.3 and 11 km of shoreline in proximity of the Westridge Marine Terminal has a medium probability (≥50 per cent) of being oiled, with the maximum (11 km) during the summer season. The RSA includes approximately 200 km of shoreline. As such, these predictions indicate that approximately 5 per cent of the RSA has medium probability of being oiled. The average maximum length of shoreline oiling for a single oil spill is 14 to 19 km, with maximum predicted for the summer season. These average maximum lengths of shoreline oiling are somewhat larger than the 50 per cent probability, but much smaller than the 10 per cent probability shoreline oiling contour.

8.2.2 Mitigated Credible Worst Case Spill

A response evaluation was conducted to contribute to development of a risk informed enhanced oil spill response capacity that would be capable of dealing with such low probability events as a credible worst case oil spill from Westridge Marine Terminal (Trans Mountain Expansion Project Oil Spill Response Simulation Study, Arachne Reef and Westridge Marine Terminal [Volume 8C, TR 8C-12, S13]). Evaluation methods are described in this report, and a summary is provided here.

Away from the terminal, the response effort will be conducted with skimmers and booms. The booms have three purposes: first, they protect sensitive shorelines; second, they concentrate the oil into thicker patches; and third they increase the encounter rate between the oil and the skimmers. More than collecting the oil, the purpose of the booms in this scenario is to deflect the oil. Modelled spill response was assumed to continue for one day. It assumed that Western Canada Marine Response Corporation (WCMRC) arrives on-site within one hour of notification, and over the next 13 hours, initiates the following strategies:

- collection booming at two locations west of the Westridge Marine Terminal;
- protective booming at pre-identified sensitive locations in Burrard Inlet;
- mobilization of eight skimming vessels;
- mobilization of two large temporary storage barges;
- mobilization of two 40-tonne mini-barges; and

- dispatch of vacuum trucks to support recovery and storage activities.

The following key performance indicators established for the modeling response evaluation are based on desired changes in spill mass balance over a one day period:

- reduce the extent of the slick remaining on the water after 1 day;
- reduce the quantity of oil on water after 1 day;
- reduce the quantity of oil reaching shore within 1 day;
- reduce the length of shoreline oiled; and
- account for any oil recovered, ensuring that it is only assessed as recovered once the simulation shows any oil that is contained in a secure tank on a skimmer, barge or supply vessel.

Oil slick thickness is predicted to be reduced to 5 microns or less in 6 hours as a result of local environmental conditions. This thin slick challenges the efficient use of mechanical skimmers which are only effective at a thickness of 50 microns or greater. Model predictions indicate that four skimmers are sufficient for the mechanical recovery operation. The four remaining skimmers on-site are therefore used in a support role for booming and sheen management. At the beginning of hour-8, task forces are assembled to recover sheen by towing sorbent-lined sections of boom between two boats.

Table 8.2.1 compares the mass balance of unmitigated and mitigated spill simulations.

TABLE 8.2.1

MASS BALANCE COMPARISON FOR THE 160 M^3 SPILL (32 M^3 ESCAPED THE PRE-DEPLOYED BOOM)

Amount (m^3)	Unmitigated Case	Mitigated Case
On shore after 1 day	16.6%	10.7%
Left on water after 1 day	0.4%	0.1%
Evaporated after 1 day	1.2%	0.9%
Dissolved after 1 day	1.8%	1.2%
Biodegraded after 1 day	< 0.1%	< 0.1%
Inside the containment area but not yet recovered	80%	0%
Recovered inside the containment boom	n/a	80%
Recovered at sea	n/a	7.1%

After 1 day, very little oil is predicted to be left on water with spill mitigation. In contrast, the unmitigated case shows about 80 per cent of oil still left on water: this oil is contained within the boom; but may escape over time if it is not recovered. The mitigation reduces the amount of shoreline oiled by ≥30 per cent. Because slick thickness reduces quickly and mechanical recovery of the sheen is not possible after 8 hours, deflective booms would be deployed at strategic areas to deflect and concentrate the oil for the skimmers. Approximately 11 m^3 of the 32 m^3 assumed to escape the pre-deployed boom is recovered. Thereafter, passive sheen management with sorbent products remains a viable but unquantifiable countermeasure for the response organization to employ.

The response evaluation contributed to a number of ‘lessons learned”:

- Proximity of ready response capability to a spill site together with site specific response plans that responders have exercised help to greatly increase the effectiveness of response. In the case of the simulation study, the modelling runs helped WCMRC gain good understanding of the key requirements that could effectively improve response. This is similar to the iterative learning achieved through oil spill exercises.
- There is no substitute for establishing an early line of defense by rapidly booming a release or damaged vessel. This knowledge is tempered by the reality that health and safety conditions, suitable nearby anchoring sites, and operational constraints may not always make this outcome possible.
- Recovery assets should be located in relatively close proximity to the spill, as would be the case for Westridge Marine Terminal.
- Use of model-derived trajectory and slick thickness information to direct skimmers can help identify optimum recovery locations. While remote sensing offers considerable opportunities for spill detection, it also has limitations. The combination of numerical modelling and remotely-sensed data provides the most powerful approach to both current and future predictions of slick positions.

8.2.3 Unmitigated Smaller Release

This scenario assumes that all of the volume released would be contained be totally contained within the boom placed around all tankers during loading operations (General Risk Analysis and Intended Methods of Reducing Risks, Volume 8C, TR 8C-12, TERMPOL 3.15). While stochastic simulations for all four seasons were completed, no oil spill trajectory was modelled as the spilled 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. Based on existing spill response plans, recovery operations for such smaller spills would be expected to be complete within a few days.

Mass balance results showed that approximately 22 to 23 per cent of the oil would evaporate, with the highest amount in the fall and lowest amount in winter, approximately 2 per cent would dissolve and 3 per cent would biodegrade, leaving approximately 72 to 73 per cent on the water surface after 5 days, with the highest amount in summer and lowest amount in the fall. However, in reality the spilled oil would be expected to be removed within this time frame.

8.3 Ecological Risk Assessment

Potential environmental effects of a spill from the pipeline or facilities, including the Westridge Marine Terminal, were previously summarized in Section 6.2 based on evidence from past case studies. This section summarizes results of the qualitative risk assessment (ERA) completed to evaluate the effects of the hypothetical Westridge Marine Terminal spill of CLWB during transfer operations. Potential environmental effects from spills at other locations along the marine transportation route have been evaluated and are provided in Volume 8A. ERA methods and findings are described in detail in Ecological Risk Assessment of Westridge Marine Terminal Spills Technical Report (TR 7-2).

The ERA discusses the range of potential effects to ecological resources by considering the probability of exposure to predicted surface oil slicks, the probability that oil will impinge upon shorelines, and the characteristics and sensitivity of potentially affected aquatic and shoreline habitats within the study area. Potential environmental effects were visualized and quantified using GIS overlays of data layers containing information on biological resources, sensitive habitats and other areas of ecological importance, and the results of seasonal oil spill modelling summarized in Section 8.2.

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

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

8.3.1 Problem Formulation

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

8.3.1.1 Spatial Boundaries

The spatial boundaries for this ERA were based on the oil spill modeling domain (Modeling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project [Volume 8C, TR 8C-12, S9). The following spatial boundaries were considered in the ERA:

- Oil spill footprint - the area predicted to be directly affected by floating oil resulting from an individual release of oil at Westridge Marine Terminal.
- RSA – the area of ecological relevance where environmental effects could potentially result from accidents and malfunctions, including the areas of English Bay, Vancouver Harbour, and Burrard Inlet east of the First and Second Narrows, including Indian Arm and Port Moody Arm. Westridge Marine Terminal is located east of the Second Narrows. This RSA reflects the confined nature of Burrard Inlet and the fact that spill-related effects were not expected to extend westward beyond the mouth of English Bay

8.3.1.2 Ecological Receptors

Potential environmental effects of the Westridge Marine Terminal spill scenarios were evaluated for four main ecological receptor group/habitat combinations:

- shoreline and near shore habitats;

- marine fish community and supporting habitat;
- marine birds and supporting habitat; and
- marine mammals and supporting habitat.

Each of the four ecological receptor groups includes a variety of individual receptors and/or habitats with differing sensitivity to oil exposure. For this reason, each receptor group was divided into sub-categories that reflected their sensitivity to oil exposure. These sub-categories, termed biological sensitivity ranking factors, ranged from a value of 1 (low sensitivity) to a value of 4 (very high sensitivity). The potential for negative environmental effects of oil exposure at any given location was indicated by the overlap of the probability of oil presence (from the oil spill modeling results), and the sensitivity of the receptor or habitat present at that location. Where a specific receptor had status as an endangered species, the status was considered as an additional factor. Likewise, the presence of provincial and national parks or other designated conservation areas represented an additional factor for consideration (*i.e.,* societal values) in addition to intrinsic biological sensitivities. A summary of the four ecological receptors is provided below. Further detail on these receptors and their biological sensitivity ranking factors is provided in Ecological Risk Assessment of Westridge Marine Terminal Spills Technical Report (TR 7-2).

8.3.1.2.1 Shoreline and Near Shore Habitats

Shoreline habitat was considered to include 13 different shore types in the intertidal or littoral zone, including the area of the foreshore and seabed that is exposed at low tide, and submerged at high tide. 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" habitat, giving a total of 14 different shoreline habitat types.

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

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

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

8.3.1.2.2 Marine Fish Community

The marine fish community was defined to include marine fish and marine invertebrates (*e.g.,* mollusks and crustaceans), but not marine mammals or birds. Acute effects of spilled oil on fish and marine invertebrates are rarely observed, except in situations where oil is confined and dispersed into shallow water. Hydrocarbon effects on fish are generally caused by exposure to relatively soluble components of the oil. As described in Section 6.2.3, BTEX compounds or light PAHs such as naphthalenes are usually considered to be the most likely contributors to acute toxicity, although some light aliphatic hydrocarbons may also contribute to toxicity. These compounds also tend to be volatile and are rapidly lost to the atmosphere, so the initial 24 to 48 hours following an oil spill is the period when acute toxicity is most likely to occur.

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

For the non-polar narcosis mode of toxic action (see Section 6.2.3 and Ecological Risk Assessment of Westridge Marine Terminal Spills Technical Report [TR 7-2]), toxicity of 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 marine fish community was related to the degree of exposure of the particular habitat to dissolved hydrocarbons. Therefore, deep water habitat was assigned a low sensitivity rank (1) and shallow water habitat a high sensitivity rank (3). The very high biological sensitivity rank (4) was assigned to developing eggs and embryos in shallow water habitat (represented here by herring spawning areas).

8.3.1.2.3 Marine Birds

Like terrestrial birds and waterfowl (see Section 6.2.3), seabirds can be highly sensitive to oil spills, due principally to the effects of oiling on feathers (*i.e.,* loss of insulative properties and buoyancy), as well as to ingestion of oil or contaminated food. In addition, birds that are gregarious are potentially at greater risk of population-level effects if oil is present in an area where they congregate or feed. This region provides migratory, nesting, feeding and wintering habitat for a wide variety of shorebirds, gulls, waterfowl and alcids (auks), although fewer auks would be expected in the more confined waters of Burrard Inlet. All of English Bay and Burrard Inlet, including Indian Arm and Port Moody Arm are identified as an Important Bird Area (IBA), due to the presence of western grebe and Barrow's goldeneye in winter (BirdLife International 2013).

Four biological sensitivity ranking classes were defined for the marine bird community, on a scale of 1 (low sensitivity) to 4 (very high sensitivity). The classification scheme reflects guild membership, as is appropriate considering the similar lifestyle, behaviour, and exposure mechanisms that accompany each guild. A low sensitivity rank (1) was assigned to shoreline dwelling species and waders that are generally widely distributed. Medium sensitivity rank (2) was assigned to species with a life history that is not exclusively marine, such as gulls and terns. Ducks and other waterfowl that tend to be moderately sensitivity to oil exposure and may congregate were assigned a high sensitivity rank (3). Finally, a very high sensitivity rank (4) was assigned to species that tend to rely heavily on the marine environment and/or have high sensitivity to oil exposure, such as auks and divers, as well as critical habitats and IBAs. As Burrard Inlet is recognized as an IBA, the entire RSA was designated as having a very high biological sensitivity factor for marine birds and marine bird habitats.

8.3.1.2.4 Marine Mammals

The marine waters of Burrard Inlet provide habitat for a variety of marine and semi-aquatic mammals including:

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

Aquatic mammals such as sea otter, river otter and mink that rely upon fur for insulation in cold ocean water are extremely sensitive to oiling, as well as having potentially high exposure to oil ingestion, if coastal habitat is oiled. Mammals that rely upon blubber for insulation are less sensitive to external oiling, although the potential for mortality cannot be ruled out due to other exposure pathways or mechanisms. Oil ingestion remains a potentially important exposure pathway, and fouling of baleen plates can have adverse effects on baleen whales, although this would not be a problem for toothed whales.

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

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

8.3.2 Exposure and Hazard/Effect Assessment

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

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

8.3.3 Risk Characterization

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

8.3.3.1 Potential Environmental Effects of a Credible Worst Case Spill

Predicted oil fate and transport for the Westridge Marine Terminal credible worst case spill is described in Section 8.2 with both mitigated and unmitigated assumptions. This section evaluates the potential ecological effects of an unmitigated spill in all four seasons.

8.3.3.1.1 Near Shore and Shoreline Habitats

Table 8.3.1 summarizes ecological risk estimates for each shoreline sensitivity rank by probability of oiling. In terms of the length of shoreline potentially affected by spilled oil, seasonal results show that between 8.3 km (winter) and 10.6 km (summer) of shoreline habitat has a high or very high probability of being oiled following the hypothetical credible worst case oil spill, compared to approximately 200 km of existing shoreline habitat within the RSA.

Shorelines with a high or very high probability of oiling (≥50 per cent and ≥90 per cent, respectively) generally represent less than 10 per cent of the available habitat belonging to that sensitivity rank within the RSA. The worst case effects are seen for shoreline with a high sensitivity rank (3), where between 4.8 per cent (spring) and 17 per cent (summer) of the available habitat may be affected.

Stochastic oil fate modelling results indicate that shoreline types with a very high biological sensitivity rank (4) have a very low probability of being oiled, and that it is unlikely that any individual oil spill would result in oiling of these areas, which are located near Port Moody. Areas with high probability of oiling (≥50 per cent) are limited to shoreline types having biological sensitivity ranks of 1 to 3, and are located in close proximity to the Westridge Marine Terminal. Areas of high probability of oiling (≥50 per cent) represent only 3.7 per cent to 4.5 per cent of the total shoreline within the RSA assigned to biological sensitivity rank 1; 3.8 per cent to 5.5 per cent of the total shoreline within the RSA assigned to biological sensitivity rank 2; and 4.8 per cent to 17 per cent of the total shoreline within the RSA assigned to biological sensitivity rank 3.

Stochastic results also indicate areas with a high probability of oiling (≥50 per cent) in proximity to the Indian Reserves at Burrard Inlet (Tsleil-Waututh First Nation) and Seymour Creek (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 8.3.1

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

Season	Biological Sensitivity Factor	Shoreline Length in RSA (km)	Affected Shoreline (by Shoreline Oiling Probabilities)					
			Length According to Probability of Oiling (km)			Percent Length According to Probability of Oiling (%)		
			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 ERA indicates that near shore and shoreline habitats would be affected by the Westridge Marine Terminal credible worst case oil spill scenario. The affected areas generally represent a small proportion of shoreline belonging to each shoreline 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 oil exposure, these habitats have a very low probability of oiling. Shoreline classes with low exposure cobble/boulder veneer over sand would be most affected. Very little of the potentially affected shoreline habitat in Burrard Inlet is the type that would tend to sequester spilled oil.

It is expected that SCAT would be applied to the spilled oil that reached shorelines, and that most of this oil could be recovered. Biological recovery from spilled oil, where shoreline communities were contacted by and harmed by the oil or by subsequent cleanup efforts, would be expected to lead to recovery of the affected habitat within two to five years. These conclusions are consistent with evidence from the Westridge delivery line release caused by third-party damage (Section 6.2.4).

8.3.3.1.2 Marine Fish Community

Table 8.3.2 summarizes ecological risk estimates for each marine fish community sensitivity rank by probability of oiling. Areas with a high (≥50 per cent) probability of oiling represent 6.4 to 11 per cent of the total area with water depths >30 m, 22 to 24 per cent of the total area with water depths between 10 and 30 m (biological sensitivity rank 2), 11 to 13 per cent of the total area with depths <10 m (biological sensitivity rank 3) and 19 to 21 per cent of the important habitat for rockfish and crab with the highest rank (biological sensitivity rank 4) typically encountered in the spring.

Between 6.4 and 11 per cent of the 49 km^2 of deep water habitat in the RSA (biological sensitivity rank 1), has a high or very high (≥50 per cent) probability of oil exposure. 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 oil in this habitat type.

For intermediate depth habitat (biological sensitivity rank 2), approximately 22 to 24 per cent of this habitat type within the RSA has a high or very high (≥50 per cent) probability of oil exposure. 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 oil in this habitat type.

TABLE 8.3.2

SUMMARY OF EFFECTS ANALYSIS FOR MARINE FISH AND MARINE FISH 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

Between 11 and 13 per cent of shallow water habitat in the RSA (biological sensitivity rank 3), has a high or very high (≥50 percent) probability of oil exposure. 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 oil in this habitat type, however, in circumstances where 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.

A total of 18 km^2 of fish habitat in the RSA is considered to be critical (biological sensitivity rank 4), and between 19 and 21 per cent of this habitat has a high or very high (≥50 per cent) probability of oil exposure for this scenario. 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 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 PAH in the oil could cause developmental effects on fish embryos. As noted for shallow water habitat, the potential for negative effects would be greatest if the spill occurred at a time when strong winds cause the oil to be driven into shallow water used as spawning or nursery areas for herring or crab.

In summary, the ERA indicates that fish habitat would be affected by the Westridge Marine Terminal credible worst case oil spill scenario. The affected areas can represent a substantial proportion (up to 30 per cent) 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 risk 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 Westridge Marine Terminal 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 the marine fish community would be short-term. 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.

8.3.3.1.3 Marine Birds Community

For marine birds, the entire RSA (representing an area 115 km^2, including all of English Bay, Vancouver Harbour and Burrard Inlet) has been assigned a biological sensitivity rank of 4 (very high) due to its designation as an 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. Although these areas demonstrate some seasonal variation, the extent of these areas is generally similar. Results summarized in Table 8.3.3 indicate that less than 15 per cent of the water surface within the IBA (biological sensitivity rank 4) has a high or very high probability (≥50 per cent) of being swept by an oil slick as a result of the credible worst case spill scenario. The areas with a very high probability of oiling (90 per cent or higher) are located in close proximity to the terminal and generally extend less than 2 km away from it.

The presence of seabirds and shorebirds is strongly seasonal, and different species could be negatively affected by spilled oil in each season. 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 per cent 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 concern (no regulatory status). 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.* 1990). Surf scoters are widely distributed along the BC coastline, especially during spring migration and Burrard Inlet is a particularly important staging ground in the winter and spring.

In summary the ERA indicates that the marine birds and marine bird habitat would be affected by the credible worst case spill scenario, however, the affected area would be small in comparison to the total available marine bird habitat present within Burrard Inlet. Less than 15 per cent 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 Westridge Marine Terminal would be most affected.

TABLE 8.3.3

SUMMARY OF EFFECTS ANALYSIS FOR MARINE BIRDS AND MARINE BIRD 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

There is clearly potential for oiling and mortality of seabirds from an accidental spill of oil during loading at the Westridge Marine Terminal. Actual effects 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 conservative scenario, modeling showed that less than 15 per cent of the area of the Burrard Inlet IBA would be swept by 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, lost individuals would likely be compensated for by natural processes within one to two years.

8.3.3.1.4 Marine Mammal Community

Modelling results identified areas of medium, high and very high effect probability for each class of marine mammals biological sensitivity rank (Table 8.3.4). For terrestrial mammals (*e.g.,* bears, moose, raccoons, *etc.*, biological sensitivity rank 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 per cent 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 significant population level effect.

For pinnipeds such as harbour seal (biological sensitivity rank 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 per cent of the available habitat. Therefore there is a relatively high probability of exposure for harbour seal inhabiting Burrard Inlet in the low likelihood event of an accidental oil spill. Some level of negative effect would be expected for animals exposed to oil, but the effects would not likely be lethal, except in the case of weaker animals such as pups or older and diseased animals.

TABLE 8.3.4

SUMMARY OF EFFECTS ANALYSIS FOR MARINE MAMMALS AND MARINE MAMMAL 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 (Biological Sensitivity Factor = 1), environmental effects are estimated as length (km) of shoreline subject to oiling, rather than the area (km^2) of affected habitat.

For whales such as the harbour porpoise (biological sensitivity rank 3), between 12 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 14 and 16 per cent of the available habitat. This reflects a relatively high probability of exposure for harbour porpoise inhabiting Burrard Inlet in the low likelihood event of an accidental oil spill. Some level of negative effect would be expected for animals exposed to oil, but the effects would not likely be lethal, except in the case of weaker animals such as calves or older and diseased animals.

For furred marine mammals such as the river otter (biological sensitivity rank 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 per cent of the available habitat. There is therefore a relatively high probability of exposure for some of the otters inhabiting Burrard Inlet in the low likelihood event of an accidental oil spill. Some level of negative effect would be expected for animals exposed to oil. Exposure during the winter season would be more stressful than exposure during the summer, but in either case, the combination of hypothermia and damage to the gastro-intestinal system caused by oil ingested through grooming the fur would have the potential to cause death.

In summary, the ERA indicates that marine mammals and marine mammal habitat would be affected would be affected by the credible worst case spill scenario; however, the affected areas would be modest in comparison to the overall habitat present within Burrard Inlet. Less than 20 per cent 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 located in proximity to the Westridge Marine Terminal would be most affected.

There is clearly potential for oiling of marine mammals following an accidental spill of oil at the Westridge Marine Terminal. Actual effects 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. With this worst case assumption, modeling showed that less than 20 per cent of the available marine mammal habitat within the RSA would be swept by 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 due to 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.

8.3.3.1.5 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 Westridge Marine Terminal would cause negative environmental effects on shoreline habitats, the marine fish community, marine birds and marine mammals, as well as their supporting habitat, within the RSA. However, the affected areas would be modest compared to all available habitat within the RSA. Based on the modelling simulations for this scenario described in Section 8.2, areas with highest probability of oiling are located around the Westridge Marine Terminal and near the confluence of Indian Arm and Burrard Inlet. Acute lethality of fish is unlikely. Damage to oiled shoreline and intertidal communities is likely, although modelling predictions indicate it would be 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, the effects would be expected to be reversible in the medium-term.

This conclusion is supported by the results of monitoring conducted following the Westridge third-party spill in 2007 (see Section 6.2.4).

8.3.3.2 Potential Environmental Effects of a Smaller Release

This section summarizes the ERA for the small evaluation of environmental effects to ecological receptors resulting from a smaller release (10 m^3 of CLWB) at the Westridge Marine Terminal during loading. 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. Based on existing spill response plans, recovery operations for such smaller spills would be expected to be complete within a few days. For this scenario, this mitigation was also considered when evaluating potential environmental effects from smaller spills.

Given that the oil spill fate modelling results were similar across all seasons (Section 8.2), 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.

8.3.3.2.1 Oil Fate and Potential Effects on Marine Water and Sediment Quality

After being released to the water surface, some of the more water-soluble constituents of the 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 and these constituents are available. Approximately 22 per cent of the oil is predicted to evaporate and disperse in the atmosphere and less than 2 per cent of the oil dissolves into the water column. The protected nature of Burrard Inlet, and the additional protection afforded by the pre-deployed boom 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 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 for the Project showed that CLWB did not sink by itself after ten days exposure to brackish water (see Gainford Study in Volume 8C, TR 8C-12, S7). Oil spill modeling indicated that negligible amounts of oil would become suspended as droplets in the water column, due to 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 oil submergence is unlikely, except to the extent that oil contacting shorelines may combine with sand and gravel particles to form an aggregate that can be submerged at low tide in the intertidal zone, or potentially transported into slightly deeper water by wave action. Therefore, it is unlikely that a smaller spill of CLWB would result in any high magnitude or long lasting negative effects in the sediment.

8.3.3.2.2 Aquatic Receptors

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), due to the relatively small spill volume, and short duration of exposure, lethality is not expected from the smaller spill, which remains confined within the containment boom. Sub-lethal population scale effects to aquatic receptors are not anticipated, and recovery would be expected to occur quickly.

8.3.3.2.3 Wildlife

Because the spilled oil would be completely retained within the containment boom, it would not contact the adjacent shoreline, and thus eliminate 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, 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 different 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, and ingestion of toxins via grooming or feeding, and reduced mobility (NRC 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 cause, the probability of a direct encounter with 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 be detectable at the population level.

8.3.3.2.4 Risk Characterization Summary for a Smaller Operational Spill

In summary, a hypothetical release of 10 m^3 of CLWB at the Westridge terminal during loading 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, population level ecological effects would not occur. Therefore, the environmental effects on marine ecological receptors are expected to be negligible.

8.3.4 Certainty and Confidence

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

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

In the event of an oil spill, the fate and effects would be strongly determined by specific characteristics of the oil, environmental conditions, and the precise locations and types of organisms exposed. The goal of scenario modelling investigations summarized in Section 8.2 was not to forecast every situation that could potentially occur, but to describe a range of possible consequences so that an informed analysis can be made as to the likely fate of oil spills under various environmental conditions. Modeling predictions are supported by the behaviour and fate of oil that was accidentally released to Burrard Inlet in 2007. In addition, unmitigated spill fate was considered, which tends to overstate slick movement and duration relative to mitigated slick fate as described in Section 8.2.

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

Ecological receptor exposure was linked to predicted probability of oil presence on water, or oiling of shorelines in three categories (*i.e.,* ≥10 per cent; ≥50 per cent and ≥90 per cent probability of oiling). It was conservatively assumed that any contact between a marine ecological receptor and oil was potentially harmful, regardless of the amount of oil present, or the duration of the exposure. This approach was considered likely to overstate, rather than understate the potential consequences of spilled oil for the Westridge Marine Terminal scenarios.

A detailed quantitative ERA for the Westridge Marine Terminal credible worst case and smaller oil spill scenarios will be provided to the NEB early in the New Year to confirm these predictions and inform Trans Mountain mitigation and ERPs.

8.4 Human Health Risk Assessment

Evidence concerning human health effects of a spill from the pipeline or facilities, including the Westridge Marine Terminal, are summarized in Section 6.3.2. This section summarizes findings from a qualitative HHRA completed for the Westridge Marine Terminal hypothetical credible worst case and smaller spill scenarios described in Sections 8.1 and 8.2 (Qualitative Human Health Risk Assessment of Westridge Marine Terminal Spills [TR 7-3]).

8.4.1 Methods

When discussing human health effects, the potential effects associated with short-term and long-term exposure to hydrocarbons are referred to as acute and chronic effects, respectively. The HHRA focused on potential health effects that could result from short-term inhalation exposure to chemical vapours released from oil released in the hypothetical scenarios. Its objective was to establish the overall likelihood, nature and severity of effects as part of a screening-level exercise. However, the approach followed differed from that adopted for the screening-level HHRA of the routine pipeline and facilities operations (see Volume 5D). Routine operations consist of planned activities for which chemical exposures and any associated health risks can be anticipated and assessed on the basis of known or reasonably well-defined exposure scenarios. In contrast, spills represent low probability, unpredictable events for which the exposures and risks must be assumed for strictly hypothetical scenarios. Accordingly, rather than following a conventional risk assessment paradigm with an emphasis on quantifying the potential risks involved, the present assessment was designed to provide a preliminary indication of the prospect for people's health to be affected by a spill, together with an indication of the types of health effects, if any, that might be experienced. Results of this qualitative assessment determine whether or not a more comprehensive assessment is needed to provide further evidence to define the nature and extent of any health effects that people might experience and mitigation measures that could be applied to reduce risks to human health.

The HHRA considered the likelihood and extent to which people's health could potentially be affected for both Westridge Marine Terminal hypothetical spill scenarios based on the following factors:

- the volume of oil spilled (Section 8.1);
- the types of chemicals contained in the spilled oil to which people could be exposed (Section 5.1);
- the extent to which people could be exposed based on predictions of how the spilled oil and the constituent chemicals would likely disperse in the environment considering time of year, weather patterns, currents and tides, wave action, and the way that spilled oil would partition between air and water over time (Section 8.2);
- the manner and pathways by which people might be exposed to the chemicals;
- the emergency response and other mitigation measures that will be taken to limit people's exposure to the chemicals in the event of a spill (Sections 4.0, 6.3.2, and 8.2.2);
- the types of health effects known to be caused by the chemicals as a function of the type, amount and duration of exposure;
- the responsiveness and sensitivity of the people who could potentially be exposed to the chemicals; and
- the types of health effects that have been reported to occur among people following oil spill incidents (Section 6.3.2).

8.4.1.1 Exposure Pathway Selection

The HHRA focused on the potential health effects that could occur among people in boats or on shore. The primary method of exposure was concluded to be inhalation of chemical vapours released from the surface of the spilled oil, particularly short-term or acute exposure during the early stages of the incident. The choice of this exposure pathway was based on the following:

- In the event of a spill into the Burrard Inlet, emergency response measures will be taken by Trans Mountain, Coast Guard authorities, the WCMRC and other spill response agencies to protect people's health, the marine environment, and the coastal shoreline. The measures are discussed in Section 4.0, and will include securing the area as well as the isolation, surveillance, monitoring, containment, and clean-up and recovery of the oil. Local, provincial and federal authorities responsible for the protection of public health, fisheries, and the marine environment and resources will be notified so that additional resources can be deployed and further protective measures can be implemented, as needed. Other response measures such as notifying the public to avoid the spill area, restricting access to the spill area, and evacuating people from the area also would be implemented. The exact emergency response measures taken will be dictated, in part, by the circumstances and real-time events surrounding the spill, including the size, behaviour and immediate hazards presented by the oil slick. For Westridge Marine Terminal spill scenario, it was assumed that WCMRC would arrive on-site within one hour of notification (Section 8.2.2). The measures will serve not only to limit any opportunities for exposure of the general public to chemical vapours released from the oil in the short-term, but also will act to preclude any reasonable opportunity for people to be exposed on a longer-term basis either by inhalation or other exposure pathways such as incidental dermal contact with the chemicals.

- If warranted, local, provincial and/or federal authorities can implement controls or issue advisories to protect public health. Examples of such controls include closure of commercial and recreational fisheries, beach closures, forced evacuation of people off-shore and/or on-shore if public health and safety is threatened, and the issuance of fish, shellfish or other seafood consumption advisories. These measures further reduce the potential opportunities for exposure of people to the chemicals released during a spill through either inhalation or other pathways on both a short-term and long-term basis.

- The potential exists for people located downwind of the oil to be exposed to chemical vapours released from the surface of the slick during the early stages of the incident because some time will elapse between the first reporting of a spill, the arrival of first responders and the implementation of the emergency response measures. Exposure to the vapours would be via inhalation on a short-term basis, with the likelihood of exposure declining as responders arrive on scene and emergency response measures are implemented.

- Direct physical contact with the spilled oil was considered unlikely, especially in the case of the smaller oil spill in which the oil slick will be completely contained within the boom. The actions taken by first responders will include securing the area, restricting access, and containing the oil slick. Appropriate regulatory authorities will be immediately notified and the public will be advised to avoid the area. In the case of the credible worst case spill scenario in which oiling of the shoreline is possible based on the simulated oil spill modelling, beach and shoreline closures will be announced, if conditions warrant. These actions will limit any exposure of the general public to the spilled oil through incidental skin contact.

- The choice of the exposure scenario was also determined, in part, by concern expressed by attendees at various community open houses, including local residents and Aboriginal peoples, over the potential health effects that could result if an accidental oil spill was to occur either on land or water, including the potential effects that might result from inhaling chemical vapours released during an incident.

8.4.1.2 Receptor Selection

As described above, emergency response measures will be taken by Trans Mountain, Coast Guard authorities, the WCMRC and other spill response agencies to protect people's health, the marine environment, and the coastal shoreline. t is expected that these response personnel arriving at the scene will be trained in emergency preparedness and response, will be equipped with appropriate personal protective equipment, will be trained and prepared for such situations, and will take appropriate precautions to avoid physical contact with the oil slick itself as well as to limit exposure to any chemical vapours that might be present. These measures will act to limit any chemical exposures and corresponding health effects that might be experienced by first responders and other response personnel.

Based on this emergency response, the assessment focused on the potential health effects that could potentially occur among members of the general public, including residents living in nearby communities downwind of the terminal as well as bystanders who might be frequenting the area at the time of the spill for work, recreation or other reasons. These bystanders include people who might be on the water in boats or people found along the shore. The assessment assumed that some of these residents and bystanders might belong to sub-populations known to show heightened sensitivity to chemical exposures, such as young children, the elderly and people with compromised health.

8.4.1.3 Chemical Selection

CLWB was the representative crude oil chosen for reasons described in Section 5.1. The actual chemicals examined as part of the HHRA (hereafter referred to as the COPCs) followed a step-wise process that is described elsewhere (Screening Level Human Health Risk Assessment of Pipeline and Facilities technical report [Volume 5D]). As part of this process, consideration was given to the following;

- the results of a bulk liquid analysis of the CLWB that identified the chemical constituents found in the diluted bitumen;
- the physical properties and characteristics of the chemical constituents, notably those properties, such as vapour pressure and Henry's Law Constant, that determine their tendency to partition into air and provide an indication of the ease with which they might volatilize from the surface of the oil slick; and
- the results of a flux chamber study used to determine the types and amounts of chemicals that could be released from the surface of spilled CLWB under simulated conditions (TERMPOL Report 3.1 [Volume 8C]).

A number of COPC were identified through this selection process, consisting principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{12}), including both aliphatic and aromatic constituents. The latter constituents included BTEX and simple PAHs, including naphthalene and acenaphthene. Trace amounts of sulphur-containing chemicals and longer-chain, semi-volatile hydrocarbons (C_{13} to C_{21}) made up the remainder of the COPCs. The assessment assumed that the COPC could be released from the surface of the oil slick though volatilization, resulting in their presence in the air as vapours at or near the source, which would then disperse in a downwind direction.

8.4.2 Effects Assessment

The assessment relied on preliminary modelled predications of the acute (short-term) COPC levels that might be encountered by people at varying distances from the oil slick for each scenario. Model outputs consisted of hour-by-hour predictions of the maximum concentrations of the COPC that people might encounter as the incident evolved. These preliminary modelled estimates served as proxies for the acute inhalation exposures that the general public, including residents and bystanders in the area, might experience during the early stages of the incident.

8.4.2.1 Smaller Release Scenario

The preliminary qualitative assessment for the smaller spill scenario of 10 m^3 of CLWB during tanker loading revealed no potential for people's health to be affected by inhalation exposure to the chemical vapours released from the surface of the oil slick. The predicted maximum air-borne concentrations of the COPC that the general public could potentially encounter were below the levels known to be associated with health effects. The absence of health effects is attributable to both the small size of the spill and the fact that the oil slick will remain within the boomed area where access will be restricted. Under these circumstances, the findings indicate that little opportunity will exist for bystanders to be exposed, even bystanders in boats, and even less opportunity for exposure will exist for people on shore.

Odours could be noticeable depending on the person's keenness of sense of smell. In all likelihood, the odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur-containing chemicals in the vapour mix. The odours themselves could contribute to discomfort, irritability and anxiety.

8.4.2.2 Credible Worst Case Spill Scenario

The preliminary qualitative assessment pertaining to the credible worst case spill scenario revealed some potential for people's health to be affected from inhalation exposure to the chemical vapours that could be released from the oil slick during the early stages of this spill scenario. Effects would be confined to bystanders in boats near the spill area and possibly people on the shoreline adjacent to the Westridge Marine Terminal. Although potentially at some risk, the prospect for these people's health to be affected is limited because exposure to the higher concentrations of the COPC associated with health effects is confined to the first few hours following the spill, with the concentrations declining quite rapidly with elapsed time. There is no indication that effects would extend to people living in communities along the Burrard Inlet, including Westridge and Capitol Hill.

The HHRA found that maximum predicted air concentrations of some COPC during the very early stages of the credible worst case scenario could be higher than exposure limits. Based on the types of chemicals that might be encountered and their known health effects, potential effects would likely be dominated by irritation of the eyes and/or breathing passages, possibly accompanied by symptoms consistent with central nervous system involvement, such as nausea, headache, light headedness and/or dizziness. In this regard, a number of the COPC are capable of acting as irritants and central nervous system depressants. The effects could range from barely noticeable to quite noticeable, depending on the exposure circumstances and the sensitivity of the individuals exposed. Odours could be apparent, dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur-containing chemicals in the vapour mix. The odours themselves could contribute to discomfort, irritability and anxiety. The exact nature and severity of any health impacts will depend on several factors, including:

- The circumstances surrounding the spill, including the time of year and meteorological conditions at the time. These circumstances will affect the extent to which chemical vapours are released from the surface of the spilled oil and the manner in which these vapours disperse.
- The person's whereabouts in relation to the spill, including their distance from the oil slick and their orientation to the slick with respect to wind direction. The preliminary modelled estimates of the exposures that could be received revealed that exposures would be highest at distances closest to the slick, declining with increasing distance. The prospect for health effects to occur as well as the severity of any effects will follow the same pattern. The prospect for people's health to be affected also will be greatest downwind of the oil slick, where the maximum concentrations of the COPC will be encountered.
- The timeliness of emergency response measures. Measures taken to either remove the hazard from the general public (*e.g.*, spill isolation, containment and mitigation) or remove the general public from the hazard (*e.g.*, securing the spill area, restricting access, notifying the public to avoid the area, evacuation of people from the area) will reduce exposure and the probability of any associated health effects. The sooner these measures can be implemented, the lower the likelihood of any effects. Prompt measures taken by Trans Mountain, the Coast Guard authorities, the WCMRC and other spill response agencies will act to reduce the potential for health effects.
- A person's sensitivity to chemical exposures. It is widely accepted that a person's age, health status and other characteristics can affect the manner and extent to which they respond to COPC exposures, with the young, the elderly and people with compromised health often showing heightened sensitivity. Since the population that could theoretically be exposed to the COPC under the spill scenario is large, the potential for exposure of sub-populations of sensitive individuals who may be at heightened risk prospect for health effects is increased.

A more focused and detailed HHRA to inform specific mitigation and ERPs will be completed and submitted to the NEB in early 2014.

Although Trans Mountain's 60-year operating history and overall pipeline industry experience demonstrate that large pipeline and facility spills are unlikely to occur, concern about the effects of large spills was an issue that was frequently noted during Aboriginal engagement and consultation with landowners and stakeholders. The hypothetical pipeline and Westridge Marine Terminal spill scenarios provided in Sections 7.0 and 8.0 are useful because they illustrate the types of environmental effects that might be observed as a result of a large spill, however unlikely. More importantly, information from the credible worst case scenario evaluations will be important in planned undertakings to fully evaluate the existing ERPs and develop necessary amendments to further minimize the risk of environmental and socio-economic effects described here.

9.0 FINANCIAL CAPACITY TO RESPOND TO A SPILL

In addition to Section 52 of the NEB Act defining the requirement for financial responsibility, the Canadian federal government has recently announced that it intends to propose legislation to enshrine a polluter pay principle for on-shore federal pipelines and require that companies operating major crude oil pipelines have a minimum of $1 billion in financial capacity to respond in the event of a spill. This section describes how TMEP anticipates meeting the current and future financial requirements with respect to an oil spill.

Trans Mountain commissioned HJ Ruitenbeek Resource Consulting to provide an estimate of the potential cost of hypothetical spills and whether the financial assurance mechanisms set out in the application are adequate to cover those potential costs. HJ Ruitenbeek Resource Consulting concluded that the maximum financial exposure to a hypothetical “small” spill is estimated to be a maximum of $20 million. They also concluded that the largest hypothetical spill (4,000 m^3) evaluated had a financial exposure of $160 million or, in a credible worst case, up to $300 million.

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. The expected capital cost for the TMEP is approximately $5.4 billion. Upon completion of the TMEP project, TMPL is projected to have $6.4 billion in assets based on the existing $1 billion of current rate base plus the increase of $5.4 billion for TMEP expansion. Financing will be arranged by Trans Mountain’s parent company Kinder Morgan Energy Partners, L.P. (KMP). KMP typically finances growth projects using a mix of 50 per cent debt and 50 per cent equity. Funding sources may include a combination of the issuance of long-term debt securities, bank financing and the issuance of public equity at KMP. Based on KMP debt and equity financing strategy, we expect that TMPL will have approximately $3.2 billion of equity upon completion of TMEP.

Trans Mountain currently has $750 million of spill liability insurance, the first $2 million which is covered by self insurance. Trans Mountain intends to maintain this level of spill liability insurance throughout the life of the TMPL asset. Combined, between the $750 million of spill liability insurance and $3.2 billion of equity upon TMEP completion, TMPL will have sufficient financial capacity to meet either the credible worst case ($300 million, as estimated by HJ Ruitenbeek Resource Consulting) or the $1 billion financial capacity that is anticipated to be legislated by the federal government.

Given that no documentation of the draft federal legislation is available, it is not clear how the polluter pay principle and $1 billion financial capacity requirement will be enshrined. However in the event that a new federal financial capacity standard results in the need for additional commitment, Trans Mountain will meet that standard.

9.1 Summary of HJ Ruitenbeek Resource Consulting

As indicated in the previous paragraphs, Trans Mountain commissioned HJ Ruitenbeek Resource Consulting to provide insight to the potential cost of hypothetical spills and whether the financial assurance mechanisms set out in the application are adequate to cover those potential costs. The full report including references is included (Appendix G, Potential Cleanup and Damage Costs of a Hypothetical Oil Spill: Assessment of Trans Mountain Expansion

Project). Trans Mountain adopts HJ Ruitenbeek evidence and provides this summary of the methods, results and conclusions herein.

A standard cleanup cost methodology was used as an initial benchmark for calculating total spill cleanup costs; these costs are based on North American pipeline spill experience and reflect adjustments for size, oil properties, exposure to water, and cleanup methods employed. Databases used in this evaluation report provide costs in $ per barrel and therefore these units of measure will generally be used in this section.

Larger spills are considered to be in the range of 1,000 m^3 to 4,000 m^3 (6,300 to 25,000 barrels) and the upper-bound cleanup costs are in the range of $3,532 to $6,358 per barrel, representative of heavy oils in remote locations and impacting watercourses. Spills under 2,500 barrels have a benchmark cleanup cost of $11,000 per barrel. These benchmark costs are all greater than International Oil Pollution Compensation Funds (IOPCF) global non-US experience in marine and near-shore areas (~$500–$2,000 per barrel) and also greater than Transport Canada spill cost estimates for Eastern Canadian waters ($830 to $6,020 per barrel). The spill cleanup cost estimates reflected in the report in Appendix G are thus regarded as credible upper bound estimates relating to hypothetical pipeline spills experienced in Canada.

A multiplier is used to account for compensation that might potentially be incurred over and above the direct spill cleanup costs. For damage costs a benchmark multiplier of 1.5 is applied to cleanup costs. This multiplier is higher than that suggested by the IOPCF experience for all point source spills (1.29), higher than that implied by the IOPCF experience for spills within the size range of interest (0.56 to 1.19), and higher than those implied by Transport Canada for spills of persistent oil in sensitive areas (0.6 to 0.85). The factor is somewhat lower than the range in US navigable waterways (1.69 to 2.27), which are characteristically high by international standards.

A series of hypothetical spills were evaluated for the purpose of the assessment of potential financial impact. Seven pipeline scenarios and one marine terminal scenario were analyzed to demonstrate the range of cleanup and damage costs for of the hypothetical spills. The size and location of these hypothetical spills is not linked in any way to other hypothetical spills described in other parts of the Application.

Hypothetical spill volumes are based on an analysis of the Pipeline and Hazardous Materials Safety Administration (PHMSA) Incident Database for the period 2002-2009 filtered for large (≥NPS 20) hazardous liquids pipelines with installation year in 1990 or later.

Pipeline leaks with mean size of about 110 m^3 (~700 barrels) may arise from hazards including manufacturing defects, operational system faults, construction faults or third party damage. Cleanup costs alone are estimated to be $1 million to $8 million; incorporating potential damage costs suggests that any single spill would have a maximum financial exposure of under $20 million.

Pipeline ruptures involving partial or full loss of containment are assessed as hypothetical spills into HCAs of 1,000 m^3 (6,290 bbl) and 2,000 m^3 (12,580 bbl), which are based on maximum outflow volumes calculated from current valve spacing. Spill volumes of 2,000 m^3 (12,580 bbl) and 4,000 m^3 (25,160 bbl) are assessed as hypothetical spills into non-HCAs. Cleanup costs for 1,000 m^3 and 2,000 m^3 HCA spills are estimated to be $40 to $45 million. Cleanup costs for 2,000 m^3 and 4000 m^3 non-HCA spills are estimated to be $32 to $64 million. The HCA spills would have a maximum financial exposure of about $110 million including an upper bound damage cost. The non-HCA spills of similar size (2,000 m^3 or less) would have a maximum financial exposure of about $80 million. The maximum financial exposure of all spills assessed through these scenarios is $160 million.

For risk management purposes a sensitivity scenario was conducted using highest cost conditions for cleanup of a large spill (involving a hypothetical pipeline release of up to 4000 m^3 of heavy oil in a remote location impacting water and requiring manual cleanup procedures) and damage costs of the order of $10,000 per barrel, which reflect among the highest found in the literature. Total spill costs in this high damage cost scenario would be of the order of $100 million to $300 million for the scenarios assessed.

A hypothetical spill at the vessel loading point of the Westridge Marine Terminal was also considered. Accidents associated with vessel operations are the responsibility of the vessel owner, but incidents at a marine terminal may fall under joint responsibility depending on the circumstances of the incident. Similar methods for calculating cleanup costs and potential damages from a hypothetical spill apply although some damage coefficients differ because of immediate availability of cleanup equipment. A spill of 103 m^3 (648 barrels) was evaluated: such a spill would generate expected cleanup costs of $7.1 million and damage costs of $6.1 million for a total financial exposure of approximately $13.2 million.

Based on available databases of North American and International spill costs and the multiple hypothetical spill scenarios considered, the largest hypothetical spill (4,000 m^3) evaluated had a financial exposure of $160 million or in a credible worst case, up to $300 million. The current and proposed financial assurances and financial structure of the project ($750 million of spill liability insurance and approximately $3.2 billion in equity) will be adequate to cover losses attributable to a spill, including cleanup and compensation for damages.

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11.0 APPENDICES

Appendix A Threat Assessment Report

Trans Mountain Expansion Pipeline

Threat Assessment

November 30, 2013

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Executive Summary

The primary objective of a threat assessment is to review the attributes for all potential threats to a pipeline system in consideration of the status of the materials, design, construction and operational variables that are associated with the pipeline system of interest. Through this review, the relevance and severity of each threat can be assessed in the context of the operating environment for the pipeline being reviewed.

On May 7th-8th 2013, a Threat Assessment Workshop was conducted on the Trans Mountain Expansion Pipeline (TMEP) at the Kinder Morgan office in Calgary, AB. Those invited were:

- Adam Lind, TMEP Sr. Pipeline Engineer – KMC
- Fred Baines, Project Director – UPI
- Ray Smith, Sr. Engineer – UPI
- Mike Davies, Sr. Project Director, Marine Development – KMC
- Malcolm Stephenson, Sr. Engineer – Stantec
- Rob Fletcher, Lead Pipeline Engineer – UPI
- Cliff Mitchell, CP Engineer – KMC consultant
- Yvanna Ireland, Manager, Operations Engineering – KMC
- Bryan Scott , Integrity and Corrosion Specialist – KMC
- Greg Toth, TMEP Project Director – KMC
- Rob Scott , TMEP Operations Liaison – KMC contractor
- John Henderson , Sr. Engineer – Stantec
- Margaret Mears , TMEP Environmental Lead – KMC
- Gary Babich, TMEP Pipeline and Construction Lead – KMC contractor
- Steve Love , Corrosion Technologist – KMC
- Trish Wiegele , Project Manager – TERA
- Terry Antoniuk , Sr. Biologist – Salmo Consulting
- Lorne Daniels, Manager, SCADA and Simulations – KMC
- Dean Monterey , TMEP Emergency Response Specialist – KMC contractor
- Alex Baumgard, Sr. Geotechnical Engineer – BGC
- Christine McFarland, Sr. Biologist – Intrinsik
- Dan Carter, Central Region Director – KMC
- Carey Johannesson, TMEP Regulatory Lead – KMC contractor

Also in attendance, representing Dynamic Risk were:

- Jim Mihell, Vice President Engineering
- Samah Hasan, Pipeline Integrity Specialist
- Vincent Soo, Pipeline Integrity Specialist
- Josh Pendleton, Account Manager
- Lorena Cala-Philips, Pipeline Integrity Engineer
- Han Wu, Project Manager

During the Threat Assessment Workshop, and during follow-up discussions, all threat attributes were discussed in terms of their relevance as well as in terms of data availability. For failure likelihood estimation, the availability and type of data dictate the specific approach that can be adopted. Therefore, the other primary goal of a threat assessment is to establish candidate approaches for estimating failure likelihood based on the availability, quality, and completeness of the data attributes for each threat.

Analysis that was undertaken subsequent to the Threat Assessment Workshop and follow-up data gathering undertook to review, on a threat-by-threat basis, the factors that influence each threat for the Trans Mountain Expansion pipeline.

The threat potential for each threat was made on the basis of a review and analysis of the threat attribute data. Additionally, a characterization of the failure likelihood estimation approach that the available data will lend themselves to was made.

Where appropriate, assumptions that will be incorporated into the quantitative failure analysis have been identified for each threat. Additionally, where mitigation measures and controls will be required in order to ensure that the magnitudes of threats for the Trans Mountain Expansion pipeline will not exceed those that are associated with best practices, those mitigation measures and controls and the assignment of responsibility for executing and implementing those measures and controls were listed.

The results of the threat assessment showed that of all threats considered, only two (SCC and 'other' threats) are characterized as negligible (i.e., this threat will not contribute in a significant way to overall risk), provided that the controls and mitigation plans cited are used on the Trans Mountain Expansion pipeline.

Equipment Failure threat was considered out of the scope of this assessment. This threat will be assessed separately by Kinder Morgan Canada (KMC) as part of a facilities assessment plan.

For the remainder of threats, quantitative estimates of failure frequency will be made. Where possible (i.e., where a limit state model that is supported by probability distributions exist for its input parameters), a reliability approach has been identified as feasible, supported by the data identified in the analysis. These threats include external corrosion and third party damage. Quantification of geotechnical and hydrological threats will be made on the basis of the results of a detailed geotechnical and hydrological evaluation that is currently under way. Internal Corrosion will be assessed based on a review of the documented performance of existing pipelines that are carrying dilbit under the same conditions of flow.

For the characterization of external corrosion failure likelihood, 'analogue' ILI datasets will be leveraged along with the specific design details (diameter, wall thickness, grade, and operating pressure) of the Trans Mountain Expansion pipeline. Under such an approach, it is important to ensure that the analogue datasets are representative (or slightly conservative) relative to the expected corrosion performance of the Trans Mountain Expansion pipeline. In this way, the reliability parameters of external corrosion feature incident rate, external corrosion feature size distribution, and external corrosion growth rate that are obtained from the analogue ILI datasets can be employed, knowing that the critical reliability data that they impart are representative, or conservative. To ensure that this is the case, several criteria were developed for vetting the analogue ILI databases that will be used.

Based on the typical operating performance characteristics of modern transmission pipelines, those threats that are not being quantified using reliability models, (manufacturing defects, construction defects, and incorrect operations) are expected to contribute in a secondary manner to overall pipeline risk. None of these threats lend themselves to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. Therefore, for these threats, an attempt will be made to achieve an estimate of failure frequency based on operating incident data. Where possible, the evaluation of threat incidence will be based on pipelines of similar design and operating parameters to the Trans Mountain Expansion pipeline.

Table of Contents

1. Introduction

Regulations and Pipeline codes governing design, operation and maintenance of pipelines ensure a minimum level of protection through proven design, specifications, quality assurance and operations requirements. In addition to compliance with all Regulations, Codes and Standards, a design process that is informed by the results of a risk assessment can pre-emptively identify potential hazards, and enables risk mitigation measures to be implemented, thereby fostering a risk-optimized design. This report documents the results of threat identification process that was undertaken in support of a risk assessment on the Trans Mountain Expansion Project.

1.1. Risk Approach

Risk can be expressed as the product of failure likelihood, and consequences of failure:

$$R = FF \times C$$

Equation 1

Where,

R	= Risk
FF	= Failure Frequency
C	= Consequences

As can be seen from Equation 1, in order to characterize risk in quantitative terms, quantitative estimates of failure likelihood are required. There are two basic approaches for estimating failure likelihood. One method is to use industry incident statistics as the basis for the making the estimate, and the other is to estimate failure likelihood based on a first-principles approach, known as ‘reliability methods’.

One of the challenges of employing a quantitative risk assessment on a new pipeline is that industry failure statistics are not directly applicable to modern pipeline designs, materials, and operating (i.e., assessment) practices that include:

- Continuous casting of steel slabs;
- Thermomechanical Controlled Processing (TMCP) technology for skelp production;
- High Strength Low Alloy (HSLA) steel design;
- Low sulphur steels;
- Inclusion shape control;
- High toughness steels;
- Implementation of quality systems and the use of highly constrained process control variables during pipe manufacture;
- Highly-constrained mechanized welding processes using low-hydrogen welding processes;
- Phased array ultrasonic inspection and 100% non-destructive inspection;
- High performance coating systems such as three-layer coatings and fusion bonded epoxy coatings;

- Design-phase identification and avoidance of geotechnical hazards through consideration of geotechnical input during routing studies;
- Design-phase identification of internal corrosion threat factors and design of mitigation plans through internal corrosion modeling;
- Identification of HVAC interference effects and development of mitigation plans through diagnostic testing of cathodic protection systems;
- Implementation of Quality Management Systems during design, construction and operations

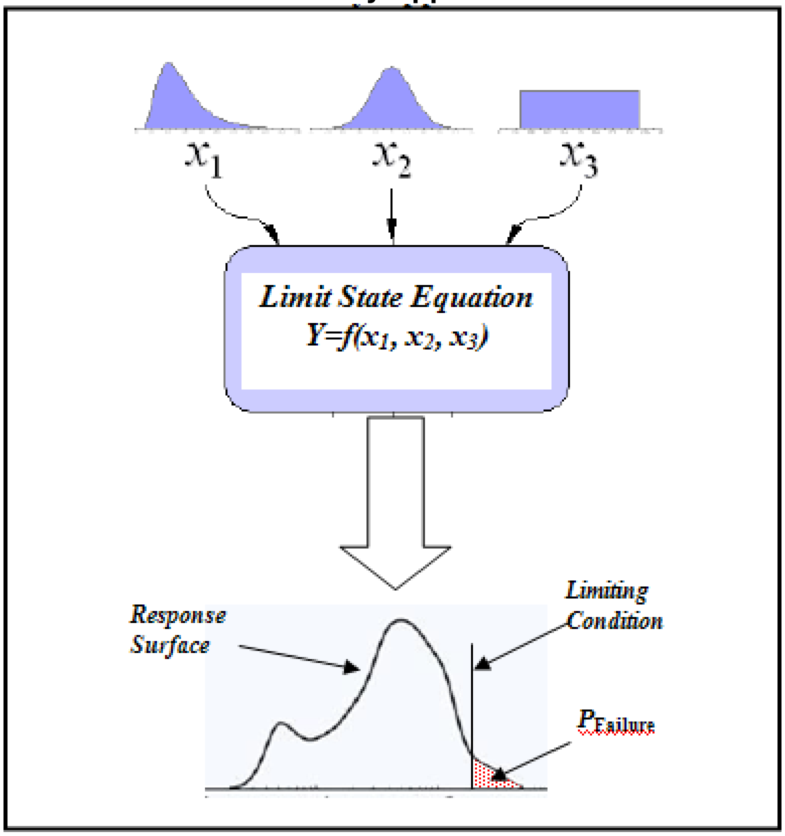
Because of the advent of these technologies, the use of industry failure statistics is not a suitable basis for estimating failure rates.

Another disadvantage of using industry failure databases as the basis of a quantitative risk assessment is that they don't address unique site-specific threats, such as geotechnical hazards.

Reliability methods have been widely adopted in the nuclear and aerospace industry, where they are used to identify and manage threats. In recent years, the pipeline industry has moved towards adopting this as a tool for managing risk and reliability, and pipeline industry research organizations such as CFER, PRCI and EPRG have developed reliability-based models for various threats. Reliability models employ limit state functions for the specific damage mechanism of interest in which the load variables and resistance variables are characterized in terms of probability density functions. This enables us to use reliability modeling techniques such as Monte Carlo Analysis to characterize the probability of incurring a failure on a pipeline. Reliability methods provide us with a powerful tool to make accurate, quantitative predictions on likelihood of failure and expected lifespan.

The Figure below illustrates how reliability methods are utilized to quantify the probability of failure, based on a defendable approach:

Figure 1
Reliability Approach



In the pipeline industry, reliability models exist for the most significant threats, including 3rd Party Damage, Internal Corrosion and External Corrosion. In addition, geotechnical threats can usually be characterized in terms of expected magnitude and associated frequency of occurrence, thereby enabling pipeline reliability to be established at each geotechnically-active site.

The basis of every reliability model is a limit state equation that describes the failure conditions for the mechanism being considered. Furthermore, at least one of the input variables to this limit state equation must be characterized as a probability density function, as illustrated in Figure 1. Therefore, a reliability approach is not possible for some threats, such as incorrect operations, where these probability density functions are not available. For these threats (which fortunately usually constitute 2nd-order threats, in terms of failure likelihood magnitude), the only alternative is to employ industry failure statistics, incorporating some professional judgement to account for differences in materials, design and operations that are characteristic of modern pipelines.

1.1. The Role of a Threat Assessment in QRA

The primary objective of a threat assessment is to review the attributes for all potential threats to a pipeline system in consideration of the status of the materials, design, construction and operational variables that are associated with the pipeline system of interest. Through this review, the relevance and severity of each threat can be assessed in the context of the operating environment for the pipeline being reviewed.

In the process of undertaking a threat assessment, all threat attributes will be discussed in terms of their relevance as well as in terms of data availability. Specific data sets are required in order to employ a reliability approach to failure likelihood estimation, and the availability and type of data that are available will dictate the specific approach that can be adopted. Therefore, the other primary goal of a threat assessment is to establish candidate approaches for estimating failure likelihood based on the availability, quality, and completeness of the data attributes for each threat.

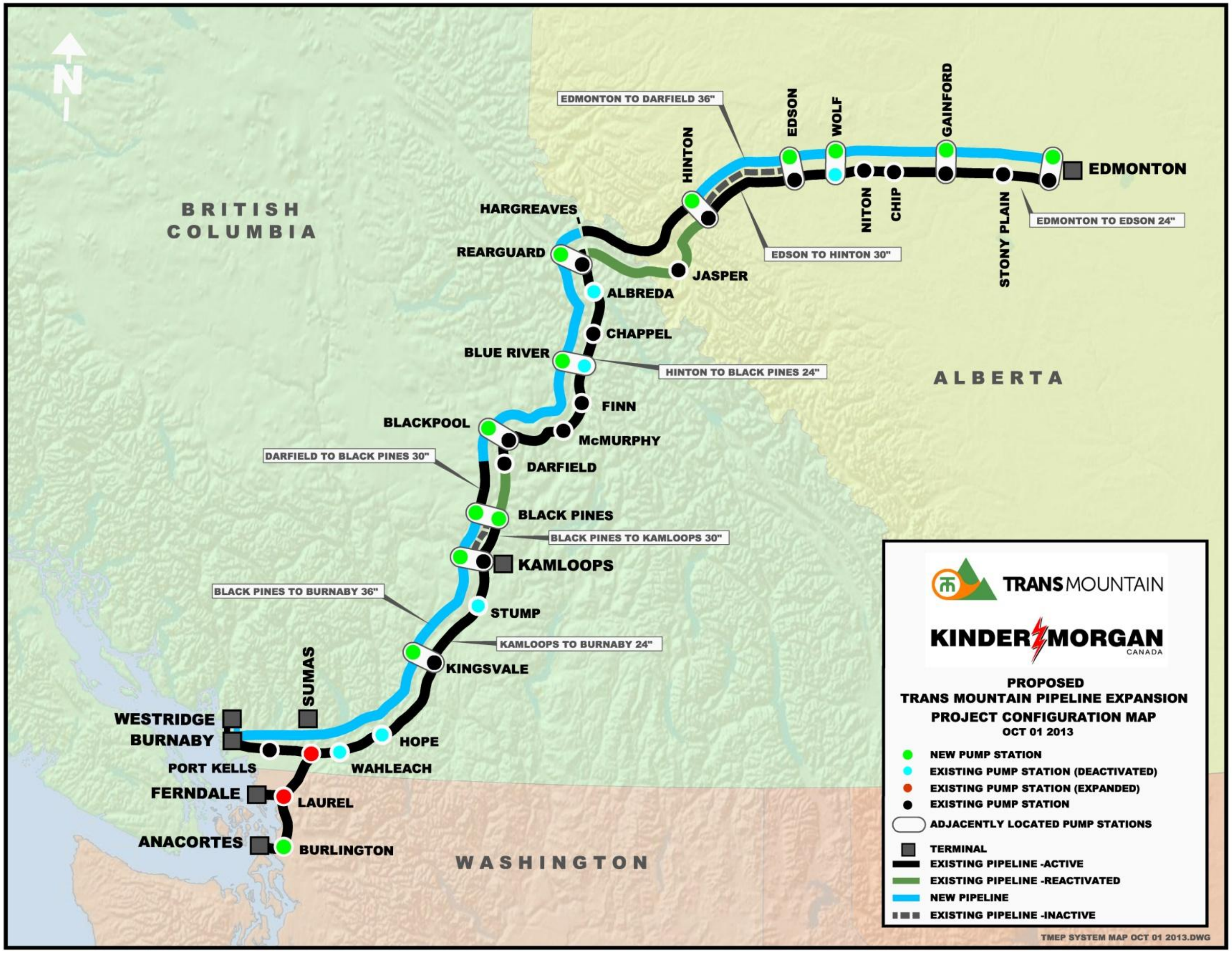
2. Scope

The threat assessment documented in this report was conducted on the NPS 30/36 Trans Mountain Expansion pipeline segments, approximately 987 km in length that will transport heavy crude oil from Edmonton, Alberta to Westridge, British Columbia. The pipeline route is provided in Figure 2, this assessment covers the new pipeline segments only (colored in blue in Figure 2).

The NPS 30/36 oil pipeline is designed to operate at pressures ranging from 3,788 kPa to 9,930 kPa, based on the maximum operating head profile. It will be operated as a low vapour pressure pipeline, with a sustainable average annual capacity of 540,000 bpd.

The pipeline is anticipated to operate through batching of heavy crude oils (e.g. diluted bitumen, diluted synthetic bitumen) but will be designed to provide flexibility for batching of light crude oils.

Figure 2 - Route of Trans Mountain Pipeline



3. Threat Assessment Approach

The threat assessment approach described in Appendix (A) of ASME B31.8S was used as the basis of the Threat Assessment Workshop, with the understanding that some of the evaluation criteria such as year of installation, failure history, etc. are not relevant, given that the pipeline has not yet been built. Although the scope of ASME B31.8S is the management of system integrity of gas pipelines, this Standard was employed as the basis of the threat assessment because the comprehensive list of threats considered in Appendix A of that standard is generally applicable to liquids pipelines.

Under the threat assessment guidelines provided in Appendix (A) of ASME B31.8S, threats are divided into 9 categories:

1. External Corrosion;
2. Internal Corrosion;
3. Stress Corrosion Cracking;
4. Manufacturing Defects;
5. Welding / Fabrication Defects;
6. Equipment Failure;
7. Third Party Damage;
8. Incorrect Operations;
9. Weather Related and Outside Force; and,
10. Other threats

In addition to addressing the relevancy and significance of each of the above threat categories, a review was undertaken of the availability, quality, and completeness of the data attributes for each threat, with respect to the type and viability of reliability approach that might ultimately be employed to quantify the magnitude of failure likelihood for each threat.

A Threat Assessment Workshop was conducted in KMC's offices in Calgary, Alberta on May 7-8, 2013. Standardized Threat Assessment forms were utilized to focus the discussion during this workshop. The information collected during the Threat Assessment Workshop and from follow-up data collection exercises is presented in the next Section.

4. Data Collection and Assessment

In this Section, the threat attributes for each of the threats listed in Section 3 are discussed on a threat-by-threat basis.

4.1. External Corrosion

A summary of the data review and assessment for this threat is provided in Table 1.

Table 1

Threat Attribute	Data Evaluation	Discussion
Coating Type	Discussion during the Threat Assessment Workshop and a review of the DBM established the following: - Line pipe in non-mountainous areas is planned to have fusion bond epoxy (FBE) coating in accordance with CSA Z245.20 and UPI Engineering Specification 19731-1801-0400. - Line pipe in mountainous areas is planned to have a three-layer polyethylene coating (i.e. a high performance composite coating (HPCC)) shall be used in accordance with CSA Z245.21 and UPI Engineering Specification 19731-1801-0470. - Locations where additional mechanical protection is needed (e.g. highway, road and railway crossings, in rocky environments or for HDD watercourse crossings) special coating protection products, such as a Dual Powder Epoxy Abrasion Resistant Overcoat (ARO) coating in accordance with UPI Engineering Specification 19731-1801-0400 is planned to be used. In some situations the use of select backfill materials or rock jacket will be a viable option to ARO coating. - Above ground installations, including pipe, mainline block valve and scraper trap assemblies, and any other equipment or structures, is planned to be painted. Paint materials and colors are to be in accordance with UPI Engineering Specification, 19731-1801-0440 - Below grade installations, including induction bends and mainline block valve assemblies are planned to be coated with a spray grade epoxy or epoxy/urethane coating in accordance with UPI Engineering Specification 19731-1801-0420 - Field girth welds are planned to be coated in accordance with UPI Engineering Specification 19731-1801-0410 or for a 3-layer coated pipe, a Two-Part coating plus a polyethylene shrink sleeve is planned to be used in accordance with Engineering Specification 19731-1801-0480.	All coating types being considered for the pipeline can be characterized as high-performance coating systems that form an efficient corrosion barrier, and that resist degradation with time. According to the hydraulic design that is proposed for the mainline, the temperature may reach an annual average temperature of approximately 25^{o}C in the pipeline. Furthermore, according to the DBM maximum temperatures in the pipeline have the potential to reach as high as 50^{o}C. Therefore, it is imperative that a coating system that is capable of accommodating these temperatures must be specified.

	- Coating of exothermic welds is planned to be carried out in accordance with UPI Engineering Specification 19731-1801-0430 - Pipe which is to be insulated is planned to be painted in accordance with UPI Engineering Specification 19731-1801-0440	
Cathodic Protection	Discussion during the Threat Assessment Workshop and a review of the DBM established the following: - The CP system for the pipeline will be designed and installed in accordance with the KMC's engineering standards and specifications. - Where portions of the pipeline will be close to alternating-current power lines, Can/CSA-C22.3 No. 6 will be followed. - Special consideration will be given to areas along the pipeline where interference from high voltage AC/DC currents may occur. These areas include places where the pipeline crosses, passes, or parallels high voltage power lines. - For mitigation KMC will run a CPCM tool at areas of concern once identified. - Rectifier systems will be used.	The DBM states that The CP system will be installed and activated, as soon as is practical, after pipeline construction. Anode bed and rectifier locations will be determined based on specific local conditions and field observations. It also states that the clearance between the TMEP pipeline and any other parallel pipeline, cable or other utility shall not be less than 0.3 m regardless of who owns the other facility. The TMEP pipeline centerline shall be offset from the existing TMPL pipeline centerline, in areas where these two (2) pipelines will be parallel, to a minimum of 6 m, except at locations of extreme congestion where the separation may be decreased on a case-by-case basis.
Soil Characteristics	The workshop notes indicate that the pipeline RoW crosses rock ditch mostly, potentially including Acid-Generating Rock.	Locations of Acid-Generating Rock will be identified and that corrosion mitigation plans will be included in the detailed engineering phase.
Above-ground pipe	The DBM does not identify potential locations of above-ground pipe.	For above ground pipe, it will be necessary to consider factors that might influence the susceptibility to atmospheric corrosion, such as pipe support design, atmospheric coating systems, and atmospheric/buried coating transitions during the detailed engineering design
Casings	Workshop notes indicate there is a possibility of using casings with inhibitors on TMEP. The use of some casings should be anticipated for bored trenchless crossings, where casings may be used to stabilize the path prior to pulling the pipe through the crossing.	Should casings be used in bored trenchless crossings as a means of stabilizing the path, then measures (such as filling the annulus with corrosion inhibitor) should be considered during the detailed design to accommodate the potential future occurrence of electrolytic and/or metallic shorts.
ILI Data	Although the TMEP is not yet built, KM Pipelines has identified an ILI data set that would provide suitable analogs representing modern pipelines using high performance coating systems from which reliability data can be derived.	In order to ensure that the analog ILI data sets are representative or conservative with respect to the corrosion performance of the TMEP pipeline, the above recommendations must be addressed during detailed design.

4.2. Internal Corrosion

Based on interviews conducted during the Threat Assessment Workshop, and an evaluation of industry standards related to the product stream and hydraulic model, an assessment of the internal corrosion potential of the dilbit (oil) pipeline was undertaken. The results of this assessment are detailed below.

4.2.1 Corrosivity of Dilbit Stream

There is some controversy related to the transmission of heavy oil via pipeline and the level of corrosivity associated with that product. Oil sands oil that is produced in the Cold Lake Region of Canada is considered a heavy crude oil with an API density of approximately 21. However, in order to facilitate transportation of this oil, diluent is blended into it. This results in a reduction in the density and viscosity of the product stream (termed ‘dilbit’) so that it can be made readily transportable.

Controversy about corrosivity of dilbit resulted in some industry efforts to investigate and provide facts about the topic. Below are names of some of the reports published:

- CEPA Sate of the Art Report “Dilbit Corrosivity”[1] issued this year addressed the concerns regarding dilbit corrosivity in comparison to conventional crude oil.
- Alberta Innovates report “Comparison of the Corrosivity of Dilbit and Conventional Crude”[2]
- Transportation Research Board Special Report 311: “Effects of Diluted Bitumen on Crude Oil Transmission Pipelines”, National Academy of Sciences, 2013.[3]

The studies examine corrosion mechanisms and susceptibilities associated with oil pipelines such as general corrosion, Bacteria and Microbiological Induced Corrosion (MIC), Under-Deposit Corrosion, Erosion, and sweet/sour corrosion. The studies indicate that the chemical and physical properties of dilbit do not differ in ways that would be expected to create a likelihood of release that is higher for a transmission pipeline transporting diluted bitumen than one transporting other crude oils.

The CEPA study indicates that under normal operations dilbit pipelines with low BS&W (0.25-0.5%) are unlikely to have free water present in them, and with a sufficiently high flow velocity inside the pipe any free water presence caused by operation upsets will be entrained in the oil and the pipe wall will continue to be oil wetted. This “entrainment velocity” can be calculated base on product properties. With flow velocities higher than a specific critical flow velocity shear forces can pose a potential risk of flow enhanced corrosion, flow enhanced corrosion implies presence of internal corrosion to start with, however, with a low BS&W those high velocities will keep water entrained in oil and therefore internal corrosion is unlikely to occur. Ideally KMC would want to operate the TMEP pipeline at flow velocities higher than the entrainment velocity and just below that critical velocity.

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[1] Penspen, “Dilbit Corrosivity," State of the Art Report, 12671-RPT-001 REV 1 ed., Canadian Energy Pipelines Association.

[2] Alberta Innovates, " Comparison of the Corrosivity of Dilbit and Conventional Crude,"2480002 ed., September 2011.

[3] Transportation Research Board Special Report 311: “Effects of Diluted Bitumen on Crude Oil Transmission Pipelines”, National Academy of Sciences, 2013.

Under deposit corrosion is a potential threat for all crude oil pipelines including dilbit pipelines, however having an appropriate cleaning programs in place can help in managing this threat. During the workshop KMC indicated that there is plan to implement a routine cleaning pig program potentially on a monthly basis. In addition, a periodic in-line inspection program will be implemented; the frequency of the inspection is yet to be determined.

4.2.1.1 *Summary of Corrosivity Evaluation*

Several properties of diluted bitumen have been the source of some controversy (and misinformation) pertaining to the corrosivity of that product, and was the focus of much critical scrutiny in the above references. Much of this controversy was with respect to the following dilbit characteristics:

- Sediment and water content;
- Flow regime;
- Sulfur content;
- total acid content;
- CO_2 and O_2 content; and,
- Microbiologically-Influenced Corrosion (MIC)

The findings of the above references with respect to these characteristics as they pertain to diluted bitumen are in mutual agreement, and are summarized below:

Sediment and Water

Shipments of diluted bitumen are transported at operating temperatures, flow rates, and pressure settings typical of crude oils with similar density and viscosity. Water and sediment content conforms to the Canadian tariff limits, which are more restrictive than those in U.S. pipeline tariffs. With solids and water (BS&W) limited to 0.5%, water and solids should be readily entrained within a turbulent flow regime. This turbulence will act to prevent the deposition of solids at the bottom of the line, reducing the potential harmful effects associated with under-deposit corrosion, although as is the case with all crude transport, special attention should be focused on segments of pipe where accumulation could happen; for example at dead legs, and measures should be taken to avoid such features during the design phase. Because of the low BS&W index, erosion is unlikely to present a threat.

Flow Regime

Flow velocities ranging between 0.75 and 2.5 meters per second would be expected to maintain turbulent flow in pipelines ranging from 8 to 48 inches in diameter when they transport crude oils with the range of viscosities (113 to 153 cSt at 20°C) reported for the diluted bitumen and other heavy crude oils. A fully-turbulent flow regime is anticipated for the TMEP pipeline.

Sulfur Content

While high sulfur content in crude oil is generally undesirable for refining, it is problematic for transmission pipelines mainly if it exists in surface-active compounds and hydrogen sulfide (H_2S). Canadian heavy crude oils and diluted bitumen contain 2.5 to 5 percent sulfur by weight. Most of the sulfur in bitumen is bound in stable hydrocarbon structures, and is not a source of corrosive hydrogen sulfide.

Total Acid Content

The Total Acid Number (TAN) of dilbit is generally higher than other crude oils, due to the greater biodegradtion of the natural bitumen, and the resulting concentrations of high-molecular-weight organic acids. Nevertheless, the type of acid in crude oil has a greater influence on corrosivity than the total acid content, and high-molecular-weight organic acids are stable in pipelines, and do not react at pipeline operating temperatures (i.e., <300^{o}C).

CO_2 and O_2 Content

In general, because diluted bitumen and other crude oils enter the pipeline system deaerated, there should be no significant difference in the concentrations of oxygen and carbon dioxide gas in products transported in the same pipelines.

Microbiologically-Influenced Corrosion

In assessing the susceptibility of dilbit to microbiologically-influenced corrosion (MIC) it is helpful to examine whether this crude oil is more prone to providing the essential resources (i.e., water and nutrients) required for microbial growth.

The water content of diluted bitumen shipments is comparable with that of other crude oil shipments, and diluted bitumen does not have constituents or operating requirements that make pipelines more prone to forming sludge that can harbor microorganisms.

Other critical nutrients are carbon, nitrogen and electron acceptors (especially oxidized sulfur compounds). While microbial growth requires carbon, it may be limited more by the scarcity of nitrogen in petroleum. Most of the nitrogen in bitumen is bound in carbon structures and unavailable. Lighter oils provide a more readily available source of degradable carbon than do heavy oils, including bitumen. More of the carbon in diluted bitumen is contained in relatively high concentrations of asphaltenes. The molecular weight and structure of asphaltenes vary, but biodegradation of these compounds is an extremely slow process that does not provide a readily available source of carbon for microorganisms.

With regard to the availability of electron acceptors, while the sulfur content is higher in diluted bitumen than in many other crude oils, the sulfur is not in oxidized forms available for sustained sulfate reduction. Furthermore, the high sulfur content of bitumen is not correlated with high H_2S content, and most of the sulfur in bitumen is organic sulfur bonded to carbon in heterocyclic rings, which are not easily degraded by microorganisms and thus largely unavailable for metabolism.

In conclusion, while diluted bitumen is not immune from the effects of MIC, it is not particularly susceptible to it, especially in comparison with other crude oils.

In conclusion:

Dilbit is no more corrosive than other conventional heavy crude oils. With solids and water (BS&W) limited to 0.5%, water and solids should be readily entrained within a turbulent flow regime. This will ensure that the pipe wall remains oil-wet (i.e., a non-corrosive condition), and prevent the deposition of solids. Nevertheless, the corrosion performance of this pipeline should be monitored through regular in-line inspections, and mitigation measures, such as cleaning and inhibition, should be considered if warranted.

4.3. Stress Corrosion Cracking

According to the CEPA Stress Corrosion Cracking Recommended Practice (2nd Edition, December, 2007), the most proven method of reducing SCC initiation on new pipelines is with the use of high performance coatings and effective CP. This document goes on to state that based on industry experience, susceptibility to SCC has been associated with coatings other than the following:

- Fusion bond epoxy (FBE);
- Urethane and liquid epoxy;
- Extruded polyethylene;
- Multi-layer or composite coatings

With respect to coatings, the DBM indicates:

"*The external coating for the pipe in non-mountainous areas shall be a fusion bond epoxy (FBE) coating in accordance with CSA Z245.20 and UPI Engineering Specification 19731-1801-0400, FBE Coating Specification. In mountainous areas, a three-layer polyethylene coating (i.e. a high performance composite coating (HPCC)) shall be used in accordance with CSA Z245.21 and UPI Engineering Specification 19731-1801-0470, Three-Layer Polyethylene Coating Specification.*

For locations where additional mechanical protection is needed (e.g. highway, road and railway crossings, in rocky environments or for HDD watercourse crossings) special coating protection products, such as a Dual Powder Epoxy Abrasion Resistant Overcoat (ARO) coating in accordance with UPI Engineering Specification 19731-1801-0400, FBE Coating Specification, shall be used. In some situations the use of select backfill materials or rock jacket will be a viable option to ARO coating…

Field girth welds shall be coated in accordance with UPI Engineering Specification 19731-1801-0410, Two-Part Girth Weld Coating Specification, or for a 3-layer coated pipe, a Two-Part coating plus a polyethylene shrink sleeve shall be used in accordance with UPI Engineering Specification 19731-1801-0480, Girth Weld Shrink Sleeve Specification."

All the pipeline specified coating systems listed above are characterized by the CEPA manual as high-performance coating systems, and as such are resistant to the formation of significant SCC. To date, no operating company has ever experienced a failure that was attributed to SCC in a pipeline that was coated with these coating systems.

In order to ensure that SCC remains an insignificant threat on the TMEP pipeline, it will be important to specify that coating repairs are completed with high performance coating systems.

4.4. Manufacturing Defects

Historically, failures associated with manufacturing defects have been associated primarily with pipe seam defects (crack, cold lap, misalignment, etc.) and hard spots. Other issues related to pipe manufacture, such as out-of-roundness, out-of-dimensional-tolerance conditions in end preparation, and high hardenability have contributed to field weldability problems, which in themselves have constituted a pipe integrity hazard.

In modern pipe manufacture, with the universal adoption of continuous casting in lieu of ingot casting practices, and with the advent of High Strength Low Allow steel designs, hard spots have been fully eliminated, although for the most part, the remainder of the above-listed issues are still a concern. In addition, in recent years, hydrostatic test failures and dimensional out-of-spec conditions have resulted from the production of pipe that does not meet minimum yield strength criteria.

The best way to safeguard against manufacturing defect related pipeline failures is through the application of carefully designed and executed pipe manufacturing and quality control practices, as dictated by rigorous skelp and pipe mill pre-qualification procedures and pipe purchase specifications.

For the TMEP project, the KMC TMX1-MP1100 rev 0, Submerged Arc Welded Steel Pipe, Standard will be applied to submerged arc welded pipe. This standard is to be used in addition to the following industry standards:

- CSA Z245.1-07
- CSA Z662-11, Oil and Gas Pipeline Systems
- ASME B31.3, Process Piping

Vendor pre-qualification will be based on past experience, capabilities and documentation on non-conformances. A short list of pre-qualified manufacturers will be selected based on the earlier criteria. Based on knowledge of the Vendor's work, mill quality audits, will be performed to review mill processes and procedures, QA/QC, and inspection and testing of the vendor's work. In addition, quality and technical assessments will be performed on skelp providers to pipe mills.

During pipe manufacture, third party inspection will be deployed in accordance with an Inspection and Test Plan (including 100% testing of all welds and hydrostatic testing) that is defined during the materials requisition process.

The final details of the order, including order-specific properties called out in the data sheet associated with the pipe purchase specification are an output of this process and are attached to the purchase order.

4.5. Construction Defects

Historically, construction defect failures have been associated primarily with welding defects and installation defects such as dents and buckles, which may be associated with improper ditch preparation and backfill, or with the use of excessive tie-in strains.

The mainline welding practices that are being planned for the TMEP pipeline include the use of a mechanized GMAW process on the pipeline segments in Alberta and manual LH-SMAW/FCAW processes on the pipeline segment in British Colombia. Because these are low hydrogen welding processes, they address, to a large extent, the potential for delayed hydrogen cracking on mainline welds. In addition, due to the mechanized nature of the GMAW process, welding variables, including joint preparation, line-up practices, wire feed speed, and voltage are all highly controlled, enhancing quality control and reducing joint-to-joint variability. This addresses the potential for excursions beyond the procedural endpoints of the welding procedure specification.

KMC TMX1-MP3902, Pipeline Double Joint Welding, standard will be applied to all double joint welding of pipe to pipe butt joints using semi-automatic or automatic welding techniques with the exception of field mechanized cross country pipeline welding and to field or shop fabrication of pipeline assembles and facilities.

According to the KMC TMX1-MP3902 standard, immediately after welding each weld procedure qualification test, a coupon shall be visually tested and fully radiographed or ultrasonically inspected as per CSA Z245.1. After the inspection is successfully completed the test coupons are destructively tested according to the ASME Boiler & Pressure Vessel Code, Section IX and KMC's standards..

Phased array ultrasonics (along with possibly radiographic inspection) will be employed as the preferred nondestructive inspection method. This technology readily accommodates a wide variety of inspection angles, and so is ideally suited to the detection of cracks and lack of fusion, which can occur on a variety of planes. 100% of all pressure retaining welds will be tested.

Prior to in-service, a caliper pig will be run and any identified defects will be inspected and cut-out. Within the first year after construction, a pipe geometry inspection tool will inspect the pipeline for dents and any OD deformations that might have been created during installation.

In order to address the potential for subsidence in deep excavations during construction, this issue will need to be addressed during the preparation of construction procedure specifications.

4.6. Equipment Failure

Equipment failure is defined in the context of pipeline transmission infrastructure as failures occurring in pressure retaining components other than pipe and fittings. Components that are included in this definition are valves, flanges, gaskets, etc. These components are subject to the same types of quality surveillance and inspection as the pipe itself. Risk factors for equipment failure are related to O&M procedures similar to the pipeline including QA, testing, visual inspections and hydrostatic testing.. These procedures detail when and how inspections and maintenance of equipment shall be performed, and what specific action is required.

During the May 7-8, 2013 workshop, KMC indicated that equipment failure threat will be assessed as part of a separate facilities risk assessment. Therefore this threat was determined to be out of this assessment scope of work.

4.7. Third Party Damage

Pipeline reliability, expressed in terms of susceptibility to failure due to 3rd Party Damage has been documented in the literature[4]. In this respect, failure susceptibility due to 3rd Party Damage can be established as the product of two independent variables; the frequency of incurring a hit by heavy equipment, and the probability of failure given such a hit. The susceptibility to failure for the TMEP pipeline will be quantified as a function of these two parameters during the detailed Quantitative Risk Assessment. The latter of the above two variables can be determined as a function of pipe design and material properties. Impact frequency due to external interference has been characterized in terms of damage prevention factors; specifically:

- Type of Land use
- One-call system availability and promotion
- Placement frequency of pipeline marker signs
- Use of buried marker tape at crossings
- 3rd Party requirements regarding notification of intent to excavate
- Patrol frequency
- Response time for locate requests
- Pipeline locating methods used
- Pipeline marking methods used
- Depth of cover

A review of the above-listed damage prevention factors for the TMEP pipeline was completed, based on an interview that was conducted during the Threat Assessment Workshop. The results of this interview are summarized in Table 2.

As part of detailed engineering, additional measures to reduce the threat of 3rd Party Damage in high risk areas will be evaluated. These measures include:

- Additional depth of cover
- Physical barriers (e.g. concrete pre-cast slabs)
- Increased pipe wall thickness.

[4] Chen, Q., and Nessim, M., "Reliability-Based Prevention of Mechanical Damage", EPRG/PRCI Proceedings of the 12th Biennial Joint Technical Meeting on Pipeline Research, May, 1999, Paper 25.

Table 2

Variable	Characterization / Data Availability
Land Use (Commercial / Industrial / High-density Residential / Low-density Residential / Agricultural / Remote)	The pipeline alignment is approximately: 60% Remote 24% Agricultural 10% High Population Areas 6% Water Bodies For the purposes of the quantitative risk assessment, land use characterizations can be obtained from the alignment and associated aerial imagery.
Method of one-call advertising	TMEP will be a member of Common Ground Alliance associations in British Columbia and Alberta. In addition, it is KMC's practice to notify by company brochures, presentations at construction industry events, direct mail-outs, landowner packages, web site, damage prevention presentations and trade shows.
Signage Placement	Signs will be placed at all road crossings, water crossings, line of sight and on road markings in urban areas.
Use of buried marker tape	KMC does not currently use buried marker tape but will consider it and other pipeline protection measures based on risk-based design results.
Patrol Frequency	Edmonton to McClure: Monthly Patrols McClure to Kingsvale: Biweekly Patrols Kingsvale to Hope: Biweekly Patrols Hope to Burnaby: Weekly patrols
Response time to notification of intent to excavate	3 business days unless KMC is able to contact the caller and agree on an alternative time.
Marking and locating methods	GIS and hand held pipeline locators. If planned ground disturbance is within 5 meters of pipe then additional visual confirmation of pipe by hand digging or hydrovac is required.
Depth of cover	DBM states: *"The depth of cover for the pipeline shall, at a minimum, be in accordance with CSA Z662 which requires a minimum depth of cover of 0.6 m in both areas of normal excavation and areas of rock excavation.* *Below grade mainline block valve assemblies shall be installed with a 0.8 m minimum depth of cover, whether in mineral soil or rock.* *The minimum depth of cover of the pipeline at facilities shall be 2.0 m in areas subject to vehicle traffic."*
RoW Condition	KMC reports unauthorized activities to the NEB and if serious to provincial occupation health and safety department (ie. Worksafe BC), NEB has authority to issue monetary penalties but have yet to see them do it. Regulatory affairs can provide more details on this. Provincial work safe has authority to issue fines or penalties if it is demonstrated that activity put workers at risk.

4.8. Incorrect Operations

Incorrect Operations failure is defined in the context of pipeline transmission infrastructure as failures that have causal factors that are related to design, as well as operation and maintenance procedures. Risk factors for Operations failure are related to the following considerations:

- Design-related:
  - Hazard identification
  - Potential to exceed maximum operating pressure
  - Safety systems
  - Management of change
  - Material selection
  - Checks
- Operations / Maintenance related:
  - Operating procedures
  - Management of change
  - SCADA and communications
  - Drug testing
  - Safety programs
  - Surveys, maps and records
  - Training
  - Mechanical error preventers

In order to assess the degree of threat associated with this threat category, a questionnaire was administered during the Threat Assessment Workshop. This questionnaire, which addresses process-related and design-related issues that are relevant to the TMEP pipeline as listed above, is provided below, along with the associated results.

Apart from this review, for process related factors, a formalized Hazard and Operability study will be completed to assess the suitability and reliability of protection systems.

Table 3
Operations Questionnaire

Contents

Section	Subject	Title	Questions	Possible Points
1.1	Design	Hazard Identification	4	4
1.2		MAOP Potential	1	12
1.3		Safety Systems	1	10
1.4		Material Selection	2	2
1.5		Checks	1	2
2.1	Operations	Operating Procedures	7	7
2.2		Management of Change	7	7
2.3		SCADA/Communications	1	3
2.4		Drug Testing	2	2
2.5		Safety Programs	1	2
2.6		Surveys/Maps/Records	2	5
2.7		Training	10	10
2.8		Mechanical Error Preventers	4	7
		Total	43	73

Notes:

1. *Survey questions for all topics other than Management of Change were based on the Incorrect Operations approach contained in "Pipeline Risk Management Manual", 3rd Edition [Muhlbauer, W.K.]. Management of Change approach was based on API RP 581 Part 2 "Risk Based Inspection Technology" – Annex 2.A – Management Systems Workbook.*
2. *Scores are assigned such that higher scores are associated with the most favourable response.*

Question #	Question	Possible Score	Actual Score
1. Design			
1.1	Hazard Identification		
	a. Has a threat assessment been performed that entertains all possible threats?	1	1
	b. Do the results of the threat assessment reflect current conditions?	1	1
	c. Have possible hazards and risks associated with the work been identified through studies such as HAZOP, risk assessment, or reliability analysis?	1	1
	d. Are the results of the above studies available in documented form?	1	1
	Section Totals	4	4
1.2	MAOP Potential		
	Characterize the ease with which MAOP could be reached on the pipeline system (select *one* response only):		
	a. Routine. Routine, normal operations could allow the system to reach MAOP. Overpressure would occur fairly rapidly due to incompressible fluid or rapid introduction of relatively high volumes of compressible fluids. Overpressure is prevented only by procedure or single-level safety device.	0	
	b. Unlikely. Overpressure can occur through a combination of procedural errors or omissions, and failure of safety devices (at least two levels of safety).	5	5
	c. Extremely Unlikely. Overpressure is theoretically possible (sufficient source pressure), but only through an extremely unlikely chain of events including errors, omissions, and safety device failures at more than two levels of redundancy.	10	
	d. Impossible. Overpressure cannot occur, under any conceivable chain of events.	12	
	Section Totals	12	5
1.3	Safety Systems		
	Describe the safety systems that are in place (select *one* response only):		
	a. No Safety Devices Present. No safety devices are present to prevent overpressure.	0	
	b. On Site, One Level. A single on-site device offers protection from overpressure.	3	
	c. On Site, ≥2 Levels. Two or more independent on-site devices offer protection from overpressure.	6	6
	d. Remote, Observation Only. Pressure is monitored from a remote location. Remote control is not possible, and automatic overpressure protection is not present.	1	
	e. Remote, Observation and Control. Pressure is monitored from a remote location. Remote control is possible, and automatic overpressure protection is not present.	3	
	f. Non-Owned, Active Witnessing. Overpressure prevention devices exist, but are not owned, maintained, or controlled by the owner of the equipment that is being protected. The owner takes steps to ensure that the safety device(s) is properly calibrated and maintained by witnessing such activities.	-2	
	g. Non-Owned, No Involvement. Overpressure prevention devices exist, but are not owned, maintained, or controlled by the owner of the equipment that is being protected. The owner does not take steps to ensure that the safety device(s) is properly calibrated and maintained by witnessing such activities.	-3	
	h. Safety Systems Not Needed. Safety systems not needed because overpressure cannot occur.	10	

Question #	Question	Possible Score	Actual Score
	Section Totals	10	6
1.4	Materials Selection		
	Are design documents available that illustrate that all piping systems were designed with consideration given to all anticipated stresses?	1	1
	Do control documents, including material specifications and design drawings for all systems and components exist and maintained in an up-to-date manner?	1	1
	Section Totals	2	2
1.5	Checks		
	Do procedures exist that require design calculations and decisions to be checked by a licensed professional engineer at key points during the design process?	2	2
	Section Totals	2	2
2. Operation			
2.1	Operating Procedures		
	Do written procedures covering all aspects of pipeline operation exist?	1	1
	Are these procedures actively used, reviewed, and revised?	1	1
	Are copies of these procedures available at field locations?	1	1
	Does a protocol exist that specifies the responsibility for procedure development and approval?	1	1
	Does a protocol exist that specifies how training is performed against these procedures?	1	1
	Does a protocol exist that specifies how compliance to these procedures is verified?	1	1
	Does a document management system exist that ensures version control, and proper access to the most current procedure documents?	1	1
	Section Totals	7	7
2.2	Management of Change		
	Is there a written MOC procedure that must be followed whenever processes, procedures or physical assets are changed?	1	1
	Are authorization procedures clearly stated and at an appropriate level?	1	1
	Do physical changes, changes in operating conditions, and changes in operating procedures invoke the MOC procedure?	1	1
	Is there a clear understanding of what constitutes a 'temporary change', and does the MOC procedure address temporary changes?	1	1
	Are temporary changes tracked to ensure that they are either removed after a reasonable period of time or reclassified as permanent?	1	1
	Do the MOC procedures specifically require the following actions whenever a change is made to an operating procedure? • Update all affected operating procedures • Update all affected maintenance programs and inspection schedules • Modify drawings, statement of operating limits, and any other safety information affected? • Notify all operations and maintenance employees who work in the area of the change, and provide training as required	1	1

Question #	Question	Possible Score	Actual Score
	• Review the effect of the proposed change on all separate but interrelated procedures		
	When changes are made in operating procedures, are there written procedures requiring that the impact of these changes on the equipment and materials of construction be reviewed to determine whether they will cause any increased rate of deterioration or failure, or will result in different failure mechanisms in the equipment?	1	1
	Section Totals	7	7
2.3	SCADA / Communications		
	Describe the SCADA / Communications systems that are in place (select *one* response only):		
	a. Level 1. No SCADA system exists, or is not used in a manner that promotes human error reduction.	0	
	b. Level 2. Some critical activities are monitored; field actions are informally coordinated through a control room; system is at least 80% operational.	1	
	c. Level 3. Most critical activities are monitored; field actions are usually coordinated through a control room; system up-time exceeds 95%.	2	2
	d. Level 4. All critical activities are monitored; all field actions are coordinated through a control room; SCADA system reliability (measured in up-time) exceeds 99.9%.	3	
	Section Totals	3	2
2.4	Drug Testing		
	Does a drug testing program exist that applies to employees who play substantial roles in pipeline operations?	1	1
	Does the testing program incorporate elements of random testing, testing for cause, pre-employment testing, post-accident testing, and return-to-work testing?	1	1
	Section Totals	2	2
2.5	Safety Programs		
	Does the company's safety program incorporate the following elements? (award partial marks for compliance with only a portion of the elements): • Written company statement of safety philosophy • Safety program designed with high level of employee participation • Strong safety performance record • Good attention to housekeeping • Signs, slogans, etc. to show an environment tuned to safety • Full-time safety personnel	2	2
	Section Totals	2	2
2.6	Surveys, Maps, Records		
	Are surveys such as those listed below conducted on a regular basis? (award partial marks for compliance with only a portion of the elements): • Close interval pipe-soil surveys • Coating condition surveys • Water crossing surveys	3	3

Question #	Question	Possible Score	Actual Score
	• ILI assessments • Population density surveys • Depth of cover surveys • Leak detection surveys • Patrols (aerial or ground-based)		
	Are detailed, clear maps and records updated regularly, and are they available to all operations staff?	2	2
	Section Totals	5	5
2.7	Training		
	Evaluate the operator training program in terms of the following elements:		
	a. Minimum training requirements are documented	2	2
	b. Incorporates testing	2	2
	c. Covers the following:		
	i. Product characteristics	0.5	0.5
	ii. Pipeline material stresses	0.5	0
	iii. Pipeline corrosion	0.5	0.5
	iv. Control and operations	0.5	0.5
	v. Maintenance	0.5	0.5
	vi. Emergency drills	0.5	0.5
	d. Training is job-procedure specific	2	2
	e. Incorporates requirements for scheduled re-training	1	1
	Section Totals	10	9.5
2.8	Mechanical Error Preventers		
	Evaluate the availability and effectiveness of the following devices designed to prevent operator error:		
	a. Lock-out devices. Installed on safety-critical valves (e.g., during blow-down and repair)	2	2
	b. Key-lock Sequence Programs. If a job procedure calls for several operations to be performed in a certain sequence, and deviations from that prescribed sequence may cause serious problems, a key-lock sequence program may be employed to prevent any action from being taken prematurely.	2	0
	c. Computer permissives. Electronic equivalent to key-lock sequence programs.	2	1
	d. Highlighting of critical instruments. e.g., painting critical valves with specific colors.	1	0
	Section Totals	7	3
	Total Points	**73**	56.5

4.9. Geotechnical / Hydrological Forces

Failures that are attributed to geotechnical and hydrological forces are typically associated with outside force events such as subsidence, earth movement, seismic activity, floods, stream erosion, and rock fall. These threats are highly site-specific in nature. In order to assess the degree of threat that a pipeline will be exposed to, a thorough evaluation of all information along the length of the pipeline must be completed. Typically, the collection and review of this information is completed in two stages; the first stage being a desktop exercise, that focuses on published information, such as soils maps, topographic maps, hydrological maps, pipeline alignment sheets, incident reports related to ground movement, hydrological events, and floods, studies, texts, and engineering reports. From this first stage of information gathering and review, potential hazard sites are identified. The second stage of information gathering and review involves data collected from site visits. Such data might include evidence of ground movement, such as slumping, cracks in soil, tilted trees, trees with diverted growth orientation, rock fall, flood marks, scour marks, etc. Where necessary, instrumentation such as slope inclinometers might be installed and monitored. On the basis of the above, the understanding of outside force mechanisms is refined. In this particular case, where several decades of operating experience exists along the bulk of the right-of-way, this operating experience, along with the background derived from the existing geohazard idenfication and monitoring program can be expected to provide a substantial portion of the information to serve as the basis of a threat assessment for Line 2.

Only once the above information is collected and analyzed can the extent of outside force threats, including the potential magnitude of movement, and estimates of movement frequency be established. Outside force mitigation plans are developed on basis of this information. The preferred mitigation strategy is threat avoidance, either by diverting the alignment or by deviating below slip zones and scour zones. In some cases, threats cannot be completely avoided, and other measures, such as long-term monitoring plans, shoring, and other forms of stabilization must be considered.

The above information gathering and mitigation plan is currently ongoing, and at this point it is premature to identify specific mitigation plans, and estimates of outside force frequency and magnitude. The information that is currently available is available as appendices to Volume 4A. Further information will be made available in time for the quantitative risk assessment, and the mitigation plans will be incorporated into the detailed design.

4.10. Other Threats

During the Threat Assessment Workshop, an open discussion was held to identify potential threat mechanisms that don't fall into one of the nine categories listed above. A wide variety of operating threats were discussed, including forest fires and concomitant failure.

With respect to forest fires, experience dictates that where a pipeline is buried in a cleared right-of-way, forest fires do not constitute a significant loss-of-containment hazard in and of themselves, since the right-of-way acts as a fire break, and the ground cover acts to insulate the pipeline. Fire breaks will need to be installed around above-ground installations, such as valve sites, or aerial crossings, and these will need to be addressed during detailed design.

Concomitant failures occur where the catastrophic failure of one pipeline (typically a natural gas pipeline, in which rapid decompression of a compressible fluid results in the formation of a large blast crater, and in which the ensuing release of natural gas is readily ignitable), can result in the uncovering of an adjacent pipeline, which may become involved in an ensuing fire. Although Line 1 will lie parallel to Line 2 for most of the route, this scenario was not considered viable, since Line 1 is a LVP pipeline.

No additional threats were identified.

5. Assessment of Threat Potential and Approach

In this Section, an assessment of threat potential is made on the basis of a review and analysis of the data in the preceding Section. Additionally, a characterization of the failure likelihood estimation approach that the available data will lend themselves to was made. The characterization of approach contained in this Section will be general in nature. For the detailed description, reference should be made to the quantitative failure likelihood report.

Where appropriate, assumptions that will be incorporated into the quantitative failure analysis have been identified for each threat. Additionally, where mitigation measures and controls will be required in order to ensure that the magnitudes of threats for the TMEP pipeline will not exceed those that are associated with best practices, those mitigation measures and controls and the assignment of responsibility for executing and implementing those measures and controls were listed.

5.1. External Corrosion

5.1.1 Threat Potential

It is expected that the pipeline will have some degree of exposure to the threat of external corrosion, and therefore the threat potential for external corrosion must be included in the quantitative failure frequency estimate.

5.1.2 Approach

As was highlighted in Section 1.1, using industry failure statistics as the basis of a quantitative estimate of failure likelihood is not desirable from several perspectives. Additionally, as with all time-dependent threats, the use of industry failure statistics does not adequately address the fact that the threat of external corrosion failure will initially be zero, and will rise over time.

A reliability approach is proposed which leverages existing ‘analogue’ ILI datasets along with the specific design details (diameter, wall thickness, grade, operating pressure) of the TMEP pipeline. Under such an approach it is important to ensure that the analogue datasets are representative (or slightly conservative) relative to the expected external corrosion performance of the TMEP pipeline. In this way, the reliability parameters of external corrosion feature incident rate, external corrosion feature size distribution, and external corrosion growth rate that are obtained from the analogue ILI datasets can be employed, knowing that the critical reliability data that they impart are representative, or conservative. To ensure that this is the case, the following measures should be adopted.

Table 4
External Corrosion Measures

Threat Factor	Area of Concern	Controls	Action
Mainline Coating Type	The mainline external coating system used in the pipeline from which the analogue ILI data are taken should be representative or conservative, relative to the expected corrosion coating performance on the TMEP pipeline.	An analogue ILI dataset that is representative of FBE coating systems will address this issue.	To be addressed during selection of analogue ILI database
Field Joint Coating	The field joint external coating system used in the pipeline from which the analogue ILI data are taken should be representative or conservative (but not too conservative), relative to the expected corrosion coating performance on the TMEP pipeline.	Ensure that TMEP pipeline specifies high performance coating systems for field joint coatings (i.e., field-applied FBE, liquid epoxy, or liquid urethane)	To be addressed by TMEP purchase specifications and detailed design
		An analogue ILI dataset that is representative of high performance field joint coating systems will address this issue. If this cannot be done, external wall loss features that are associated with girth welds will not be considered in the analysis.	To be addressed during selection of analogue ILI database and / or during quantitative analysis
Temperature effects on external coatings	Operating temperatures that exceed the maximum temperature rating of the mainline and field joint coating systems can result in significantly degraded coating performance over time	Ensure that coating systems that are specified for mainline and field girth welds are rated to withstand the expected maximum operating temperatures of the TMEP Pipeline (50°C)	To be addressed by TMEP purchase specifications and detailed design
		Ensure that the analogue ILI dataset is representative of pipeline that have not been operated above the maximum temperature rating of either the mainline or field girth weld coating systems.	To be addressed during selection of analogue ILI database
Cathodic Protection	Ensure that CP performance in pipeline from which analogue ILI dataset is obtained is representative of CP performance expected in TMEP pipeline.	Ensure that CP systems for TMEP pipeline are designed and operated in accordance with the requirements of CSA Z662 and OCC-1.	To be addressed by TMEP detailed design, and in operating procedures.
		Identify potential sources of interference (such as from induced AC power lines), and incorporate appropriate mitigations into cathodic protection systems	To be addressed by TMEP detailed design, and in operating procedures.
		Ensure that a mitigation plan for tellurics, including consideration of potential-controlled rectifiers, is addressed during the detailed design phase.	To be addressed by TMEP detailed design, and in operating procedures.

		Ensure that the analogue ILI dataset is representative of pipeline that have not been operated outside of cathodic protection potential criteria.	To be addressed during selection of analogue ILI database
Soil Characteristics	Ensure that soil characteristics in pipeline from which analogue ILI dataset is obtained is representative of soil characteristics expected in TMEP pipeline.	Identify any locations of acid-generating rock, and formulate appropriate mitigation plans where it exists along the pipeline right-of-way.	To be addressed by TMEP detailed design
		Ensure that the analogue ILI dataset is not representative of unusual soil conditions or aggressiveness	To be addressed during selection of analogue ILI database
Above-ground pipe	Ensure that sections of above-ground pipe do not constitute increased levels of external corrosion threat	Consider factors that might influence the susceptibility to atmospheric corrosion, such as pipe support design, atmospheric coating systems, and atmospheric/buried coating transitions during the detailed engineering design	To be addressed by TMEP detailed design
Casings	Ensure that casings do not constitute increased levels of external corrosion threat. The use of some casings should be anticipated for bored trenchless crossings, where casings may be used to stabilize the path prior to pulling the pipe through the crossing.	Measures (such as filling the annulus with corrosion inhibitor) should be considered during the detailed design to accommodate the potential future occurrence of electrolytic and/or metallic shorts.	To be addressed by TMEP detailed design
ILI Data	Potential for manufacturing defects to be misinterpreted as corrosion defects, leading to unrealistically high corrosion feature incidence rates and aggressive apparent growth rate distributions	Utilize a dataset from a pipeline that is old enough to mask the effects of manufacturing defects.	To be addressed during selection of analogue ILI database

5.2. Internal Corrosion

5.2.1 Threat Potential

The corrosivity analysis contained in Section 4.2.1 has indicated that the product stream in conjunction with the operating and flow characteristics should render the pipe wall in an oil-wet (i.e., non-corrosive) conditon, although ongoing monitoring with a view to implementing appropriate mitigation strategies is warranted. In addition, the internal corrosion control measures summarized in Table 5 should be adopted.

5.2.2 Approach

A significant amount of operating experience with dilbit has been reported, and is available in the public record.* A review of this evidence will be completed to provide guidance in establishing estimates of failure likelihood due to internal corrosion.

* Particularly with respect to evidence submitted during Hearing Order OH-4-2011, Northern Gateway Pipelines Inc. Enbridge Northern Gateway Project Application of 27 May, 2010.

Table 5
Internal Corrosion Measures

Threat Factor	Area of Concern	Controls	Action
Water Content	Elevated water content can result in stratification in some flow regimes, and may result in enhanced corrosivity	Control BS&W for TMEP pipeline to 0.5% max.	Reflects current tariff specification. Safeguards to be addressed by strict enforcement of tariffs and controls
		Maintain turbulent flow to entrain what little water that exists in the product stream flow	Reflects current design. Design of operating safeguards to be addressed during development of operating procedures.
	Ensure that water content in pipeline from which analogue ILI dataset is obtained is representative of water content expected in TMEP.	Ensure that the analogue ILI dataset is representative of BS&W contents of 0.5% max.	To be addressed during selection of analogue ILI database
Deposit of Solids	Solid deposition can result in under-deposit corrosion	Ensure that design product stream velocities exceed threshold for solid deposition.	Reflects current design. Design of operating safeguards to be addressed during development of operating procedures.
	Accumulation of solids could occur in dead legs, leading to under-deposit corrosion at those locations	Ensure that dead legs are eliminated or minimized in the final design.	To be addressed by TMEP detailed design.
Microbial Corrosion	Operating temperature is favourable to increase in MIC activity for Line 2.	During the operation, monitor flow conditions for MIC susceptibility, and use biocides, if necessary	To be addressed by TMEP detailed design, and in operating procedures.

5.3. Stress Corrosion Cracking

5.3.1 Threat Potential

Based on industry experience, susceptibility to SCC has been associated with coatings other than the following:

- Fusion bond epoxy (FBE);
- Urethane and liquid epoxy;
- Extruded polyethylene;
- Multi-layer or composite coatings

The threat potential for SCC is anticipated to be negligible (i.e., this threat will not contribute in a significant way to overall risk), provided that the coating systems used on the TMEP pipeline are limited to those listed above. This will need to be addressed by TMEP purchase specifications and detailed design.

5.4. Manufacturing Defects

5.4.1 Threat Potential

KMC's pipe procurement program specifies rigorous controls to ensure the quality of line pipe to be supplied to the TMEP project. Although CSA Z662-11 specifies the use of Category I pipe, with no proven notch toughness for LVP pipelines, Category II pipe, with specified requirements on fracture toughness and fracture appearance will be used. Apart from pipe purchase specifications that exceed the requirements of CSA Z662-11, controls will be implemented that include supplier pre-qualification practices that focus on technical and quality criteria, as well as 100% 3rd party pipe mill quality surveillance that conforms to a Test Plan that is defined during the material requisition process. No improvements are recommended to these controls, and given the presence of the controls, the threat of manufacturing defects is not anticipated to be a significant contributor to overall risk for the TMEP pipeline.

5.4.2 Approach

The threat of manufacturing defects does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. Despite the fact that this threat is not anticipated to contribute significantly to overall risk, an attempt will be made to achieve an upper-bound estimate of failure frequency based on industry operating experience of recent installations of pipeline.

5.5. Construction Defects

5.5.1 Threat Potential

KMC's construction practices along with the Quality Management Program and Quality Assurance processes used in the construction of the TMEP pipeline establish the controls to ensure the quality of the pipeline installation, including welding processes. Rigorous quality checks will be employed, including 100% NDT using phased array ultrasonics and/or X-ray inspection, as well as 100% inspection with a pipe size and deformation tool after installation to ensure that the pipeline is free of dents, buckles, and excessive out-of-round conditions. Tight controls imposed on line pipe carbon equivalent as well as the use of a mechanized low hydrogen welding process in which procedural variables are tightly controlled precludes the likelihood of weld cracking, or other systemic welding-related defects.

Manual weld processes will be subject to detailed weld procedure qualification and 100% ultrasonic and x-ray inspection.

No improvements are recommended to these controls, and given the presence of the controls; the threat of construction defects is not anticipated to be a significant contributor to overall risk for the TMEP.

5.5.2 Approach

The threat of construction defects does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. Despite the fact that this threat is not anticipated to contribute significantly to overall risk, an attempt will be made to achieve an upper-bound estimate of failure frequency based on industry operating experience of recent installations of pipelines.

5.6. Equipment Failure

5.6.1 Threat Potential

During the May 7-8, 2013 workshop, KMC indicated that equipment failure threat will be assessed as part of a separate facilities risk assessment. Therefore this threat was determined to be out of this assessment scope of work.

5.7. Third Party Damage

5.7.1 Threat Potential

All pipelines experience some level of threat due to third party damage, the magnitude of this threat being a function of the effectiveness of damage prevention measures, adjacent land use, depth of cover, material properties and pipeline design. Although damage prevention measures can help to offset this threat, third party damage can never be fully neutralized, and so this is expected to be one of the primary threats in contributing to overall pipeline risk.

5.7.2 Approach

A reliability model exists that considers all the parameters of damage prevention measures, adjacent land use, depth of cover, material properties and pipeline design, and this model will be used here (see Reference 4). The reliability approach employs a fault tree model to estimate hit frequency, and a separate stochastic model to predict probability of failure, given a hit.

5.8. Incorrect Operations

5.8.1 Threat Potential

All pipelines experience some level of threat due to incorrect operations, the magnitude of this threat being a function of the effectiveness of design-related and operations/maintenance related practices and measures. Although design, operations and maintenance practices can help to offset this threat, incorrect operations can never be fully neutralized, and so this is expected to be one of the primary threats in contributing to overall pipeline risk.

5.8.2 Approach

The threat of incorrect operations does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. Reflecting this fact, an attempt will be made to achieve an estimate of failure frequency based on operating incident data, related to this threat, modified by the results of the Operations Questionnaire that was administered during the Threat Assessment Workshop (See Table 3).

While detailed design, operating and maintenance procedures have not been completed at this stage, an evaluation of the operating procedures that was completed during the Threat Assessment Workshop identified potential areas for further improvement. These measures include the following:

- Include pipeline materials stresses in the operator training curriculum so that they can be aware of the impacts of any changes in operating conditions on pipeline integrity.
- Implement more mechanical error preventers by highlighting of critical instruments. e.g., painting critical valves with specific colors.

5.9. Geotechnical / Hydrological Forces

5.9.1 Threat Potential

The TMEP pipeline transects several mountain ranges. These mountain ranges harbour potential for a wide range of geotechnical and hydrological conditions, and so while mitigation measures will be implemented to avoid or manage these conditions, it is unavoidable that the pipeline will experience some level of threat due to outside forces. Therefore, this is expected to be one of the primary threats in contributing to overall pipeline risk.

5.9.2 Approach

In order to assess the degree of threat that a pipeline will be exposed to, a thorough evaluation of all information along the length of the pipeline is currently being completed. Information reviewed will include the 60 years of operating experience and existing geohazard inventories and analysis relevant to Line 1. Published information such as seismic reports, soils maps, topographic maps, hydrological maps, pipeline alignment sheets, incident reports related to ground movement, hydrological events, and floods, studies, texts, and engineering reports will be reviewed. From this initial data gathering and review, potential hazard sites will be identified, with follow-up site visits to collect and analyze site-specific information, such as evidence of ground movement, slumping, cracks in soil, tilted trees, trees with diverted growth orientation, rock fall, flood marks, scour marks, etc.

Once the above information is collected and analyzed, the extent of outside force threat, including the potential magnitude of movement, and estimates of movement frequency will be established, based on the conceptual design and design assumptions.

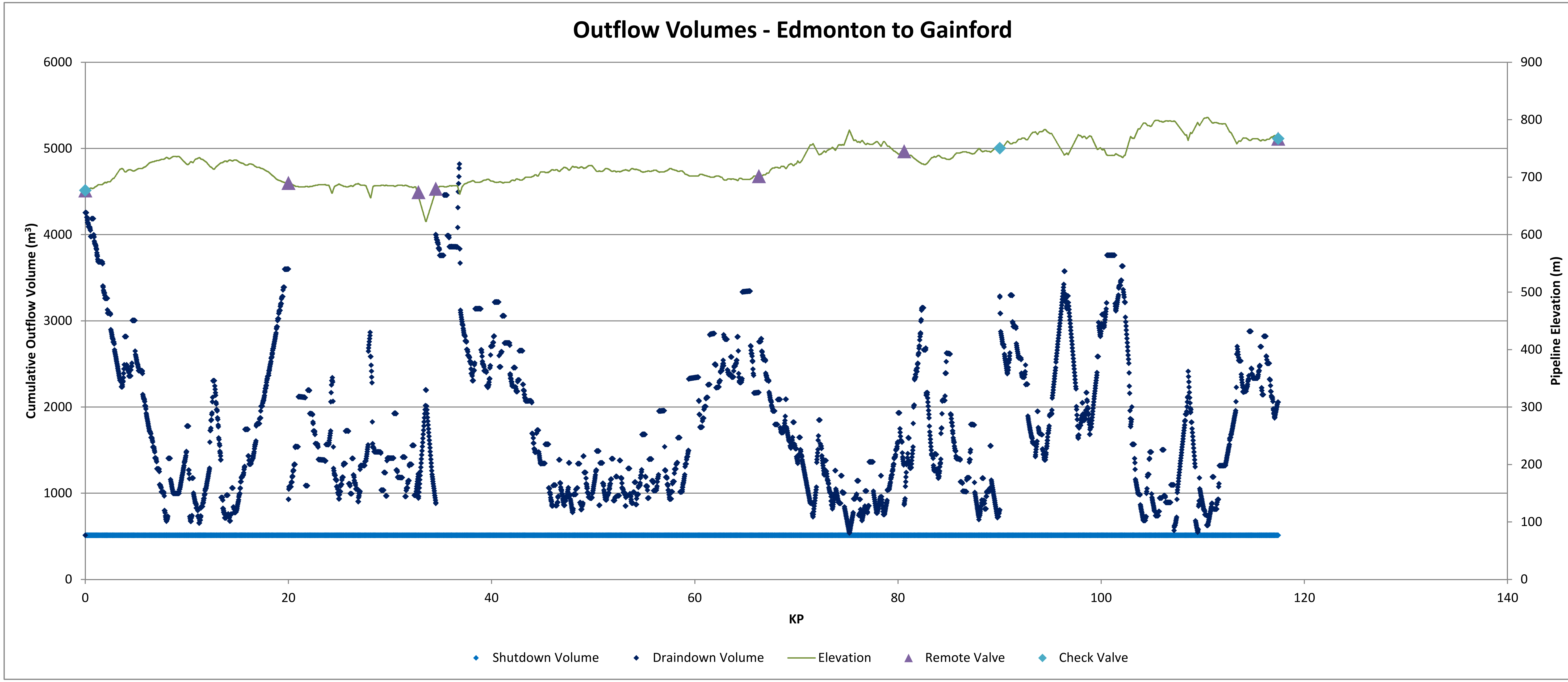
The above information gathering is currently ongoing, and at this point it is premature to identify specific sites, mitigation plans, and estimates of outside force frequency and magnitude. This information will be made available in time for the quantitative failure likelihood assessment, and the mitigation plans will be incorporated into the detailed design.

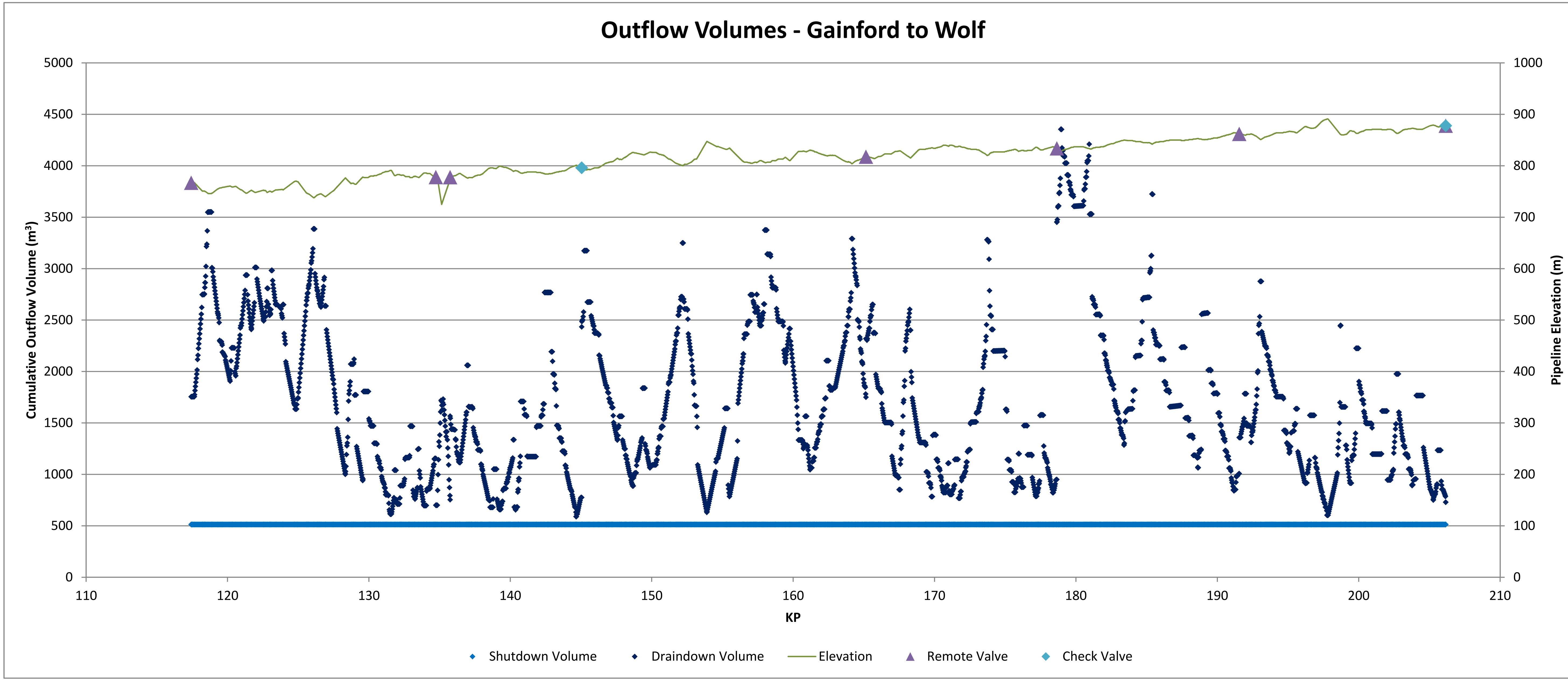
Geotechnical/Hydrological threat potential is iterative. Design parameters such as pipeline centerline, depth of cover, water crossing geometry and methodology will affect the final geotechnical threat assessment.

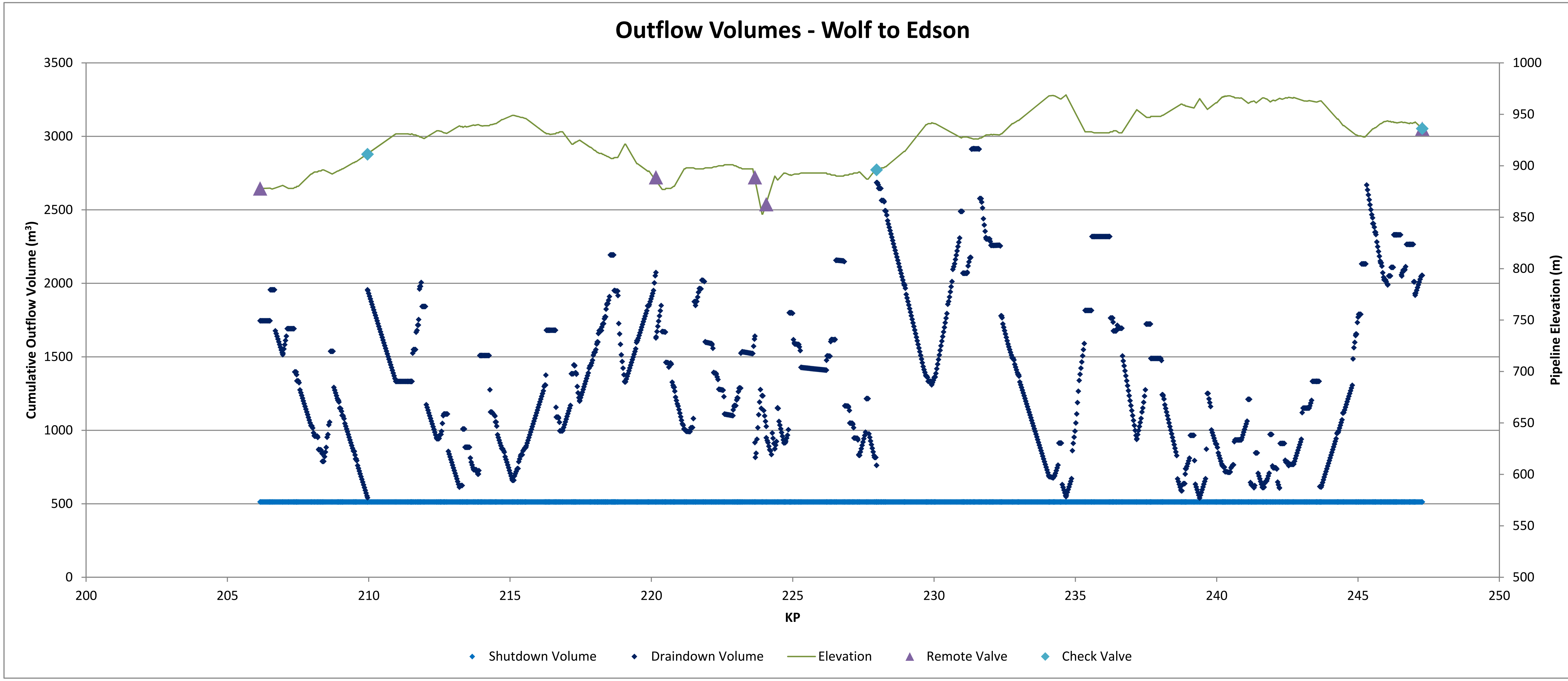
5.10. Other Threats

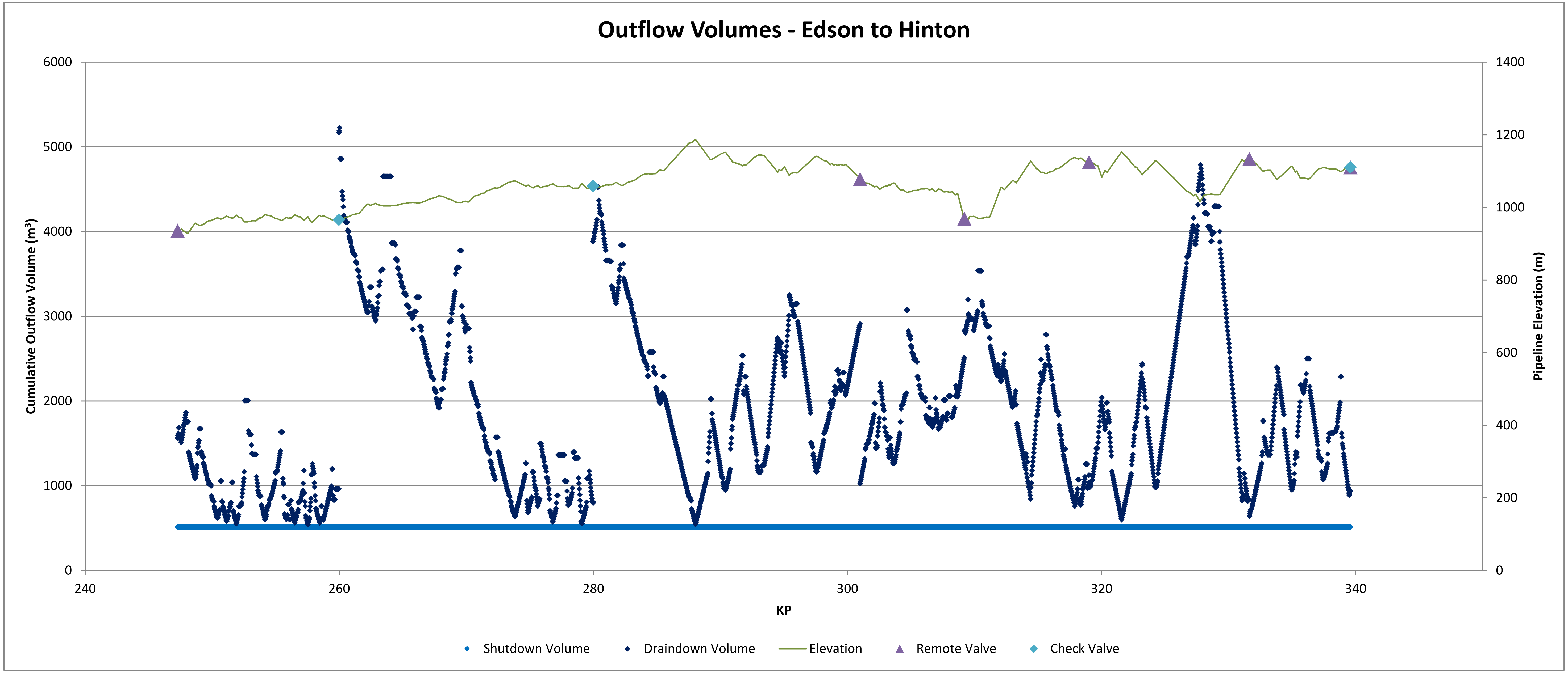
During the Threat Assessment Workshop, an open discussion was held to identify potential threat mechanisms that don't fall into one of the nine categories listed above. No additional threats were identified.

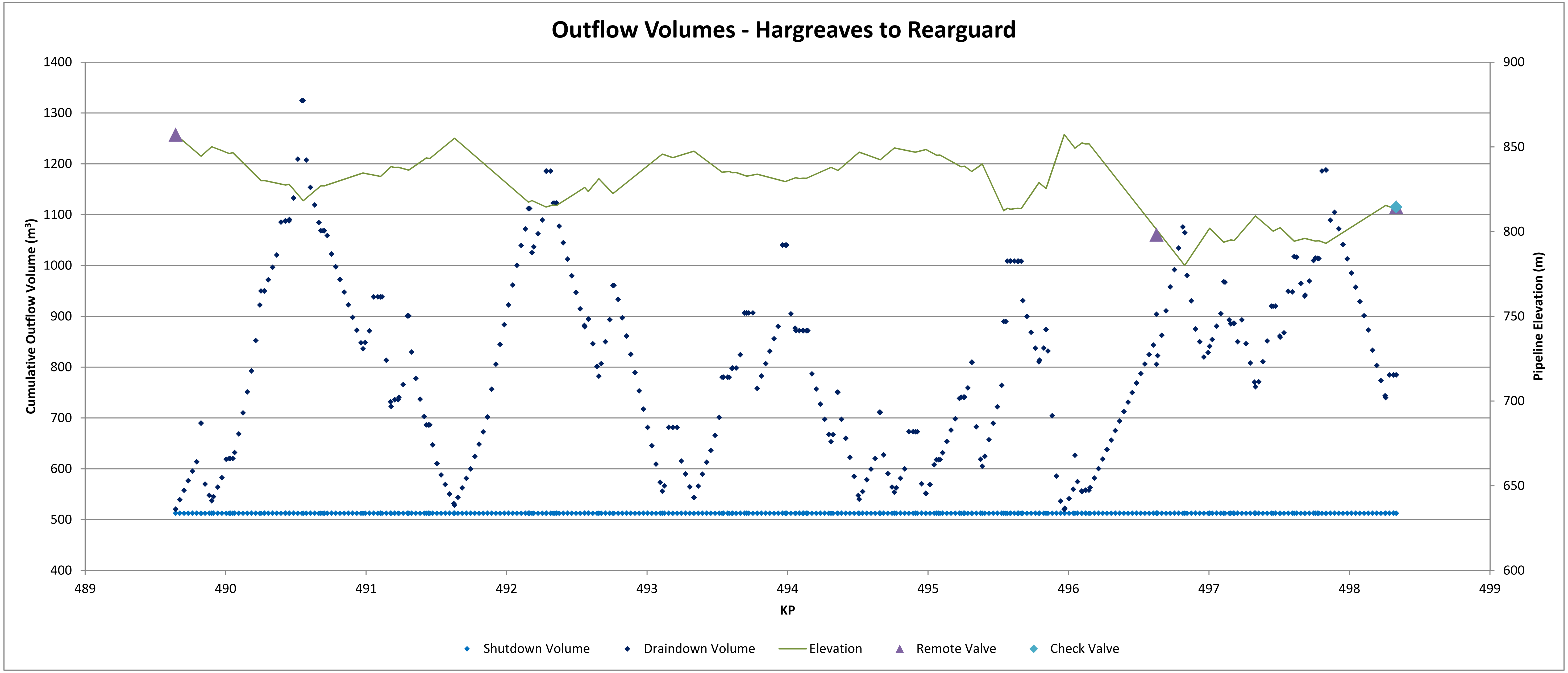
Appendix B Oil Spill Outflow Model Results

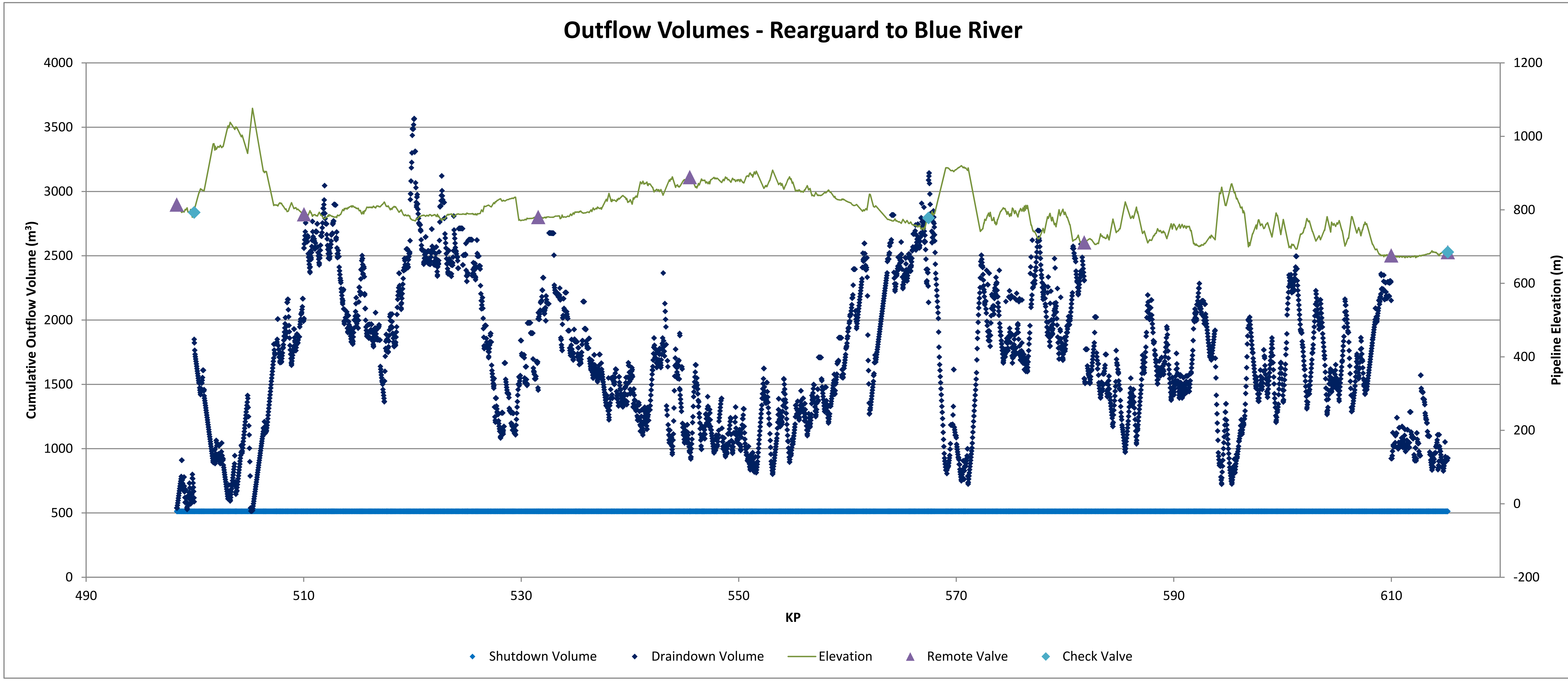

Outflow Volumes - Edmonton to Gainford
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
6000
5000
4000
3000
2000
1000
0
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

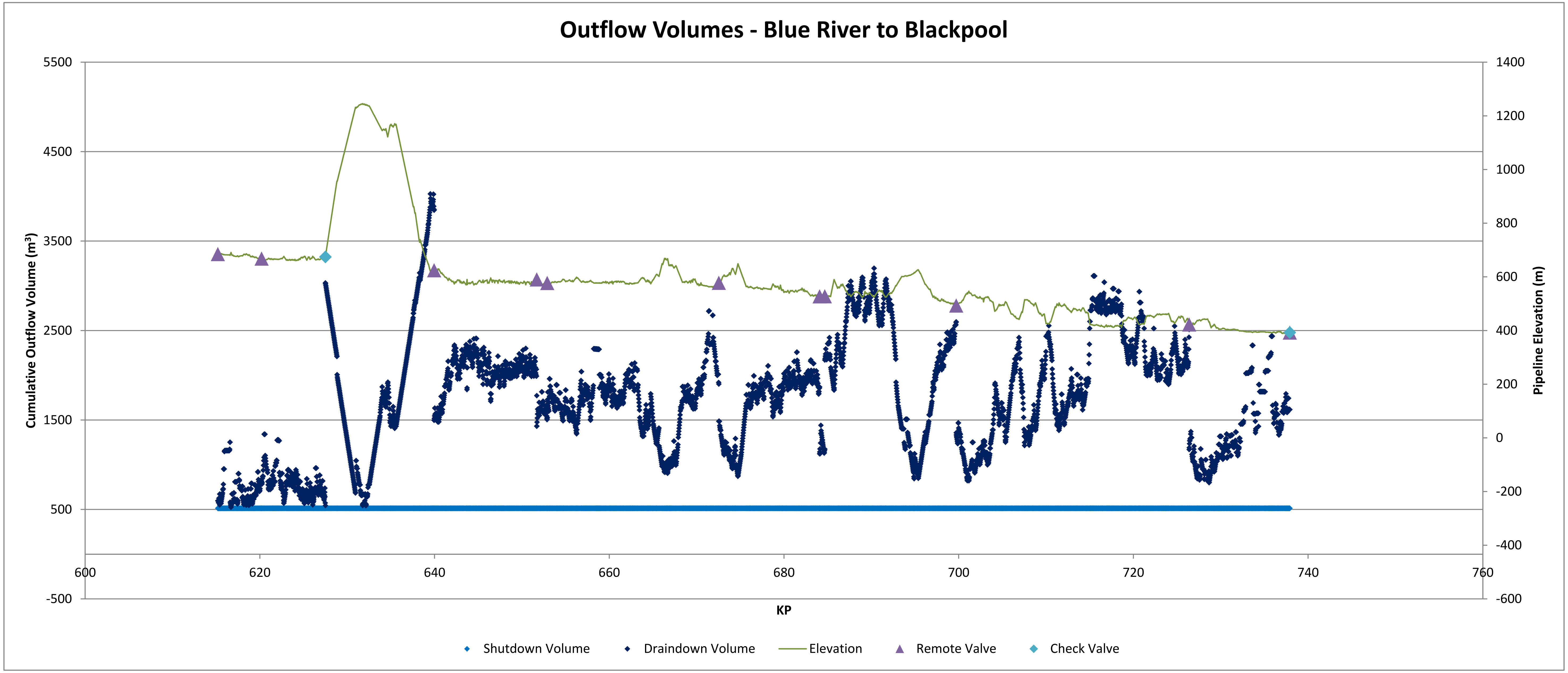

Outflow Volumes - Gainford to Wolf
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0
100
200
300
400
500
600
700
800
900
1000
110
120
130
140
150
160
170
180
190
200
210
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

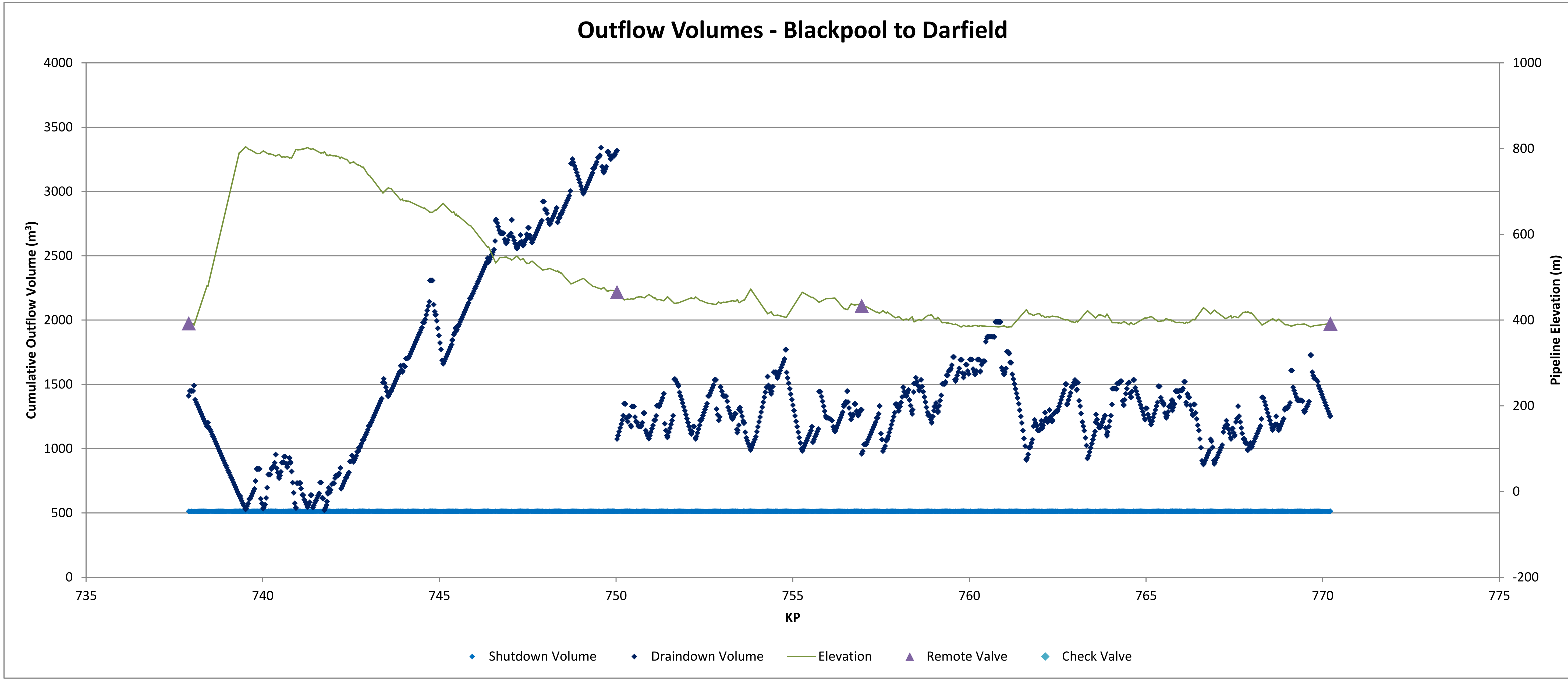

Outflow Volumes - Wolf to Edson
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
3500
3000
2500
2000
1500
1000
500
0
1000
950
900
850
800
750
700
650
600
550
500
200
205
210
215
220
225
230
235
240
245
250
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

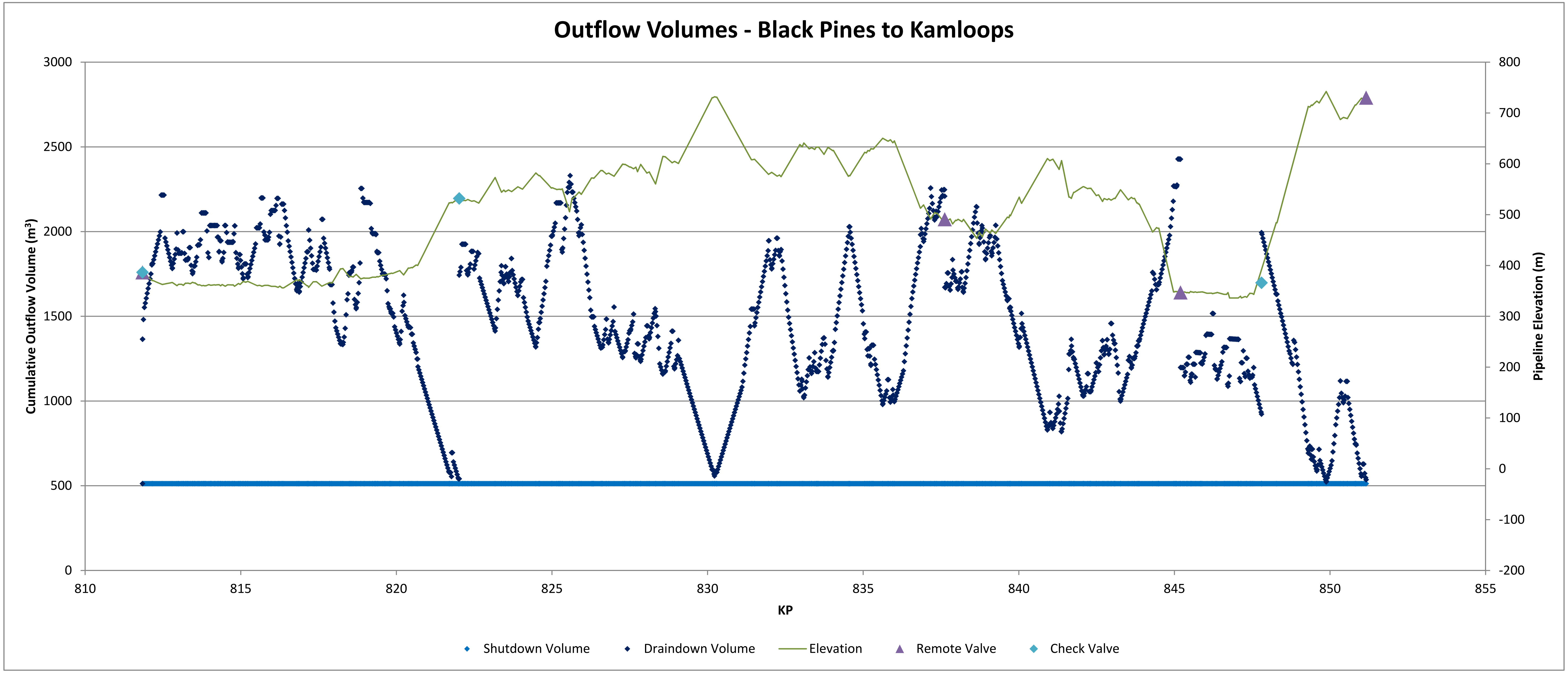

Outflow Volumes - Edson to Hinton
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
0
1000
2000
3000
4000
5000
6000
0
200
400
600
800
1000
1200
1400
240
260
280
300
320
340
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

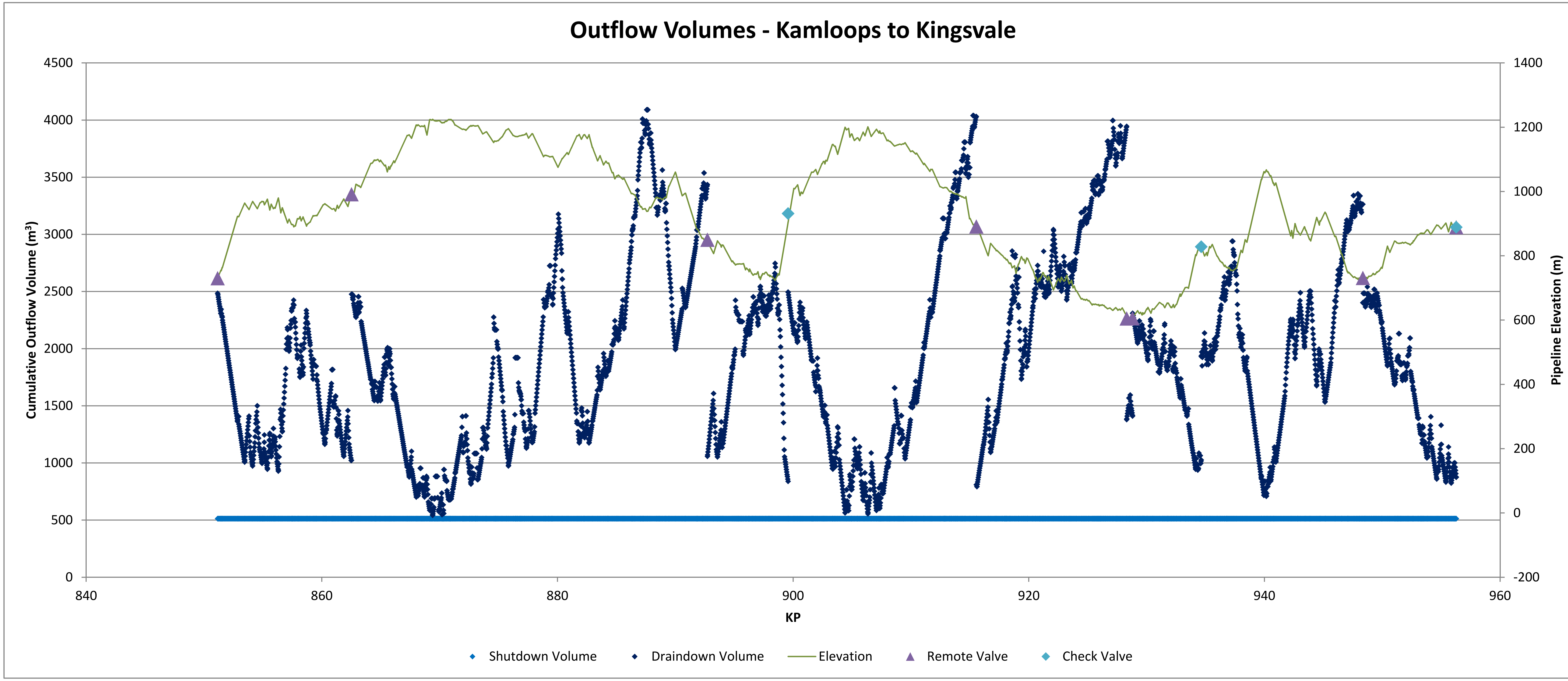

Outflow Volumes - Hargreaves to Rearguard
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
1400
1300
1200
1100
1000
900
800
700
600
500
400
900
850
800
750
700
650
600
489
490
491
492
493
494
495
496
497
498
499
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

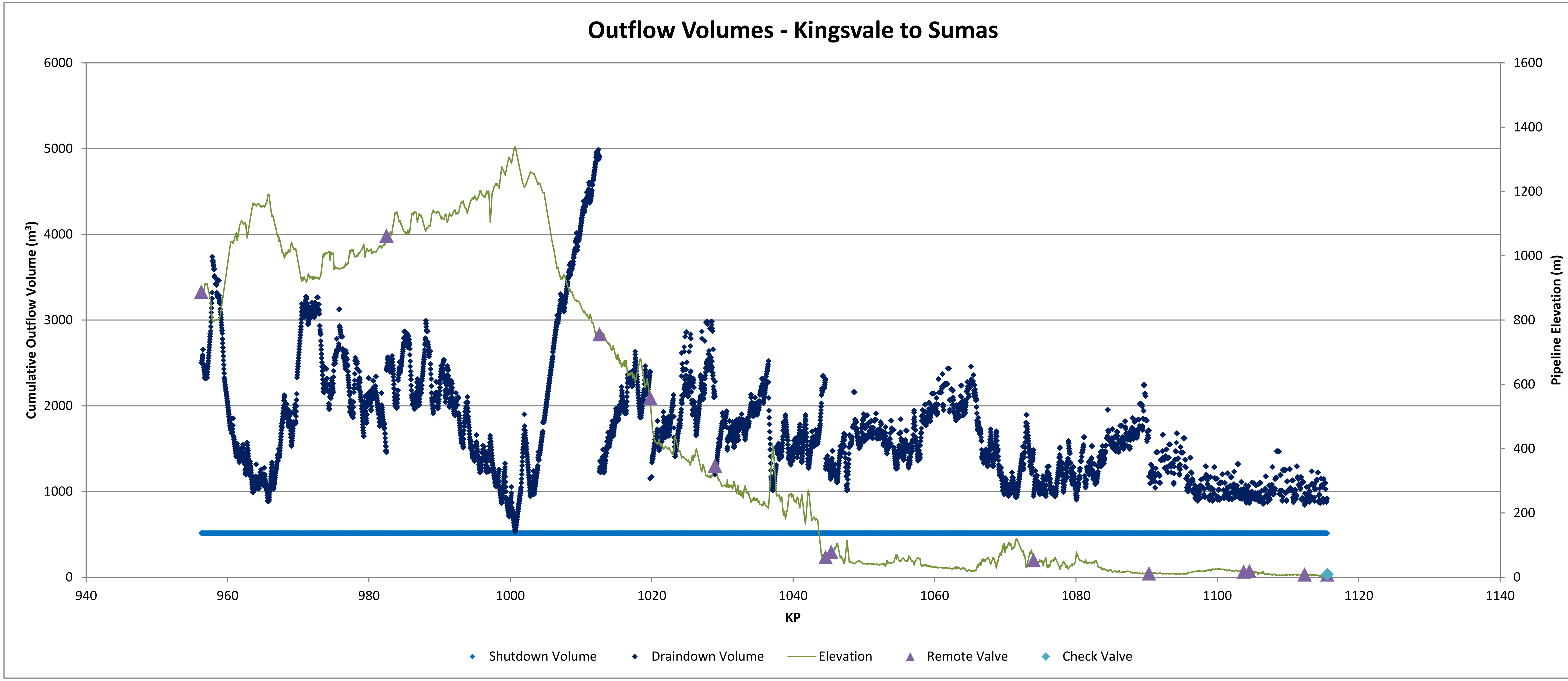

Outflow Volumes - Rearguard to Blue River
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
0
500
1000
1500
2000
2500
3000
3500
4000
-200
0
200
400
600
800
1000
1200
490
510
530
550
570
590
610
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

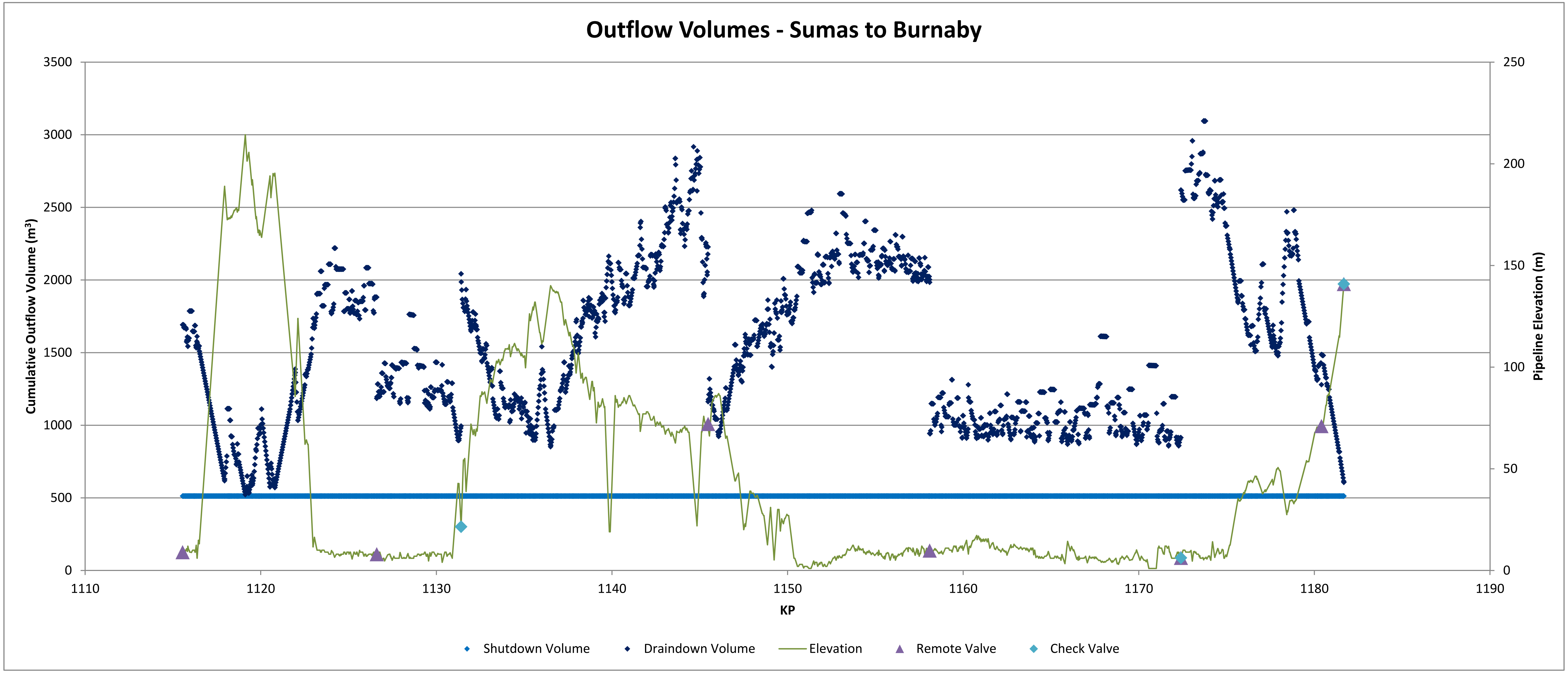

Outflow Volumes - Blue River to Blackpool
Cumulative Outflow Volume (m3)
Pipeline Elevation (m)
5500
4500
3500
2500
1500
500
-500
1400
1200
1000
800
600
400
200
0
-200
-400
-600
600
620
640
660
680
700
720
740
760
KP
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

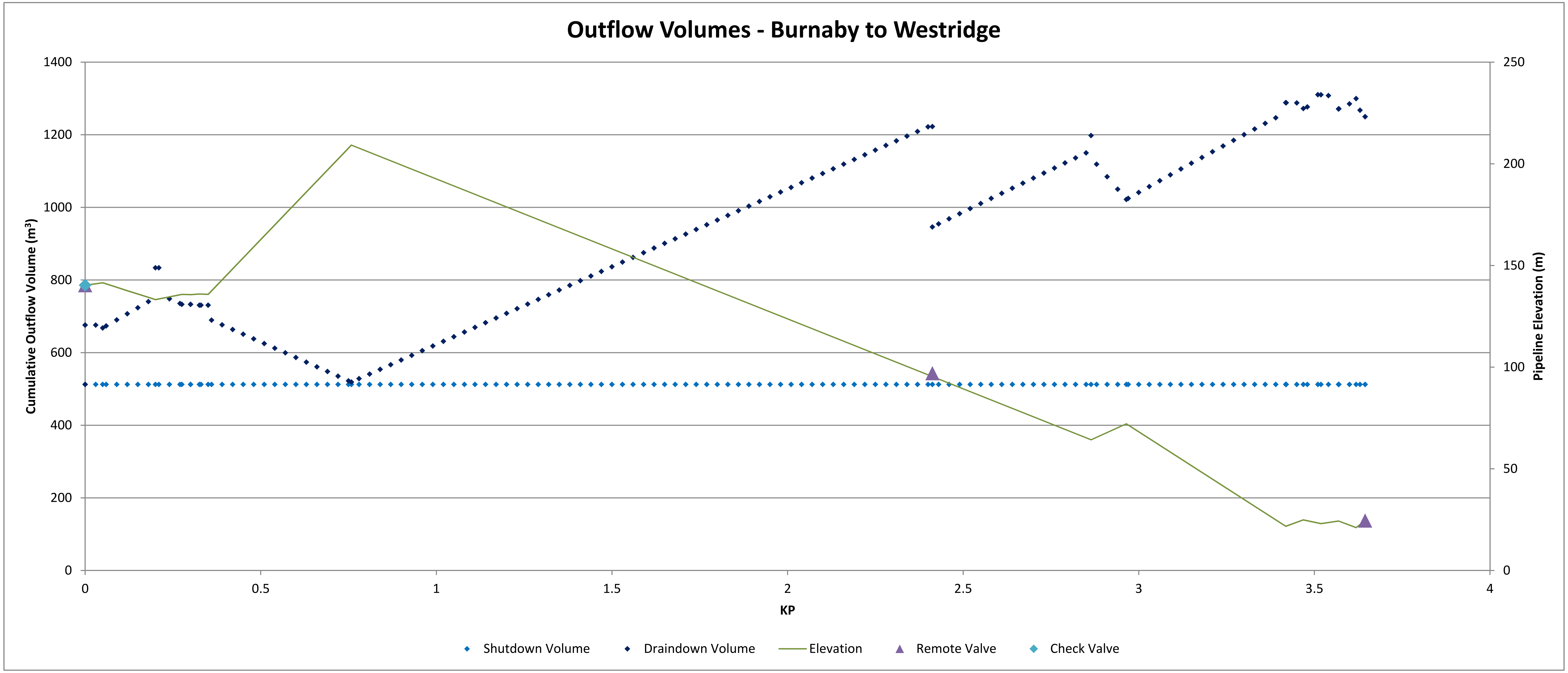

Outflow Volumes - Blackpool to Darfield
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
0
500
1000
1500
2000
2500
3000
3500
4000
-200
0
200
400
600
800
1000
735
740
745
750
755
760
765
770
775
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve


Outflow Volumes - Black Pines to Kamloops
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
3000
2500
2000
1500
1000
500
0
800
700
600
500
400
300
200
100
0
-100
-200
810
815
820
825
830
835
840
845
850
855
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

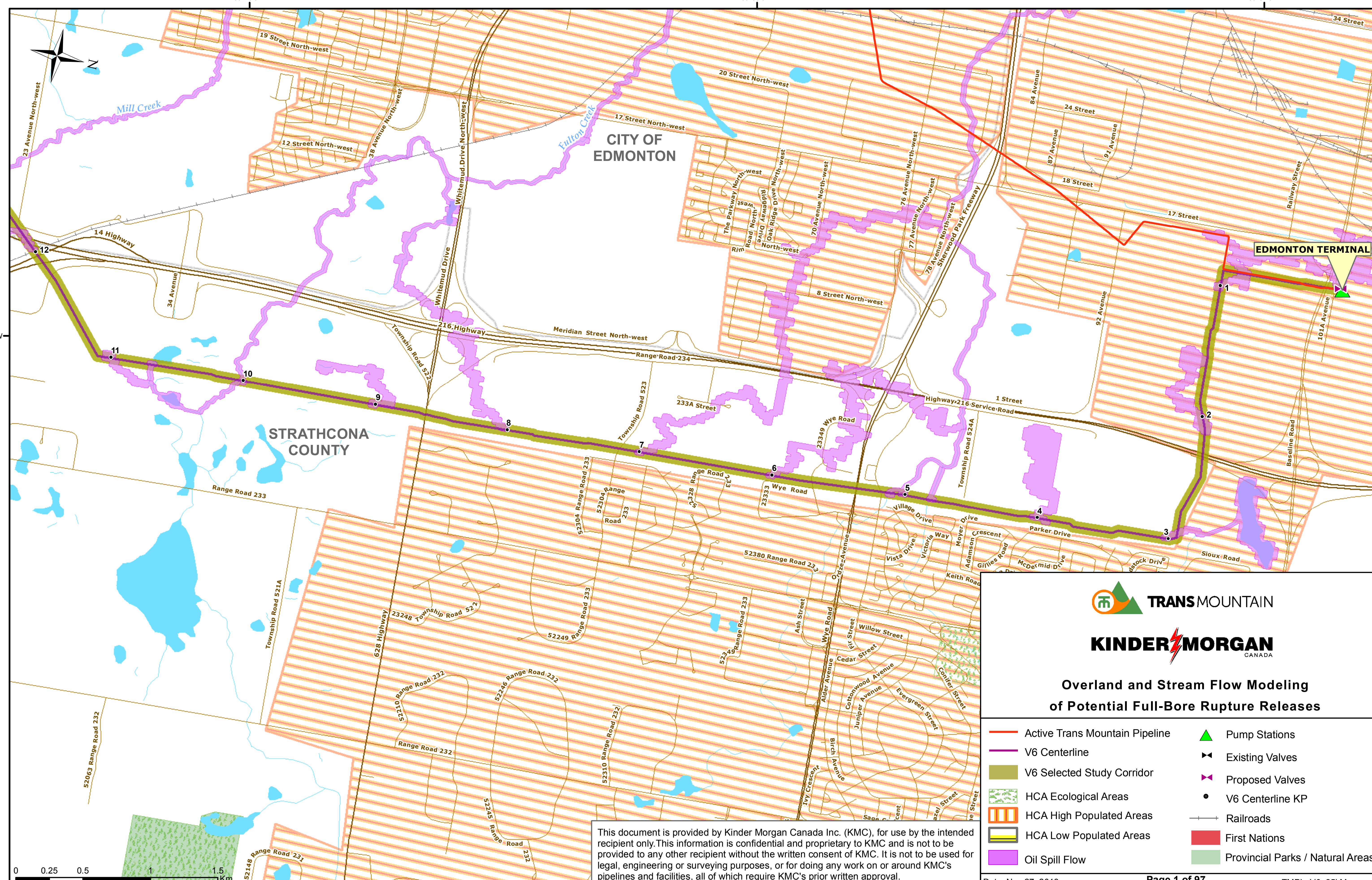

Outflow Volumes - Kamloops to Kingsvale
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1400
1200
1000
800
600
400
200
0
-200
840
860
880
900
920
940
960
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve


Outflow Volumes - Kingsvale to Sumas
Cumulative Outflow Volume (m³)
0
1000
2000
3000
4000
5000
6000
Pipeline Elevation (m)
0
200
400
600
800
1000
1200
1400
1600
KP
940
960
980
1000
1020
1040
1060
1080
1100
1120
1140
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve


Outflow Volumes - Sumas to Burnaby
Cumulative Outflow Volume (m³)
3500
3000
2500
2000
1500
1000
500
0
Pipeline Elevation (m)
250
200
150
100
50
0
1110
1120
1130
1140
1150
1160
1170
1180
1190
KP
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve


Outflow Volumes - Burnaby to Westridge
Cumulative Outflow Volume (m³)
Pipeline Elevation (m)
KP
0
200
400
600
800
1000
1200
1400
0.5
1
1.5
2
2.5
3
3.5
4
50
100
150
200
250
Shutdown Volume
Draindown Volume
Elevation
Remote Valve
Check Valve

Appendix C Overland and Stream Flow Modeling of Potential Full-Bore Rupture



TRANS MOUNTAIN

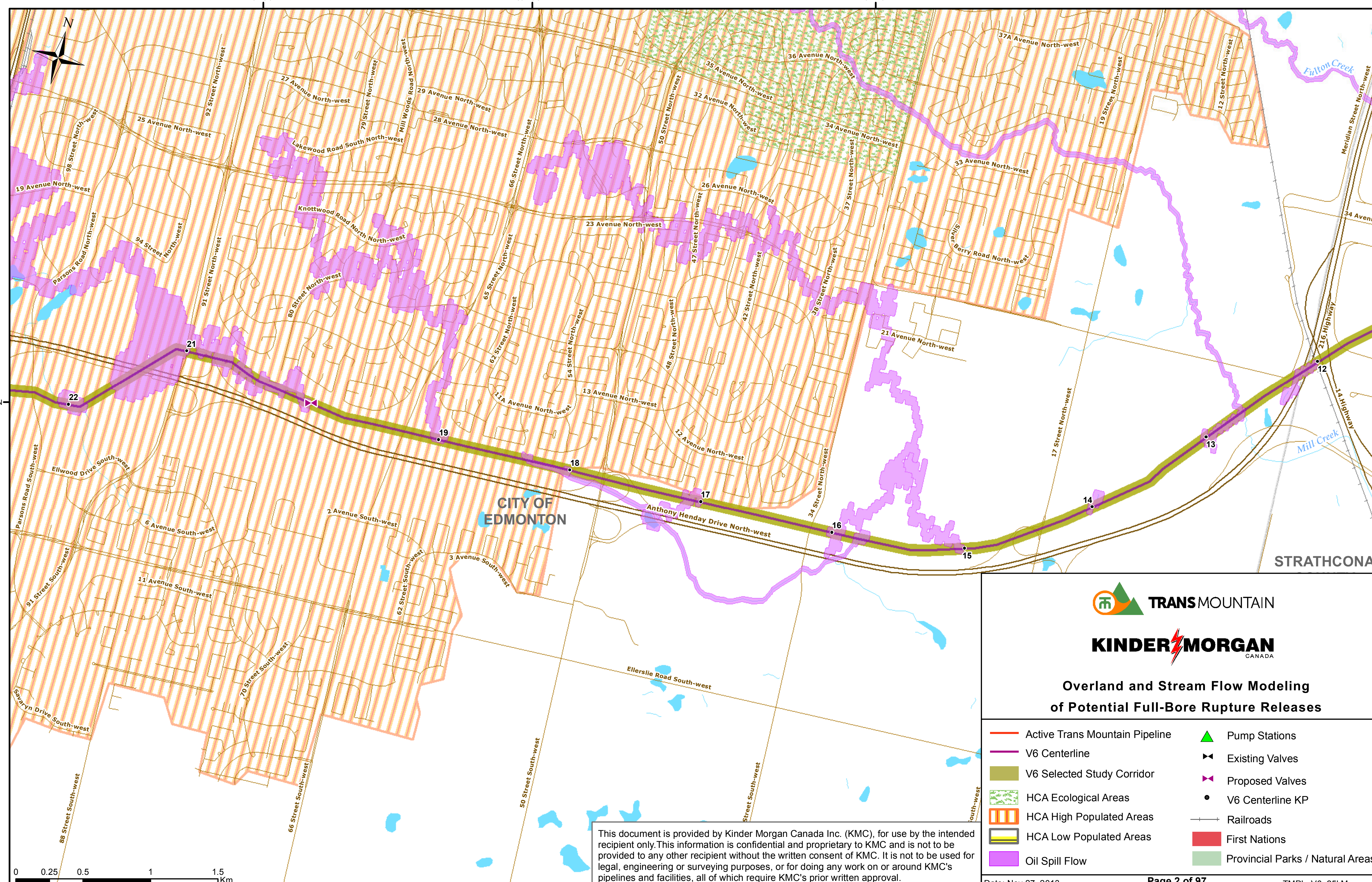
KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

- Active Trans Mountain Pipeline
- V6 Centerline
- V6 Selected Study Corridor
- HCA Ecological Areas
- HCA High Populated Areas
- HCA Low Populated Areas
- Oil Spill Flow
- Pump Stations
- Existing Valves
- Proposed Valves
- V6 Centerline KP
- Railroads
- First Nations
- Provincial Parks / Natural Areas

Date: Nov 27, 2013

TMPL_V6_25kMaps.mxd



TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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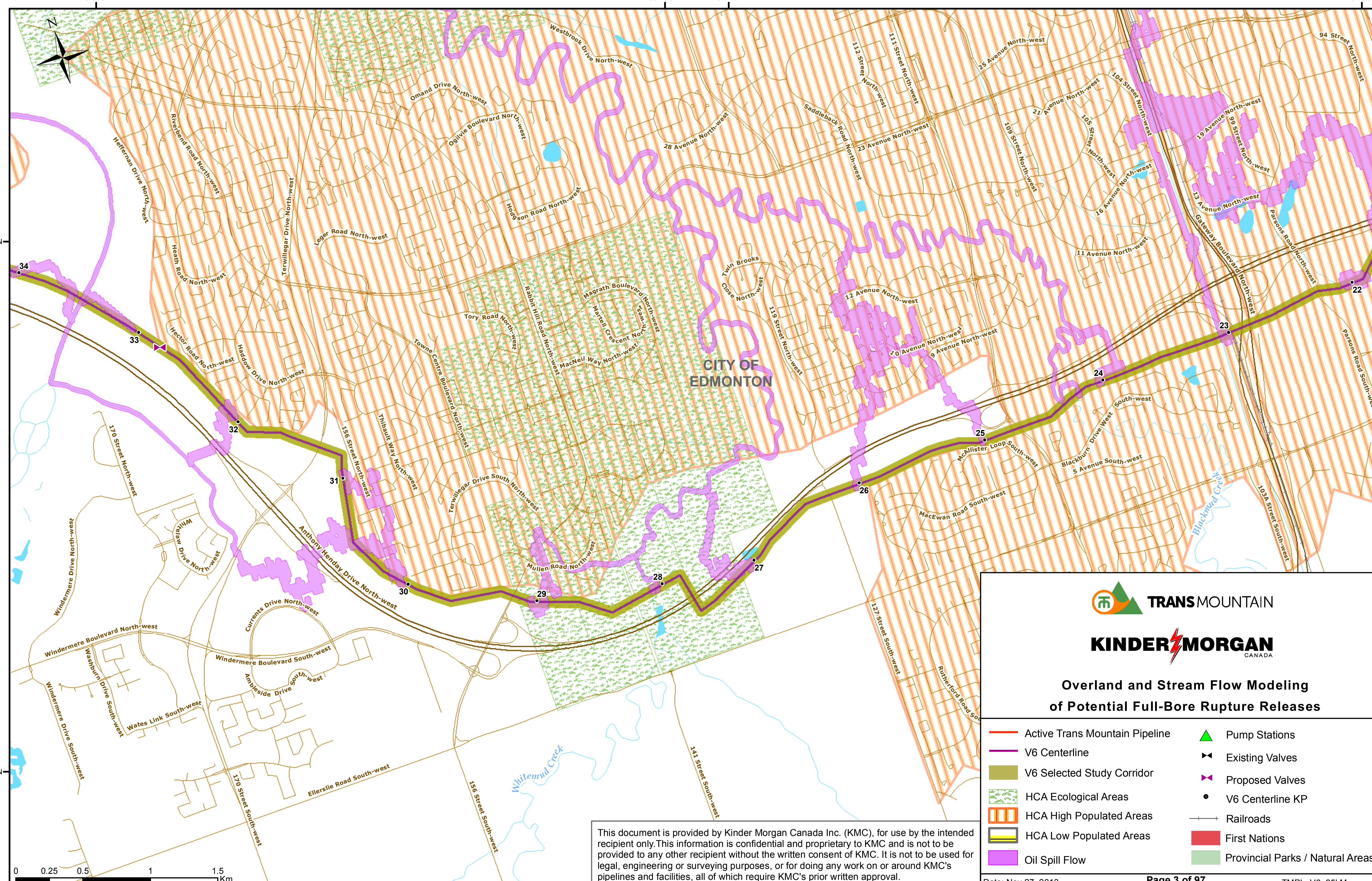

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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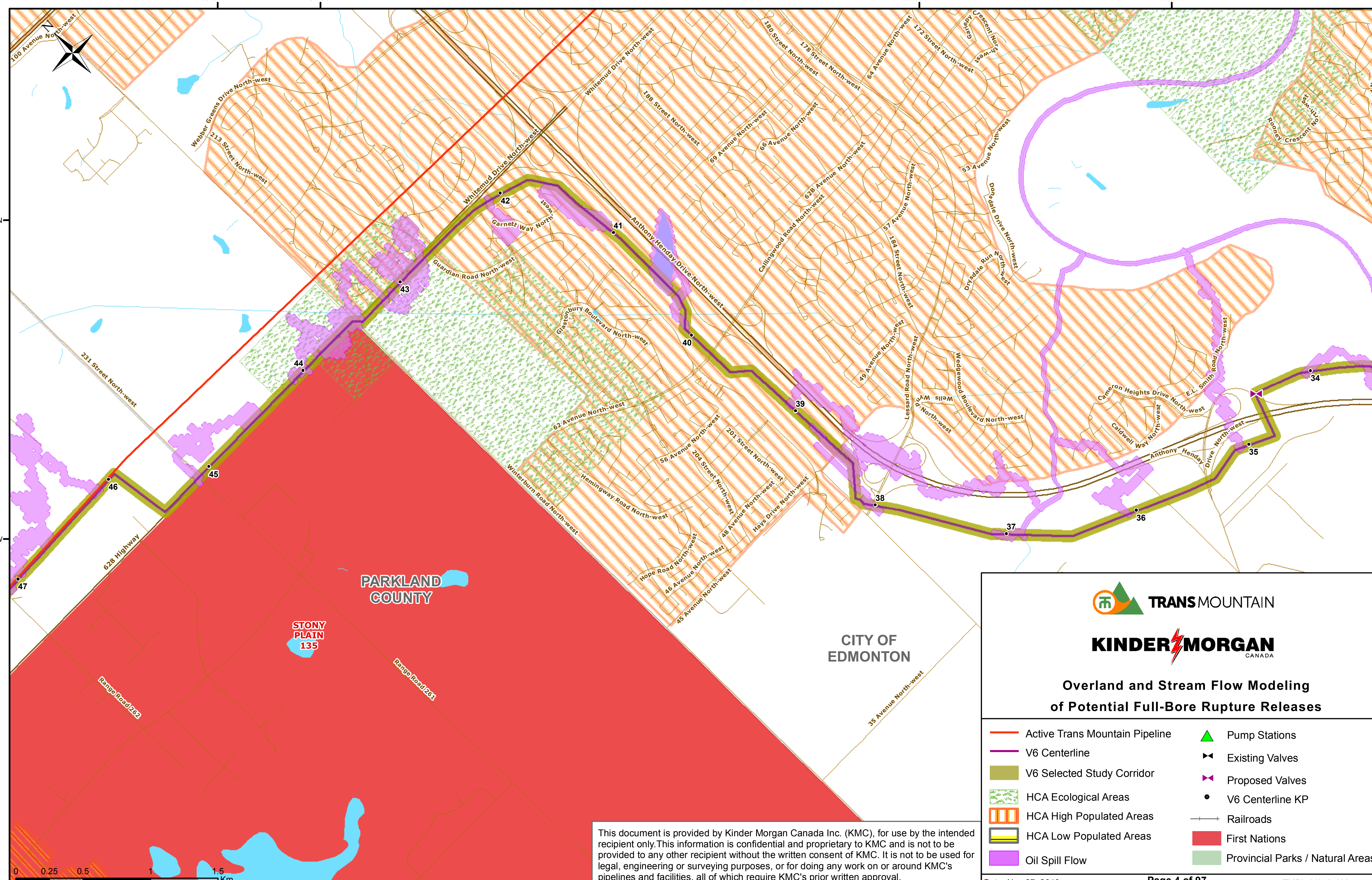

TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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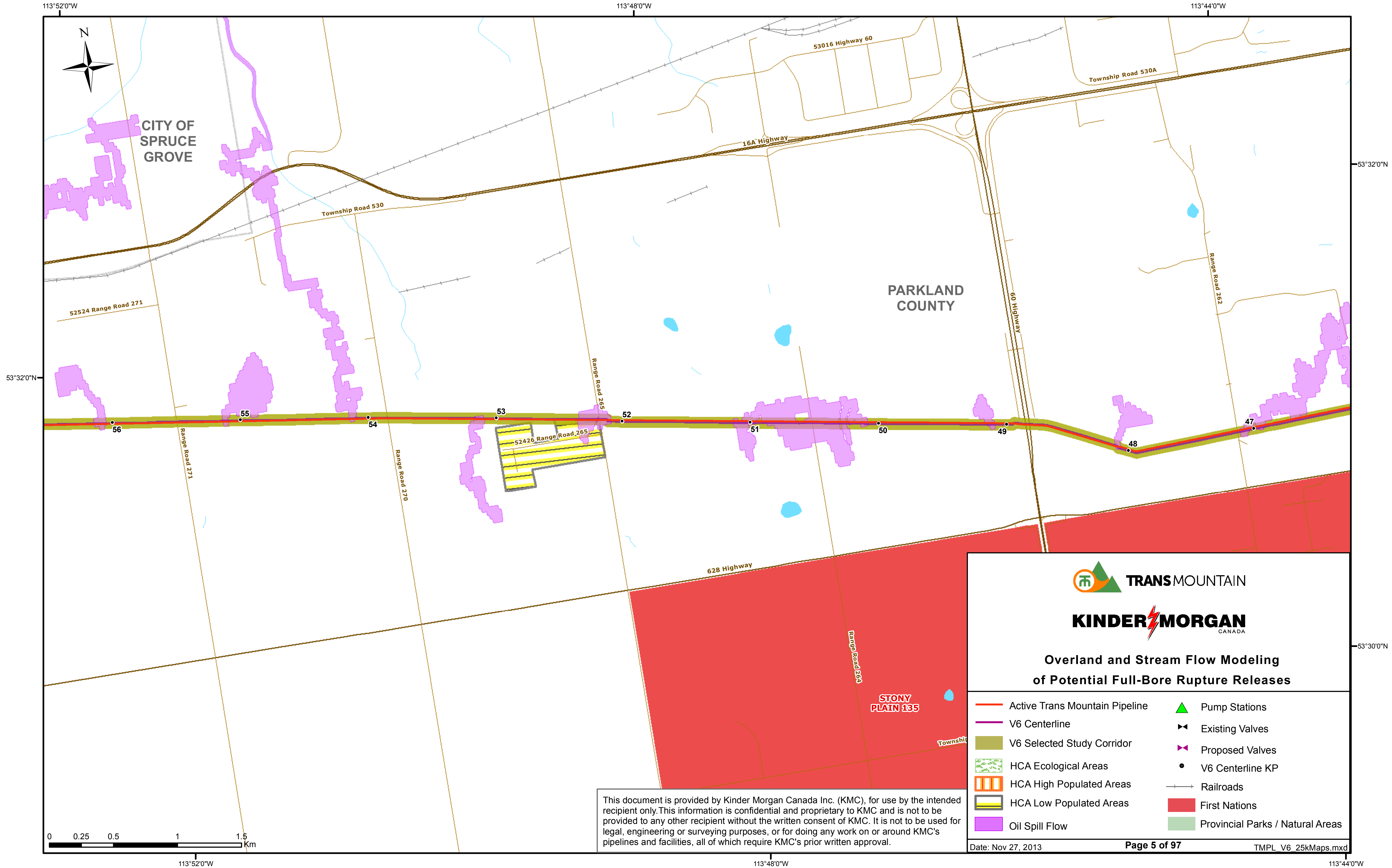
- Railroads
- First Nations
- Provincial Parks / Natural Areas

0 0.25 0.5 1 1.5 Km



TRANSMOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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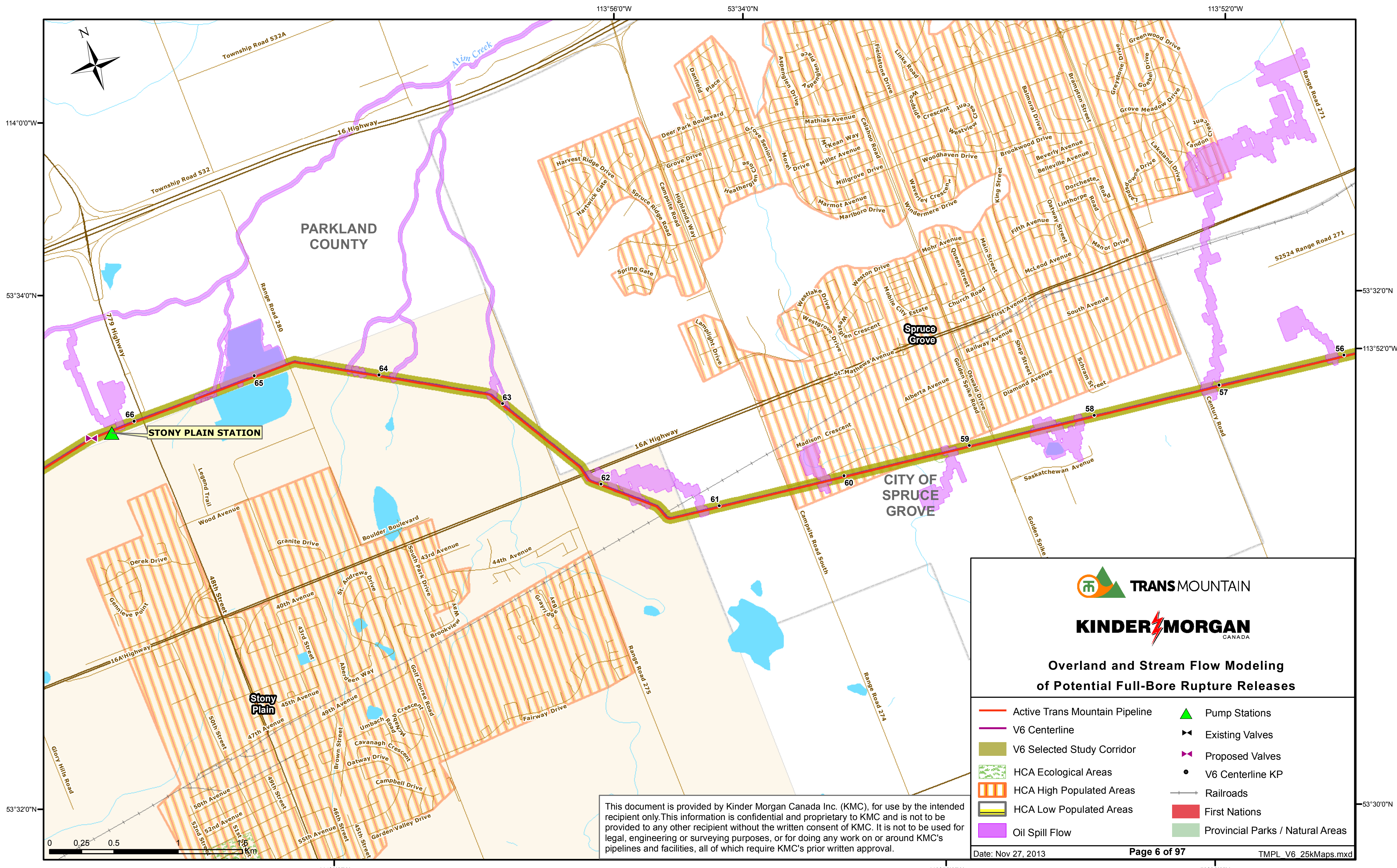
Date: Nov 27, 2013

TMPL_V6_25kMaps.mxd



113°56'0"W
53°34'0"N
113°52'0"W
114°0'0"W
53°32'0"N
53°30'0"N
N
PARKLAND COUNTY
CITY OF SPRUCE GROVE
Spruce Grove
Stony Plain
STONY PLAIN STATION
Atim Creek
16 Highway
16A Highway
779 Highway
Township Road 532A
Township Road 532
Range Road 280
Range Road 275
Range Road 274
Range Road 271
52524 Range Road 271
Century Road
Golden Spike Road
Campsite Road South
Glory Hills Road
48th Street
Saskatchewan Avenue
56
57
58
59
60
61
62
63
64
65
66
TRANS MOUNTAIN
KINDER MORGAN CANADA
Overland and Stream Flow Modeling
of Potential Full-Bore Rupture Releases
Active Trans Mountain Pipeline
V6 Centerline
V6 Selected Study Corridor
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Pump Stations
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0 0.25 0.5 1 1.5 Km
Date: Nov 27, 2013
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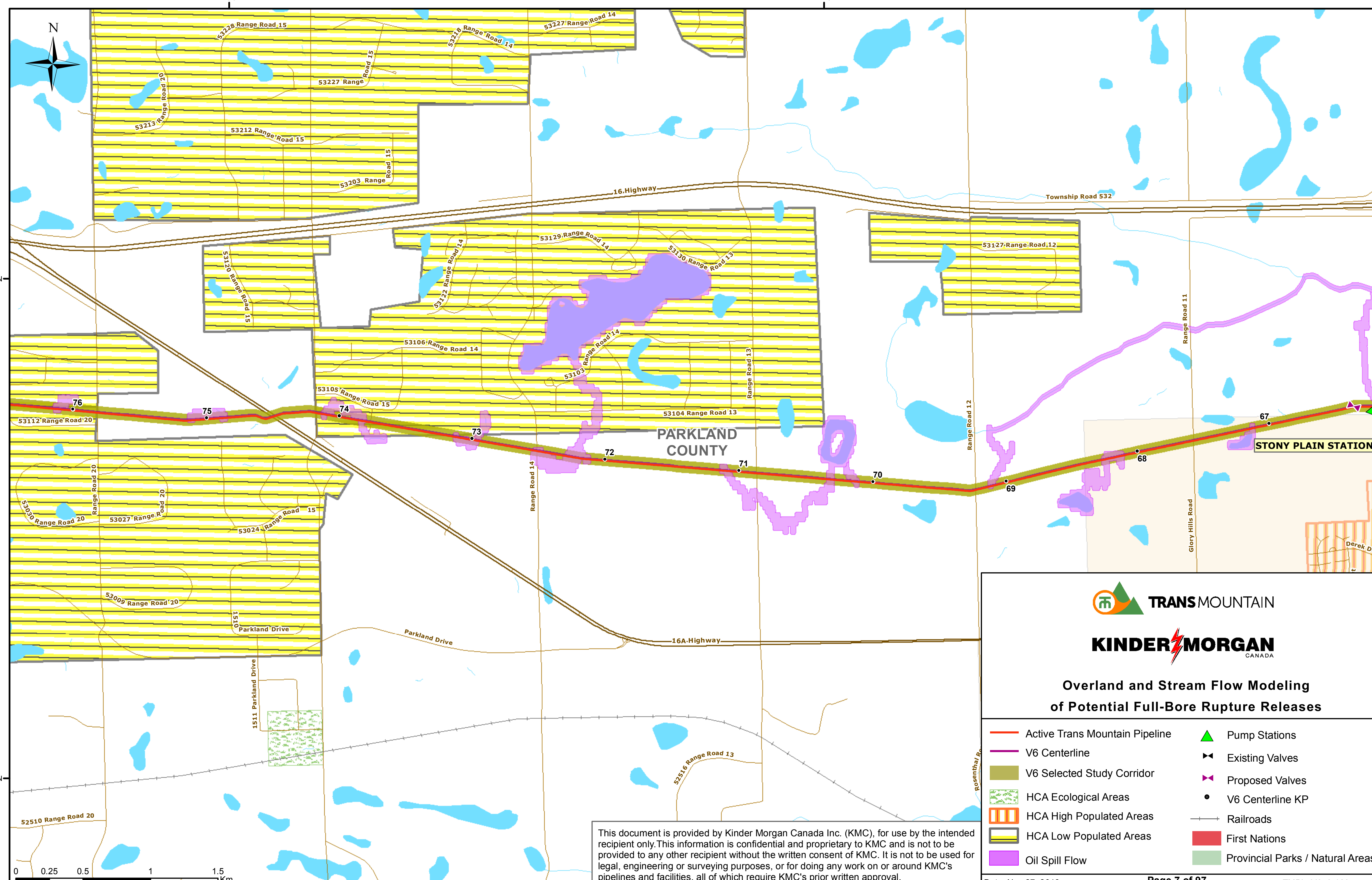
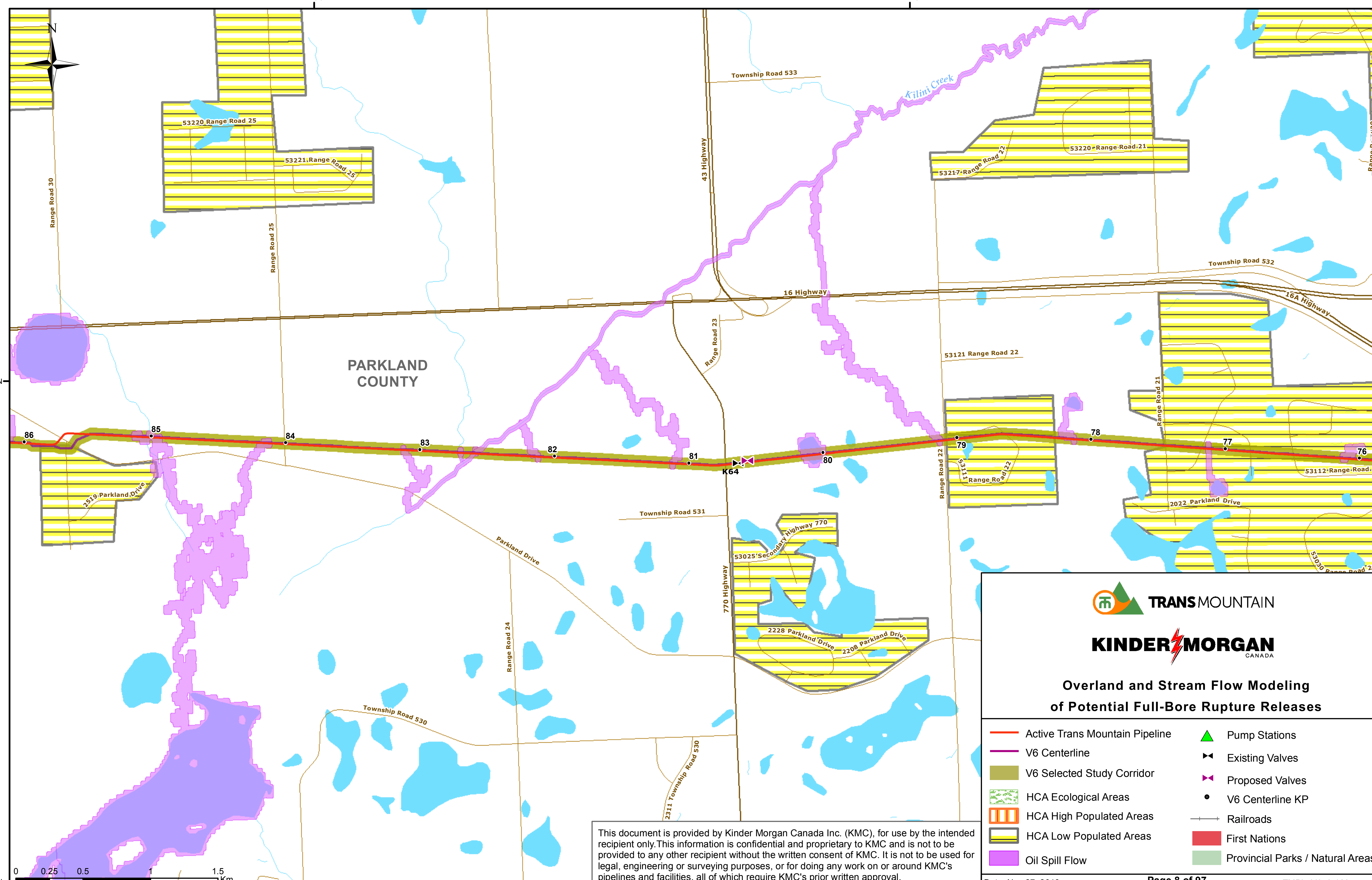
TMPL_V6_25kMaps.mxd



Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

Date: Nov 27, 2013

TMPL_V6_25kMaps.mxd



TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

- Active Trans Mountain Pipeline
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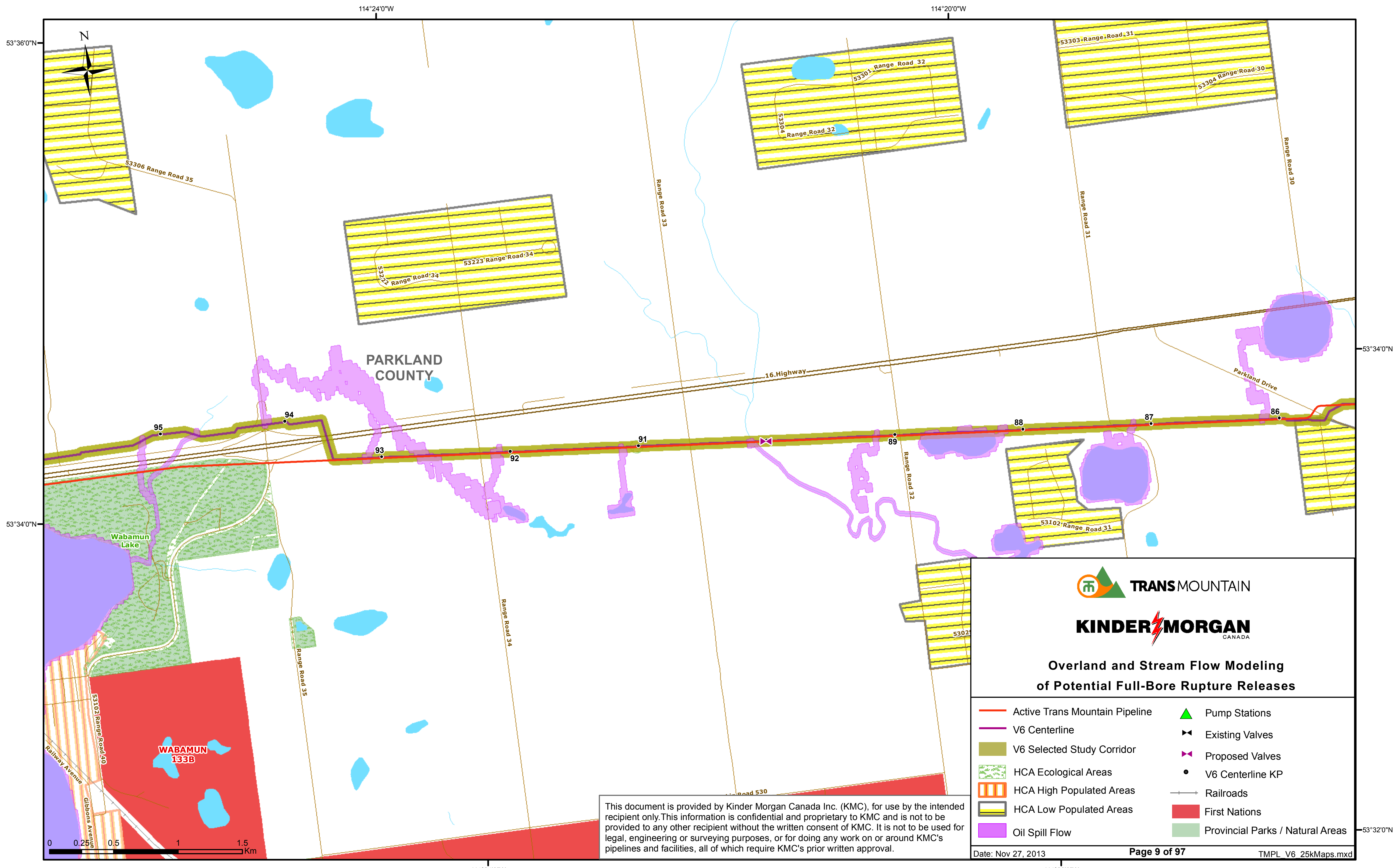
TMPL_V6_25kMaps.mxd



114°24'0"W
114°20'0"W
53°36'0"N
53°34'0"N
53°32'0"N
N
PARKLAND COUNTY
16 Highway
Parkland Drive
53306 Range Road 35
53223 Range Road 34
53222 Range Road 34
53301 Range Road 32
53304 Range Road 32
53303 Range Road 31
53304 Range Road 30
53102 Range Road 31
53102 Range Road 40
Range Road 33
Range Road 31
Range Road 30
Range Road 32
Range Road 34
Range Road 35
Railway Avenue
Gibbons Avenue
Wabamun Lake
WABAMUN 133B
95
94
93
92
91
89
88
87
86
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
KINDER MORGAN CANADA
Overland and Stream Flow Modeling
of Potential Full-Bore Rupture Releases
Active Trans Mountain Pipeline
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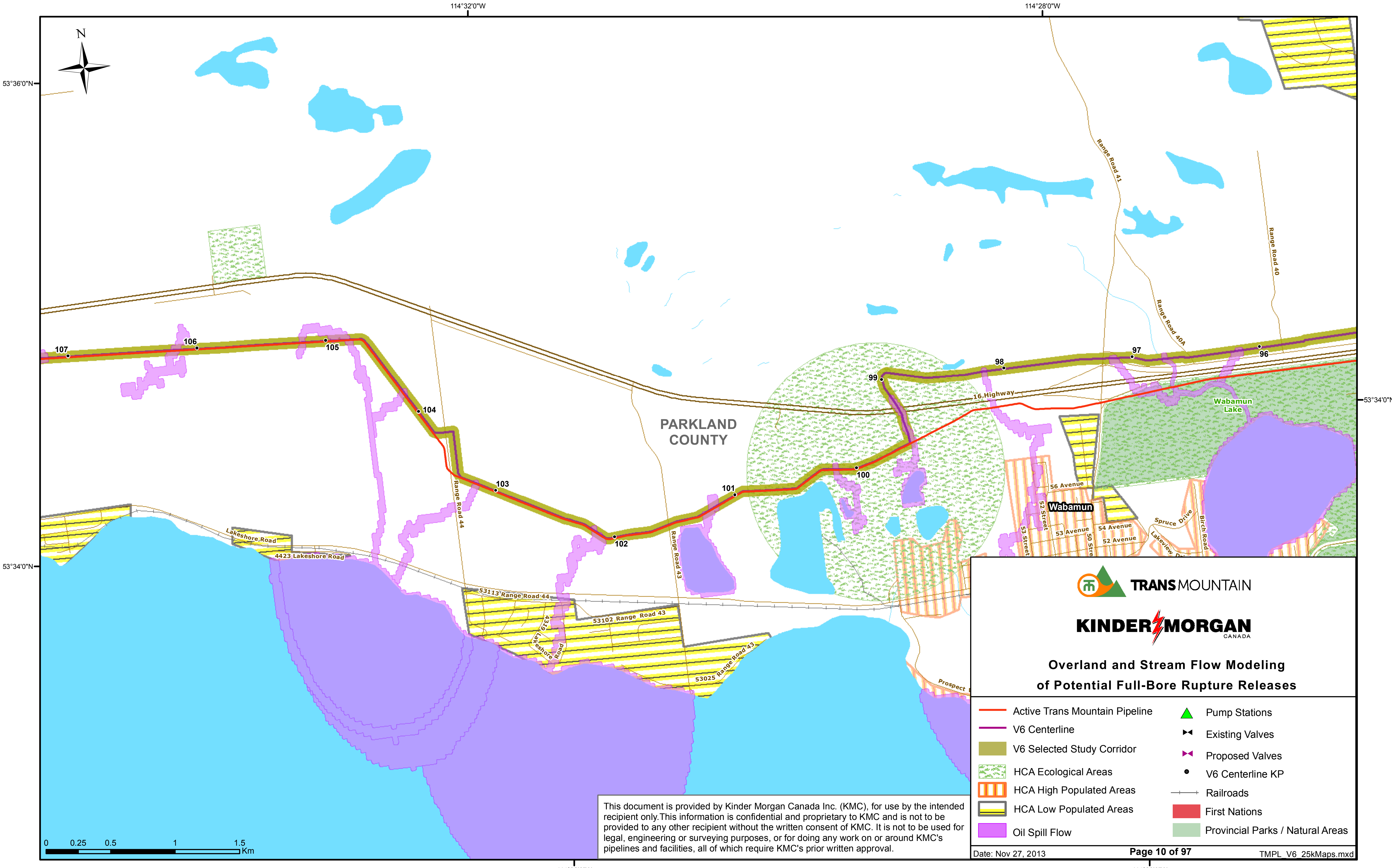
Date: Nov 27, 2013
Page 9 of 97
TMPL_V6_25kMaps.mxd



114°32'0"W
114°28'0"W
53°36'0"N
53°34'0"N
N
107
106
105
104
103
102
101
100
99
98
97
96
PARKLAND COUNTY
16 Highway
Range Road 41
Range Road 40A
Range Road 40
Range Road 44
Range Road 43
Lakeshore Road
4423 Lakeshore Road
53113 Range Road 44
53102 Range Road 43
53025 Range Road 43
Wabamun
Wabamun Lake
56 Avenue
54 Avenue
53 Avenue
52 Avenue
52 Street
53 Street
Spruce Drive
Birch Road
Prospect
TRANS MOUNTAIN
KINDER MORGAN CANADA
Overland and Stream Flow Modeling
of Potential Full-Bore Rupture Releases
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0 0.25 0.5 1 1.5 Km
Date: Nov 27, 2013
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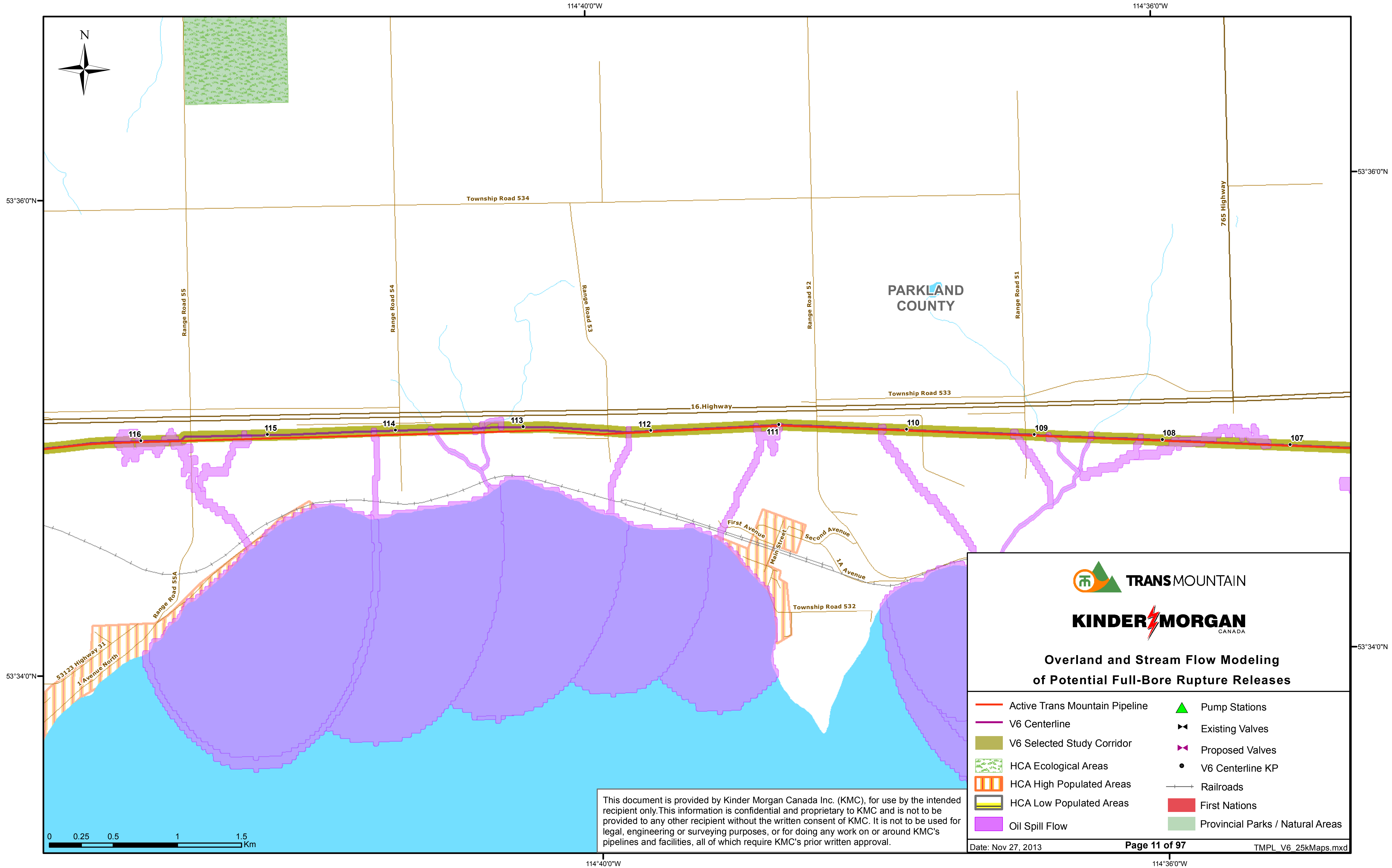
TMPL_V6_25kMaps.mxd



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114°36'0"W
53°36'0"N
53°34'0"N
N
PARKLAND COUNTY
Township Road 534
Township Road 533
Township Road 532
16.Highway
765 Highway
Range Road 55
Range Road 54
Range Road 53
Range Road 52
Range Road 51
Range Road 55A
53123 Highway 31
1 Avenue North
First Avenue
Second Avenue
Main Street
1A Avenue
116
115
114
113
112
111
110
109
108
107
0 0.25 0.5 1 1.5 Km
TRANSMOUNTAIN
KINDER MORGAN CANADA
Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases
Active Trans Mountain Pipeline
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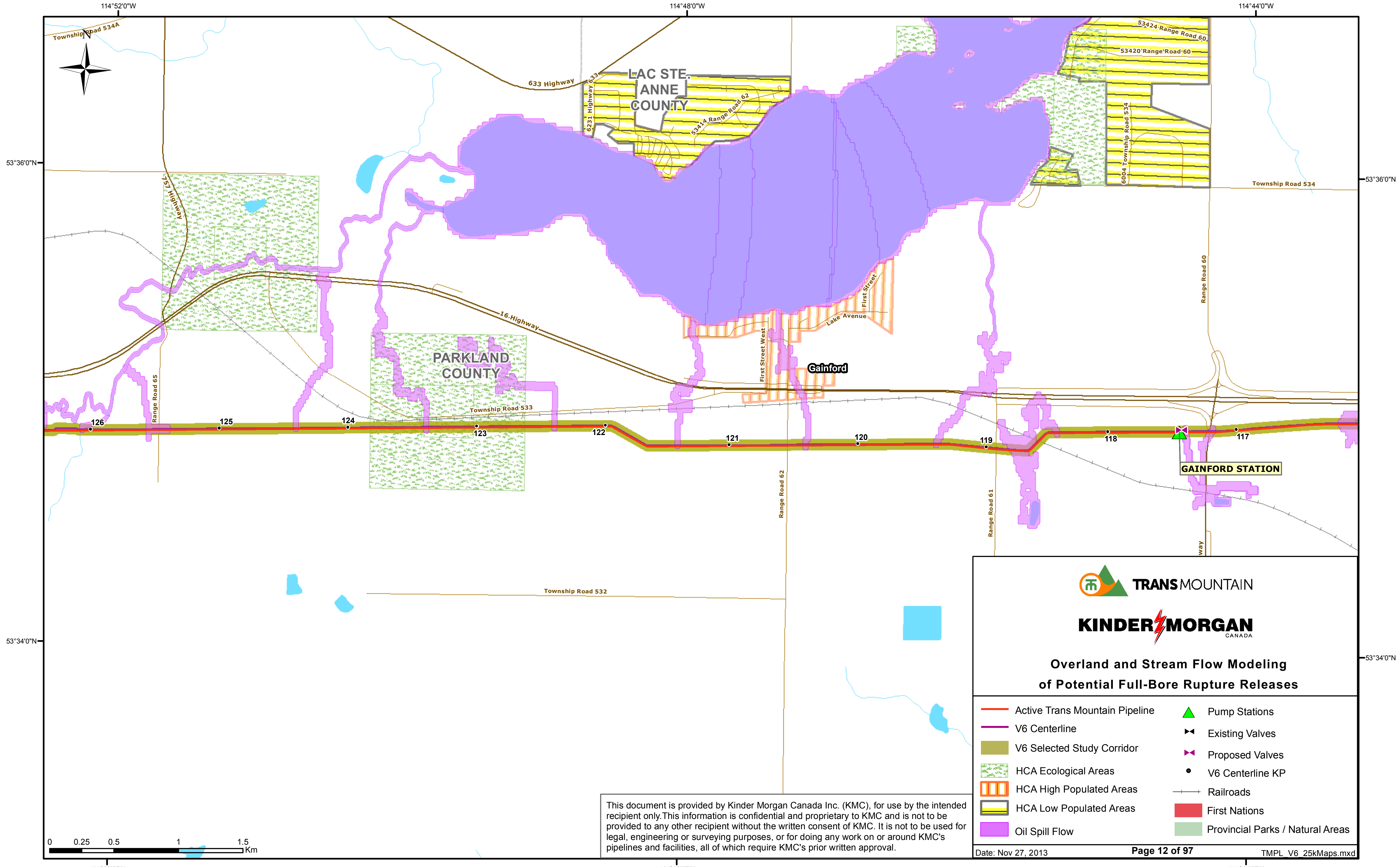
Date: Nov 27, 2013
Page 11 of 97
TMPL_V6_25kMaps.mxd



114°52'0"W
114°48'0"W
114°44'0"W
53°36'0"N
53°34'0"N
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Township Road 534A
633 Highway
LAC STE. ANNE COUNTY
6231 Highway 633
53414 Range Road 62
53424 Range Road 60
53420 Range Road 60
6004 Township Road 534
Township Road 534
757 Highway
16 Highway
PARKLAND COUNTY
Township Road 533
Range Road 65
First Street
Lake Avenue
First Street West
Gainford
Range Road 60
Range Road 62
Range Road 61
GAINFORD STATION
126
125
124
123
122
121
120
119
118
117
Township Road 532
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
KINDER MORGAN CANADA
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Active Trans Mountain Pipeline
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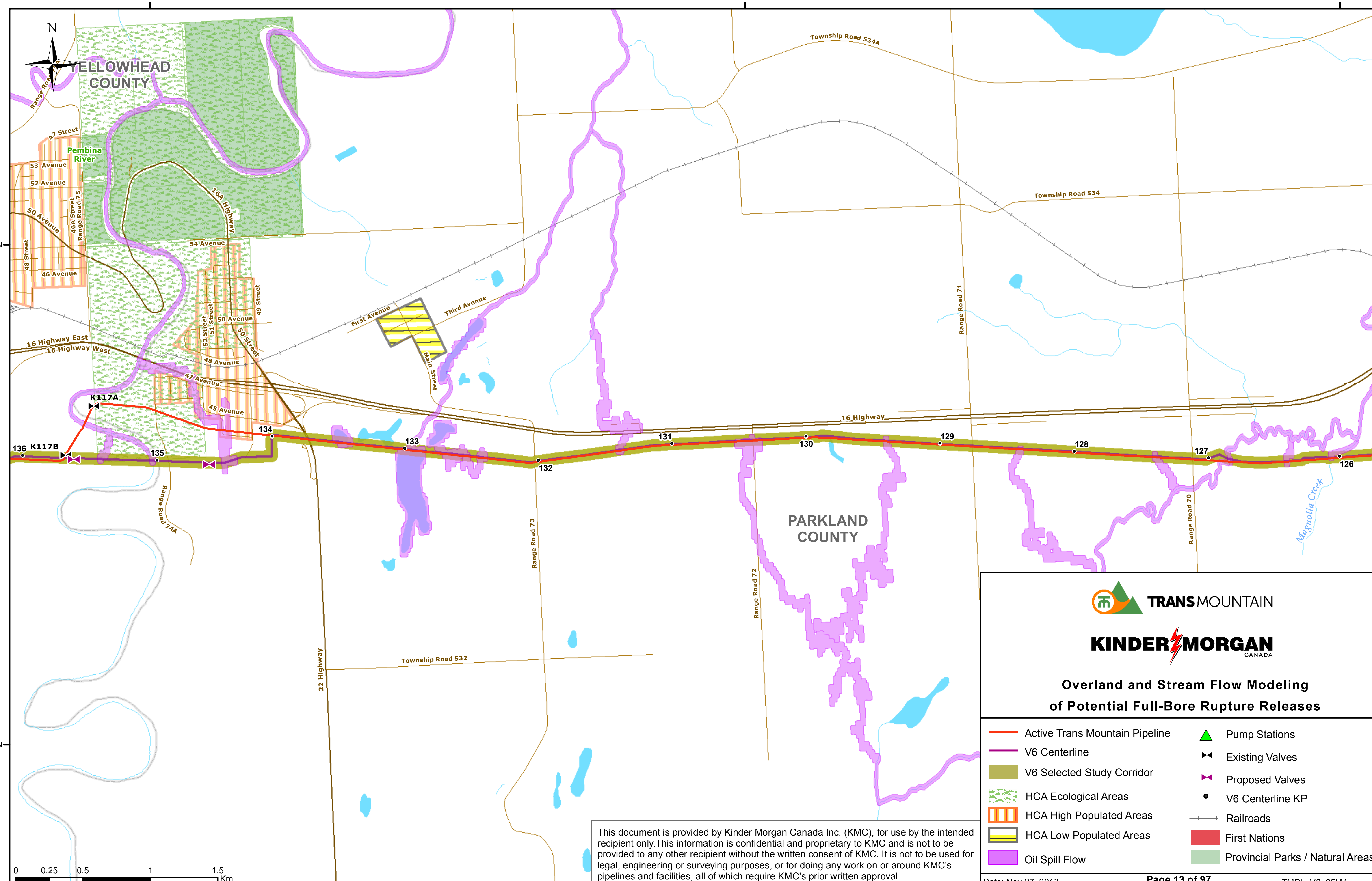
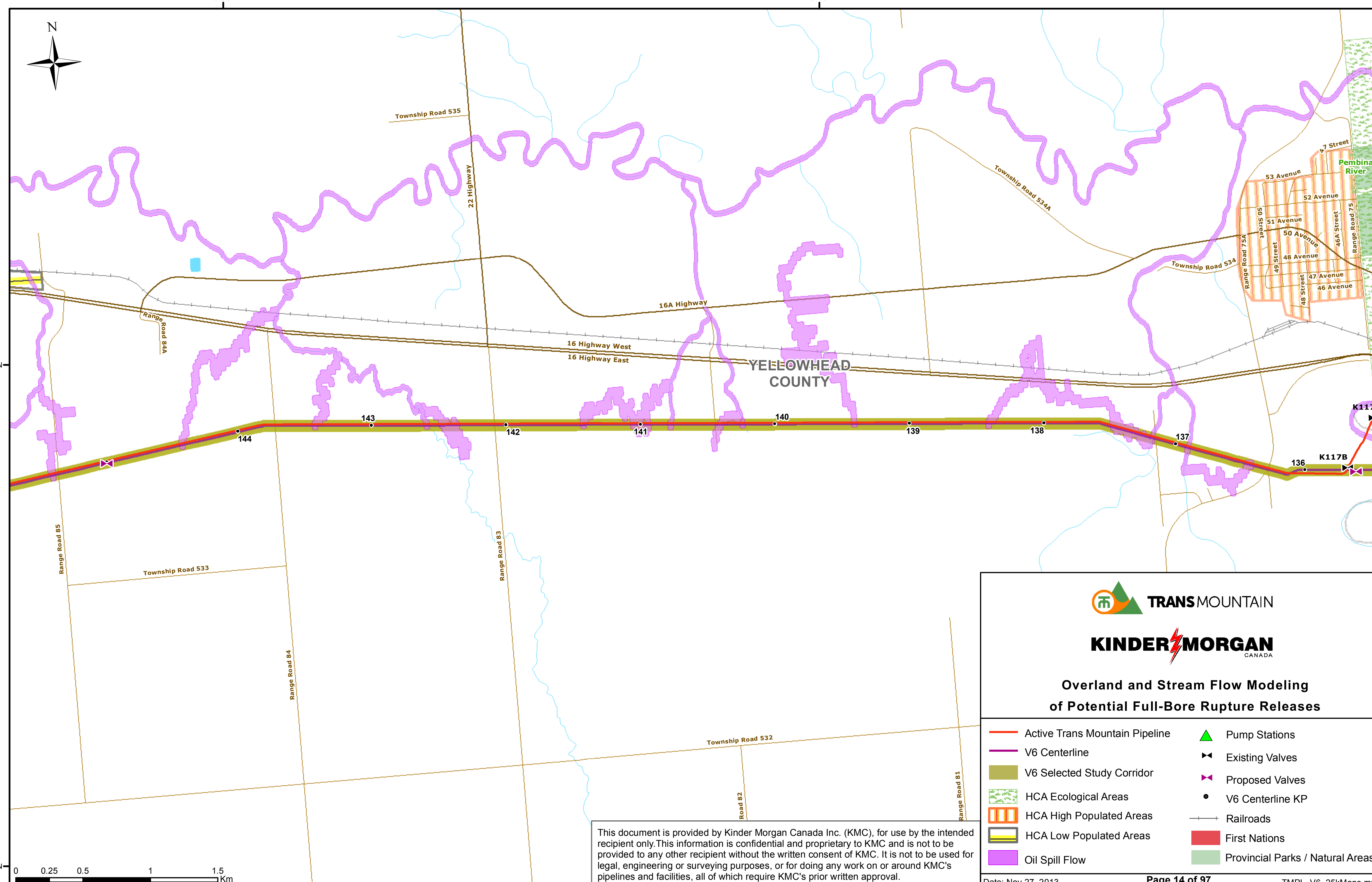
Date: Nov 27, 2013
Page 12 of 97
TMPL_V6_25kMaps.mxd



Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases



TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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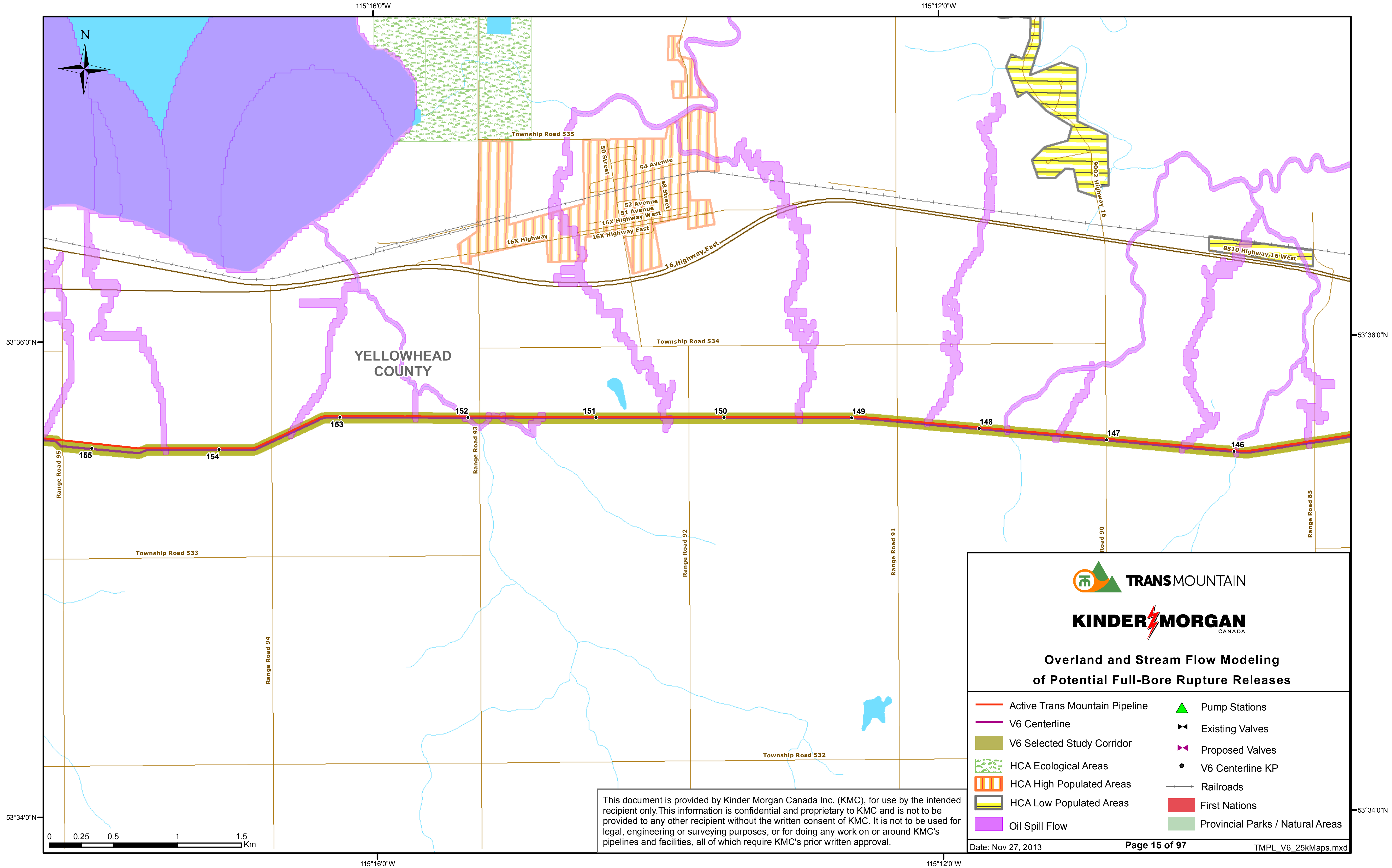

TRANS MOUNTAIN

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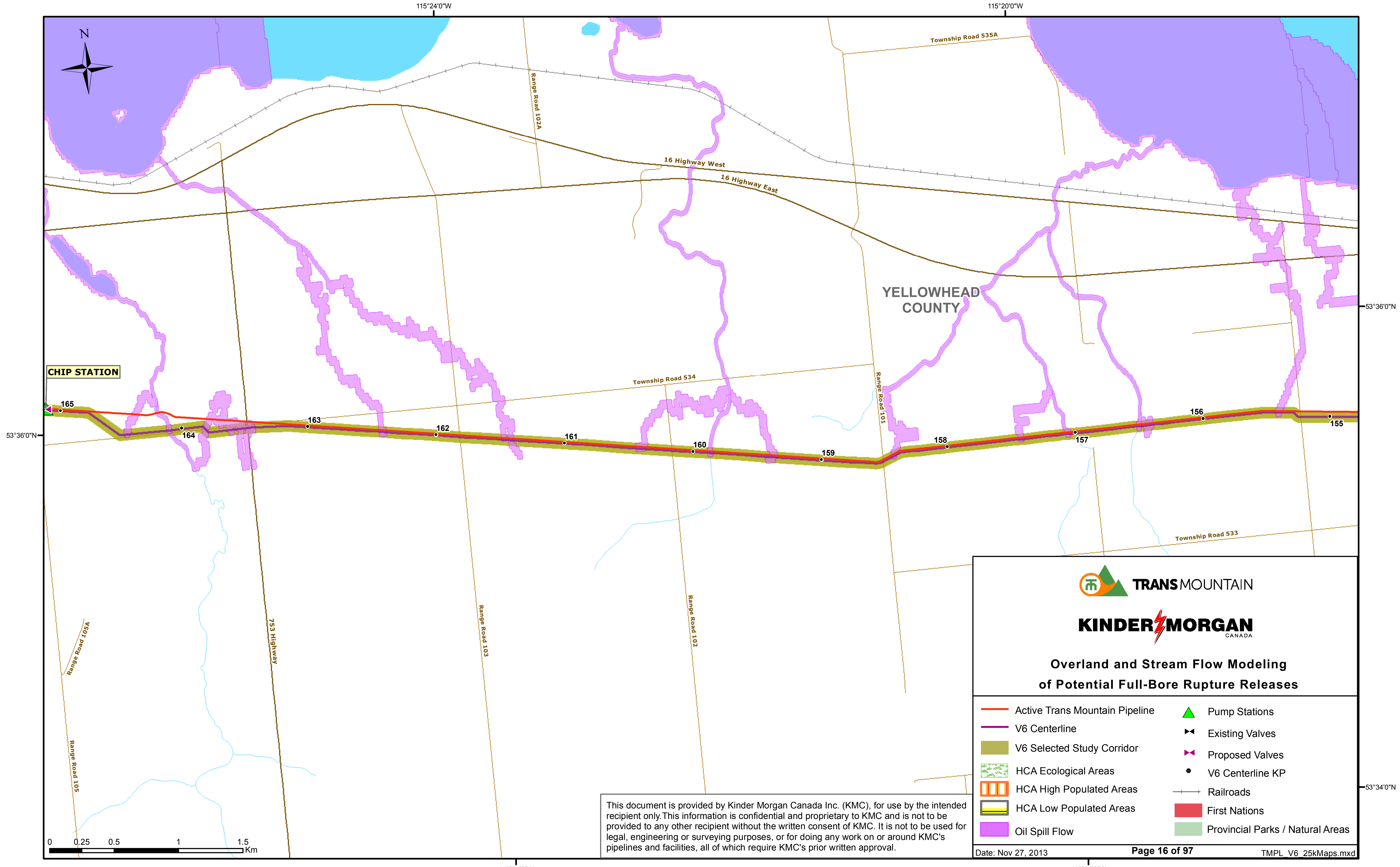
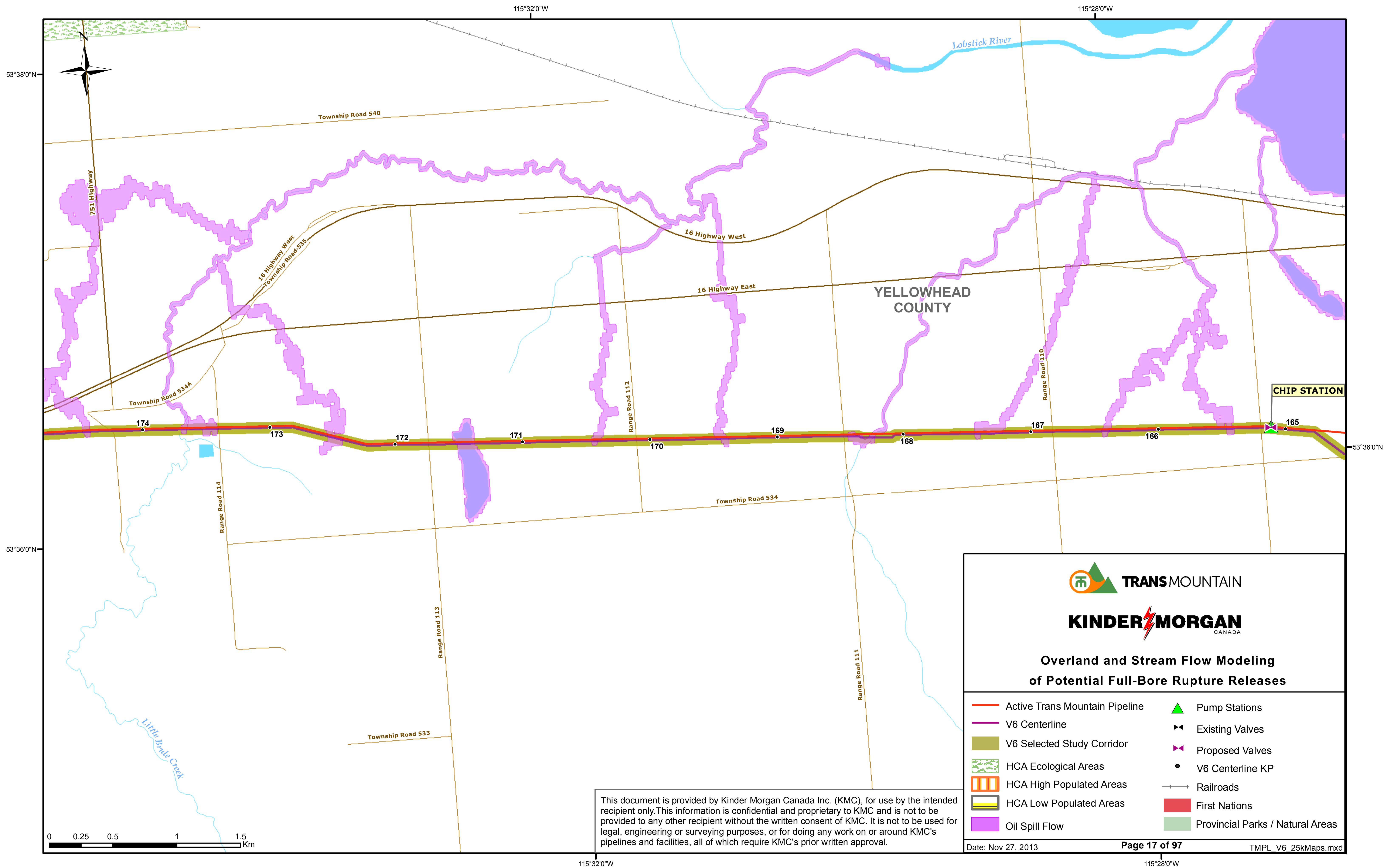


TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

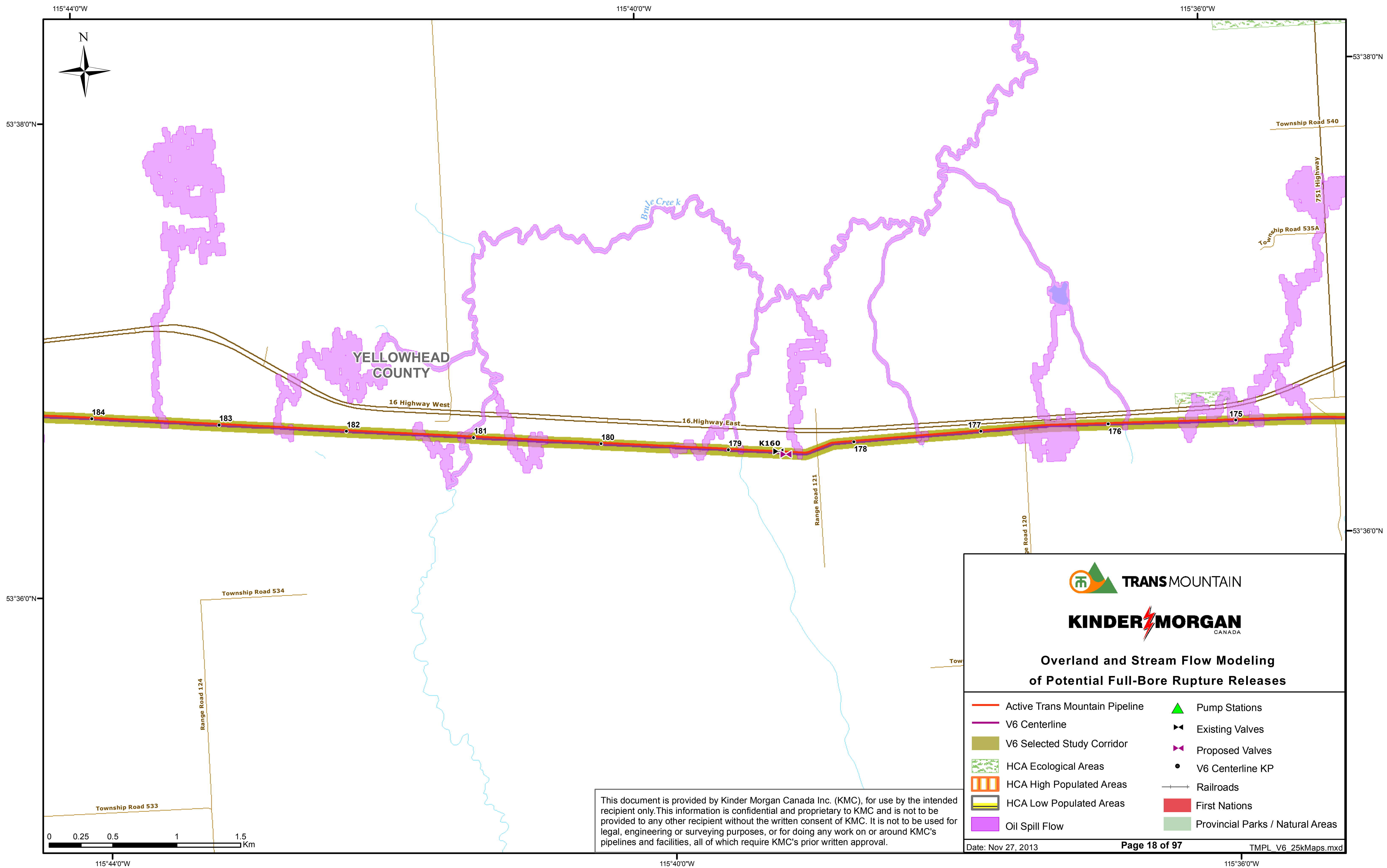
Legend	Legend
Active Trans Mountain Pipeline	Pump Stations
V6 Centerline	Existing Valves
V6 Selected Study Corridor	Proposed Valves
HCA Ecological Areas	V6 Centerline KP
HCA High Populated Areas	Railroads
HCA Low Populated Areas	First Nations
Oil Spill Flow	Provincial Parks / Natural Areas



TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases



TRANS MOUNTAIN

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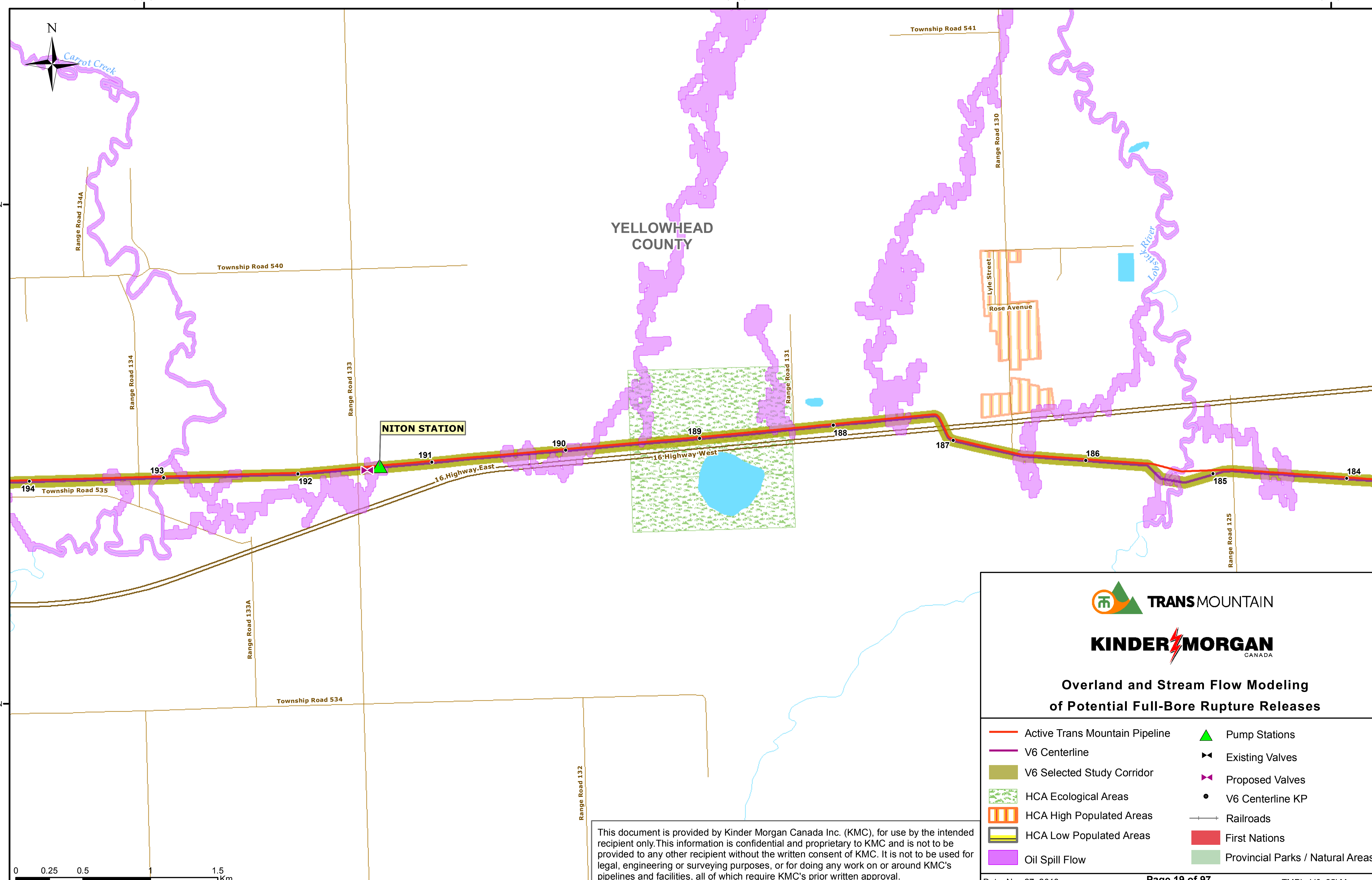
TMPL_V6_25kMaps.mxd



TRANS MOUNTAIN

KINDER MORGAN CANADA

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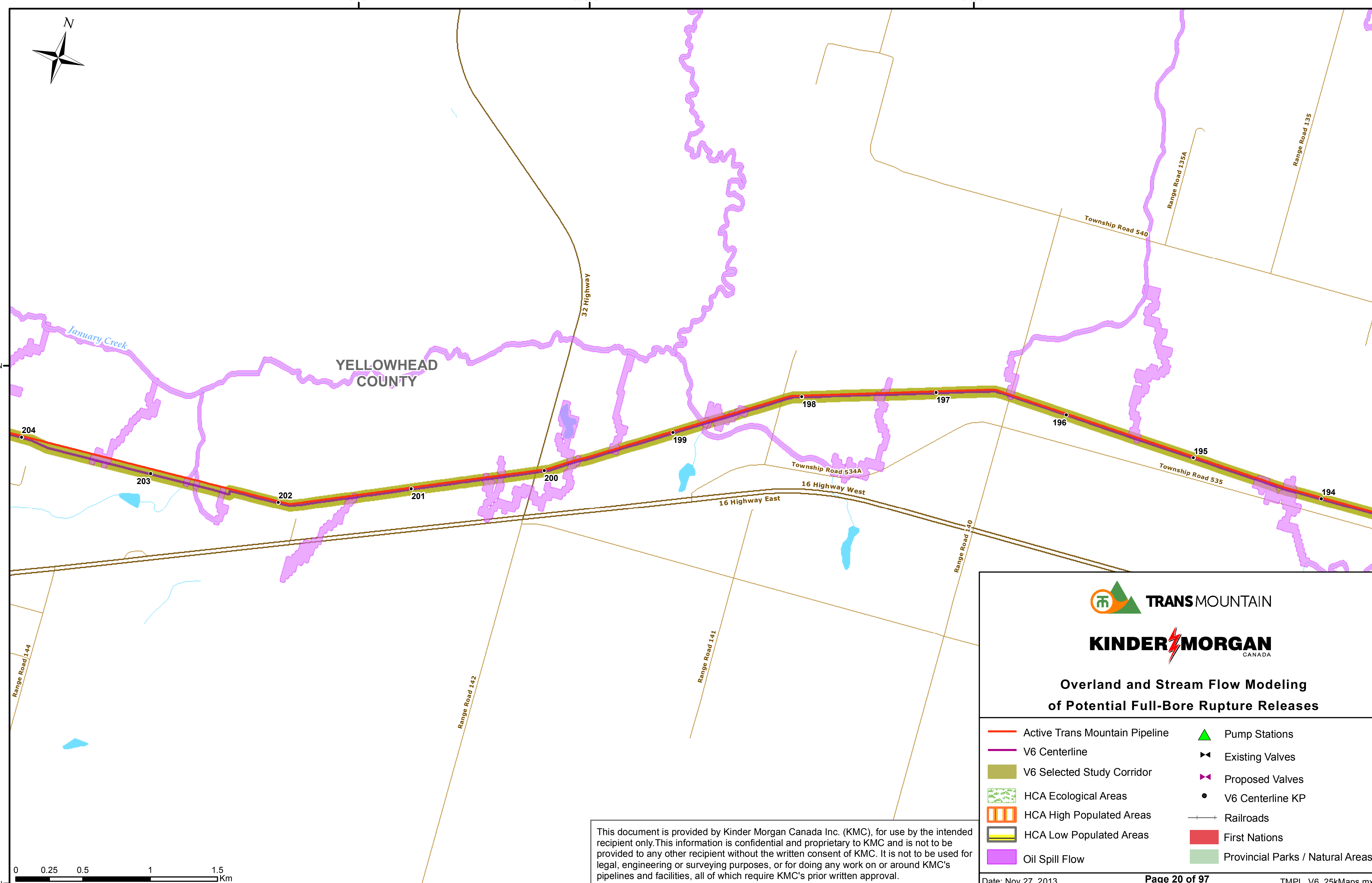
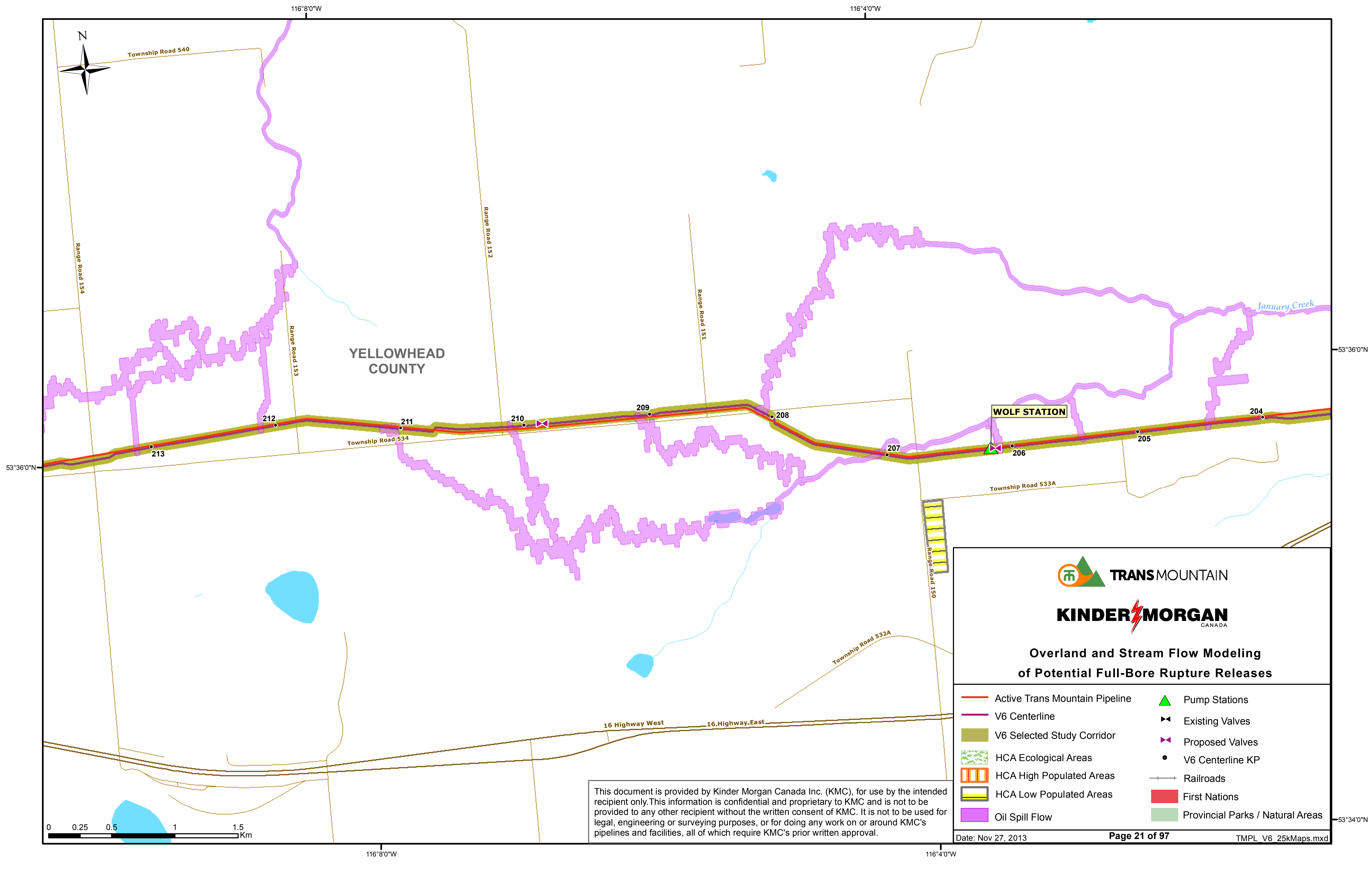


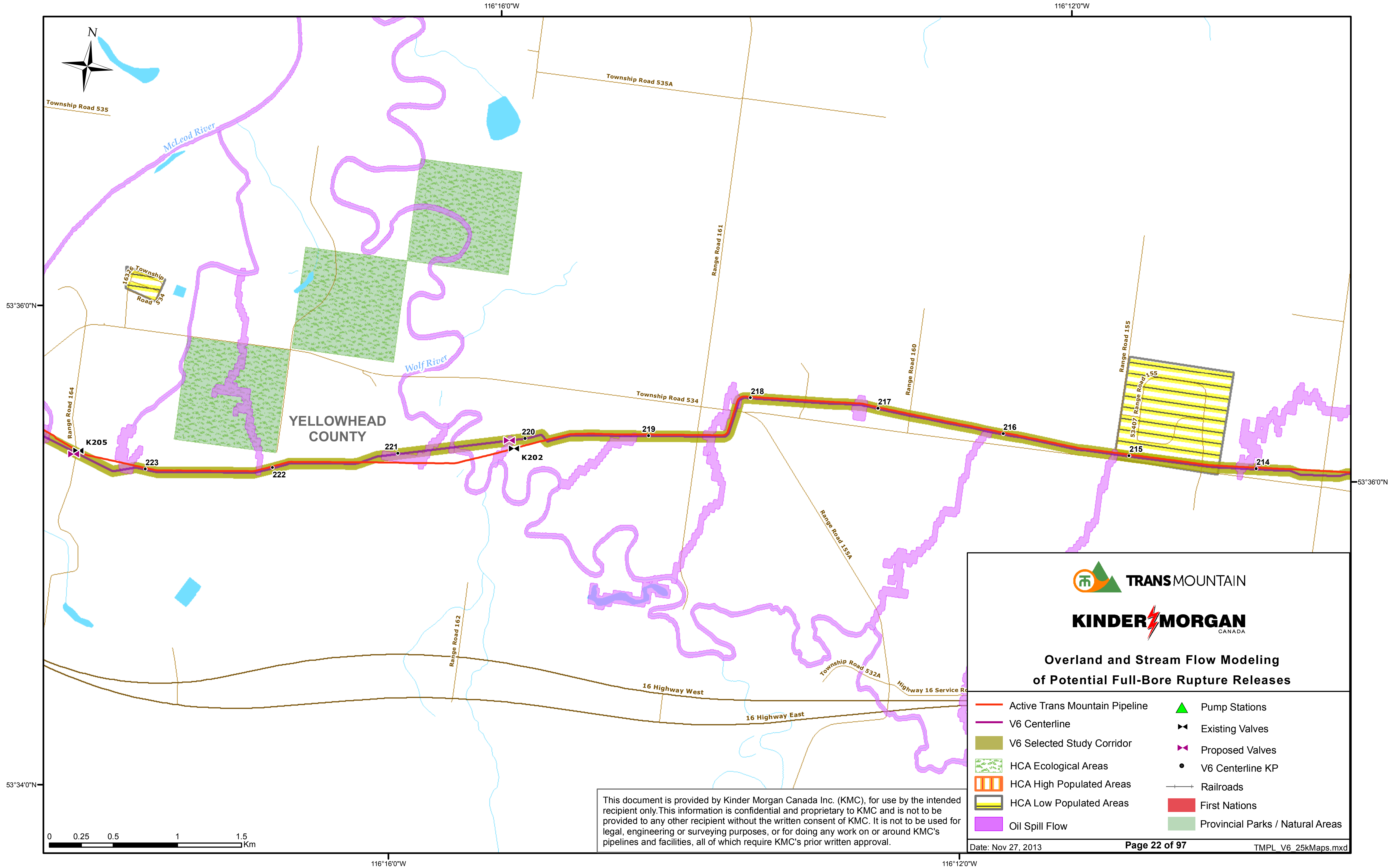
Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases



Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

Date: Nov 27, 2013

TMPL_V6_25kMaps.mxd



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Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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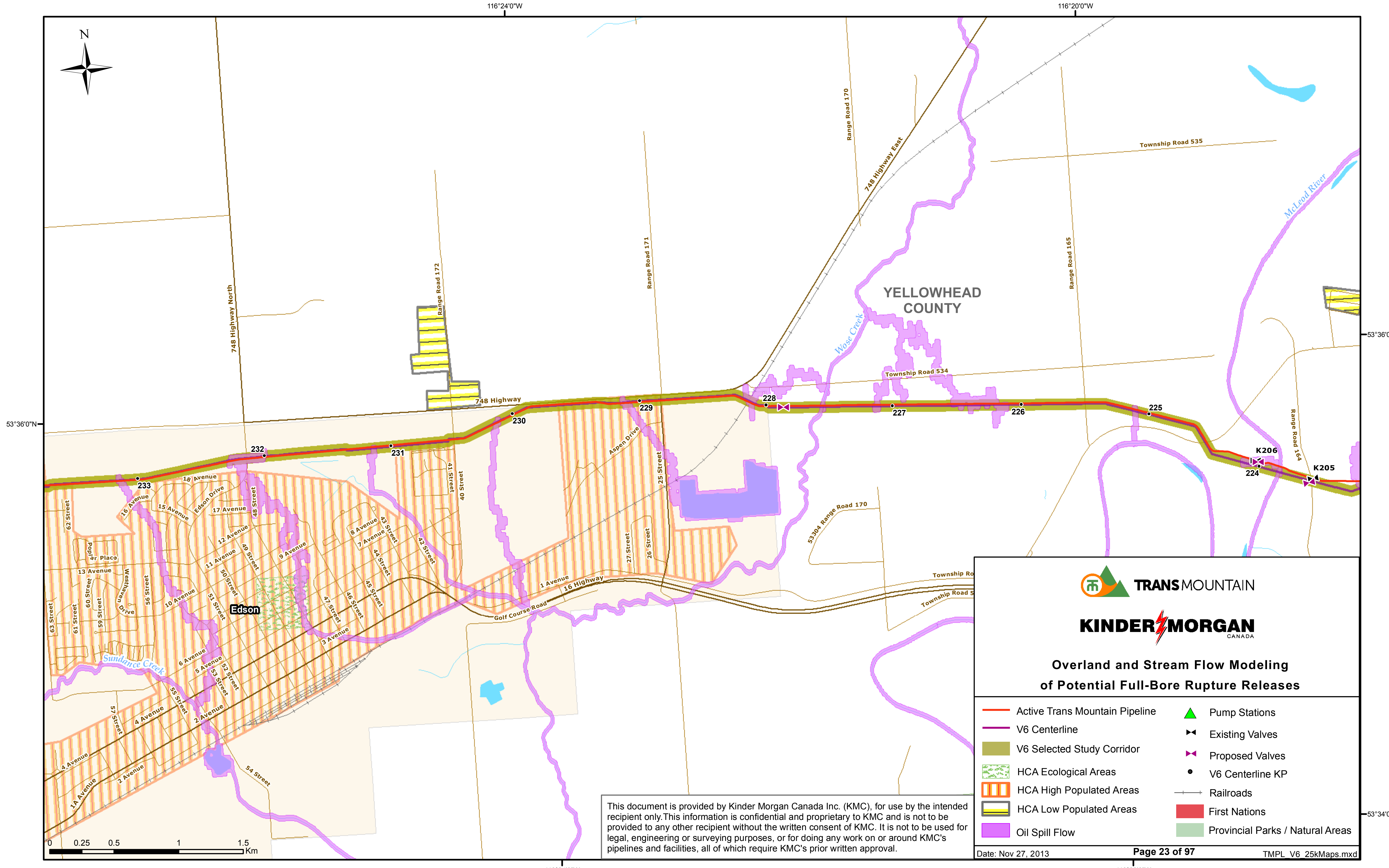
116°24'0"W
116°20'0"W
53°36'0"N
53°34'0"N
N
YELLOWHEAD COUNTY
Edson
748 Highway
748 Highway North
748 Highway East
16 Highway
Range Road 172
Range Road 171
Range Road 170
Range Road 165
Range Road 164
Township Road 535
Township Road 534
53304 Range Road 170
Golf Course Road
Aspen Drive
Wose Creek
McLeod River
Sundance Creek
233
232
231
230
229
228
227
226
225
224
K206
K205
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
KINDER MORGAN CANADA
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Proposed Valves
V6 Centerline KP
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Date: Nov 27, 2013
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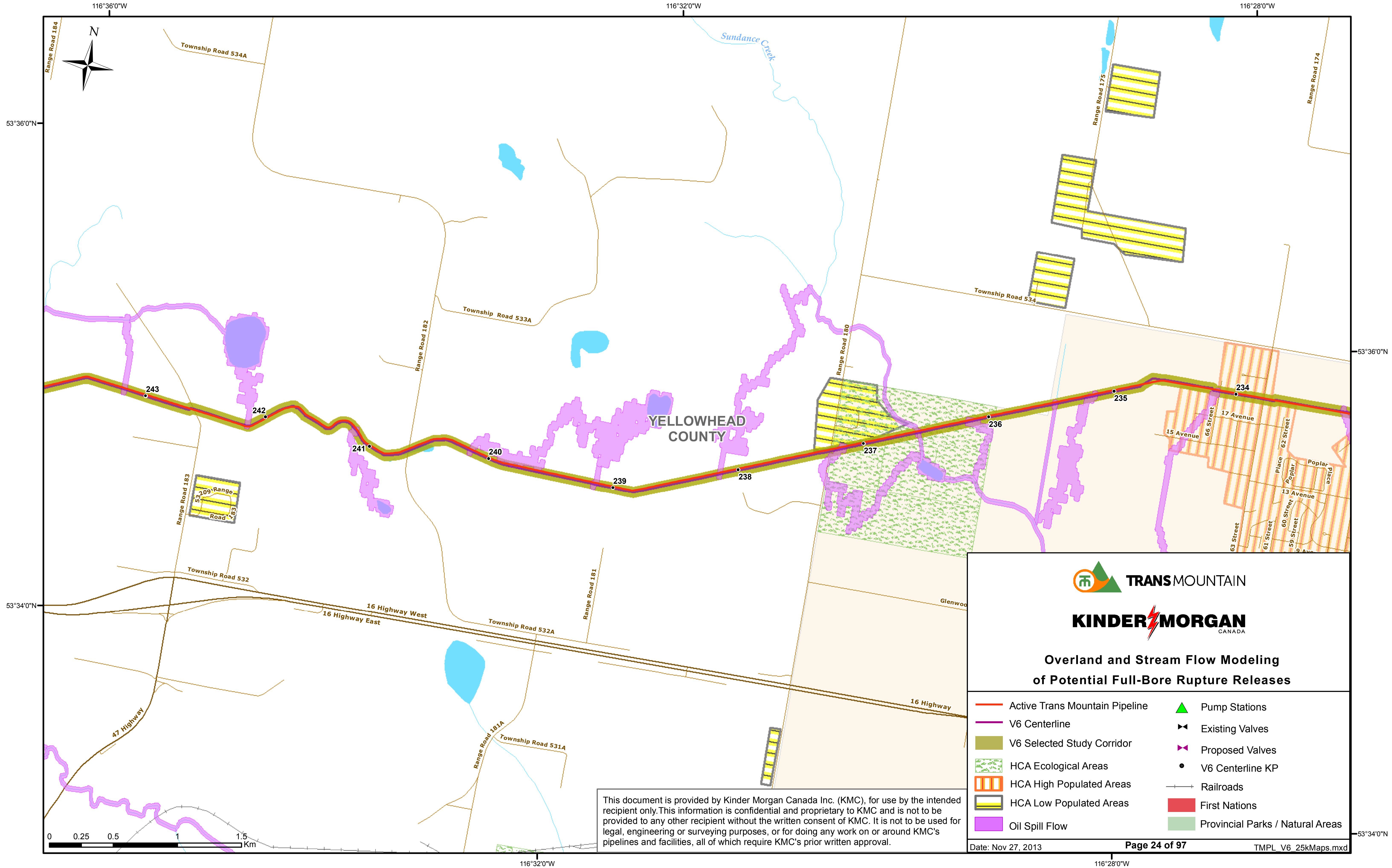
TMPL_V6_25kMaps.mxd



116°36'0"W
116°32'0"W
116°28'0"W
53°36'0"N
53°34'0"N
N
Range Road 184
Township Road 534A
Sundance Creek
Range Road 175
Range Road 174
Township Road 533A
Township Road 534
Range Road 182
Range Road 180
Range Road 183
53209 Range Road 183
243
242
241
240
239
238
237
236
235
234
YELLOWHEAD COUNTY
17 Avenue
15 Avenue
66 Street
62 Street
Poplar Place
13 Avenue
63 Street
61 Street
60 Street
59 Street
Township Road 532
16 Highway West
16 Highway East
Township Road 532A
Range Road 181
16 Highway
47 Highway
Range Road 181A
Township Road 531A
Glenwood
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
KINDER MORGAN CANADA
Overland and Stream Flow Modeling
of Potential Full-Bore Rupture Releases
Active Trans Mountain Pipeline
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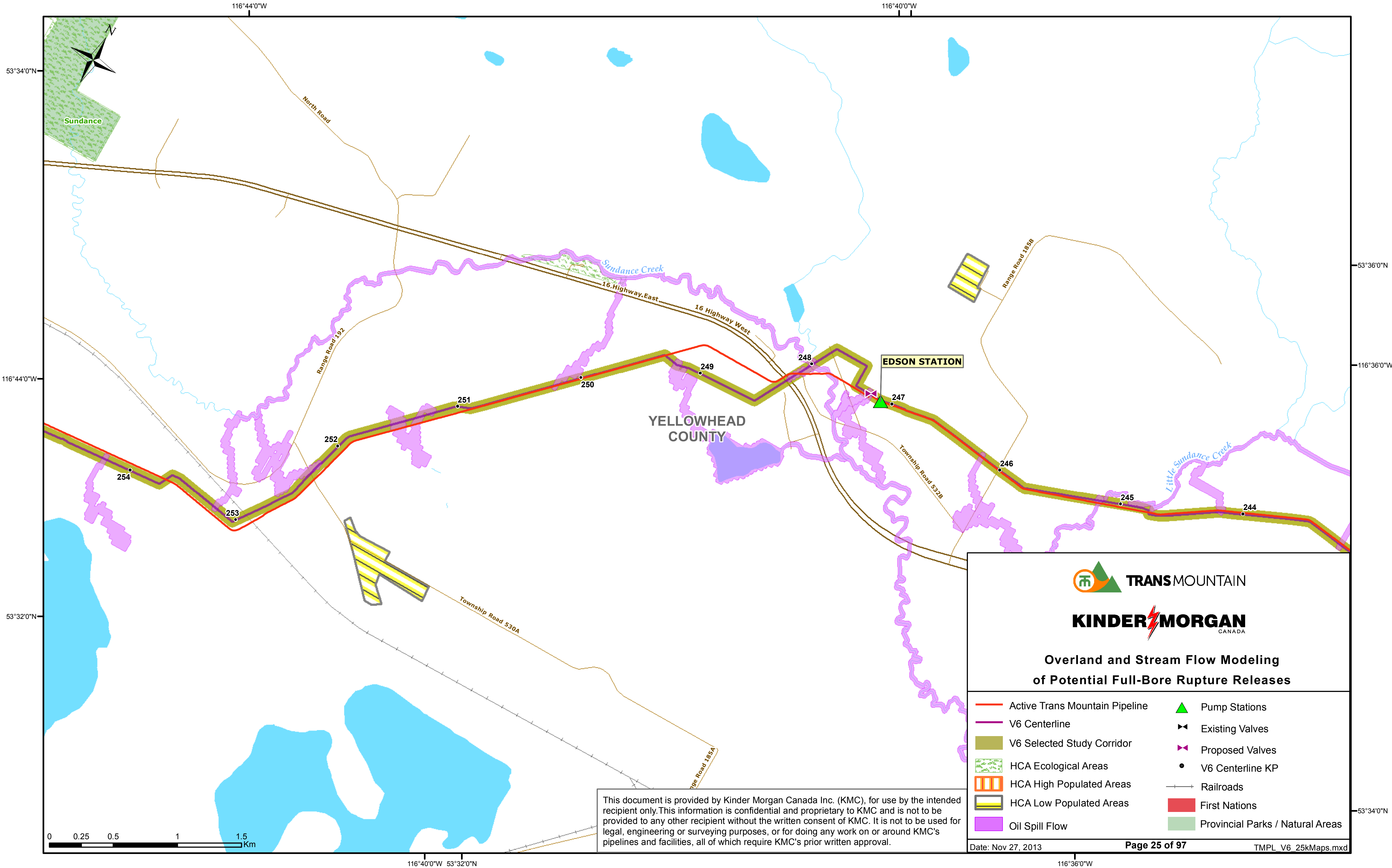

TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

- Active Trans Mountain Pipeline
- V6 Centerline
- V6 Selected Study Corridor
- HCA Ecological Areas
- HCA High Populated Areas
- HCA Low Populated Areas
- Oil Spill Flow
- Pump Stations
- Existing Valves
- Proposed Valves
- V6 Centerline KP
- Railroads
- First Nations
- Provincial Parks / Natural Areas

Date: Nov 27, 2013

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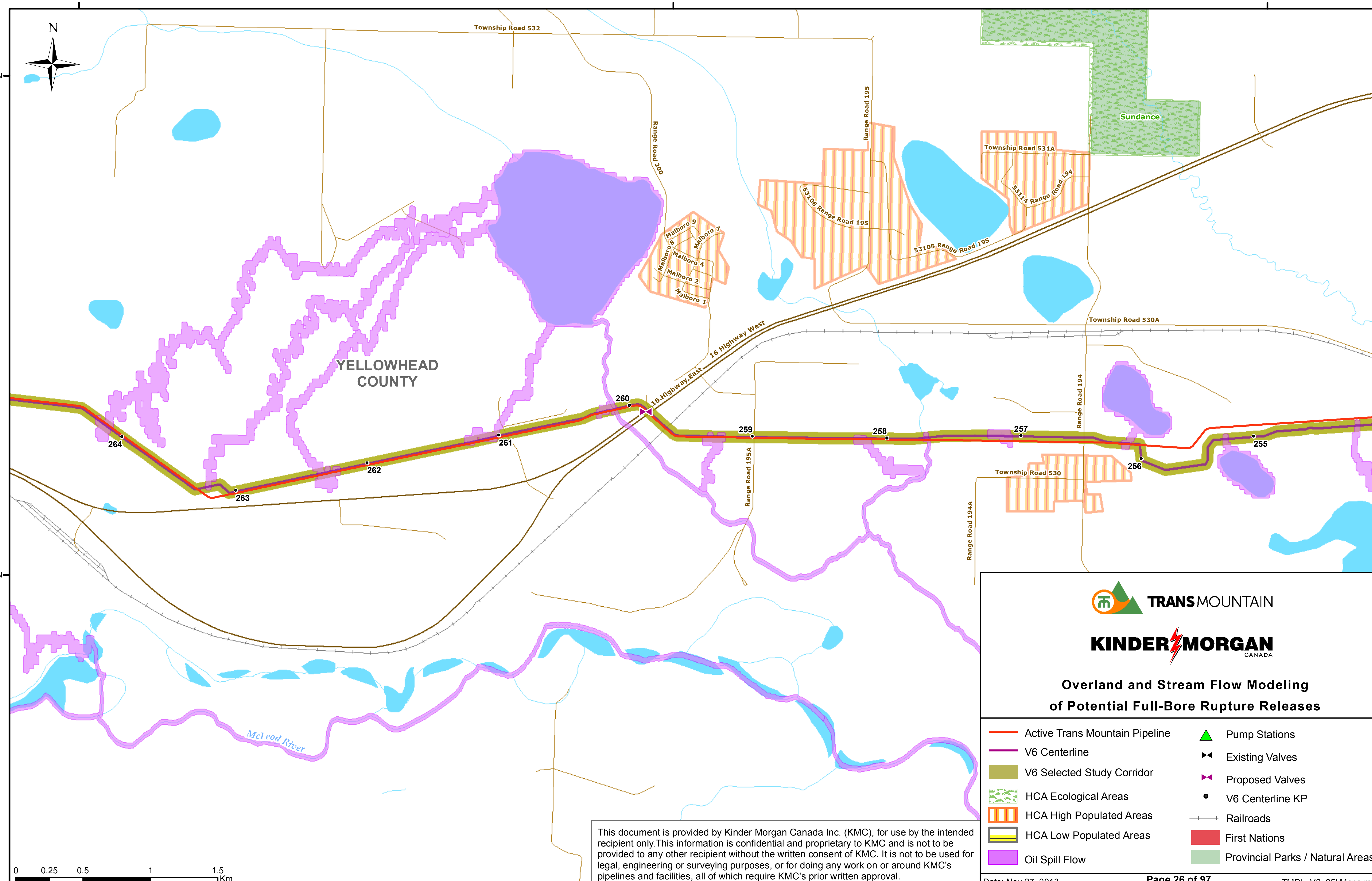

TRANS MOUNTAIN

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Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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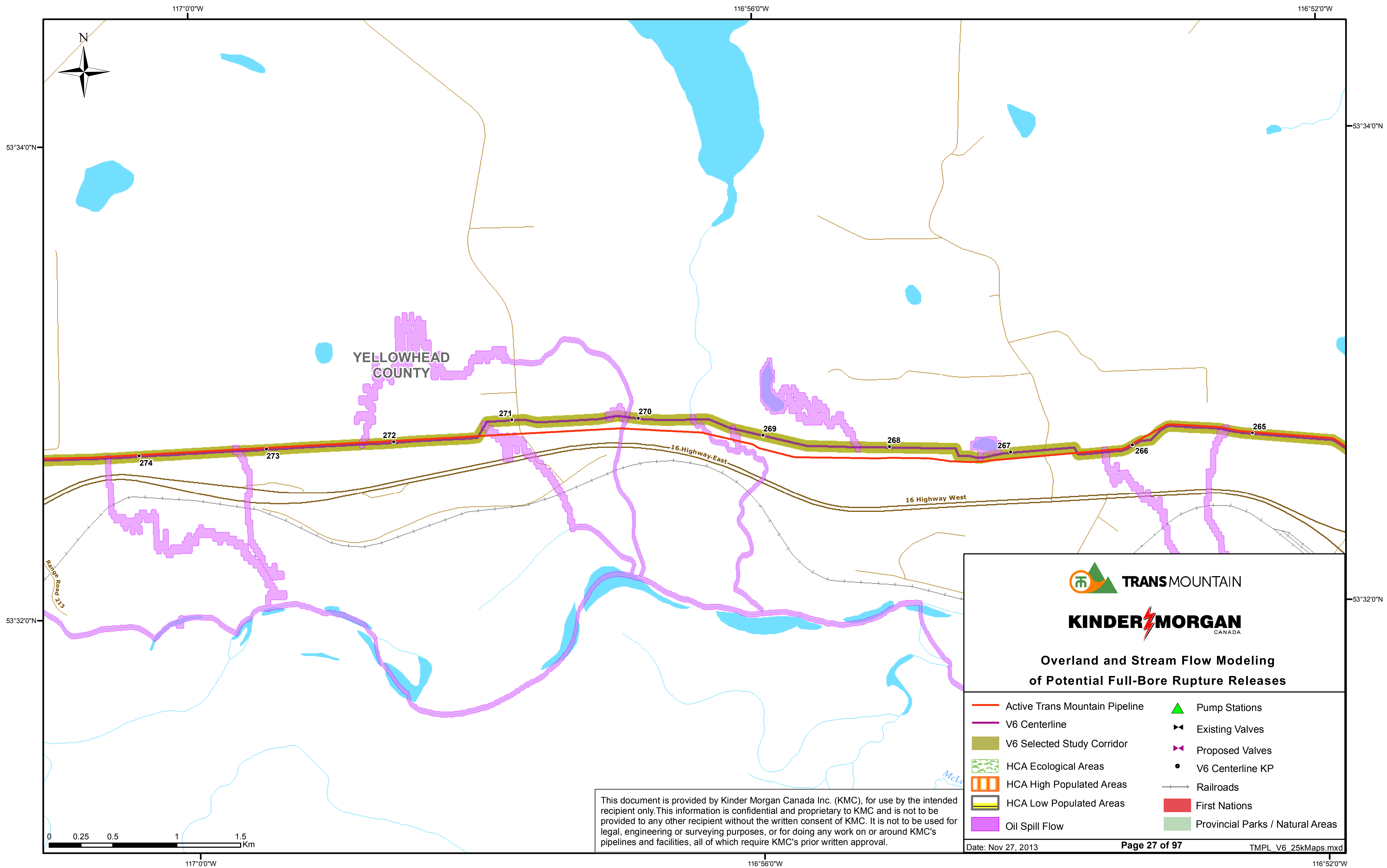

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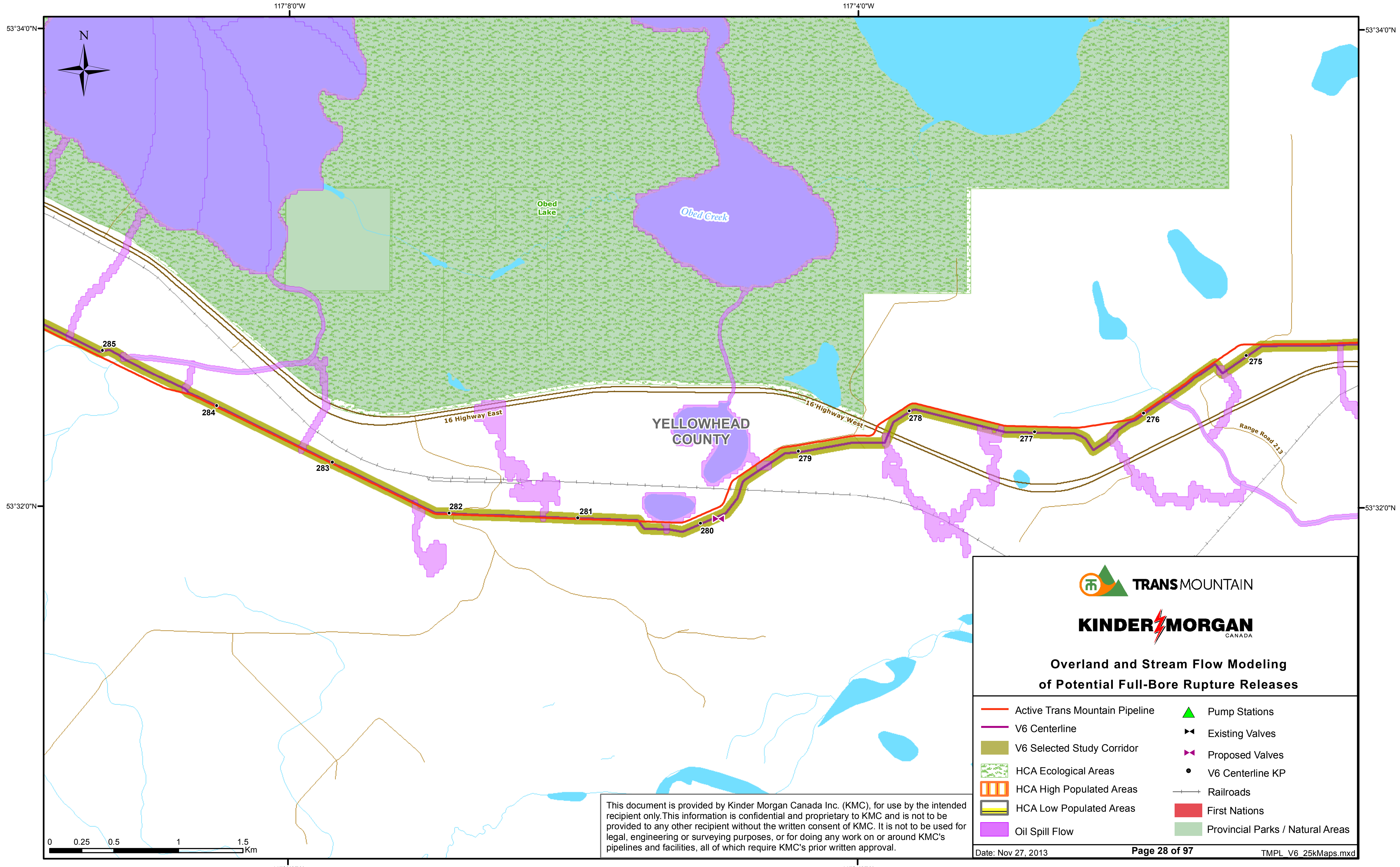

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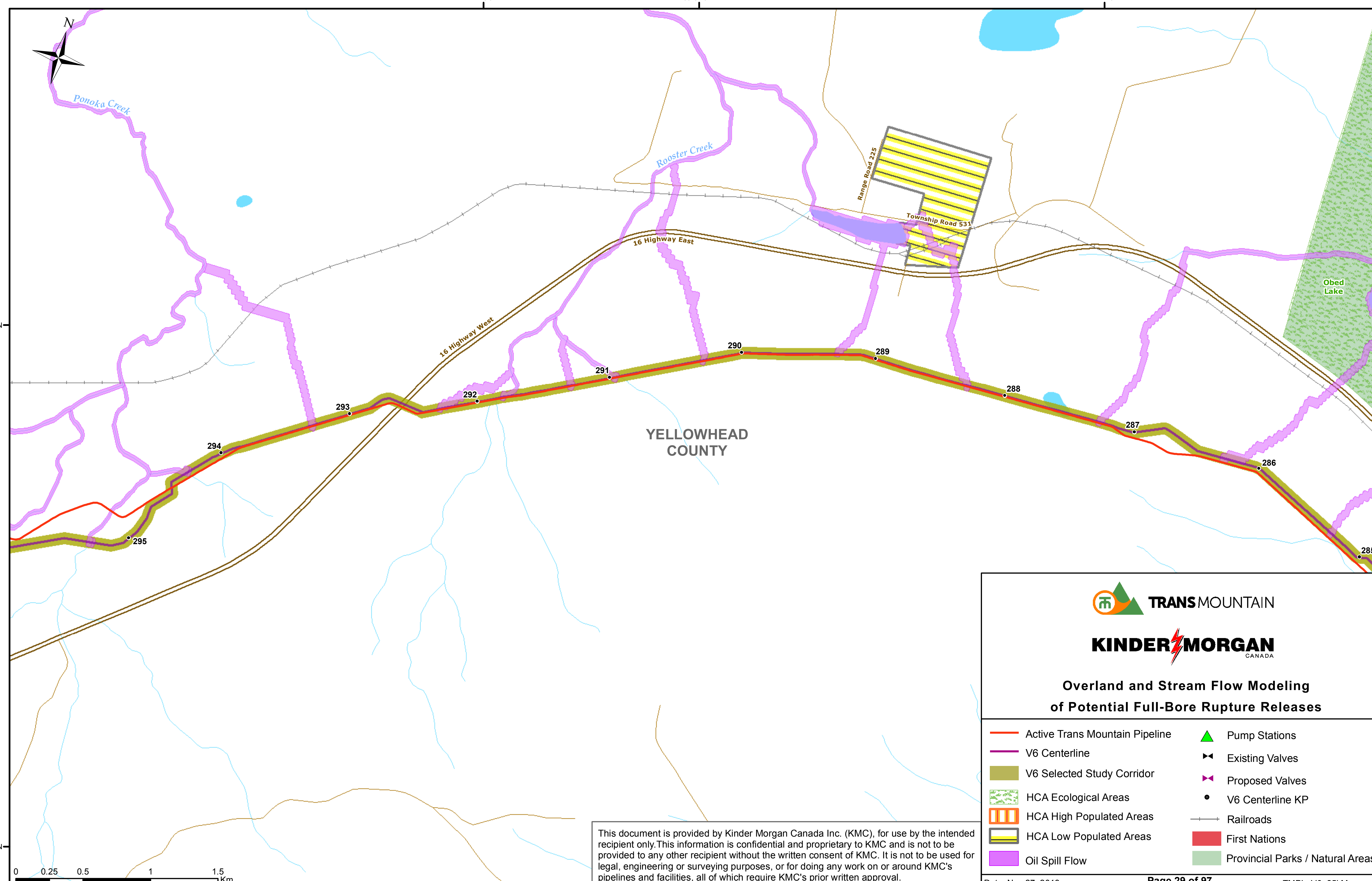

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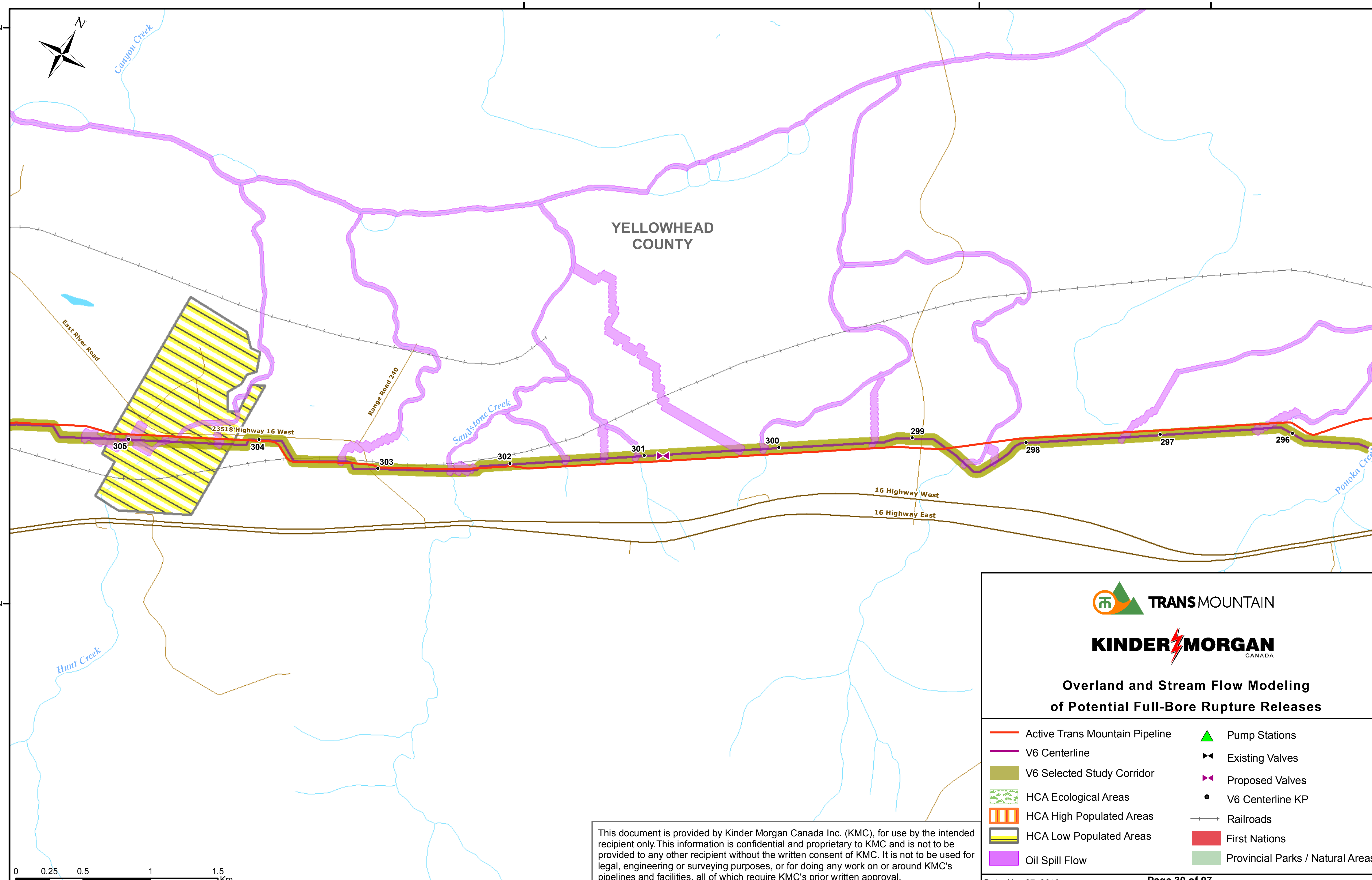

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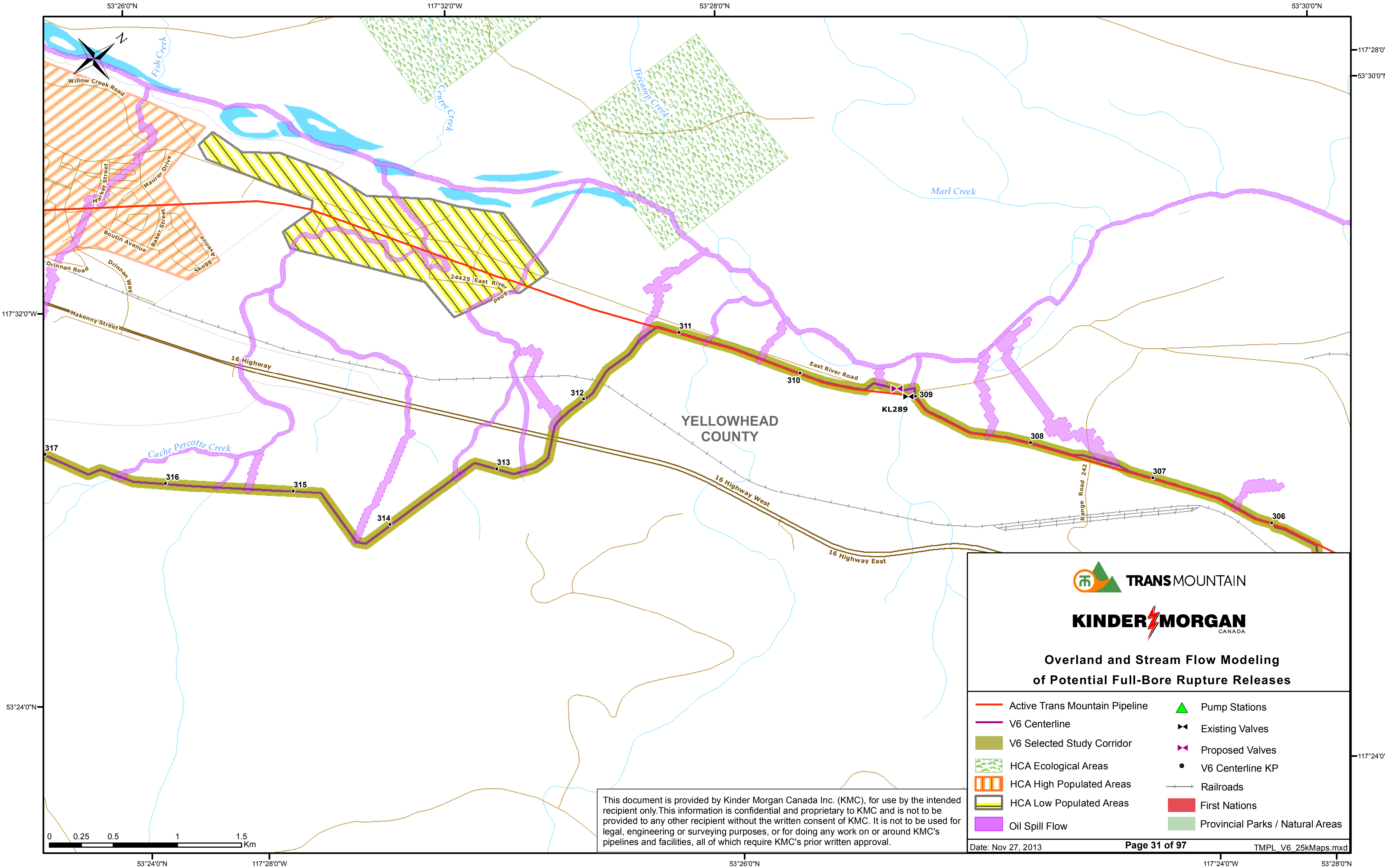

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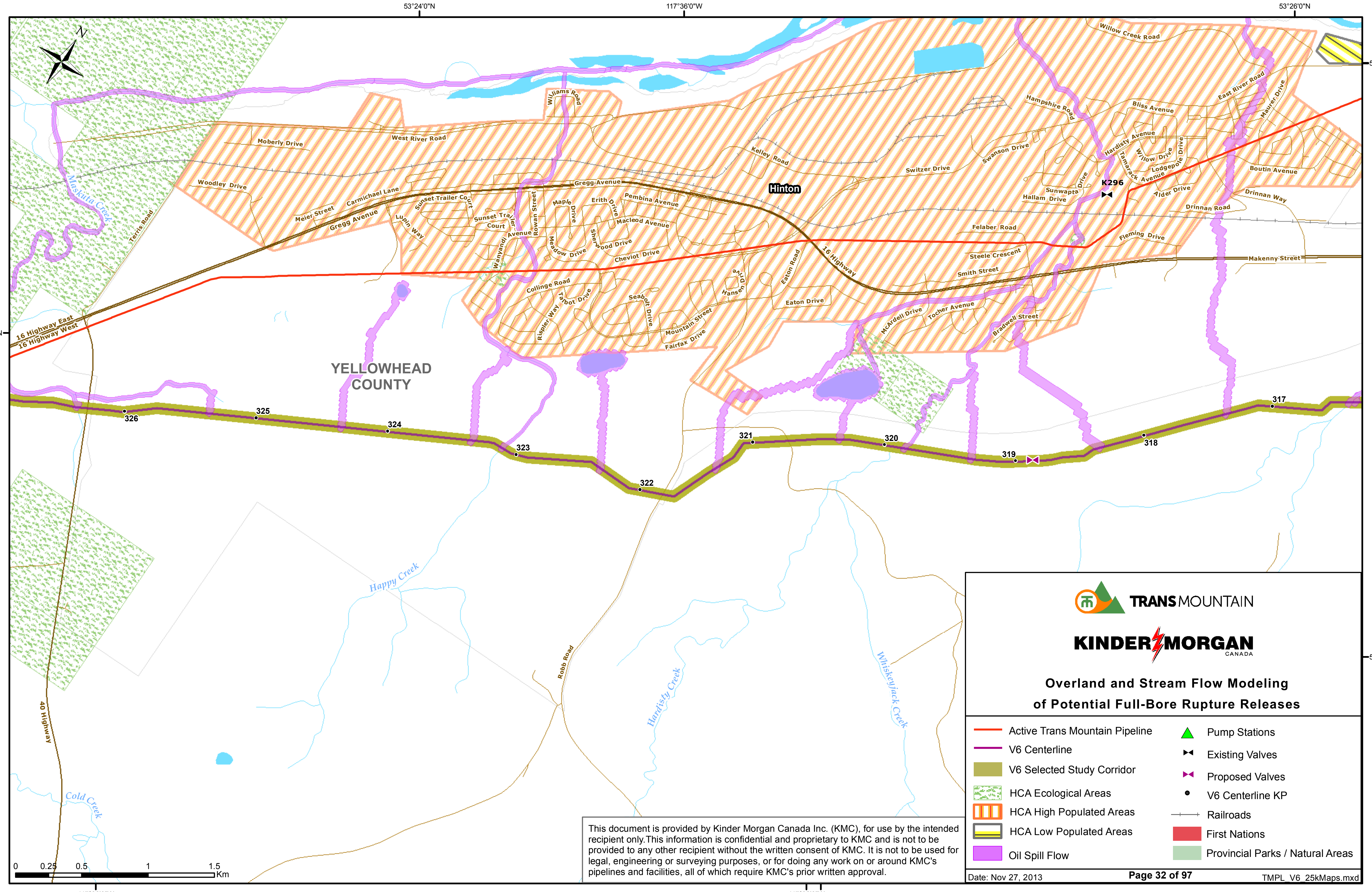

53°24'0"N
117°36'0"W
53°26'0"N
53°22'0"N
53°24'0"N
117°36'0"W
117°32'0"W
N
Hinton
YELLOWHEAD COUNTY
K296
326
325
324
323
322
321
320
319
318
317
Willow Creek Road
Williams Road
Moberly Drive
West River Road
Woodley Drive
Kelley Road
Hampshire Road
Bliss Avenue
East River Road
Maurer Drive
Swanson Drive
Switzer Drive
Hardisty Avenue
Willow Drive
Tamarack Avenue
Lodgepole Drive
Boutin Avenue
Sunwapta Drive
Hallam Drive
Alder Drive
Drinnan Way
Drinnan Road
Gregg Avenue
Carmichael Lane
Meier Street
Sunset Trailer Court
Lupin Way
Rowan Street
Maple Drive
Erith Drive
Pembina Avenue
Macleod Avenue
Wanyandi Avenue
Meadow Drive
Sherwood Drive
Cheviot Drive
Felaber Road
Fleming Drive
Steele Crescent
Smith Street
Makenny Street
16 Highway
Eaton Road
Eaton Drive
Hansen Drive
Collinge Road
Talbot Drive
Seabolt Drive
Ripley Way
Mountain Street
Fairfax Drive
McArdell Drive
Tocher Avenue
Bradwell Street
Terris Road
Maskuta Creek
16 Highway East
16 Highway West
40 Highway
Happy Creek
Robb Road
Hardisty Creek
Whiskeyjack Creek
Cold Creek
0 0.25 0.5 1 1.5 Km
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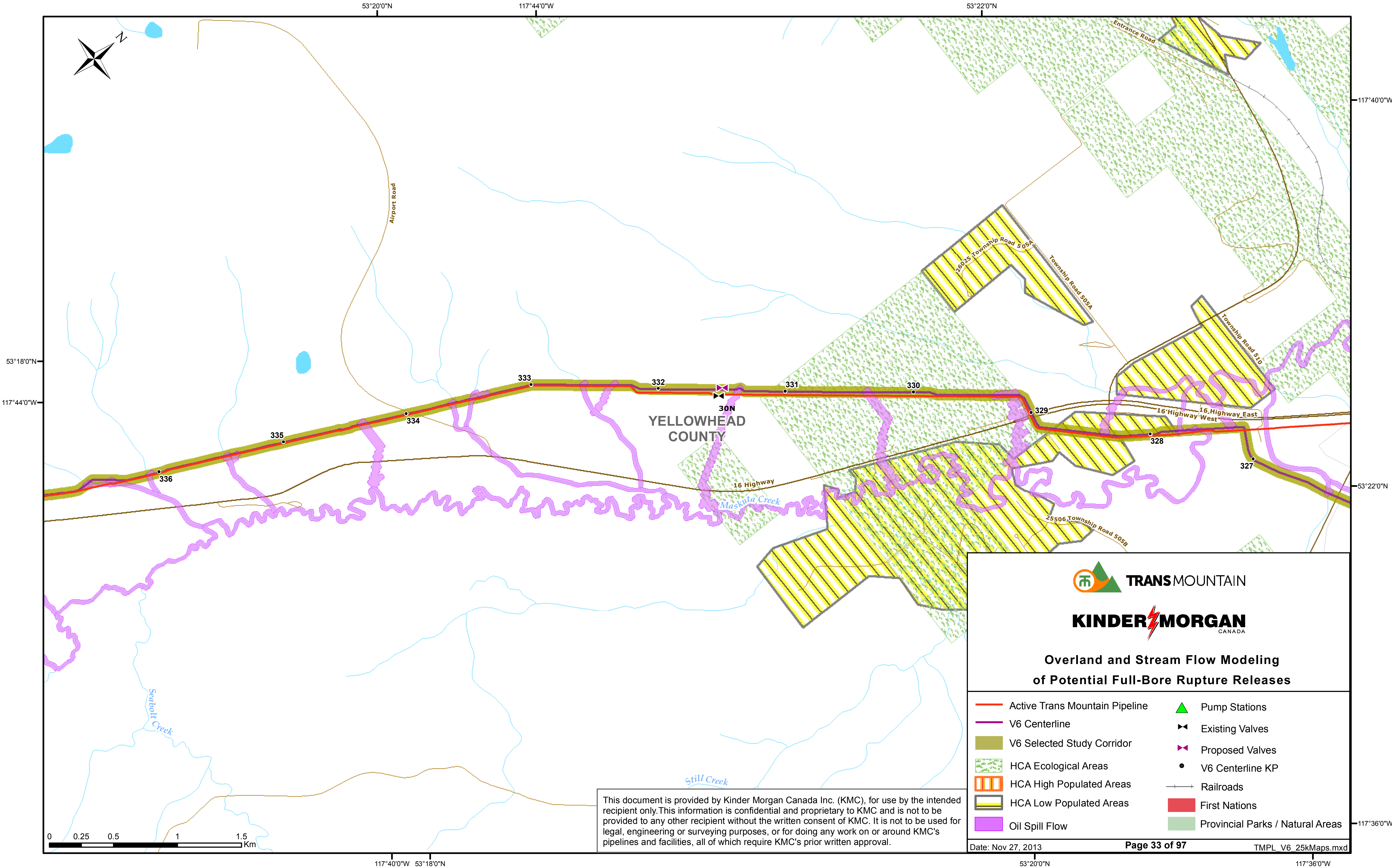

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53°22'0"N
117°40'0"W
53°18'0"N
117°44'0"W
53°22'0"N
117°36'0"W
117°40'0"W 53°18'0"N
53°20'0"N
117°36'0"W
N
Airport Road
Entrance Road
26025 Township Road 505A
Township Road 505A
Township Road 510
16 Highway West
16 Highway East
16 Highway
25506 Township Road 505B
Maskuta Creek
Seabolt Creek
Still Creek
YELLOWHEAD COUNTY
336
335
334
333
332
331
330
329
328
327
30N
0 0.25 0.5 1 1.5 Km
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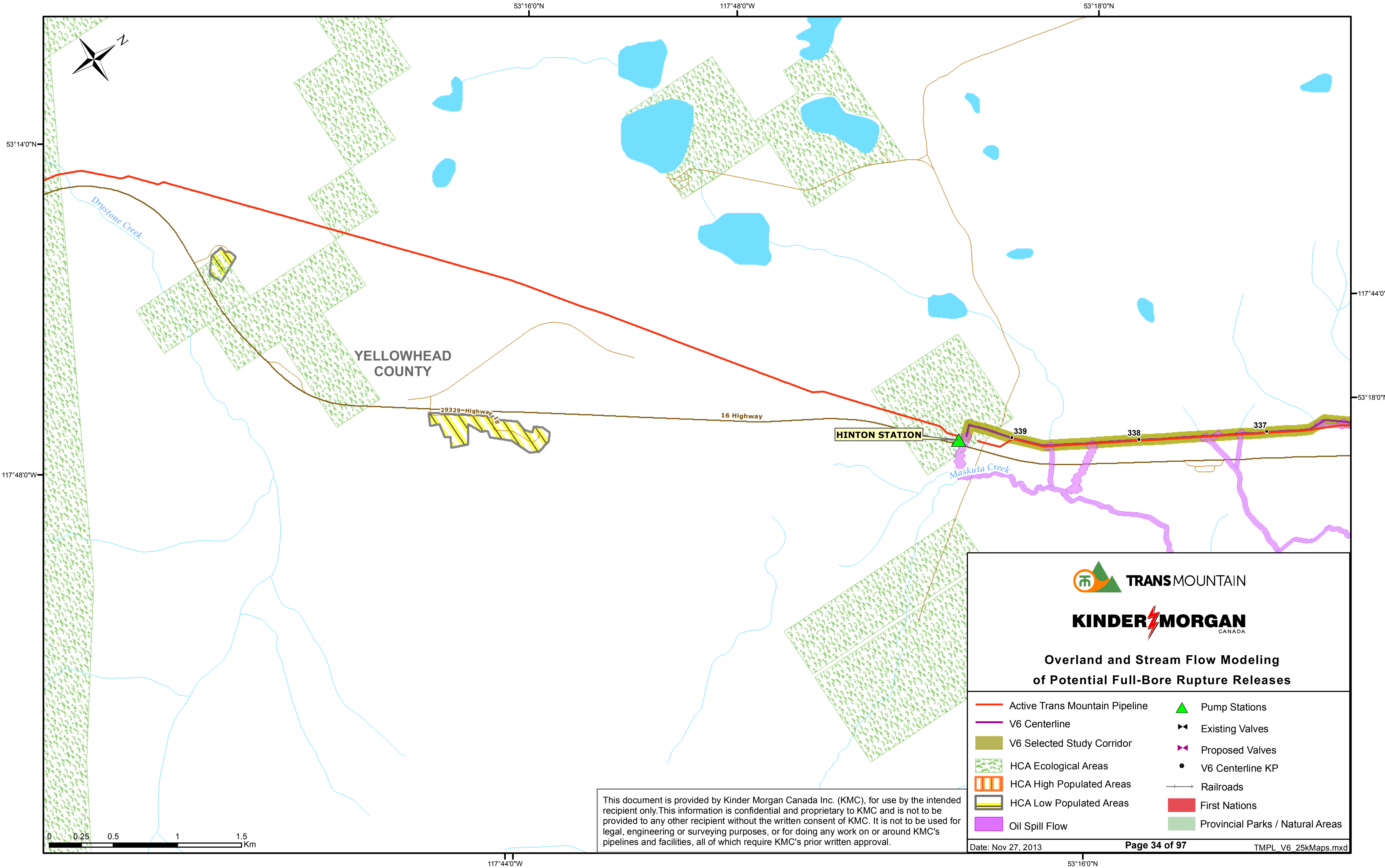

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117°44'0"W
117°48'0"W
53°18'0"N
117°44'0"W
53°16'0"N
N
Drystone Creek
YELLOWHEAD
COUNTY
29329 Highway 16
16 Highway
HINTON STATION
339
338
337
Maskuta Creek
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
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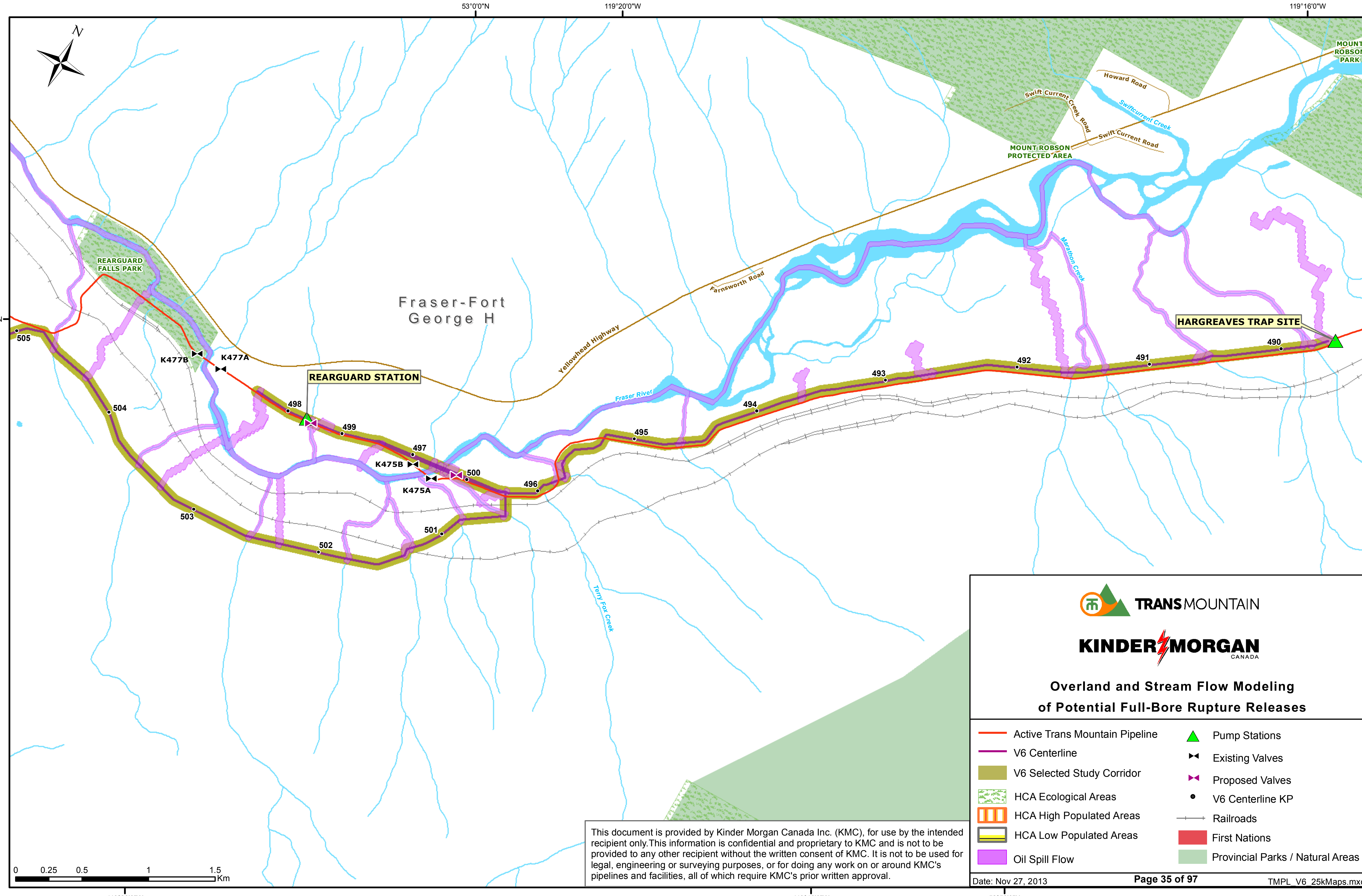

53°0'0"N
119°20'0"W
119°16'0"W
52°58'0"N
53°0'0"N
N
MOUNT ROBSON PARK
Howard Road
Swift Current Creek Road
Swiftcurrent Creek
Swift Current Road
MOUNT ROBSON PROTECTED AREA
REARGUARD FALLS PARK
Fraser-Fort George H
Farnsworth Road
Yellowhead Highway
Marathon Creek
HARGREAVES TRAP SITE
REARGUARD STATION
Fraser River
Terry Fox Creek
K477B
K477A
K475B
K475A
505
504
503
502
501
500
499
498
497
496
495
494
493
492
491
490
0 0.25 0.5 1 1.5 Km
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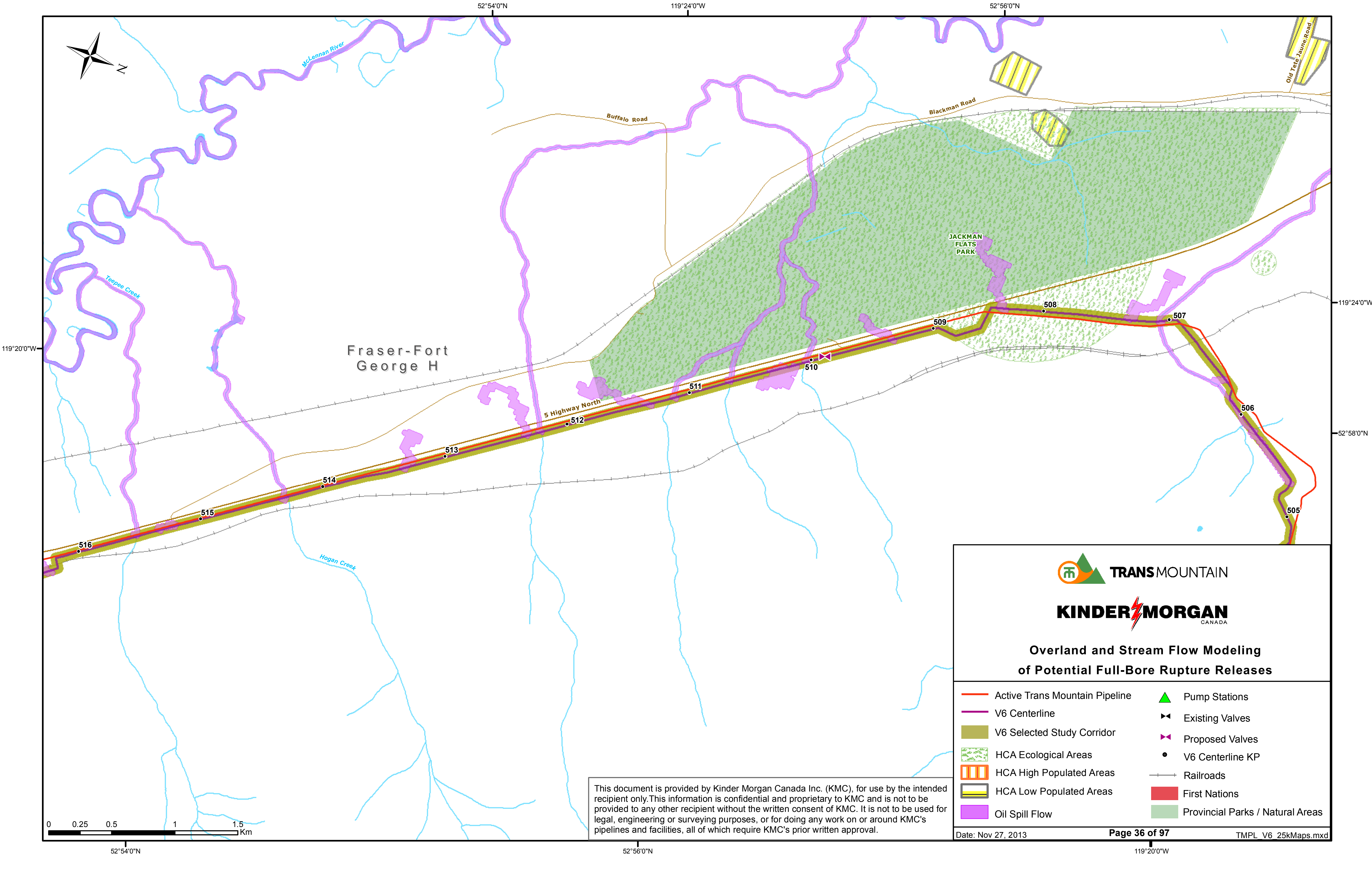

TRANS MOUNTAIN

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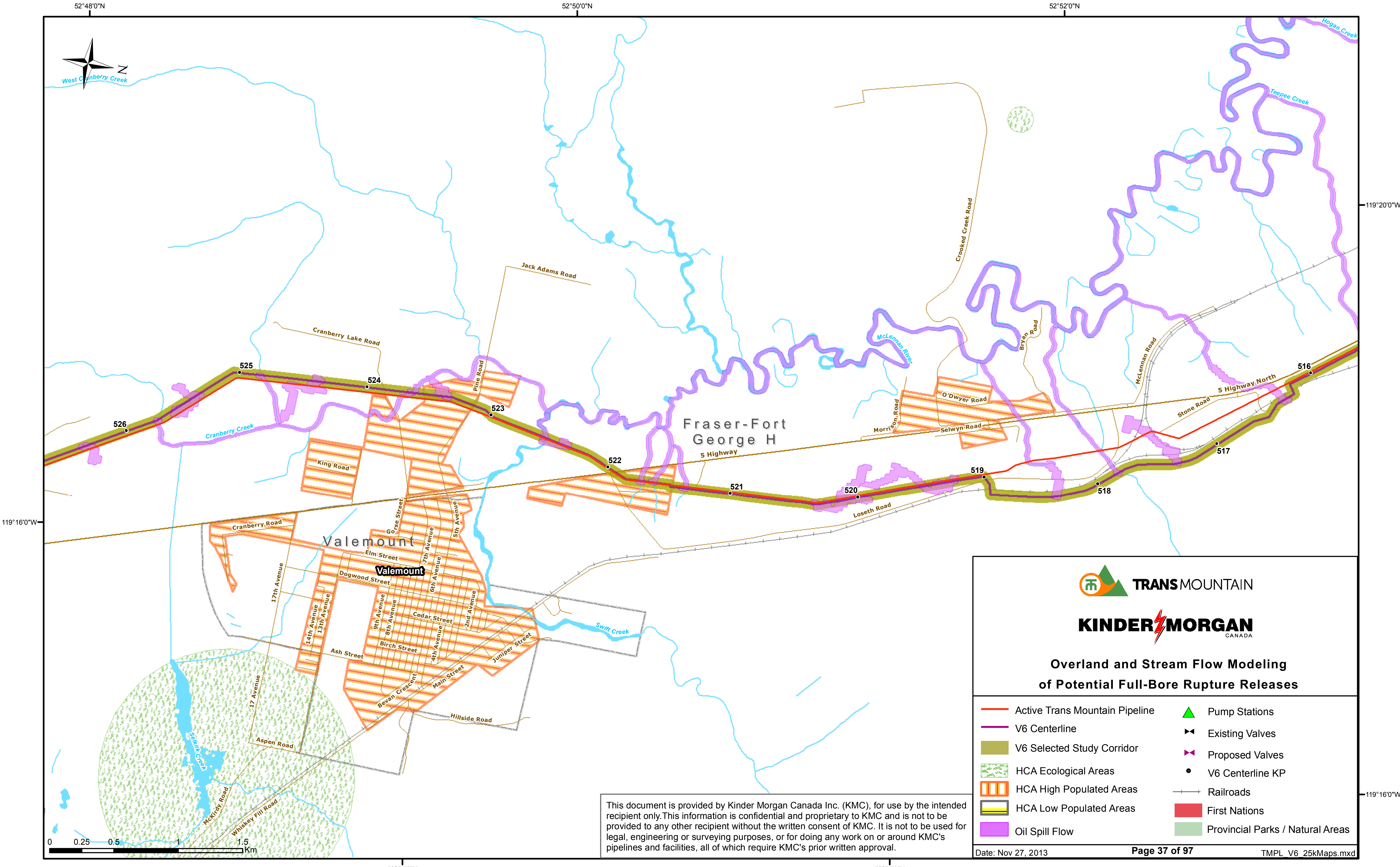

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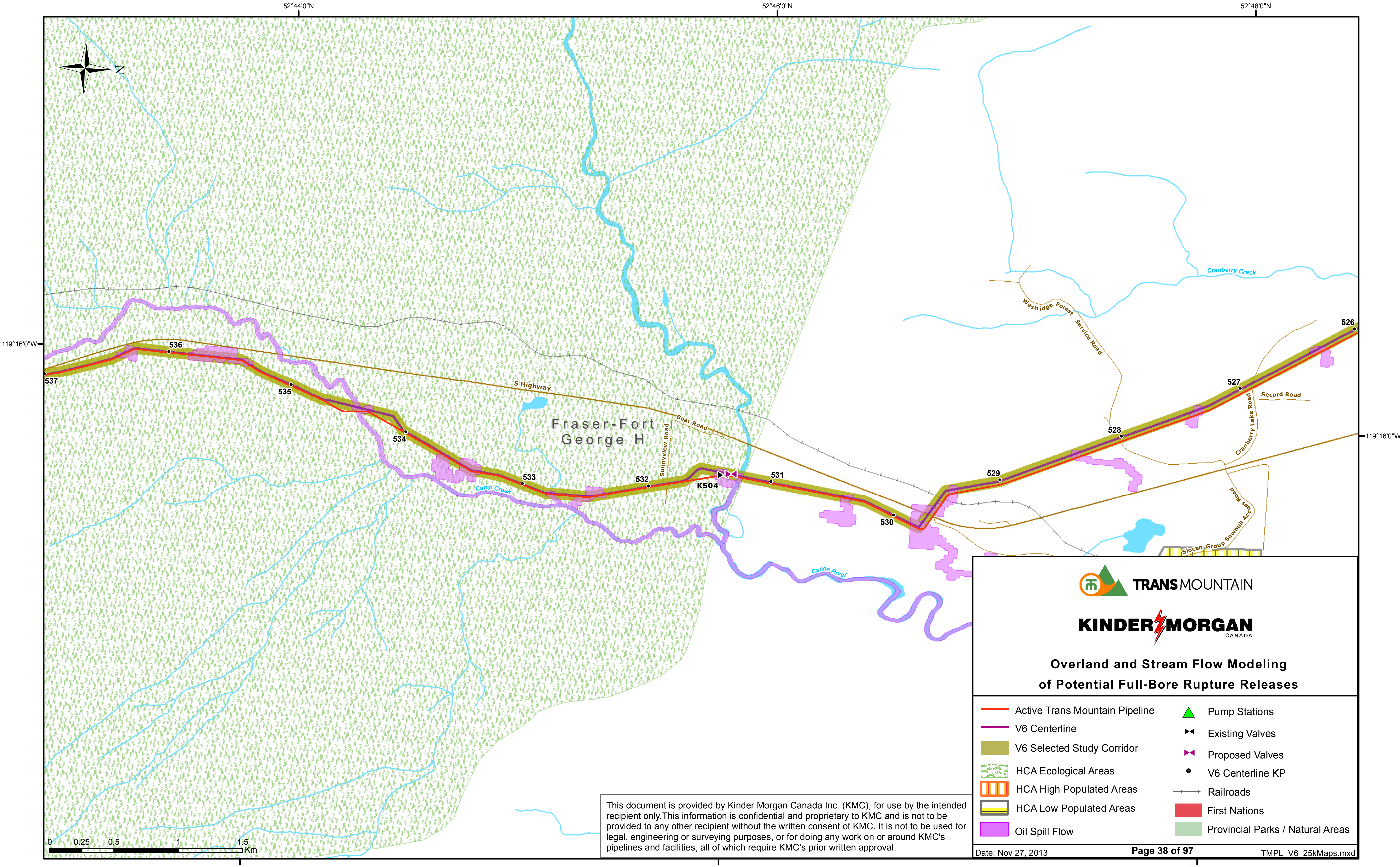

TRANSMOUNTAIN

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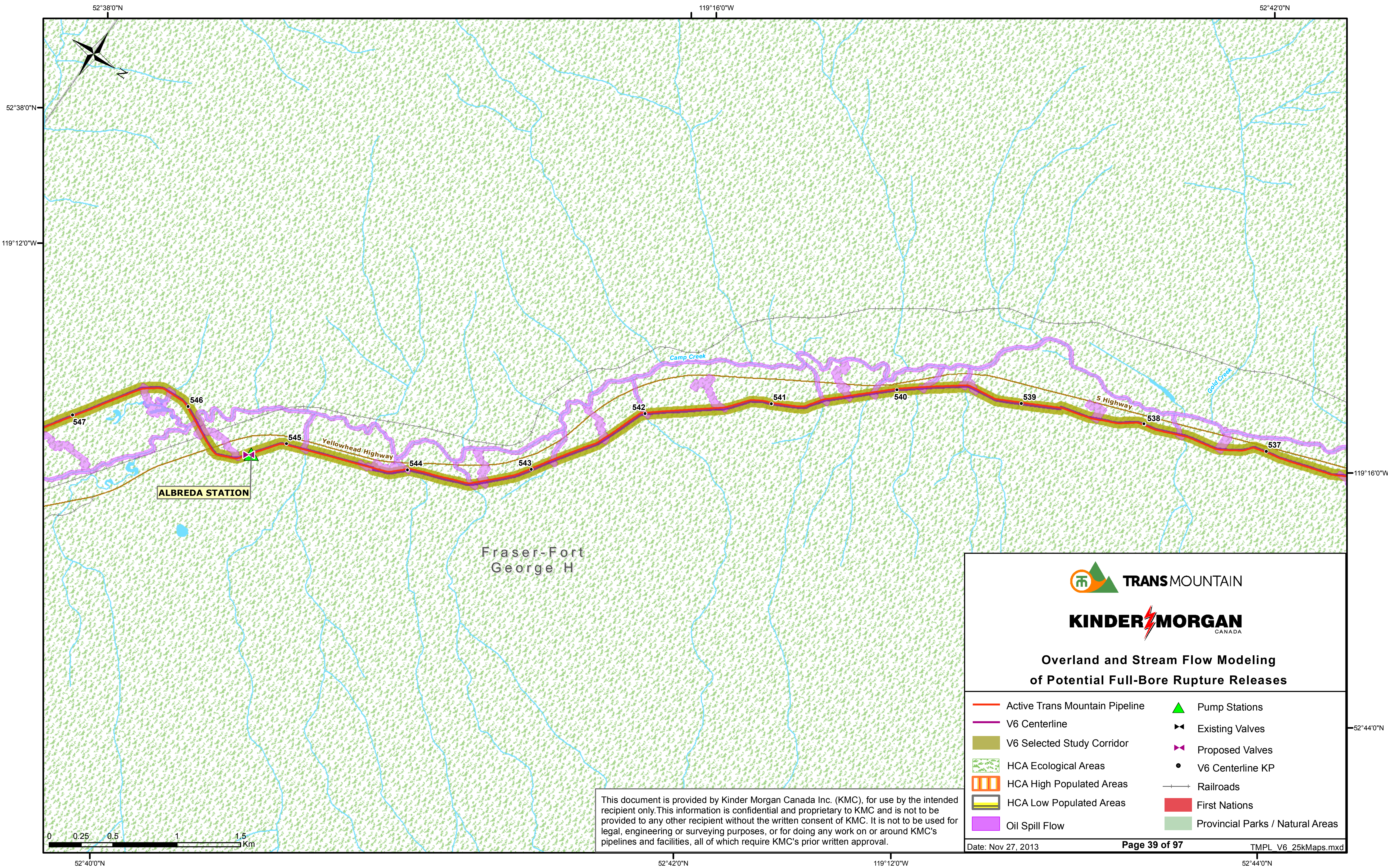
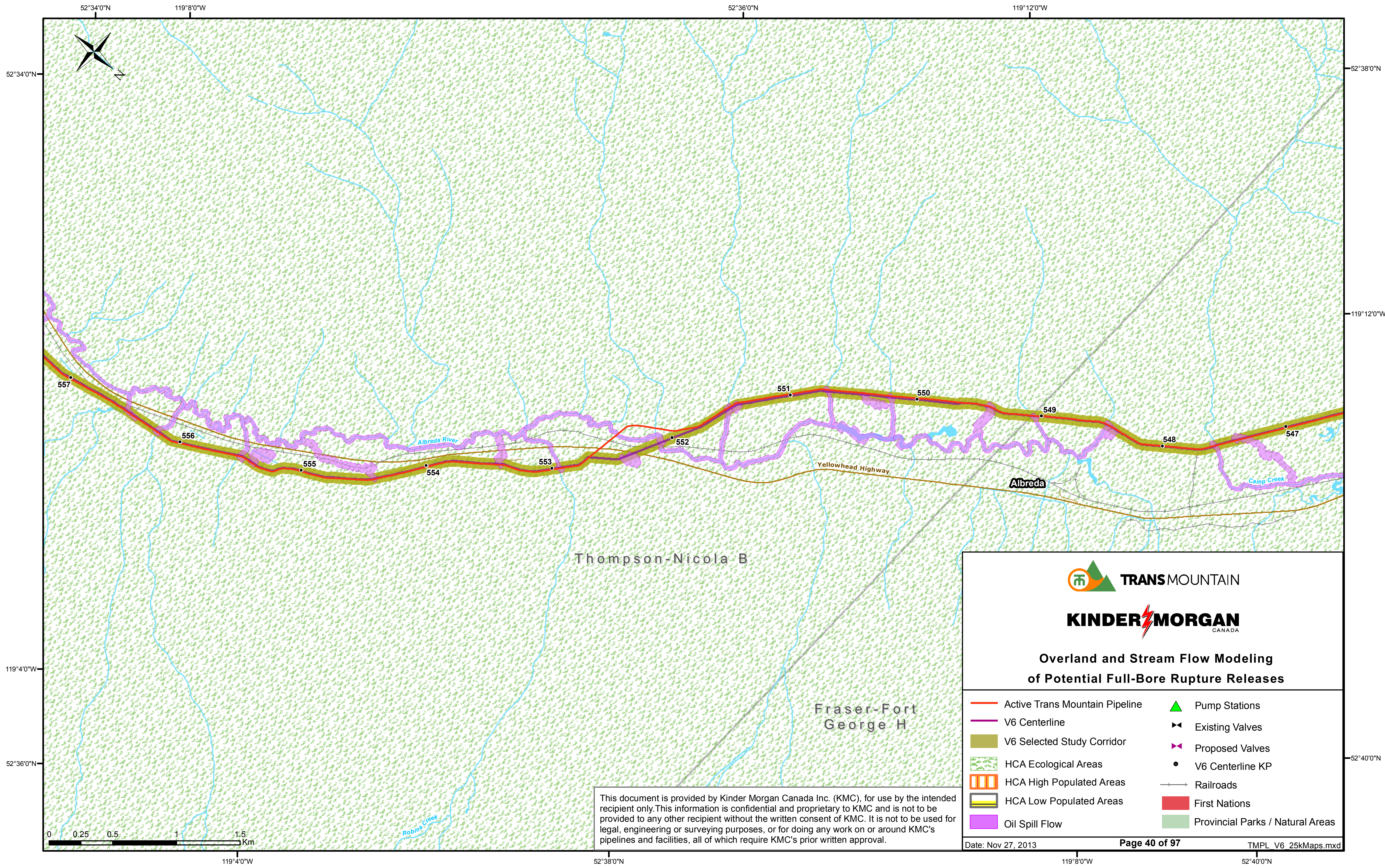
First Nations
Provincial Parks / Natural Areas



TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases



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119°8'0"W
52°36'0"N
119°12'0"W
52°38'0"N
119°4'0"W
52°40'0"N
119°8'0"W
557
556
555
554
553
552
551
550
549
548
547
Albreda River
Yellowhead Highway
Albreda
Camp Creek
Robina Creek
Thompson-Nicola B
Fraser-Fort George H
0 0.25 0.5 1 1.5 Km
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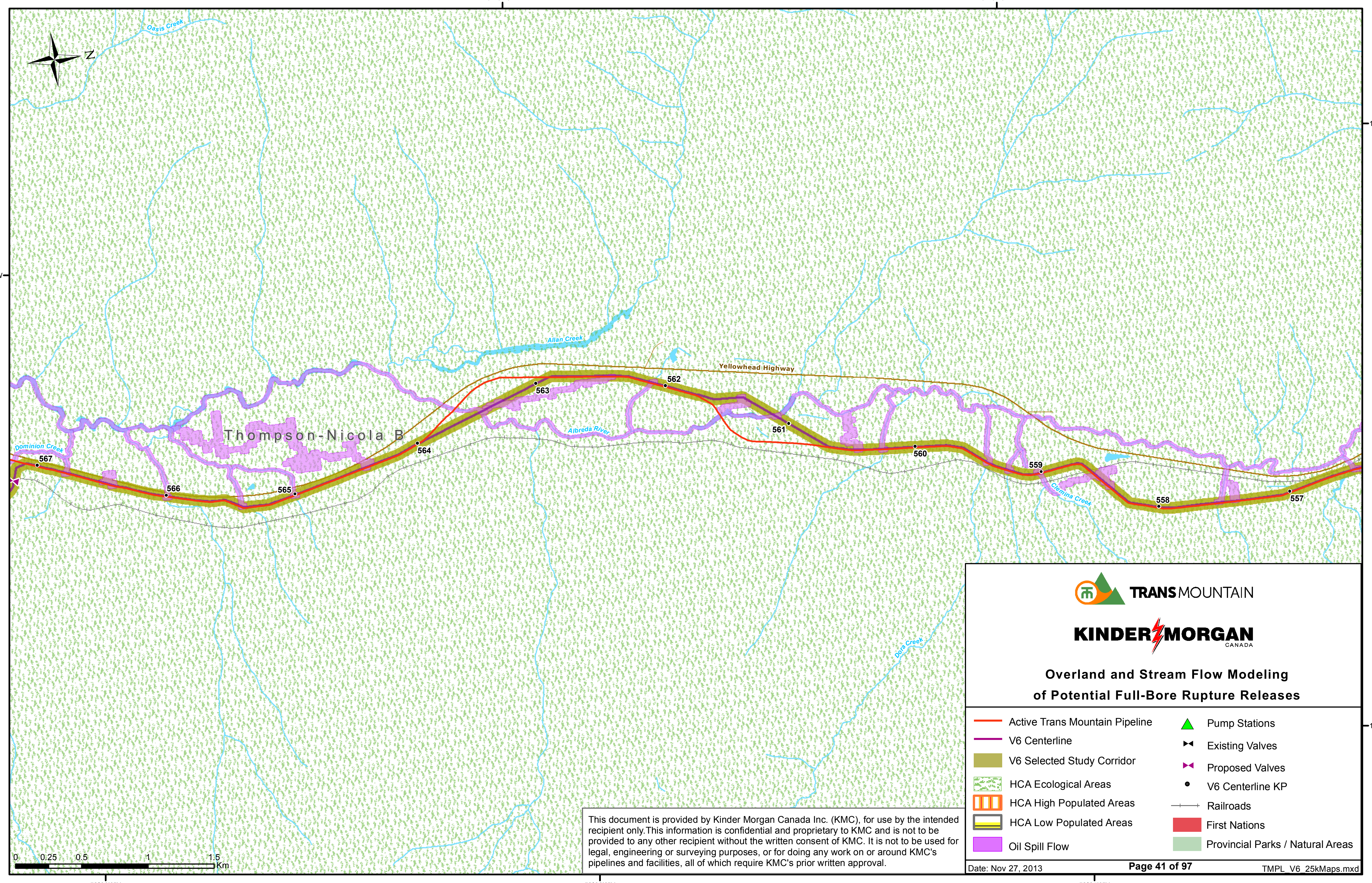

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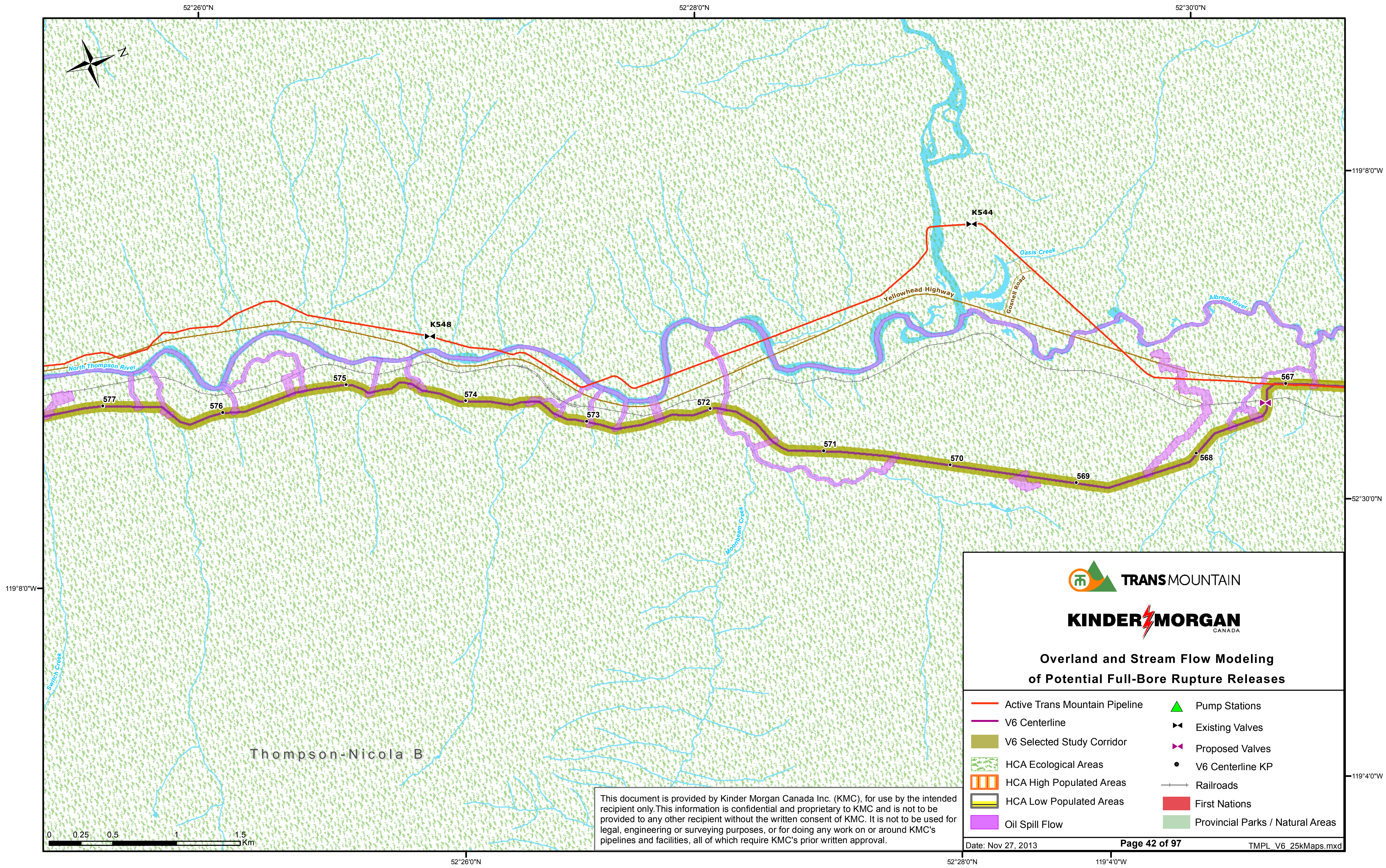

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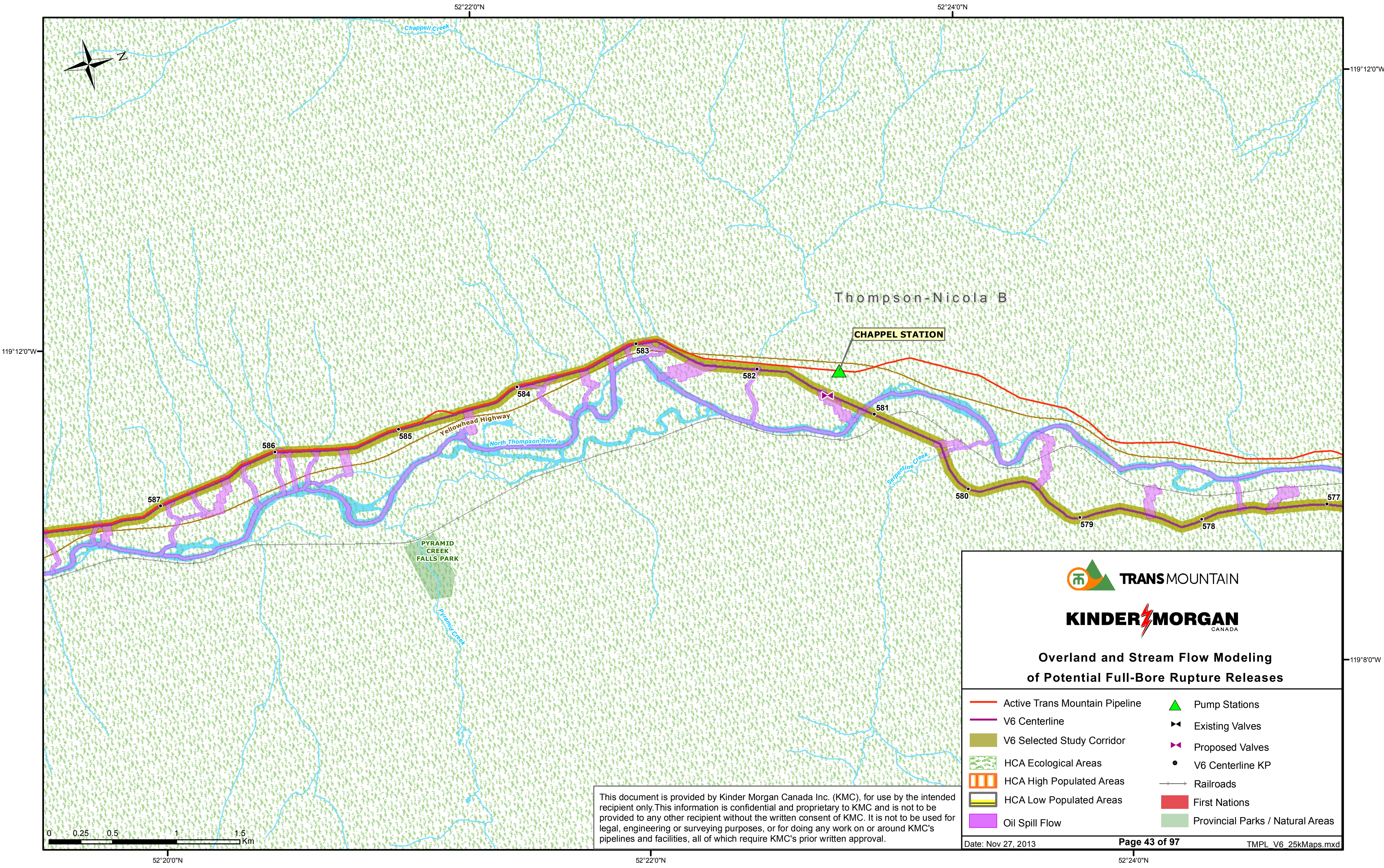

52°22'0"N
52°24'0"N
119°12'0"W
119°8'0"W
52°20'0"N
Chappell Creek
Thompson-Nicola B
CHAPPEL STATION
583
582
581
584
585
586
587
580
579
578
577
Yellowhead Highway
North Thompson River
Serpentine Creek
PYRAMID CREEK FALLS PARK
Pyramid Creek
0 0.25 0.5 1 1.5 Km
TRANSMOUNTAIN
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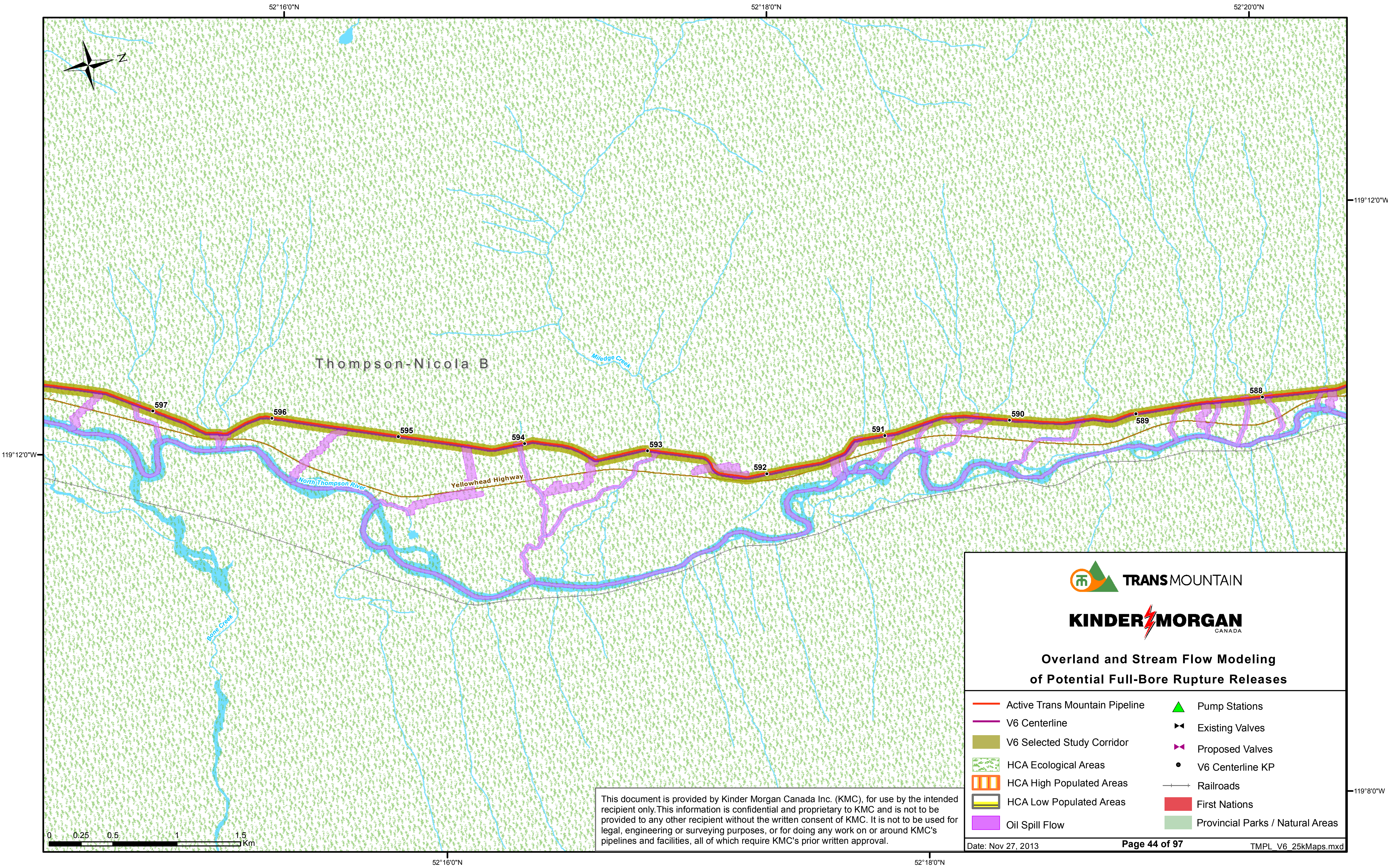
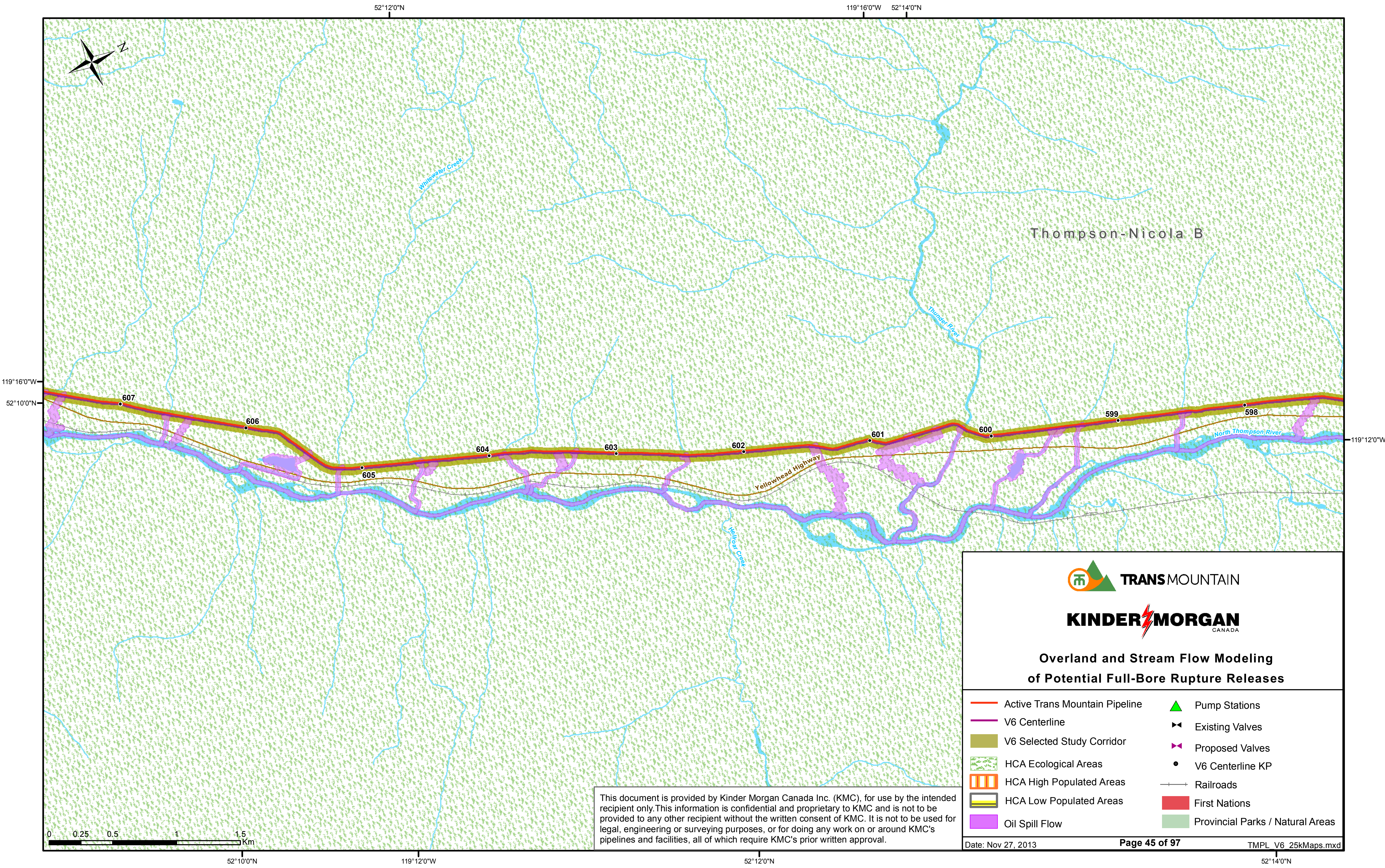


Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases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52°10'0"N
119°12'0"W
52°12'0"N
52°14'0"N
N
Whitewater Creek
Thunder River
Thompson-Nicola B
North Thompson River
Yellowhead Highway
Hellroar Creek
607
606
605
604
603
602
601
600
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598
0 0.25 0.5 1 1.5 Km
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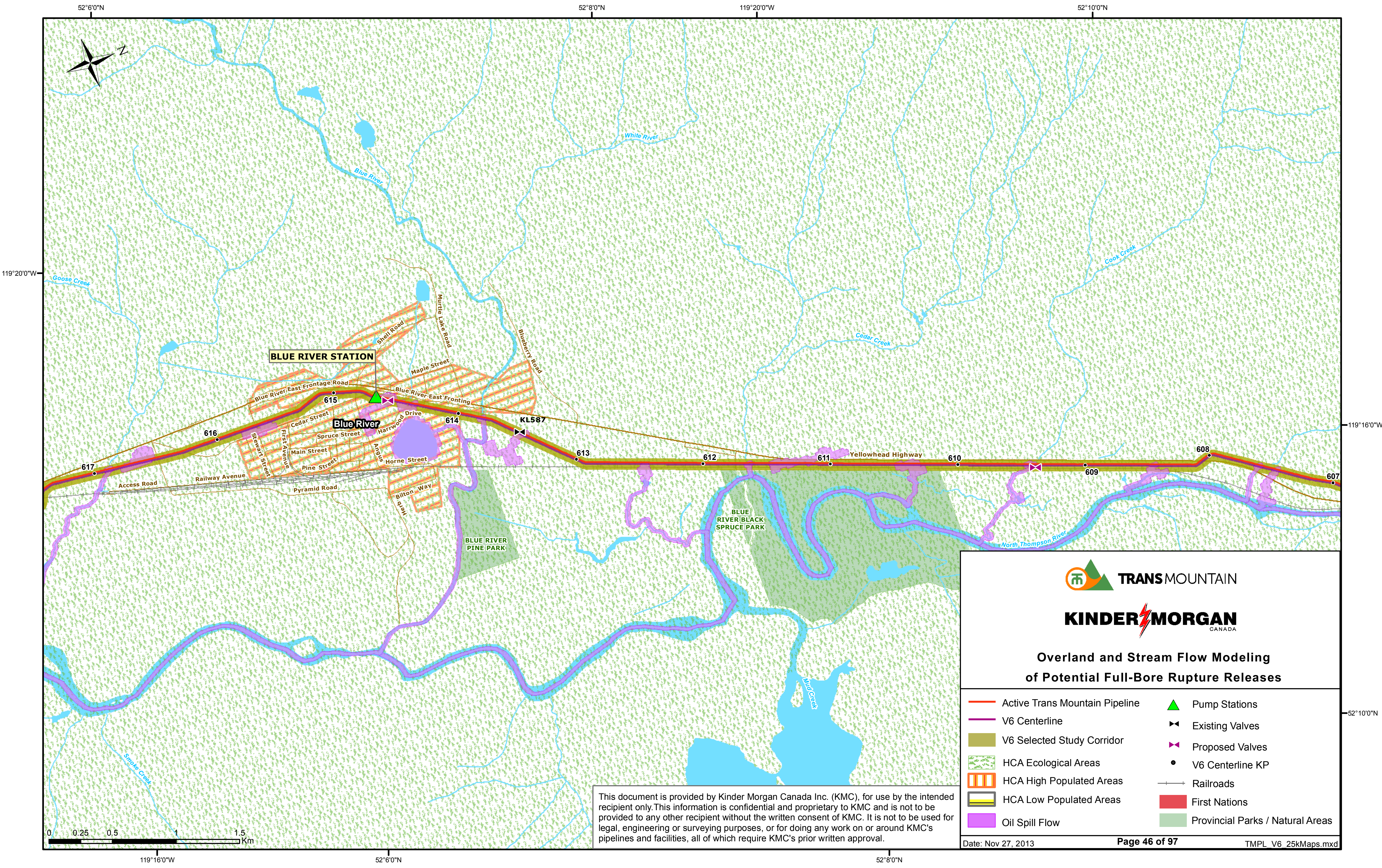
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52°6'0"N
52°8'0"N
N
White River
Blue River
Goose Creek
Cook Creek
Cedar Creek
BLUE RIVER STATION
Blue River
Shell Road
Murtle Lake Road
Blueberry Road
Maple Street
Blue River East Frontage Road
Blue River East Fronting
Cedar Street
Harrwood Drive
Spruce Street
Main Street
Pine Street
Stewart Street
First Avenue
Angus
Horne Street
Railway Avenue
Access Road
Pyramid Road
Bilton Way
Herb
Yellowhead Highway
KL587
617
616
615
614
613
612
611
610
609
608
607
BLUE RIVER PINE PARK
BLUE RIVER BLACK SPRUCE PARK
North Thompson River
Mud Creek
Smoke Creek
0 0.25 0.5 1 1.5 Km
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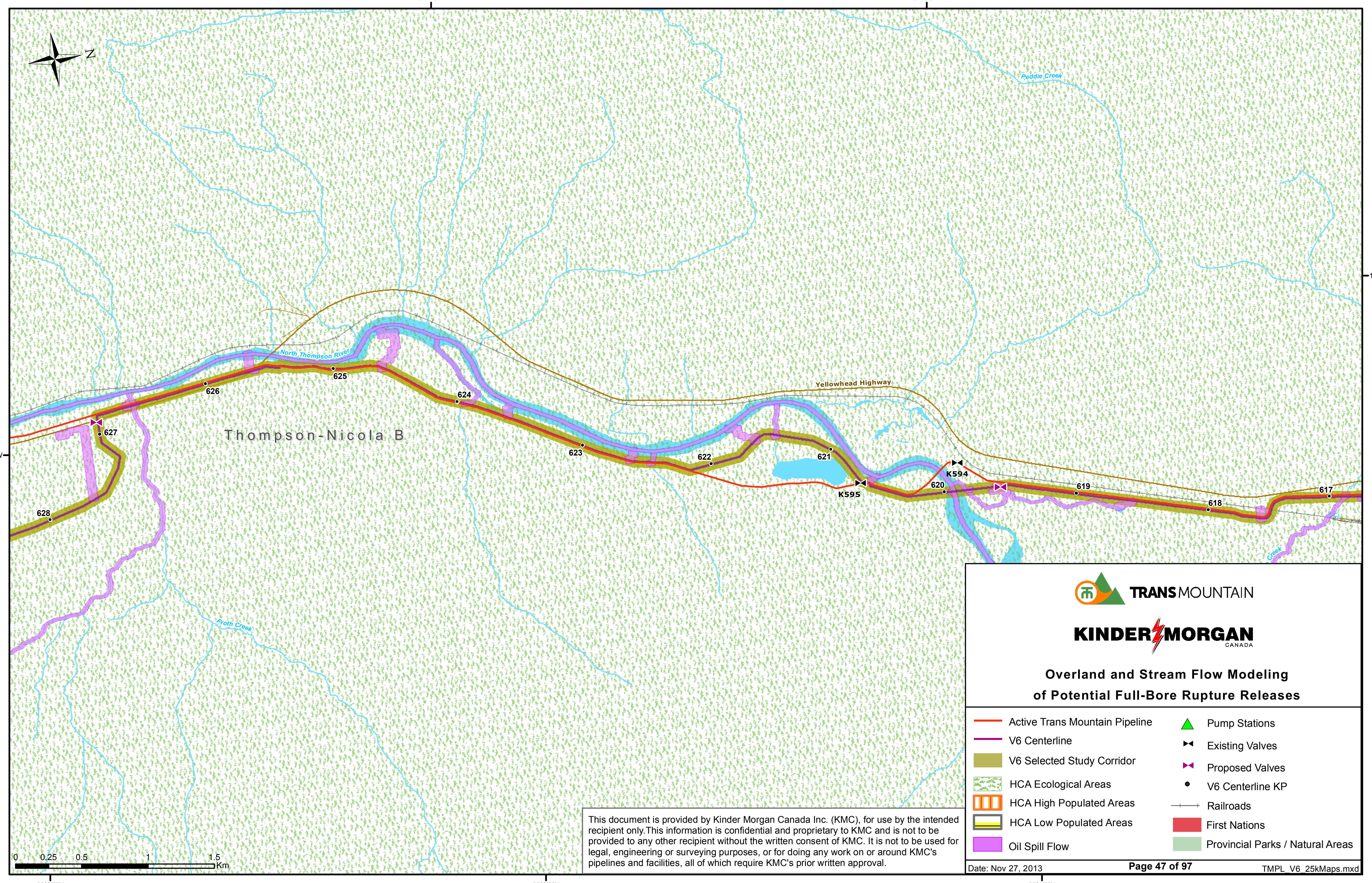


TRANS MOUNTAIN

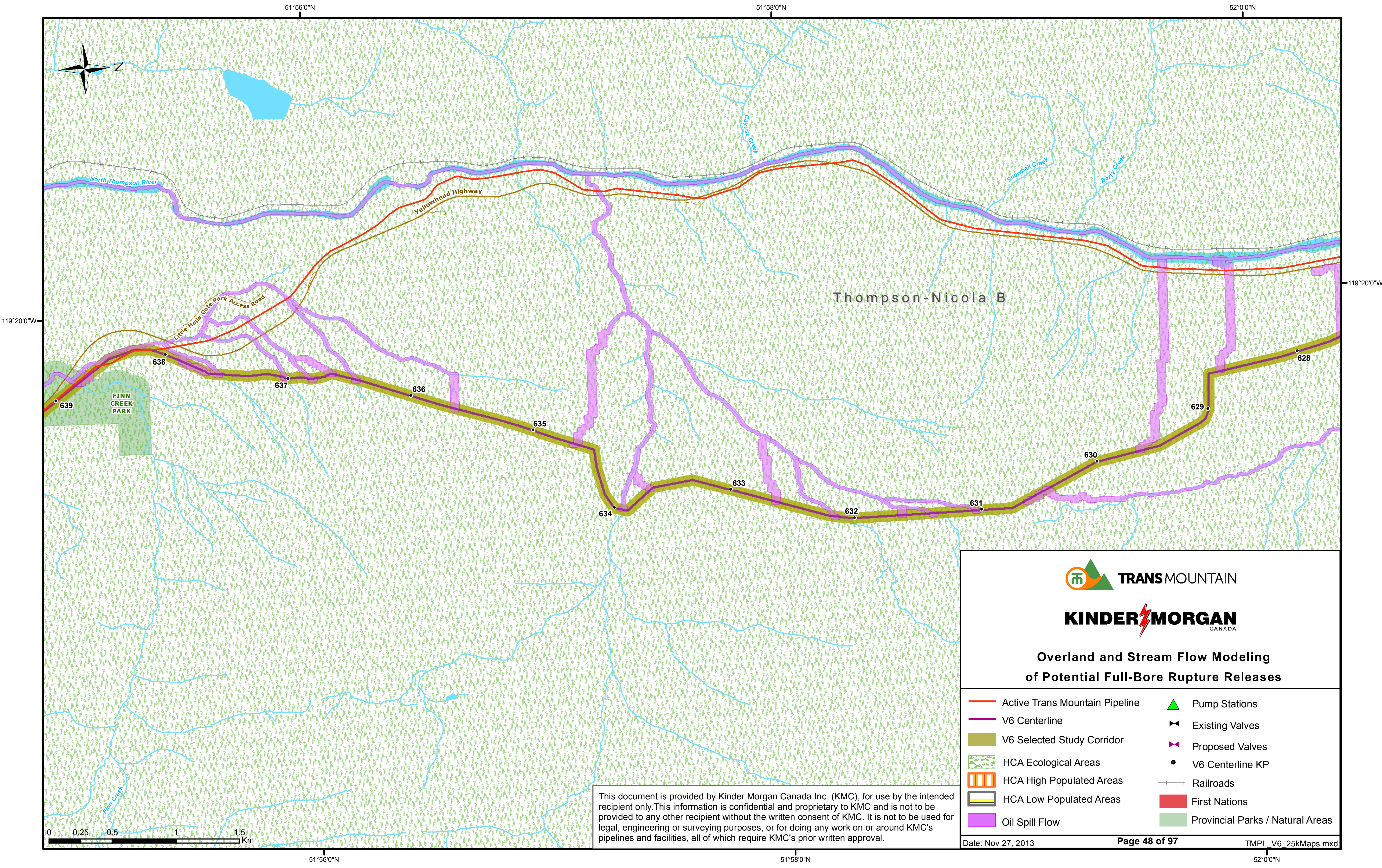
KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

- Active Trans Mountain Pipeline
- V6 Centerline
- V6 Selected Study Corridor
- HCA Ecological Areas
- HCA High Populated Areas
- HCA Low Populated Areas
- Oil Spill Flow
- Pump Stations
- Existing Valves
- Proposed Valves
- V6 Centerline KP
- Railroads
- First Nations
- Provincial Parks / Natural Areas

Date: Nov 27, 2013

TMPL_V6_25kMaps.mxd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51°58'0"N
52°0'0"N
119°20'0"W
N
North Thompson River
Yellowhead Highway
Little Hells Gate Park Access Road
Coyote Creek
Snowball Creek
Berry Creek
Finn Creek
FINN CREEK PARK
Thompson-Nicola B
639
638
637
636
635
634
633
632
631
630
629
628
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
KINDER MORGAN CANADA
Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases
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V6 Centerline KP
Railroads
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Provincial Parks / Natural Areas
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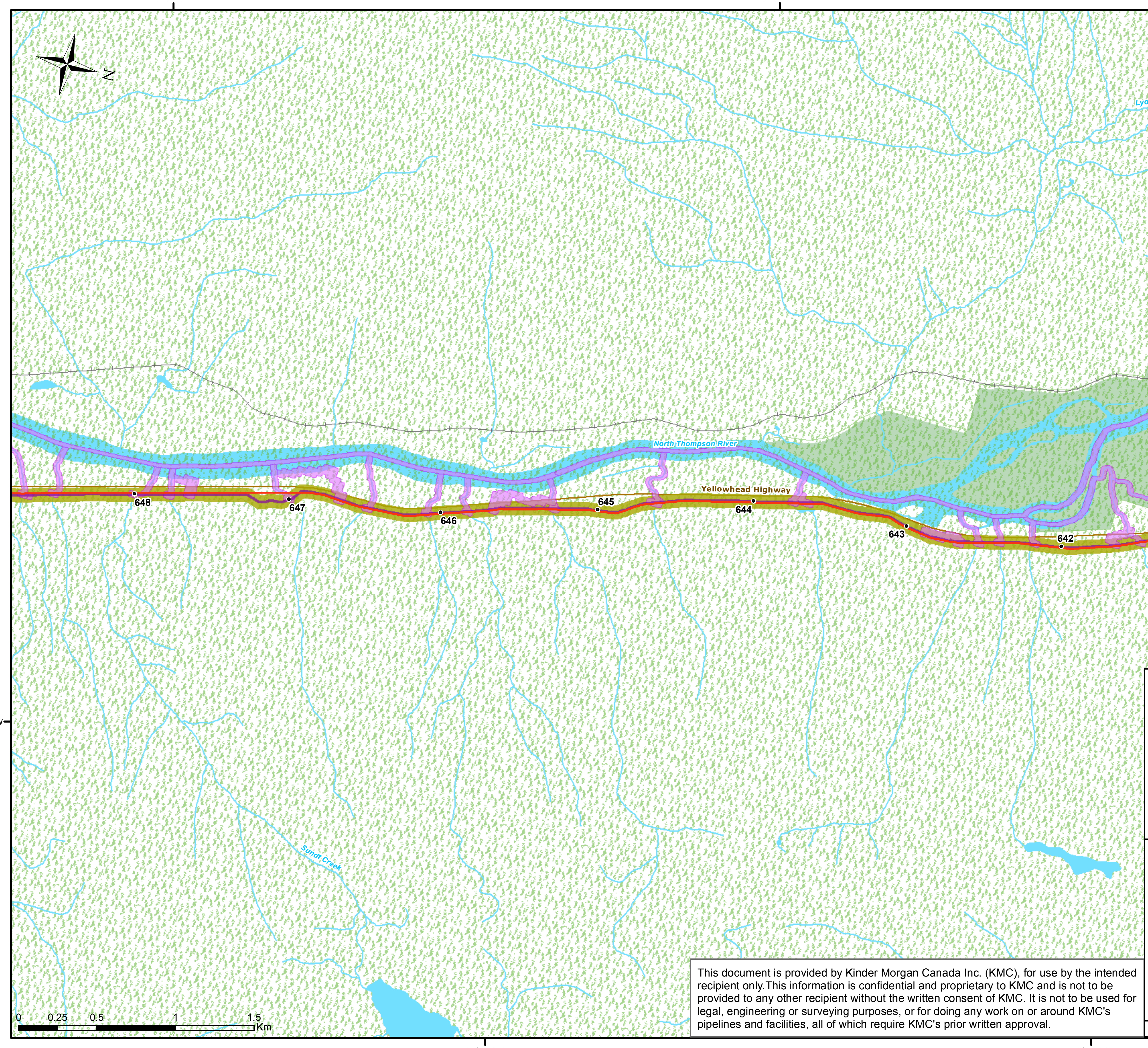

TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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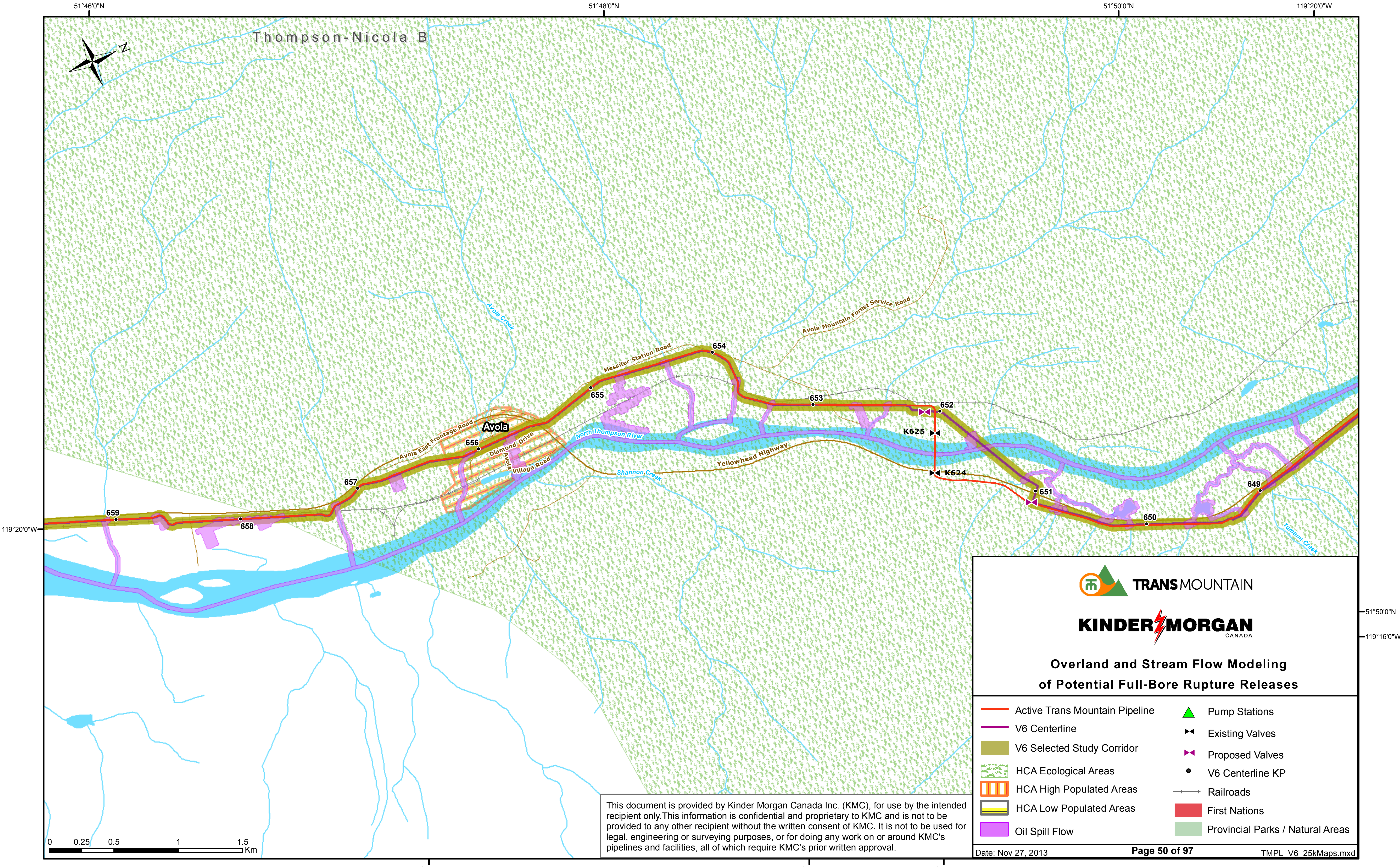
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51°50'0"N
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Thompson-Nicola B
N
Avola
Avola Creek
Messiter Station Road
Avola Mountain Forest Service Road
Avola East Frontage Road
Diamond Drive
Avola Village Road
North Thompson River
Yellowhead Highway
Shannon Creek
Tumtum Creek
659
658
657
656
655
654
653
652
651
650
649
K625
K624
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KINDER MORGAN
CANADA
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0 0.25 0.5 1 1.5
Km
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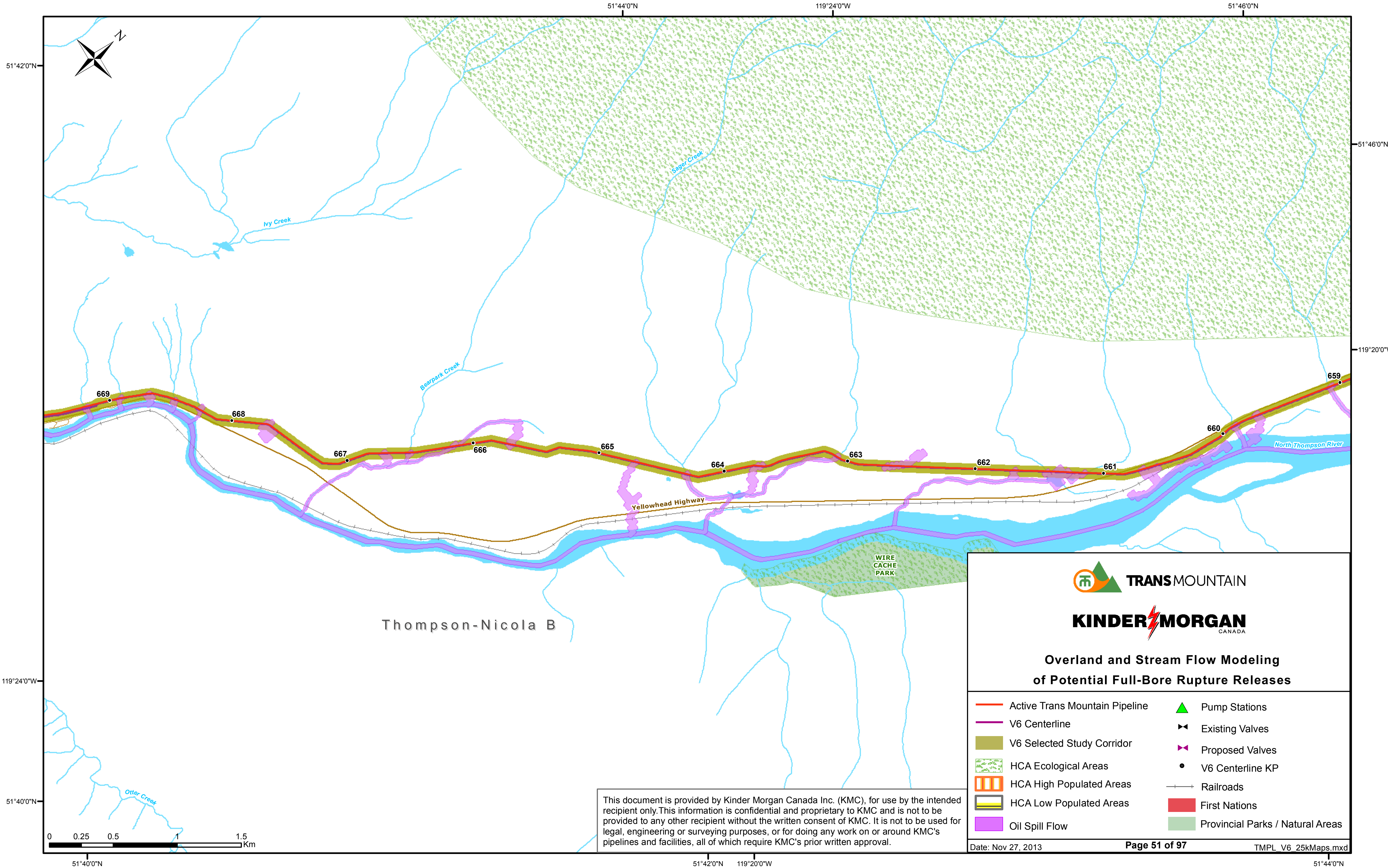

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51°40'0"N
51°40'0"N
51°42'0"N
119°20'0"W
51°44'0"N
N
Ivy Creek
Sager Creek
Bearpark Creek
Yellowhead Highway
North Thompson River
Otter Creek
WIRE CACHE PARK
Thompson-Nicola B
669
668
667
666
665
664
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662
661
660
659
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
KINDER MORGAN CANADA
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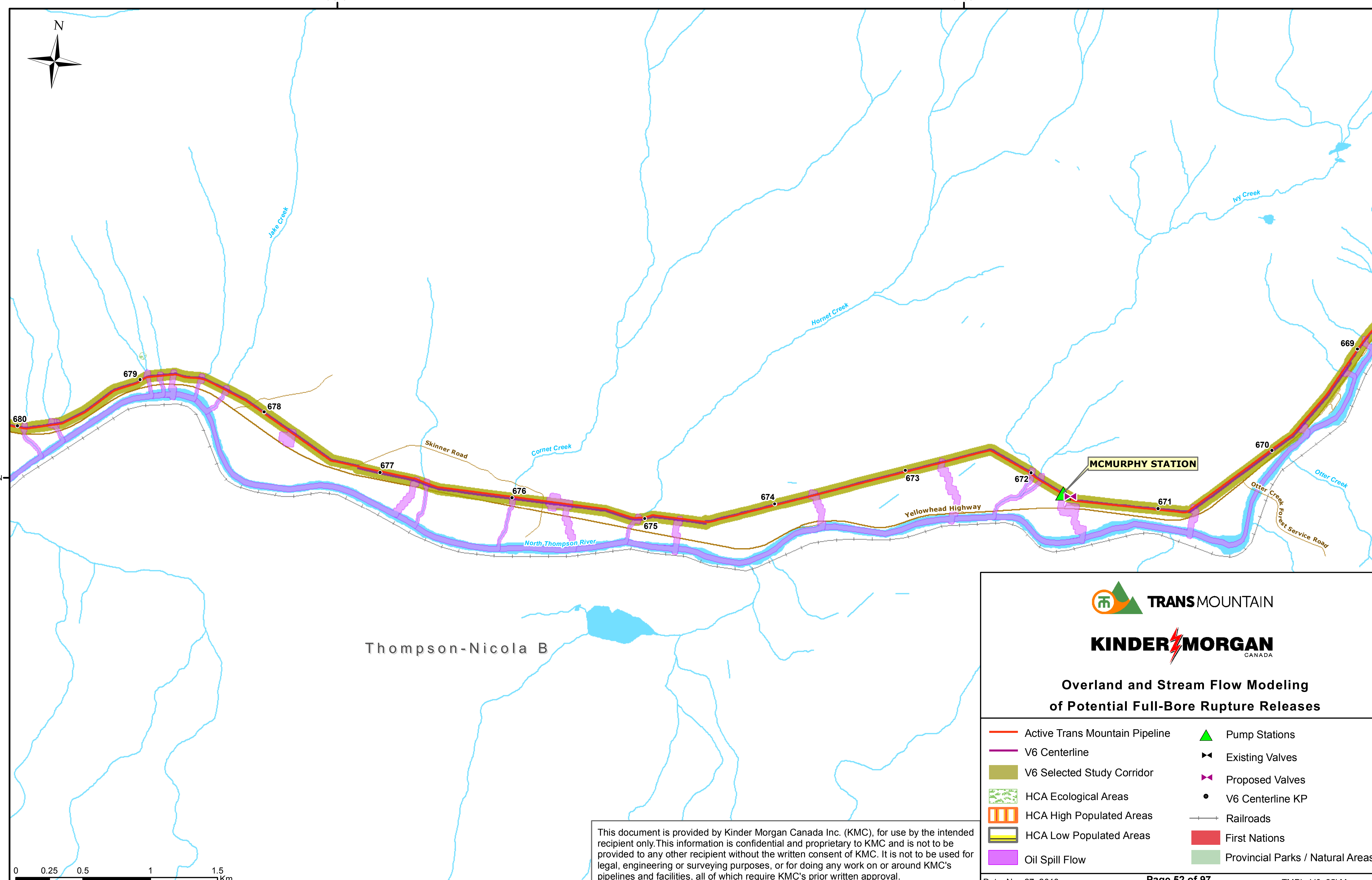


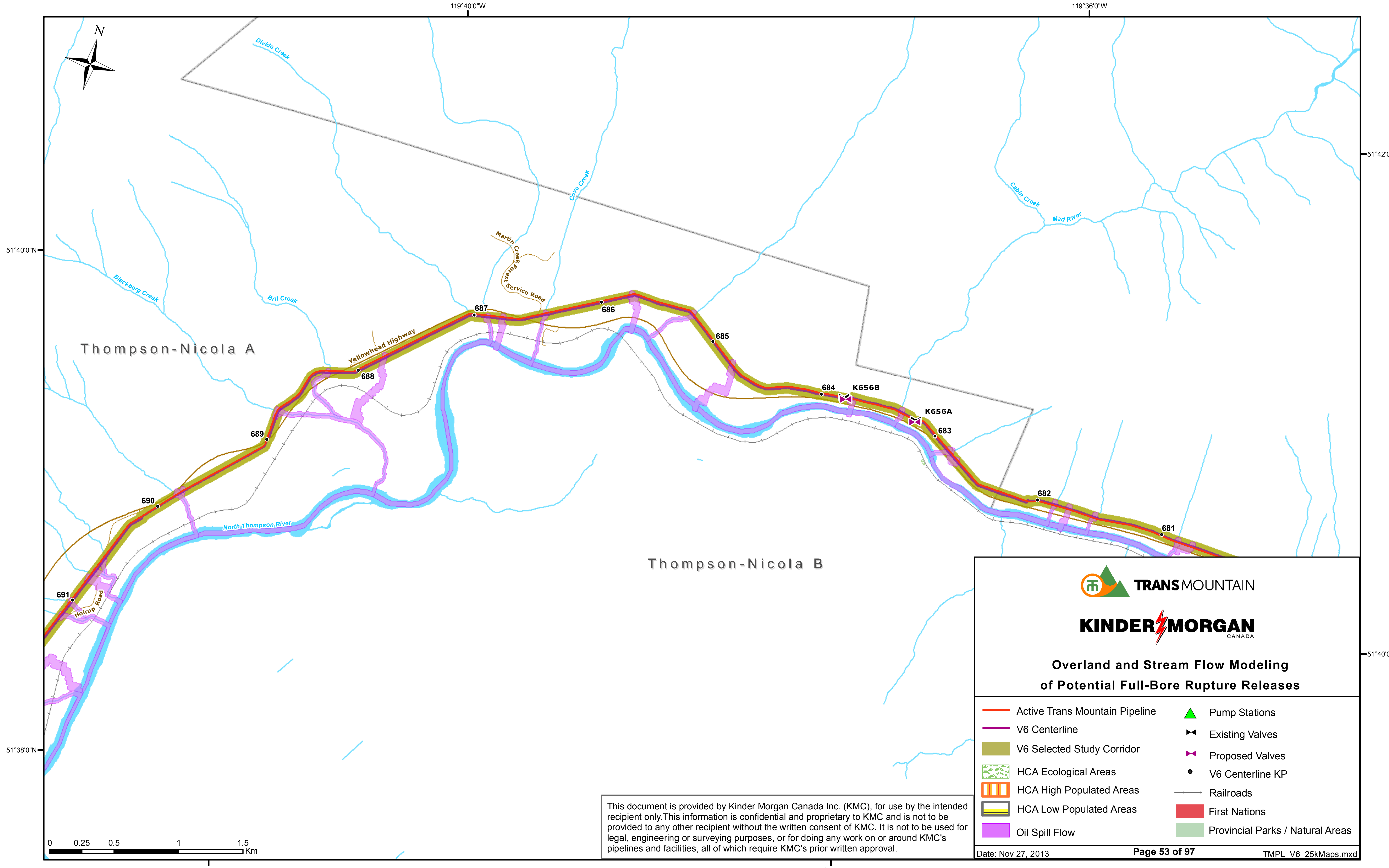
TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

Date: Nov 27, 2013

TMPL_V6_25kMaps.mxd



TRANSMOUNTAIN

KINDER MORGAN CANADA

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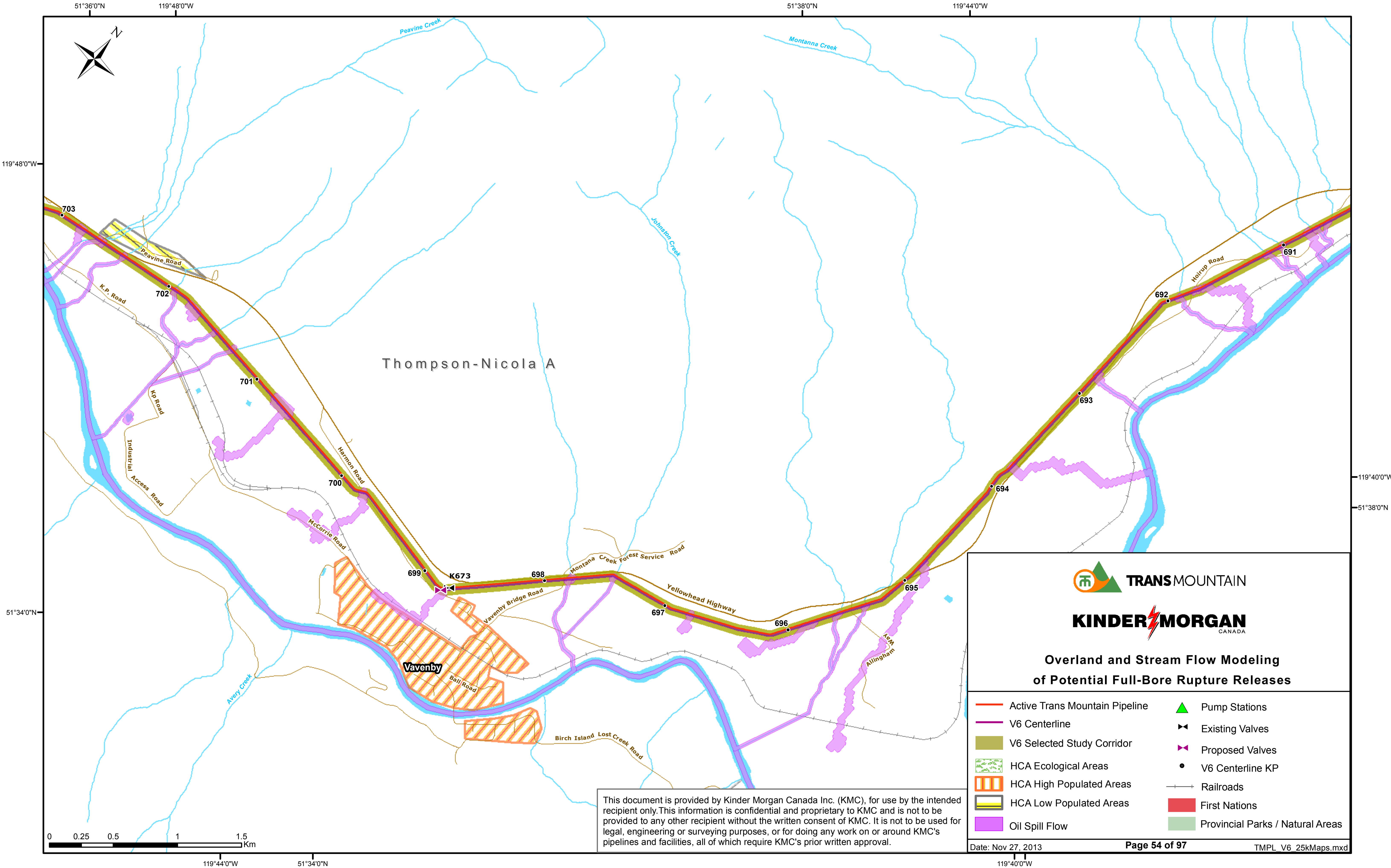
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51°34'0"N
119°44'0"W
51°34'0"N
119°40'0"W
N
Peavine Creek
Montanna Creek
Johnston Creek
Avery Creek
Thompson-Nicola A
Vavenby
Peavine Road
K.P. Road
Kp Road
Industrial Access Road
Harmon Road
McCorrie Road
Vavenby Bridge Road
Ball Road
Birch Island Lost Creek Road
Montana Creek Forest Service Road
Yellowhead Highway
Allingham Way
Hoirup Road
703
702
701
700
699
K673
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0 0.25 0.5 1 1.5 Km
TRANSMOUNTAIN
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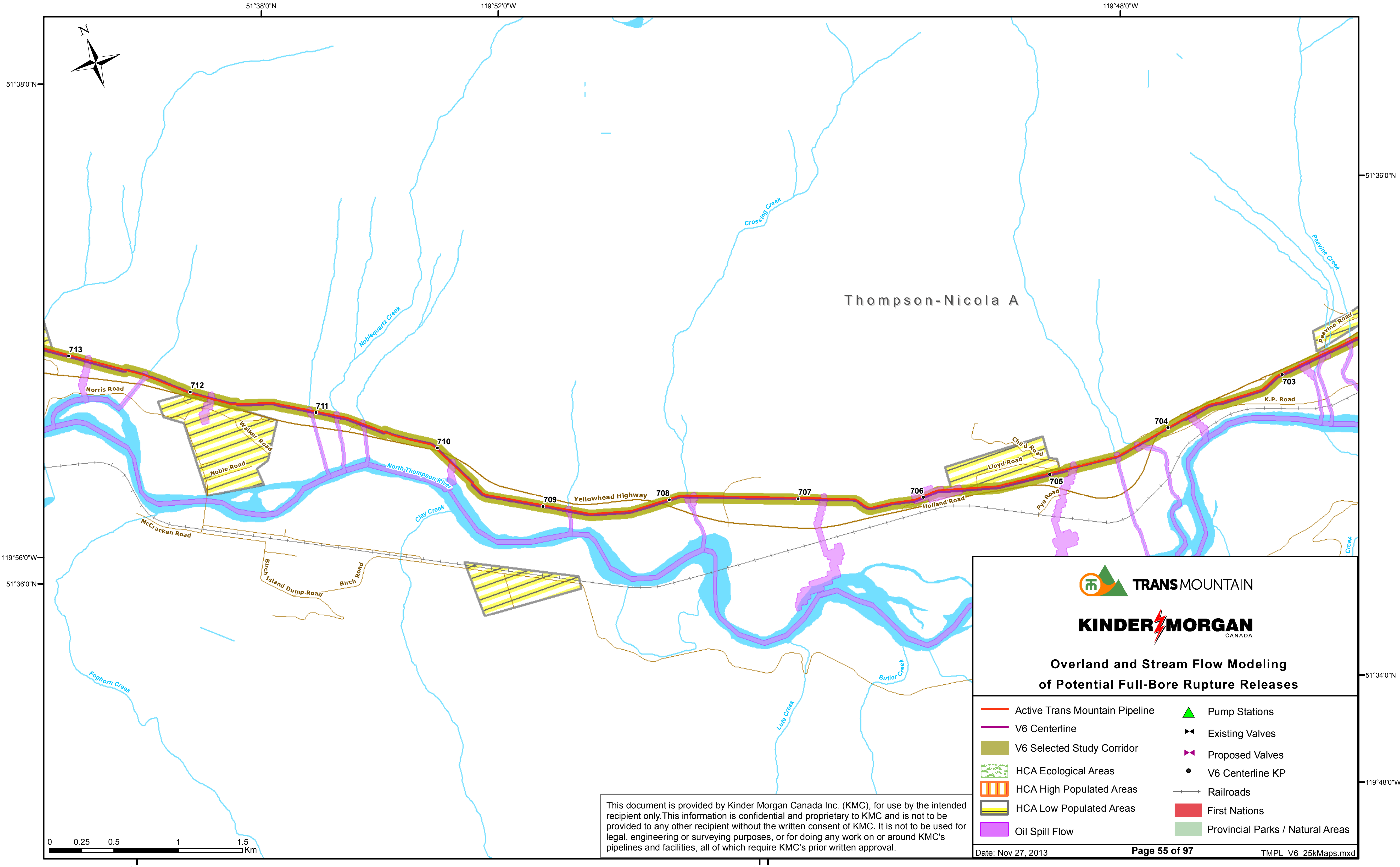

TRANS MOUNTAIN

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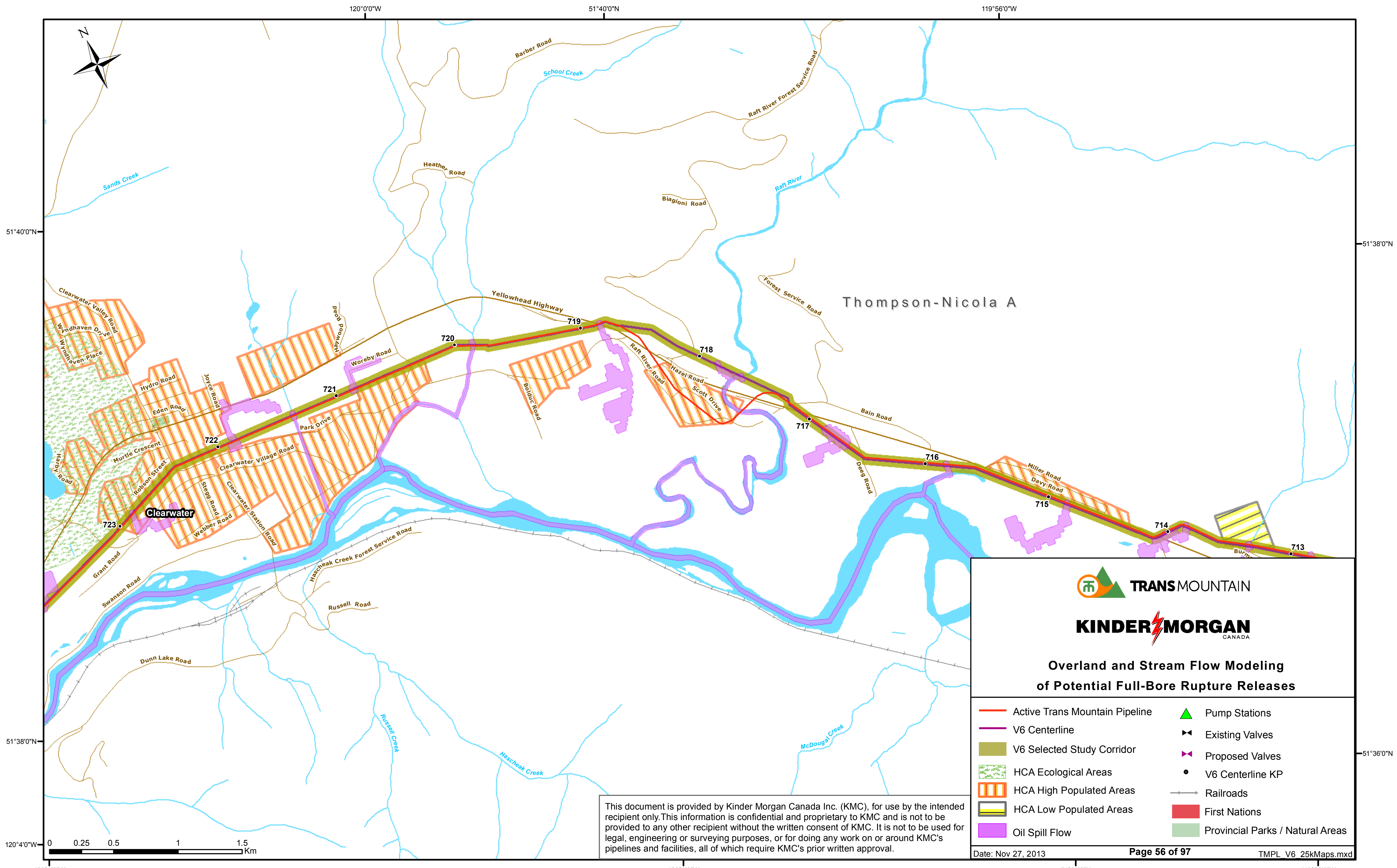

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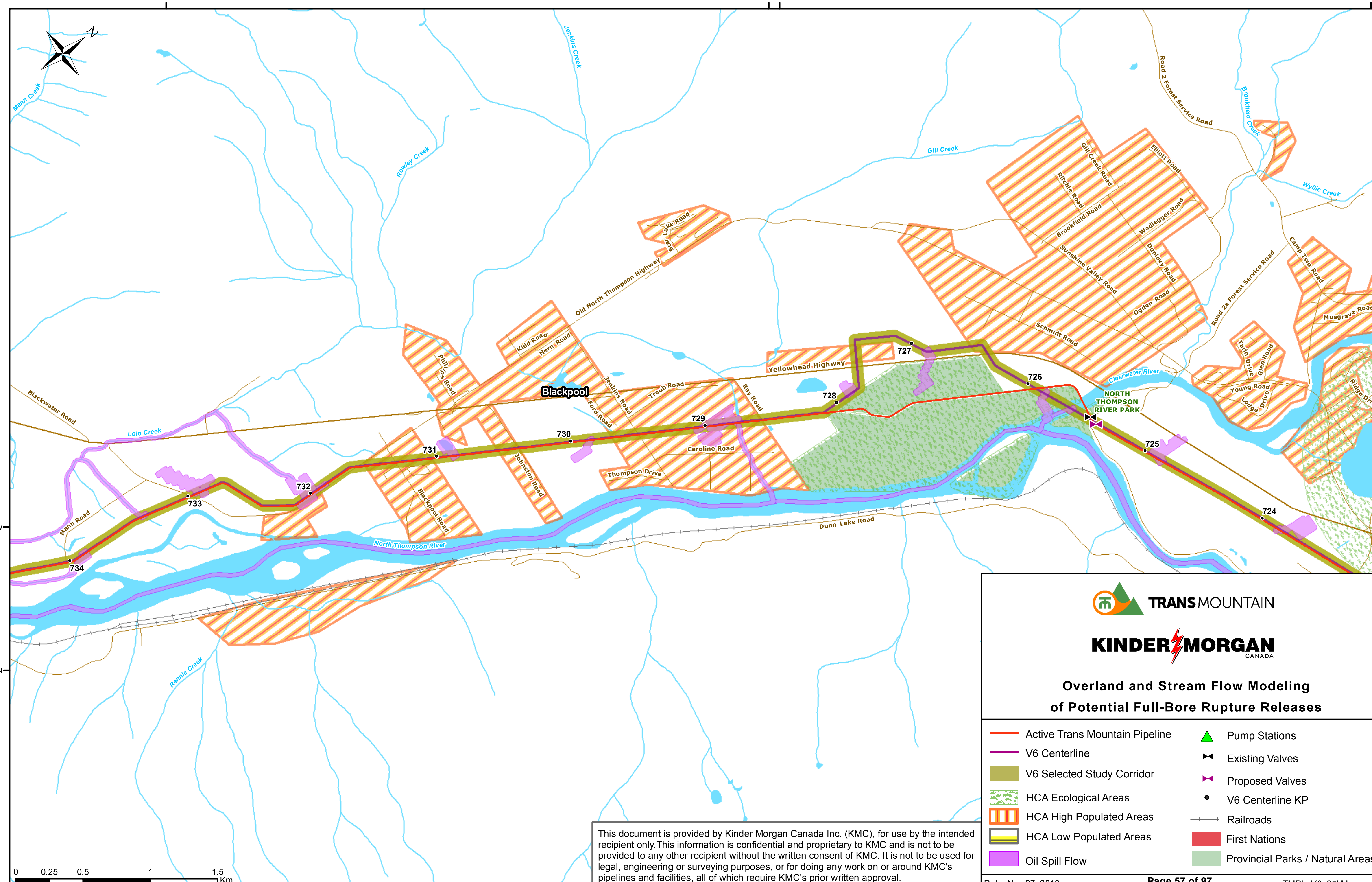

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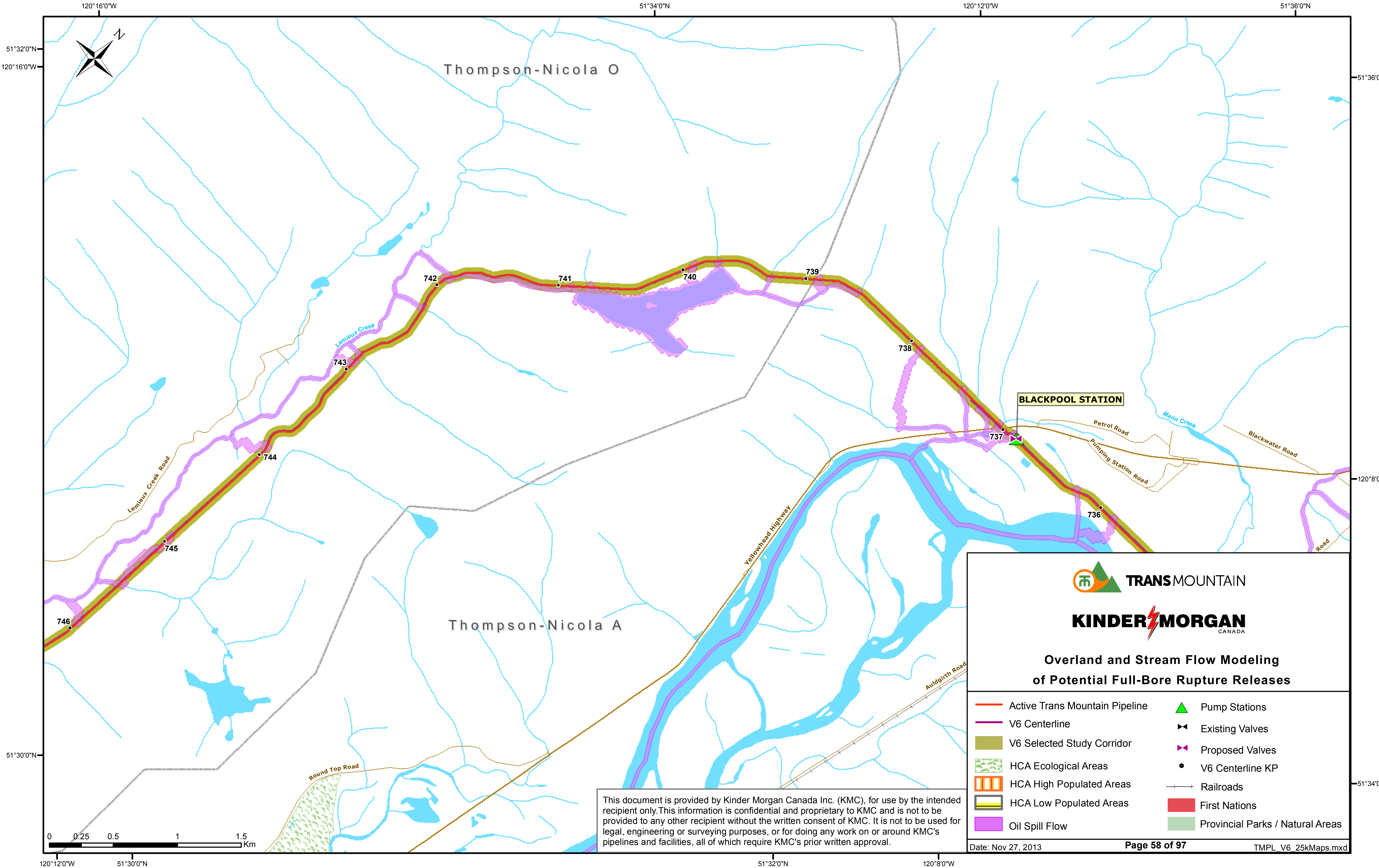

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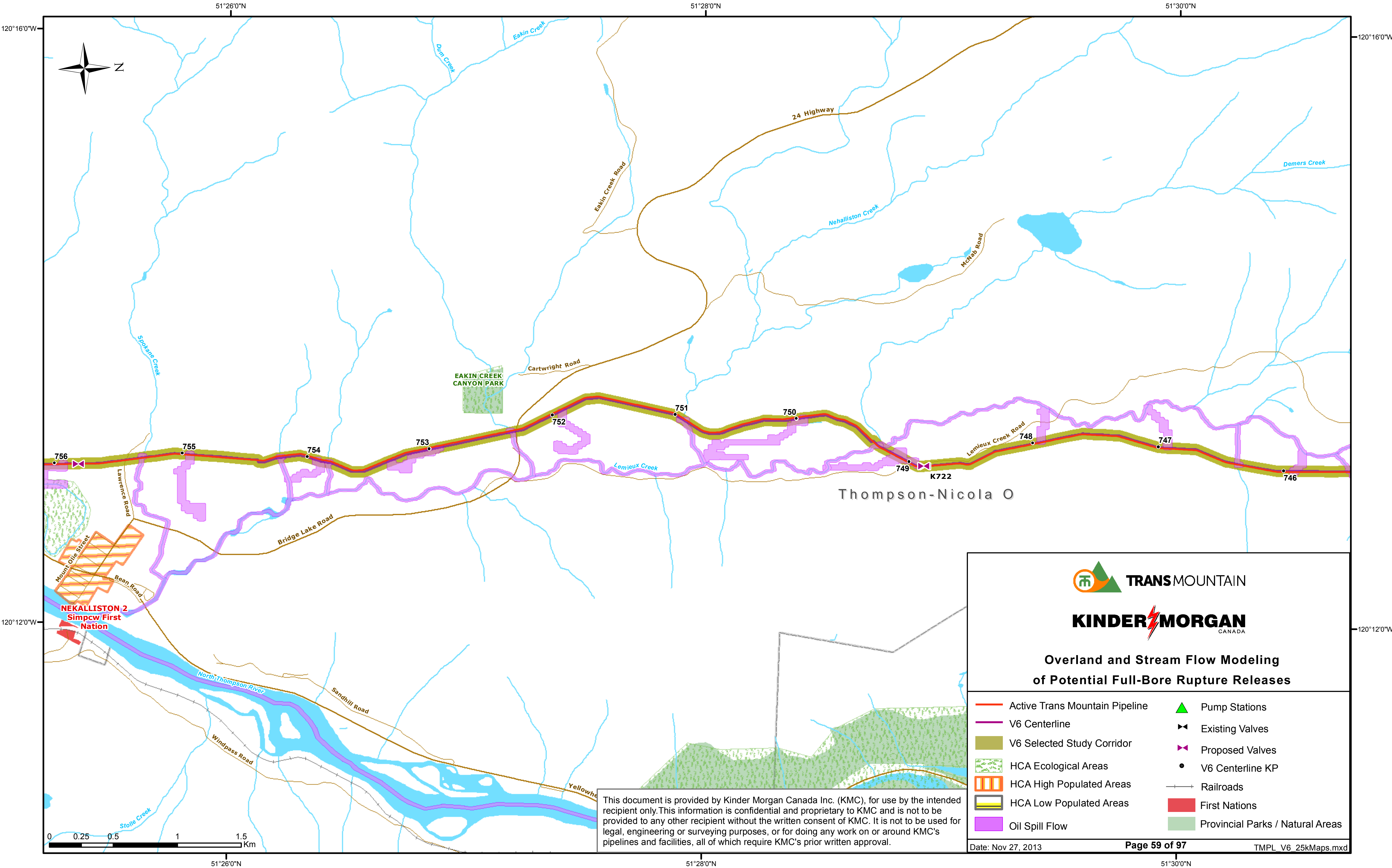
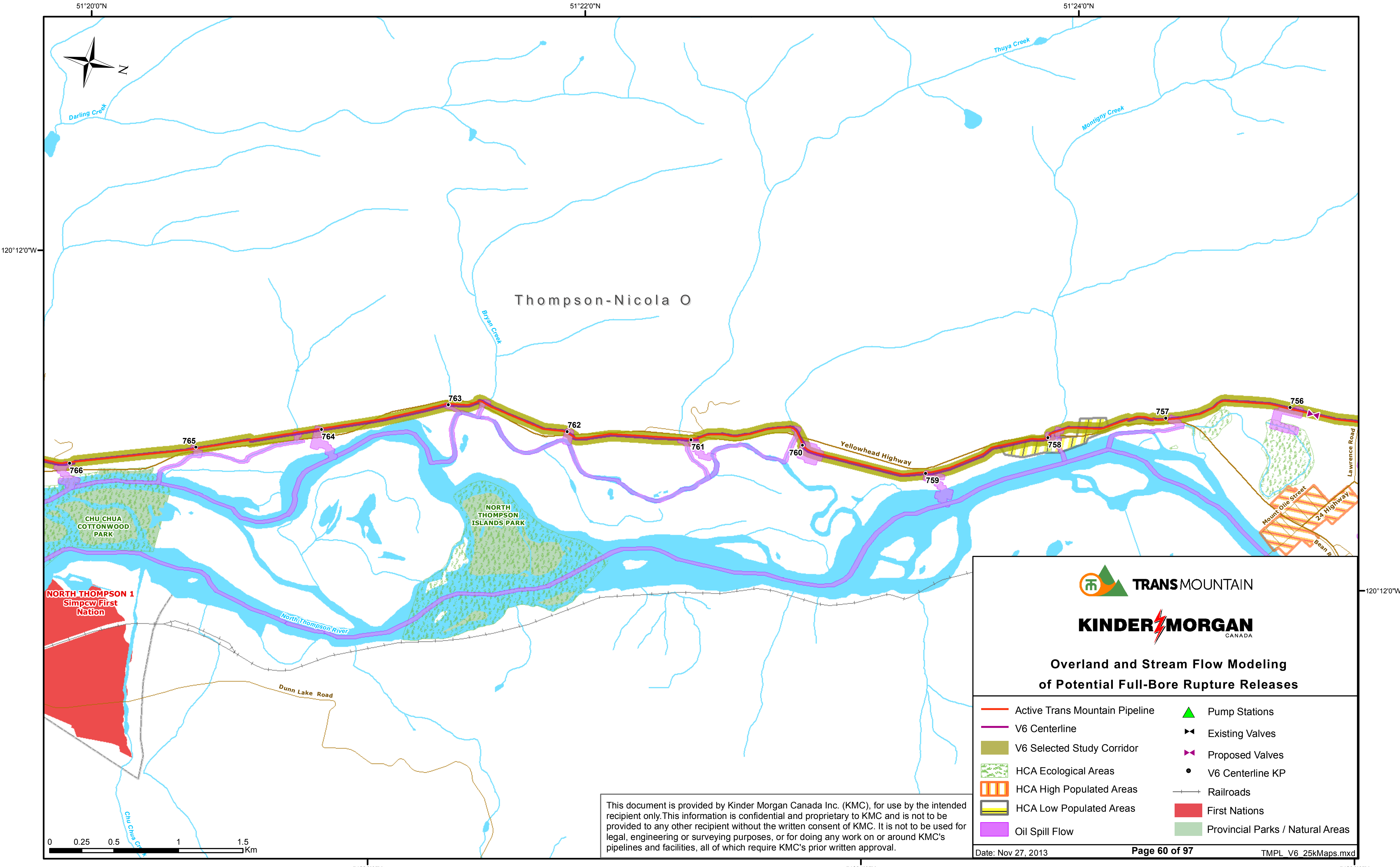


TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

Active Trans Mountain Pipeline	Pump Stations
V6 Centerline	Existing Valves
V6 Selected Study Corridor	Proposed Valves
HCA Ecological Areas	V6 Centerline KP
HCA High Populated Areas	Railroads
HCA Low Populated Areas	First Nations
Oil Spill Flow	Provincial Parks / Natural Areas



TRANS MOUNTAIN

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Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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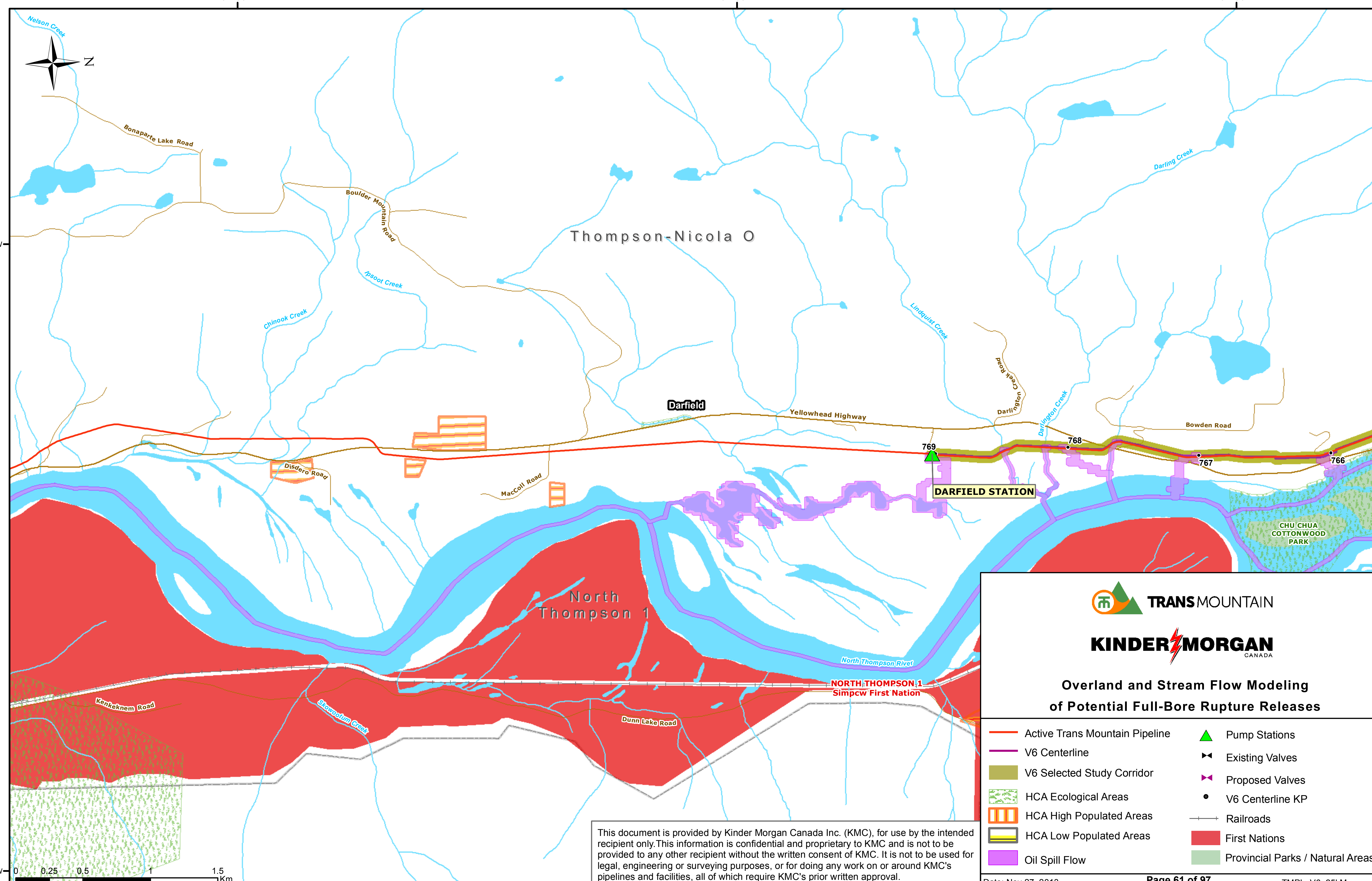

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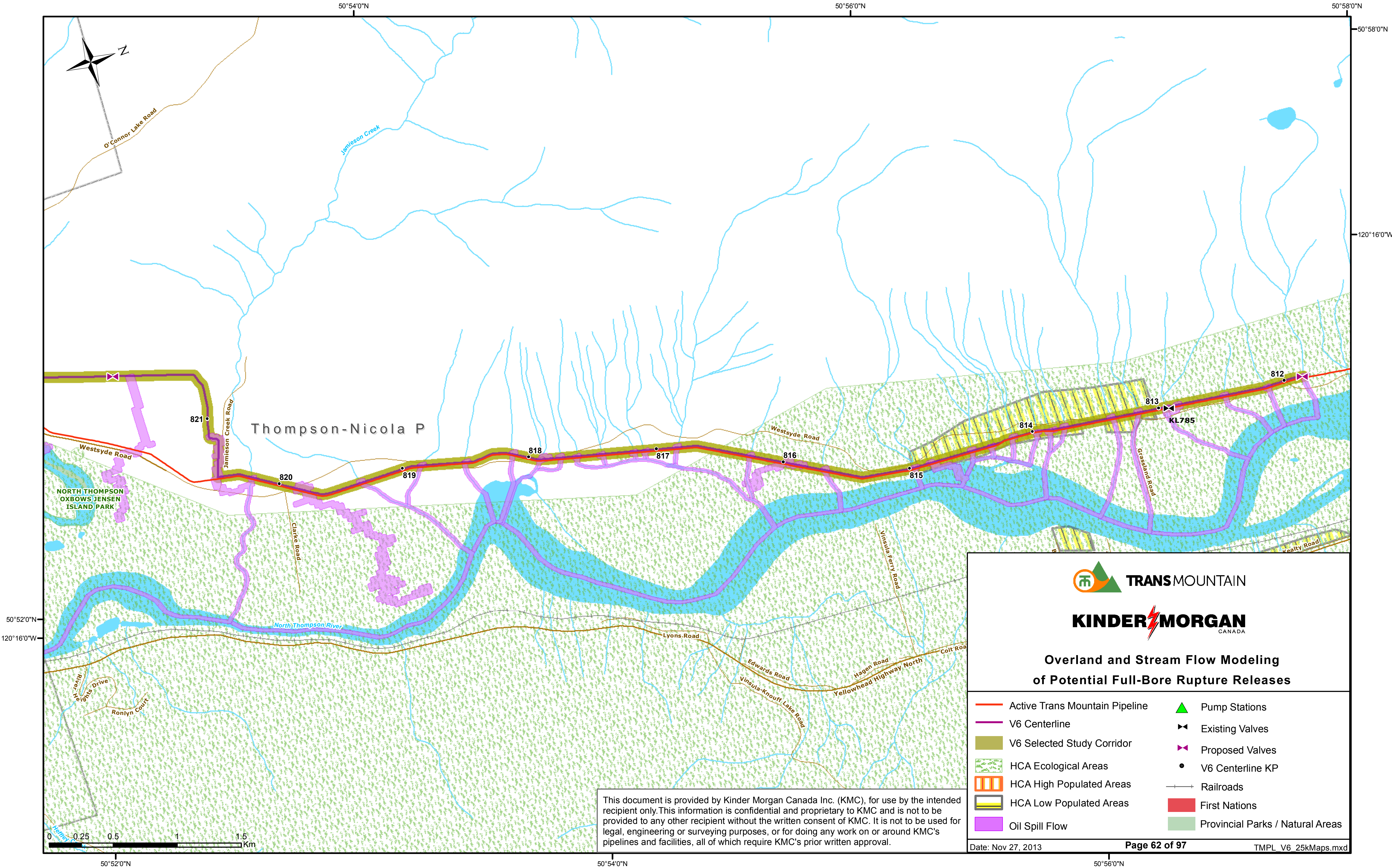

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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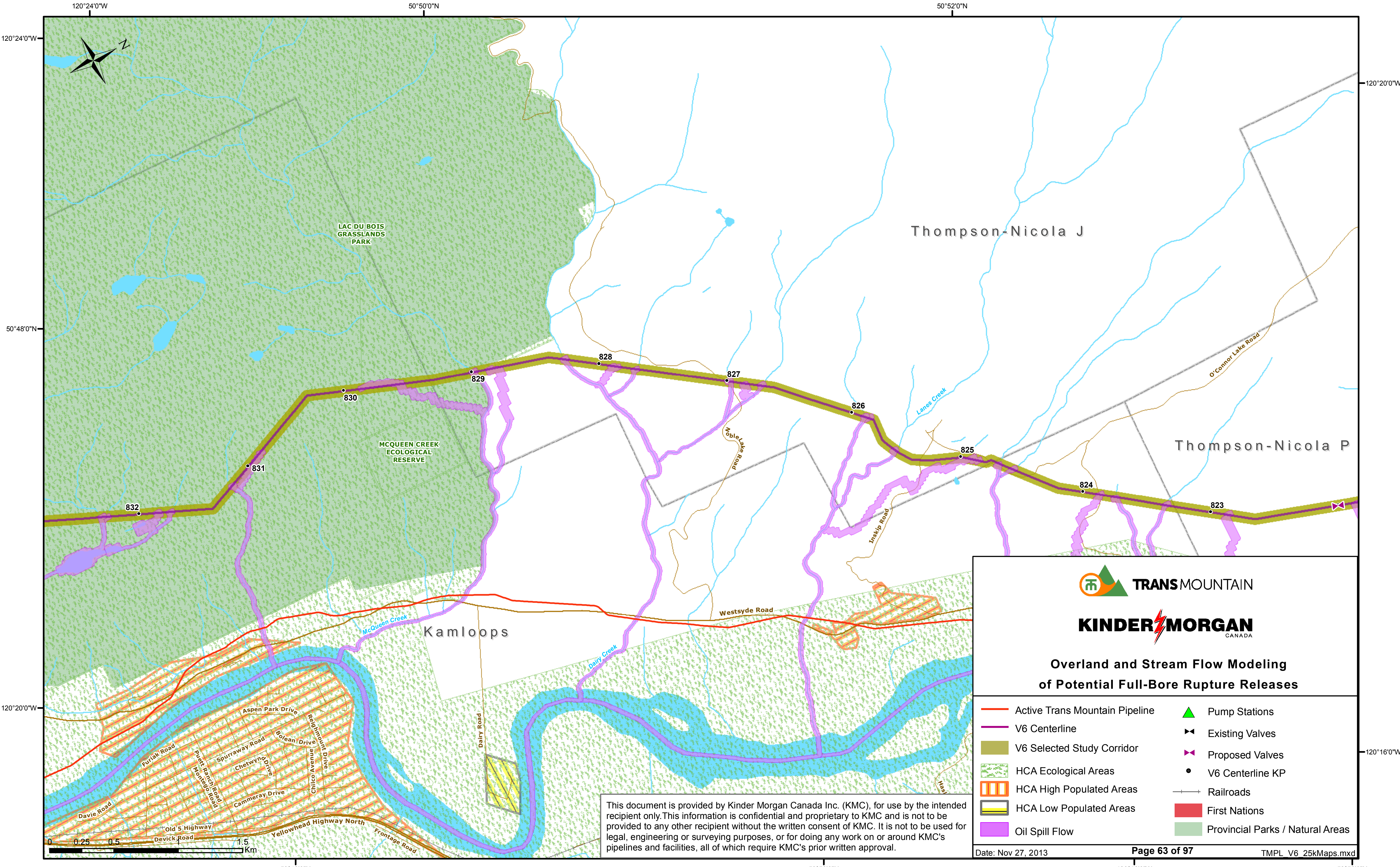

120°24'0"W
50°50'0"N
50°52'0"N
120°20'0"W
50°48'0"N
120°16'0"W
LAC DU BOIS GRASSLANDS PARK
MCQUEEN CREEK ECOLOGICAL RESERVE
Thompson-Nicola J
Thompson-Nicola P
Kamloops
832
831
830
829
828
827
826
825
824
823
McQueen Creek
Dairy Creek
Lanes Creek
Noble Lake Road
Inskip Road
O'Connor Lake Road
Westsyde Road
Dairy Road
Aspen Park Drive
Bolean Drive
Reighmount Drive
Chilco Avenue
Furlak Road
Spurraway Road
Chetwynd Drive
Puett Ranch Road
Montego Road
Cammeray Drive
Davie Road
Old 5 Highway
Devick Road
Yellowhead Highway North
Frontage Road
0 0.25 0.5 1 1.5 Km
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HCA Low Populated Areas
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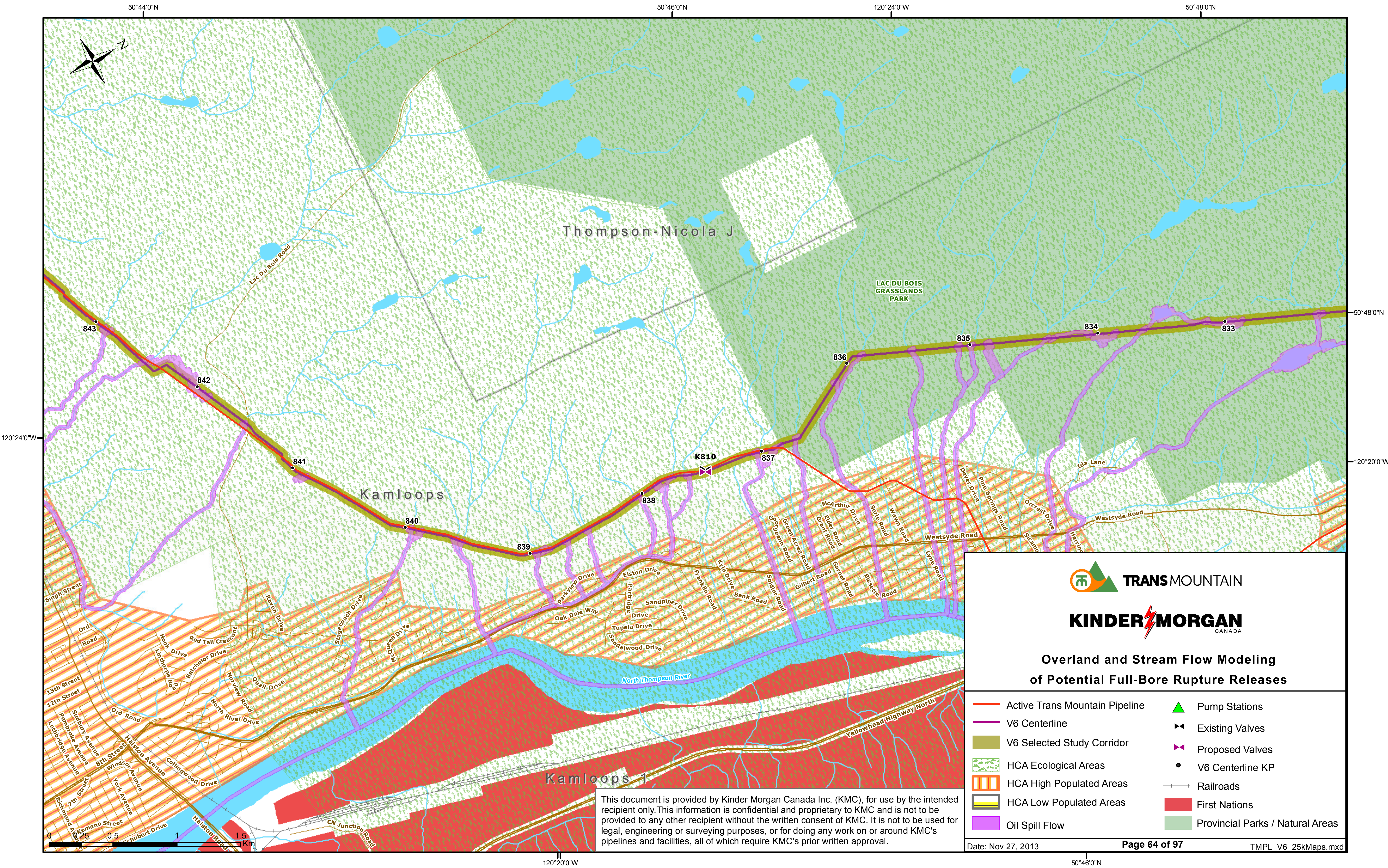
Railroads
First Nations
Provincial Parks / Natural Areas



TRANS MOUNTAIN

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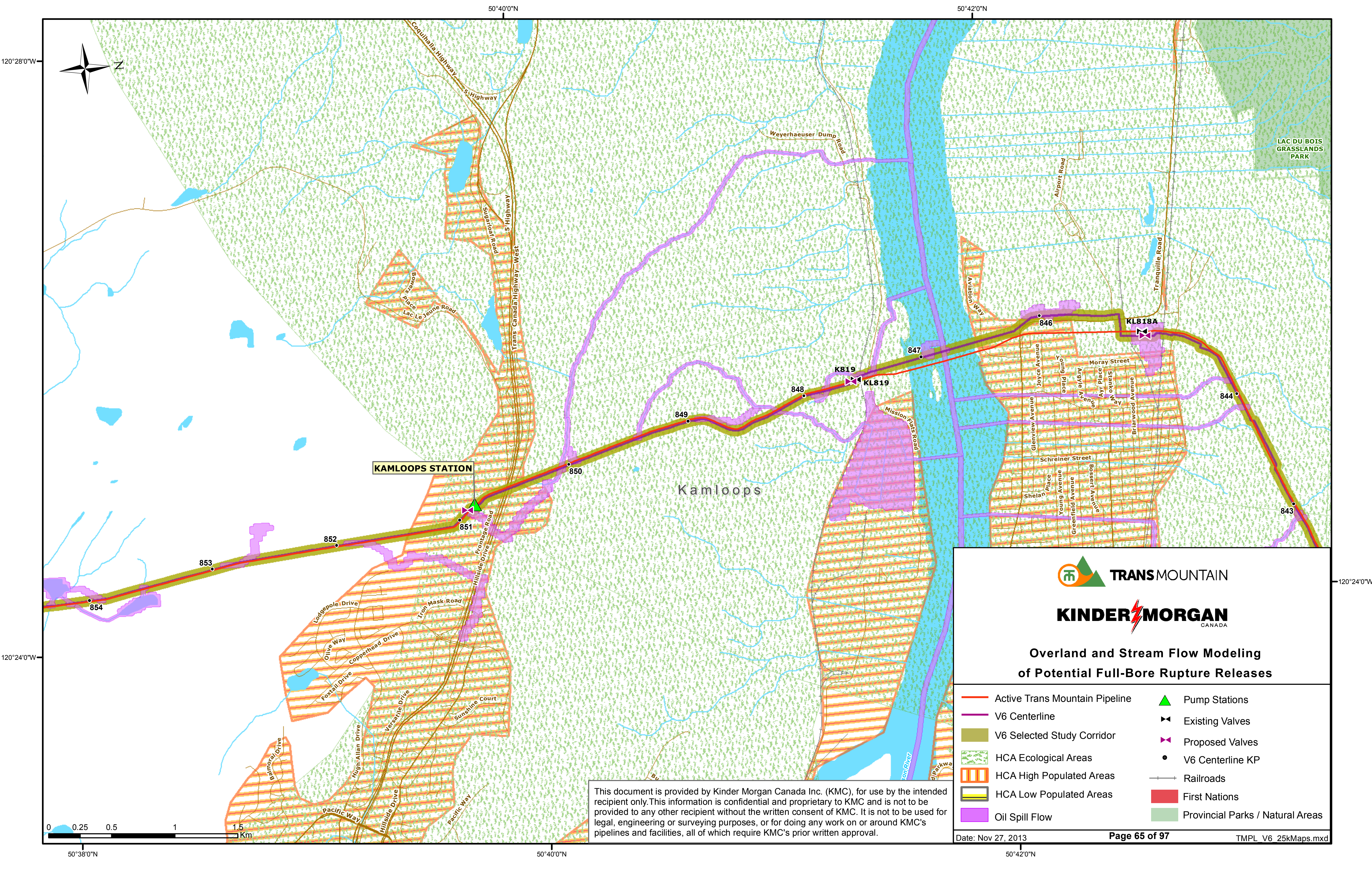

50°40'0"N
50°42'0"N
120°28'0"W
120°24'0"W
50°38'0"N
N
Coquihalla Highway
5 Highway
Sugarloaf Road
Trans Canada Highway West
Bowers Place
Lac Le Jeune Road
Weyerhaeuser Dump Road
Airport Road
Tranquille Road
Aviation Way
LAC DU BOIS GRASSLANDS PARK
KAMLOOPS STATION
Kamloops
K819
KL819
KL818A
Mission Flats Road
Moray Street
Joyce Avenue
Young Place
Argyle Avenue
Ayr Place
Stanko Way
Briarwood Avenue
Glenview Avenue
Schreiner Street
Shelan Place
Young Avenue
Greenfield Avenue
Bossert Avenue
Frontage Road
Hillside Drive
Iron Mask Road
Lodgepole Drive
Olive Way
Copperhead Drive
Foxtail Drive
Versatile Drive
Sunshine Court
Hugh Allan Drive
Balmoral Drive
Pacific Way
843
844
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847
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849
850
851
852
853
854
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
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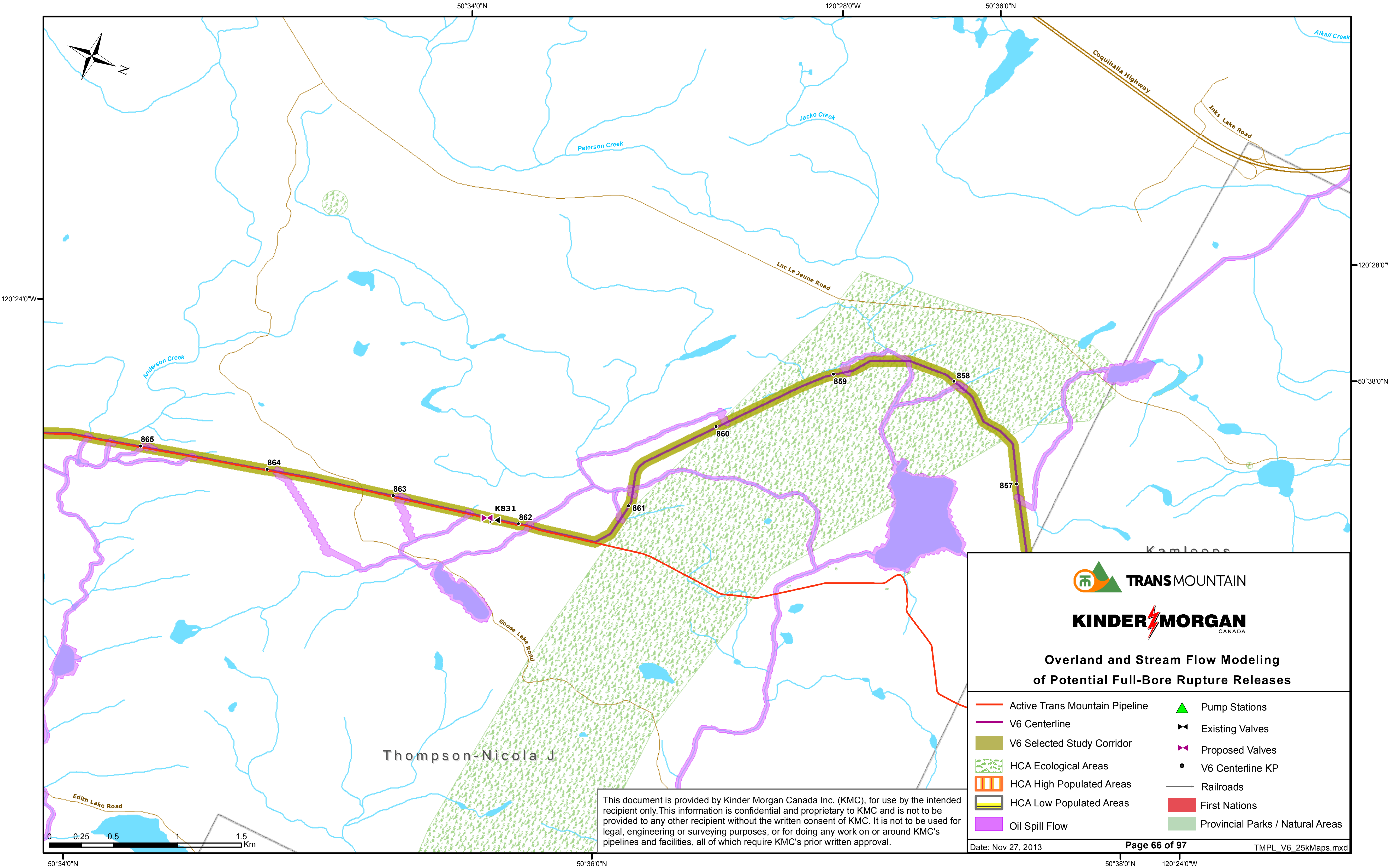

50°34'0"N
120°28'0"W
50°36'0"N
120°24'0"W
120°28'0"W
50°38'0"N
Alkali Creek
Coquihalla Highway
Inks Lake Road
Jacko Creek
Peterson Creek
Lac Le Jeune Road
Anderson Creek
Goose Lake Road
Edith Lake Road
Thompson-Nicola J
Kamloops
N
865
864
863
K831
862
861
860
859
858
857
0
0.25
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1
1.5
Km
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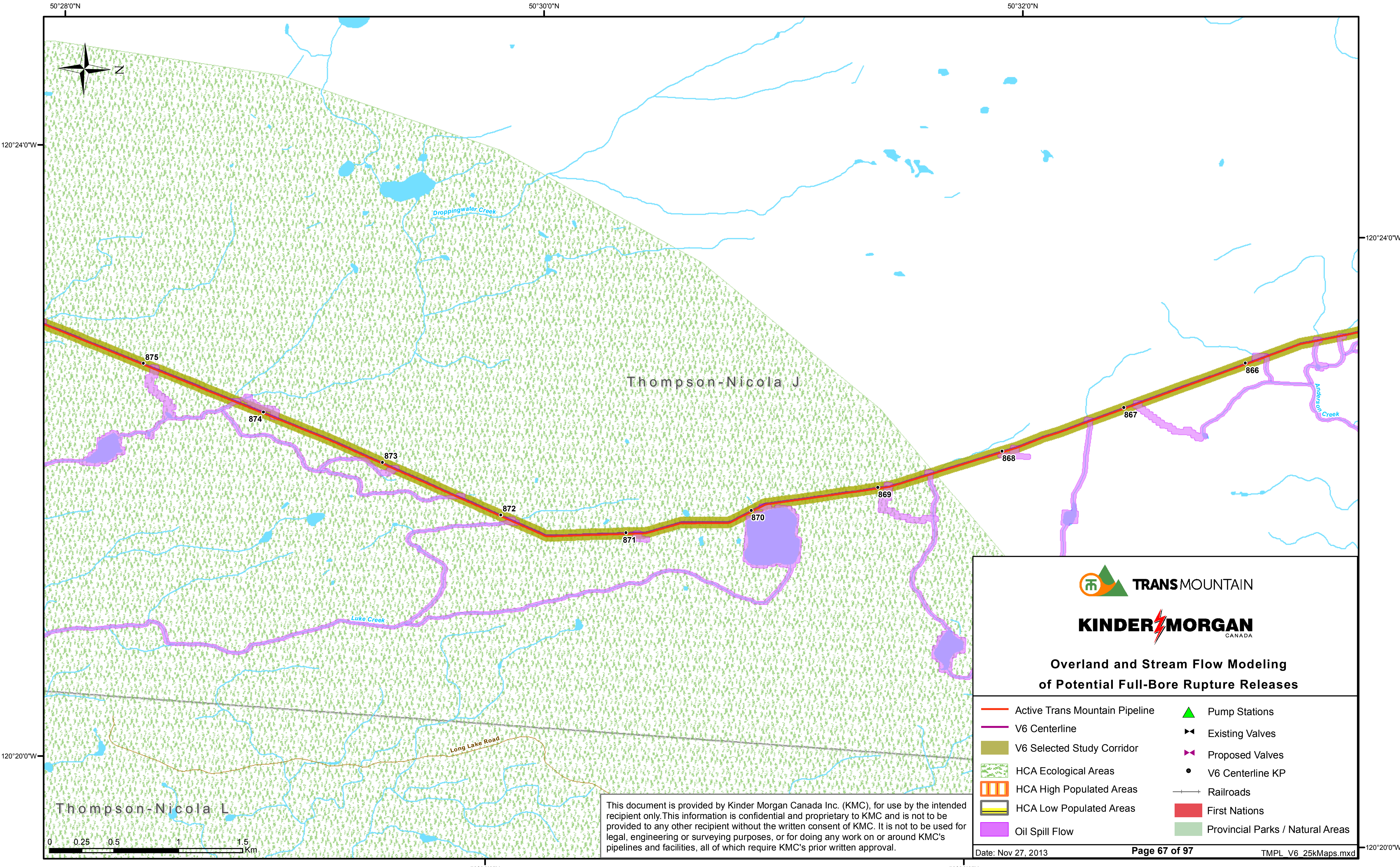
50°34'0"N
50°36'0"N
50°38'0"N
120°24'0"W


50°28'0"N
50°30'0"N
50°32'0"N
120°24'0"W
120°20'0"W
N
Droppingwater Creek
Thompson-Nicola J
Thompson-Nicola L
Luke Creek
Anderson Creek
Long Lake Road
875
874
873
872
871
870
869
868
867
866
0 0.25 0.5 1 1.5 Km
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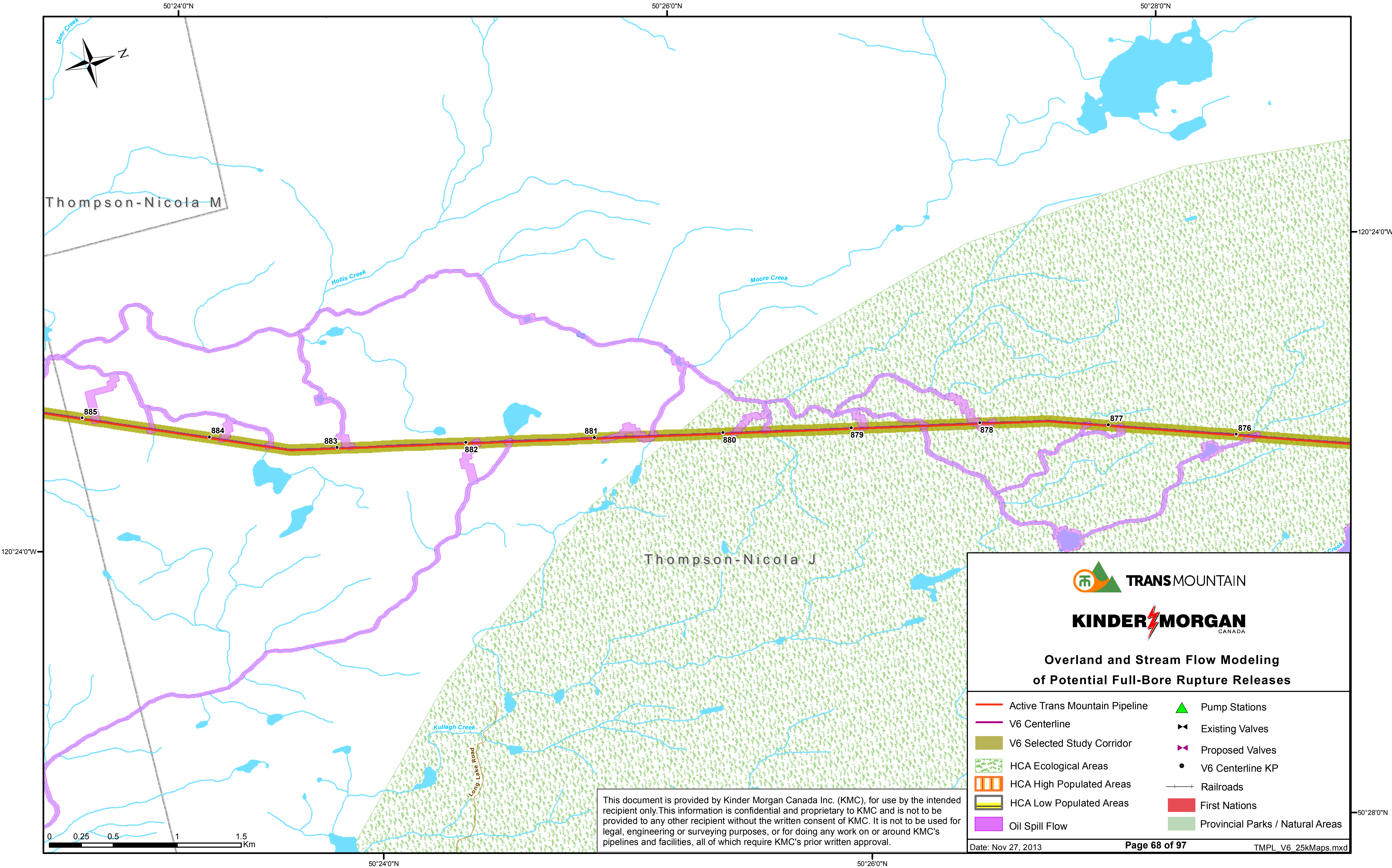

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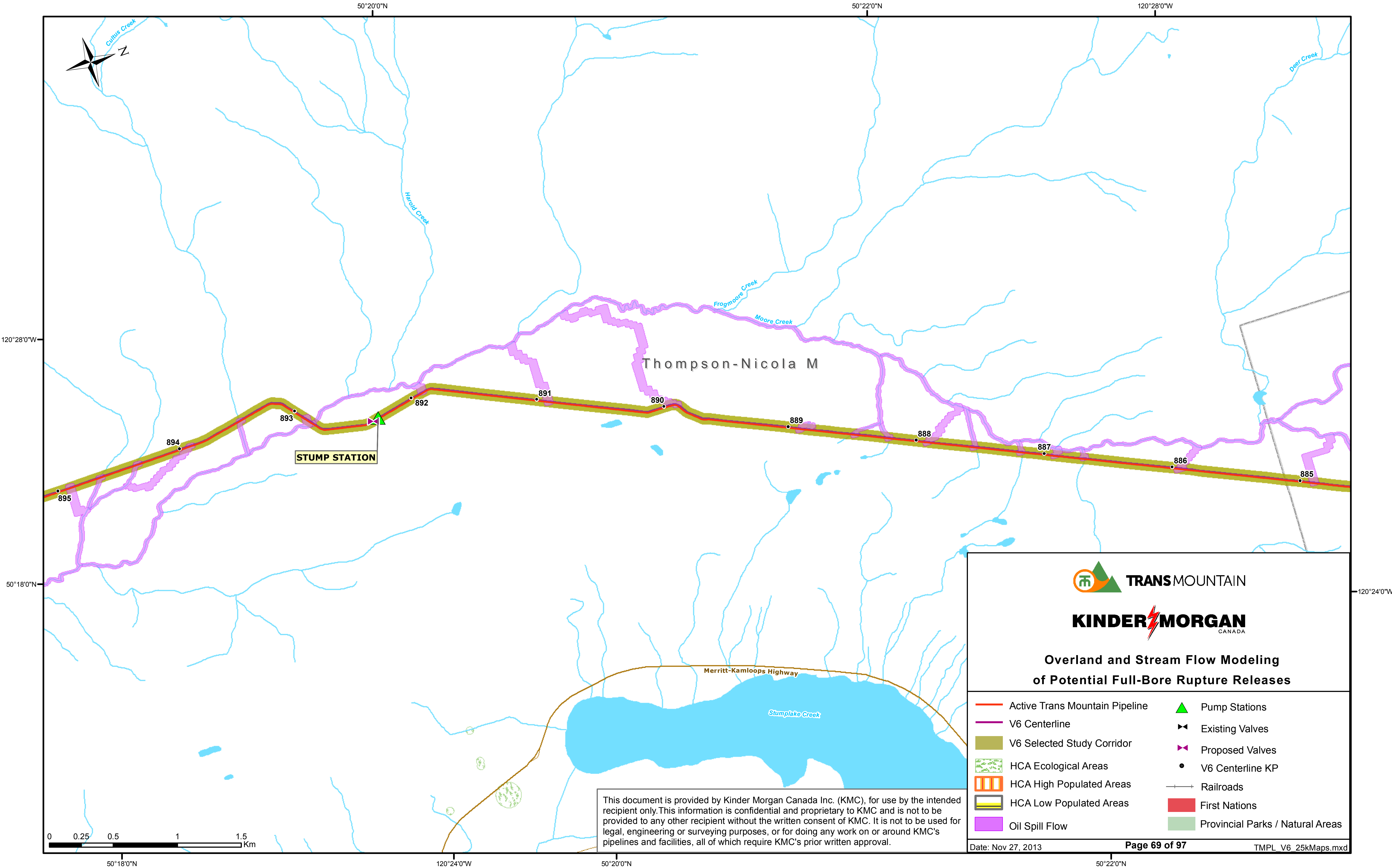

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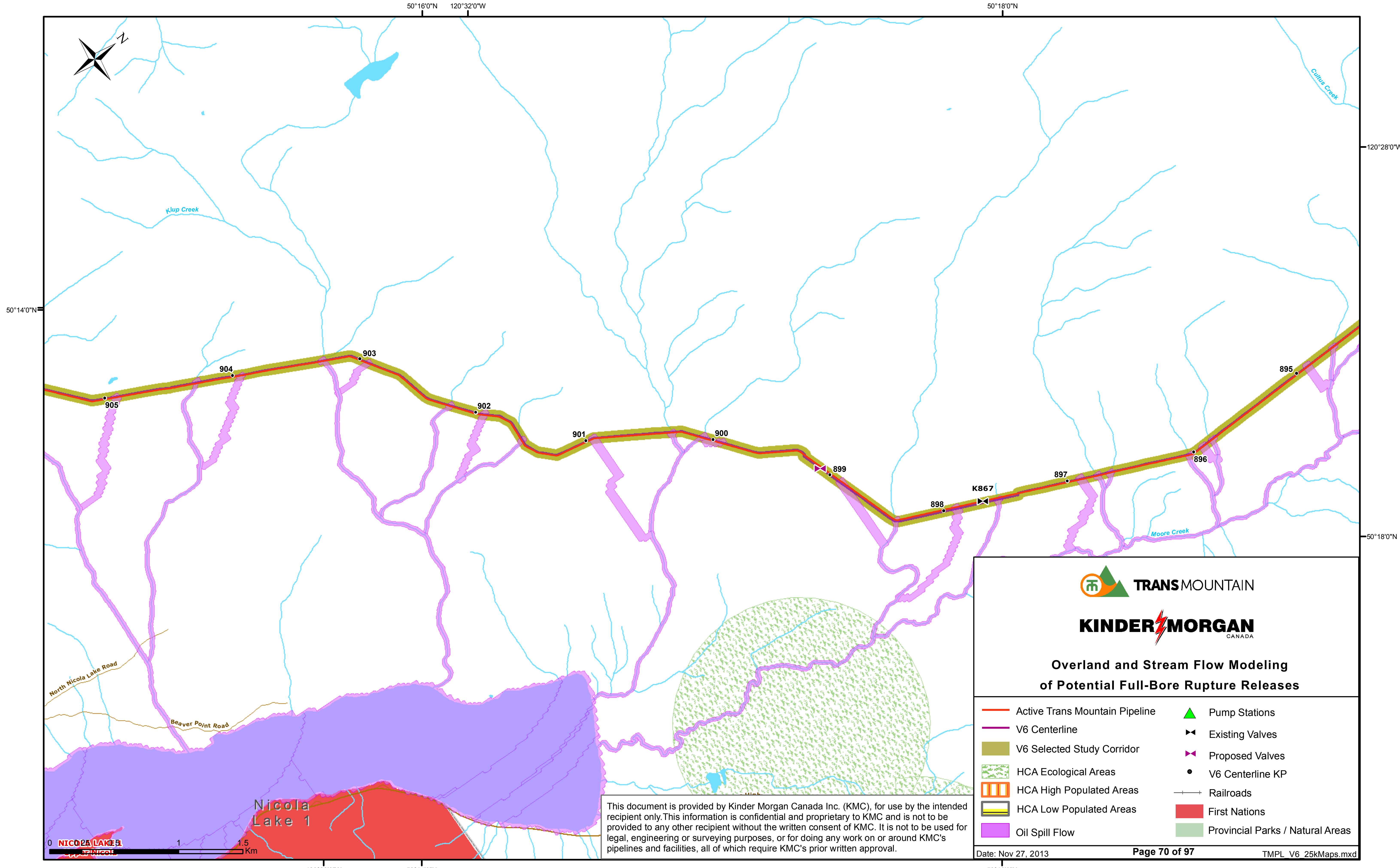

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120°32'0"W
50°18'0"N
120°28'0"W
50°14'0"N
50°18'0"N
120°28'0"W
50°14'0"N
50°16'0"N
N
Klup Creek
Cullus Creek
Moore Creek
North Nicola Lake Road
Beaver Point Road
Nicola Lake 1
NICOLA LAKE 1
905
904
903
902
901
900
899
898
K867
897
896
895
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
KINDER MORGAN CANADA
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Active Trans Mountain Pipeline
V6 Centerline
V6 Selected Study Corridor
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Pump Stations
Existing Valves
Proposed Valves
V6 Centerline KP
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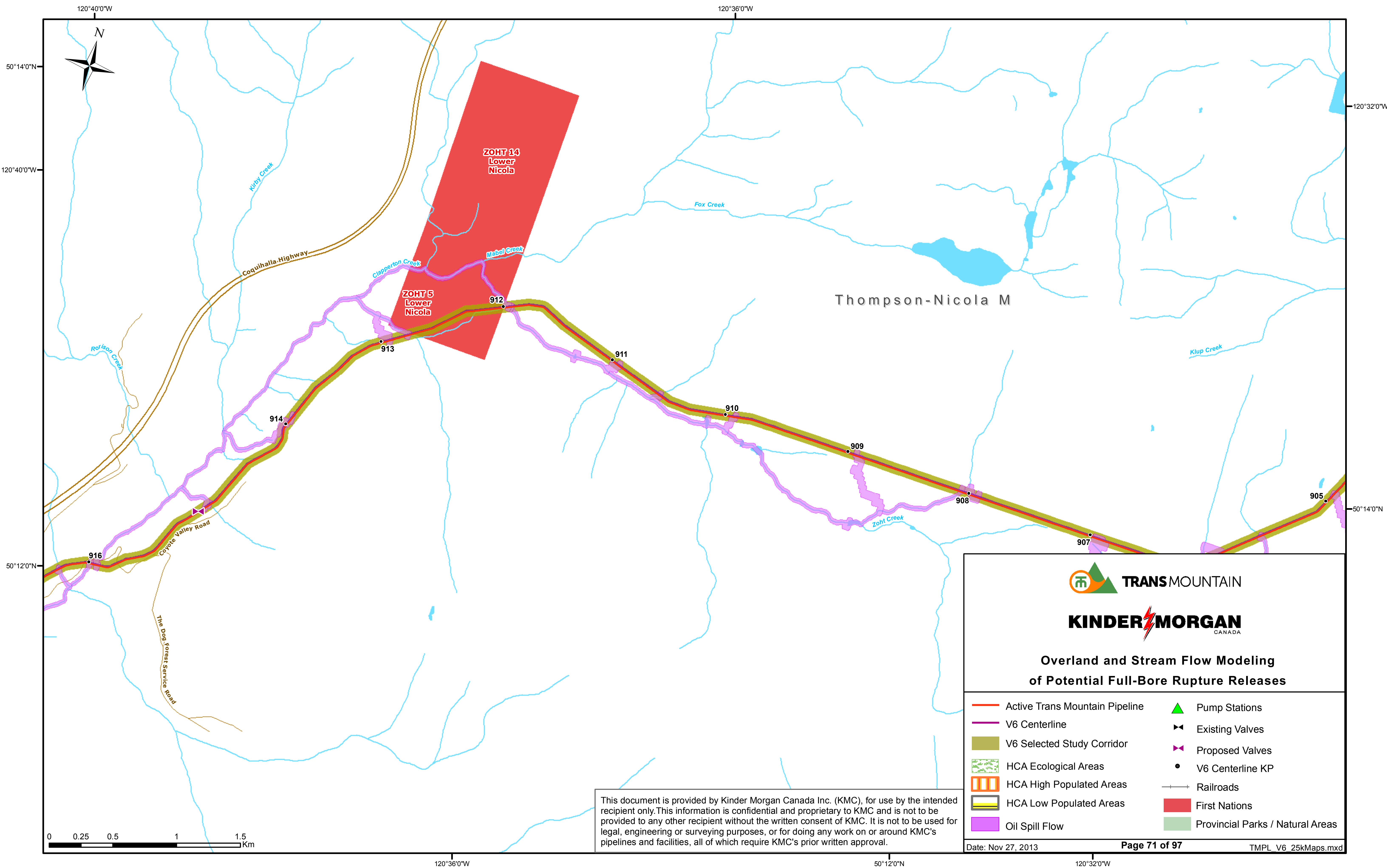

120°40'0"W
120°36'0"W
50°14'0"N
120°40'0"W
120°32'0"W
50°14'0"N
50°12'0"N
120°36'0"W
50°12'0"N
120°32'0"W
N
ZOHT 14
Lower
Nicola
ZOHT 5
Lower
Nicola
Kirby Creek
Fox Creek
Coquihalla Highway
Clapperton Creek
Mabel Creek
Thompson-Nicola M
Rorison Creek
Klup Creek
Zoht Creek
Coyote Valley Road
The Dog Forest Service Road
912
913
911
910
914
909
908
907
905
916
0
0.25
0.5
1
1.5
Km
TRANSMOUNTAIN
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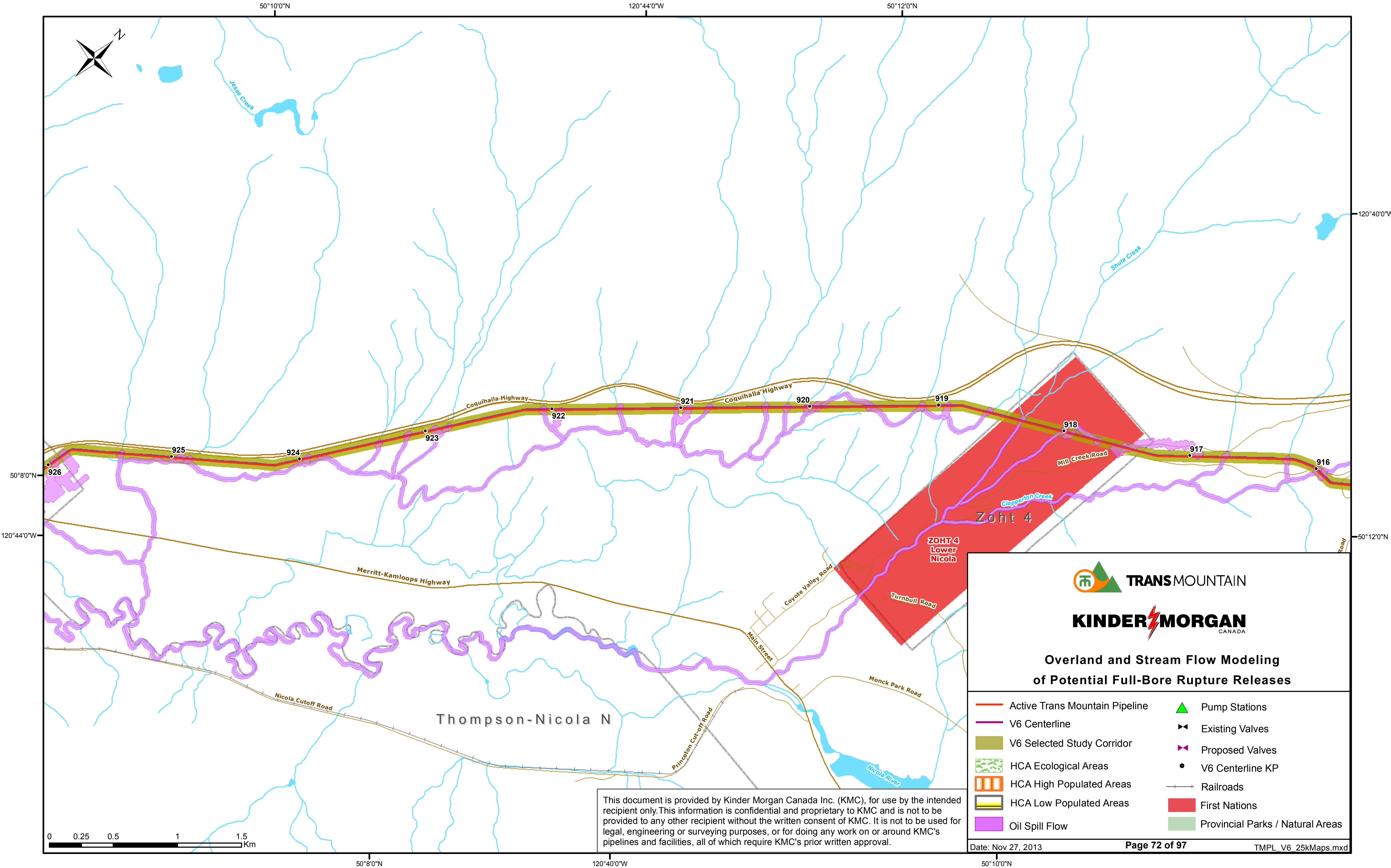

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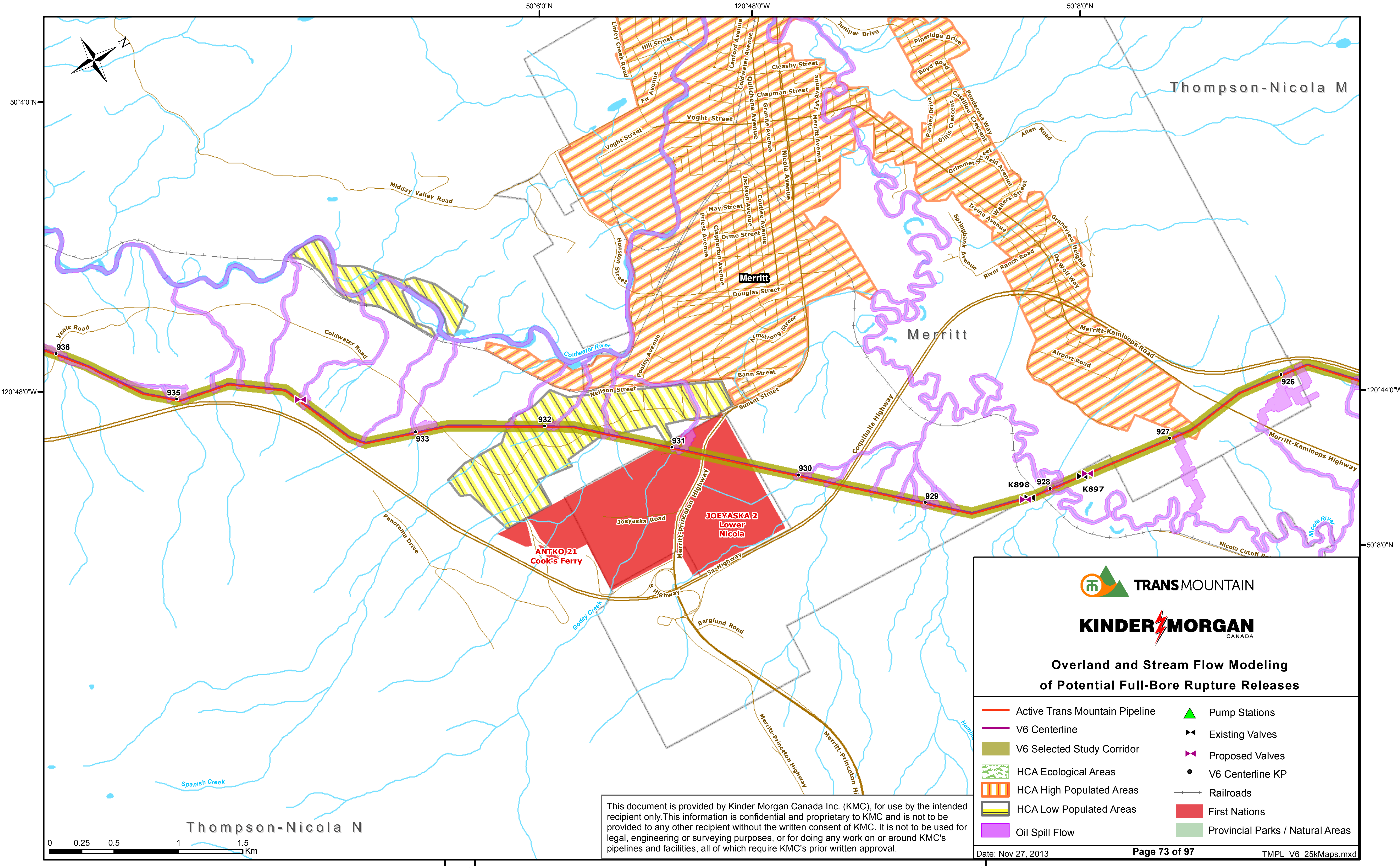
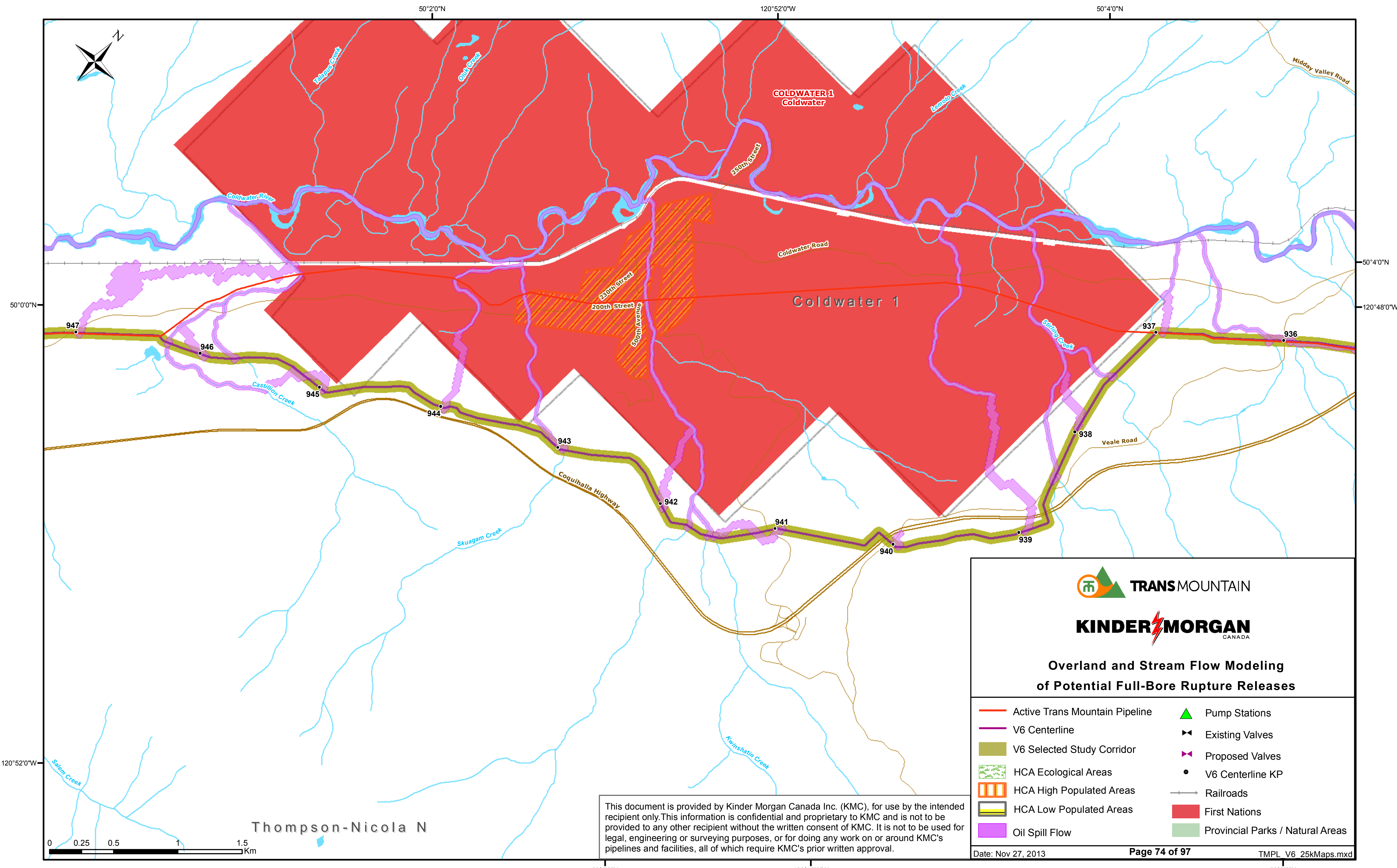


Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases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120°52'0"W
50°4'0"N
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120°52'0"W
50°4'0"N
120°48'0"W
50°0'0"N
120°48'0"W
50°2'0"N
N
Talapus Creek
Olub Creek
COLDWATER 1
Coldwater
Lemoto Creek
Midday Valley Road
250th Street
Coldwater River
Coldwater Road
230th Street
200th Street
500th Avenue
Coldwater 1
Stirling Creek
947
946
945
944
943
942
941
940
939
938
937
936
Castillion Creek
Veale Road
Coquihalla Highway
Skuagam Creek
Kwinshatin Creek
Salem Creek
Thompson-Nicola N
0
0.25
0.5
1
1.5
Km
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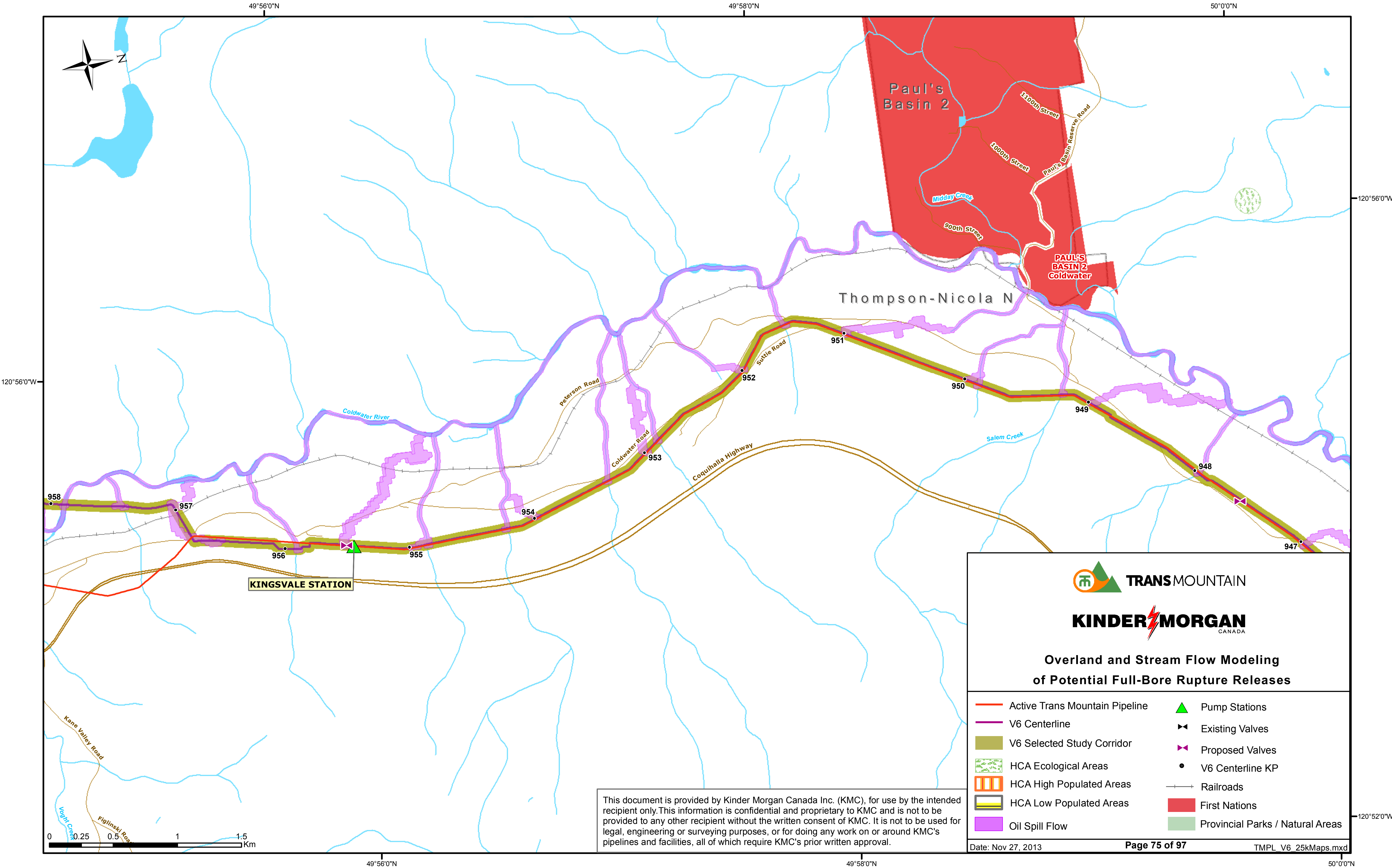

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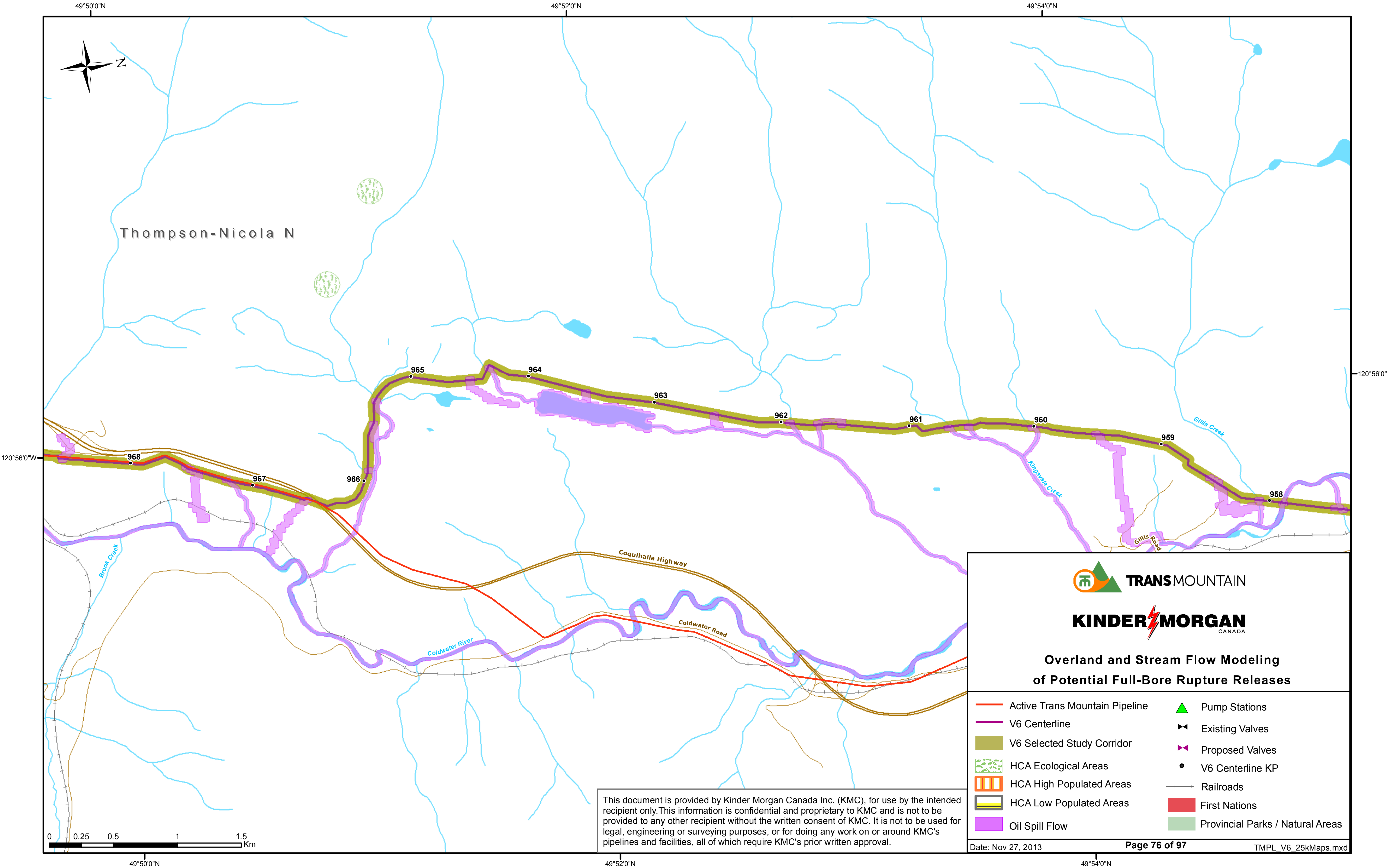
49°50'0"N
49°52'0"N
49°54'0"N
120°56'0"W
N
Thompson-Nicola N
965
964
963
962
961
960
959
958
968
967
966
Gillis Creek
Kingsvale Creek
Gillis Road
Brook Creek
Coquihalla Highway
Coldwater Road
Coldwater River
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0 0.25 0.5 1 1.5 Km
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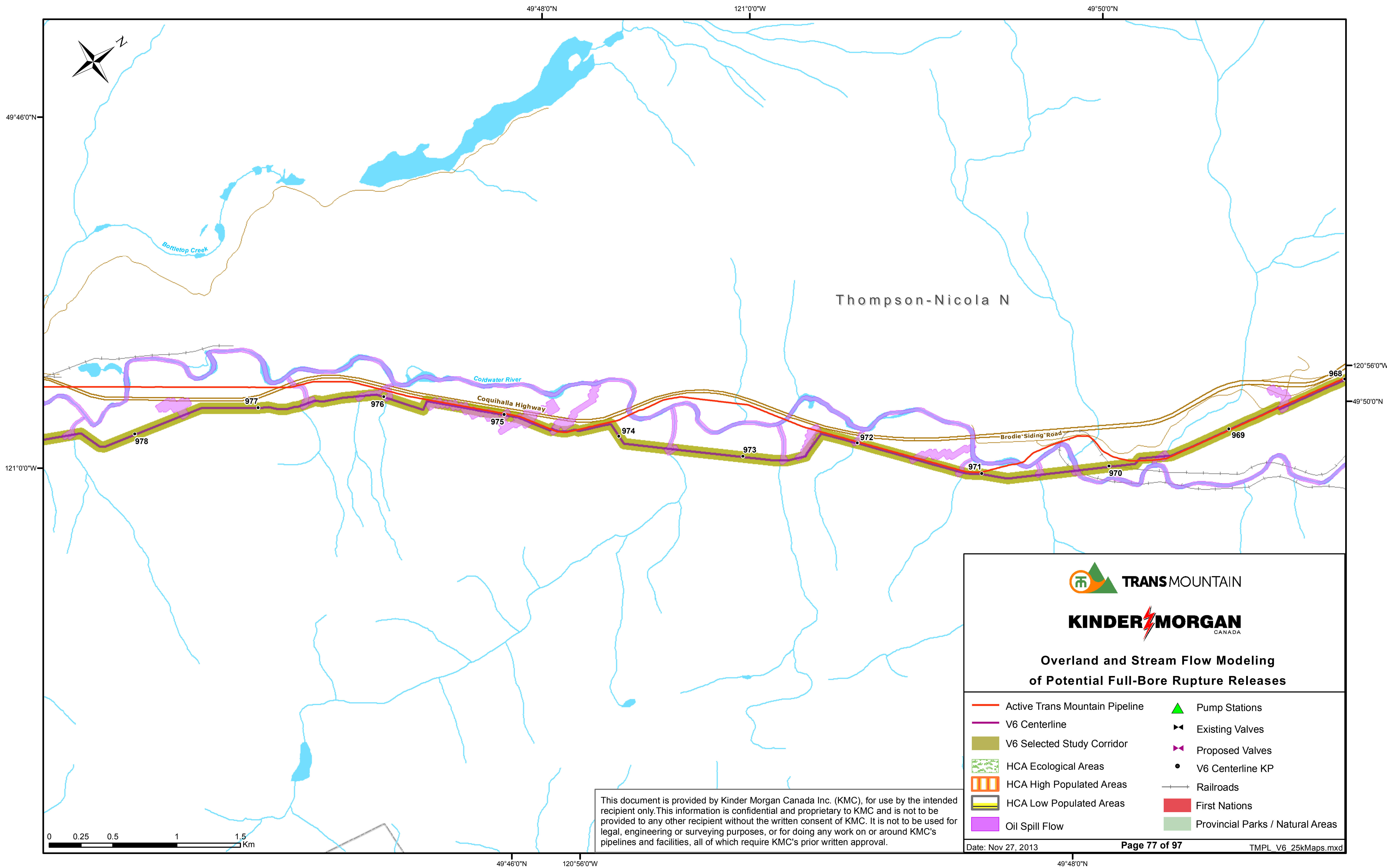
49°50'0"N
49°52'0"N
49°54'0"N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49°46'0"N
120°56'0"W
49°48'0"N
N
Bottletop Creek
Thompson-Nicola N
Coldwater River
Coquihalla Highway
Brodie Siding Road
968
969
970
971
972
973
974
975
976
977
978
0 0.25 0.5 1 1.5 Km
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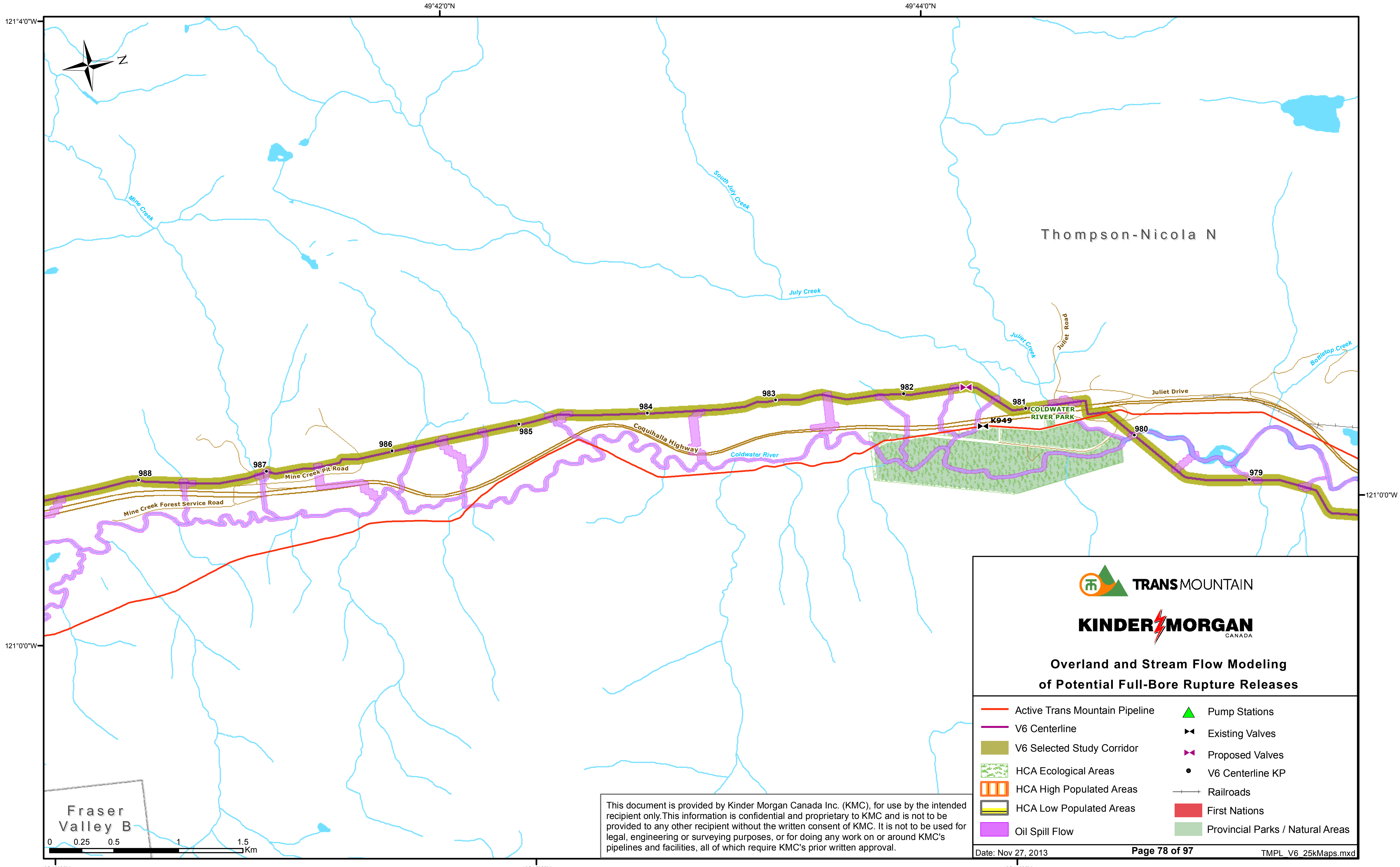

49°42'0"N
49°44'0"N
121°4'0"W
121°0'0"W
49°40'0"N
N
Mine Creek
South July Creek
July Creek
Juliet Creek
Juliet Road
Bottletop Creek
Juliet Drive
Thompson-Nicola N
Fraser Valley B
988
987
986
985
984
983
982
981
980
979
K949
COLDWATER RIVER PARK
Mine Creek Pit Road
Mine Creek Forest Service Road
Coquihalla Highway
Coldwater River
0 0.25 0.5 1 1.5 Km
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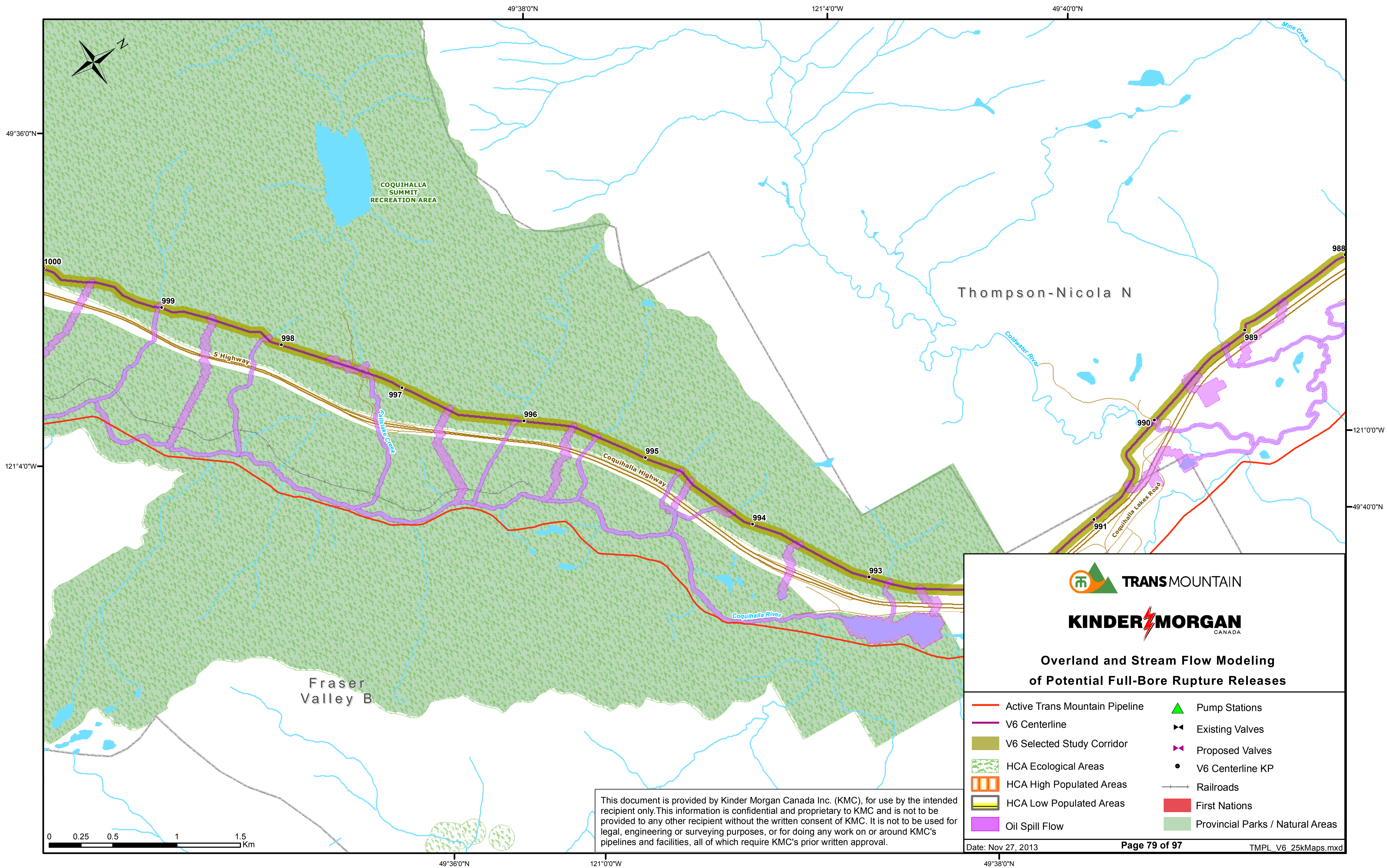

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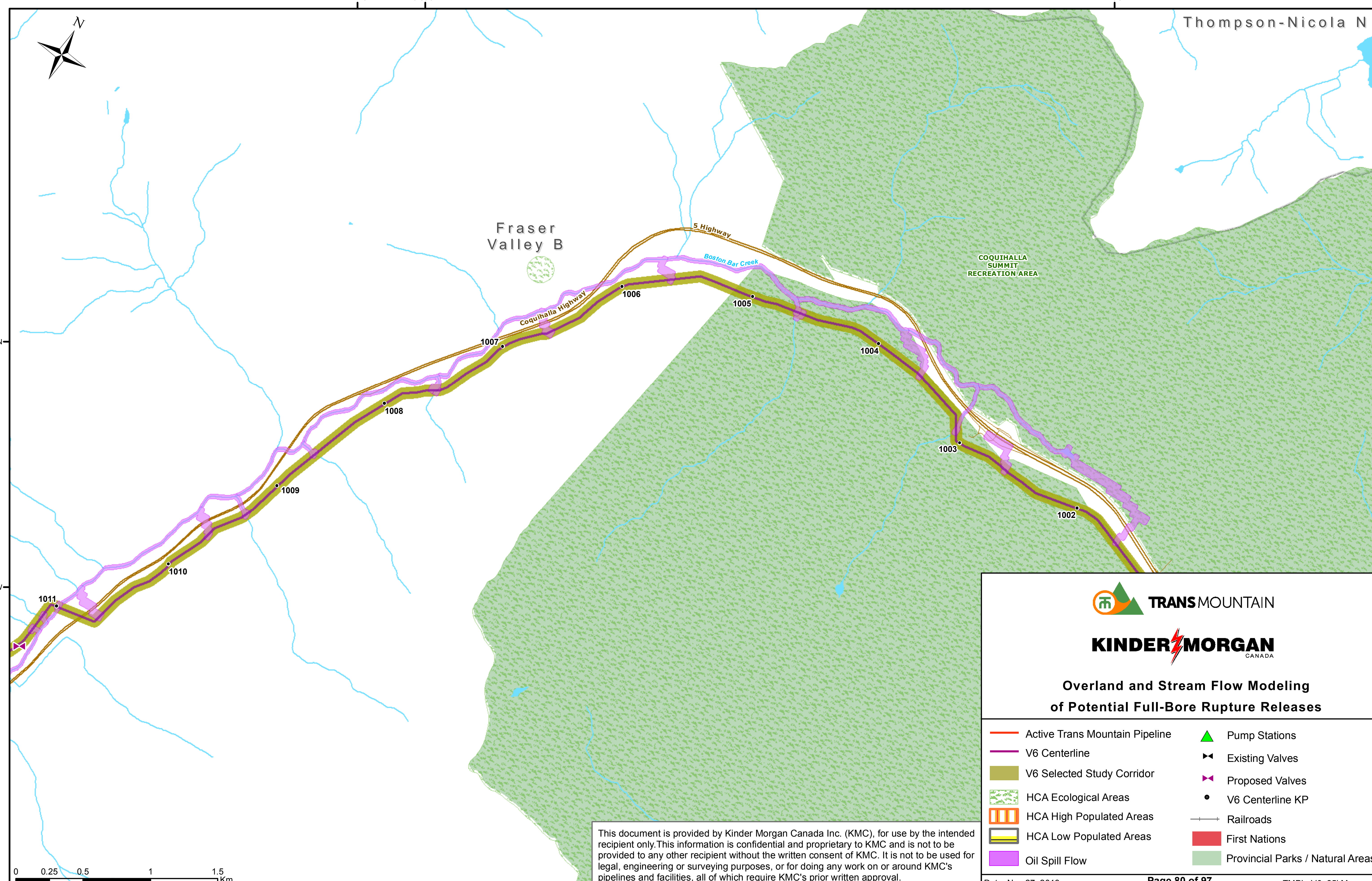

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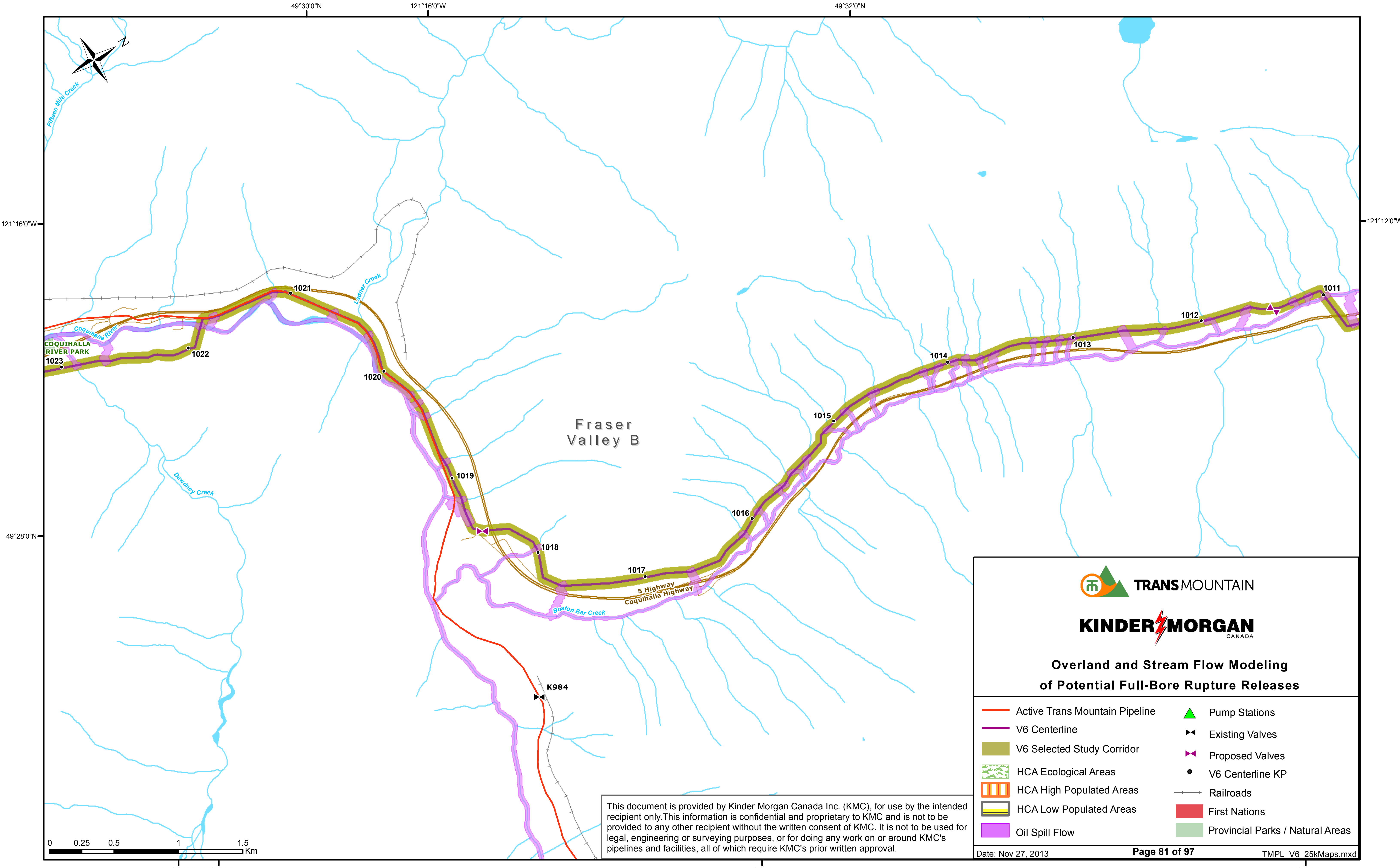

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

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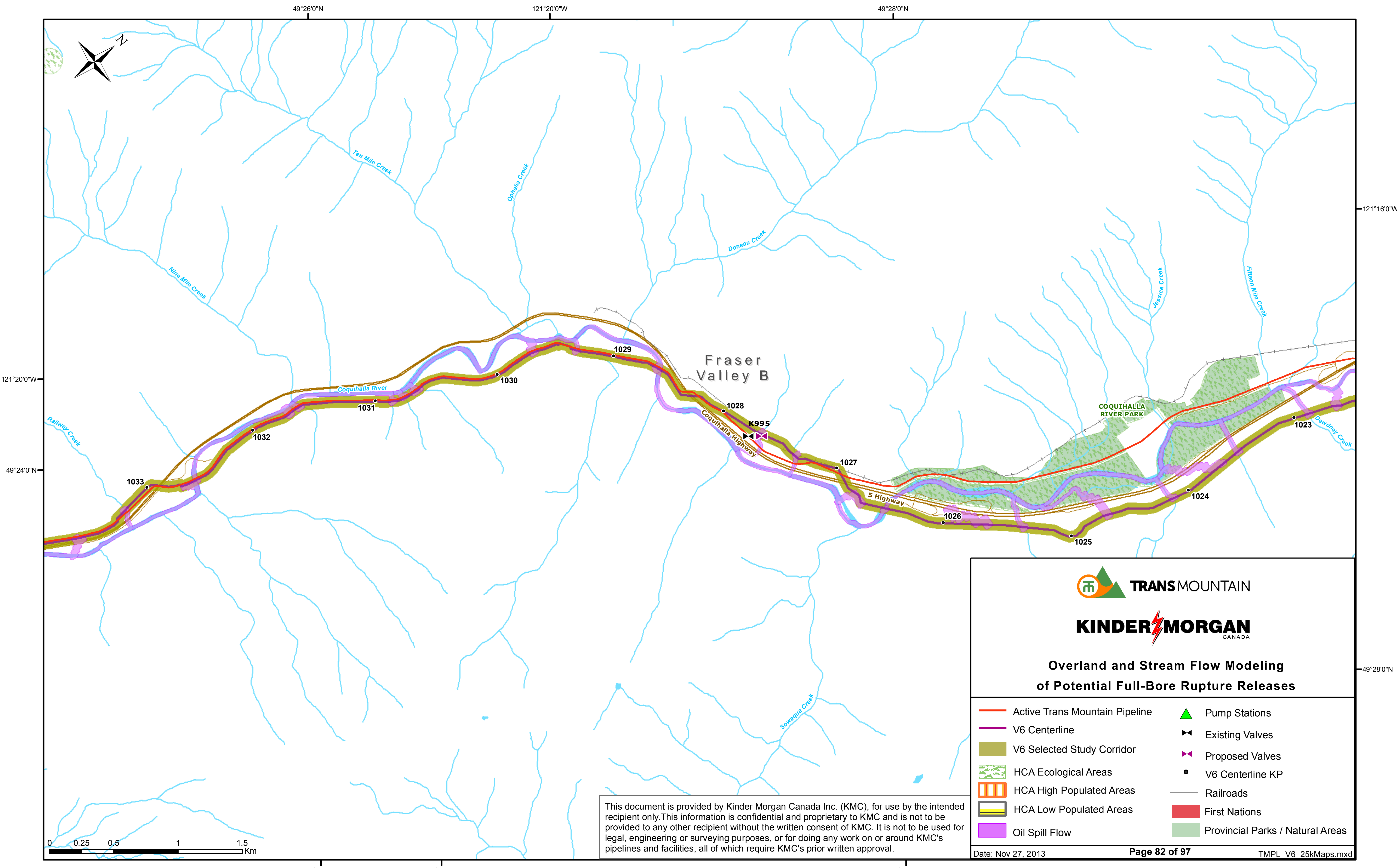

49°26'0"N
121°20'0"W
49°28'0"N
121°16'0"W
121°20'0"W
49°24'0"N
49°28'0"N
49°24'0"N
121°16'0"W
49°26'0"N
Ten Mile Creek
Ophelia Creek
Deneau Creek
Nine Mile Creek
Jessica Creek
Fifteen Mile Creek
Railway Creek
Dewdney Creek
Sowaqua Creek
Coquihalla River
Coquihalla Highway
5 Highway
COQUIHALLA RIVER PARK
Fraser Valley B
K995
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
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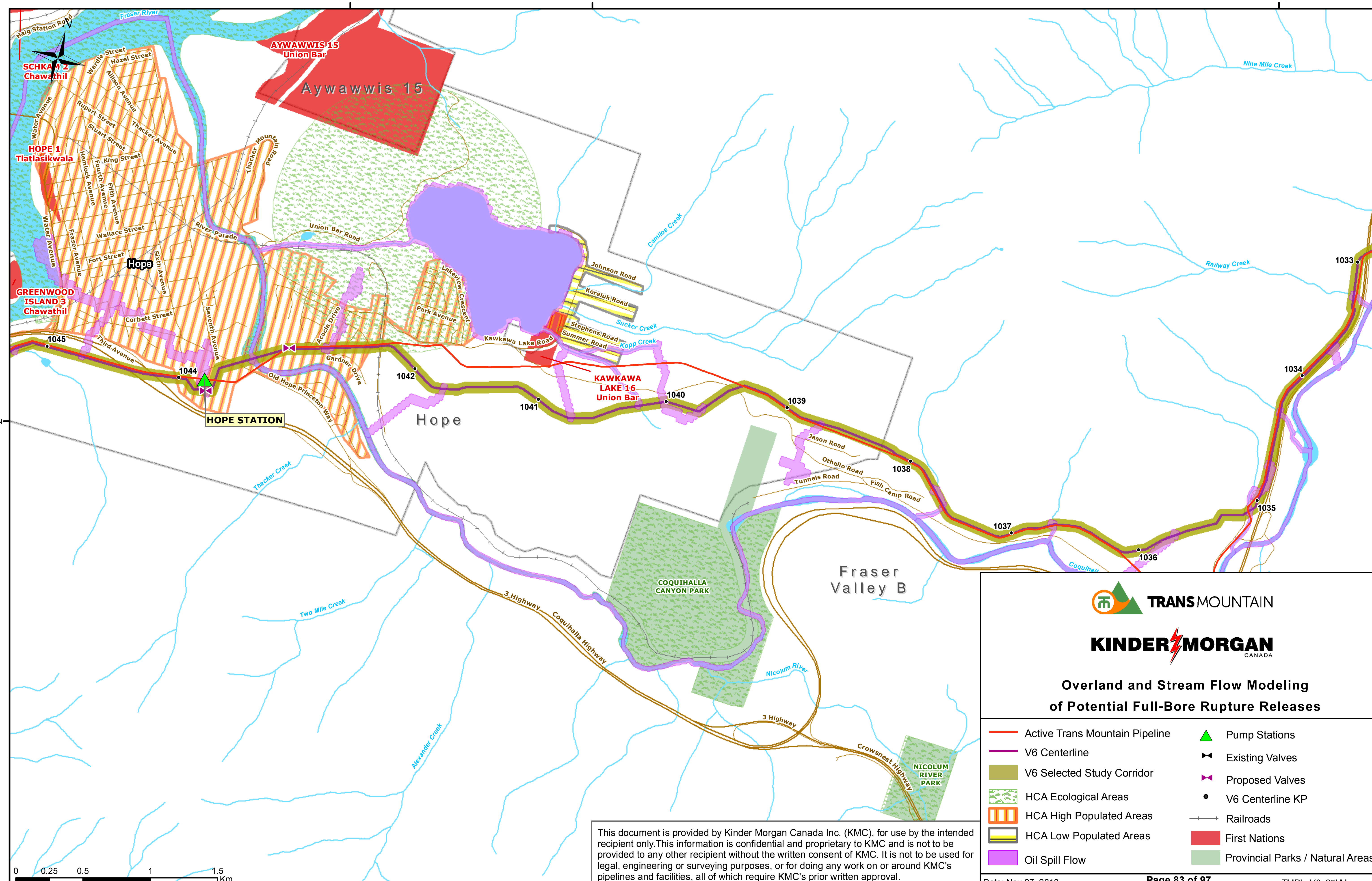

49°24'0"N
121°24'0"W
121°20'0"W
49°22'0"N
Fraser River
Haig Station Road
SCHKAM 2
Chawathil
AYWAWWIS 15
Union Bar
Aywawwis 15
HOPE 1
Tlatlasikwala
GREENWOOD
ISLAND 3
Chawathil
Hope
HOPE STATION
KAWKAWA
LAKE 16
Union Bar
Wardle Street
Hazel Street
Allison Avenue
Rupert Street
Stuart Street
Thacker Avenue
Water Avenue
King Street
Hemlock Avenue
Fourth Avenue
Fifth Avenue
Wallace Street
Fort Street
Sixth Avenue
Fraser Avenue
River Parade
Union Bar Road
Thacker Mountain Road
Corbett Street
Third Avenue
Seventh Avenue
Acacia Drive
Gardner Drive
Old Hope Princeton Way
Park Avenue
Lakeview Crescent
Kawkawa Lake Road
Johnson Road
Kereluk Road
Stephens Road
Summer Road
Sucker Creek
Kopp Creek
Camillos Creek
Railway Creek
Nine Mile Creek
Jason Road
Othello Road
Tunnels Road
Fish Camp Road
Thacker Creek
Two Mile Creek
Alexander Creek
Nicolum River
Coquihalla
3 Highway
Coquihalla Highway
Crowsnest Highway
COQUIHALLA CANYON PARK
NICOLUM RIVER PARK
Fraser Valley B
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1044
1045
0 0.25 0.5 1 1.5 Km
TRANS MOUNTAIN
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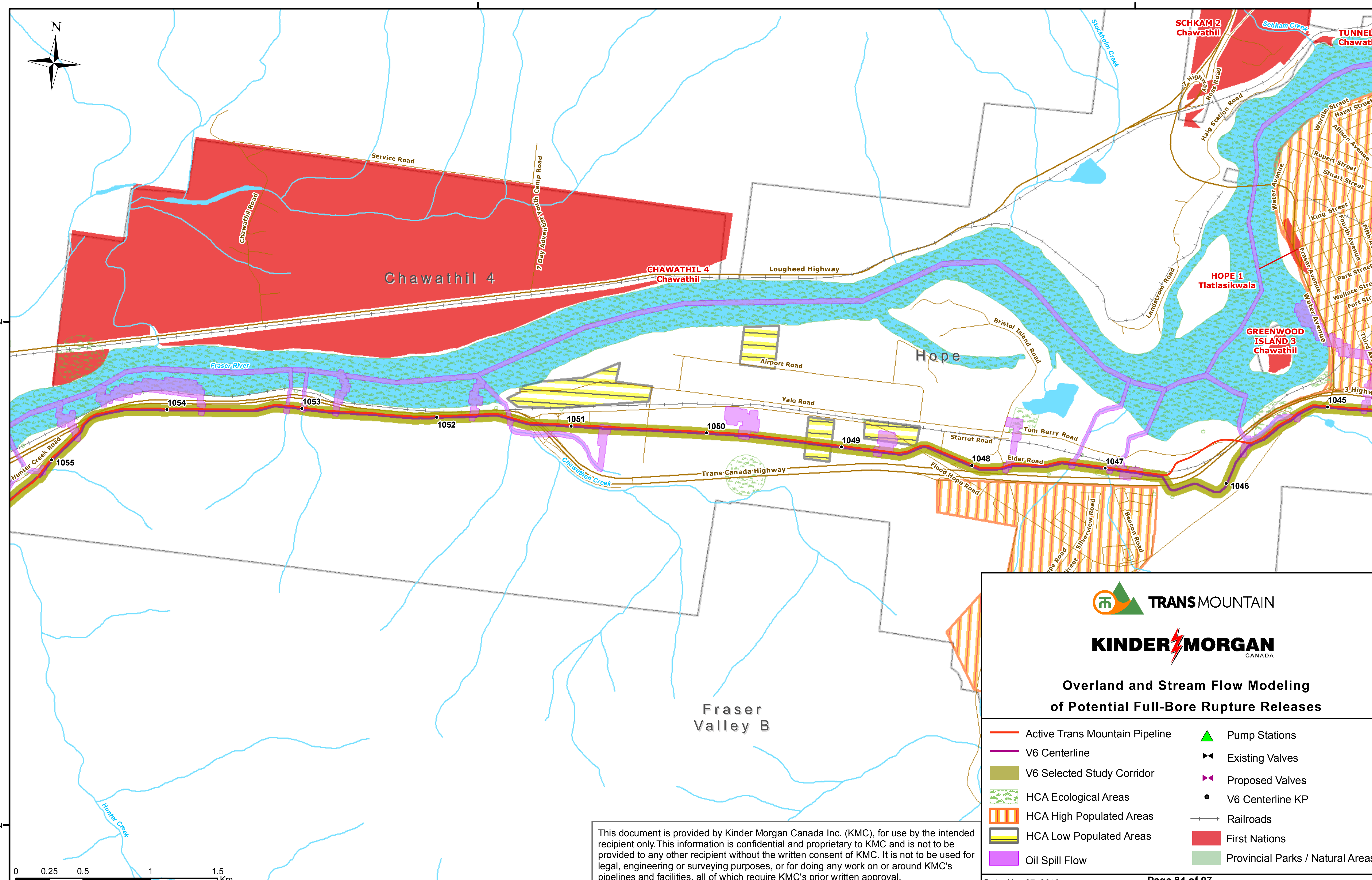

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V6 Centerline	Existing Valves
V6 Selected Study Corridor	Proposed Valves
HCA Ecological Areas	V6 Centerline KP
HCA High Populated Areas	Railroads
HCA Low Populated Areas	First Nations
Oil Spill Flow	Provincial Parks / Natural Areas

Date: Nov 27, 2013

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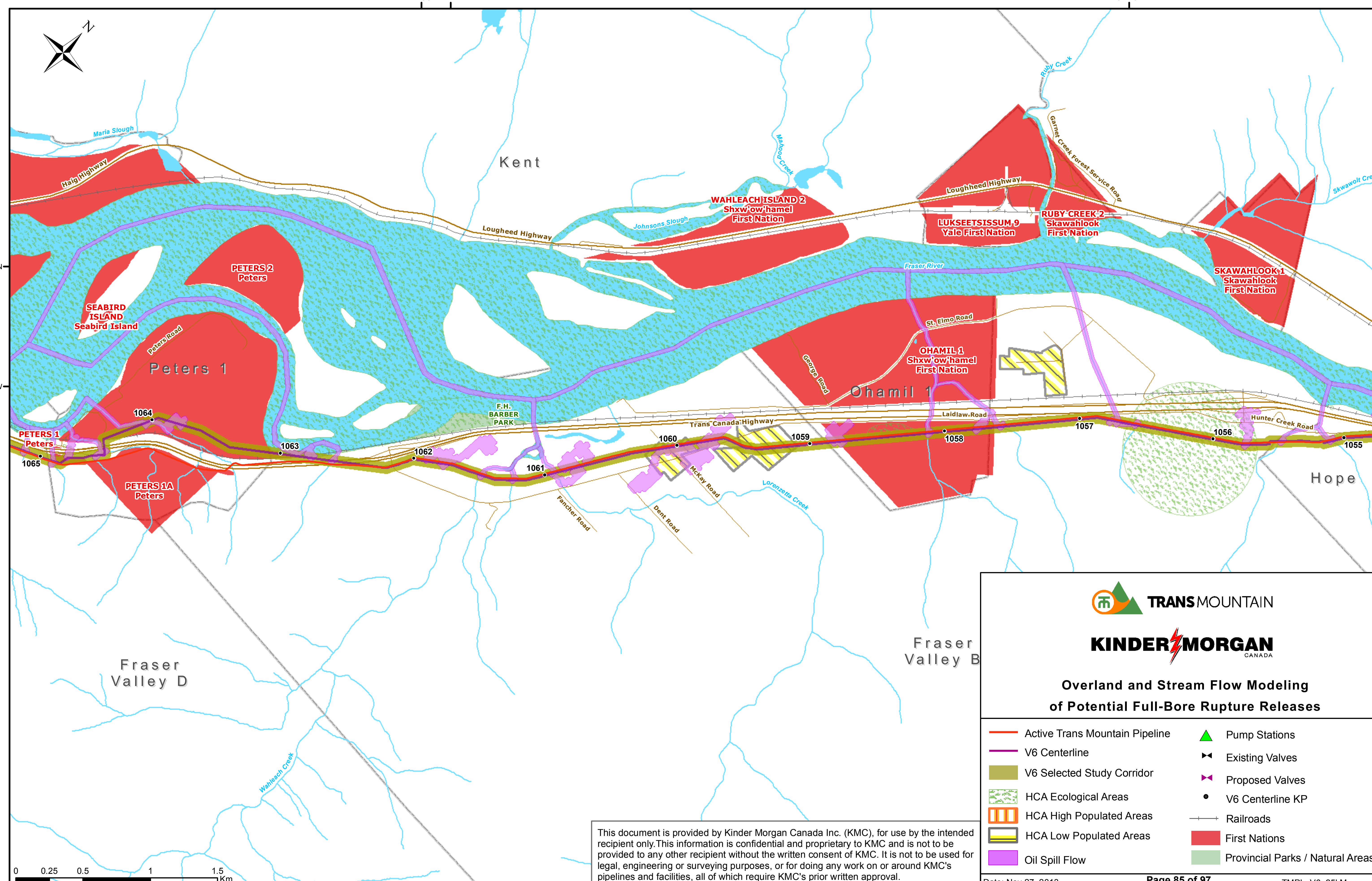

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- Proposed Valves
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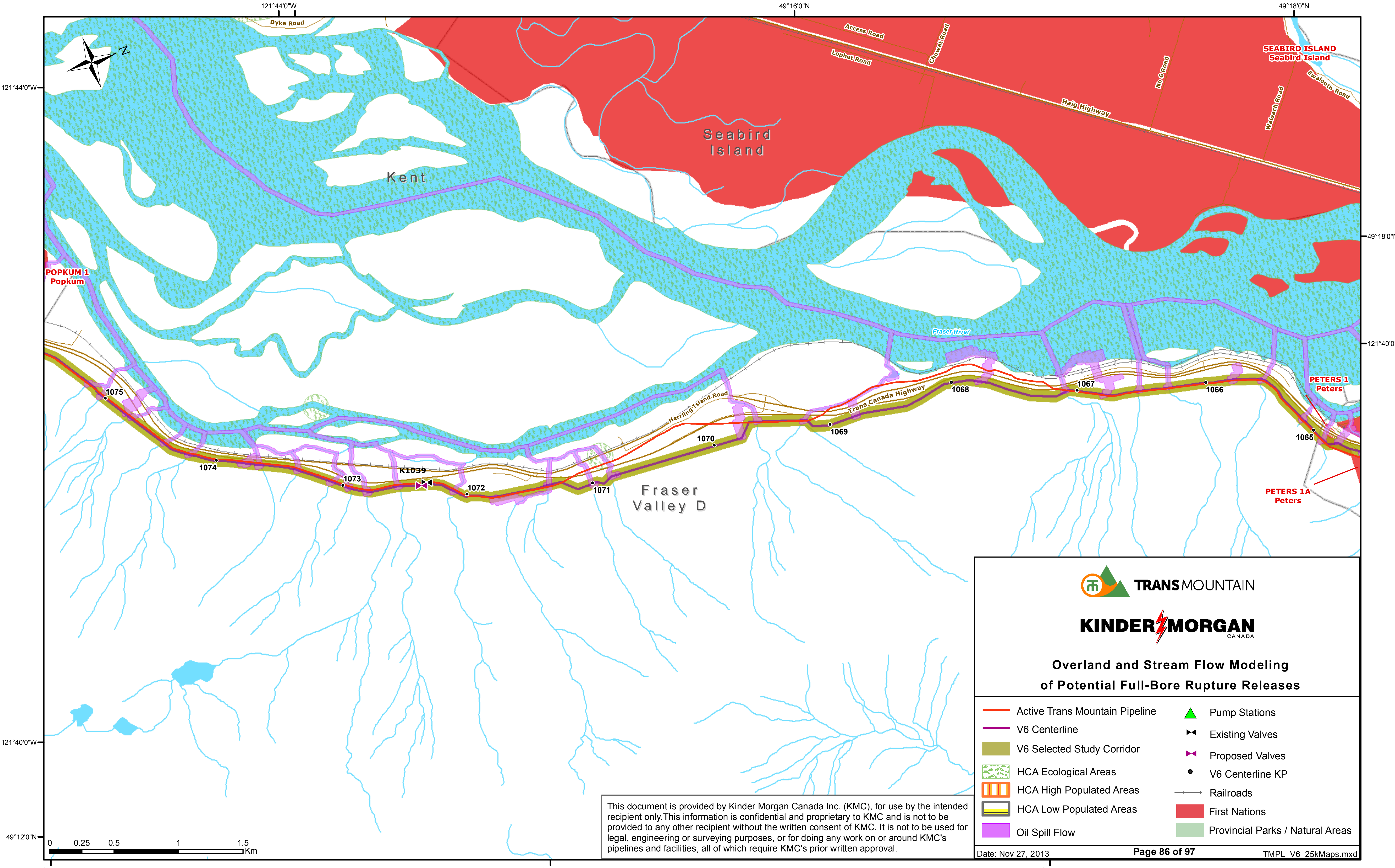

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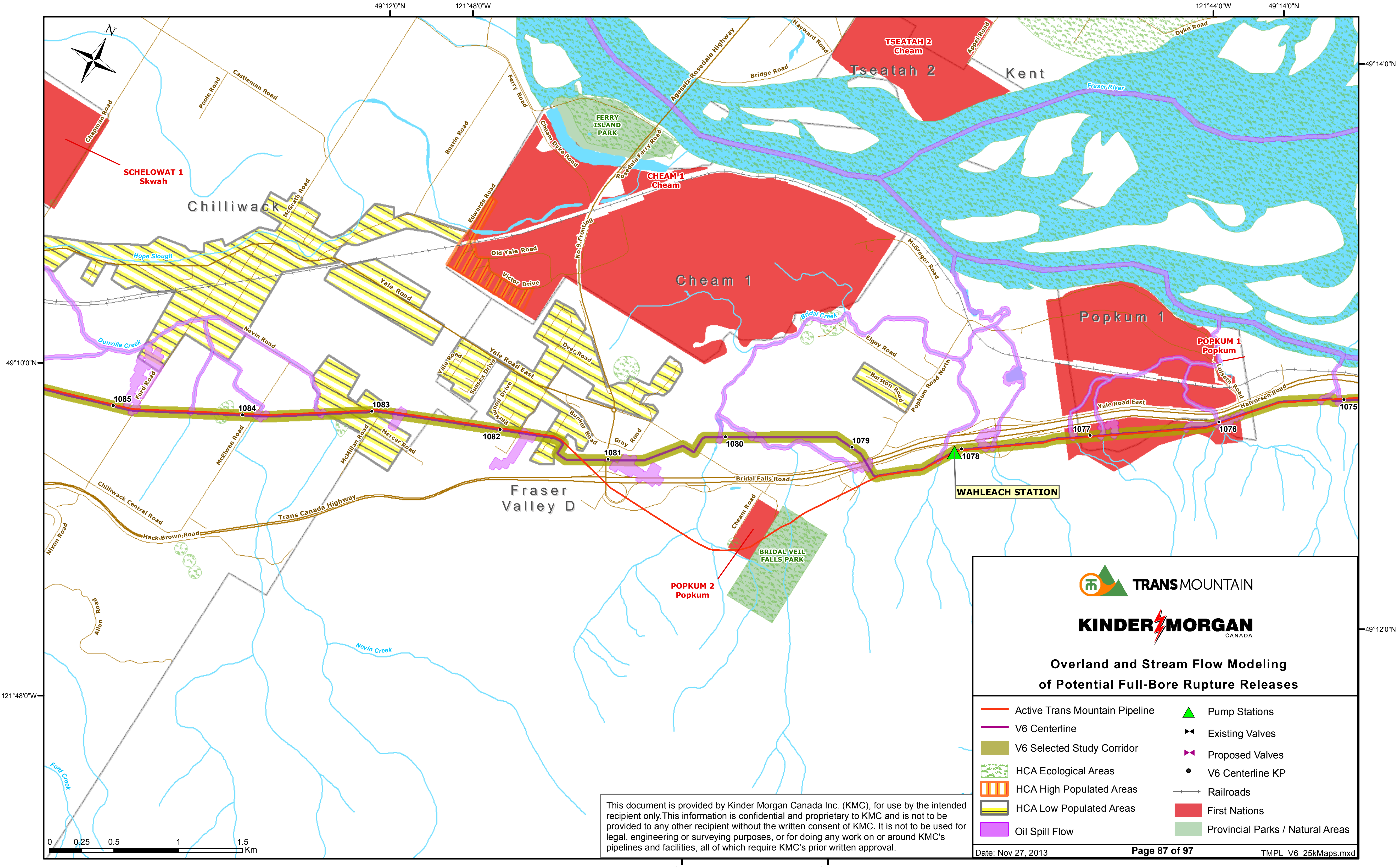

49°12'0"N
121°48'0"W
121°44'0"W
49°14'0"N
49°10'0"N
N
SCHELOWAT 1
Skwah
Chilliwack
TSEATAH 2
Cheam
Tseatah 2
Kent
FERRY ISLAND PARK
CHEAM 1
Cheam
Cheam 1
Popkum 1
POPKUM 1
Popkum
POPKUM 2
Popkum
BRIDAL VEIL FALLS PARK
Fraser Valley D
Fraser River
Hope Slough
Dunville Creek
Bridal Creek
Nevin Creek
Ford Creek
Chapman Road
Castleman Road
Poole Road
McGrath Road
Bustin Road
Ferry Road
Cheam Dyke Road
Rosedale Ferry Road
Agassiz-Rosedale Highway
Hayward Road
Bridge Road
Appel Road
Dyke Road
Edwards Road
Old Yale Road
Victor Drive
No.9 Fronting
Yale Road
Nevin Road
Ford Road
Yale Road East
Sussex Drive
Dyer Road
Parkwood Drive
Bunker Road
Gray Road
McGregor Road
Elgey Road
Berston Road
Popkum Road North
Luiseth Road
Halvorsen Road
McElwee Road
McMillan Road
Mercer Road
Bridal Falls Road
Cheam Road
Chilliwack Central Road
Trans Canada Highway
Hack Brown Road
Nixon Road
Allan Road
1085
1084
1083
1082
1081
1080
1079
1078
1077
1076
1075
WAHLEACH STATION
TRANS MOUNTAIN
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0 0.25 0.5 1 1.5 Km
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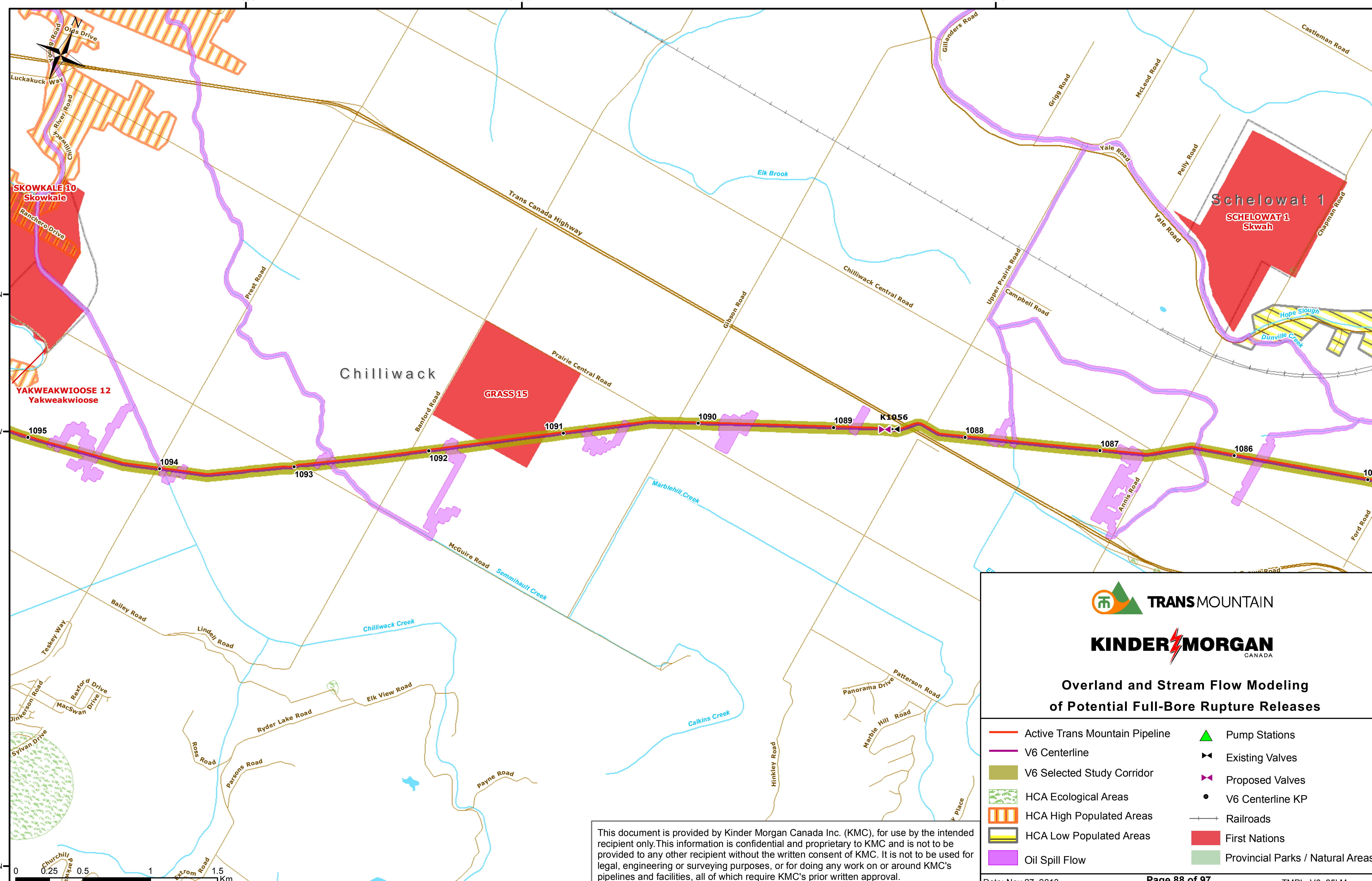

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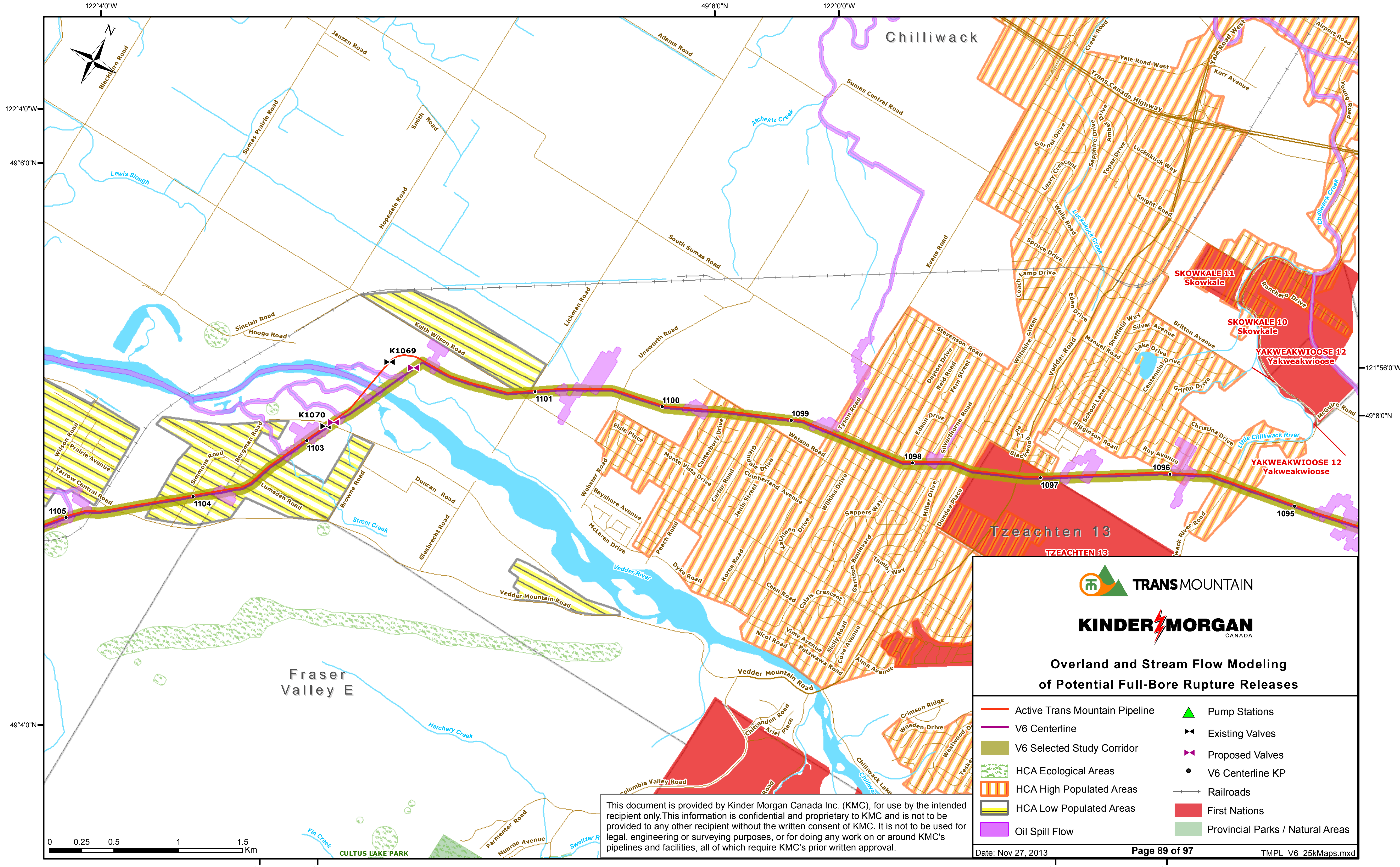
0 0.25 0.5 1 1.5 Km
121°56'0"W
49°10'0"N
121°52'0"W
49°8'0"N
121°48'0"W
49°6'0"N
Chilliwack
SKOWKALE 10
Skowkale
YAKWEAKWIOOSE 12
Yakweakwioose
GRASS 15
Schelowat 1
SCHELOWAT 1
Skwah
1095
1094
1093
1092
1091
1090
1089
K1056
1088
1087
1086
1085
Trans Canada Highway
Chilliwack Central Road
Prairie Central Road
McGuire Road
Gibson Road
Banford Road
Prest Road
Upper Prairie Road
Campbell Road
Yale Road
Gillanders Road
Grigg Road
McLeod Road
Pelly Road
Chapman Road
Castleman Road
Annis Road
Ford Road
Luckakuck Way
Olds Drive
Ranchero Drive
Bailey Road
Lindell Road
Teskey Way
Rexford Drive
MacSwan Drive
Sylvan Drive
Ryder Lake Road
Elk View Road
Ross Road
Parsons Road
Payne Road
Hinkley Road
Panorama Drive
Patterson Road
Marble Hill Road
Extrom Road
Elk Brook
Marblehill Creek
Semmihault Creek
Chilliwack Creek
Calkins Creek
Hope Slough
Dunville Creek



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Vedder River
Lewis Slough
Atchelitz Creek
Luckakuck Creek
Chilliwack Creek
Little Chilliwack River
Street Creek
Hatchery Creek
Fin Creek
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Sumas Central Road
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TRANS MOUNTAIN
KINDER MORGAN CANADA
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V6 Selected Study Corridor
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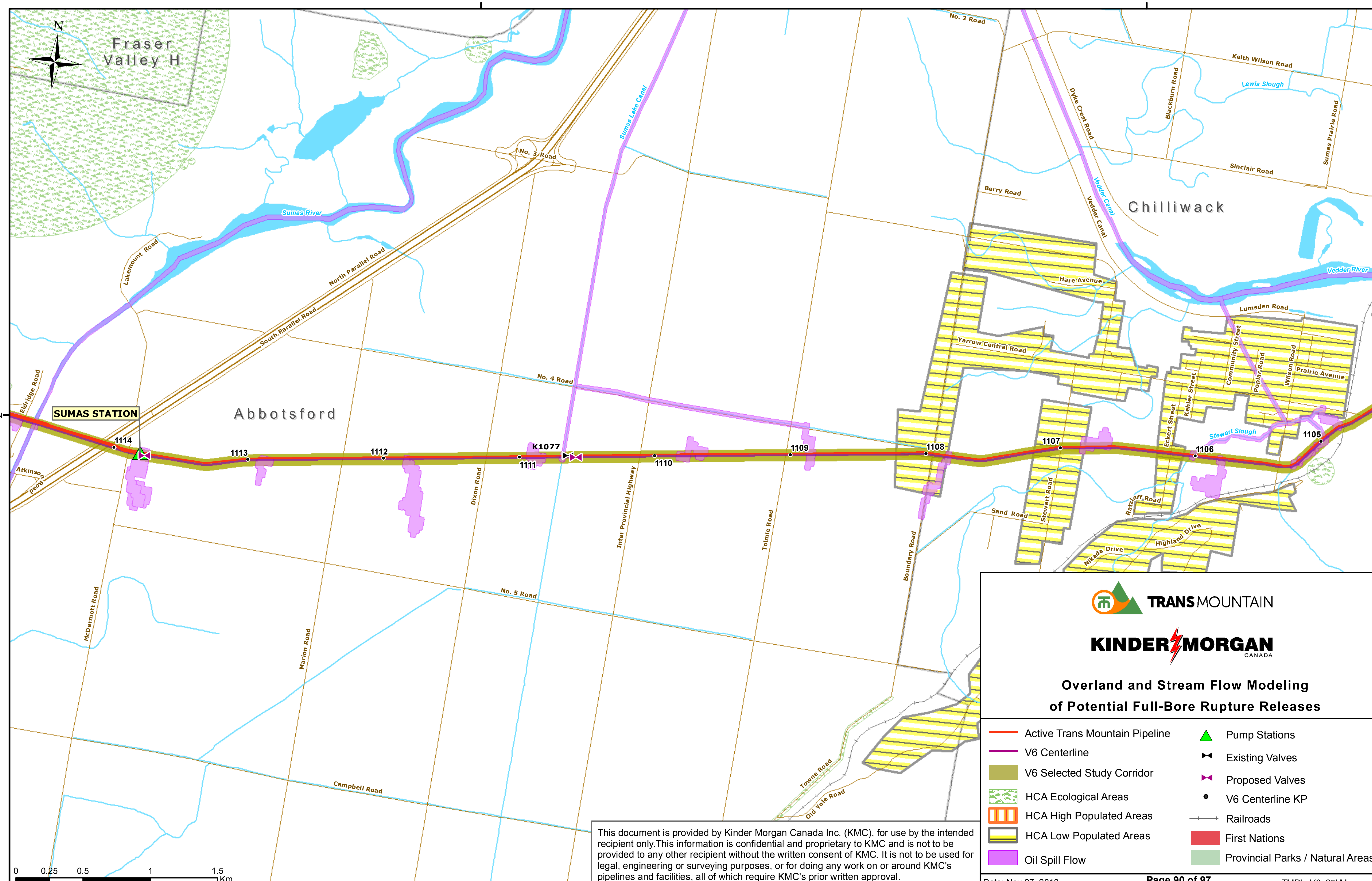

TRANS MOUNTAIN

KINDER MORGAN CANADA

Overland and Stream Flow Modeling of Potential Full-Bore Rupture Releases

Legend	
Active Trans Mountain Pipeline	Pump Stations
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HCA Ecological Areas	V6 Centerline KP
HCA High Populated Areas	Railroads
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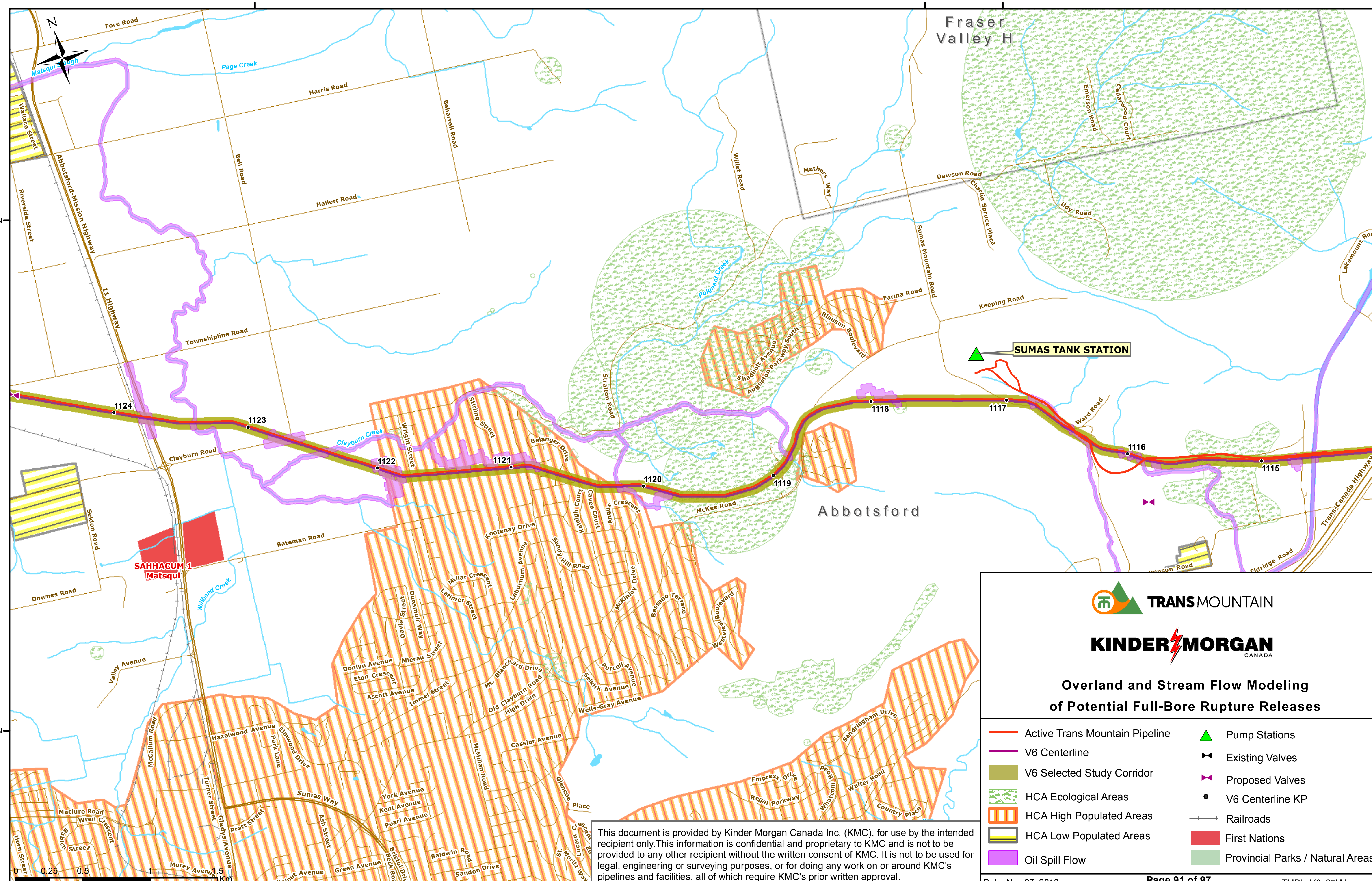
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Townshipline Road
Clayburn Road
Clayburn Creek
Bateman Road
Downes Road
Willband Creek
Bell Road
Beharrell Road
Abbotsford-Mission Highway
11 Highway
Riverside Street
Wallace Street
Seldon Road
Willet Road
Mathers Way
Dawson Road
Sumas Mountain Road
Farina Road
Keeping Road
Ward Road
Poignant Creek
Stirling Street
Belanger Drive
Straiton Road
McKee Road
Kootenay Drive
Sandy Hill Road
Emerson Road
Cedarwood Court
Charlie Spruce Place
Udy Road
Lakemount Road
Trans-Canada Highway
Eldridge Road
Valley Avenue
Hazelwood Avenue
Sumas Way
McMillan Road
Cassiar Avenue
Wells-Gray Avenue
Sandringham Drive
Walter Road
Empress Drive
Regal Parkway
Country Place
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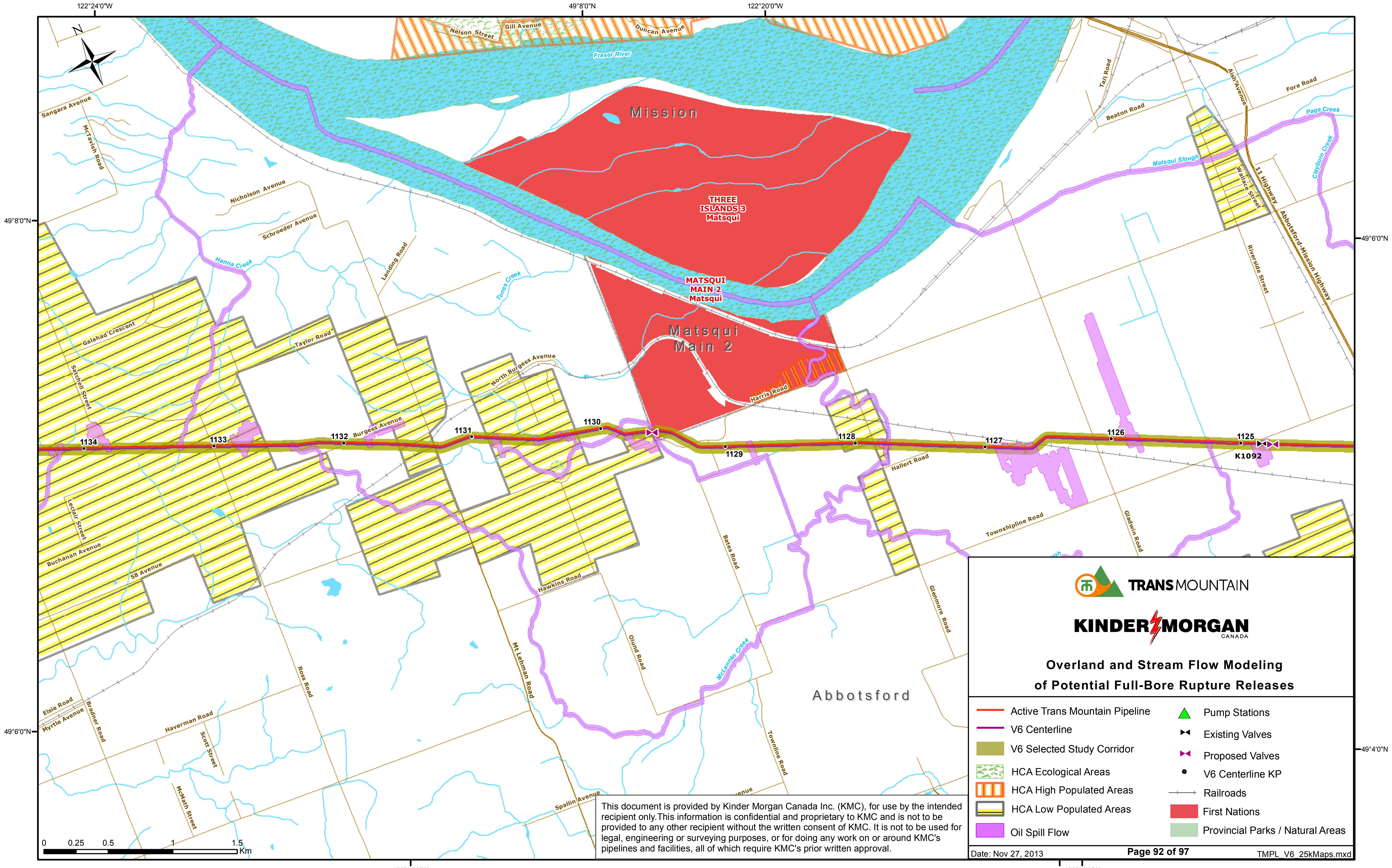

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Hanna Creek
Tunes Creek
McLennan Creek
Matsqui Slough
Page Creek
Clayburn Creek
Nelson Street
Gill Avenue
Duncan Avenue
Sangara Avenue
McTavish Road
Nicholson Avenue
Schroeder Avenue
Landing Road
Galahad Crescent
Taylor Road
Satchell Street
North Burgess Avenue
Burgess Avenue
Harris Road
Hallert Road
Leclair Street
Buchanan Avenue
58 Avenue
Hawkins Road
Bates Road
Olund Road
Mt Lehman Road
Ross Road
Glenmore Road
Townshipline Road
Gladwin Road
Townline Road
Elsie Road
Myrtle Avenue
Bradner Road
Haverman Road
Scott Street
McMath Street
Spallin Avenue
Tall Road
Beaton Road
Aish Avenue
Fore Road
Wallace Street
11 Highway
Abbotsford-Mission Highway
Riverside Street
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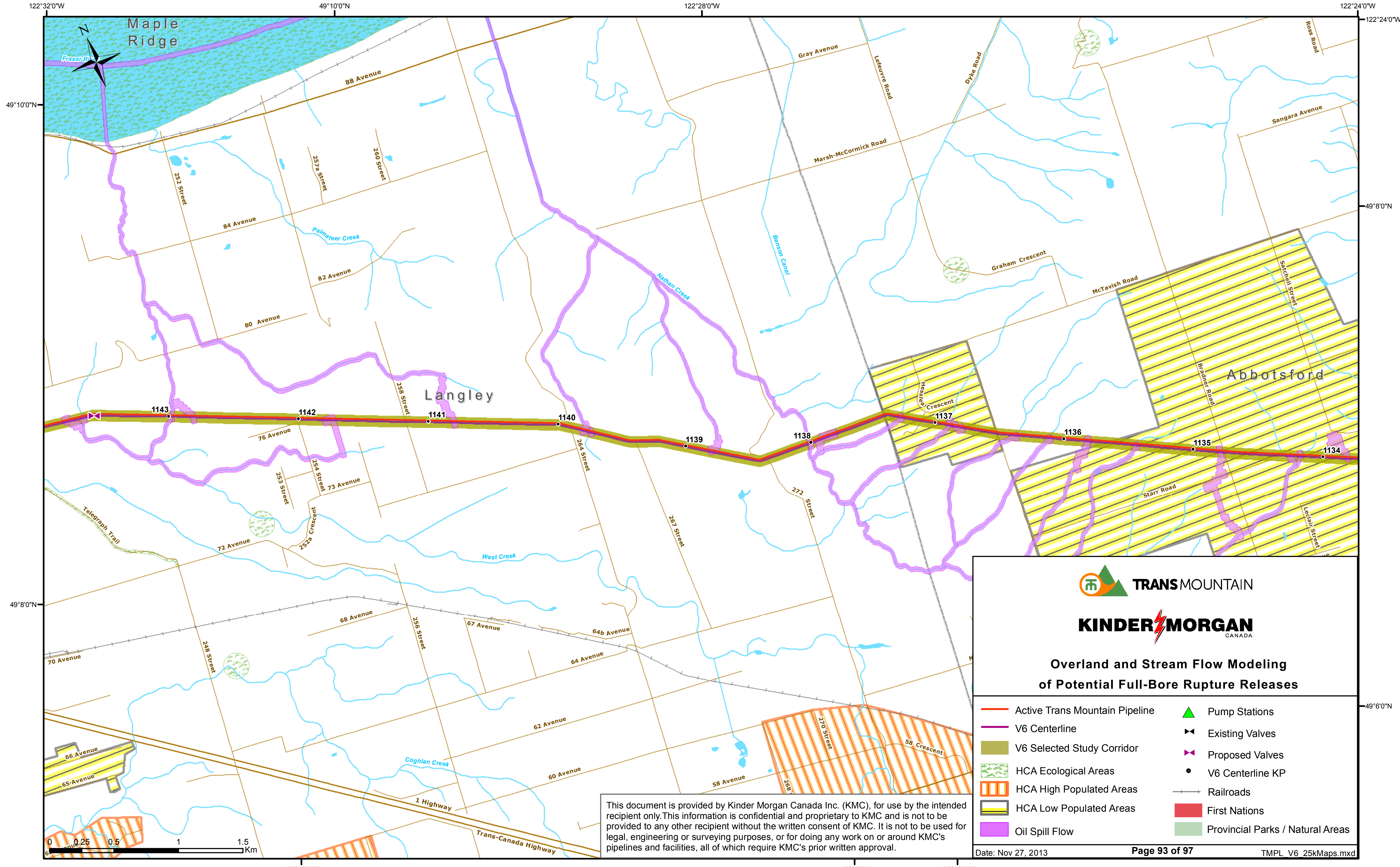

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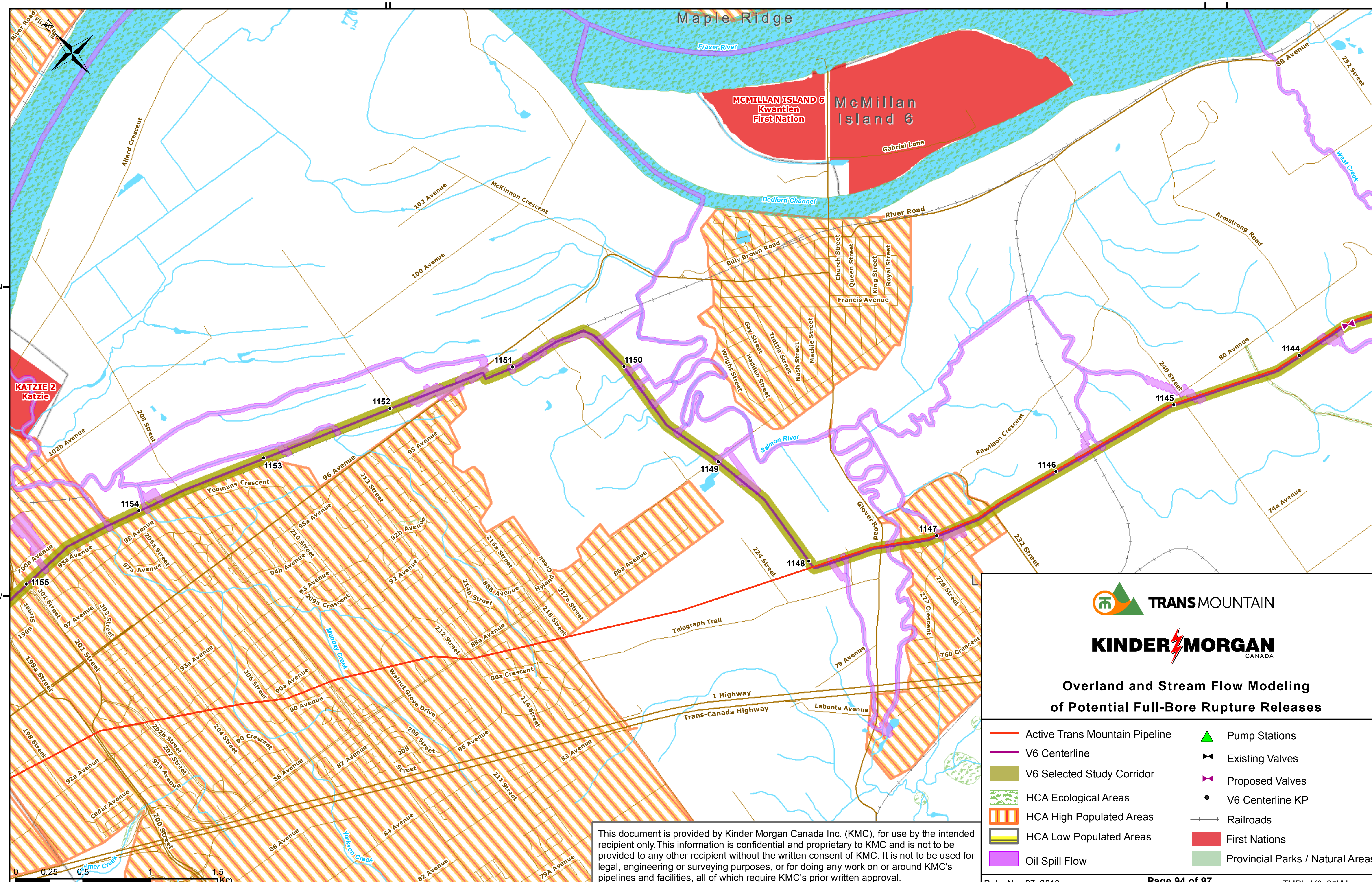

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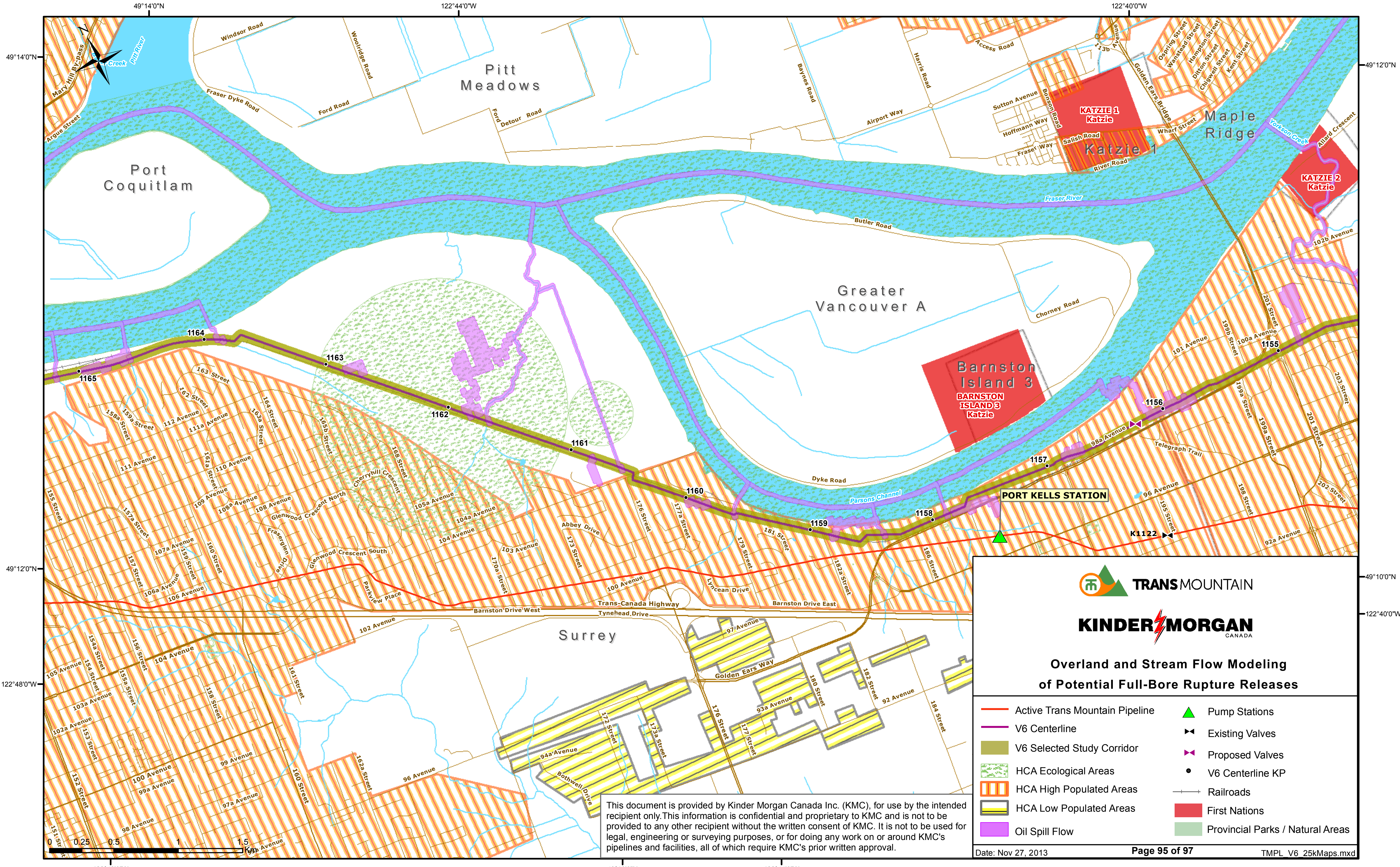

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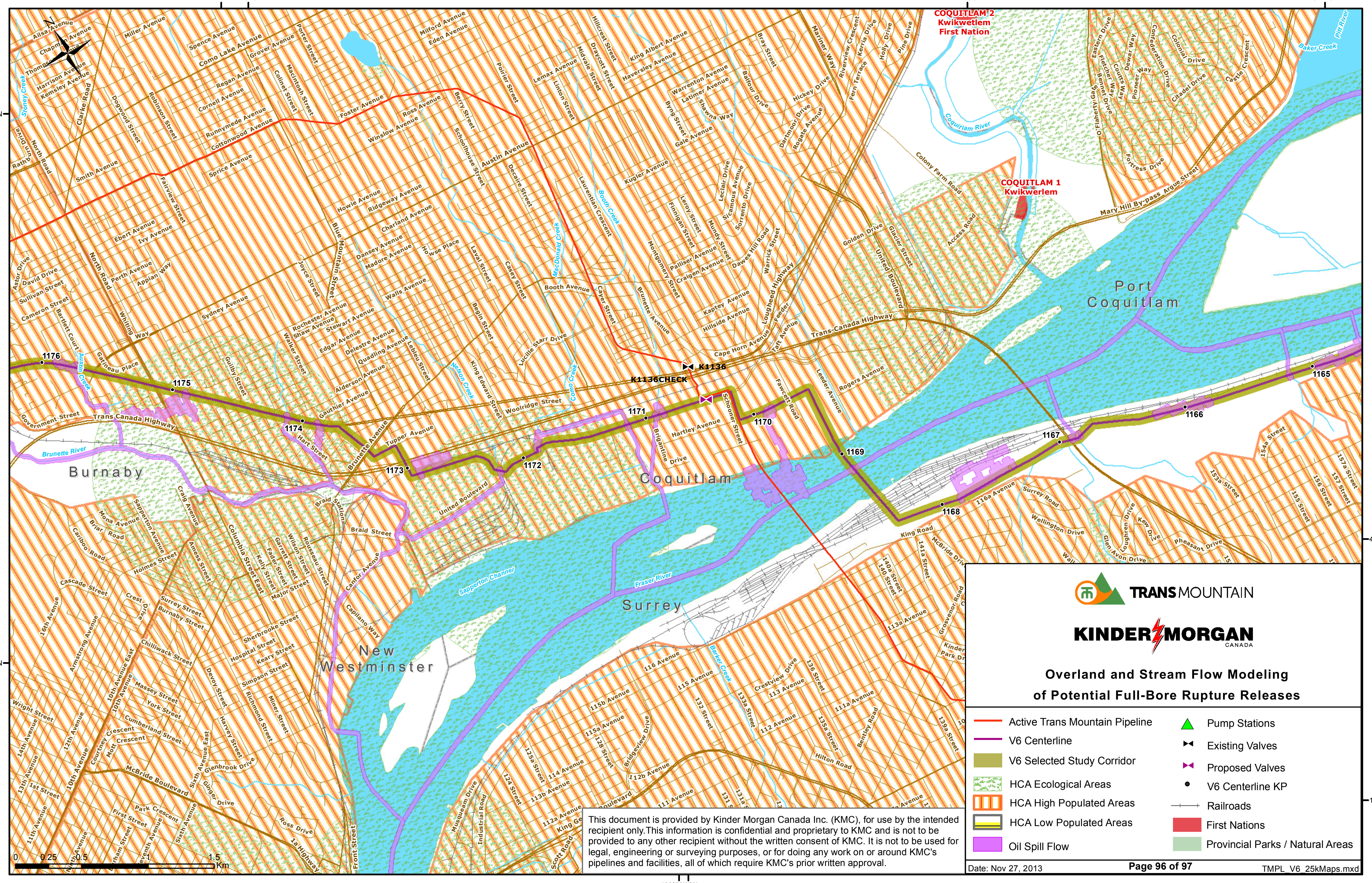
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New Westminster
Surrey
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Coquitlam River
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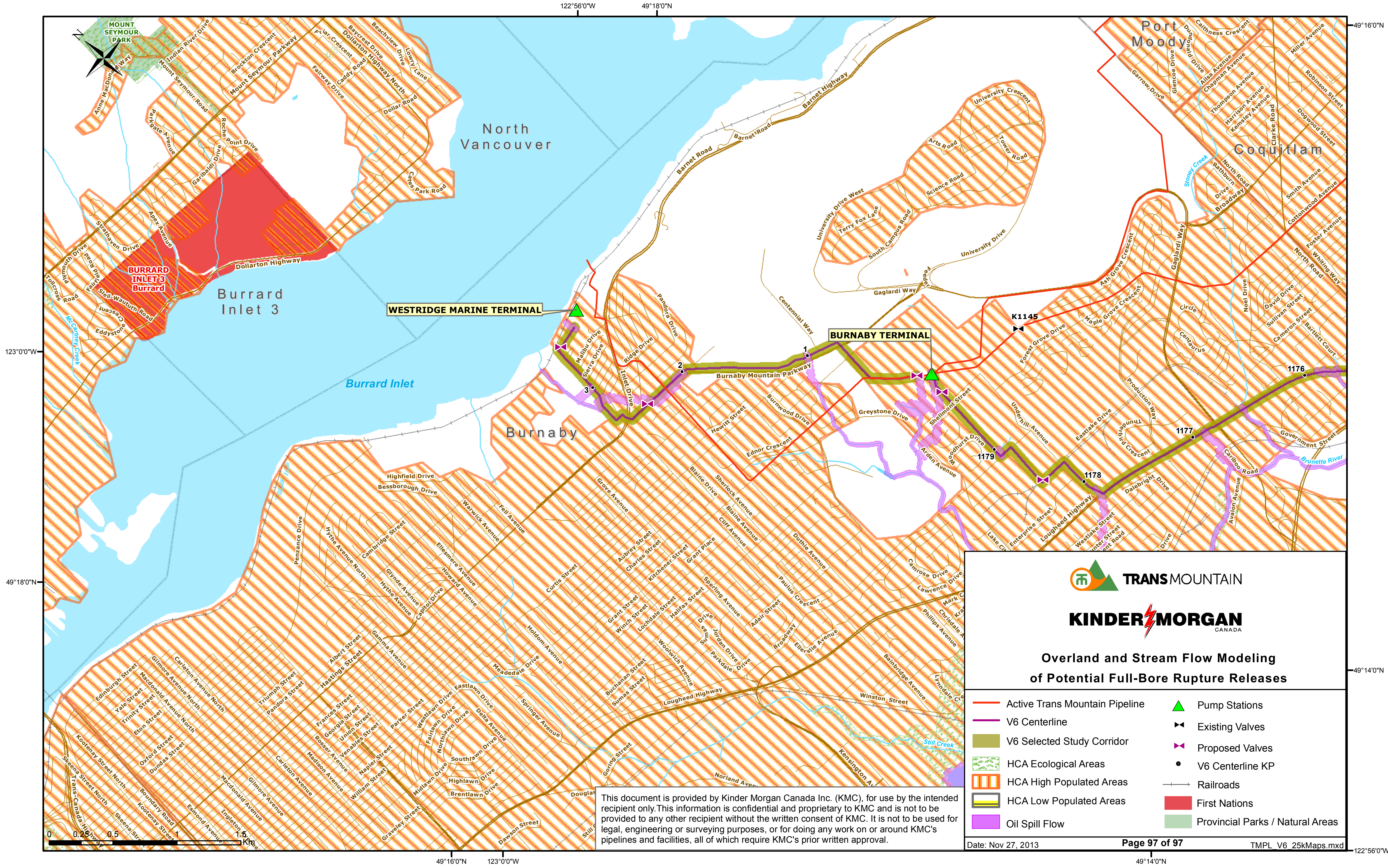
Trans-Canada Highway
Lougheed Highway
Mary Hill By-pass
United Boulevard



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WESTRIDGE MARINE TERMINAL
BURNABY TERMINAL
North Vancouver
Burrard Inlet 3
Burrard Inlet
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Appendix D Simulations of Hypothetical Oil Spills from the Trans Mountain Expansion Project Pipeline – P1 V6 Route

REPORT

SIMULATIONS OF HYPOTHETICAL OIL SPILLS FROM THE TRANS MOUNTAIN EXPANSION PROJECT PIPELINE – P1 V6 ROUTE

PREPARED FOR:

Trans Mountain Expansion Project

2013-178

AUTHOR:

Chris Galagan

Jeremy Fontenault

DATE SUBMITTED

27 November, 2013

RPS asa

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Introduction

RPS ASA simulated hypothetical spills occurring along the route of the proposed Trans Mountain expansion pipeline in Alberta and British Columbia, Canada. RPS ASA used its OILMAP Land model to determine the overland and downstream pathways of the spills using volumes provided by Trans Mountain at locations distributed along the proposed pipeline route. The output from the modeling, consisting of the predicted oil pathways and spill point locations, has been provided as ESRI shape files. This report describes the operational and environmental data used in the modeling and the model results. Figure 1 shows the pipeline centerlines used to locate spill points for the modeling.

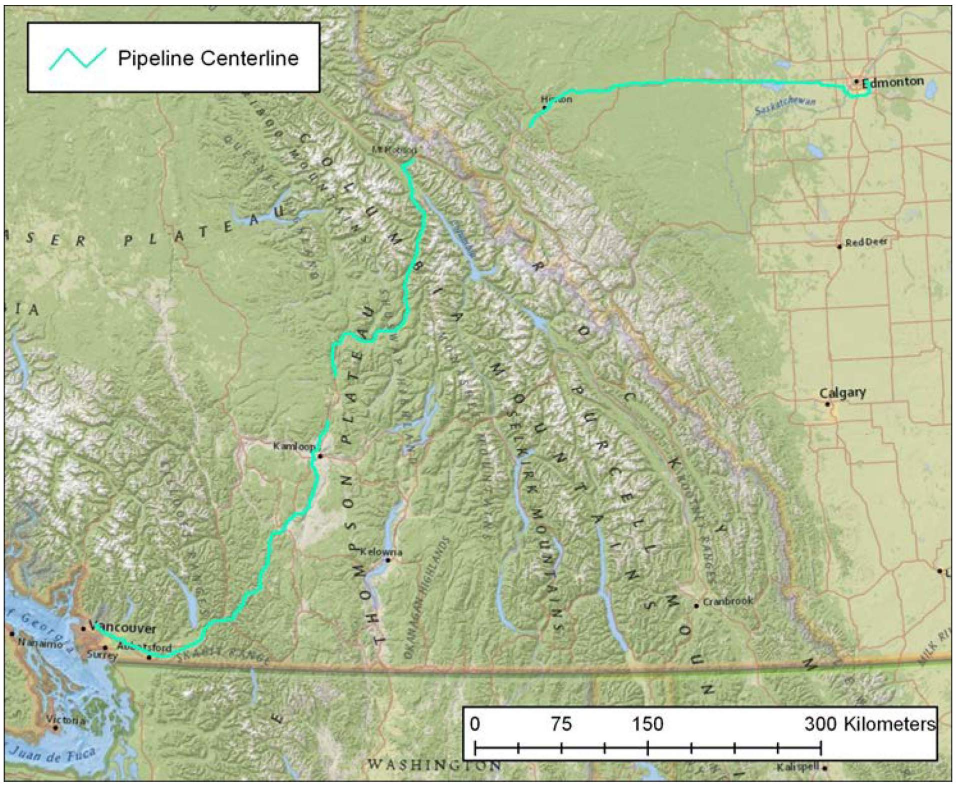


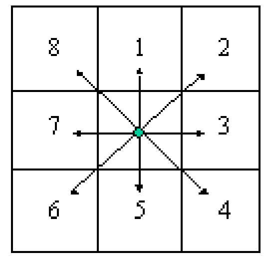
Figure 1. Map of the Trans Mountain expansion pipeline centerlines used for locating spill points used in the modeling.

Description of the OILMAP Land Model

OILMAP Land is a model system containing tools to generate spill points along a pipeline centerline, calculate the product volume discharged at each point resulting from a catastrophic break of the line, and model the overland and downstream pathways of hazardous liquid spills using standard geospatial data and appropriate environmental parameters. The model outputs spill pathways in geospatial data formats that may be used to perform HCA and other types of analysis.

Spill Pathway Determination

Land based spills travel down slope over land and often end up in a stream or other surface water feature. Prediction of flow over land and through the surface water network requires two fundamentally different modeling approaches. Oil flow over land is governed by the physical nature of the land surface and the degree of slope over which it flows. The land transport model calculates an oil mass balance that accounts for oil adhesion to land over the oiled path, the formation of small puddles, oil pooling in large depressions on the land surface, and oil evaporation to the atmosphere. Once the oil reaches a stream or lake its flow is governed by surface currents, requiring a different modeling approach. The water transport model moves oil on the water surface at a defined velocity and calculates the quantity of oil retained on the shore and oil evaporation to the atmosphere.



Calculating the Spill Path over Land

Starting at the spill location, the model determines the steepest descent direction in the eight adjacent cells of the land elevation grid. The oil moves to the neighboring cell with the lowest elevation. This process repeats successively until a flat area or depression is reached. In a flat area, the model searches the minimum distance path to a next lowest cell (i.e. looks beyond the eight adjacent cells) and moves the spill to that cell. In a depression area, the depression is filled before the spill continues down slope. Overland flow of the oil continues until the path reaches a stream or other surface water feature, or until the total spill volume is depleted from loss to the land surface and evaporation. The final spill path over land forms a chain of channels and pooled sections. A channel section is where no pooling occurs and the width of the spill path is dependent on the slope of the land surface. A pooled section consists of an area of one or more contiguous elevation grid cells that form a depression in which the spilled product has collected. Figure 2 depicts a conceptual diagram of the flow of oil over the land surface as simulated by the OILMAP Land model.

The digital elevation data used is necessarily coarse and only approximates topography that could potentially direct the flow of the spill or cause pools to form. Features such as roads, railway tracks and ditches that would impede or re-direct oil flow are not always captured in elevation data at the available scale.

The amount of oil retained on the land surface as oil flows down slope is determined by the nature of the land cover. A land cover type data grid specifies the amount of oil retention based on the cover type so that as oil traverses the land a variable loss rate is calculated. This loss value varies between 2 and 200 millimeters (0.08 – 7.9 inches) for the range of land cover types typically encountered. These oil loss rates are based on surface hydrologic studies (ASCE 1969, Kouwen 2001, and Schwartz et al 2002).

Separate from oil adherence based on land cover type, oil pooled on the land surface is the volume of oil retained within depressions defined in the land elevation grid. The oil retained on the ground is the sum of adhesion and pooling. Total oil loss during a spill simulation includes losses to the ground plus evaporative loss to the atmosphere (described below).

The velocity (V) of the leading edge of the spill as it travels over the land surface is determined by the slope of the land surface using Manning's Equation:

$$V = 1/n \, R^{2/3} \, S^{1/2}$$

Where R is the hydraulic radius, S is the slope, and n is a dimensionless number that characterizes the flow resistance. As an example, assuming n is 0.05 and R is 0.122m:

$V = 4.92 \, S^{1/2}$ (meter/sec)

The width of the oil flow path is also determined by slope; the width increases as the slope of the land surface decreases and decreases with increasing land surface slope. The path width is typically 1-2 meters, and cannot exceed the dimension of the land elevation grid cells.

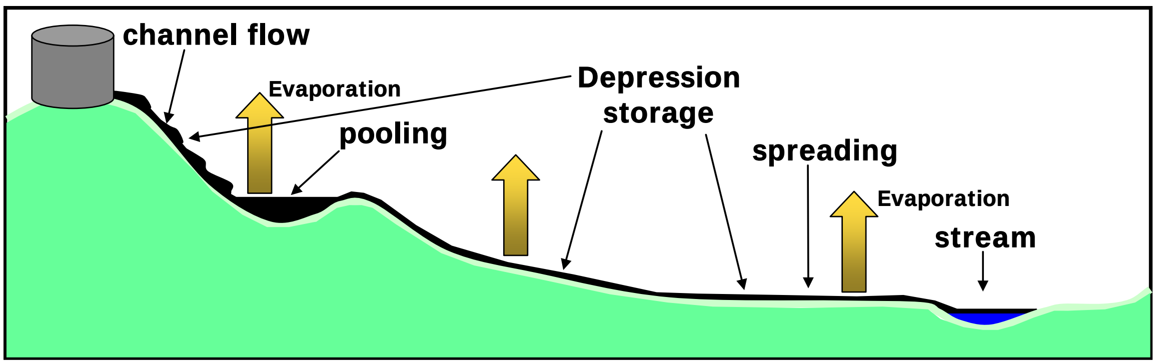


Figure 2. Conceptual diagram of the land transport model showing the possible fate of oil as it moves over the land surface.

<u>Water Transport</u>

Once the spilled oil enters a stream it is transported through the stream network at a velocity defined by the speed and direction of surface currents in each stream reach. While in the stream network, oil is lost by adhesion to the shore and by evaporation to the atmosphere. Figure 3 depicts a conceptual diagram of the water transport portion of the model. Total travel time and the velocity of the surface current in the stream control the distance the oil will travel downstream. Total travel times are typically defined in spill response plans as the time required to respond to and stop a catastrophic release. Oil is modeled to travel downstream until all available oil is lost to the shoreline or to evaporation, or the simulation reaches the downstream travel time. The 24-hour travel time used in the modeling does not reflect spill control response times.

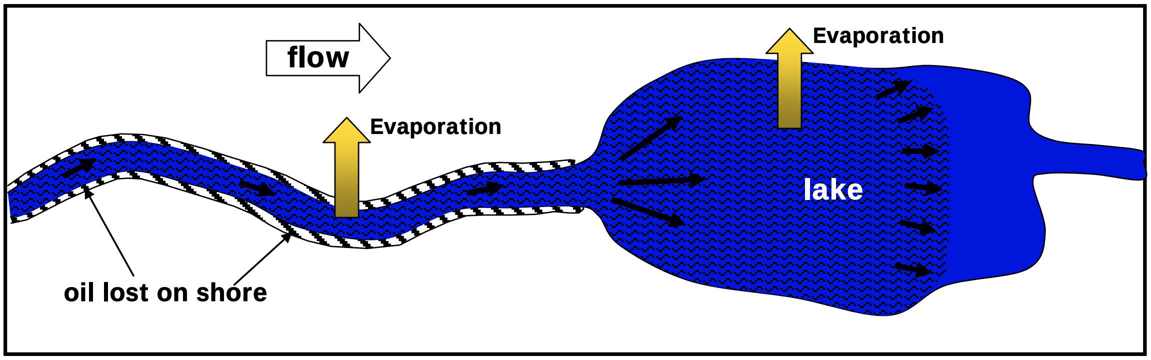


Figure 3. Conceptual diagram of the water transport model showing the possible fate of oil entering the surface water network.

Oil is transported downstream at the current speed defined for each stream reach. The current speeds are calculated using the relationship between drainage area and stream flow determined from gauged streams throughout the region of the pipeline corridor. Using the area/flow relationship from gauged streams, flow for un-gauged streams can be estimated if the drainage area is known. Once flow is known the current speed can be calculated using an equation developed by Jobson (1996). This method is the same used by the USGS for calculating stream current speeds for its National Hydrography Dataset (NHD Plus). This method uses regression analyses on hydraulic variables for over 980 time-of-travel studies from about 90 different rivers in the U.S. These rivers represent a range of sizes, slopes, and channel geometries. Four principal parameters are used in the Jobson method: drainage area, reach slope, mean annual discharge, and discharge at the time of the measurement. Based on this analysis, regression equations were developed to relate velocity to drainage area and the other parameters. For the modeling reported here, the current speeds calculated using this method are for a maximum monthly mean flow condition.

The model does not take into account any braiding, debris, backwater, log jams or other impediments to downstream travel and assumes a straight-sided channel. Adherence of the spilled product occurs along the simulated banks.

When oil encounters a lake the slick will spread across the lake surface until it covers the entire lake or it reaches a minimum thickness. If the minimum thickness is reached, spreading stops and the oil travels no farther. The minimum thickness can be varied according to the oil type. If oil covers the lake surface before reaching the minimum thickness it continues in any out-flowing streams at the surface current velocity specified for the stream reach.

Oil is retained on stream shorelines as it is transported downstream by surface currents. Five different stream shore types are defined, each with a specified bank width and oil retention thickness. Oil volume adhering to the shoreline is calculated as the length of the shoreline oiled times the specified bank width times the oil thickness. Shoreline retention thickness values for different shore types are shown in Table 1.

Table 1. River shore types and associated oil retention values used in the model.

Shore Type	Shore Width	Oil Thickness		
		Light Oil	Medium Oil	Heavy Oil
Bedrock	1.6 ft (0.5 m)	1 mm	2 mm	4 mm
Gravel	3.3 ft (1 m)	2 mm	9 mm	15 mm
Sand/Gravel	6.6 ft (2 m)	3 mm	13 mm	20 mm
Sand	16.4 ft (5 m)	4 mm	17 mm	25 mm
Marsh	65.6 ft (20 m)	6 mm	30 mm	40 mm

Evaporation

Oil evaporates as it spreads over land or water. The most volatile hydrocarbons (low carbon number) evaporate most rapidly, typically in less than a day and sometimes in under an hour (McAuliffe, 1989). OILMAP Land uses a method called the Evaporative Exposure Model of Stiver and Mackay (1984) which is used in oil spill models of all kinds, both water and land based, to predict the volume fraction evaporated.

Several simplifying assumptions are made that directly affect the amount of oil predicted to evaporate. In general, the rate of evaporation depends on surface area, oil thickness, and vapor oil pressure, which are functions of the composition of the oil, and on wind speed, air and land temperature. The mass of oil evaporated is particularly sensitive to the surface area of the spreading oil and the time period over which evaporation is calculated. On the land surface, area and evaporation time are functions of the slope defined by the elevation grid and the size of the depressions encountered. A steeper slope causes the oil to travel faster but along a narrower path, while a lower slope slows the speed of advance and increases the width of the oiled path.

In the stream network, oil surface area and evaporation time are functions of the stream surface area (total length of the oiled stream times the width) and stream velocity.

Oil loss to evaporation ceases once the total oil spill volume is released and the simulation is terminated. Termination may occur for a number of reasons including:

- Oil loss to the ground surface, stream banks, and evaporation
- The stream travel time is exceeded
- The spill reaches its minimum thickness on a lake surface
- The spill reaches a dead end in the stream network, or the coastline.

In reality, oil will continue to evaporate from the ground or water surface, increasing the total evaporation amount. This conservative calculation of evaporative loss is consistent with a worst-case scenario approach.

Application of the Model

Outflow point locations were provided by Trans Mountain for the pipeline segments shown in Figure 1. The outflow points were spaced at a 30-meter interval along the pipeline centerline and at additional selected locations, including stream crossings. Spill points used in the modeling were created at a 1-kilometer interval along the pipeline centerline and at stream crossings. The release volume for each spill point was determined by selecting the maximum total release volume from all outflow points within the 1-kilometer segment. Spill points at stream crossings were also assigned the maximum release volume for the 1-kilometer segment they fall within. The model was run once for each spill to determine the pathway over land and down streams.

Environmental Data

Land Elevation

The land surface was defined using elevation data from the 1 arc-second (about 30 meters) resolution National Elevation Dataset (NED) provided by the United States Geological Survey (USGS). The NED is derived from elevation data obtained from a number of sources, processed to a common coordinate system and vertical unit, and provided as a seamless dataset. Elevations are stored as meters referenced to the North American Vertical Datum of 1988 (NAVD 88) and based on the North American Datum 1983 (NAD83) horizontal reference datum.

Surface Water

The surface water streams and lakes network was defined using the National Hydro Network dataset. It provides geospatial vector data describing hydrographic features such as lakes, reservoirs, rivers, streams and canals in the form of a linear drainage network that is used by the model to route spills downstream.

The NHN is available to the public from the GeoBase web site (www.geobase.ca) but it requires some processing and QA/QC steps to make it usable by the OILMAP Land model. The dataset is comprised of data from federal and provincial/territorial sources, coordinated jointly by the federal government and provincial and territorial partners. The NHN is a vector data product primarily designed to allow hydrographic network analysis. It is intended for water flow analysis, water and watershed management, environmental and hydrographical applications.

Land Cover Type

The characteristics (other than elevation) of the land surface are defined using the LCC 2000 dataset developed by Natural Resources Canada, Earth Sciences Sector and published in 2009. The data were the result of vectorization of classified Landsat 5 and Landsat 7 ortho-imagery for agricultural and forest areas in Canada, and for Northern Territories. The digital data were obtained from geobase.ca. Details of the classification system can be found in Wulder and Nelson, 2003.

Model Results

The OILMAP Land model was used to simulate 1,822 individual hypothetical spills from points distributed at a 1-kilometer interval and at stream crossings along the proposed Trans Mountain Expansion pipeline route (see Figure 1).

The model output has been provided in ESRI shape file format. Shape files containing the spill points and the model calculated spill pathways (plumes) have been provided for each of the 13 pipeline segments modeled. Each spill point is given a unique ID number per pipeline segment that can be used to relate the point to the resulting plume. Figure 4 shows the spill points and plumes for a short section of the Edmonton to Gainford pipeline segment.

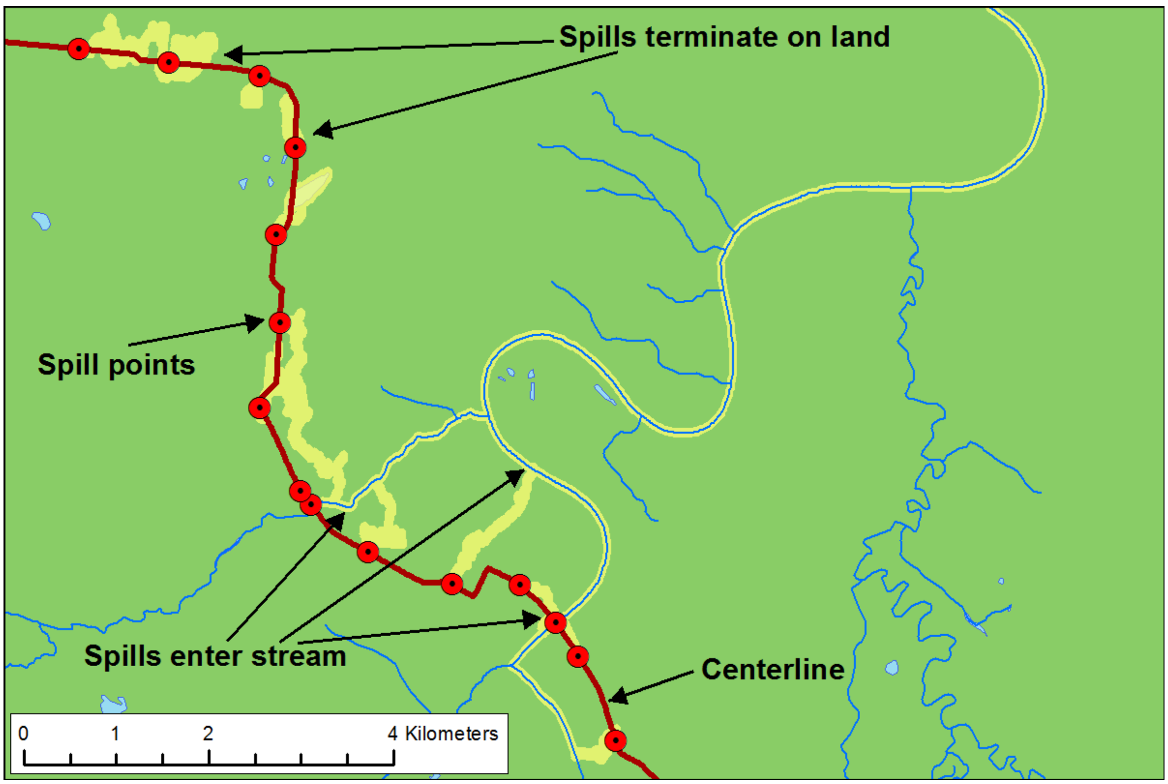


Figure 4. Map showing spill plumes along a section of the Edmonton to Gainford pipeline segment in Alberta.

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Appendix E Facility Integrity Hazards Listings

Facility Integrity Hazards – Tanks		
Event or Hazard	**Preventative Measure(s)**	**Consequence Reduction Measures**
Appurtenance leak	API 653 in-service and out of service inspections	Routine facility check, creep alarms, containment berms
Brittle Fracture	API 650 design, commissioning hydrostatic testing	containment berms
External Corrosion	External coating systems, API 653 in-service and out of service inspections	Routine facility check, creep alarms, containment berms
Shell Internal Corrosion	Bottom 3ft of shell is internally coated, API 653 in-service and out of service inspections, biocide treatments	Routine facility check, creep alarms, containment berms
Mixer seal leak	Routine site inspections, mixer replacement program	Routine facility check, creep alarms, containment berms
Over-pressure-vacuum on fixed roof tank	P/V vents and vent maintenance and testing	Frangible shell to roof joint, containment berms, routine facility check
Shell to floor weld failure from settlement	API 653 in-service and out of service inspections	Routine facility check, creep alarms, containment berms
Tank over-fill	Tank Overfill protection in accordance with API 2350, maintenance and testing of level switches and ESD circuit	containment berms
Vehicle Impact with tank/ appurtenance	controlled site access, bollards	containment berms
wind damage to shell	API 650 design, wind girders	containment berms
EFR Corrosion	External coating of floating roof, internal coating of floating roof in vapour spaces, expanded scope of in service and out of service inspections to address floating roof corrosion	Roof drains normally closed, tank shell, monthly inspections, containment berms
Floating roof jams with shell and sinks	Monthly roof inspection from gauging platform, annual roof inspection, API in service and out of service inspections, gauge pole centers roof	Roof drains normally closed, tank shell, monthly inspections, containment berms
Freezing damage to roof drain system	Winterization in cold climates, heat tracing of shell water drain nozzle and valve at locations with high winter rain and potential for freezing temperatures.	Routine facility check, creep alarms, containment berms
Roof sinks from overloading	pontoons and pontoon inspection and mitigation, roof drain monitoring, monthly inspections, vacuum breaker, tank leg pins	Roof drains normally closed, tank shell, monthly inspections, containment berms
EFR leg damages floor	Striker plates on tank floor, low operating limits for tanks, legs set for operating position, floating roof anti-rotation device	Creep alarms, under tank liner (where applicable), under tank leak detection (where applicable)

Facility Integrity Hazards – Tanks		
Event or Hazard	**Preventative Measure(s)**	**Consequence Reduction Measures**
floor weld cracking	API 653 out of service inspections	Routine facility check, creep alarms, containment berms
Topside floor corrosion	Tank floor lining, striker plates, API 653 out of service inspections, biocide treatments	Creep alarms, under tank liner (where applicable), under tank leak detection (where applicable)
Underside floor corrosion	Cathodic protection, API 653 out of service inspections	Creep alarms, under tank liner (where applicable), under tank leak detection (where applicable)
Full or partial surface tank fire	Floating roof with primary and secondary seals, controlled site access, hot work permitting system at all locations (some locations have: rim seal foam dams, foam piping and pourers for rim seal fire fighting, hazardous area electrical design, rim fire detection system)	Firewater, foam and equipment available for major tank fire (where applicable), containment berms, spacing and firewater systems to NFPA30. Fire eyes on some tanks
Tank area fire	Vegetation control in tank bay, controlled site access, hot work permitting system	Firewater, foam and equipment available for major tank fire (where applicable), containment berms, spacing and firewater systems to NFPA30
Tank rim seal fire	Floating roof with primary and secondary seals, controlled site access, hot work permitting system, ground shunts, tank grounding system	firewater, foam and equipment available for rim seal fire (where applicable), containment berms, spacing and firewater systems to NFPA30
Sump tank external corrosion	External coating or non-metallic structure,	Groundwater monitoring well
Sump tank internal corrosion	Internal coating or non-metallic structure, biocide treatments,	Groundwater monitoring well
Sump tank crack or puncture	Internal inspections, double walled tank with interstitial space monitoring, installation procedures, protective bollards above buried tanks	Groundwater monitoring well
Sump overfill	Sump level indication/creep alarm, high level ESD, high-high level ESD	Hydrocarbon detector in drainage path (where applicable)

Facility Integrity Hazards – Piping (Includes above and below ground piping, valves and fittings)		
Event or Hazard	**Preventative Measure(s)**	**Consequence Reduction Measures**
Excessive pipe strain	Stress analysis during design, change management, above ground piping inspection, backfilling standards	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
External Corrosion	External coatings, above ground piping inspection, Facility Piping Assessment Program, Cathodic protection (for U/G)	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Flange Leak	Flange bolting standard,	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)

Facility Integrity Hazards – Piping (Includes above and below ground piping, valves and fittings)		
Event or Hazard	**Preventative Measure(s)**	**Consequence Reduction Measures**
Internal Corrosion	Facility piping assessment program, in service or maintenance flushing	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Internal Erosion	Facility piping assessment program	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Overpressure	Hydrostatic testing, full flow and thermal relief valves	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Vandalism	Site security	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Vehicle Impact	Controlled access, bollards`	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Water Freezing in line or valve	Heat tracing, winterization, in-service or maintenance flushing, water content controlled by tariff	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Impact from excavation equipment	Safe work permit system, damage prevention standards	Inspector required for inspection of piping in facilities
Vibration	Above ground piping inspection,	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Valve left or bumped open inadvertently	Plugs or blinds on all open pipe ends, drain/vent checklists, valve locks or pins	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
Valve stem seal failure	Snug gland nuts	Routine facility check (for A/G), hydrocarbon detector in drainage path (where applicable), secondary containment (where applicable)
piping area fire	Controlled drainage away from piping areas, hazardous area electrical design, combustible gas detection instrumentation (where applicable)	Fire fighting water, foam and equipment
EFR Roof drain piping corrosion	API Out of Service Inspections	Winterization Procedure, EFR drain valves operated in normally closed position

Facility Integrity Hazards – Pumps		
Event or Hazard	**Preventative Measure(s)**	**Consequence Reduction Measures**
Case erosion	Internal inspection	Routine facility check, combustible gas detection, secondary containment, ESD system
Excessive vibration	vibration protection, precision alignment, routine site check	Routine facility check, combustible gas detection, secondary containment, ESD system
Overpressure	Hydrostatic testing, proper design, overpressure protection instrumentation (where applicable), relief valves (where applicable)	Routine facility check, combustible gas detection, secondary containment, ESD system
Over temperature	Casing high temperature shutdown, pump bearing high temperature shutdown, incomplete sequence shutdown	Routine facility check, combustible gas detection, secondary containment, ESD system
Seal failure	vibration protection, precision alignment	Seal fail detection and containment systems, combustible gas detection, ESD system, secondary containment
Fire in pump room	Combustible gas detection system, ESD System, hazardous area electrical design, permit requirements for hot work	Fire eyes, ESD system, secondary containment
Corrosion of deep well booster pump cans	Out of service inspections	Routine facility check

Appendix F Special Tactics for Spill Response

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1.0 DISPERSANTS

While the existing planning standards focus on mechanical recovery, other response measures including the use of dispersants and in-situ burning exist and have proven effective in minimizing environmental harm in the event of a spill. However, the effectiveness of these measures can diminish as weathering of the oil progresses. While these methods are not appropriate in all cases, having conditional pre-approval for their use would avoid delays that diminish their effectiveness in situations when they offer a desirable means of diminishing environmental harm. Response organizations should be empowered with conditional preapprovals for in-situ burning, the use of dispersants and beach-cleaning agents.

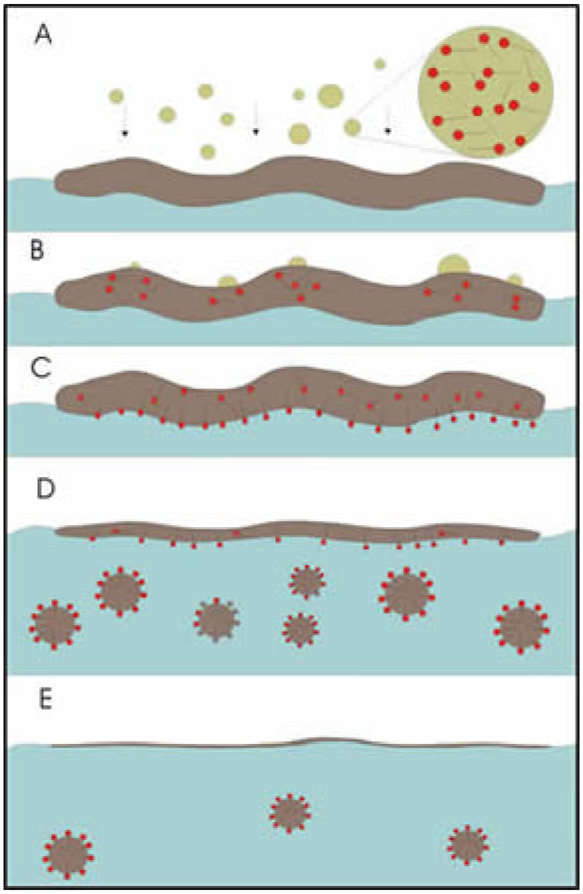
When used appropriately, dispersants can be an effective method of response to an oil spill. They are capable of rapidly removing large amounts of certain oil types from the sea surface by transferring it into the water column. Following dispersant application, wave energy will cause the oil slick to break up into small oil droplets that are rapidly diluted and subsequently biodegraded by micro-organisms occurring naturally in the marine environment. They can also delay the formation of persistent water-in-oil emulsions. In common with other response techniques, the decision to use dispersants must be given careful consideration and take into account oil characteristics, sea and weather conditions, as well as surrounding environmental sensitivities.

Dispersants are a group of chemicals designed to be sprayed onto oil slicks to accelerate the process of natural dispersion. Significant environmental and economic benefits can be achieved, particularly when other at-sea response techniques are limited by weather conditions or the availability of resources. In certain situations, dispersants may provide the only means of removing significant quantities of surface oil quickly, thereby minimising or preventing damage to important sensitive resources. Their use is intended to minimise the damage caused by floating oil, for example to birds or before the oil may hit a sensitive shorelines. However, in common with all spill response options, the use of dispersants has limitations and its use should be carefully planned and controlled. Dispersant use will also depend upon national regulations governing the use of these products.

1.1 How Chemical Dispersion Works

Natural dispersion of an oil slick occurs when waves and other turbulence at the sea surface cause all or part of the slick to break up into droplets and enter into the water column. The addition of dispersants is intended to accelerate this natural process.

Dispersants have two main components: a surfactant and a solvent. Surfactants molecules are made up of two parts: an oleophilic part (with an attraction to oil) and a hydrophilic part (with an attraction to water). When dispersants are sprayed onto an oil slick, the solvent will transport and distribute the surfactants through the oil slick to the oil/water interface where they arrange themselves so that the oleophilic part of the molecule is in the oil and the hydrophilic part is in the water. This creates a reduction in the surface tension at the oil/water interface and small oil droplets will break away from the oil slick with the help of wave energy. These droplets will be of varying sizes and although the larger ones may rise back to the surface some will remain in suspension and will drift apart and become degraded by naturally occurring bacteria. If dispersion is successful, a characteristic brown plume will spread slowly down from the water surface a few minutes after treatment.



Notes: A: Dispersant droplets containing surfactants are sprayed onto the oil.

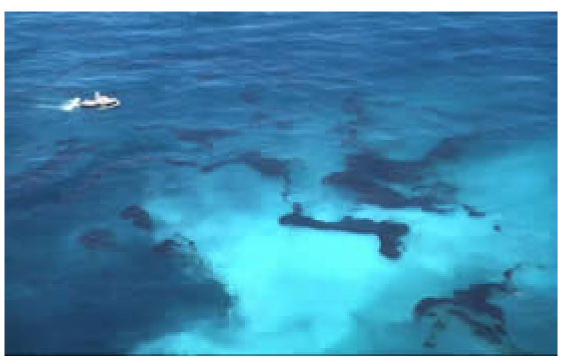
B: The solvent carries the surfactant into the oil.

C: The surfactant molecules migrate to the oil/water interface and reduce surface tension, allowing.

D: small oil droplets to break away from the slick.

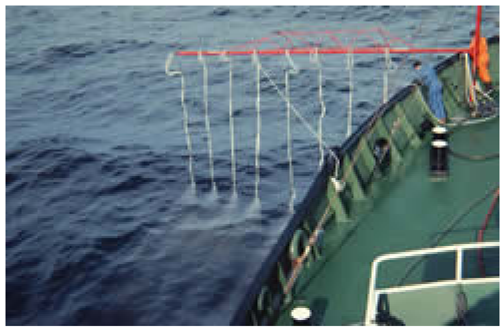
E: The droplets disperse by turbulent mixing, leaving only sheen on the water surface.

1.2 Limitations



Dispersants have little effect on very viscous, floating oils, as they tend to run off the oil into the water before the solvent can penetrate. As a general rule, dispersants are capable of dispersing most liquid oils and emulsions with viscosities of less than 2000 centistokes, equivalent to a medium fuel oil at 10-20ºC. They are unsuitable for dealing with viscous emulsions (mousse) or oils which have a pour point near to or above that of the ambient temperature. Even those oils which can be dispersed initially become resistant after a period of time as the viscosity increases as a result of evaporation and emulsification. For a particular oil, the time available before dispersant stops being effective depends upon such factors as sea state and temperature but is unlikely to be longer than a day or two. Dispersants can, however, be more effective with viscous oils on shorelines because the contact time may be prolonged allowing better penetration of the dispersant into the oil.

1.3 Methods of Application at Sea



Dispersants can be applied to open water by a variety of methods. In general workboats are more suitable for treating minor spills in harbours or confined waters. Large multi-engine planes are best equipped for handling large off-shore spills. Small, single-engine aircrafts and helicopters are suitable for treating smaller spills and near shore areas. Regardless of the method used, the droplet size of the dispersant is important as it needs to be sufficiently large to overcome the effects of wind and evaporative loss but not so large that it will result in the droplets being able to pierce through the oil slick. A uniform spray pattern of larger droplets, "rain drops", is required rather than a fog or a mist. Ultimately, whichever method of application is used, the key to a successful response using chemical dispersants is the ability to target the thickest part of the oil slick within a short time and before weathering or sea state render the oil undispersable.

1.4 Vessel Spraying

Dispersants are usually applied from boats equipped with spray arms. In a typical spray arm system, pumps are used to pump dispersants from a storage tank through a set of nozzles calibrated to produce a uniform spray pattern of droplets.

Spray units can be portable or permanently installed on a vessel and systems are available which deliver the dispersant either undiluted or diluted with sea water. Spray arms are usually mounted as far forward on the vessel as possible to avoid the effect of the bow wave which can push the oil beyond the spray swath. Mounting the spray arms on the bow allows the vessel to travel faster and, because freeboard area is often greater at the bow also allows for longer spray arms. This combination allows optimisation of the amount of oil which can be treated (increasing the encounter rate) with a limited dispersant payload. If spray arms are not available, fire hoses or monitors are sometimes used to apply diluted concentrate dispersants. However, optimum dilution of the dispersant is difficult to achieve because of the very high flow rates and wastage of dispersant is a common problem. The high-powered jet of water also makes it difficult to apply the dispersant as a uniform spray of droplets and it frequently pierces through the oil making it ineffective. Thus fire monitors are unlikely to be an effective application tool unless specially modified for the purpose.

Vessels offer certain advantages for dispersant spraying because they are usually readily available, easy to load and deploy, have cost advantages over aircraft and can apply dispersant fairly accurately to specific areas of a slick. Nevertheless, they also have serious limitations, particularly for larger spills, because of the low treatment rate which they offer and the added difficulty of locating the heaviest concentrations of oil from the bridge of a vessel. Furthermore, when slicks become fragmented or form narrow windrows, it is inevitable that some dispersant will be sprayed onto clear sea. These problems can be partially overcome by controlling the operation from spotter aircraft.

1.5 Aerial Spraying

The spraying of dispersant from an aircraft has the significant advantages of rapid response, good visibility, high treatment rates and optimum dispersant use. In addition, aircraft allow treatment of spills at greater distances from the shore than with vessels.

Two categories of aircraft are used: those designed for agricultural or pest control operations which require minor modification for dispersant application, and those which have been specifically adapted for the application of dispersant. Several types of helicopter have also been adapted to spray dispersants although most are able to carry an under slung bucket spray systems without the need for modifications. The ideal aircraft will be determined primarily by the size and location of the spill, although in reality local availability will be the crucial factor. The endurance, fuel consumption, turn around time, payload and the ability to operate from short or improvised landing strips are all important. In addition, the aircraft should be capable of operating at low altitude and relatively low speeds (50-150 knots) and be highly manoeuvrable.

Only type 3 dispersants are suitable for aerial spraying, since they require no mixing beyond that provided by the natural movement of the sea. The relatively low dose rate required also makes the best use of available payload.

1.6 Shoreline Application

Dispersants are sometimes used to remove oil from hard surfaces such as rocks, sea walls and other manmade structures, particularly during the final stages of clean-up. However, it is important to remove the bulk of the stranded oil by other means first. Shores subjected to strong wave action are often cleaned naturally and they should not be sprayed unless the oil has to be removed immediately.

Dispersants may be applied to the surface and scrubbed into the oil before flushing with sea water. The dispersed oil cannot be collected and for this reason dispersant use on the shoreline is restricted to areas of low environmental concern. Shoreline cleaners may also be used but it is important to note that their mechanism of action is different from that of dispersants. Degreasers are often carried on board ships to deal with small spillages of oil on deck but most are more toxic than dispersant and should not be used as a dispersant at sea or as a shoreline cleaner. Today it is recommended to use citrus-based chemical cleaners as these usually have a lower environmental impact than traditional chemical cleaners.

1.7 Monitoring Dispersant Effectiveness

It is essential that the effectiveness of chemical dispersion should be monitored continually and the response terminated as soon as the dispersant is no longer working. Successful dispersion will usually produce a coffee-coloured plume spreading under the water surface. However, visual observation of effectiveness may be impaired in poor weather conditions, in waters with high sediment content, when dispersing pale-coloured oils or in poor light. It is inappropriate to spray at night. Experience has shown that for the application of dispersants to be worthwhile, the oil will need to disperse sufficiently rapidly to effect a change in appearance of the slick and a subsequent reduction in oiled area, which should be visible from the air shortly after spraying. Conversely, if there is no change in oil appearance or coverage, and the dispersant runs off the oil to create a milky white plume in the water, the dispersant is not working. Equally, if the oil has become fragmented and widely scattered, it is unlikely that sufficient oil will be removed from the water surface by the dispersant to achieve a significant reduction in pollution damage.

Ultra-violet fluorimetry (UVF) is sometimes used to provide ‘real-time’ data on the concentration of dispersed oil in the water column during the application of dispersants. Typically, the variation in the concentration of fluorescent components is measured at least 1 metre under the slick using a fluorimeter that is towed behind a sampling boat. In open water, dispersion is demonstrated by a significant increase in the concentration of oil detected by the sensor compared with that measured prior to dispersant application. However, when used operationally, UVF does not provide a quantitative measurement of the amount of oil that is actually being removed from the sea surface and it should be used in combination with visual observations to decide whether a worthwhile response can be achieved.

1.8 Environmental Considerations

The use of dispersants has in the past tended to provoke controversy since their application can be seen as a deliberate introduction into the sea of an additional pollutant into the water. Many of the first dispersants used in the 70s and 80s did show high toxicity to marine organisms. However, today there is a wealth of laboratory data indicating that modern dispersants and oil/dispersant mixtures exhibit relatively low toxicity to marine organisms.

The rapid dilution of the dispersed oil, the proximity to sensitive areas as well as the direction of currents and the mixing depths of surface waters are all factors which should be considered when deciding upon dispersant use. In the open sea, dispersed oil concentrations after spraying are unlikely to remain high for more than a few hours and significant biological effects are therefore improbable. In shallow waters close to the shore, where water exchange is poor, higher concentrations may persist for long periods and may give rise to adverse effects. However, the controlled application of dispersants may, on occasions, be beneficial in that it may reduce damage to adjacent ecologically sensitive shorelines by oiling.

The decision on whether or not to use dispersants rather than other response options will need to take into account the cost-effectiveness and conflicting priorities for protecting different resources from pollution damage. On occasions the benefit gained by using dispersants to protect coastal amenities, sea birds and intertidal marine life may far outweigh disadvantages such as the potential for temporary tainting of fish stocks. Certain resources such as water intakes, mariculture facilities or fish spawning areas are difficult to protect from dispersed oil and spraying may be decided against when near to these resources. Detailed contingency planning will aid in this decision process.

Trans Mountain proposes the use of dispersants as one means to respond to oil spills. Specific and detailed plans for the use of dispersants and consultations with government officials will be held to seek approval of these plans.

2.0 IN-SITU BURNING

Like dispersant use, in-situ burning is a tactic that can, under the right circumstances, be extremely effective in spill response; especially if it can be deployed quickly. In-situ burning is the oldest technique applied to oil spills and is also one of the techniques that have been explored in scientific depth. The successful use of in-situ burning on the Deepwater Horizon spill in the Gulf of Mexico drew attention to the technique and left a positive image of burning. Burning is proposed by Trans Mountain to provide a rapid means to remove oil in the event of a spill onto water.

2.1 The Basics of Burning

The fundamentals of in-situ burning are similar to that of any fire, namely that fuel, oxygen, and an ignition source are required (Fingas 2011). Fuel is provided by the vaporization of oil. The vaporization of the oil must be sufficient to yield a steady-state burning, that is one in which the amount of vaporization is about the same as that consumed by the fire. Once an oil slick is burning, it burns down the pool of oil at a rate of 2 to 4 mm per minute. If not enough vapours are produced, the fire will either not start or will be quickly extinguished. The amount of vapours produced is dependent on the amount of heat radiated back to the oil. This has been estimated to be about 2 to 3% of the heat from a pool fire (Fingas 2011). If the oil slick is too thin, some of this heat is conducted to the water layer below it. Since most oils have the same insulation factor, most slicks must be about 1 to 3 mm thick to yield a quantitative burn. Once burning, the heat radiated back to the slick and the insulation are usually sufficient to allow combustion down to about 1 mm of oil.

The amount of oil that can be removed in a given time depends on the fuel and on the area covered by the oil. As a general rule, oil burn rate is about 2,000 to 5,000 L/m^2.day in a typical contained area. Several tests have shown that this does not vary significantly with oil weathering but varies with oil type (Fingas 2011, Mabile 2012). Emulsified oil may burn slower as its water content increases the heat requirement. Figure 1 shows one of the burns carried out during the Deepwater Horizon spill (Mabile 2012). This weathered oil was burning at a rate of about 5 tons per hour.

Flame spreading rates do not vary much with heavy fuel type, but vary significantly with wind, especially with wind direction. Flame spreading rates range from 0.01 to 0.02 m/s (0.02 to 0.04 knots). Downwind flame spreading rates range from 0.02 to 0.04 m/s (0.04 to 0.08 knots), and up to 0.16 m/s (0.3 knots) for high winds.

This oil burn has an area of about 800 square meters, which implies that the fire is consuming about 5 tons per hour of weathered oil. This burn was ignited using a home-made igniter with a flare and a plastic bottle of diesel fuel.

2.2 The Advantages and Disadvantages

Advantages of in-situ burning include: rapid removal of oil from the water surface; requirement for less equipment and labour than many other techniques; significant reduction in the amount of material requiring disposal; significant removal of volatile oil components; requirement of less equipment and labour than other techniques and may be the only solution possible, such as in oil-in-ice situations and in wetlands (ASTM 2008).

Disadvantages of in-situ burning include the following: creation of a smoke plume; residues of the burn may have to be removed; oil must be a sufficient thickness to burn quantitatively, thus may require containment; and danger of the fire spreading to other combustible materials. And finally, burning oil is sometimes not viewed as an appealing alternative to collecting the oil and reprocessing it for reuse. In fact, recovered oil is usually incinerated as it often contains too many contaminants to be economically reused.

Source: Photograph from Elastec/American Marine.

Notes: This oil burn has an area of about 800 square meters which implies that the fire is consuming about 5 tons per hour of weathered oil. This burn was ignited using a home-made igniter igniter - a flare and a plastic bottle of diesel fuel.

Figure 1 Oil Being Burned During the Deepwater Horizon Incident within a Fire-resistant Boom

2.3 Weather and Physical Conditions for Burning

Weather conditions such as wind speed, gusts, shifts in wind direction, wave height and geometry, and water currents can influence the safety and effectiveness of a burn operation. Strong winds can make it difficult to ignite oil during in-situ burning. Once oil is ignited, high winds can extinguish the fire or make it difficult to control. In general, oil can be successfully ignited and burned safely at wind speeds less than 20 m/s (40 knots).

The effects of air and water temperatures on the ability to ignite and burn oil slicks is not well documented, however, tank tests have shown that air temperatures as low as - 20°C and water temperatures as low as -5°C, did not affect the ability of a slick to burn. Rain might lower the efficiency of the burn due to the cooling effect of the water.

High sea states can make it difficult to contain oil. Waves higher than 1 m can cause the oil to splash over the containment boom or otherwise cause boom failure. High waves can also contribute to the emulsification of oil, which could make it more difficult to ignite.

Tests in ice-covered areas have shown that ice coverage has a minimal effect on the ability of a slick to burn. In fact, ice is typically used as a natural method to contain oil for burning.

Burning can be done safely at night if oil conditions, weather conditions, and sea conditions are well known. Towing booms at night could be safe in open seas with escort. Burning at night would be a relatively safe choice in the case of a thicker, uncontained spill at sea, especially if the spill is offshore and its extent is well known. Some nearshore spills and spills in marshes have been burned at night, which is a relatively safe practice when the concentrations and location of the oil are known and precautions can be taken to ensure that the fire does not spread to surrounding areas.

2.4 Emissions from Burning

The prime products of fuel combustion are carbon dioxide and water. All other emissions are by-products. Smoke and emissions are the major concerns for in-situ burning. Basically, the major concern for humans or the environment is the particulate matter in the smoke. Polyaromatic hydrocarbons, or PAHs, are a primary concern in the emissions from burning oil, both in the soot particles and as a gaseous emission. Most of the PAHs in oil are burned except those left in the residue and the soot. The amount of residue varies but is generally less than 10% of the starting oil, and the soot is less than 0.1 to 2%. Another major concern related to the emissions from burning crude oil is with the other possible compounds that might be produced. Further information on emissions appears below.

Extensive measurements of burn emissions were carried out by an international consortium (Fingas 2011). The results of testing on more than 50 burns are summarized here.

Particulate Matter/Soot - All burns produce particulate matter which is the only emission from an oil fire that exceeds recommended human health concern levels close to fires. Concentrations at ground level (1.5 m) can still be above normal health concern levels (35 $\mu g/m^3$) as close downwind as 500 m from a crude oil fire. The greatest concern is the smaller or respirable particulates. The PM-2.5 fraction (very fine particles) is currently the subject of concern (Fingas 2011). In summary, the smoke from in-situ burns is analogous to forest fires in that the major danger is particulate material. This issue is now understood and safe distances to burns can be predicted.

Polyaromatic Hydrocarbons (PAHs) - Crude oil burns result in polyaromatic hydrocarbons (PAHs) downwind of the fire, but the concentration on the particulate matter, both in the plume and the particulate precipitation at ground level, is often an order-of-magnitude less than the concentration of PAHs in the starting oil. This includes the concentration of multi-ringed PAHs (which are of more health concern) that are often created in other combustion processes such as low-temperature incinerators and diesel engines. There is a slight increase in the concentration of multi-ringed PAHs in the burn residue. When considering the mass balance of the burn, however, most of the PAHs, including the multi-ringed PAHs are destroyed by the fire.

Volatile Organic Compounds (VOCs) - Volatile organic compounds are compounds that have high enough vapour pressures to be gaseous at normal temperatures. When oil is burned, these compounds evaporate and are released. The emission of volatile compounds was measured at several test burns. One-hundred and forty-eight volatile organic compounds have been measured from fires and evaporating slicks (Fingas 2011). The concentrations of VOCs are relatively low in burns compared to an evaporating slick. Concentrations are below human health levels of concern even very close to the fire.

Dioxins and Dibenzofurans - Dioxins and dibenzofurans are highly toxic compounds often produced by burning chlorine-containing organic material. Particulates precipitated downwind and residue produced from several fires have been analyzed for dioxins and dibenzofurans.

These toxic compounds were at background levels, indicating no production by crude oil fires (Fingas 2011, Aurell and Gullett 2010).

Carbonyls - Oil burns produce low amounts of partially-oxidized material, sometimes referred to as carbonyls or by their main constituents, aldehydes (formaldehyde, acetaldehyde, etc.) or ketones (acetone, etc.). Carbonyls from crude oil fires are at very low concentrations and are well below health concern levels even close to the fire.

Carbon Dioxide - Carbon dioxide is the end result of combustion and is found in increased concentrations around a burn. Normal atmospheric levels are about 300 ppm and levels near a burn can be around 500 ppm, this presents no danger to humans.

Carbon Monoxide - Carbon monoxide levels are usually at or below the lowest detection levels of the instruments and thus do not pose any hazard to humans.

Sulphur Dioxide - Sulphur dioxide, per se, is usually not detected at significant levels or sometimes not even at measurable levels in the area of an in-situ oil burn. Sulphuric acid, or sulphur dioxide that has reacted with water, is detected at fires and levels, although not of concern, appears to correspond to the sulphur content of the oil.

Other Compounds - There is a concern when burning crude oil about any 'hidden' compounds that might be produced. Soot and residue samples were extracted and 'totally' analyzed in various ways in several studies. While the studies were not conclusive, no compounds of the several hundred identified were of serious environmental or health concern. The soot analysis revealed that the bulk of the material was carbon and that all other detectable compounds were present on this carbon matrix in abundances of parts-per-million or less. The most frequent compounds identified were aldehydes, ketones, esters, acetates, and acids, all of which are formed by incomplete oxygenation of the oil. Similar analysis of the residue shows that the same minority compounds are present at about the same levels. The bulk of the residue is unburned oil without some of the volatile components.

2.5 Ignition

Igniting the oil on water is a technical matter, the important principles are that ignition must occur very close to the oil surface and that sustained heat is required (ASTM 2007b). Lighting oil fires is often simple. The fires during the Deepwater Horizon spill in the US Gulf of Mexico, were lit using a homemade ignition device consisting of a marine safety flare, a plastic bottle of diesel fuel wrapped with duct tape and floats. The flare burns the bottle of diesel fuel, the diesel fuel pours out, and then is ignited. The diesel fuel burning is sufficient to start the oil burning. This ignition device is illustrated in Figure 2.

More volatile fuels such as lighter crudes can be ignited easier, but require caution because of rapid flame spreading. A variety of ignition devices or methods, both commercial and non-commercial, have been used to ignite oil slicks (ASTM 2007b). In general, an ignition device must meet two basic criteria in order to be effective. It must apply sufficient heat to produce enough oil vapours to ignite the oil and then keep it burning and secondly, it must be safe to use. Safety issues are foremost when operating ignition devices.

A sophisticated device used today for igniting oil slicks is the helitorch igniter. These are helicopter-slung devices that dispense packets of burning, gelled fuel and produce an 800°C flame that lasts up to 6 minutes (Fingas 2011, ASTM 2007b). This type of igniter was designed for the forestry industry and is used extensively for forest fire management. One such device is illustrated in Figure 3.

As noted earlier, ignition of heavier oils is best carried out using a primer such as diesel fuel or kerosene, and a small wick such as a piece of cardboard or sorbent (Mabile 2012). This enables a start similar to lighting a candle. The flames will then spread to the un-ignited oil nearby. Large-scale heavy oil ignition might be accomplished by applying primer and then using the helitorch to ignite this primer. Use of a gelled fuel igniter was found inadequate to directly ignite heavy fuels without the use of a primer (Fingas 2011).

Notes: The inset shows the igniter used. This consists of a bottle of diesel fuel and a marine safety flare (similar to a road flare) surrounded by styrofoam floats. Such igniters were used to start more than 400 burns during the Gulf oil spill.

Figure 2 A Burn Team Waits for Their Igniter to Start a More Extensive Fire in the Fire-resistant Boom

Notes: Helitorches are made for lighting back- fires in forest fire control and are useful for igniting spilled oil in-situ burns.

Figure 3 A Helitorch in Operation in Forest Fire Control

2.6 Containment

Burning oil on water typically requires that the oil be thickened using fire-resistant booms. Oil typically can be easily ignited if it is thicker than about 2 mm and this will burn down to about 1 mm. Containment will also help prevent fire spreading, adding a margin of safety.

The biggest concern with containment booms for in-situ burning is the ability of the boom's components to withstand heat for long periods of time. A standard has been devised by the American Society for Testing and Materials (ASTM) to test the durability of fire-resistant booms for in-situ burning (ASTM 2007a). The standard is a minimum 5-hour test involving three 1-hour burning periods with two 1-hour cool-down periods between the burning periods. Fire-resistant booms are also tested for strength, integrity, and oil containment capabilities in a tank facility.

The different types of fire-resistant booms are water-cooled booms, stainless steel booms, thermally resistant booms, and ceramic booms. Fire-resistant booms require special handling, especially stainless steel booms, because of their size and weight. Thermally-resistant booms are similar in appearance and handle like conventional booms, but are built of many layers of fire-resistant materials. The fire-resistant boom shown in Figure 1 is a thermally-resistant boom as is the one shown in Figure 4.

Fire-resistant booms manufactured today are generally designed to survive several burns at one site, but are then disposed of or refurbished.

Notes: The reddish oil is heavy oil emulsified with water. This emulsified oil burned after being started by the heat from the burning un-emulsified black oil.

Figure 4 A View of a Fire-resistant Boom with Highly Weathered Oil Burning

2.7 Efficiency

Burn efficiency is the initial volume of oil before burning, less the volume remaining as residue, divided by the initial volume of the oil. The amount of soot produced is usually ignored in calculating burn efficiency. Efficiency is largely a function of oil thickness. For example, a slick of 2 mm burning down to 1 mm yields a maximum efficiency of 50%. A pool of oil 20 mm thick burns to approximately 1 mm, yielding an efficiency of about 95%. In a towed boom situation, burn efficiency is higher as the oil layer is concentrated at the rear. Current research has shown that other factors such as oil type and low water content only marginally affect efficiency.

Soot is formed in all fires. The amount of soot produced is not precisely known because of the difficulty of measuring soot from large fires. It is believed that the amount of soot is about 0.01 to 2% for crude and heavy oil fires (Fingas 2011).

2.8 Fuel Type

Most fuel types will burn readily - that is why they are ‘fuels’. The following table shows the burn characteristics and rates of the various fuel types.

TABLE 1

BURNING PROPERTIES OF VARIOUS FUELS

Fuel	Burnability	Ease of Ignition	Flame Spread	Burning Rate* (mm/min)	Sootiness of Flame	Efficiency Range (%)
Diesel Fuel	high	easy	moderate	3.5	very high	90-98
Light Crude	high	easy	moderate	3.5	high	85-98
Medium Crude	moderate	easy	moderate	3.5	medium	80-95
Heavy Crude	moderate	medium	moderate	3	medium	75-90
Weathered Crude	moderate	add primer	slow	2.5 to 3	low	60-90
Heavy Fuel Oil	moderate	add primer	slow	2 to 3	low	60-90
Weathered Dilbit	moderate	add primer	slow	2 to 3	low	60-90
Waste Oil	very low	add primer	slow	1 to 2	medium	15-50

** typical rates only --- to get the rate in Litre/m^2/hour multiply by 60*

2.9 Health, Safety and Monitoring

The primary environmental and health concerns related to in-situ burning are the emissions produced by the fire. The measurements of emissions have revealed several facts about the quantity, fate, and behaviour of the basic emissions from burning. Overall, emissions are now understood to the extent that emission levels and safe distances downwind can be calculated for fires of various sizes and types. A typical crude oil burn (500 m^2 in area) would not exceed health limits for emissions beyond about 500 m from the fire. People and the environment can be protected by ensuring that the burn is kept the minimum distances away from populated and sensitive areas. In general, depending on weather conditions, in-situ burning would not be carried out within 1 km of heavily populated areas and generally not within 4 km after adding a wide safety margin. Weather conditions to be considered include the presence or absence of an inversion and the wind direction. Procedures for calculating these safe distances have been developed. All burns include field monitoring of particulate and gaseous emissions.

2.10 Consideration of Burning as an Option

Burning is often compared to other options such as skimming and dispersants. In some marine spill situations, the best cleanup strategy may involve a combination of mechanical recovery techniques and burning for various portions of a spill. For example, burning can be applied in open water and oil that has already moved closer to shore can be recovered with booms and skimmers. Burning does not preclude the use of other countermeasures on other parts of the slick. When combining different cleanup techniques, the objective should be to find the optimal mix of equipment, personnel, and techniques that results in the least environmental impact of the spill. The selection of burning is advantageous in terms of the large removal rate, as shown in Table 2.

TABLE 2

APPROXIMATE COMPARISON OF COUNTERMEASURES*

	Light crude			Heavy Crude			Bunker C/Weathered Dilbit		
	Presumed Effectiveness	Hours to clean	tons/ hour	Presumed Effectiveness	Hours to clean	tons/ hour	Presumed Effectiveness	Hours to clean	tons/ hour
Brush Drum Skimmer	80	7.5	8	85	10	6	90	12	6
Large Weir Skimmer	80	1.5	40	85	3	20	90	3	20
Large Brush Skimmer	80	0.5	120	85	0.7	90	90	0.8	85
Dispersants	20	0.2	75	13	0.2	40	3	0.2	10
In-situ Burning	95	0.2	360	95	0.3	240	95	0.3	240

**there are many assumptions in the table including capacities of two average skimmers, dispersant effectiveness, but the burn rate is actual. This comparison is for a 150 m boom filled over time with 75 tons of oil and removed at the operating rates*

2.11 Scenarios for Burning

<u>At Sea</u>

Burning at sea is one situation where in-situ burning can be applied. There are several distinct steps involved in burning oil spills at sea. When an oil spill occurs, the situation is examined and analyzed for possible countermeasures. The type of oil, its thickness, and its state at the time burning could be applied, are reviewed. If burning is possible and of advantage, final planning will then take place. An operational plan is implemented using pre-established scenarios, check lists, and safety procedures. In most cases, containment will be required either because the slick is already too thin to ignite or will be too thin within hours. The decision tree is shown in Figure 5.

Personnel and equipment are then transported to the site. Fire-resistant boom is deployed downwind of the spill and a tow begun. When enough oil collected in the boom, it is ignited. The boom tow is resumed and continued until the fire is extinguished or the tow is stopped for operational reasons. The burning and progress of the tow are monitored by personnel on aircraft and on a larger ship from which an overview of the slick and conditions is possible. The monitoring crew can also direct the boom tow vessels to slick concentrations upwind. During the burn, monitoring normally includes estimating the area of oil burning at specific time intervals so that the total amount burned can be estimated. The amount of residue is similarly estimated. Particulate matter downwind is monitored to record the exposure levels.

The burn could be stopped in an emergency by releasing one end of the boom tow or by speeding up the tow so that oil is submerged under the water. If the burning stops because there is not enough oil in the boom, the tow can be resumed going downwind and then turning around into the wind before reigniting. After the burn operation is finished, for the day or for the single burn, the burn residue should be removed from the boom. As the burn residue is very viscous, a heavy-oil skimmer may be required if there is a large amount of material. A small amount of residue can be removed by hand using shovels or sorbents.

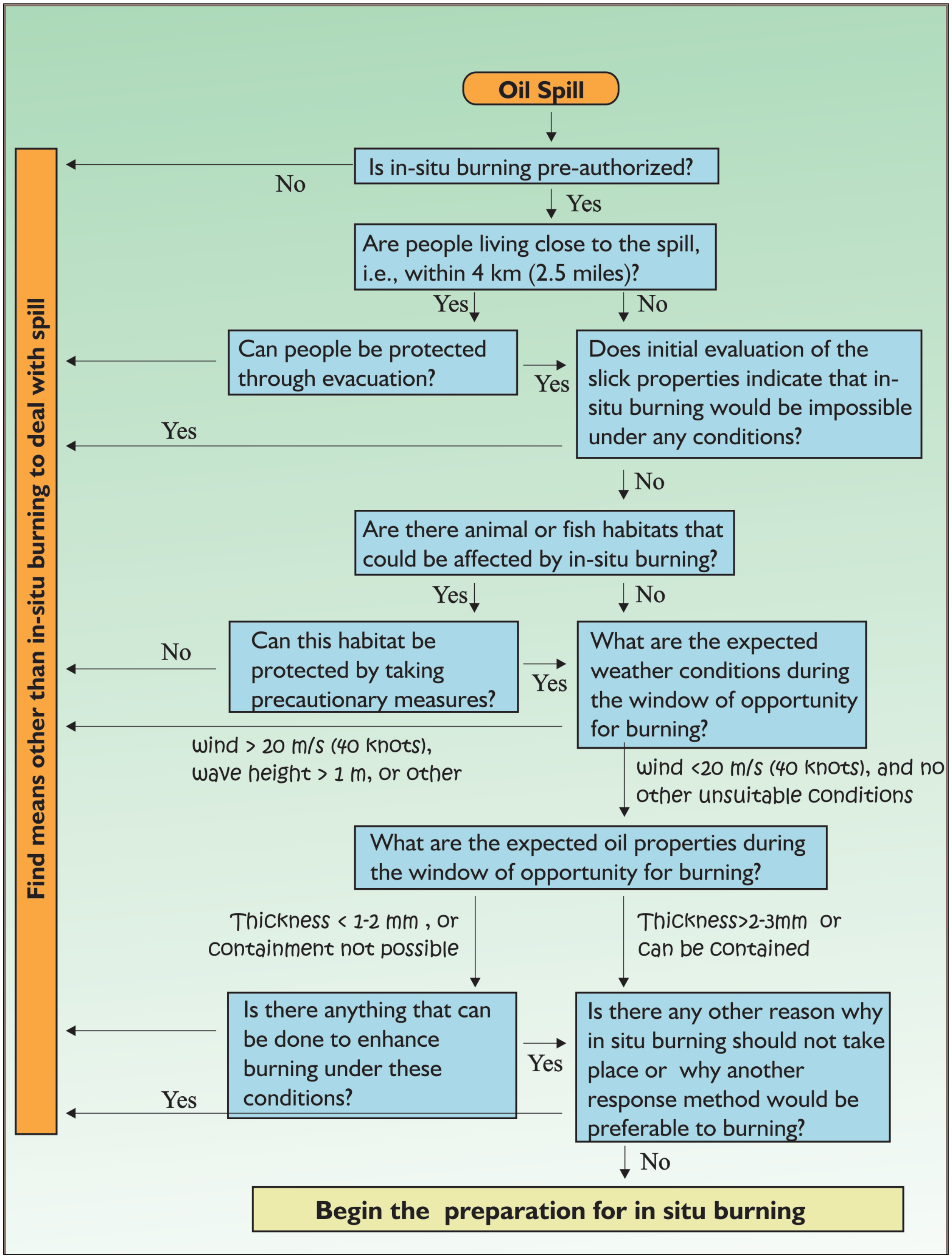


Figure 5 **Decision Flowchart for In-situ Burning**

On Rivers

On rivers the situation is similar to at sea, however, one end of the boom and burn may be on the shore. On rivers the currents may exceed 0.5 m/s or 1 knot and thus booms are often used in the deflection mode. The boom is then deployed at various angles to the current so that the critical velocity (0.5 m/s) is not exceeded. The oil can then be deflected to areas where it can be burned. If strong currents prevent the optimal positioning of the boom in relation to the current, several booms can be deployed in a cascading pattern to progressively move oil toward one side of the watercourse. This technique is effective in wide rivers or where strong currents may cause a single boom to fail. When booms are used for deflection, the forces of the current on the boom are usually so powerful that stronger booms are required and they must be anchored along their entire length. Burning at the site of the area of deflection may be carried out without a fire-resistant boom if there is no contact with combustible material. Several successful burns have been carried out on rivers (Fingas 2011).

On Land

Burning on land is a much older and much more used technique than oil in-situ burning on water (Fingas 2011). Many of the same considerations in this overall burning section apply to land as might apply to burning on water. There are several important differences to consider, however. First, the ease of ignition and minimum burning thickness may not apply if there is combustible material such as dried grass available. Burning in cases where there is dried vegetative material or wood in the target area, is simply a matter of igniting that material. Both the dried vegetative material and oil will burn, depending on the circumstances. It should be borne in mind that burning is often used on land to remove combustible material as a fire prevention method as well as to control certain plant species. The effects on land are a largely a function of how much heat is transferred into the soil which, in turn, is a function of how quickly the fire passes over and soil moisture content.

With Ice

Many test burns have been conducted on or among ice floes. The ice serves as a natural barrier to the spreading of the oil. Much of the early burn work was carried out as a countermeasure for oil in ice (Fingas 2011). There are many research papers on this, many of these from 1974 to 1986 (Fingas 2011).

In Marshes

Several marsh burns have been conducted around the world, including recent well- documented burns in Louisiana and Texas, one of which is shown in Figure 6 (Baustian *et al.* 2010, ASTM 2010). These burns were largely successful and provided important information on protecting the marsh plants and the best time of year to burn. The roots of marsh plants, which also house the propagation portion of the plants, are sensitive to heat. If burning is conducted at a dry time of year, such as in late summer, these roots could be damaged.

Flooding is a useful technique for flushing oil out of a marsh while protecting the roots of marsh plants. This can sometimes be accomplished by putting a berm across the drainage ditches or by pumping water into the high areas of the marsh. Care must be taken to use flood water of similar salinity to that normally in the marsh and to restore the natural drainage in the marsh after the flood. Often marshes cannot be flooded, however, and thus burning could be conducted when the marsh is wet, such as in spring. If a marsh cannot be burned within about one month of oiling, there is usually no benefit to burning because the oil will already have penetrated and severely damaged the plant life.

When burning in marshes, care must be taken to prevent damage to shrubs and trees that grow in the back and higher areas of the marsh. A firebreak must be available to prevent the fire from spreading outside the marsh and to ensure that wind will not drive the fire into nearby forested areas.

Source: Photograph from the US National Oceanic and Atmospheric Administration.

Notes: The marsh was extensively oiled as a result of a hurricane causing damage to oil facilities. This burn was successful and the marsh largely regenerated by the next season.

Figure 6 A View of a Salt Marsh Burn in Louisiana

2.12 The Plans

Trans Mountain proposes the use of in-situ burning as one means to respond to oil spills. Burning will be developed in emergency response plans as a technique for responding to spills. Specific and detailed plans for the burns will be created in line with the discussion above. Consultations with government officials will be held to seek approval of these plans and areas in which burns can be conducted and under what conditions. Equipment will be put into place. Training sessions will be carried out to ensure that crews are in readiness.

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Appendix G Potential Cleanup and Damage Costs of a Hypothetical Oil Spill: Assessment of Trans Mountain Expansion Project

POTENTIAL CLEANUP & DAMAGE COSTS OF A HYPOTHETICAL OIL SPILL:

ASSESSMENT OF TRANS MOUNTAIN EXPANSION PROJECT

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Acronyms

BC	British Columbia
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act [US]
CPCN	Certificate of Public Convenience and Necessity
DRAS	Dynamic Risk Assessment Systems
EGS	Ecosystem Goods and Services
EMA	Environmental Management Act [BC]
EPEA	Environmental Protection and Enhancement Act [Alberta]
HCA	High Consequence Area
IMO	International Maritime Organization
IOPC	International Oil Pollution Compensation (Funds)
ITOPF	International Tanker Owners Pollution Federation
KMC	Kinder Morgan Canada Inc.
NEB	National Energy Board
NRDA	Natural Resource Damage Assessment
OPA	Oil Pollution Act [US 1990]
PHMSA	Pipeline and Hazardous Materials Safety Administration [US Department of Transportation]
ROW	Right of Way
SOPF	Ship source Oil Pollution Fund [Canada]
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain pipeline [system]
US	United States
USEPA	United States Environmental Protection Agency
WCMRC	Western Canada Marine Response Corporation
YVR	Vancouver International Airport

Section 1 – Background

Project Overview

Purpose and Scope of Report

The purpose of this report is to provide an assessment of potential spill costs associated with a variety of hypothetical spills arising from the future operation of the Project.

The assessment is undertaken to provide insights into a number of issues, including:

- The potential costs of spills over the lifetime of the project.
- Whether financial assurance mechanisms for financial redress to cover those potential costs are adequate given the scale and availability of such mechanisms; future mechanisms include a wide variety of potential sources, including TMEP resources, insurance, industry resources, national funding sources, and (for tanker source spills) international sources.
- The availability and desirability of using insurance as an assurance mechanism.

The scope of the assessment focuses on hypothetical spills of heavy oil (including diluted bitumen and products with similar properties) over the operating life of the Project. More specifically, it reflects inclusion of the following:

- Defined hazards on the *pipeline* segments of the Project. The hazards consist of those being considered in independent technical risk analyses, and include primarily the following: manufacturing defects, construction defects, incorrect operations, third party damages, and geohazards. Hazards associated with hypothetical leaks from equipment failure at pumping stations are excluded from the analysis, as any such leaks are assumed to be contained on TMEP property. The risk of external and internal corrosion related failures are regarded as negligible for this Project and are also not treated here.
- Terminal operations. Quantitative technical risk analyses of operations at the Westridge Marine Terminal form the basis for estimating the costs associated with a specific hypothetical spill arising from tanker loading. The report also outlines relevant financial assurances in place to cover such a hypothetical situation.
- Hypothetical spills. These spills commence on the pipeline ROW and spread outside of this easement, potentially having impacts on public resources in terrestrial, freshwater, and coastal marine environments.
- Attributable costs. These include both direct cleanup costs and natural resource damage (or “environmental”) costs, which are directly attributable to the spill.

- Estimates based on best available information and methodologies. To inform the assessment of potential spill costs, the estimates reflect conservative but credible assumptions. Information draws upon Project specific design parameters, as well as global spill experience.

- Impacts. Impacts are assessed only to the extent that they are directly attributable to the spill and that they occur on land within BC or Alberta, or in Canadian waters. The assessment focuses on spill costs incurred by Canadians, which include those having rights and obligations under Canadian laws if they are residents, businesses or organizations within these areas. All potentially affected parties are treated equally when considering economic costs or losses. No differential distributional weighting is applied to any specific group, age cohort, gender, social characteristic or location.

The report acknowledges the following issues relating to potential spill costs, but these issues *do not form* the focus of this assessment. They are included to shed light on certain factors that are relevant to the potential costs and financial assurances associated with hypothetical land based spills from the Project.

- Tanker operations in Canadian Waters. No numerical assessment is undertaken of costs associated with any specific hypothetical tanker spill, but the report does reference relevant financial assurances in place to cover such a situation. These assurances are associated with tanker operations and are not within the legal responsibility of the TMEP.

- Passive use values. Passive use values are explicitly excluded from the cost estimates. These represent a category of values associated with ecosystem goods and services (EGS) that are experienced by some parts of the population even though they do not directly use the EGS. Loss of such values is not explicitly separated and compensated in any jurisdiction; methodological issues do not permit their credible measurement and attribution.

It is not possible to predict the financial cost of any single spill, as it generally will depend on a range of biophysical factors, which themselves exhibit normal natural variations through time and space. Location, season, weather, product spilled, site access, mitigation methods applied after a spill, and remediation endpoints all play a role in determining the eventual cost of a spill. The approach taken in any such assessment therefore relies on using best available existing information and then on applying such information to a given hypothetical scenario. It must be stressed that spills remain low probability events. Spills are to be avoided, and regulators, operators, and users of pipeline infrastructure correctly seek to achieve a safe operation with zero spills. If a spill occurs, analysis of the circumstances informs future operations thus helping to approach the zero spill target. Experience thus draws from a wide array of rare events, and applies statistical methods coupled with informed judgment over what is relevant in various situations. In risk assessments of this nature, it is conventional to undertake the analyses in a manner that errs on the side of caution; where a range of possible outcomes might occur, risk analyses will typically choose a plausible hypothetical situation near the means and conduct a sensitivity analysis relating to a credible worst case scenario. It is always possible to describe a situation that looks worse than whatever formal scenario might be analyzed; any such thought experiments in themselves may serve a purpose for contingency planning or for establishing additional mitigation measures. But implausible extreme scenarios represent outcomes and likelihoods that are more severe and less likely than situations that we face in our daily lives as individuals and societies.

This assessment does not seek to determine what is acceptable risk from either an individual or social perspective. It does, however, seek to elaborate the potential financial implications of rare events associated with pipeline spills so as to permit improved risk communication, informed discussion, and – ultimately – better decision-making. While we all may be aware of a worst possible outcome, or a best possible outcome, we do not make our decisions solely on the extremes.

The jurisdiction and regulatory regime in which a spill occurs also has a bearing on cleanup costs. This assessment addresses impacts in Canada. A common instinct is to assume that Canadian costs would be comparable to those in our immediate neighbor: the United States (US). But this assumption would be flawed. Experience with both terrestrial and marine spills shows that the US has among the highest per unit spill costs in the world. Studies undertaken by Etkin on historical spills through the 1980s and 1990s showed that average cleanup costs per tonne spilled in the US were an order of magnitude greater than those in Canada; Canadian spill costs were also systematically lower than those in Europe and East Asia. [1] Similar experience exists with insurance claims internationally. Etkin attributes the higher costs in the US to a number of institutional factors and opines that the higher costs "can be attributed to a large extent on the response requirements stipulated by the Oil Pollution Act of 1990 (OPA 90)."

Outline of Report

This report is organized in five sections as follows. This Section 1 provides general background information on the Project and on the scope and purpose of this report. Section 2 introduces and discusses a number of concepts relating to financial responsibility, financial assurances, and commercial insurance for land-based spills; it also provides a brief treatment of marine terminal spills within these contexts. Section 3 provides general background to the methodologies and information sources used for this assessment. Section 4 provides the results of the analyses, working first through the various hazards considered, spill sizes and scenarios; implications for spill cost assessment of a hypothetical spill associated with the Westridge Marine Terminal operations are also included within these analyses. Section 5 concludes with a summary of the main findings.

Annex A summarizes key aspects of the regulatory basis for pipeline spill prevention and remediation in Canada. Annex B provides supplementary information tables that accompany the analytical assumptions and results in the report.

[1] For example, over the period 1974-99 the ratio of US:Canada unit costs for spills was about 12:1 including the Exxon Valdez spill and 4:1 excluding it; unit costs for spills in Canada were 72% those in Europe and 40% those in East Asia. Etkin DS (1999). Estimating Cleanup Costs for Oil Spills. Oil Spill Intelligence Report, International Oil Spill Conference Paper #168.

Section 2 – Concepts

This Section introduces and discusses a number of concepts relating to financial responsibility, financial assurances, and commercial insurance for land-based spills; it also provides a brief treatment of marine spills within these contexts. Marine spills are relevant to the analysis of land-based spill costs for a number of reasons: land-based spills can impact coastal estuaries, coastlines, and the near shore marine environment; information relating to damage and cleanup costs for ship-source marine spills provides further data that can be used in estimating the costs in high consequence areas such as estuaries or coastal reaches; and, emergencies arising from terminal operations involving tanker loading can potentially jointly trigger provisions in both the tanker insurance and the pipeline terminal insurance.

Responsibility and Financial Liability

Canadian legislation (see Annex A for summary) details who is responsible for pipeline spills and what the extent is of associated financial liabilities. Pursuant to section 75 of the NEB Act, pipeline companies must pay compensation for all damage sustained by them as a result of the operation of a pipeline. There are no limits placed on liability for the prevention, remediation and cleanup of oil spills. Nor is there any limitation placed on liability for damages to persons, property and the environment. Provincial legislation has comparable provisions.

Industry practice for addressing financial responsibility and compensation is governed by the general law of insurance and an operator's obligations to its insurers regarding the reporting, investigation and adjustment of compensation claims. However, practices for addressing financial responsibility and compensation are also subject to a process for assessing and compensating damages claimed pursuant to the NEB Act. Section 90 of the NEB Act establishes a process for arbitration proceedings and the appointment of a federal arbitration tribunal to settle any disputes regarding damages claims.

The clarity of responsibility and liability under law can have direct impacts on the eventual spill costs themselves. In Canada, as noted above, there is little ambiguity regarding pipeline spills, and mechanisms for financial redress are well established. Similar clarity is provided regarding ship-source spills; in Canada and internationally these remain the responsibility of tanker operators and owners, and compensation schemes are governed by international laws relating to insurance requirements of such operators and owners, complemented by guaranty funds such as the International Oil Pollution Compensation Fund (IOPCF) and the Canada Ship-source Oil Pollution Fund (SOPF) (see Volume 8A). Spills at a terminal are also subject to ship-source pollution provisions if the spill originates from the ship, and are the responsibility of the terminal operator if they occur outright from the terminal in the absence of any loading activities; where ambiguity arises, co-insurance provisions associated with the terminal operating provisions govern the recovery of costs. In all instances, emergency response efforts led by TMEP focus first on containing the spill and its physical and financial impacts within clearly pre-determined command structures and protocols.

Different countries have different means of determining spill liability; these can have a bearing on eventual spill costs. As noted in Section 1, spill costs in the US, all other things equal, have historically been significantly higher than those in other jurisdictions. Care must therefore be taken in simply extrapolating the numbers from US spill experience to hypothetical spills in

Canada; at best they serve as a benchmark for establishing a very conservative upper bound to hypothetical spill costs in Canada. We will revisit this later in subsequent Sections when showing the derivation of specific assumptions relating to spill costs for given hypothetical scenarios.

Role of Financial Assurance Mechanisms

It is industry practice to use a mix of financial assurance mechanisms, which are essentially a combination of self-insurance (based on company assets, income, and access to financing) and operational insurance (obtained through commercial markets). This mix typically depends, *inter alia*, upon internal and external assessments of risks, means for spreading these risks among shareholders and shippers, an operator's financial position, and provisions in the Tariff and shipping agreements that regulate or stipulate what portion of tolls remain payable in event of a shutdown and on how costs can be recovered through tariff structures.

Trans Mountain Pipeline ULC, for example, currently maintains a General Liability insurance program with an annual limit totaling US$750 million; coverage for pollution legal liability is included within this program. The first $2 million is covered by self insurance or through insurance of the shippers per flow through treatment as described in the NEB Approval (TO-001-2013) of the Application to Approve Incentive Toll Settlement for the Year 2013-15. But regardless of whether insurance covers losses or liabilities, operators are required under regulatory provisions to make good any damages caused. Losses and claims in excess of insurance coverage could be covered by cash from operations, the issuance of debt, commercial paper and/or credit facility draws, expected future access to capital markets, or the sale of assets. Upon commissioning of the Project, Trans Mountain structure is projected at $6.4 billion in assets with approximately $3.2 billion in equity.

It is generally acknowledged that, in the event of a spill, it is important to return to operations as soon as practically and safely possible. Service is therefore generally restored, with concurrence of regulators, after appropriate inspections, mitigation measures, repairs, and tests have been completed. Restoration of service is frequently measured in days or weeks rather than months or years.

Role of Insurance

Commercially available operational insurance is accepted as one method for assuring that any costs associated with a spill can be covered. Companies in the liquids transport industry rely on insurance for many construction and operational needs. Construction phase insurance may typically include Builder's All Risk/Course of Construction Insurance against risks of direct physical loss or direct physical damage to project works, and Construction Wrap Up Liability Insurance Program responding to legal liability for third party property damage and injuries arising from construction activities. For operational phases of projects, operators routinely hold a Property and Business Interruption Insurance Program, responding to physical loss or damage to key facilities and pipeline at major water crossings, including loss or earnings while shut down; this provides a guaranty of continuous income subject to policy terms and conditions. Also, General Liability Insurance policies consist of primary and excess liabilities that respond to legal liability for third party property damage and injuries resulting from operations, including pollution legal liability. Finally, Aircraft, Aviation and Automobile Liability insurance is normally held through the course of operations requiring vehicle and aircraft use in connection with operations. Marine terminal operations also carry a number of associated insurance plans, including Marine Terminal Operators Liability insurance, Wharfinger's Liability insurance, and Stevedor's Liability insurance.

It is important to note, however, that insurance is itself a risk sharing mechanism that follows traditional concepts associated with economic efficiency, as follows:

- Risk transfer. Insurance provides an opportunity for transferring certain downside risks to third parties, thereby protecting the financial viability of an operation. This is effective in circumstances where uncertain hazards could result in large liabilities that exceed the financial resources of a single company.

- Risk pooling. Insurance provides an opportunity for pooling risks of different operations if the hazards are rare and if risks across the insurable parties are uncorrelated (i.e., if there is no reason to believe that everybody will be struck by the same hazards at the same time).

- No additional hazard. Insurance is effective if the act of insuring something does not increase the riskiness of the activity. If risks are higher in the presence of insurance, this is a situation of "moral hazard"; moral hazard may arise, for example, if operators feel that there is less need to be vigilant about operations because they have a limited downside. Moral hazard within the insurance industry can be managed through specifying deductibles (implying that operators still retain a financial interest) or through specifying maximum coverage limits (as is done with General Liability Limits and with mechanisms such as the SOPF and the IOPC Funds.) In Canada, to date, there is no reason to believe that moral hazard is an issue: operators continue to have the full responsibility of meeting any costs associated with accidents or unsafe operations.

In the Canadian context, spill insurance is not regulated but a number of models of the above have emerged. Companies routinely have coverage, which includes pollution legal liability, across their entire operations as part of their normal business planning to transfer risks to commercial insurers. Risk pooling was instrumental in establishing Canada's world class system of funds to address ship-source pollution: the initial Maritime Pollution Claims Fund was established in 1973 and was capitalized through a levy collected from 1972-1976 on oil imported into or shipped from a place in Canada.[2] The money was subsequently transferred to the SOPF in 1989: the Fund has operated successfully through paying for cleanup costs by self-generated income and recovering costs from other mechanisms such as the IOPC Funds. The pooled risk model provides funding that effectively complements resources available through

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[2] A full treatment of the different tiers of insurance available for vessel operations is provided in Volume 8A of the Project Application. These collectively provide assurances of about $1.3 billion. The maximum liability of the Canada SOPF during the fiscal year commencing April 1, 2013 is $161,293,660 for all claims from one oil spill; it increases annually through indexing. The Minister of Transport has the statutory power to impose a levy of 48.37 cents per metric ton of oil, as defined in the Act, imported by ship into or shipped from a place in Canada in bulk as cargo. The levy is indexed to the consumer price index annually. No levy has been imposed since 1976. As at March 31, 2013, the accumulated surplus in the SOPF was $398,906,816. (SOPF: The Administrator's Annual Report 2012-2013.)

international conventions. International conventions apply only to spills of persistent oil from sea-going tankers. The SOPF is unique in that it not only covers sea-going tankers, but it is intended to pay claims regarding oil spills from all classes of ship such as general cargo vessels, cruise ships, ferries and other non-tankers. The SOPF covers both persistent and non-persistent oil spills. In addition, the SOPF applies to “ghost” spills, where the identity of the ship that caused the discharge cannot be established. A widely defined class of persons in the Canadian fishing industry may also claim for loss of income caused by an oil spill from a ship.

Section 3 – Methodologies and Information Sources

This Section provides general background to the methodologies and information sources used for this assessment.

Methodologies

The general approach to the spill cost assessment is to rely upon estimated unit costs (expressed in dollars per barrel or $/bbl), distinguishing between: (i) direct "cleanup" costs; and, (ii) "damage" costs associated with secondary environmental and social costs to third parties. This approach follows the convention of much of the literature, and provides a basis for extrapolating historical information to hypothetical situations. The derivation of this summary metric can be much more complicated. It is shorthand for a rather complex series of events and circumstances, many of which may be highly uncertain.

Unit costs are then applied to potential spill volumes (outflows) at different sites. For modeling purposes, we distinguish between: (i) high consequence areas (HCAs) exhibiting particularly sensitive conditions along the pipeline ROW; and, (ii) other areas (non-HCA). For outflows we refer to "leaks" as smaller outflows; "ruptures" refer to loss of containment that might cause full or partial loss of oil between upstream and downstream isolation valves, depending on elevation profile and hydraulic conditions. Loss of containment does not arise from all hazards.

The methodology does not require specific assessments using primary data relating to resource values, businesses, or individual livelihoods at every area potentially impacted by a spill. Such a detailed assessment is beyond the scope of this exercise for a number of reasons. First, the life of the project is such that it is impossible to predict what resource values, businesses, or third party interests may be impacted at any future date or location. Second, the risk analysis is for the entire length of pipeline and its associated operations; the probabilistic nature of this analysis is such that financial consequences are assessed for the pipeline length as a whole rather than for any specific site. The probability of a given site being impacted (taken for example as a 1 km segment) is typically expressed in terms of a few chances in a million in any given year.[3] Cumulatively these can add up, but rather than addressing the few chances in a million for a specific site and time the analysis addresses the length of the pipeline and the duration of its operation; it then relies on estimates of impacts in average or high consequence areas, as the case may be. Third, risk analyses themselves inform risk management actions. For example, if some HCAs are more likely to face higher hazards then it is normal to put greater mitigation measures in place for those sites so that losses are further limited. The approach used here thus considers likely costs or losses, but (as noted previously) employs conservative assumptions that would tend to overestimate such costs.

For improved risk communication, the conclusions also presents some spill cost results in the context of event probability. Such an event probability is usually expressed as its frequency of occurrence in a single year, or the "return period" of the event expressed as the inverse of its

[3] A preliminary analysis of frequencies is provided in Volume 7 as well as discussion in TMEP Threat Assessment, Dynamic Risk Assessment Systems (DRAS) 2013. For example, initial runs of the third party damage model based on preliminary routes and hydraulics indicate that the average value for the frequency of this threat over the pipeline is in the order of 5.1×10^{-6} failures/km-yr.

frequency of occurrence in a single year. Spill risk event probabilities are always less than unity. Spill risks referenced in this assessment rely on work conducted by DRAS presented in Volume 7.

To summarize, an oil spill is thus an event with an associated probability of occurrence. Large spills may be rare but have impacts with high total costs. Small spills may be more frequent but have impacts with lower total costs. The literature on oil spill costs typically separates two elements, which can be added: (i) cleanup costs; and, (ii) damage costs. The total cost, is the sum of these two items:

Total Conditional Cost = Total Conditional Cleanup Cost + Total Conditional Damage Cost

The term “conditional” in the above is usually implicit and it is included here just as a reminder that it can be understood to mean: “assuming a spill occurs”.

Again, it is stressed that more generally the costs per barrel can vary according to many factors. Indeed, spill costs and damages tend to exhibit economies of scale such that larger spills have lower unit cleanup cost and damage costs.

It should be noted also that the “dual” approach of separating spill cleanup costs from damage costs is itself at times problematic and prone to double counting if they are added together. It is not unusual for documented cleanup costs to include some immediate and direct compensation for third party social, environmental, or resource damages.[4] These latter costs should normally be included as part of the overall damage costs rather than the direct cleanup costs. But, again, institutional or operational factors often consider any costs that are incurred early in the process to be part of cleanup rather than damages. Indeed, in the State of Washington for persistent oils, costs incurred for damage remediation in the first 48 hours after a spill event are eligible for credit against any eventual damage assessment; these costs thus tend to be counted as part of the immediate cleanup efforts instead of as damage remediation. The approach taken to such situations in this assessment is to acknowledge that some double counting may occur and to describe the total cost as likely being an over-estimate because of these circumstances.

Information Sources and Selected Cost Data

The analyses undertaken in this assessment do not rely on a single source, but are informed by a number of sources that are relevant to this Project. Because spills are a relatively rare phenomenon, this approach permits the use of a broader range of information. The sources summarized below refer both to terrestrial and to marine spill costs. Although this assessment concerns itself with pipeline spills, the hypothetical spill modeling considers circumstances when they impact a coastal or estuarine environment. Databases such as those maintained by the IOPC Funds – which relate to costs associated with tanker spills into the marine environment – also therefore have relevance to pipeline spills that may make their way to a marine or brackish water environment. Similarly, spill cost experience in coastal and terrestrial environments in Washington State serves to inform potential damage costs, although it is again acknowledged that unit costs derived from US experience are likely to result in overestimates of any costs incurred in Canada.

[4] See: (i) Etkin DS. 2004. Modeling Oil Spill Response and Damage Costs. USEPA; (ii) Kontovas CA, Psaraftis HN, Ventikos NP. 2010. An empirical analysis of IOPCF oil spill cost data. *Marine Pollution Bulletin* 60(9):1455-1466.

Unless otherwise noted, all financial figures are expressed in 2013 terms; these were derived using standard publicly available exchange rates, price deflators, and GDP deflators as relevant. For the convenience of presentation, figures are routinely rounded.

Terrestrial Spill Cleanup Costs

In various publications, Etkin has provided a wealth of costing information relating to oilspill cleanup and damage costs in North America.[5] Her methods underline that actual spill costs depend on numerous factors, but her assessments of spill cost data from decades of samples have shown that most of the variation in unit spill costs can be explained by spill volume, oil type, proximity to water, dispersion along shorelines, location remoteness, and cleanup methods.

As noted previously, the Etkin data contains US spill costs that are considerably higher than what is typical for Canada. Consequently, the use of these costs as the initial benchmark for future hypothetical terrestrial spill cleanup costs in Canada results in a conservative estimate that is appropriate for informing potential financial exposure.

All other things equal, unit spill costs are higher for heavy oils, for impacts on water, for remote locations, and for manual cleanup techniques; also economy of scale in cleanup are realized such that larger spills tend to have lower unit cleanup costs. Annex B summarizes the resultant ranges from combining assumptions, and the algorithm provides a transparent means for estimating costs. It indicates that for reference conditions (representing light oils, inexpensive mechanical cleanup, no impacts on water or shorelines, and readily accessible spill sites), the cost range is from $553/bbl to $7,372/bbl, with the highest costs associated with small spills (<240 bbl) and the lowest unit costs associated with larger spills (>12,000 bbl). For heavy oils spilled at remote sites impacting waterways and 100 km of shorelines or estuaries, these costs would increase by a factor of 3.38: the adjusted value for a larger spill would be $1,869/bbl. If this larger spill also required manual cleanup the expected cost would further increase by a factor of 1.89: a larger spill of heavy oil under remote conditions, impacting water and shorelines requiring manual cleanup would thus cost $3,532/bbl for cleanup. In considering assessments of third party damages, Etkin concentrated on those spills impacting navigable waters from 1980-2002 and found that on average the damages added another 187% to cleanup costs, with a range of 169% to 227% depending on the sampling period within the spill history polled. These ratios, as we see below, are among the highest encountered in the literature.

Insights from this analysis are also seen in other experience. Apart from making sense intuitively in terms of what contributes to higher or lower cleanup costs, they also underline that spills requiring some manual cleanup in a riparian or marine environment will be among the most costly to address. This also permits us to rely on cost and damage information from various marine and estuarine studies to inform cleanup costs.

Marine and Coastal Cleanup Costs – IOPC Funds

The IOPC Funds maintain information relating to all spill claims from tanker operations occurring in States that are signatory to the various conventions. Canada is a signatory; the US is not a signatory. Spill costs in this database thus exclude spills that occurred in a US jurisdiction. They also thus avoid some of the estimating biases that may rely on using US information. A comprehensive analysis of the spill information of the IOPC Fund information was undertaken

[5] Etkin (1999, 2004), *op. cit.*

by Kontovas *et al.* (2010). The analyses provide information on both cleanup and total costs, with the difference attributable to environmental damage costs that were eligible under international conventions. A notable result is that the regression analyses over the period 1979–2006 again replicated the common result that smaller spills were more expensive to cleanup on a unit basis than were larger spills. A spill of 240 bbl (equivalent to about 38 m^3) into a marine or coastal environment has an expected cleanup cost of $1,950/bbl and a total cost including damages of $3,030/bbl. [6] For a larger spill of 12,000 bbl (equivalent to 1,900 m^3) the corresponding cleanup costs would be $484/bbl and a total cost including damages of $1,050/bbl. Kontovas *et al.* finds that the damage costs add approximately an additional 129% to cleanup costs at the median and recommends using this factor for point estimates. For the spill sizes considered here the ratios fall in a range of 56% to 116%.

Natural Resource Damage Assessment (NRDA) in Washington State

Damage cost assessments have been undertaken in the US since 1990 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Oil Pollution Act.[7] NRDA estimates the extent of third party damages arising from a spill event, and includes complex methodologies for determining damage costs. Washington State has maintained a spill database and documented the results of the assessments, or the imposition of compensation payments using "schedules" for determining the amount of damages. Until the end of 2012, the schedule assessed damages in a range of $1-$100/gallon of product spilled. After extensive public reviews and additional technical studies, this schedule was amended for larger spills (≥1,000 gallons = ~23.8 bbl) that currently place damages in the range of $3-$300/gallon, implying a maximum damage cost of $12,600/bbl of product spilled (compared to $4,200/bbl previously). Credit is available if restoration and remediation efforts are done during the initial cleanup phase such that eventual payments would be reduced; the initial cleanup is minimally 24 hours for non-persistent oils and 48 hours for persistent oils. Damages depend on various parameters including oil type; the 2013 Schedule defines five groups of oils by density, and a typical diluted bitumen would be a "Group 3" oil (defined as 0.85-0.949 specific gravity) and would *not* normally be subject to the highest damage cost.

The database of 529 spills dating from 1991 to 2013 provides some further insights into damage payments that were associated with these spills (amounts that follow are for settled spill claims up to and including 2012, adjusted from date of spill using imputed Washington State GDP deflators to 2013 for analytical purposes; damages may have occurred for a longer time period before closing the claim). Of the spills in the database, the mean size was 8 bbl, and only

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[6] Kontovas *et al*. express regression results in a formulaic form representing the fitted data. The equation of the fitted model of cleanup cost is LOG10 (Cleanup)=4.64773 + 0.643615 LOG10(V); V=volume in tonnes , i.e., Cleanup cost = 44,435*(V^0.644). For total costs the result is TC=51,432*(V^0.728). These show the declining unit costs to size; base costs are expressed for a 2009 base year in US$ and corrected to a 2013 base year using a factor of 1.08.

[7] The BC Government put forward policy remarks advocating adoption of processes such as the NRDA process in Washington State. (Technical Analysis: Requirements for British Columbia to Consider Support for Heavy Oil Pipelines. Incl. Press Release 2012ENV0047-001074; 23 July 2012, Vancouver) NRDA is a process adopted to determine the nature and extent of damages that can be compensated arising from an activity or incident. It seeks potentially to attach an economic value to these damages that in turn informs compensation payments. Canada has no such process, as its legislative basis is different (Annex A). Moreover, the statistical infrastructure remains limited to conduct such analyses, especially at site-specific scales (see Statistics Canada, November 2013. Human Activity and the Environment: Measuring Ecosystem Goods and Services. Ministry of Industry: Ottawa.)

18 spills (3.4%) were over 50 bbl. The average spill damage cost was $655/bbl; the maximum was $5,610/bbl. The median spill damage cost was similar to the mean: $640/bbl.

Damage Costs – Impacted Land Base (BC and Alberta)

Environmental economic valuation work conducted by Anielski (2012)[8] provided a basis for estimating the value of ecosystem goods and services in a mix of biomes through Alberta and BC, along a proposed pipeline ROW from Edmonton to Kitimat. The work used typical values for EGS within the context of a mix of environments including riparian habitats, coastal habitats, agricultural lands, undisturbed forest and previously disturbed forests. It relied upon values taken from similar habitats in Western Canada to derive per hectare values of goods and services. These were in turn translated into unit costs for spills that demonstrated a worst case impact in a widespread area equivalent to $10,200/bbl. The resultant values were regarded as conservatively high, in that they assumed that in many cases the existing land use would not be disturbed by ongoing activities. The values also included impacts on greenhouse gas emissions (which are not currently compensated through any form of financial mechanism) and a range of other ecosystem values which are not compensable. Moreover, the values assumed that once an area was disturbed or impacted it would remain impacted for 15 years without recovery.

Atlantic Canada Spill Cost Study (Transport Canada)

In 2007 Transport Canada[9] reviewed shipping operations to estimate the costs (cleanup and indirect environmental) of ship operations along the South Coast of Newfoundland. In its assessment, it considered potential future impacts from existing and potentially new activities that might have a bearing on oil spill risks in Canadian coastal waters. The study reviewed a total projected volume of 411 million barrels of annual movements of crude and product, of which 78% (322 million barrels a year) was linked to operations at North Atlantic (Come by Chance) refinery and Whiffen Head terminal (both in Placentia Bay, Newfoundland). The results placed cleanup costs in a range of $830/bbl to $6,020/bbl (2013$) for high persistence oil that would potentially damage Canadian coastlines. The study also implies damage costs to be in the range of $0.60 to $0.85 for every $1.00 of cleanup in Canada's East Coast navigable waterways; the lower factor is for large spills greater than 10,000 barrels. These damage costs reflect potential impacts through onshore and near-shore damages to fisheries, aquaculture and tourism.

Selected Terrestrial Spill Costs in Canada

Cleanup costs for spills in Canada are generally proprietary and are not recorded in public documents. Nonetheless, some reported information is available that places some context for the broader experiences noted above. Among the highest unit costs for cleanup are those associated with a train derailment causing the Wabamun spill (2005) that released approximately 4,400 barrels of oil and pole treating oil into a heavily used recreational lake in Alberta; total costs for cleanup and damages were approximately $33,000/bbl, of which about

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[8] Anielski M. 2012. Evaluation of Natural Capital and Ecological Goods and Services at Risk Associated with the Proposed Enbridge Northern Gateway Pipeline. Anielski Management Inc. Edmonton. Attachment 4 to Northern Gateway Reply Evidence. Exhibit B83-6 (A2V1S0). The purpose of these analyses was not for calculating liability or financial exposure, but for inclusion within a social cost-benefit analysis, which sought to conduct a sensitivity test for full inclusion of an upper bound cost of environmental externalities associated with spills.

[9] Transport Canada. 2007. Synopsis Report – Environmental Oil Spill Risk Assessment for the South Coast of Newfoundland, Edition 1 September 2007, Revised 11/2007. Report TP14740E.

$10,000/bbl were third party damages. Some larger spills associated with pipeline accidents demonstrated lower cleanup and damage costs: the Pine River 6,200 bbl spill in 2000 had a cost including third party settlements of about $6,600/bbl; the 2011 Rainbow pipeline spill of 28,000 bbl near Little Buffalo, Alberta, had cleanup costs of about $2,500/bbl. A smaller 2007 spill of about 1,500 bbl into Burrard Inlet experienced cleanup costs estimated to be $11,000/bbl.

Summary of Spill Cost Assumptions

For the purposes of this assessment, we use the Etkin cleanup cost algorithms as an initial benchmark for calculating total spill cleanup costs (Annex B). For larger spills in the range of 1,000-4,000 m^3 or approximately 6,300 to 25,000 barrels (used within the scenarios described subsequently) they yield upper-bound cleanup costs (using manual cleanup) in a range of $3,532 to $6,358 per barrel for heavy oils in remote locations striking freshwater and sensitive coastlines. Modest spills under 2,500 barrels have a benchmark cleanup cost of $11,000/bbl. Note that these benchmarks are all greater than the ranges applied by Kontovas *et al.* (~$500–$2,000/bbl) and by Transport Canada ($830/bbl to $6,020/bbl); they also reflect the costs of pipeline spills experienced in Canada in the examples above.

For damage costs we choose a benchmark multiplier of 1.5 applied to cleanup costs, which is conservatively applied across all pipeline spills for analyzing the scenarios. This multiplier is higher than that implied by IOPC Fund experience for all point source spills (1.29), higher than that implied by IOPC Fund experience through the regression results of Kontovas *et al.* for spills within the size range of interest (0.56 to 1.19), and higher than those implied by Transport Canada for spills of persistent oil in sensitive areas (0.6 to 0.85). The factor is somewhat lower than the range for US navigable waterways (1.69 to 2.27), which are in turn high by international standards. The factor is also lower than that which would be implied by the Anielski study ($10,200/bbl) and the Washington State NRDA schedule maximum ($12,600/bbl) if these were in turn applied to an average to moderate spill having benchmark costs of $6,358 or less. For this reason, the pipeline rupture scenarios are also conducted using a sensitivity analysis reflecting a fixed damage amount of $10,000/bbl. This is again still regarded as a “high” estimate as the Anielski study included non-compensable impacts using conservative estimates.

Section 4 – Analysis and Results

This Section provides the results of the analyses, working first through the various hazards considered, spill sizes and scenarios.

Hazards and Spill Sizes

The hypothetical spills considered here potentially arise from manufacturing defects, construction defects, third party damage, incorrect operations and geohazards. Technical assessments of the risks associated with these threats are being undertaken through all stages of pipeline design. This assessment is based on findings for Route P1 V4 and rely on DRAS (2013).[10] Specifically, the assessment included here reflects the following:

- Spill volume losses due to construction defects, manufacturing defects, and incorrect operations, are based on an analysis of the PHMSA Incident Database for the period 2002-2009 filtered for large (≥20") hazardous liquids pipelines with installation year in 1990 or later.

- The analyses reflect relevant hazards along the approximately 987 km of buried pipeline.

- Failures arising from external corrosion and internal corrosion are treated as negligible.

- Significant outflows entering the environment due to equipment failure at pump stations is regarded as negligible.

Spill sizes for non-rupture events are based on the statistics available in the PHMSA database. For the period described above, these result in the following findings:

- A total of 23 events relating to manufacturing defects, operational system faults, and construction faults resulted in a mean spill of 692 barrels (~110 m^3).

- A total of 8 third party strikes caused spills that did not result in a full loss of containment; these resulted in a mean spill of 758 barrels (~120 m^3).

The PHMSA database does not provide an adequate statistical sample of ruptures involving partial or full loss of containment, as such events are rare. Rupture volumes were evaluated using a scenario approach to describe outcomes from moderate spill sizes to larger spill sizes. The larger spill sizes correspond to a maximum spill of 2,000 m^3 (12,580 bbl) in HCAs and 4,000 m^3 (25,160 bbl) in non-HCAs.

To place the risks in perspective, recall that consequences can differ along the pipeline ROW. Simple inspection of the pipeline ROW indicates, for example, that about 10% of the pipeline falls within high population areas and 14% is in the sensitive areas of the BC Lower Mainland. These areas can be considered, to varying degrees, as HCAs: cleanup costs will normally be

[10] Summarized in Volume 7 Section 3.0 of the Project Application.

higher and third party damage costs may similarly be higher. Such increased costs are reflected in the scenario analyses that follow.

Scenario Results – Pipeline Spill

The scenario analyses involve a series of six cases, which are intended to demonstrate the cleanup and damage costs of hypothetical spills. As noted previously, spills are rare events and the costs should also be taken in the context of their expected frequency of occurrence. For potential liability reasons, limits of insurances and financial assurances are of greater concern for larger spills in high consequence areas, even though these will be rarer events than small spills or leaks, which may never have impacts outside of the pipeline ROW. Cleanup and damage costs for all scenarios using the benchmarks noted in Section 3 are provided in Annex B.

For leaks, the scenarios consider two spill volumes representing: (i) the mean spill associated with such events in the PHMSA database (715 bbl); and, (ii) the median of such events (30 bbl). The scenario assumes that the heavy oil spills are in remote areas, that 25% of the spilled volume reaches water, that they require manual cleanup, and that they have no shoreline impacts in the coastal or estuarine environment. Cleanup costs for the mean spill (715 bbl) are \$11,000/bbl, while those for the median spill (30 bbl) are approximately \$34,000. Cleanup costs alone are estimated to be \$1-8 million; incorporating potential damage costs using a 1.5 factor suggests that all such spills would have a maximum financial exposure of under \$20 million.

The hypothetical rupture scenarios consider spill sizes of 1,000 m^3 (6,290 bbl), 2,000 m^3 (12,580 bbl), and 4,000 m^3 (25,160 bbl), also shown in Annex B. These spill sizes were selected as credible worst case scenarios, based on the outflow modeling results conducted by Dynamic Risk Assessment Systems (Volume 7). The outflow modeling results are computed for every portion of the pipeline to resolutions as fine as one meter in length; they reflected designed valve placements, releases during shutdown, and maximum static drainage given the elevation profile. The results demonstrate also that outflows are lower in HCAs than in the pipeline corridor as a whole: median outflows in the BC Lower Mainland, for example, are about 1,365 m^3 (8,590 bbl) while for the modeled corridor as a whole they are about 1,615 m^3 (10,160 bbl). Maximum credible outflows for the corridor as a whole correspond to 4,000 m^3; for HCAs they correspond to 2,000 m^3.

The specific rupture scenarios include two spills into a HCA: (i) an "average" size spill of 1,000 m^3 and a larger spill of 2,000 m^3. All of the high cost parameters apply to these spills including those associated with heavy oils, remote locations (which also can reflect seasonal difficulties in accessible locations such as the BC Lower Mainland), full exposure to water, manual cleanup, and up to 100 km of oiling on coastlines or estuaries. The rupture scenarios also include two large spills (2,000 m^3 and 4,000 m^3]) into non-HCAs: these still reflect remote location and manual cleanup for heavy oils, but exclude shoreline impacts and (as with the leaks) show only 25% reaching water. The hypothetical rupture releases are potentially larger in the non-HCA areas because pipeline design considerations have pro-actively included features that will limit volume releases near HCAs (such as isolation valves near river crossings). Cleanup costs for this set of ruptures are about \$2,600/bbl for the non-HCA scenarios and from approximately \$3,500 to \$6,400/bbl for the spills in the HCA scenarios. In this reference case, cleanup costs for the HCA spills are \$40-\$45 million, and for the non-HCA spills are \$32-

$64 million. Incorporating potential damage costs using a 1.5 factor suggests that the HCA spills would have a maximum financial exposure of about $110 million. The non-HCA spills of similar size (2,000 m^3 or less) would have a maximum financial exposure of about $80 million. The maximum financial exposure of all spills modeled through these scenarios is $160 million, corresponding to the 4,000 m^3 spill.

Under the rupture scenarios, the damage costs use an estimating factor of 1.5, but this yields damage costs that are less than what may be implied by some sources (Anielski, Washington State). As described in Section 3, a sensitivity case is thus also considered reflecting damage costs of the order of $10,000/bbl. This would impose a financial exposure of about $125 million for the 2,000 m^3 spill considered as the largest in the scenarios involving a HCA; financial exposure for damages would be $250 million for a 4,000 m^3 spill. Total spill costs in this high damage cost scenario would be of the order of $100 million to $300 million for the scenarios modeled.

Scenario Results – Westridge Marine Terminal Spill

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.

Marine Terminal Operations

If oil were released directly from the Trans Mountain Westridge Terminal, Kinder Morgan would be the Responsible Party. The potential volume and dispersal of a terminal spill is low because tanker loading is a manned operation, there is only a limited amount of oil in the terminal piping at any given time and the water side of the terminal is surrounded by a marine boom whenever a vessel is being loaded.

Data from the International Tanker Owners Pollution Federation (ITOPF) covering 43 years of tanker operations at terminals worldwide show that 88% of spills involve discharge of under 50 barrels into the environment, most commonly due to equipment failure (Table 4.1). We estimate the costs of a maximum credible spill size to be that associated with a release of about 103 m^3 (648 bbl). Using the Etkin (2004) estimating factors relating to a non-remote site, nearshore water exposure, and heavy oil properties, the mid-point cleanup cost is expected to be $9,200/bbl within a range of $6,370–$12,030/bbl depending upon cleanup methods; the highest cleanup cost assumes all manual cleanup with no mechanical or other methods. We conservatively adopt a value in the top quintile ($11,000/bbl) as a benchmark cleanup cost because shoreline oiling will be limited due to permanent booming and spill mitigation equipment is readily available and deployable onsite. The cleanup cost of this hypothetical spill is thus expected to be approximately $7.1 million. For environmental costs in Canadian shorelines we rely on Transport Canada factored cost data for Atlantic Canada and apply a multiplier of 0.85, which is that corresponding to a modest spill under 250 m^3; the resultant estimated maximum damage costs would be $6.1 million. Total costs would be maximum $13.2 million. As with discussions elsewhere in this assessment, this is regarded as a conservative (high) estimate because of the nature of the assumptions and information sources.

Table 4.1 – Spills involving tanker loading/discharging operations, 1970–2012
(ITOPF Oil Tanker Spill Statistics 2012)

Size (barrels)	Total	Allision/ Collision	Grounding	Hull Failure	Equipment Failure	Fire/ Explosion	Other	Unknown
<50	3157 (88%)	1	2	324	1124	50	842	814
50-5000	390 (11%)	4	0	36	143	8	96	103
>5000	41 (1%)	1	2	0	11	13	8	6
Total	3588	6	4	360	1278	71	946	923

Section 5 – Conclusion

The purpose of this report is to provide an assessment of potential spill costs associated with a variety of hypothetical spills arising from the future operation of the Trans Mountain Expansion Project. The scope of the assessment focuses on hypothetical spills of heavy oil (including diluted bitumen and products with similar properties) over the operating life of the Project. The costs include direct cleanup costs and potential third party damage costs from hypothetical pipeline spills.

The significant findings include:

- Pipeline leaks with mean size of about 110 m^3 (~700 barrels) may arise from hazards including manufacturing defects, operational system faults, construction faults or third party damage. Cleanup costs alone are estimated to be $1-8 million; incorporating potential damage costs suggests that any single spill would have a maximum financial exposure of under $20 million.

- Pipeline ruptures involving partial or full loss of containment are modeled for hypothetical spills of 1,000 m^3 (6,290 bbl), 2,000 m^3 (12,580 bbl) and 4,000 m^3 (25,160 bbl) into High Consequence Areas (HCAs) involving oil in waterways and shoreline oiling, as well as into other areas (non-HCAs). The spills into HCAs are generally under 2,000 m^3. Cleanup costs for HCA spills are $40-$45 million, and for the non-HCA spills are $32-$64 million. The HCA spills would have a maximum financial exposure of about $110 million including damage costs. The non-HCA spills of similar size (2,000 m^3 or less) would have a maximum financial exposure of about $80 million. The maximum financial exposure of all spills modeled through these scenarios is $160 million.

- Some sources suggest using higher damage costs for risk management purposes. A sensitivity scenario was thus conducted using highest cost conditions for cleanup of a large spill (involving a hypothetical pipeline release of up to 4,000 m^3 of heavy oil in a remote location impacting water and requiring manual cleanup procedures) and damage costs of the order of $10,000/bbl, which reflect among the highest found in the literature. Total spill costs in this high damage cost scenario would be of the order of $100 million to $300 million for the scenarios modeled.

- Based on best available information, a hypothetical spill at the vessel loading point of the Westridge Marine Terminal was also considered. Accidents associated with vessel operations are the responsibility of the vessel owner, but incidents at a marine terminal may fall under joint responsibility depending on the circumstances of the incident. Similar methods for calculating cleanup costs and potential damages from a hypothetical spill apply although some damage coefficients differ because of immediate availability of cleanup equipment. A spill of 103 m^3 (648 bbl) was evaluated: such a spill would generate expected cleanup costs of $7.1 million and damage costs of $6.1 million for a total financial exposure of $13.2 million.

It is industry practice to use a mix of financial assurance mechanisms to cover any potential financial exposure associated with an oil spill. These mechanisms are essentially a combination of self-insurance (based on company assets, income, and access to financing) and operational insurance (obtained through commercial markets). The regulated pipeline industry also has opportunities to recover pollution costs through future tolls imposed on shippers; financial security can also be assured in some cases through ongoing payments, which may be contractual obligations of shippers even in the event of pipeline shutdown after a spill occurs.

The current and proposed financial assurances and financial structure of the Project ($750 million of spill liability insurance and approximately $3.2 billion in equity) will be adequate to cover losses attributable to a spill and to ensure that the Project remains viable over its lifetime.

Annexes

Annex A – Federal, Alberta and BC Regulatory Requirements

Annex B – Land-based Spill Costs and Scenario Results

Annex A – Federal, Alberta and BC Regulations

This Annex summarizes key aspects of the regulatory basis for pipeline spill prevention and remediation in Canada.

Federal Legislation

Responsibility for the prevention, remediation and cleanup of pipeline spills is primarily addressed by the *National Energy Board Act* (“NEB Act”), its regulations and guidance provided to industry by the National Energy Board (“NEB”). Section 48(2) of the NEB Act gives the Board the power to make regulations providing for the protection of property and the environment. Pursuant to this regulatory authority the NEB has enacted section 48 of the *Onshore Pipeline Regulations*, 1999 SOR/99-294. Under this provision pipeline companies regulated by the NEB must develop and implement an Environment Protection Program to anticipate, prevent, mitigate and manage conditions that have the potential to adversely affect the environment. The NEB has developed the Remediation Process Guide that must be followed by companies that it regulates. This Guide establishes stringent criteria for soil and groundwater remediation in order to minimize risks to the public and environment as a result of oil spills.

Pursuant to section 51.1(2)(b) of the NEB Act, NEB inspectors are given broad enforcement powers, which include the authority to order pipeline companies to take any measures necessary to ensure safety of the public and employees and the protection of property or the environment.

Pursuant to section 75 of the NEB Act, pipeline companies regulated by the NEB must pay compensation to all persons interested, for all damage sustained by them as a result of the construction or operation of a pipeline. Pursuant to the NEB Act, there are no limits placed on liability for the prevention, remediation and cleanup of oil spills. Nor is there any limitation placed on liability for damages to persons, property and the environment.

To the extent that a spill affected or had the potential to affect waters frequented by fish regulated by the *Fisheries Act*, that legislation would also apply. The pipeline operator would have the duty to report the spill and take all reasonable measures to prevent, counteract, mitigate or remedy any adverse effects that result or may result from the spill (sections 38(4), 38(5) and 38(6)); fisheries inspectors have the power to take all reasonable measures at the expense of the person responsible (section 38(7.1)). In the event that the Federal government or Provincial governments incur costs as a result of a spill, the owner of the oil spilled or anyone who contributes to the spill (i.e. the pipeline operator) are jointly and severally liable to pay such costs (section 42(1)). Licensed commercial fishermen are also able to recover any losses they suffer from the pipeline operator and owner of the oil (section 42(3)).

Provincial Legislation (Alberta)

Oil spills in Alberta, including those from pipelines regulated by the NEB, are governed by *Environmental Protection and Enhancement Act* RSA 2000 c. E-12 (“EPEA”). Pursuant to section 112(1) of EPEA the person responsible for the oil spilled must take all reasonable measures to repair, remedy and confine the effects of a spill in addition to remediating, managing, removing or otherwise disposing of oil so as to prevent an adverse effect or a further adverse effect. It is then the responsibility of such person to restore the environment to a condition satisfactory to the Director under EPEA. There is no maximum liability under the Alberta legislation.

Provincial Legislation (British Columbia)

Oil spills in British Columbia, including those from pipelines regulated by the NEB, are governed by the *Environmental Management Act*, SBC 2003, c. 53 (“EMA”).

Section 6(4) of the EMA prohibits the introduction of “waste into the environment in such a manner or quantity as to cause pollution”. The term “waste” includes “effluent” which is defined broadly to include any substance that injures or is capable of injuring personal health and safety or damages or is capable of damaging the environment.

Section 79 addresses spill prevention, abatement and reporting. The Minister of Environment may order any person who is in possession, charge or control of a polluting substance to undertake measures, at the person’s expense, to prevent or abate a spill (section 79(2) and (3)). Section 79(5) requires a person who was in possession, charge or control of a polluting substance immediately prior to a spill to report the release.

Section 80 sets out spill response powers available to the Provincial government. Section 80(2.1) enables the government to undertake a wide array of response and restoration measures directly. Subsections (4) (6) authorize the government to recover the incurred spill response costs from a person who had possession, charge or control of the spilled substance. EMA does not set limits to the recoverable costs.

EMA additionally authorizes the “director” under the Act to issue pollution prevention orders (section 81) and pollution abatement orders (section 83). Section 87 enables the Minister to take certain measures directly after declaring an “environmental emergency”, defined to include a “spill or leakage of oil”. Section 88 authorizes the Minister to recover costs respecting these measures from the person who caused the spill. EMA does not set limits to the recoverable costs.

Annex B – Land-based Spill Costs and Scenario Results

This Annex provides supplementary information tables to accompany the analytical assumptions and results in the report.

Table B.1 – Typical unit cleanup and damage costs from oil spills. This presents a tabular summary of the cost estimating based on Etkin (2004) for oil spill cleanup costs in North America. The damage costs are added to the cleanup costs and refer to high consequence areas in US navigable waterways.

		Reference Spill			
Spill Size Category		Larger	Average	Modest	Small
Spill Size Upper Value in Range	bbl	23,800	11,900	2,380	238
Spill Size Lower Value in Range	bbl	11,900	2,400	238	-
North American Average Cleanup Costs	US$/tonne ($1999)	19,815	19,815	19,815	19,815
Inflation factor 1999-2012		1.302	1.302	1.302	1.302
North American Average Cleanup Costs	US$/tonne ($2013)	25,799	25,799	25,799	25,799
	$/bbl (C$2013)	3,686	3,686	3,686	3,686
Spill Size Multiplier reflecting Scale effects	(per Etkin, 2004)	0.15	0.27	0.65	2.00
Expected Cleanup Cost Reflecting Scale	$/bbl (C$2013)	553	995	2,396	7,372
Spill-specific Multiplicative Factors:					
Remoteness Factor	(Range 1.00 – 1.20)	1.00	1.00	1.00	1.00
Nearshore Water Exposure	(Range 1.00 – 1.46)	1.00	1.00	1.00	1.00
Oil Type	(Range 1.00 – 1.82)	1.00	1.00	1.00	1.00
Shoreline Impacts - 100 km	(Range 1.00 – 1.06)	1.00	1.00	1.00	1.00
Cumulative Multiplicative Factors	(Range 1.00 – 3.38)	1.00	1.00	1.00	1.00
Multiplier for Manual Cleanup	(Range 1.00 – 1.89)	1.00	1.00	1.00	1.00
Expected Lower Bound Cleanup Costs	$/bbl (C$2013)	553	995	2,396	7,372
Additive Damage Costs (ratio to cleanup costs; includes third party, social and environmental damages)					
Minimum: 1.69	$/bbl (C$2013)	934	1,682	4,049	12,459
Mean: 1.87	$/bbl (C$2013)	1,034	1,861	4,480	13,786
Maximum 2.27	$/bbl (C$2013)	1,255	2,259	5,439	16,734

Note: ignores foreign exchange rate differences.
Source: Based on Etkin (2004).
Associated Assumptions:

Inflation 1999-2010	1.24
Inflation 2010-2013	1.06
bbl/tonne	7.00
bbl/m3	6.29

Table B.2 – Cleanup and damage cost estimates from oil spill scenarios along the Project pipeline right of way. This presents the results of spill costs assuming the cleanup cost parameters provided in Table B.1 are applied to the spill size and impact area types (HCA = High Consequence Area) associated with the six pipeline spill scenarios described in the assessment. The scenario involving a spill during loading at the Westridge Marine Terminal is also shown. Damage cost multipliers are assumed as 1.5 for the pipeline spill scenarios and 0.85 for the Westridge Marine Terminal spill scenario.

		Rupture				Leak		Terminal
Source of Spill		Pipeline	Pipeline	Pipeline	Pipeline	Pipeline	Pipeline	Loading
Assumed Spill Size in Scenario (m3)		1,000	2,000	2,000	4,000	4.8	113.7	103
Assumed Spill Size in Scenario (bbl)		6,290	12,580	12,580	25,160	30	715	648
Impact Area Type		HCA	HCA	non-HCA	non-HCA	non-HCA	non-HCA	HCA
Spill Size Category		Average	Larger	Larger	Larger	Small	Modest	Modest
Spill Size Upper Value in Range	bbl	11,900	23,800	23,800	23,800	238	2,380	2,380
Spill Size Lower Value in Range	bbl	2,400	11,900	11,900	11,900	-	238	238
North American Average Cleanup Costs	$/bbl (C$2013)	3,686	3,686	3,686	3,686	3,686	3,686	3,686
Spill Size Multiplier reflecting Scale effects	(per Etkin, 2004)	0.27	0.15	0.15	0.15	2	0.65	0.65
Expected Cleanup Cost Reflecting Scale	$/bbl (C$2013)	995	553	553	553	7,372	2,396	2,396
Spill-specific Multiplicative Factors:								
Remoteness Factor	(Range 1.00 – 1.20)	1.20	1.20	1.20	1.20	1.20	1.20	1.00
Nearshore Water Exposure	(Range 1.00 – 1.46)	1.46	1.46	1.12	1.12	1.12	1.12	1.46
Oil Type (DilBit assumed like Heavy Oil)	(Range 1.00 – 1.82)	1.82	1.82	1.82	1.82	1.82	1.82	1.82
Shoreline Impacts - 100 km	(Range 1.00 – 1.06)	1.06	1.06	1.00	1.00	1.00	1.00	1.00
Cumulative Multiplicative Factors		3.38	3.38	2.45	2.45	2.45	2.45	2.66
Expected Lower Bound Cleanup Costs	$/bbl (C$2013)	3,364	1,869	1,352	1,352	18,033	5,861	6,366
Multiplier for Manual Cleanup	(Range 1.00 – 1.89)	1.89	1.89	1.89	1.89	1.89	1.89	1.73
Expected Upper Bound Cleanup Costs	$/bbl (C$2013)	6,358	3,532	2,556	2,556	34,081	11,076	11,000
Expected Cleanup Costs (mid-point)	$/bbl (C$2013)	4,861	2,700	1,954	1,954	26,057	8,469	8,683
Scenario Damage Cost Multiplier		1.50	1.50	1.50	1.50	1.50	1.50	0.85
Expected Upper Bound Damage Costs	$/bbl (C$2013)	9,536	5,298	3,834	3,834	51,122	16,615	9,350
Total Upper Bound Costs	$/bbl (C$2013)	15,894	8,830	6,390	6,390	85,204	27,691	20,350

Reference Case (Damage Cost based on multipliers) – million C$							
Spill Cleanup Cost (Upper Bound)	40.0	44.4	32.2	64.3	1.0	7.9	7.1
Spill Damage Cost (Upper Bound)	60.0	66.6	48.2	96.5	1.5	11.9	6.1
Spill Total Cost (Upper Bound)	100.0	111.1	80.4	160.8	2.6	19.8	13.2

Sensitivity Case ($10,000/bbl Damage Cost) – million C$				
Spill Cleanup Cost (Upper Bound)	40.0	44.4	32.2	64.3
Spill Damage Cost (Upper Bound)	62.9	125.8	125.8	251.6
Spill Total Cost (Upper Bound)	102.9	170.2	158.0	315.9

QUALITATIVE ECOLOGICAL RISK ASSESSMENT OF PIPELINE SPILLS

Technical Report for the Trans Mountain Pipeline ULC,

Trans Mountain Expansion Project

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EXECUTIVE SUMMARY

The purpose of this Ecological Risk Assessment (ERA) report is to evaluate the potential for ecological receptors (*e.g.,* fish, fish eggs, invertebrates, amphibians, reptiles, birds, mammals, and plants) to experience negative environmental effects as a result of exposure to crude oil released to the environment as a result of the Project. The following summary is based upon the assumption that an oil spill as a result of construction of the Trans Mountain Pipeline would be a low probability event.

Because of the nature of spills to land (*i.e.,* the limited spatial extent of environmental effects in the context of much larger habitat units) and the existence of legislated processes pertaining to environmental remediation following such spills, the ecological risk assessment does not directly consider effects to terrestrial environments. Conversely, crude oil entering aquatic environments has the potential to spread or be advected rapidly downstream, and as a result has the potential to affect much more of the available habitat. Aquatic ecosystems are known to be sensitive to spilled oil, and therefore this ERA report focuses on spills that enter aquatic environments.

The proposed TMEP pipeline corridor crosses 474 defined watercourses between Edmonton, Alberta and Burnaby, British Columbia, and runs parallel to several large rivers for a considerable portion of the distance. Where the pipeline runs parallel to a river, the potential for that river to be affected by oil in the unlikely event of an oil spill increases in proportion to the length of the pipeline corridor within the watershed, and the proximity of the corridor to the river. Based upon these and other criteria, hypothetical oil spill locations were selected in proximity to the Athabasca River near Hinton, Alberta; the North Thompson River near Darfield, British Columbia; the Fraser River near Hope, British Columbia; and the Fraser River near the Port Mann Bridge in greater Vancouver. This last location was selected to be as close as possible to the Fraser River Delta, in order to evaluate potential environmental effects of spilled oil on ecological receptors unique to the Delta, a tidal estuary.

Although the proposed TMEP pipeline will potentially carry a variety of crude oils, diluted bitumen is expected to comprise a large percentage of the oil shipped. For that reason, a sample of Cold Lake Winter Blend (CLWB) was procured and tested to provide information on the physical and chemical characteristics of a representative product. CLWB was selected because it is currently transported by Trans Mountain and is expected to remain a major product transported by the new pipeline. In addition, the diluent in CLWB is condensate (a light hydrocarbon mixture derived from natural gas liquids), which is volatile and relatively water-soluble. Due to the higher level of risk associated with inhalation of volatiles and/or exposure to dissolved hydrocarbons, CLWB was considered to be a conservative choice for the ERA, as opposed to heavy crude oil mixed with alternative diluents such as synthetic oil, which contain fewer volatile and less water soluble constituents.

A literature review was conducted to identify and acquire information on actual and modelled spills of heavy crude oils in the freshwater environment, and case studies were selected to inform predictions about the potential fate and transport and ecological effects of a diluted bitumen spill resulting from the Project. Actual spill case studies included the Kalamazoo River spill, East Walker River spill, Pine River spill, Wabamun Lake spill, Yellowstone River spill, OSSA II Pipeline spill, and the DM 932 barge spill, with crude oil types ranging from light crude oil to diluted bitumen and bunker type products. TMEP studies involving the behaviour of diluted bitumen on water in meso-scale experimental trials carried out at Gainford, Alberta (Witt O'Brien's *et al.* 2013) were also reviewed. Finally, modelling case studies included predictions of oil spill fate and ecological effects conducted for the Enbridge Northern Gateway Project, representing a diluted bitumen and a synthetic crude oil, with hypothetical spill locations on the Athabasca, Crooked, Morice and Kitimat rivers in Alberta and British Columbia, as well as a predictions of oil spill fate and ecological effects of Jet "A" fuel released to the lower Fraser River near Vancouver.

When crude oil is spilled, volatile components quickly evaporate, and more water-soluble components can dissolve into the water. The amount of hydrocarbon that will dissolve into the water depends upon a number of factors, including the availability of relatively water soluble hydrocarbons, the amount of mixing energy in the water column, and the viscosity of the oil. If there is sufficient mixing energy to entrain droplets of oil into the water column, then the rate of dissolution is increased in comparison to the case

when oil is simply floating on the water surface. High oil viscosity increases the amount of mixing energy required. The resulting concentration of dissolved hydrocarbon depends upon the amount of oil released, relative to the amount of water flowing in the river. Therefore, high potential for acute effects to aquatic organisms occurs when light oils containing a high percentage of mono-aromatic hydrocarbons (MAH) and other light hydrocarbons are released into streams or small rivers with high gradients leading to high-energy mixing. Lower potential for such effects is observed as oils become more viscous, with lower percentages of MAH present, and as the level of turbulence decreases as river size increases, or river gradient decreases.

Once in the water column, oil droplets may be exposed to suspended sediments; if there is adequate contact, the particulate matter may adhere to the oil droplets and the resulting oil-mineral aggregate (OMA) may become neutrally to negatively buoyant and remain submerged or sink in the water column. Formation of substantial quantities of OMA requires high suspended sediment concentrations, and is enhanced by salinity, which is not normally present in freshwater ecosystems. Oil may also contact sand and gravel particles along shorelines, resulting in initial stranding of oil that may sink if it later re-enters the water column. In high flows, submerged oil is transported downstream and prevented from settling on the riverbed. In contrast, low flows have the potential to result in high levels of sedimentation of submerged oil, particularly in quiescent areas where silty sediments accumulate.

For spills in winter, direct environmental effects of spilled oil may depend upon the amount of snow and ice cover, as snow can absorb spilled oil, and ice cover on watercourses can prevent or limit contact between the oil and running water. Many ecological receptors are absent or dormant during the winter, and would not be exposed to the spilled oil. For such spills, there is a high potential to recover most of the spilled oil so that oil spill effects on ecological receptors can be minimal. Spills to rivers that are not ice covered in winter, however, would have environmental effects similar to the environmental effects of spills at other times of the year.

For the four locations considered in this study (the Athabasca River near Hinton, Alberta; the North Thompson River near Darfield, British Columbia; the Fraser River near Hope, British Columbia and the Fraser River as it enters the Delta, near Vancouver), seasonal flow regimes are such that high flows are observed during the summer, as snow and ice melt in the mountain headwater regions. Low flows are typically observed in winter, as water equivalents build up in snowpack. Spring and fall represent shoulder seasons when flows are intermediate. Using information from the actual spill events and modelling case studies, the likely behaviour of spilled heavy crude oil, and extent of oiling, was predicted for each river system. Stochastic modeling was used to predict the fate and transport of oil for the Fraser River Delta, due to the unique nature and complexity of this environment. For the other three spill examples, professional judgement was used, based upon the case studies.

From the predicted distribution of crude oil in the environment in each of the rivers, for winter, summer, and spring and fall seasons, interactions between spilled oil and ecological receptor groups were evaluated. Ecological receptor groups included aquatic biota (vegetation, benthic invertebrates, fish including eggs and larvae, and amphibians), terrestrial plant and soil invertebrate communities in riparian areas, mammals (with grizzly bear, moose, muskrat and river otter selected as representative types), birds (with bald eagle, Canada goose, great blue heron, mallard, spotted sandpiper and tree swallow selected as representative types) and reptiles (with the Western painted turtle selected as a representative) for the Delta oil spill scenario, two additional ecological receptors (biofilm and Western sandpiper) were evaluated.

For each river, season and ecological receptor type, the expected spatial extent, magnitude, duration and reversibility of negative environmental effects was evaluated, again with reference to case studies. The spatial extent of environmental effects was found to vary, depending upon the season and river characteristics, and both the spatial extent and magnitude of environmental effects was often rated as "high", at least locally. However, effect durations taking into consideration oil spill response and restoration activities were typically less than five years, and often 12 to 24 months, and all rated negative environmental effects were considered to be "reversible". Evidence from the case studies showed overwhelmingly that freshwater ecosystems can recover from oil spills, often within relatively short periods of time.

Taking all of these factors into consideration, it is clear that a crude oil spill into a freshwater environment could have substantial negative environmental effects that could be long-lasting if prompt and effective measures are not taken to mitigate the immediate impacts by containment and recovery. However, as described in Volume 7, the probability of a crude oil spill reaching freshwater is very low. This confirms that spill prevention, preparedness, and effective response activities must always be a primary focus to reduce the probability of an oil spill to be as low as reasonably practical (ALARP), and to have adequate oil spill response plans and procedures in place that have proven capability to reduce the magnitude and extent of actual effects.

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DEFINITIONS AND ACRONYM LIST

Definition/Acronym	Full Name
‰	parts per thousand
AB	Alberta
acute	short-term
AER	Alberta Energy Regulator
AESRD	Alberta Environment and Sustainable Resource Development
ASRD	Alberta Sustainable Resource Development
AWB	Access Western Blend
AWC	Athabasca Watershed Council
bbl/d	barrels/day
BC	British Columbia
BC MELP	British Columbia Ministry of Environment, Lands and Parks
BC MOE	British Columbia Ministry Of Environment
bpd	barrels per day
BSD	Blue Sac Disease
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CCME	Canadian Council of Ministers of the Environment
chronic	long-term
CLWB	Cold Lake Winter Blend
COPC	Chemical of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPCN	Certificate of Public Convenience & Necessity
CSM	Conceptual Site Model
DFO	Department of Fisheries and Oceans
EA	Environmental Assessment

Definition/Acronym	Full Name
EHHRA	Ecological and Human Health Risk Assessment for Pipeline Spills (Stantec *et al.* 2012)
EPEA	*Environmental Protection and Enhancement Act* of Alberta
ERA	Ecological Risk Assessment
ERCB	Energy Resources Conservation Board
ESA	Environmental and Socio-economic Assessment
EVOS	Exxon Valdez Oil Spill
EWRTC	East Walker River Trustee Council
HDD	horizontal directional drilling
HDD	horizontal directional drill
HFO	Heavy Fuel Oil
HI	Hazard Index
HQ	Hazard Quotient
KMC	Kinder Morgan Canada Inc.
LOAEL	Lowest Observed Negative Effects Level
MAH	Mono aromatic hydrocarbons
masl	metres above sea level
NEB	National Energy Board
NEB Act	*National Energy Board Act*
NEBA	Net Environmental Benefits Analysis
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Negative Effects Level
NOAEL	no observed negative effects level
NRC	National Research Council
NTSB	National Transportation Safety Board

Definition/Acronym	Full Name
NTSB	National Transportation Safety Board
OMA	oil-mineral aggregate
OSR	oil spill response
PAH	Polycyclic aromatic hydrocarbons
Project	Trans Mountain Expansion Project
PTO	pole treating oil
QRA	Quantitative Risk Assessment
SARA	*Species at Risk Act*
SCAT	Shoreline Clean-up and Assessment Techniques
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain Pipeline
TPAH	Total Polycyclic Aromatic Hydrocarbons
Trans Mountain	Trans Mountain Pipeline ULC
TRV	Toxicity Reference Value
TSBC	Transportation Safety Board of Canada
TSS	total suspended solids
TUC	Transit Utility Corridor
UC	Unified Command
US	United States
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USFWS	United States Fish & Wildlife Service
UV	ultraviolet light

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, government agencies (*e.g.,* regulators and municipalities), stakeholders, and the general public. Information on the Project is also available at www.transmountain.com.

1.2. Purpose

Any crude oil spill, however unlikely, has the potential to cause negative environmental effects. As such, Trans Mountain considers accident prevention and environmental protection to be key commitments for the Project. Accident prevention and environmental protection measures for the Project are described in numerous places throughout the Application. It is to be stressed that the hypothetical oil spill scenarios put forward in this volume are considered to be unlikely events, with a low probability of occurrence.

While accidental spill events resulting from the Project could affect a variety of aquatic and terrestrial habitats (*e.g.,* forests, wetlands, rivers), the most serious effects are expected to be in the aquatic environment (as described in the Hazard Assessment in Section 6.2.2.1). Therefore, the purpose of the ecological risk assessment (ERA) is to evaluate the potential that valued ecosystem components (ecological receptors) such as fish, fish eggs, invertebrates, amphibians, reptiles, birds, mammals, and plants would experience negative effects as a result of exposure to chemicals of potential concern (COPC) released to the freshwater or estuarine environment following an accidental pipeline spill as a result of the Project. Spills to the marine environment resulting from marine terminal operations (*e.g.,* an accident during vessel loading at the Westridge Terminal) are assessed in Volume 7. Spills to the marine environment resulting from accidents during marine transportation (*e.g.,* a vessel collision or grounding incident) are assessed in Volume 8A.

The ERA has been prepared in support of the Application to the NEB and will be used to inform pipeline and facility design and emergency response planning.

1.3. Objectives

For the purpose of the ERA, oil spills were qualitatively assessed over a range of watercourses and flow conditions found in the freshwater environment traversed by the Project. The ERA examined a range of potential acute and chronic environmental effects to aquatic organisms and wildlife. The key objectives of the ERA were the following:

1. Make predictions about the fate and transport of hypothetical releases of diluted bitumen into representative freshwater environments along the proposed pipeline corridor, under a range of flow conditions.
2. Assess the ecological effects that could result from hypothetical pipeline releases of diluted bitumen to the freshwater environments along the proposed pipeline corridor.
3. Assess long-term recovery of the freshwater environment after a hypothetical spill of diluted bitumen resulting from the Project.

1.4. Organization of the Report

Table 1.1 provides a summary of how the ERA is organized.

TABLE 1.1 ORGANIZATION OF THE ECOLOGICAL RISK ASSESSMENT

Report Section	Content
Executive Summary	A non-technical summary of key findings to assist the reader in quickly understanding the most important aspects and conclusions of the report.
Section 1 – Introduction	An introductory section that describes the role of the ecological risk assessment. This section provides the context for the qualitative ecological risk assessment.
Section 2 – Consultation and Engagement	Describes the consultation and engagement activities conducted to inform Aboriginal communities, stakeholders, the public and government regulatory authorities about the approach to assessing potential environmental effects of the Project, and to seek input throughout the Project planning process
Section 3 – Pipeline Spills in the Terrestrial Environment	Describes the regulatory framework and response to hypothetical land-based pipeline spills, including response and mitigation strategies and remediation standards. Provides an evaluation of the potential environmental effects of spills in various terrestrial ecosystems along the pipeline corridor in response to spills in wetlands and forested and agricultural lands.
Section 4 – Description of the Freshwater Environment	Describes the exiting conditions within the freshwater environment along the proposed pipeline corridor.
Section 5 – Qualitative Ecological Risk Assessment Framework	A description of the methods used in the qualitative ecological risk assessment of acute and chronic ecological effects associated with a hypothetical pipeline spill in the freshwater environment along the proposed pipeline corridor.
Section 6 – Qualitative Ecological Risk Assessment	A qualitative assessment of the acute and chronic effects associated with a hypothetical pipeline spill in the freshwater environment along the proposed pipeline corridor. Includes the Problem Formulation, Exposure Assessment, Hazard Assessment, and Risk Characterization steps described in Section 5.
Section 7 – Summary and Conclusions	A summary of the findings of the ecological risk assessment.
Section 8 – References	A list of references cited.

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, Aboriginal engagement and landowner relations 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 pipeline spills 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 pipeline spills which may be affected by the construction and operation of the Project. Information collected through the public consultation, Aboriginal engagement and landowner relations programs for the Project was considered in the development of this technical report, and the assessment of pipeline spills 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 PIPELINE SPILLS IN THE TERRESTRIAL ENVIRONMENT

As the movement of oil on land tends to be relatively limited and simpler in comparison to aquatic environments, response strategies can be more accurately targeted for land-based spills than for those in the aquatic environment. Land-based spills (*e.g.,* spills to commercial or agricultural land, forested areas, and wetlands not having a free water surface) are not considered directly in the ERA; instead, the regulatory requirements and response strategies for pipeline spills in the terrestrial environment are discussed in this section. This is not to suggest that spills of crude oil to land will not result in negative environmental effects. Rather, it is an acknowledgement that spills that are limited to terrestrial habitats are likely to result in negative environmental effects that are more limited in spatial extent, and present fewer challenges for containment and recovery of spilled oil, as well as environmental restoration, than spills to water.

3.1. Regulation of Pipeline Spills in the Terrestrial Environment

Industry and regulatory authorities at the federal, provincial and local levels, share the responsibility to prepare for and respond to environmental emergencies, including land-based oil spills, with the common goal of protecting people, property and the environment. Small spills, such as those that may occur at a tank farm or pumping station within a facility, are generally dealt with directly by the facility operator (with reporting to the NEB as required). A larger spill with potential to cause off-site or off-right-of-way environmental effects could involve the mobilization and involvement of additional resources, under a Unified Command (UC) structure. Although a single Incident Commander normally handles the command function at an accident site, the Incident Command structure can be expanded into a Unified Command. The UC is an executive structure that includes the Responsible Party as well as regulators and other parties having key expertise related to the incident. This structure is used in order to coordinate an effective response while at the same time carrying out jurisdictional responsibilities. The UC helps to promote good and timely decision making and is responsible for overall management of the incident.

3.1.1. National Energy Board

The NEB is an independent federal regulatory authorities with the responsibility to regulate the construction and operation of interprovincial and international oil and gas pipelines and power lines. Established by the *National Energy Board Act*, the purpose of the NEB is to promote safety and security, environmental protection, and efficient energy infrastructure and markets in the Canadian public interest. Because the Project crosses provincial boundaries (*i.e.,* Alberta and British Columbia), it is subject to regulation by the NEB.

NEB-regulated companies are required to maintain an up-to-date emergency procedures manual that addresses emergency management, environmental protection, and worker and public safety. In the event of a pipeline spill or release, companies are responsible for reporting the incident to the NEB, and for implementing the emergency management procedures outlined in the manual.

NEB-regulated pipelines are also regulated under the *Canada Oil and Gas Operations Act* and the *Onshore Pipeline Regulations 1999 (OPR-99)*, whereby in the event of a spill, companies are required to:

- Take reasonable measures to prevent further spillage
- Repair or remedy any condition resulting from the spill
- Reduce or mitigate any danger to life, health, property, or the environment.

The NEB has published a *Remediation Process Guide* (NEB 2011) to aid companies in the event of a spill. Upon detection, the company must report the spill to the NEB and all applicable regulators (*e.g.,* Transportation Safety Board, provincial or territorial authorities). The company is then required to complete an Environmental Site Assessment and, if remediation is required, a Remedial Action Plan. The most stringent clean-up criteria must be used for remediation of soil and groundwater (*i.e.,* the lower of provincial, territorial, or those developed by the Canadian Council of Ministers of the Environment

(CCME)), and the site is considered clean once the NEB approves the Remediation Closure Report, which demonstrates that all applicable standards have been met.

3.1.2. Provincial Regulatory Authorities

Although the Project will be regulated by the NEB, the involvement of other provincial and municipal regulatory authorities may be required depending on the particular circumstances of spill and site location. The involvement of provincial and municipal regulatory authorities is required when one or more of the following occurs as a result of a spill:

- Contamination has occurred off-site
- The type of contamination has the potential for off-site migration
- The magnitude of the release has the potential for off-site migration of contaminants.

For on-site contamination from a spill, the involvement of provincial and municipal regulatory authorities may be required depending on a number of factors, including, but not limited to, the applicable provincial and municipal legislation and regulatory requirements, circumstances of the spill and site location.

3.1.2.1. Alberta

For NEB-regulated Projects, spills in Alberta are regulated by applicable provincial and municipal regulatory authorities, in addition to the NEB (and other applicable Federal regulatory authorities). For spills involving on-site or off-site contamination, Alberta Environment and Sustainable Resource Development (AESRD) must be immediately notified in accordance with the *Environmental Protection and Enhancement Act* of Alberta (*EPEA*) and the *Release Reporting Regulation* under *EPEA*. Under *EPEA*, reportable spills include those spills that have a substance released into the environment that could cause a negative effect, which is defined as "impairment of or damage to the environment, human health or safety or property". Other definitions of reportable spills may be included in other applicable *Acts, Regulations* and *Bylaws*.

The Project proponent must comply with reporting, containment and clean-up requirements for spills in accordance with the applicable Alberta regulatory requirements for the Project, which may include, but are not limited to:

- Regulatory requirements under *EPEA*, Alberta Tier 1 or Tier 2 Soil and Groundwater Remediation Guidelines (Alberta Environment 2010), and Surface Water Quality Guidelines for Use in Alberta (Alberta Environment 1999).
- Regulatory requirements under provincial and municipal legislation for clean-up related activities, which may include, but are not limited to the applicable requirements under the *Water Act* (Alberta), *Historical Resources Conservation Act* (Alberta), Municipal Bylaws, Albertan wildlife, plants, habitat and species protection legislation, and other applicable *Acts*, *Regulations* and *Bylaws*.

For non-NEB regulated projects:

- Spills in Alberta are regulated under Alberta Energy Regulator Directives (formerly Energy Resources Conservation Board (ERCB) Directives), the *Oil and Gas Conservation Act* and *Regulations (151/71)*, the *Pipeline Act* and *Regulations (91/2005)*, the *Environmental Protection and Enhancement Act* and *Regulations*, and other applicable *Acts*, *Regulations* and *Bylaws*.
- As of June 2013, the Government of Alberta proclaimed the *Responsible Energy Development Act*, under which the Alberta Energy Regulator (AER) was launched. The AER replaces the ERCB and takes on the energy-related regulatory functions of the Alberta Ministry of Environment and Sustainable Resource Development with respect to public lands, water and the environment. The AER is currently being phased in; all phases will be complete in spring 2014.

3.1.2.2. British Columbia

In British Columbia, the Ministry of Environment's scope and responsibilities with respect to oil spills are set out in the *Environmental Management Act* and the *Spill Reporting Regulation (BC Reg. 263/90)*. The *Environmental Management Act* sets out requirements for disposal of oil and hazardous materials, spill prevention and reporting, and pollution abatement. The *Spill Reporting Regulation* under the *Act* outlines the process for reporting spills, as well as the amounts of hazardous materials that must be reported if they are spilled. It requires the person in possession, charge, or control of the spilled substance to take all reasonable and practical actions to stop, contain, and minimize the effects of the spill.

British Columbia's land-based spill preparedness and response regime is guided by the "polluter-pay principle" in which industrial and commercial sectors that pose a risk to the environment and public safety have the responsibility to address risks and effects to human health and the environment. Industrial facilities that store, manufacture, transport, recycle, or handle dangerous goods, hazardous wastes, or hazardous chemicals should prepare a response (contingency) plan to respond to emergencies involving an accidental release of these substances into the environment.

When a spill occurs, the Responsible Party is expected to report the spill if a reportable level has been spilled into the environment, and to implement the operational decisions set out in the emergency response plan. Often the Responsible Party will either have a contractor that can be called in to respond to the spill or will have an Incident Management Team set up in case a spill occurs.

The Responsible Party is expected to take reasonable steps to contain the spill, and to restore the environment to its pre-spill condition. In many cases, the clean-up of a spill during the response is sufficient and no further investigation is required (British Columbia Ministry of Environment [BC MOE] 2009a). However, if additional follow-up is needed beyond the initial emergency response actions, such as continued monitoring, risk management, or extensive remediation, further actions would be conducted in accordance with the *Environmental Management Act* and *Contaminated Sites Regulation (BC Reg. 375/96)*.

Schedules contained in the *Contaminated Sites Regulation* define the numerical standards for soil, water, vapour, and sediment that are used to determine if a site is contaminated. Following that determination, a site owner/operator has the option of either cleaning up to the numerical standards listed in the Schedules or cleaning up to risk-based (site-specific) standards (BC MOE 2009b). Upon completion of clean-up activities, sampling and analyses are conducted and/or inspections and regular environmental monitoring are performed to confirm results.

3.2. Clean-up, Treatment, and Remediation Endpoints

The response actions and times for a land-based pipeline spill would depend on multiple factors including the volume and type of oil spilled, ground and air temperature, proximity to environmentally- or culturally-sensitive and/or human use areas, and surface conditions (*i.e.,* roughness, vegetation type and cover, soil type, permeability, snow cover). In addition, the selection of appropriate control and containment techniques would consider the following, which would be assessed and monitored at the time of a spill:

- Nature of the substrate
- Slope of the terrain
- Volume and thickness of the spilled oil
- Degree of penetration and potential for migration of the oil through the soil
- Presence and level of the water table and freshwater rivers and streams
- Biological community, resources, and cultural use.

As described in the General Oil Spill Response Plan, when containing a release on land, responders will attempt to:

- Confine the affected site to as small an area as possible
- Prevent the released hydrocarbons from leaving the site
- Prevent surface water runoff from entering or leaving the site
- Prevent unauthorized humans and wildlife from entering the site
- Prevent the released hydrocarbons from reaching a waterway.

These goals are typically accomplished by using one or a combination of the following techniques:

- Earth or lined sand bag dikes
- Sorbent dikes
- Snow or ice dikes
- Trenches
- Culvert blocks
- Bell holes.

Once contained on land, the released hydrocarbons would be recovered using suction or pumping. After the removal of liquid or pooled hydrocarbons, additional clean-up would continue using appropriate techniques (*e.g.,* manual clean-up, sorbents, controlled burning, water flushing).

Plans for final site remediation, reclamation, and restoration activities would be developed as the emergency phase of spill response neared completion, typically after all free-phase liquid hydrocarbons and gross oiling had been removed and site assessments had been completed.

3.3. Net Environmental Benefits Analysis

During and after the clean-up of a large oil spill, the UC (comprising the response team, regulatory authorities, Aboriginal groups and other stakeholders) may review the remediation endpoints for the clean-up in combination with a Net Environmental Benefits Analysis (NEBA). The NEBA assesses the net environmental benefits gained by clean-up and remediation, in consideration of the environmental injuries caused by those activities (Efroymson *et al.* 2003), with the objective of enhancing recovery outcomes while minimizing further environmental damage.

Endpoints are characteristics of the environment that are considered to be an acceptable condition after clean-up and remediation (*e.g.,* amount of weathered oil along a riverbank, amount of residual hydrocarbon remaining in soils). At a certain point in time, the environmental benefits that would be gained from further removal of residual hydrocarbons would be outweighed by potential damage caused by the clean-up or treatment activities. For example, removal of relatively low levels of weathered hydrocarbons could require extensive disturbance of riverbanks or wetlands which, if too intrusive, could delay rather than accelerate recovery (Baker 1995, 1997, Owens and Sergy 2003, 2007), or could permanently alter habitat.

An analysis of the net environmental benefits is required to assess the various recommended endpoints that promote natural recovery. Once the defined endpoint for a specific habitat (or substrate) is attained through clean-up and remediation measures, the residual hydrocarbons may be allowed to continue weathering through natural attenuation processes (*e.g.,* biological degradation by microorganisms), which would continue to reduce their concentrations over time. The affected site would be monitored regularly to confirm that rehabilitation and recovery of the affected areas were successful. The need for and scope of monitoring would be determined in consultation with regulatory authorities, participating Aboriginal groups, and stakeholders, as appropriate.

3.4. Response and Mitigation for Land-based Spills

3.4.1. Agricultural Lands

A generic description of land-based spills is included in Section 6.2.1. A typical response to a pipeline spill in an area of agricultural land is described in the Application, Volume 7. Important elements of these standards have been summarized in the General Oil Spill Response Plan.

After completion of source control and containment actions, clean-up would likely include excavation and disposal of hydrocarbons and affected soils, and the remediation of groundwater, if applicable. The remediation of groundwater may involve one or more specialized treatment processes (*e.g., in situ* treatment, bioremediation, phytoremediation). To maintain use for agriculture, the priority would be to restore land capability within a reasonable amount of time. If the land is used for food production, excavation and replacement of soil is likely the most appropriate option. Affected soils would be replaced with soil of equal soil capability. Where possible, clean topsoil would be segregated and used for site reclamation.

Final site remediation, reclamation, and restoration activities require plans that would be developed and implemented as the emergency phase of spill response neared completion (*i.e.,* typically after all free-phase liquid hydrocarbons and obvious oiling have been removed). Site-specific treatment plans would be required if groundwater was affected.

During emergency response activities, it is estimated that a small portion of diluted bitumen would weather, mainly through evaporation, in the first few days or hours, respectively. However, evaporation rates are likely to be lower during cold weather. Based on professional knowledge and general experience, approximately 99% of the recoverable volume (*i.e.,* volume remaining taking into account evaporation and dissolution) would be recovered for inland spills that do not reach groundwater or surface water, leaving an approximate residual volume of less than 1%. The residual volume would then be subject to natural biodegradation and attenuation, which could be verified through test pits or drilling monitoring wells.

Given that land-based spills usually affect relatively small areas, there is a greater potential for predictions of the movement and environmental effects of a spill than for those in the aquatic environment. There are also greater operational opportunities and flexibility, and greater recovery potential (Owens 2002), as well as established response protocols and legislative frameworks for remediation. As a result, spill scenarios involving agricultural land are not considered further in the ERA.

3.4.2. Forested Areas

The pipeline will be located within a narrow right-of-way that will be maintained in grass and forb cover for the life of the Project. As a result, hydrocarbon spills from the pipeline would have to extend beyond this right-of-way to have an off-site effect on adjacent forested areas. This could occur through downslope movement of hydrocarbons on the surface, sub-surface, or in groundwater.

A generic description of land-based spills is included in Section 6.2.1. The description of response and mitigation for agricultural lands (Section 3.4.1) would also generally be applicable to forested areas, although the terrain could be more challenging, and site access could be more difficult.

Clearing and temporary roads may be required, as well as slope stabilization measures. During the initial response, objectives would include confining the hydrocarbon release to as small an area as reasonably possible, managing surface water, and preventing the contamination from reaching waterways or other environmentally-sensitive sites (*e.g.,* biologically important areas, cultural sites, human use areas). To access the spill site and to accomplish the response objectives, efforts would be made to limit the amount of vegetation clearing and soil removal. Where possible, unaffected topsoil would be segregated and used during reclamation.

After free oil has been recovered, careful consideration would be given to the amount of additional clean-up that would be conducted. Clean-up decisions would need to consider net environmental benefit analyses (as described in Section 3.3).

Additional logistical challenges and factors that may be of importance in responding to spills in forested areas include:

- Working on steep and uneven slopes
- Cleaning or removal and disposal of wood and organic debris
- Preserving topsoil
- Dealing with snow accumulations and the handling and disposal of contaminated snow
- Surface water management
- Presence of wildlife.

It is anticipated that in a typical forest spill scenario, less of the recoverable oil would be collected than for a similar spill to agricultural land. In general, land and other environmental media that would be affected by pipeline spills would be remediated to the applicable provincial environmental quality standards. As a result, spill scenarios involving forested areas are not considered further in the ERA.

3.4.3. Wetlands

Wetlands are considered to be environmentally sensitive areas; therefore, response options would be considered carefully to avoid further damage from clean-up and remediation activities. The response actions and times would differ depending on various factors including the oil type, amount spilled, meteorological conditions, and water level. In general, after the initial assessment, containment in wetlands would:

- Confine the released hydrocarbons to as small an area as possible
- Prevent the hydrocarbons from reaching to an area where water movement could cause their rapid dispersion
- Control wildlife and unauthorized humans from entering the site
- Restrict the potential for additional oiling of vegetation.

Containment of a release into wetlands would typically include one or more of the following techniques:

- Earth or sand dikes
- Snow/ice dikes
- Trenches
- Containment booms
- Containment weirs
- Water-inflated dams.

Once contained, hydrocarbons would typically be recovered from wetlands using the following techniques:

- Suction
- Pumping
- Fresh water flushing
- Oil skimming.

In general, other issues that would need to be considered include:

- Soil disturbance
- Hydrodynamic effects
- Soil replacement
- Vegetation preservation

- Natural attenuation
- Wildlife presence.

After free oil has been recovered, careful consideration would be given to the amount of additional clean-up that would be conducted. Clean-up decisions would need to consider net environmental benefit analyses (as described in Section 3.3).

Depending on the site and the amount of oiling, it is likely that a combination of clean-up methods (*i.e.,* manual clean-up, sorbents, in situ burning, excavation) and natural attenuation could be used. The final remedial objectives and approach would be the decisions of the Unified Command based on:

- Amount, location, type, and persistence of the hydrocarbons
- Nature and uses of the area
- Effects of various clean-up methods on the area and on native animal and plant species.

Natural attenuation would be considered if:

- Clean-up activities were more harmful than allowing the habitat to recover naturally
- Hydrocarbon exposure would not cause further harm to environmentally sensitive areas of the site or adjacent shoreline area
- Presence of the residual contamination was within applicable standards and was acceptable in terms of the area's use.

Final site remediation, reclamation, and restoration activities would require plans that would be developed as the emergency phase of spill response neared completion (*i.e.,* typically after all free-phase liquid hydrocarbons and obvious oiling have been removed). These plans may consider bioremediation as a type of natural attenuation.

Because of the uncertainty over the extent of burning or removal of soil and materials (*i.e.,* peat), a conservative approach was taken in estimating the recovery of hydrocarbons. Without burning or aggressive excavation, a residual volume of approximately 20% to 30% of the spilled oil could remain on the wetland surface, in soil pore spaces, or bound to vegetation after initial weathering and recovery operations. Oil remaining after clean-up endpoints had been reached would continue to degrade, weather, and dissipate naturally. As a result, spill scenarios involving wetlands not having a free water surface were not considered further in the ERA.

3.5. Summary of Land-Based Spills

Due to the more confined and predictable nature of land-based spills (as opposed to those in the aquatic environment), they are more readily addressed through standard remediation strategies. Recovery of oil, often involving the physical removal of vegetation and surface soils, is usually practical and effective. Such response efforts would typically lead to a requirement for re-vegetation of the land subsequent to physical rehabilitation. While it is recognized that where mature forest is lost, such habitat can not be replaced in a short period of time, land-based spills (including the overland flowpath of spills that may enter aquatic environments) are considered to have recovered once site soils meet relevant soil quality guidelines, the site is re-vegetated, and all regulatory requirements have been met.

The environmental effects of a large crude oil spill to agricultural or forested land would undoubtedly be substantial. Unless there was a unique environmental feature such as critical habitat for an endangered mammal, bird, or plant species present, however, the environmental effects would generally be localized, reversible through the spill response and clean-up process, and affect only a small area of land in the context of the larger ecoregion within which effects would occur. Compensation to landowners for lost productive capacity would also mitigate damages. In the broader sense, therefore, and given their low probability of occurrence, the environmental effects of a crude oil spill to the terrestrial environment could be considered to be "not significant" in the context of the Environmental and Socio-economic Assessment (ESA) process.

Wetlands are transitional between terrestrial ecosystems and aquatic ecosystems, and as such, present a range of physical and biological properties. Where there is no free water surface (*e.g.,* bogs and fens), the presence of vegetation such as peat and organic soils create conditions that limit the spread of hydrocarbons, and response and mitigation strategies can be applied as described in Section 3.4.3. In cases where there is a free water surface that facilitates the rapid spreading and downstream transport of oil (*e.g.,* marshes, wet swamps, beaver impoundments, small open water bodies), wetlands will be more similar to watercourses both in terms of the receptors present and their sensitivity, and in terms of the remediation and rehabilitation methods implemented; the effects of hypothetical spills to the freshwater environment (which includes wetlands with a free water surface) are assessed in the ERA.

4.0 DESCRIPTION OF THE FRESHWATER ENVIRONMENT

The configuration of the Trans Mountain Expansion Project is shown in Figure 4.1. The proposed pipeline corridor originates in Alberta at the existing (Trans Mountain) Edmonton Terminal in Sherwood Park. From the Edmonton Terminal, the proposed pipeline corridor extends south, then west along the Edmonton Transit Utility Corridor (TUC), before diverging to the west towards the Town of Stony Plain. From the Stony Plain area, the proposed pipeline corridor generally parallels Highway 16 to Hinton, occasionally alternating between the north and south approaches of the highway. The Edmonton to Hinton Segment is approximately 340 km long and spans the North Saskatchewan and Athabasca River Basins. Within these basins, the following eight watersheds are crossed: Lower North Saskatchewan River; Middle North Saskatchewan River; Upper North Saskatchewan River; Sturgeon River; Pembina River; Lower McLeod River; Upper McLeod River; and Athabasca River.

Within British Columbia, the proposed pipeline corridor has been separated into the following construction segments: Hargreaves to Darfield, Black Pines to Hope, Hope to Burnaby, and Burnaby to Westridge. The proposed pipeline corridor spans two major drainage basins in British Columbia, which include the Fraser River Basin for much of its length, and the Columbia River Basin between Cedarside and Albreda. It also spans eastern portions of the existing BC Hydro 500 kV right-of-way near the settlement of Aspen Grove. Within the two river basins, the following thirteen watersheds are crossed: Upper Fraser River; Canoe Reach; Upper North Thompson River; Clearwater River; Lower North Thompson River; Thompson River; South Thompson River; Lower Nicola River; Fraser Canyon; Harrison River; Chilliwack River; Lower Fraser River; and Squamish.

The proposed pipeline corridor crosses 474 defined watercourses and also passes close to a number of important lakes and watercourses, such as Wabamun Lake and the Athabasca, North Thompson and Fraser Rivers. Figures 4.2 and 4.3 show the watersheds and major watercourses crossed by the proposed pipeline corridor.

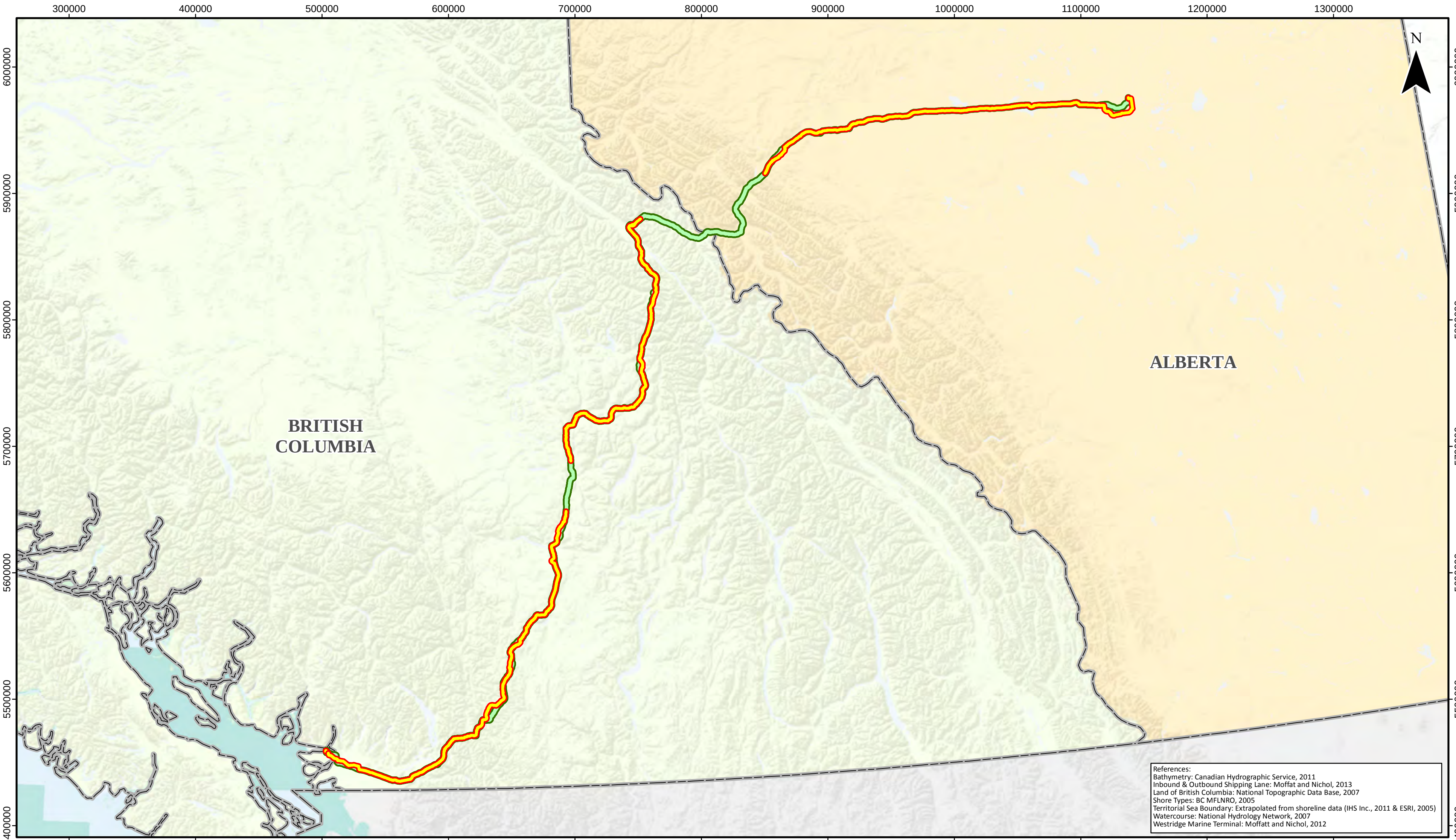
Detailed fisheries information including the characteristics, fish species and status of fish species present in watercourses crossed by the proposed pipeline corridor are described in the fisheries reports prepared by TERA Environmental Consultants (2013) for the Province of Alberta, and by Triton Environmental Consultants (2013) for the Province of British Columbia.

The following sections summarize information on the existing conditions within each river basin traversed by the Project.

4.1. North Saskatchewan River Basin

The North Saskatchewan River originates in the Columbia Icefield in Banff National Park at an elevation of approximately 2,200 metres above sea level (masl). It flows approximately 1,400 km in a generally northeast direction through Edmonton to its confluence with the South Saskatchewan River in central Saskatchewan at an elevation of approximately 400 masl.

Within the North Saskatchewan River Basin, the Project crosses through four watersheds (Lower, Middle and Upper North Saskatchewan River and Sturgeon River) and the following larger watercourses: Goldbar Creek; Mill Creek; Whitemud Creek; Blackmud Creek; Dog Creek; Atim Creek; Kilini Creek; and the North Saskatchewan River (as shown in Table 4.1).



Stantec

Trans Mountain Expansion Project Proposed Pipeline Corridor

Existing Trans Mountain Pipeline

Provincial Boundary

TRANS MOUNTAIN

SCALE: 1:4,500,000

0 50 100 150 200 km

ALL LOCATIONS APPROXIMATE

MAP NUMBER		PAGE
123110494_032_TRANSMOUNTAINROUTE_OVERVIEW		SHEET 1 OF 1
DATE Nov 2013	TERA REF. 7894	REVISION A
SCALE 1:4,500,000	PAGE SIZE 8.5 x 11	DISCIPLINE AQ
DRAWN ZB	CHECKED MS	DESIGN ZB

FIGURE: 4.1

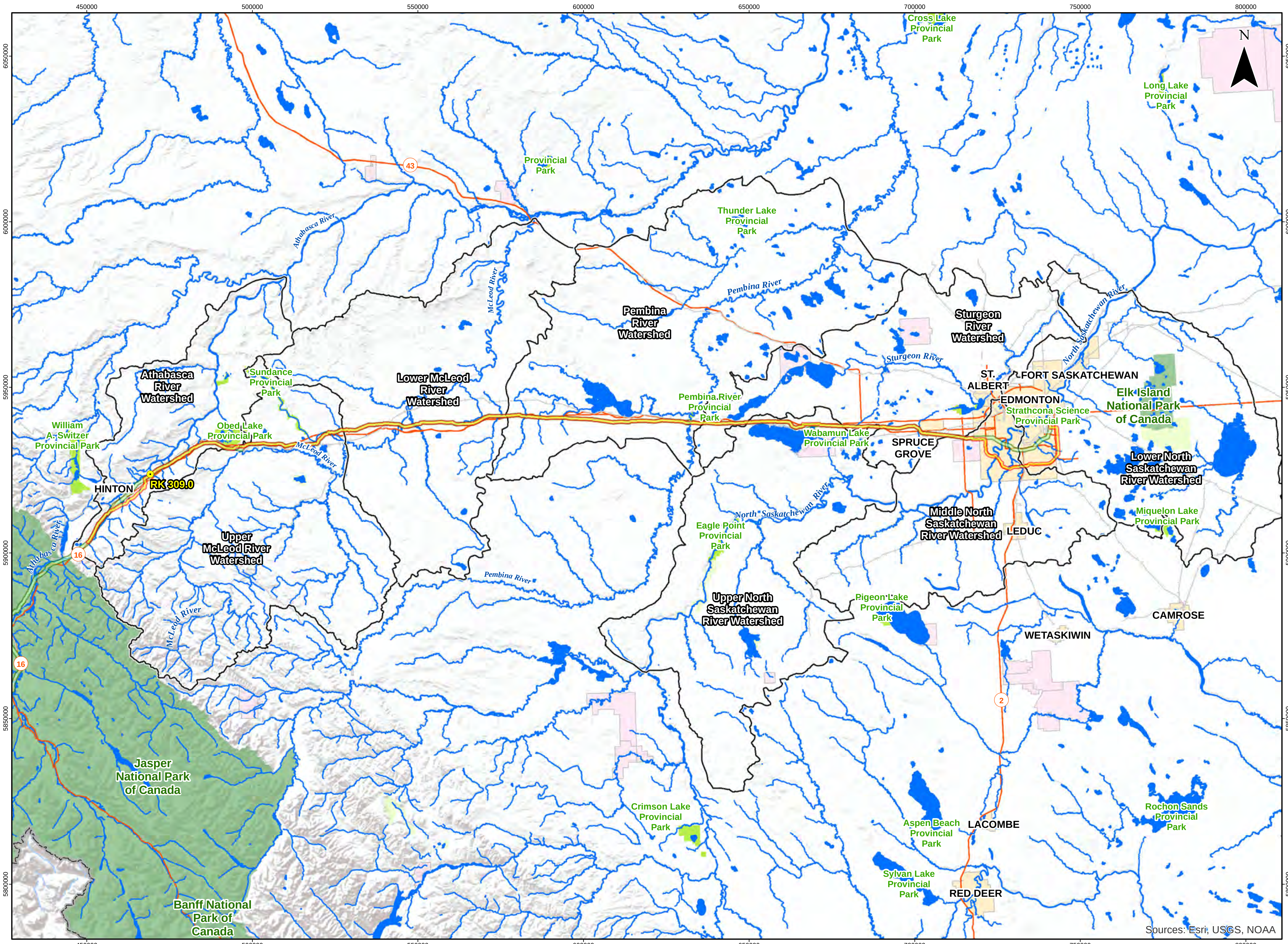
TRANS MOUNTAIN EXPANSION PROJECT

TRANS MOUNTAIN EXPANSION PROJECT

TRANS MOUNTAIN

FIGURE: 4.2

AQUATIC ENVIRONMENT TRAVERSED BY THE TRANS MOUNTAIN EXPANSION PROJECT IN ALBERTA



Representative Spill Location
Trans Mountain Expansion Project Proposed Pipeline Corridor
Existing Trans Mountain Pipeline
Highway
Railway
Watershed Boundary
City / Town / District Municipality
Indian Reserve
National Park
Provincial Park
Protected Area / Natural Area / Provincial Recreation Area / Wilderness Provincial Park / Conservancy Area
Provincial Boundary

Projection: UTM Zone 11N (p. 1 to 77), UTM Zone 10N (p. 78 to 146). Route Revision: 2; Facilities; B/W & Colour Imagery: 2008-2011: Provided by KMC, 2012; Existing Infrastructure: IHS Inc., 2012; Transportation: IHS Inc., 2012, BC Crown Registry and Geographic Base Branch, 2010, Natural Resources Canada, 2011; Geopolitical Boundaries: Natural Resources Canada, 2003, AltaLIS, 2012, IHS Inc., 2011, BC FLNRO, 2007, ESRI, 2005; First Nation Lands: Government of Canada, 2012, AltaLIS, 2010, IHS Inc., 2011; Hydrology: Natural Resources Canada, 2007, BC Crown Registry and Geographic Base Branch, 2008; Parks and Protected Areas: Natural Resources Canada, 2012, AltaLIS, 2012, BC FLNRO, 2008; Club Root Infested Areas: Provided by KMC, 2012; Access and Private Land: KMC & TERA, 2012. 1:50,000 NTS Maps: © 2012. Produced under license from Her Majesty the Queen in Right of Canada, with permission of NRCan.

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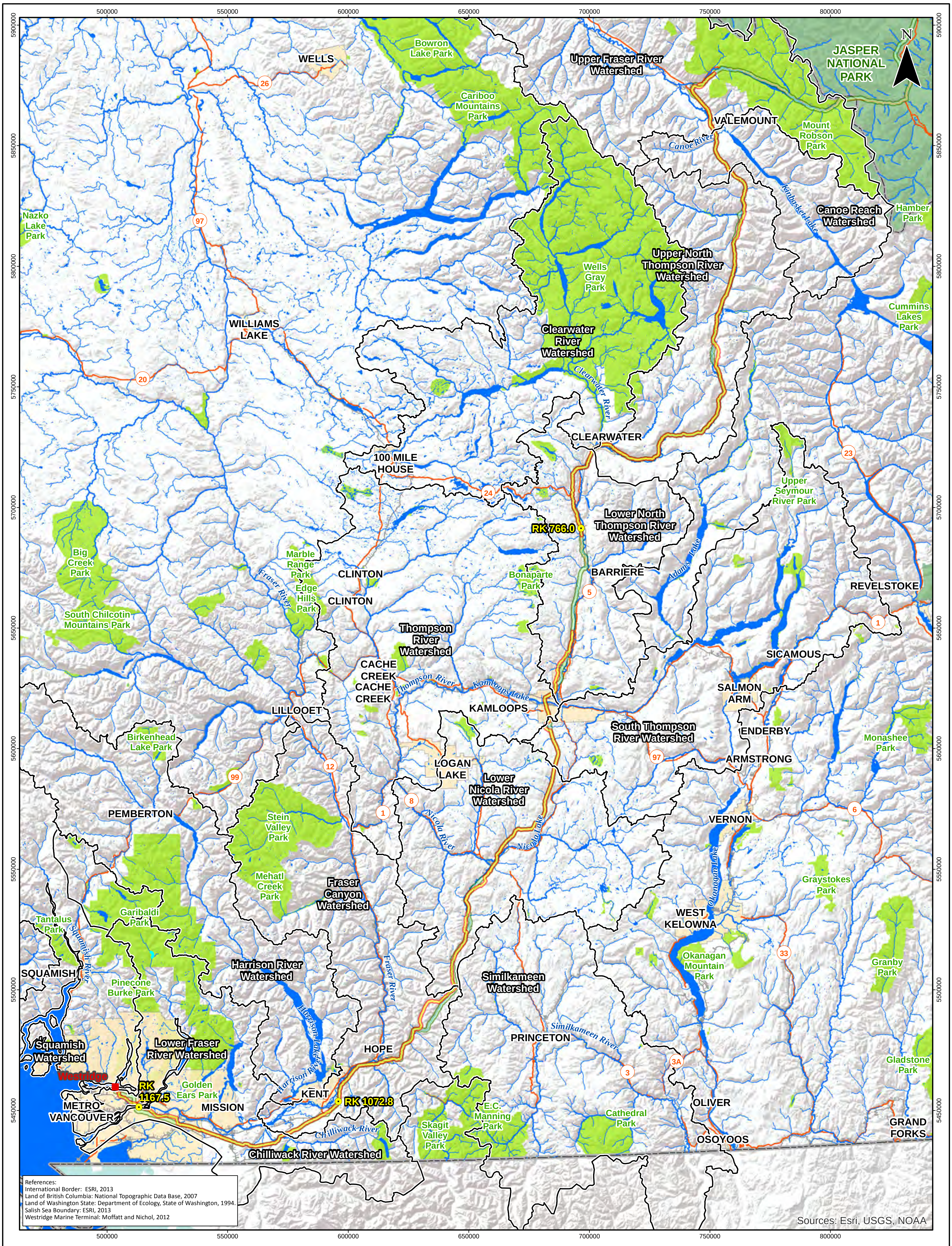
MAP NUMBER 123110494_030_AQUATICENV_AB		PAGE SHEET 1 OF 2
DATE 29 Nov 2013	TERA REF. 7894	REVISION A
SCALE 1:1,100,000	PAGE SIZE 11x17	DISCIPLINE AQ
DRAWN ZB	CHECKED MS	DESIGN ZB

SCALE: 1:1,100,000

0 5 10 15 20 km

ALL LOCATIONS APPROXIMATE

123110494_030_AquaticEnv_AB.mxd



References:
International Border: ESRI, 2013
Land of British Columbia: National Topographic Data Base, 2007
Land of Washington State: Department of Ecology, State of Washington, 1994.
Salish Sea Boundary: ESRI, 2013
Westridge Marine Terminal: Moffatt and Nichol, 2012

Stantec

SCALE: 1:1,500,000
0 5 10 15 20 km

ALL LOCATIONS APPROXIMATE

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

MAP NUMBER 123110494_031_AQUATICENV_BC		PAGE SHEET 2 OF 2
DATE 29 Nov 2013	TERA REF. 7894	REVISION A
SCALE 1:1,500,000	PAGE SIZE 11x17	DISCIPLINE AQ
DRAWN ZB	CHECKED MS	DESIGN ZB

123110494_031_AquaticEnv_BC.mxd

- Terminal
- Representative Spill Location
- Trans Mountain Expansion Project Proposed Pipeline Corridor
- Existing Trans Mountain Pipeline
- Highway
- Railway
- Watershed Boundary
- City / Town / District Municipality
- National Park
- Provincial Park
- Provincial Boundary

TRANS MOUNTAIN

FIGURE: 4.3

AQUATIC ENVIRONMENT TRAVERSED BY THE TRANS MOUNTAIN EXPANSION PROJECT IN BRITISH COLUMBIA

TABLE 4.1 SUMMARY OF WATERSHEDS AND MAJOR WATERCOURSE CROSSINGS IN THE NORTH SASKATCHEWAN RIVER BASIN

Watersheds Crossed by the Project	Major Watercourses Crossed by the Project
Lower North Saskatchewan River	• Goldbar Creek • Mill Creek
Middle North Saskatchewan River	• Blackmud Creek • Whitemud Creek • North Saskatchewan River
Sturgeon River	• Dog Creek • Atim Creek • Kilini Creek
Upper North Saskatchewan River	• n/a

The Project traverses the upper and middle reaches of the North Saskatchewan River Basin. Land use in the upper reach (headwaters to Devon) is dominated by forestry and agriculture, with some industry (*e.g.,* oil and gas, power generation) and municipal development (Alberta Environment 2007). In the middle reach (Devon to Pakan), land use is dominated by industrial and municipal development (*i.e.,* Edmonton and Fort Saskatchewan) (Alberta Environment 2007).

Peak flows vary depending on the size and location of the watercourse. As shown in Table 4.2, lower elevation streams (*e.g.,* Whitemud Creek) reach peak flows earlier (*e.g.,* April) than higher elevation streams due to early spring snowmelt on the plains. Lowest flows occur just prior to freeze-up (*e.g.,* October). In contrast, higher elevation streams such as the North Saskatchewan River reach peak flows later in the season (*e.g.,* June) as a result of glacier and mountain snowmelt. Lowest flows occur in winter (*e.g.,* February). Water flows in the North Saskatchewan River are also regulated by two large hydroelectric dams. The Bighorn Dam is located on the North Saskatchewan River at Abraham Lake in the foothills of the Rocky Mountains, and the Brazeau Dam is located on the Brazeau Reservoir near the Brazeau River's confluence with the North Saskatchewan River. The Bighorn and Brazeau dams are located upstream from the proposed pipeline corridor, approximately 330 km and 190 km, respectively. In general, these dams increase winter flows and decrease summer flows (Partners for the Saskatchewan River Basin 2009).

TABLE 4.2 STREAMFLOWS FROM HYDROLOGICAL STATIONS NEAR WATERCOURSE CROSSINGS IN THE NORTH SASKATCHEWAN RIVER BASIN

Station Name, Station Number	Approximate Location of Station Relative to the Project	Month and Mean Monthly Discharge (m^3/s) during the Lowest Flow Period	Month and Mean Monthly Discharge (m^3/s) during the Highest Flow Period
Whitemud Creek near Ellerslie 05DF006	10 km upstream	October 0.03 m^3/s	April 2.3 m^3/s
North Saskatchewan River at Edmonton 05DF001	10 km downstream	February 69.1 m^3/s	June 484.0 m^3/s

Notes: Streamflow data from the Water Survey of Canada (Environment Canada 2013)

Water quality is rated as 'good' (*i.e.,* minor impairment relative to reference or natural conditions) in the upper reach of the North Saskatchewan River Basin and as 'fair' (*i.e.,* moderate impairment relative to reference or natural conditions) in the middle reach (as a result of nutrient enrichment); all reaches showed an increase in concentrations of dissolved solids over the period from the 1980s to 2004, possibly due to low river discharges (Alberta Environment 2007). Bottom substrates in the upper reach consist primarily of cobble, pebble and gravel, and are colonized by benthic invertebrates that prefer clean substrates, well-oxygenated water, and swift currents (*e.g.,* mayflies, caddisflies, stoneflies) (Alberta Environment 2007). In the middle reach, sediments downstream of Edmonton tend to be higher in organic carbon and trace metals than those upstream, and benthic algae and invertebrate communities reflect changes associated with nutrient enrichment (Alberta Environment 2007).

Indicator fish species previously documented in the North Saskatchewan River Basin include lake sturgeon, bull trout, burbot, walleye and northern pike. Other species of management concern include lake trout, brook trout, brown trout, cutthroat trout, goldeye, mountain whitefish, sauger, spoonhead sculpin, silver redhorse, quillback and northern redbelly dace.

4.2. Athabasca River Basin

The Athabasca River originates in Jasper National Park, in an unnamed lake at the toe of the Athabasca Glacier at an elevation of approximately 1,500 masl. It flows for approximately 1,231 km in a generally northeast direction across the province and drains into Lake Athabasca, north of the City of Fort McMurray at an elevation of approximately 200 masl.

As shown in Table 4.3, the watersheds crossed by the Project within the Athabasca River Basin include the Pembina River, the Lower McLeod River, the Upper McLeod River and the Athabasca River watersheds. Major watercourses crossed by the proposed pipeline corridor include the Pembina, McLeod and Lobstick Rivers and Zeb-igler, Carrot, January, Brule, Little Brule, Wolf, Bench, Carrot, Rooster, Ponoka, Roundcroft, Sandstone, Hunt, Trail, Hardisty, Maskuta, Sundance and Little Sundance Creeks.

TABLE 4.3 SUMMARY OF WATERSHEDS AND WATERCOURSE CROSSINGS IN THE ATHABASCA RIVER BASIN

Watersheds	Major Watercourses Crossed by the Project
Pembina River	• Zeb-igler Creek • Little Brule Creek • Brule Creek • Lobstick River • Pembina River
Lower McLeod River	• Carrot Creek • January Creek • Wolf Creek • Bench Creek • McLeod River
Upper McLeod River	• Little Sundance Creek • Sundance Creek
Athabasca River	• Rooster Creek • Ponoka Creek • Roundcraft Creek • Sandstone Creek • Hunt Creek • Trail Creek • Hardisty Creek • Maskuta Creek

The Project crosses the middle and upper reaches of the Athabasca River Basin. Land uses in these areas include agriculture, industry (*e.g.,* pulp mills) and municipalities. The Athabasca River receives discharges from various pulp and paper mills and municipal wastewater treatment plants (*i.e.,* in Jasper, Hinton, Whitecourt, Athabasca and Fort McMurray), which contribute to nutrient enrichment and lower dissolved oxygen concentrations (Alberta Environment 2007).

As shown in Table 4.4, water flows in the Athabasca River Basin show similar seasonal patterns. Flows are lowest during February and discharge begins to increase during the spring. Peak flows vary depending on the size and location of the waterbody; lower elevation streams reach peak flows earlier due to early spring snowmelt on the plains.

TABLE 4.4 STREAMFLOWS FROM HYDROLOGICAL STATIONS NEAR WATERCOURSE CROSSINGS IN THE ATHABASCA RIVER BASIN

Station Name, Station Number	Approximate Location of Station Relative to the Project	Month and Mean Monthly Discharge (m^3/s) during the Lowest Flow Period	Month and Mean Monthly Discharge (m^3/s) during the Highest Flow Period
Wolf Creek at Highway No. 16A 07AG003	500 m downstream	February 0.52 m^3/s	July 9.3 m^3/s
Pembina River near Entwistle 07BB002	2 km downstream	February 2.3 m^3/s	May 49.6 m^3/s
McLeod River near Whitecourt 07AG004	75 km downstream	February 4.1 m^3/s	June 110.0 m^3/s

Notes: Streamflow data from the Water Survey of Canada (Environment Canada 2013)

Water quality is rated as 'excellent' (*i.e.,* no measurable impairment relative to reference or natural conditions) in the upper reach of the Athabasca River and as 'good' in the middle reach (Alberta Environment 2007). Effluent discharges from pulp and paper mills and wastewater treatment plants result in increased nutrient concentrations downstream of these point sources. Sediment quality in the middle reach is rated as 'fair' (*i.e.,* contaminant concentrations show moderate degradation relative to reference or natural conditions) (Alberta Environment 2007). Sediments in both the upper and middle reaches are directly affected by the accumulation of organic contaminants from industrial and other human activity.

The McLeod River, a major tributary that is crossed by the Project, discharges large volumes of water and suspended sediment (and associated nutrient loads) to the Athabasca River. Water quality is rated as 'fair' as a result of inputs from various sources including forestry operations, mining (*e.g.,* selenium from coal mining), and agriculture (Alberta Environment 2007).

Nutrient enrichment in the naturally nutrient poor stretches of the Athabasca River results in increased benthic algal biomass and invertebrate abundance (*i.e.,* midge larvae) downstream of point sources (Alberta Environment 2007).

Indicator fish species that have been previously documented in the Athabasca River Basin include bull trout, Arctic grayling, Athabasca rainbow trout, northern pike, walleye and burbot. Other species of management concern include brown trout, brook trout, rainbow trout (native populations), mountain whitefish, yellow perch, goldeye, spoonhead sculpin and northern redbelly dace.

The Athabasca Watershed Council (AWC) is an independent, non-profit organization that is a designated Watershed Planning and Advisory Council working in partnership with the Government of Alberta to assess the condition of the Athabasca watershed and prepare plans and solutions to address watershed issues to protect and improve water quality and ecosystem function (Government of Alberta 2013).

An Integrated Watershed Management Plan for the Athabasca River watershed is currently under development by the AWC (AWC 2013). The purpose of the plan, to be fully implemented over the next several years, is to provide a guide for the protection, maintenance and restoration of the Athabasca watershed that balances environmental, social and economic needs. Once complete, the plan will be presented to all sectors, communities and citizens who have interest and commitment to the ecological health and sustainability of the watersheds, for voluntary implementation of recommendations.

The AWC is currently working to identify environmental issues in the watershed by compiling, analyzing and interpreting scientific and technical information into a multi-phase Athabasca State of the Watershed Report. Recommended solutions to issues identified in the various phases of the report will be compiled into the Athabasca Integrated Watershed Management Plan (AWC 2013).

Human activities within the Athabasca River watershed pose risks to surface water quality. For example, agricultural runoff causes nutrient and chemical loading such as phosphorus, nitrogen, pesticides and fecal organisms. These can lead to algal blooms, increased pathogens and nitrates in drinking water, and the emission of odors and gases into the air. Common industrial contaminants from oil sands, pulp mills, coal mining and municipal sewage treatment discharged or leaked into surface water can pose risks to animal and human health. Due to the potential risks posed by point and non-point source contamination of surface water, the maintenance of surface water quality is a high management priority in the Athabasca River Watershed (FIERA Biological Consulting 2012).

4.3. Columbia River Basin

The Columbia River originates in the Rocky Mountain Trench at an elevation of 820 masl. It flows northwest through the Columbia Valley to Kinbasket Lake, after which it flows south, eventually crossing the border into the United States of America before draining into the Pacific Ocean. The total length of the Columbia River is approximately 1,930 km, of which 668 km is located in Canada.

The main stem of the Columbia River is not crossed by the Project, although there are four crossings of watercourses that drain into the Columbia River Basin, including a proposed crossing of Canoe River and three crossings of Camp Creek (Table 4.5).

TABLE 4.5 SUMMARY OF WATERSHEDS AND NAMED WATERCOURSE CROSSINGS IN THE COLUMBIA RIVER BASIN

Watersheds	Major Watercourses Crossed by the Project
Canoe Reach	• Canoe River • Camp Creek

Canoe River originates from the South Canoe Glacier near Mount Sir John Thompson in the Caribou Mountains and flows southeast for approximately 40 km to its confluence with Kinbasket Lake. This arm of Kinbasket Lake is referred to as Canoe Reach because it was previously the lower reach of the Canoe River. Canoe Reach was created when lower portions of the Canoe River were flooded during installation of the Mica Dam in 1973.

Within Canada, valley bottoms along the middle and lower reaches of the Columbia River Basin have been heavily modified by industrial development, hydroelectric dams, agriculture, transportation and communication networks, rural settlement and municipalities (BC MOE 2013a). The upper reach is located upstream of the Project and therefore not anticipated to be affected by the Project.

As shown in Table 4.6, water flows on Canoe River show peak flows during July (43.7 m^3/s) and lowest flows during February (1.65 m^3/s). These results are consistent with other mountain-fed watercourses in which flows correlate with delayed snowmelt in the mountains.

TABLE 4.6 STREAMFLOWS FROM HYDROLOGICAL STATIONS NEAR WATERCOURSE CROSSINGS IN THE COLUMBIA RIVER BASIN

Station Name, Station Number	Approximate Location of Station Relative to the Project	Month and Mean Monthly Discharge (m^3/s) during the Lowest Flow Period	Month and Mean Monthly Discharge (m^3/s) during the Highest Flow Period
Canoe River below Kimmel Creek 08NC004	9.4 km upstream	February 1.7 m^3/s	July 43.7 m^3/s

Notes: Streamflow data from the Water Survey of Canada (Environment Canada 2013)

Important sportfish species found in Canoe River include bull trout, rainbow trout, mountain whitefish and pygmy whitefish. Non-sportfish species include longnose sucker and slimy sculpin. Kokanee also migrate through the lower reaches of the Canoe River to access Camp Creek, which is an important spawning and rearing tributary for sportfish including kokanee, bull trout and rainbow trout. Non-sportfish species in Canoe River and Camp Creek include slimy sculpin, prickly sculpin and lake chub.

4.4. Fraser River Basin

The Fraser River, which is the longest river in British Columbia (approximately 1,370 km), originates at the base of Cube Ridge in Mount Robson Provincial Park in the Rocky Mountains. It flows northwest to Prince George before heading south to the Lower Mainland, where it enters the Strait of Georgia near the City of Vancouver. The Fraser River has been proclaimed nationally as a Canadian Heritage River (Canadian Heritage Rivers System 2011).

As shown in Table 4.7, the watersheds traversed by the Project within the Fraser River Basin include the Upper Fraser River, Upper North Thompson River, Lower North Thompson River, Clearwater River, Thompson River, South Thompson River, Lower Nicola River, Fraser Canyon, Harrison River, Chilliwack River, Lower Fraser River and Squamish. Major watercourses crossed by the Project include the Fraser River, North Thompson River, Clearwater River, Thompson River, South Thompson River, Nicola River, Coldwater River, Coquihalla River, Lower Fraser River and Chilliwack River.

TABLE 4.7 SUMMARY OF WATERSHEDS AND MAJOR WATERCOURSE CROSSINGS IN THE FRASER RIVER BASIN

Watersheds	Major Watercourses Crossed by the Project
Upper Fraser River	• Fraser River
Upper North Thompson River	• North Thompson River
Lower North Thompson River	• North Thompson River
Clearwater River	• Clearwater River
Thompson River	• Thompson River
South Thompson River	• South Thompson River
Lower Nicola River	• Nicola River • Coldwater River
Fraser Canyon	• Coquihalla River • Lower Fraser River
Harrison River	• Lower Fraser River
Chilliwack River	• Chilliwack River • Lower Fraser River
Lower Fraser River	• Lower Fraser River
Squamish	• Lower Fraser River

The Project traverses the middle of the Fraser River Basin; the corridor runs parallel to the Upper Fraser River, the North Thompson River and the Lower Fraser River from Hope to Surrey. Land uses in the river basin include forestry, agriculture, livestock grazing, industry (*e.g.,* pulp and paper), transportation and utility corridors, municipalities and recreation (*e.g.,* fishing, hiking, skiing).

Water flows within the Fraser River Basin vary depending on the size and location of the watercourse. As shown in Table 4.8, peak flows generally occur in spring/early summer (*i.e.,* May and June). West of the Rocky Mountains, small watercourses (*e.g.,* West Creek near Fort Langley) experience peak flows in early winter as a result of the heavy autumn and winter rains that result from the rain shadow effect of the Rocky Mountains. At higher elevations, lowest flows occur in the winter prior to freeze-up (*e.g.,* January to March), whereas at lower elevations, lowest flows occur at the end of the dry season (*e.g.,* August and September).

TABLE 4.8 STREAMFLOWS FROM HYDROLOGICAL STATIONS NEAR WATERCOURSE CROSSINGS IN THE FRASER RIVER BASIN

Station Name, Station Number	Approximate Location of Station Relative to the Project	Month and Mean Monthly Discharge (m^3/s) during the Lowest Flow Period	Month and Mean Monthly Discharge (m^3/s) during the Highest Flow Period
Fraser River at Red Pass 08KA007	25.3 km upstream	March 5.3 m^3/s	June 153 m^3/s
North Thompson River at Birch Island 08LB047	59.4 km downstream	February 28.1 m^3/s	June 446 m^3/s
Clearwater River near Clearwater Station 08LA001	2.3 km upstream	February 45.1 m^3/s	June 717 m^3/s
Thompson River at Kamloops 08LF023	5.7 km upstream	February 137 m^3/s	June 2070 m^3/s
Nicola River at Outlet of Nicola Lake 08LG065	7.2 km upstream	January 1.5 m^3/s	June 16.6 m^3/s
Coldwater River near Brookmere 08LG048	4.9 km downstream	September 1.2 m^3/s	May 23.5 m^3/s
Coquihalla River below Needle Creek 08MF062	13 km upstream	September 0.83 m^3/s	May 9.9 m^3/s
Coquihalla River above Alexander Creek 08MF068	2.6 km upstream	September 9.1 m^3/s	May 68.5 m^3/s
Chilliwack River at Vedder Crossing 08MH001	4 km upstream	September 34.4 m^3/s	June 137 m^3/s
West Creek near Fort Langley 08MH098	Within proposed pipeline corridor	August 0.03 m^3/s	January 0.98 m^3/s
Fraser River at Port Mann Pumping Station 08MH126	0.5 km upstream	January 1,780 m^3/s	June 8,590 m^3/s

Notes: Streamflow data from the Water Survey of Canada (Environment Canada 2013)

Major rivers to be crossed by the Project in the Fraser River Basin include the Fraser, Thompson (North, South and mainstem), Clearwater, Nicola, Coldwater and Coquihalla rivers.

The Fraser River Watershed provides spawning and rearing habitat for six species of Pacific salmon (including steelhead trout) and is the largest salmon producing river in British Columbia. Chinook salmon are the only known Pacific salmon species to spawn and rear in the Upper Fraser River mainstem and tributaries (Fedorenko *et al.* 1983). Other important sportfish species in the Upper Fraser River Watershed include rainbow trout, bull trout, lake whitefish, pygmy whitefish, mountain whitefish, burbot and white sturgeon. Non-sportfish species include slimy sculpin, lake chub, longnose dace, longnose sucker, northern pikeminnow, peamouth chub and redside shiner.

The lower Fraser River and its estuary provide critical rearing, staging and migratory habitat for adult and juvenile salmon. This section of the Fraser River is also important as resident salmon undergo physiological changes to acclimatize from a saline to freshwater environment (adult salmon) and from a freshwater to saline existence (juvenile salmon) (Langer 2010). Lower Fraser tributaries also provide key spawning areas for Pacific salmon.

The Fraser River is one of three major rivers on the Pacific coast that supports spawning populations of white sturgeon (Hanson and Cochnauer 1992). Key spawning and rearing areas for white sturgeon have been identified upstream from the proposed Fraser River crossing located between the district of Mission and the town of Yale (Perrin *et al.* 2000). One important spawning site is the Fraser mainstem downstream (0.5 km) from the confluence with the Coquihalla River (COSEWIC 2003). The lower reaches of the Fraser River are used predominantly for feeding and migration which may also include lower portions of the Sumas and Chilliwack rivers. Green sturgeon observations are rare in freshwater and there are no known spawning sites in BC; however, there are some historical records in the lower Fraser River (the most recent was near Fort Langley in 2005) (McPhail 2007).

The North Thompson River flows east towards Highway 5 and south for approximately 325 km before joining up with the South Thompson River at Kamloops. The confluence between the North and South Thompson rivers marks the beginning of the mainstem Thompson River. The North Thompson River and tributaries provide important spawning and nursery habitat for coho and chinook salmon. Other species of management concern include pink salmon, bull trout, mountain whitefish, round whitefish and rainbow trout. Non-sportfish species include western brook lamprey, bridgelip sucker, largescale sucker, longnose sucker, prickly sculpin, slimy sculpin, torrent sculpin, lake chub, northern pikeminnow, peamouth chub, redside shiner, leopard dace and longnose dace. Mountain sucker is known to reside in the North Thompson River mainstem.

The South Thompson River flows from Little Shuswap Lake in east central BC, and travels 56 km in a southwest direction to its junction with the Thompson River at Kamloops. The South Thompson mainstem and tributaries provide important spawning and rearing habitat for sockeye, chinook, coho, steelhead and lake trout. Other sportfish species in the South Thompson River Watershed include rainbow trout and mountain whitefish. Non-sportfish include chub, sculpin, largescale sucker, dace, northern pikeminnow, redside shiner and sucker.

The mainstem Thompson River drains from Kamloops Lake near the Town of Savana and flows southwest for approximately 120 km before reaching its confluence with the Fraser River. The Thompson River is the largest tributary to the Fraser River and supports five species of Pacific salmon including chinook, coho, sockeye, pink and steelhead. Other important sportfish species include burbot, bull trout, kokanee, mountain whitefish and rainbow trout. White sturgeon have also been recorded in the Thompson River mainstem. Non-sportfish species include lamprey, redside shiner, peamouth chub, northern pikeminnow, longnose sucker, largescale sucker and prickly sculpin.

The Clearwater River is the largest tributary to the upper North Thompson River, flowing mainly south for 201 km from its headwaters to the confluence with the Upper North Thompson River. The Clearwater River is a major chinook spawning system and provides important spawning and rearing habitat for sockeye and coho. Resident sportfish species include rainbow trout, bull trout and mountain whitefish. Non-sportfish species include redside shiner, slimy sculpin and longnose dace.

The Nicola River is a major tributary to the Thompson River. It drains west from the Thompson Plateau and feeds both Douglas and Nicola lakes. From the outlet to Nicola Lake, the Nicola River meanders northwest for approximately 85 km to its confluence with the Thompson River near the Town of Spences Bridge. The Nicola River provides valuable spawning and rearing habitat for Pacific salmon including chinook, coho, sockeye, pink and steelhead. Other important sportfish species include burbot, bull trout, kokanee, mountain whitefish, lake whitefish, lake trout and rainbow trout. Non-sportfish species include western brook lamprey, river lamprey, Pacific lamprey, redside shiner, peamouth chub, northern pikeminnow, bridgelip sucker, longnose sucker, white sucker, chiselmouth, leopard dace, prickly sculpin and slimy sculpin. Chiselmouth is known to reside in the Nicola River mainstem.

The Coldwater River flows for approximately 95 km, mostly paralleling Highway 5, before draining into the Nicola River near the City of Merritt. Important sportfish species include coho, steelhead, bull trout, mountain whitefish and rainbow trout. Non-sportfish species include longnose dace, leopard dace, bridgelip sucker, longnose sucker, slimy sculpin, prickly sculpin, redside shiner and Pacific lamprey. The Coldwater River has been the focus of a number of salmon conservation initiatives in the past and was selected by the Pacific Salmon Endowment Fund Society as the first watershed to receive attention in the Thompson-Nicola region for recovery of coho and steelhead (LGL Ltd. Environmental Research Associates 2007).

The Coquihalla River flows through the Cascade Mountains, following Highway 5 and Old Coquihalla Road for approximately 56 km to its confluence with the Fraser River at the District of Hope. The Coquihalla River is a major tributary to the lower Fraser River and is known to support all six species of Pacific salmonids. Other important sportfish species include bull trout, mountain whitefish, cutthroat trout and rainbow trout; non-sportfish species include coastrange sculpin, largescale sucker and leopard dace.

5.0 QUALITATIVE ECOLOGICAL RISK ASSESSMENT FRAMEWORK

The primary focus of the ERA is the assessment of the potential negative effects on the health of ecological receptors from the dispersion of COPCs associated with a hypothetical spill of heavy crude oil to a freshwater environment during pipeline operations.

The ERA has been conducted according to accepted ecological risk assessment methods and guidance published by regulatory authorities, including the Canadian Council of Ministers of Environment (CCME 1996, 1997), Federal Contaminated Sites Action Plan (2012), and the United States Environmental Protection Agency (1998). It is important to note that the referenced guidance was developed to apply to sites where contamination with COPCs is present, and where the role of the ERA is to assess the significance of such contamination in the context of site remediation and environmental restoration. In the present context (*i.e.,* as part of the ESA process for a proposed pipeline) the hypothetical releases of COPCs to the aquatic environment are considered to be unlikely accident scenarios.

Risk is often defined as being the product of the probability of an event occurring, and the magnitude of the consequences of that event. In ecological and human health risk assessment, a Venn diagram (Figure 5.1) is commonly used to illustrate the concept that risk involves the simultaneous presence (or overlap) of a hazard (*e.g.,* spilled oil), a receptor (*e.g.,* a fish or a grizzly bear), and a pathway allowing the receptor to become exposed to the hazard (*e.g.,* oil deposition to sediment so that fish eggs are exposed to PAHs, or deposition of oil on a river bank so that a bear encounters and ingests some of the oil). A risk is deemed to be present when all three components occur simultaneously (*i.e.,* at the intersection of the three circles in Figure 5.1). No risk is present if any one of the receptor, the hazard, or the pathway is not present (or can be controlled). In the present context, the probability of the initial accident is artificially deemed to be 1.0 (*i.e.,* a pipeline failure leading to a release of diluted bitumen to the aquatic environment is assumed to have occurred). The ERA therefore assesses the consequences of the hypothetical accident given the assumption that the hazard (spilled heavy crude oil) is present in the environment.

FIGURE 5.1 ECOLOGICAL RISK ASSESSMENT FRAMEWORK

The ERA follows a standard protocol that is composed of the following steps:

- Problem Formulation
- Exposure Assessment
- Hazard Assessment
- Risk Characterization
- Discussion of Certainty and Confidence.

The terminology and methodology of this framework follows that which has been laid out by the CCME (1996). The methodological framework of the ERA and the chronology of the process steps are presented in Figure 5.1. The framework and methods for the ERA are described in the following sub-sections.

This is a screening-level ERA, and will be carried out using qualitative methods. Risk to ecological receptors will be evaluated taking into consideration their likely degree of exposure to diluted bitumen either as a whole product, or as chemical constituents (*e.g.,* PAHs) within the whole product. This measure of exposure will be integrated with the intrinsic sensitivity of the ecological receptors to crude oil or its chemical constituents. The ERA will consider a variety of lines of evidence regarding the environmental effects of and recovery from oil spills, including laboratory and field exposure studies, data from actual accidental oil spills, and results from other studies that have modelled or simulated the environmental effects of oil spills. Environmental effects of spilled oil will be described for each ecological receptor type in the context of the spatial extent, magnitude, direction and reversibility of the environmental effects.

5.1. Problem Formulation

The Problem Formulation is an information gathering and interpretation step that focuses the ERA on the primary areas of concern for the Project. The Problem Formulation defines the nature and scope of the work to be conducted, enables practical boundaries to be placed on the overall scope of work, and directs the ERA at the key areas and issues of concern.

The key tasks requiring evaluation within the Problem Formulation step include:

- Identification of COPCs and mechanisms of COPC release to the environment
- Identification and characterization of ecological receptors
- Identification of exposure media and pathways.

The outcome of these tasks forms the basis for the approach taken for the ERA.

5.2. Exposure Assessment

The Exposure Assessment evaluates data related to the COPCs, ecological receptors and exposure pathways identified during the Problem Formulation. Previous studies on oil spills in similar environments provide a basis for evaluating the fate and transport and effects of hypothetical pipeline spills resulting from the Project. As such, a literature review was conducted to identify and acquire information on real-life and modelled oil spills in similar environments. From the scientific literature in peer reviewed journals, government reports and technical documents, case studies were selected and the information used to evaluate the potential consequences of a hypothetical diluted bitumen spill resulting from the Project.

5.3. Hazard Assessment

The Hazard Assessment identifies the potential negative effects associated with acute (short-term) and chronic (long-term) exposure of ecological receptors to COPCs resulting from a hypothetical pipeline spill.

The ecological effects of a COPC 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 a COPC is dependent on:

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

5.4. Risk Characterization

The Risk Characterization integrates the information from the Exposure Assessment and Hazard Assessment with the biophysical characteristics of the freshwater environments traversed by the Project to provide a qualitative estimate of risk for each receptor group. 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.

In this ERA, which is being conducted in support of an ESA Report, specific terminology regarding environmental effects is adopted in order to meet those requirements. In an ESA, key considerations regarding environmental effects typically include:

- Impact Balance of the Residual Environmental Effect: is it positive, neutral, or negative
- Spatial Boundaries of the Environmental Effects: usually limited to a defined footprint, a local study area, a regional study area, or affecting larger areas such as a province, more than one province, or beyond the boundaries of Canada
- Temporal Context: considering how long will a disturbance last, how frequently will a disturbance occur, and whether the disturbance is reversible
- Effect Magnitude: considering whether the residual effects are negligible, low, medium or high in terms of existing baseline conditions and regulatory standards
- Probability of Occurrence: considering whether an environmental effect is likely to occur, or unlikely to occur
- Level of Confidence: an assessment of the degree of certainty related to the assessment of the environmental effect and its significance.

Accidents and malfunctions are evaluated using a slightly different approach than most other Project environmental effects, in the sense that environmental effects of construction of operation of the Project, and their duration, can usually be described with a moderate to high level of confidence. Accidents, on the other hand, may or may not occur, and serious accidents such as a pipeline rupture are expected to have a very low probability of occurring. All of the residual environmental effects of an accident leading to an 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 and malfunctions:

- Spatial Extent and Boundaries - pipeline oil spills do not fit within a conventional framework of Project Footprint, Local Study Area and Regional Study Area, as spilled oil could easily leave the defined right-of-way and be transported a considerable distance after reaching a watercourse. 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 full bore rupture oil spill scenarios 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 pipeline accident.

5.5. Discussion of 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.

6.0 QUALITATIVE ECOLOGICAL RISK ASSESSMENT

6.1. Problem Formulation

The objective of the Problem Formulation is to develop a focused understanding of how COPCs migrate from the source (*i.e.,* the location of a hypothetical pipeline spill), travel overland to reach a watercourse, and ultimately contact or are taken up by ecological receptors associated with the aquatic environment. The main points addressed in the Problem Formation are the following:

- Identification of chemicals of potential concern
- Identification of representative hypothetical spill scenarios
- Identification of ecological receptors (also referred to as indicators or valued ecosystem components)
- Identification of exposure pathways.

The results of these activities are then summarized in an ecological conceptual site model that provides a visual depiction of the relevant pathways linking the source of the COPCs in various environmental media and biota to the ecological receptors of interest.

6.1.1. Identification of Chemicals of Potential Concern

The proposed pipeline will transport crude oil from the Edmonton Terminal, located in Sherwood Park, Alberta, to storage facilities at the Burnaby Terminal in Burnaby, British Columbia, and from there to the Westridge Marine Terminal (also located in Burnaby, British Columbia). At the Westridge Marine Terminal, ships will be loaded with these hydrocarbon products. The proposed pipeline (Line 2) will consist of three new sections of 914 mm (NPS 36) outside diameter pipeline with a capacity of up to 540,000 barrels per day (bpd). The configuration of this line will include existing 762 mm (NPS 30) and 914.4 mm outside diameter pipeline loops from Edson, Alberta to Hargreaves, British Columbia, and from Darfield to Black Pines, British Columbia, as well as new 914 mm pipeline segments from Edmonton to Edson (335 km), Hargreaves to Darfield (275 km) and Black Pines to Burnaby (363 km). The final short section of new pipeline between the Burnaby and Westridge terminals (the Westridge delivery lines) will involve twin pipes of 762 mm (NPS 30) outside diameter. Further details of the existing and proposed expanded configuration of the Trans Mountain Pipeline can be found in the Trans Mountain NEB application. The primary type of hydrocarbon to be transported in the proposed pipeline is diluted bitumen, which is a form of heavy crude oil mixed with diluent to meet tariff specifications for viscosity, density and other physical properties. The qualitative ERA is therefore focused on the potential environmental effects of hypothetical releases of diluted bitumen to the environment.

Cold Lake Winter Blend (CLWB) was the formulation of diluted bitumen that was selected for evaluation in the ERA because it is currently transported by Trans Mountain and is expected to remain a major product transported by the new pipeline. In addition, the diluent in CLWB is condensate (a light hydrocarbon mixture derived from natural gas liquids), which is volatile and relatively water-soluble. Due to the higher level of risk associated with inhalation of volatiles and/or exposure to dissolved hydrocarbons, CLWB was considered to be a conservative choice for the ERA, as opposed to heavy crude oil mixed with alternative diluents such as synthetic oil, which contain fewer volatile and less water soluble constituents.

6.1.1.1. Physical Properties of Representative Cold Lake Winter Blend

A sample of the representative diluted bitumen to be evaluated in the ERA (*i.e.,* CLWB) was provided by Trans Mountain. The sample was subsequently subjected to detailed physical and chemical analyses in order to gain an understanding of the particular hydrocarbon fractions present, as well as the individual COPCs present for the Project.

Example physical properties of CLWB are listed in Table 6.1. Note that all transported hydrocarbons will meet Trans Mountain pipeline quality specifications as outlined in (KMC 2013).

TABLE 6.1 PHYSICAL PROPERTIES FOR COLD LAKE WINTER BLEND DILUTED BITUMEN

Physical Property	Units	Cold Lake Winter Blend Diluted Bitumen
Interfacial Tension	dyne/cm	42
Absolute Density @ 15°C	kg/m³	926
Measured Relative Density @ 15°C	N/A	0.9268
American Petroleum Institute (API) Gravity @ 15°C	N/A	21.2
Closed Cup Flash Point	°C	<-35
Pour Point	°C	-33
Viscosity @ 5°C – kinematic	cSt	542.1
Viscosity @ 10°C – kinematic	cSt	371.2
Viscosity @ 15°C – kinematic	cSt	261.6
Viscosity @ 30°C – kinematic	cSt	105.9
Viscosity @ 40°C – kinematic	cSt	64.09
Viscosity @ 60°C – kinematic	cSt	28.63
Gas Equivalency Factor	m³ gas / m³ liquid	86.6

Source: Analysis performed by Maxxam Analytics, with the exception of viscosity at 5, 10, and 15°C, which were calculated from the measured values at higher temperature following ASTM D-341 by C. Brown (pers. comm. 2013).

6.1.1.2. Chemical Properties of Representative Cold Lake Winter Blend

The majority of the chemical analysis carried out on the sample of CLWB was done by Maxxam Analytics, with confirmatory analysis for selected test groups carried out by Research and Productivity Council (Fredericton, New Brunswick). The following analytical packages were included:

- Trace elements
- Petroleum hydrocarbons
- Polycyclic aromatic hydrocarbons (PAH)
- Alkylated PAH
- Pentachlorophenol and phenol
- Volatile organic compounds (VOC)
- Alkylated mono aromatic hydrocarbons (MAH).

Table 6.2 provides a full list of trace elements and organic compounds analyzed in the CLWB. Copies of the original laboratory certificates are provided in Appendix A of this report.

TABLE 6.2 CHEMICAL CONSTITUENTS OF COLD LAKE WINTER BLEND DILUTED BITUMEN

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Metals			
Aluminum	<1	Mercury	0.021
Barium	<1	Molybdenum	5
Beryllium	<1	Nickel	46.8
Boron	1	Phosphorus	0.8
Cadmium	<1	Potassium	1
Calcium	2	Silicon	2
Chromium	<1	Silver	<1
Cobalt	<1	Sodium	12
Copper	<1	Strontium	<1
Iron	3	Sulphur	37,100
Lead	<1	Tin	<1
Lithium	<1	Titanium	1
Magnesium	<1	Vanadium	135
Manganese	<1	Zinc	<1
Sulfur Compounds			
Hydrogen Sulphide (H_2S)	<0.5	n-Propanethiol	<0.5
Carbonyl Sulphide	<0.5	Thiophene/sec-Butanethiol	2.9
Methanethiol	<0.5	Diethyl Sulphide	<0.5
Ethanethiol	1.1	Iso-Butanethiol	<0.5
Dimethyl Sulphide	1.7	n-Butanethiol	0.5
Carbon Disulphide	<0.5	Dimethyl Disulphide	<0.5

TABLE 6.2 CHEMICAL CONSTITUENTS OF COLD LAKE WINTER BLEND DILUTED BITUMEN

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Iso-Propanethiol	2.5	n-Pentanethiol	<0.5
t-Butanethiol	<0.5	n-Hexanethiol	0.5
Methyl Ethyl Sulphide	0.9	n-Heptanethiol	<0.5
SAPA (Saturates, Aromatics, Polars, Asphaltenes)			
Saturates	318,000	Polars	398,000
Aromatics	203,000	Asphaltenes	80,000
Summary Composition			
Methane	<100	n-Butane	5,100
Ethane	<100	Iso-Pentane	31,600
Propane	400	n-Pentane	34,200
Iso-Butane	1,000		
BTEX (Benzene, Toluene, Ethylbenzene, Xylenes)			
Benzene	1,800	Ethylbenzene	470
Toluene	3,900	Xylenes	3,500
PHCs (Petroleum Hydrocarbons)			
F1 (C_6-C_{10}) - BTEX	110,000	Aliphatics >C_{21}-C_{34}	60,000
F2 (C_{10}-C_{16})	82,000	Aliphatics >C_{34}-C_{50}	23,000
F3 (C_{16}-C_{34})	260,000	Aromatics >C_8-C_{10}	<6,000
F4 (C_{34}-C_{50})	110,000	Aromatics >C_{10}-C_{12}	4,100
Aliphatics C_6-C_8	55,000	Aromatics >C_{12}-C_{16}	22,000
Aliphatics >C_8-C_{10}	20,000	Aromatics >C_{16}-C_{21}	47,000
Aliphatics >C_{10}-C_{12}	16,000	Aromatics >C_{21}-C_{34}	120,000
Aliphatics >C_{12}-C_{16}	40,000	Aromatics >C_{34}-C_{50}	77,000
Aliphatics >C_{16}-C_{21}	46,000		
SVOCs – PAHs (Semi Volatile Organic Compounds – PAHs)			
Acenaphthene	12	Fluoranthene	7.3
C1-Acenaphthene	<4.5	C1-fluoranthene/pyrene	75
Acenaphthylene	<4.5	C2-fluoranthene/pyrene	200
Acridine	39	C3-fluoranthene/pyrene	340
Anthracene	6.6	C4-fluoranthene/pyrene	170
Benzo(a)anthracene	5.6	Fluorene	21
C1-benzo(a)anthracene/chrysene	59	C1-Fluorene	150
C2-benzo(a)anthracene/chrysene	230	C2-Fluorene	300
C3-benzo(a)anthracene/chrysene	110	C3-Fluorene	770
C4-benzo(a)anthracene/chrysene	37	Indeno(1,2,3-cd)pyrene	<4.5
Benzo(b&j)fluoranthene	6.7	2-Methylnaphthalene	80
Benzo(k)fluoranthene	<4.5	Naphthalene	34
C1-benzo(b,j,k)fluoranthene/benzo(a)pyrene	21	C1-Naphthalene	160
C2-benzo(b,j,k)fluoranthene/benzo(a)pyrene	37	C2-Naphthalene	600
Benzo(g,h,i)perylene	4.8	C3-Naphthalene	780
Benzo(c)phenanthrene	<4.5	C4-Naphthalene	810
Benzo(a)pyrene	5.8	Phenanthrene	63
Benzo(e)pyrene	5.1	C1-phenanthrene/anthracene	310
Biphenyl	7.3	C2-phenanthrene/anthracene	550
C1-biphenyl	50	C3-phenanthrene/anthracene	660
C2-biphenyl	84	C4-phenanthrene/anthracene	230
Chrysene	8.6	Perylene	9
Dibenz(a,h)anthracene	<4.5	Pyrene	<13
Dibenzothiophene	44	Quinoline	<8.9
C1-dibenzothiophene	330	Retene	43
C2-dibenzothiophene	910		
C3-dibenzothiophene	700		
C4-dibenzothiophene	440		
SVOCs – Phenols (Semi Volatile Organic Compounds – Phenols)			
Cresols	<16	2,4-dinitrophenol	<43
Phenol	<8.1	2,6-dichlorophenol	<8.5
3 & 4-chlorophenol	<21	2-chlorophenol	<4.3
2,3,5,6-tetrachlorophenol	<4.3	2-methylphenol	<8.7
2,3,4,6-tetrachlorophenol	<4.3	2-nitrophenol	<43
2,4,5-trichlorophenol	<4.3	3 & 4-methylphenol	16

TABLE 6.2 CHEMICAL CONSTITUENTS OF COLD LAKE WINTER BLEND DILUTED BITUMEN

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
2,4,6-trichlorophenol	<4.3	4,6-dinitro-2-methylphenol	<43
2,3,5-trichlorophenol	<4.3	4-chloro-3-methylphenol	<4.3
2,3,4-trichlorophenol	<4.3	4-nitrophenol	<43
2,4-dichlorophenol	<6.3	Pentachlorophenol	<4.3
2,4-dimethylphenol	29		
VOCs (Volatile Organic Compounds)			
Bromodichloromethane	<150	Methyl methacrylate	<200
Bromoform	<250	Methyl-tert-butylether (MTBE)	<150
Bromomethane	<100	Styrene	<100
Carbon tetrachloride	<100	1,1,1,2-tetrachloroethane	<500
Chlorobenzene	<100	1,1,2,2-tetrachloroethane	<250
Chlorodibromomethane	<100	Tetrachloroethene	<100
Chloroethane	<100	1,2,3-trichlorobenzene	<200
Chloroform	<100	1,2,4-trichlorobenzene	<200
Chloromethane	<150	1,3,5-trichlorobenzene	<200
1,2-dibromoethane	<100	1,1,1-trichloroethane	<100
1,2-dichlorobenzene	<100	1,1,2-trichloroethane	<100
1,3-dichlorobenzene	<100	Trichloroethene	<50
1,4-dichlorobenzene	<100	Trichlorofluoromethane	<100
1,1-dichloroethane	<100	1,2,4-trimethylbenzene	300
1,2-dichloroethane	<100	1,3,5-trimethylbenzene	<2,500
1,1-dichloroethene	<100	Vinyl chloride	<50
cis-1,2-dichloroethene	<100	neo-Hexane	<100
trans-1,2-dichloroethene	<100	Methylcyclopentane	8,000
Dichloromethane	<150	Cyclohexane	10,000
1,2-dichloropropane	<100	Methylcyclohexane	10,500
cis-1,3-dichloropropene	<100		
trans-1,3-dichloropropene	<100		

Source: Analysis performed by Maxxam Analytics.

Non-petroleum compounds in crude oils, such as metals, are seldom of environmental concern as primary pollutants. For example, after the discharge of an estimated 160 to 340 million gallons of crude oil during the 1991 Gulf War, trace metal concentrations in oiled intertidal and sub-tidal sediments remained below background levels (Fowler *et al.* 1993 in Hugenin *et al.* 1996). Similarly, the USEPA (2011a) concluded in response to a crude oil spill into the Yellowstone River in Montana that metal concentrations in the spilled oil were present only at very low levels, and as such were unlikely to pose any threat to human life or the environment. Likewise, Anderson (2006) concluded that there was no post-spill evidence of an increase in water or sediment metal concentrations at Wabamun Lake, Alberta, following a spill of bunker “C” fuel oil and pole treating oil in 2005.

As indicated in Table 6.2, the measured concentrations of trace metals in CLWB are generally very low (<1 mg/kg), with the exception of nickel (46.8 mg/kg) and vanadium (135 mg/kg). However, it is believed that these trace metals are likely to remain largely associated with the diluted bitumen following a spill. Therefore, the ERA focuses on the environmental effects of hydrocarbons (*i.e.,* crude oil and its hydrocarbon constituents) released into the freshwater environment.

6.1.2. Identification of Representative Hypothetical Spill Scenarios

Four locations were selected as representative locations for hypothetical spill scenarios. The selection was guided by consideration of the following engineering and environmental/socio-economic risk factors:

Environmental and socio-economic considerations (where available):

- Spill locations should be reflective of areas of expressed concern for spills by Aboriginal peoples or the general public.

- Spill locations should support evaluation of potential effects to traditional use, other human use or infrastructure (*e.g.,* potable water intakes or treatment facilities).
- Spill locations should support evaluation of potential effects to environmentally sensitive resources (*e.g.,* spawning grounds for salmon).
- Spill locations should be located so that large spill volumes could potentially enter a watercourse.
- Spill locations should reflect a range of watercourse types.

Engineering considerations:

- Spill locations should be based on the results of Quantitative Risk Assessment (QRA) so that locations can be linked to accurate failure probability estimates.
- Spill volumes should be based on the predicted type of failure forecast from the QRA and Trans Mountain's existing risk algorithms, and should also be realistic in terms of site-specific drain-down volumes.

Based on discussions with Trans Mountain, potential hypothetical spill locations were narrowed to three general areas, including an inland river system in Alberta (*i.e.,* the Athabasca River), an inland river system in British Columbia (*i.e.,* the North Thompson River), and a coastal river system in British Columbia (*i.e.,* the lower Fraser River). The ERA was therefore focused on the environmental effects that could result from hypothetical spill scenarios at locations on these rivers. Trans Mountain commissioned an independent outflow analysis based on preliminary valve spacing to quantify the oil volume that would be released in the event of an incident. Modeling assumed a full-bore rupture with hole on the bottom of the pipe, which provided worst-case outflows for the purpose of the ERA. Predicted outflow volumes for the four locations were used. Subsequent Quantitative Risk Assessment full-bore volume rupture estimates show slightly different predicted release volumes. The ERA has not been modified to reflect this refinement as the ecological consequences described below are still valid. Based on the Reference Kilometre (RK) posts for the proposed pipeline, the selected representative hypothetical spill scenarios include:

- RK 309.0, which is located upstream of Hinton, Alberta, with potential for oil to flow into the Athabasca River. A worst-case oil spill volume of approximately 2,700 m^3 was estimated at this location based upon a full-bore rupture scenario.
- RK 766.0, which is located upstream of Darfield, British Columbia, with potential for oil to flow into the North Thompson River. A worst-case oil spill volume of approximately 1,400 m^3 was estimated at this location based upon a full-bore rupture scenario.
- RK 1072.8, which is located downstream of Hope, British Columbia, with potential for oil to flow into the Fraser River. A worst-case oil spill volume of approximately 1,300 m^3 was estimated at this location based upon a full-bore rupture scenario.
- RK 1167.5, which is located downstream of the Port Mann Bridge in Surrey, British Columbia, with potential for oil to flow into the lower Fraser River and thence to the Fraser River Estuary. A worst-case oil spill volume of approximately 1,250 m^3 was estimated at this location based upon a full-bore rupture scenario.

At each location, the potential environmental effects of a full-bore pipeline rupture were evaluated. A full-bore rupture means that the pipeline is to all intents and purposes severed or burst, so that the opening is equivalent to the cross-sectional area of the pipe(regardless of the mechanism leading to the rupture), and that crude oil spills freely from an opening that is equivalent to the diameter of the pipeline. The change in flow characteristics due to the rupture would be detected at the control centre and the pipeline would be shut down. It was assumed that the location of the full-bore rupture was at a low point between two control valves, and that oil continues to drain by gravity from the pipeline, between the location of the rupture and the nearest valves. A full-bore rupture as described here was therefore considered to be a credible worst-case scenario.

Lesser damage to the pipeline, such as a 2 inch (5.08 cm) diameter hole punched into the pipeline could still result in a substantial spill of crude oil (estimated to be up to 65% of the volume of a full-bore rupture) due to the additional time it would take for detection of the leak, and the potential for drainage of oil from the pipeline before the hole could be repaired. This type of damage could occur if a third party were to accidentally strike the line while excavating without proper authorization. Smaller leaks could be difficult to detect at the control centre, and would more likely be detected in the field during inspections. The release volume for such spills is difficult to predict; however, even very small spills, if they reached the surface water would be readily detected due to the presence of a visible sheen that could be traced back to the source.

For each hypothetical spill scenario, it was conservatively assumed that spilled oil would flow overland to the nearest watercourse, and that very little holdup of oil on land would occur, so that most of the estimated volume of spilled crude oil would enter the aquatic environment close to the point of release. Making the assumption that the damage to the pipeline occurred near a topographic low point maximizes the hypothetical spill volume (due to drain-down of the pipeline following the initial volume that was released under pressure before the pipeline was shut down), but also implies that the hypothetical spill occurred in proximity to a watercourse.

Therefore, while there would be environmental effects on land (*i.e.,* effects on plants, soil invertebrates, soil quality, and terrestrial wildlife receptors that contacted the spilled oil), these effects would be small in the context of the terrestrial ecozone within which the spill occurred, and would be addressed, remediated and/or compensated through existing legislative frameworks as described in Section 2.0 of this report. This assumption is justified because the large spill volumes assumed here would occur only if the pipeline damage occurred near a topographic low point. Near topographic high points, that portion of the total spill volume that results from the drain-down of the line would be considerably reduced.

The characteristics of the aquatic environment close to and downstream from the representative hypothetical spill locations are described in the following sections.

6.1.2.1. Tributary to the Athabasca River near Hinton, Alberta at RK 309.0

The hypothetical spill location at RK 309.0 is located approximately 9 km northeast of Hinton, Alberta and approximately 2 km south of the Athabasca River, at an elevation of approximately 975 masl.

The Athabasca River originates in Jasper National Park, in an unnamed lake at the toe of the Athabasca Glacier. At the hypothetical spill location near Hinton, spilled oil would follow local terrain to a gully that leads to the river valley floor, and from there to the Athabasca River. The next major settlement downstream from Hinton is Whitecourt, approximately 190 km downstream as the river flows.

The proposed crossing of Trail Creek, a small tributary to the Athabasca River at RK 309.0 (defined as AB-169 in Volume 5C occurs within Alberta's Fish Management Zone, Eastern Slopes (ES) Watershed Unit ES3 (Alberta Sustainable Resource Development [ASRD] 2009). Trail Creek is a first order watercourse that flows northwesterly from the proposed pipeline corridor. The creek is an unmapped watercourse (Alberta Environment 2006) but inherits a Class C designation and has a September 1 to July 15 restricted activity period (AESRD 2013, Alberta Environment 2006). Land use throughout the reach of the Athabasca River between Hinton and Whitecourt is predominantly rural, with most of the land having forest cover. Development, including oil and gas infrastructure, is widespread in this region, and the network of roads and other corridors provide good access to the river at regular intervals.

Trail Creek comprises discontinuous sections of marginally defined channel upstream, at, and immediately downstream from the proposed pipeline crossing (TERA Environmental Consultants 2013). Channel definition becomes continuous and more apparent after its confluence with another unnamed tributary approximately 150 m downstream from the proposed pipeline corridor's theoretical centre line. In the local study area (LSA; approximately 100 m upstream to at least 300 m downstream and 30 m back from each bank edge) of the proposed pipeline crossing, the channel and wetted widths of Trail Creek average <1.0 m and water depths rarely exceed 0.2 m. Substrate is composed of embedded fines and organics, and banks, where defined, are generally vertical but low (*i.e.,* <0.3 m). No previous information regarding fish species presence or absence exists for the watercourse and no fish were captured during the Project's aquatic assessment. Fish habitat potential for all life stages of all species was rated as either 'low' or 'none'. Discharge as measured in May 2013 was minimal (*i.e.,* <0.003 m^3/s), and it is expected that the channel may be frozen to bottom in winter. Gradient in the LSA ranged between 0.5% and 4%.

The crossing of Trail Creek occurs approximately 0.3 km from the main stem of the river. The potential presence of fish in the lower reaches of the tributary cannot be ruled out.

The Athabasca River near the hypothetical spill location is a seventh-order watercourse with high fish habitat value. Substrate composition near the confluence with the unnamed tributary is presumed to consist primarily of un-embedded coarse material (gravels and cobbles).

The Athabasca River in the vicinity of the hypothetical spill scenario supports several important fish species, including but not limited to bull trout, Arctic grayling, mountain whitefish and Athabasca rainbow trout. It is realistic to expect that suitable rearing, wintering, migration and spawning habitat for fish occurs in the Athabasca River near the confluence of the unnamed tributary.

The intervale in the area of the hypothetical spill location is downstream from Hinton, undeveloped, and forested. The elevation of the river at this location is approximately 955 masl. Near Hinton, the Athabasca River has a width of approximately 100 to 300 m and is gently meandering with gravel and cobble banks, and numerous gravel bars or islands that become exposed during periods of low flow. Many of the islands, which are typically 200 to 500 m in length and 100 to 200 m wide, are high enough to support forest cover similar to that found on the adjacent river banks. The islands and bars create side channels and may create backwaters where they are close to the river banks.

At a distance of 20 km downstream from Hinton, the river falls to an elevation of approximately 943 masl, with a generally steady gradient. By 40 km downstream, the river has an elevation of approximately 920 masl; by 60 km downstream, it has an elevation of approximately 885 masl, with the gradient increasing in the second half of this reach; by 80 km downstream, it has an elevation of approximately 856 masl; and by 100 km downstream, it has an elevation of approximately 811 masl. The river gradients range from approximately 0.1% to 0.3% throughout the last reach. Overall, the characteristics of the Athabasca River are relatively uniform throughout the Hinton to Whitecourt reach.

Only one major tributary, the Berland River, joins the Athabasca River within 100 km downstream of Hinton. The Berland River is not crossed by the proposed pipeline corridor but many small tributaries on the right bank of the Athabasca River are crossed by the Project.

The waters of the Athabasca River are turbid, reflecting their glacial origin; however, the concentrations of total suspended solids (TSS) in the river water do not appear to fall in a range that would trigger oil-mineral aggregation (OMA) formation.

The Water Survey of Canada maintains a hydrometric station on the Athabasca River at Hinton, Alberta (Station No. 07AD002) (Environment Canada 2011a). This station is located approximately 7 km upstream of the convergence with Trail Creek. Discharge at this station has been recorded for all years since 1961 and show that peak flows occur during freshet in June. During this period, the mean monthly flow is 489 m^3/s. Flows typically diminish during the later summer months, through fall and winter. Low flows typically occur in March, when the monthly average is 32.5 m^3/s. Data for this recording station, including maximum, minimum and mean monthly discharges, are summarized in Figure 6.1 and Table 6.3.

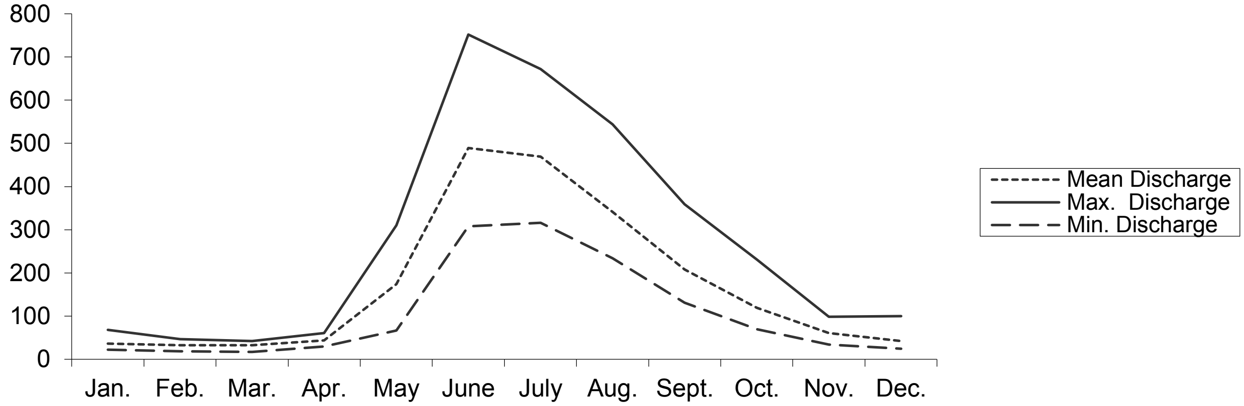


FIGURE 6.1 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE ATHABASCA RIVER AT HINTON, ALBERTA (STATION 07AD002)

TABLE 6.3 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE ATHABASCA RIVER AT HINTON, ALBERTA (STATION 07AD002)

Discharge	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Discharge	36.1	32.6	32.5	43.9	174	489	469	341	208	119	60.7	42.3
Max. Discharge	68.3	46.6	42.2	60.6	310	752	672	544	359	231	98.6	100
Min. Discharge	22.5	18.7	16.9	29.7	66.4	308	316	234	131	69.6	34.4	24.1
Years of Streamflow Record:	1961 to 2011											
Maximum Daily Discharge:	1,430 m³/s on June 7, 2007											
Minimum Daily Discharge:	10.8 m³/s on March 14, 1963											
Effective Drainage Area:	9,720 km2											

Source: Environment Canada 2011a

The Water Survey of Canada also maintains a hydrometric station on the Athabasca River near Windfall, Alberta (Station No. 07AE001) (Environment Canada 2011b). This station is located approximately 156 km downstream of the convergence with Trail Creek. Larger tributaries downstream of the confluence with Trail Creek that contribute to the greater volume at this station include Berland River, Oldman Creek, Pass Creek and Windfall Creek. Discharge at this station has been recorded for all years since 1960. The annual high flow event typically occurs from June to August and flows gradually decline through late summer and fall. Mean monthly flows are lowest in March at 49.6 m³/s and mean flows are highest during the late spring freshet with a peak in June at 628.0 m³/s. Data for this monitoring station are summarized in Figure 6.2 and Table 6.4.

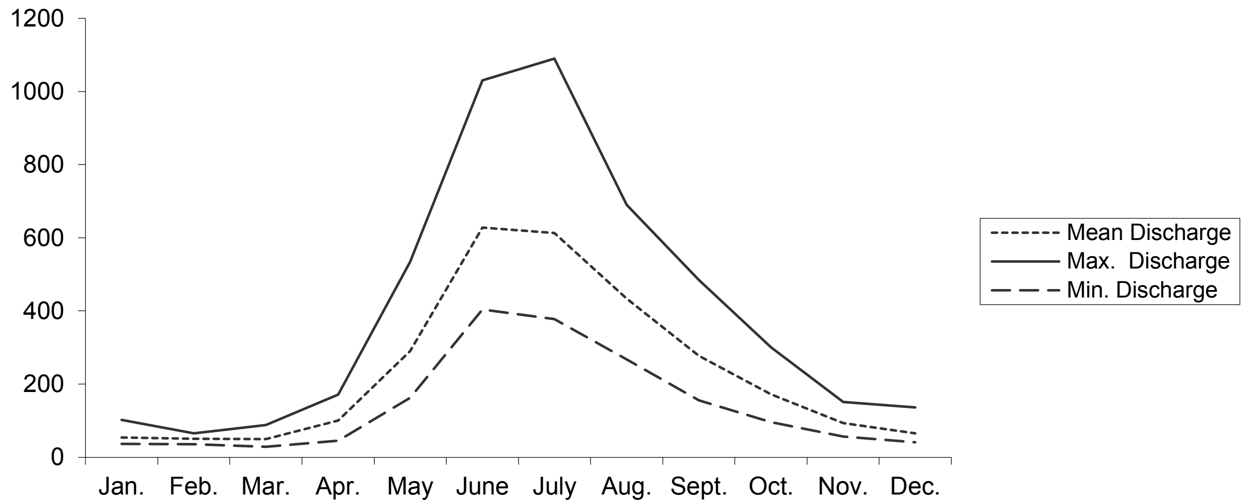


FIGURE 6.2 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE ATHABASCA RIVER NEAR WINDFALL, ALBERTA (STATION 07AE001)

TABLE 6.4 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE ATHABASCA RIVER NEAR WINDFALL, ALBERTA (STATION 07AE001)

Discharge	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Discharge	53.7	50.2	49.6	100	290	628	613	434	277	172	93.6	65.1
Max. Discharge	102	65.3	88.3	171	534	1030	1090	690	484	301	151	136
Min. Discharge	36.4	35.7	28.1	45.5	162	404	378	267	155	95.8	56.2	40.9
Years of Streamflow Record:		1960 to 2011										
Maximum Daily Discharge:		2,130 m^3/s on July 10, 1965										
Minimum Daily Discharge:		19.3 m^3/s on November 23, 1977										
Effective Drainage Area:		19,600 km^2										

Source: Environment Canada 2011b

6.1.2.2. North Thompson River near Darfield, British Columbia at RK 766.0

The hypothetical spill location at RK 766.0 is located approximately 3.5 km north of Darfield, British Columbia, and approximately 120 m west of the North Thompson River, at an elevation of approximately 409 masl.

The North Thompson River originates at the Thompson Glacier in the Cariboo Mountains west of Valemount, British Columbia and flows generally south towards Kamloops and its confluence with the South Thompson River. For most of its length, the North Thompson River is paralleled by Highway 5 and the Canadian National Railway (both of which cross the river at various locations), in addition to the existing Trans Mountain pipeline. The North Thompson River passes by small communities, the largest being Blue River, Clearwater and Barriere. The Clearwater River joins the North Thompson River as a tributary at the Town of Clearwater. The North Thompson and South Thompson rivers merge at Kamloops, British Columbia, forming the Thompson River. The Thompson River is the largest tributary of the Fraser River.

The hypothetical spill scenario near the North Thompson River represents a remote pipeline crossing at RK 766.0 within the Thompson-Nicola Region (Region 3) of British Columbia (Triton Environmental Consultants 2013). The North Thompson River has a British Columbia stream class of S1A (>100 m wide) and meanders sinuously in an occasionally confined channel. Near the hypothetical spill location riparian vegetation is moderately high with heavily cultivated areas.

The North Thompson River is a high-order watercourse with high fish and wildlife values. The main stem and its tributaries provide important spawning and rearing habitat for coho, chinook and sockeye salmon. Fish species of special concern in the North Thompson River include coho salmon (interior Fraser population) and provincially blue-listed bull trout and mountain sucker. Key mountain sucker distribution in the North Thompson River includes a section of river near Heffley, which is approximately 50 km downstream from the hypothetical spill location. Other fish species historically found in the area include pink salmon records from lower the North Thompson sub-basin only (Knapp *et al.* 1982), bull trout, mountain whitefish, round whitefish, rainbow trout, western brook lamprey, bridgelip sucker, largescale sucker, longnose sucker, prickly sculpin, slimy sculpin, torrent sculpin, lake chub, northern pikeminnow, peamouth chub, redside shiner, leopard dace and longnose dace.

The intervale in the area of the hypothetical spill location is under agricultural land use, with steep valley walls rising to over 900 m to the west, and over 1,500 m to the east. The hill slopes are predominantly forested and forestry is an important activity in the region. The elevation of the river at this location is approximately 381 masl. Near Darfield, the North Thompson River has a width of approximately 250 to 500 m and is gently meandering within the intervale of a well-defined valley, although constrictions at some locations force the river into a channel as narrow as 70 m. The river has gravel and cobble banks and occasional islands or gravel bars that become exposed during periods of low flow. The islands, which range in length from 200 m to 1 km, may support scattered shrubs, scrub, or forest cover similar to that found on the adjacent river banks. Many of the islands show evidence of being overwashed during periods of high flow. The islands and bars create side channels and may create backwaters where they are close to the river banks. Owing to the presence of Highway 5, there is good access to the river for most of this section of the proposed pipeline corridor.

At a distance of 20 km downstream from the hypothetical spill location, the river falls to an elevation of approximately 375 masl, with a generally steady gradient. By 40 km downstream, the river has an elevation of approximately 367 masl; by 60 km downstream, the river has an elevation of approximately 350 masl, with some steeper gradients occurring in the last 4 km of this reach; and by 80 km downstream, the river has an elevation of approximately 341 masl. Proceeding downstream, the river meets the South Thompson River and by 100 km downstream, the Thompson River has an elevation of approximately 335 masl and enters Kamloops Lake, which is a large water body approximately 30 km in length. The river gradients range from approximately 0.02% to 0.1% throughout this reach, although locally higher gradients are present. Overall, the characteristics of the North Thompson River are relatively uniform throughout the Darfield to Kamloops reach. Kamloops Lake provides a still-water section that would tend to trap any oil that was carried downstream, making it likely that any spill entering the lake would effectively terminate at this point.

Other than the junction with the South Thompson River, no major tributaries join the North Thompson River between Darfield and Kamloops. The waters of the North Thompson River are turbid, reflecting their glacial origin; however, the concentrations of TSS in the river water do not appear to fall in a range that would trigger OMA formation.

The Water Survey of Canada maintains a hydrometric station on the North Thompson River at McLure, BC (Station No. 08LB064) (Environment Canada 2011c). This station is located approximately 16 km downstream of the hypothetical spill location. Discharge at this station has been recorded for all years since 1958. The annual high flow event typically occurs from May to July and flows gradually decline through summer and fall. Mean monthly flows are lowest in February at 85.9 m^3/s and highest during the spring freshet with a peak in June at 1,330 m^3/s. Data for this monitoring station are summarized in Figure 6.3 and Table 6.5. Tributaries between the hypothetical spill site and the hydrometric station, such as Barrier River and Louis Creek, contribute to an incremental increase in volume at the station compared to flows at the hypothetical spill location.

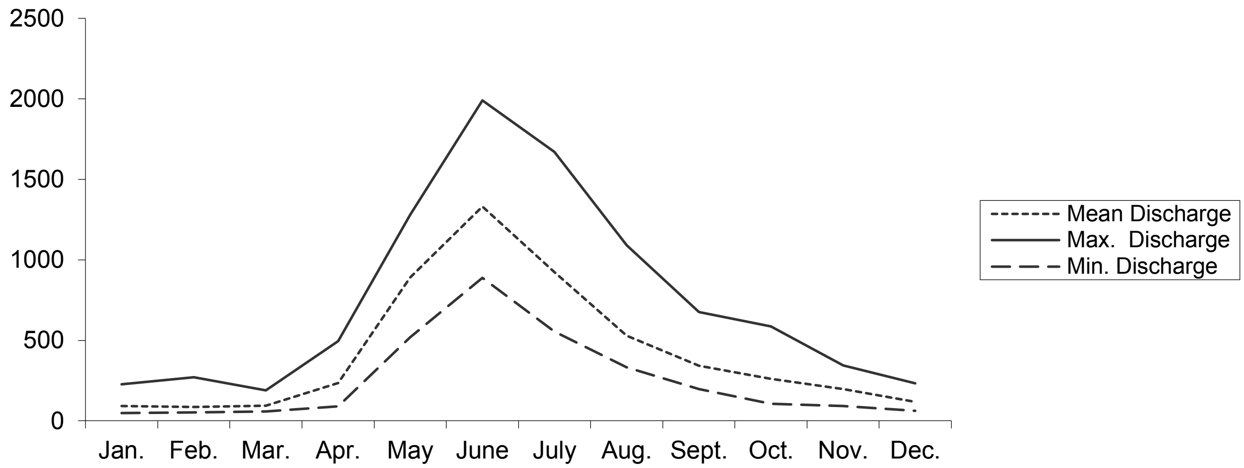


FIGURE 6.3 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE NORTH THOMPSON RIVER AT McLURE, BC (STATION 08LB064)

TABLE 6.5 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE NORTH THOMPSON RIVER AT McLURE, BC (STATION 08LB064)

Discharge	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Discharge	92.1	85.9	95.1	236	890	1,330	923	528	343	261	198	118
Max. Discharge	228	271	190	495	1,280	1,990	1,670	1,090	676	587	344	233
Min. Discharge	49.4	52.3	58	90.6	519	889	554	333	198	106	93	62.3
Years of Streamflow Record:		1958 to 2011										
Maximum Daily Discharge:		2,740 m³/s on June 13, 1972										
Minimum Daily Discharge:		36 m³/s on February 4, 1988										
Gross Drainage Area:		19,600 km2										

Source: Environment Canada 2011c

Water quality was monitored at the North Thompson River at North Kamloops by the British Columbia Ministry of Environment, Lands and Parks (BC MELP 1997) from 1987 to 1995 at site number 0600164. No environmentally relevant trends were observed over the testing period. Partial treatment and disinfection of drinking water was found to be needed due to frequent high fecal coliform, *Escherichia coli* (*E. coli*) and turbidity levels. Occasionally, naturally high levels of aluminum, copper, iron and zinc exceeding guidelines for aquatic life or drinking water were observed in winter and fall. During spring freshet, higher levels of aluminum, chromium, copper, iron, manganese and titanium were observed in conjunction with high levels of turbidity, suggesting that the metals were in particulate form, not biologically available. The study also found that guidelines were consistently met for most of the sampled variables, including nitrate/nitrite, pH, specific conductivity and dissolved sulphate, and that the water was well buffered against acid inputs (BC MELP 1997).

There were no substantial industrial discharges into the river at the time of the study. However, activities associated with agriculture, urbanization and forestry were notable stresses on water quality, particularly downstream from McLure, due to higher population and agricultural land uses (BC MELP 1997).

6.1.2.3. Fraser River near Hope, British Columbia at RK 1072.8

The proposed pipeline corridor approaches the Fraser River at Hope, British Columbia, and runs generally parallel to the river on the left bank until it reaches Surrey, close to its terminus at Burnaby. The Fraser River is the longest river in British Columbia, originating near Mount Robson in the Rocky Mountains, and discharging into the Strait of Georgia near Vancouver. The Fraser River is a major watershed for the Rocky Mountains and flooding is a regular concern in the lower Fraser River valley because the spring freshet, a mixture of heavy rains and spring thaw, is unpredictable.

The hypothetical spill location at RK 1072.8 is approximately 5 km southeast of Agassiz, British Columbia, and on the opposite side of the Fraser River. The location is at an elevation of approximately 44 masl, near the toe of the hill slope at the edge of the floodplain of the Fraser River. The intervale in the area of the hypothetical spill location is quite narrow, but broadens out downstream in an area known as the Fraser Valley to include much of the arable and residential lands associated with the lower mainland of British Columbia (*i.e.,* the areas around Abbotsford, Langley and Chilliwack). The elevation of the Fraser River near the hypothetical spill location is approximately 19 masl.

The Fraser River is a high-order watercourse with high fish and wildlife values. It has a British Columbia stream class of S1A (>100 m wide) and flows sinuously in an unconfined channel. Fish species of special concern previously recorded as present within the Fraser River include *Species at Risk Act* (*SARA*)-listed green and white sturgeon. White sturgeon is generally abundant and populations are stable, while green sturgeon observations are extremely rare in freshwater. Species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as being of conservation concern include sockeye (Cultus Lake population) and coho salmon (interior Fraser population), while Provincially-listed species include blue-listed bull trout and eulachon. *SARA* listed species of salish sucker and nootsack dace have been identified as present in key tributaries to the Fraser River, including Salmon River and Stoney, Semmihault, and Chilliwack creeks. Westslope cutthroat trout (*SARA*-listed and blue-listed as a species of Special Concern in BC) are also present in lower Fraser drainages, but have limited concern because they are introduced. Other species include coastal cutthroat trout, rainbow trout, mountain whitefish, pygmy whitefish, kokanee, burbot, black crappie, brown bullhead, brassy minnow, coastrange sculpin, slimy sculpin, pacific staghorn sculpin, carp, largescale sucker, emerald shiner, leopard dace, lake chub, longnose sucker, longnose dace, longfin smelt, northern pikeminnow, peamouth chub, Pacific lamprey, river lamprey, western brook lamprey, redside shiner, starry flounder, American shad, surf smelt and white sucker.

The area downstream from Hope includes abundant side channels. Large cultivated regions are also located adjacent to the river and moderate amounts of riparian vegetation are still in place. The section of habitat downstream from Hope is equally important for salmon and steelhead migration. Key mountain sucker (blue-listed) distribution includes the gravel deposition region of the lower Fraser River (near the District of Hope downstream to roughly the mouth of the Sumas River). This section of the Fraser River is critical for white sturgeon as key spawning and rearing areas have been identified between the district of Mission and the town of Yale (Perrin *et al.* 2000). Another important spawning site for white sturgeon is the Fraser River mainstem, which is located downstream (0.5 km) from the confluence with the Coquihalla River (COSEWIC 2003). White Sturgeon predominantly use the lower reaches of the Fraser River, as well as lower portions of the Sumas and Chilliwack rivers, for feeding and migration purposes.

At the hypothetical spill location of RK 1072.8, spilled oil would most likely follow local terrain to the ditch associated with Highway 1 (a distance of approximately 150 m) and then follow the ditch to a nearby creek that drains into the Fraser River floodplain. The floodplain at this location is characterized by a complex of old oxbows and former stream channels. Higher areas have forest cover, and forest harvesting is evident; lower areas would include seasonally fluctuating wetlands. The stream flow in this area appears to follow the left bank of the river for some distance (approximately 6 km) before entering the main stream near the settlement of Popkum, and it is likely that spilled oil would also exhibit this behavior. The next major settlements downstream from Popkum are the communities of Fairfield and Chilliwack, although these communities are set back from the Fraser River by approximately 1 km or more. Notwithstanding this setback distance, Chilliwack has been subject to serious flooding on more than one occasion over the past 150 years.

Near Agassiz, the Fraser River has a width that varies between approximately 300 m (where there is a single main channel) and 1.7 km (where there is braiding of the channel with islands). The river is gently meandering with many islands and gravel bars that become exposed during periods of low flow near Agassiz, although the channel becomes more defined and islands become fewer moving downstream.

Many of the islands, which are typically 200 to 500 m in length and 100 to 200 m wide, are high enough to support forest cover similar to that found on the adjacent river banks. The islands and bars create side channels and may create backwaters where they are close to the river banks. Near Mission, BC (approximately 50 km downstream from the hypothetical spill location), the river undergoes a transition from a wandering gravel-bedded river to a single-thread, sand-bedded channel. This transition also marks the upstream extent of tidal influence, although salt water intrusion does not extend past the head of the Delta at New Westminster.

At a distance of 20 km downstream from the hypothetical spill location, the river falls to an elevation of approximately 10 masl, with a generally steady gradient of approximately 0.05%. By 40 km downstream, the river has an elevation of approximately 6.5 masl, and the gradient over this reach is approximately 0.02%. By 60 km downstream, the river has an elevation of approximately 5 masl, and from this point on, the river approaches sea level with a gradient of 0.01% or less, and becomes tidal in its lower reaches.

The Fraser River is known to carry a high sediment load (Attard 2012), consisting mainly of fine quaternary glacial deposits eroded directly from river banks and terraces. Total suspended sediment concentrations were measured at Mission, BC by Attard (2012) where the river channel is almost 500 m wide and 7 to 8 m deep with a sand bottom. Most observed TSS concentrations were less than 100 mg/L, although the total range of values was from <10 mg/L to about 350 mg/L, the higher values being found close to the riverbed. Concentrations of TSS in the upper 5 m of the water column were low (around 20 mg/L) in April 2010, but increased with the freshet to values in the range of 100 mg/L near the surface of the river in May and June 2010 (Attard 2012). The TSS is dominated by fine sediment (fine silt and clay) during low flows, with increasing transport of coarser sediment (sand) during high flows. The coarser sediment; however, shows increasing concentrations towards the riverbed, whereas the finer silt and clay particles are relatively uniformly distributed throughout the water column (Attard 2012).

The Coquihalla River enters the Fraser River a short distance downstream from the hypothetical spill location. From the confluence with the Coquihalla River, the Fraser River flows west, draining into the Strait of Georgia approximately 145 km downstream. The Sumas River and one of its larger tributaries, the Vedder River, enter the Fraser River approximately 61 km downstream from the confluence with Coquihalla River. These tributaries have lower turbidity than the main stem of the Fraser River.

The Water Survey of Canada maintains a hydrometric station on the Fraser River at Hope, BC (Station No. 08MF005) (Environment Canada 2011d). This station is approximately 1 km downstream of the confluence with the Coquihalla River. Discharge at this station has been recorded for all years since 1912. The annual high flow event typically occurs from May to July and flows gradually decline through summer and fall. Mean monthly flows are lowest in March at 871 m^3/s and highest during the spring freshet with a peak in June at 6,980 m^3/s. Data for this watercourse are summarized in Figure 6.4 and Table 6.6.

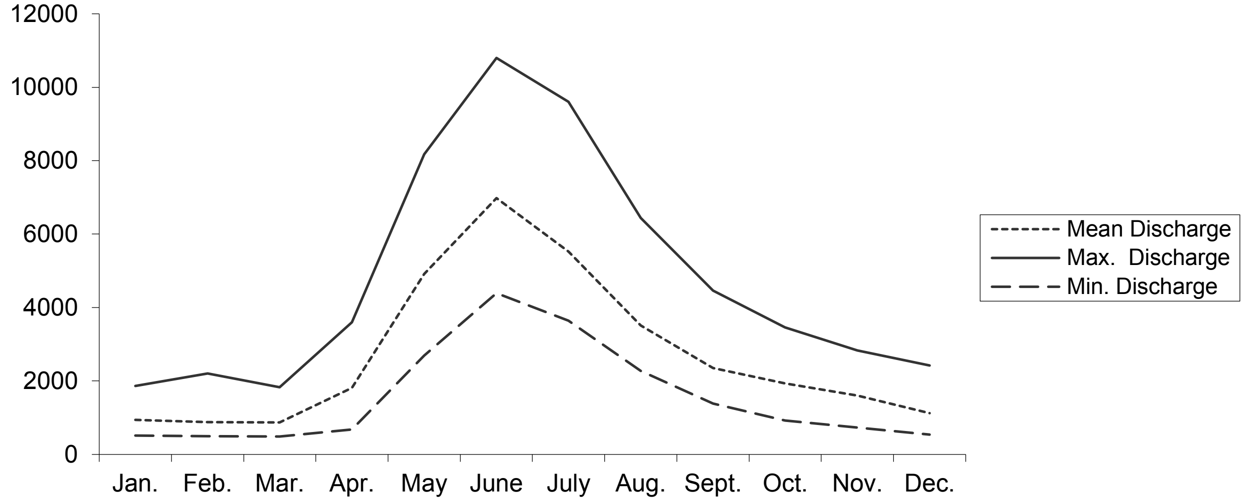


FIGURE 6.4 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE FRASER RIVER AT HOPE, BC (STATION 08MF005)

TABLE 6.6 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE FRASER RIVER AT HOPE, BC (STATION 08MF005)

Discharge	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Discharge	935	876	871	1,810	4,910	6,980	5,520	3,510	2,350	1,930	1,600	1,120
Max. Discharge	1,860	2,200	1,830	3,600	8,170	10,800	9,600	6,440	4,460	3,460	2,830	2,420
Min. Discharge	516	497	482	676	2,690	4,390	3,640	2,270	1,380	924	727	540
Years of Streamflow Record:	1912 to 2011											
Maximum Daily Discharge:	15,200 m^3/s on May 31, 1948											
Minimum Daily Discharge:	340 m^3/s on January 8, 1916											
Gross Drainage Area:	217,000 km^2											

Source: Environment Canada 2011d

The Water Survey of Canada also maintains a hydrometric station on the lower Fraser River at Mission, BC (Station No. 08MH024) (Environment Canada 2011e). Discharge at this station has been recorded for 32 years since 1965; however, continuous monitoring was only recorded from 1965 to 1992. The annual high flow event typically occurs from May to July, then flows abruptly decline during mid to late summer, gradually declining through fall and remaining low during winter. Mean monthly flows are lowest in February at 1,400 m^3/s and highest during the spring freshet with a peak in June at 8,110 m^3/s. Data for this monitoring station are presented in Figure 6.5 and Table 6.7.

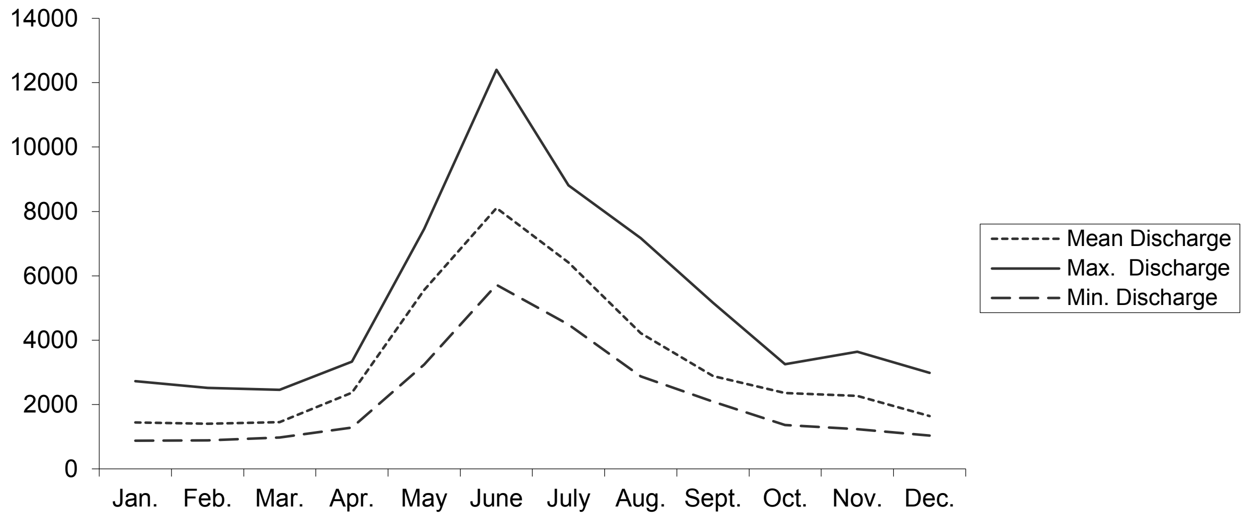


FIGURE 6.5 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE LOWER FRASER RIVER AT MISSION, BC (STATION 08MH024)

TABLE 6.7 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE LOWER FRASER RIVER AT MISSION, BC (STATION 08MH024)

Discharge	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Discharge	1,440	1,400	1,450	2,370	5,560	8,110	6,420	4,220	2,890	2,360	2,270	1,640
Max. Discharge	2,730	2,520	2,460	3,330	7,460	12,400	8,810	7,170	5,160	3,250	3,640	2,990
Min. Discharge	881	889	973	1,290	3,240	5,720	4,490	2,880	2,090	1,370	1,240	1,040
Years of Streamflow Record:	1965 to 1992											
Maximum Daily Discharge:	13,500 m^3/s on June 22, 1967											
Minimum Daily Discharge:	648 m^3/s on February 15, 1980											
Gross Drainage Area:	228,000 km2											

Source: Environment Canada 2011e

The main influences affecting water quality of the Fraser River at Hope are treated effluent from pulp mills at Prince George, Quesnel and Kamloops, treated municipal wastewater effluent from Prince George, Quesnel, Williams Lake and Kamloops, and non-point sources of pollution from agriculture, forestry and urban areas (Environment Canada 2004).

In the *Water Quality Assessment of Fraser River at Hope (1979-2004)*, it was determined that higher levels of certain parameters, including most metals, correlated with increased turbidity associated with increased flows. The study found that metal concentrations during periods of high turbidity that exceeded guidelines or site-specific water quality objectives were not biologically available and therefore of little concern (BC MOE 2007a).

In the latest *Environmental Trends in British Columbia: 2007* report, water quality for the Fraser River at Hope for the 2002-2004 reporting period was given a CCME Water Quality Index rating of “Good” (*i.e.,* water quality is protected with only a minor degree of threat or impairment; measurements rarely exceed water quality guidelines and, usually, by a narrow margin) (BC MOE 2007b). Water quality for the Fraser River at Hope is considered to be improving largely due to decreases in wastewater effluent at pulp mills (BC MOE 2007b).

6.1.2.4. Fraser River and Delta near the Port Mann Bridge at RK 1167.5

The hypothetical spill location at RK 1167.5 is located close to the mouth of the Fraser River, between the Port Mann Bridge and the point at which the proposed pipeline will pass below the Fraser River on its way to the Burnaby Terminal. Below the Port Mann Bridge, the pipeline will be close to the river bank and adjacent to rail yards. In this area, the most likely failure scenario would be third-party damage to the pipeline, resulting in a puncture and leading to a loss of oil that would migrate to the river. From the area of the hypothetical spill to the open water at the mouth of the estuary is a distance of approximately 30 km. The elevation of the river in this reach would be very close to sea level and the river would be under tidal influence. Salt water intrusion would extend almost to the vicinity of the Port Mann Bridge, and water could be fresh at the surface, but saline below the surface. Riparian vegetation has been cleared in many areas and log decks and barges are frequently present.

The lower Fraser River main stem and its estuary provide critical rearing, staging and migratory habitat for adult and juvenile salmon. In addition, salmon undergo great physiological changes in this section of the Fraser River to acclimatize from a saline to freshwater environment (adult salmon) and from a freshwater to saline existence (juvenile salmon) (Langer 2010). Lower Fraser River tributaries also provide key spawning areas for Pacific salmon.

One major group of Fraser River coho salmon occupies coastal and lower Fraser River tributaries (Simpson *et al.* 2001) while the other is an interior population aggregate that use tributaries above the District of Hope (Irvine *et al.* 2001). Spawning for pink and chum salmon tends to be concentrated in Fraser River tributaries below the District of Hope and chum salmon have been reported to spawn in at least 120 tributaries to the lower Fraser River (Labelle 2009). A major fall-run Chinook salmon population spawns in the Chilliwack and Harrison rivers (DFO 1999). Sockeye salmon are distributed throughout much of the lower Fraser River; key habitat includes the Chilliwack River watershed and microhabitats within freshwater and tidal areas of the lower Fraser River that are used for rearing and migration (Johannes *et al.* 2011). Steelhead are also common to lower Fraser River tributaries and some key spawning areas include the Coquihalla River, Chilliwack River, Salmon River and Silverhope Creek (Lill 2002).

At the hypothetical spill location, oil would most likely travel overland until reaching a drainage ditch near the railway lands, where it could potentially follow storm drainage systems, culverts and other preferential pathways to the Fraser River.

Approximately 7.5 km below the hypothetical spill location, the river starts to split into multiple channels as it enters the Delta. Depending upon seasonal flow regimes and the tide, these channels provide multiple pathways by which spilled oil could reach the sea.

High suspended sediment loads tend to undergo flocculation as they transition from freshwater to sea water. This results in a larger effective particle size and a tendency for the flocculated particles to settle more rapidly than the non-flocculated particles. This deposition of sand, silt and clay is the process that built the Delta, and an ongoing supply of such particles is an important factor in sustaining both the Delta, and the biological productivity of the delta ecosystem.

The Water Survey of Canada maintains a hydrometric station on the Fraser River at Port Mann Pumping Station, BC (Station No. 08MH126) (Environment Canada 2011f). This station is within approximately 1 km of the proposed crossing location of the Fraser River at RK 1167.5. Discharge at this station was recorded for 18 years between 1965 and 1992. The annual high flow event typically occurs from May to July, then flows abruptly decline during mid to late summer, gradually declining through fall and remaining low during winter. Mean monthly flows are lowest in January at 1,780 m^3/s and highest during the spring freshet with a peak in June at 8,590 m^3/s. Data for this monitoring station are presented in Figure 6.6 and Table 6.8. In the lower sections of the Fraser River, flows are subject to semi-diurnal tidal movements. Surface water levels in this lower reach are subject to meso-tidal ranges, with differences of around 2 m between high and low water recorded adjacent to the Port Mann Bridge. A tidal bore associated with the daily tides extends approximately 45 km further upstream from the Port Mann Bridge.

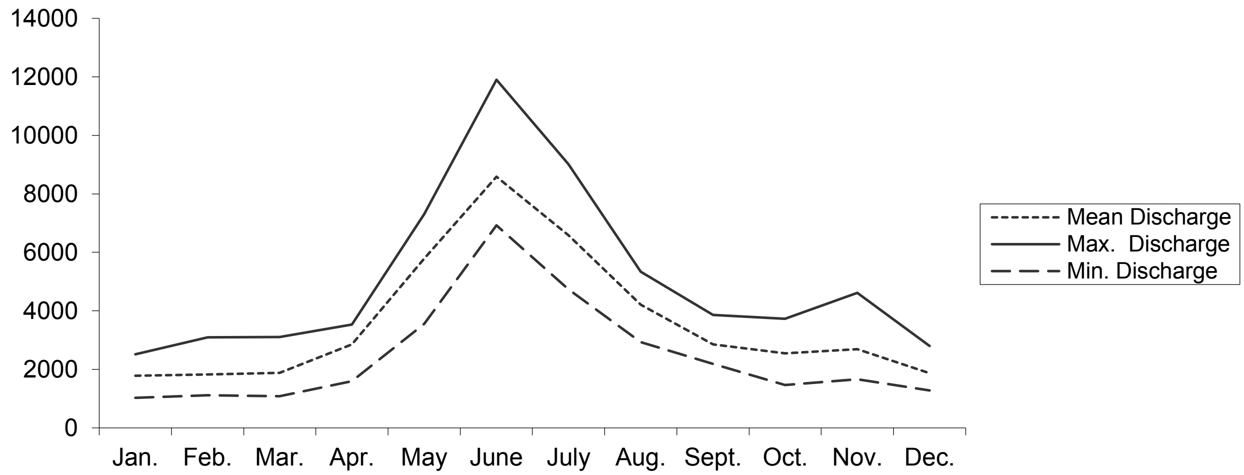


FIGURE 6.6 HISTORICAL MEAN MONTHLY STREAMFLOW (m^3/s) SUMMARY FOR THE FRASER RIVER AT PORT MANN PUMPING STATION, BC (STATION 08MH126)

TABLE 6.8 HISTORICAL MEAN MONTHLY STREAMFLOW (M^3/S) SUMMARY FOR THE FRASER RIVER AT PORT MANN PUMPING STATION, BC (STATION 08MH126)

Discharge	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Discharge	1,780	1,820	1,880	2,850	5,790	8,590	6,580	4,210	2,850	2,550	2,690	1,870
Max. Discharge	2,510	3,090	3,110	3,530	7,310	11,900	9,010	5,340	3,860	3,730	4,610	2,800
Min. Discharge	1,030	1,110	1,080	1,600	3,550	6,920	4,740	2,930	2,190	1,460	1,660	1,280
Years of Streamflow Record:	1965 to 1972 and 1983 to 1992											
Maximum Daily Discharge:	13,700 m^3/s on June 22, 1967											
Minimum Daily Discharge:	621 m^3/s on February 6, 1985											
Gross Drainage Area:	232,000 km^2											

Source: Environment Canada 2011f

The Fraser River becomes increasingly complex as it enters the Delta area, due to interactions between fresh and salt water, increasing channel complexity, tidal variations with attendant effects on river currents, salinity, and areas of exposed mudflat, as well as the potential for spilled oil to be transported through the Delta and into the marine environment of the Strait of Georgia. Therefore, the potential fate and transport of crude oil that could be spilled in the lower reaches of the Fraser River was investigated using stochastic modeling (EBA 2013). The results of the stochastic modeling are summarized in blocks, each representing three months of the year, in Appendix B. To maximize the potential for crude oil from a hypothetical spill to reach the Delta, a spill location was selected near the location of the horizontal directional drill (HDD) passage beneath the Fraser River, from the south side to the north side. Because of the depth and degree of protection that is afforded to the pipeline in an HDD, as well as the thicker pipe walls, a full bore rupture of the pipeline at such a location is an extremely unlikely event. The more probable and credible accident scenario in the lower reaches of the Fraser River is therefore a third party damage to the line, such as could be caused by a backhoe or similar equipment striking the pipeline in an unauthorized excavation. Despite the very low probability of a full bore rupture, a spill volume of 1,250 m^3 was selected for this assessment (Table 6.17). The more likely scenario of third-party damage to the pipeline was estimated to have a credible worst case spill volume of 812.5 m^3.

The Fraser River at the hypothetical spill location is subject to semi-diurnal flow reversal caused by the rising tide, at least during periods of low river flow, so that spilled oil could be transported a short distance upstream with the rising tide and favourable winds. On the falling tide, spilled crude oil would be rapidly advected downstream, so that it could reach the river mouth in one to two days during winter (low river flow), or in less than one day or less in summer (high river flow). Variations in the time required for spilled crude oil to reach the river mouth in any season would depend primarily on the state of the tide at the time of spill initiation. Sediment substrates in the river are predominantly sandy, although muddy sediments can be found in more protected or backwater areas (VAFFC 2012a, Attard 2012).

From the Port Mann Bridge downstream to the George Massey Tunnel, the river banks are highly industrialized, with a shipping channel, rail yards, wharves, docks, barge traffic and log booms. The first major divide in the river channel occurs about 7.5 km downstream from the hypothetical spill location, at the upstream end of Annacis Island. Here the river divides into three channels, one forming the north shore of the large island that is occupied by the City of Richmond, the second forming the north shore of Annacis Island. The main river channel continues to the south of Annacis Island until it reaches the George Massey Tunnel. A short distance downstream from the tunnel, the main channel divides again so that the main flow of the river (forming the south shore of Richmond) passes to the north of a complex of mudflats and wetlands, while smaller channels loop southwards before dividing again on the upstream end of Westham Island. Some of this flow returns to the main channel along the north side of Westham Island, whereas some flow is diverted southwest around the south side of Westham Island. Westham Island is used primarily for farming, and is protected by dykes on its upstream side. The west side of Westham Island is more natural, and grades into Roberts Bank.

There are three large areas of intertidal mudflat associated with the Delta. On the west side of Richmond, Sturgeon Bank extends from the west end of Vancouver, past Vancouver International Airport, and Richmond, ending where the main channel of the Fraser River divides it from Roberts Bank. Roberts Bank comprises the outer edge of the Delta south of the main river channel, extending towards Tsawwassen, where coal and ferry terminals project into the Strait of Georgia. On the east side of the Tsawassen peninsula lies Boundary Bay, not directly in contact with the Fraser River, but also supporting extensive mudflats. The tip of the Tsawassen peninsula (Point Roberts) is US territory, whereas the interior of Boundary Bay is Canadian territory. Sediment substrates in the “mudflat” areas can be characterized as predominantly sandy, or predominantly muddy. Mud substrates predominate in the high mudflat areas, and in subtidal sediments of the Strait of Georgia; sand substrates predominate over most of intertidal zones of the Sturgeon and Roberts Banks. The Fraser River Delta and Boundary Bay have received designations as a Hemisphere Shorebird Reserve, and a globally Important Bird Area; and in addition are designated as a wetland of international important under the United Nations RAMSAR convention.

Beyond the Delta lies the Strait of Georgia, and associated islands such as Gabriola Island, Valdes Island and Galiano Island lying some 20 to 35 km distant, between Nanaimo and Victoria on Vancouver Island. These and others comprise the Gulf Islands on the Canadian side, whereas on the US side there are the San Juan Islands which together separate the Strait of Georgia from the Juan de Fuca Strait.

The river channels and mudflats associated with the Fraser River Delta, as well as areas of mudflat, salt marsh, and other wetlands along the Fraser River and associated islands in the river and Delta are regarded as important fish habitat (including migratory, spawning and rearing habitat), as well as providing habitat for birds (including migratory birds) and other wildlife species.

6.1.3. Identification of Ecological Receptors

For the purpose of this qualitative ERA, it was neither practical nor necessary to individually assess every receptor that may potentially be affected by a hypothetical spill. Instead, the potential negative effects of pipeline spills to the freshwater environment were assessed for different groups of ecological receptors that might be exposed to spilled oil as a result of their habitats and life cycles.

The environmental effects of a spill at the hypothetical scenario locations were considered to be representative of the environmental effects that could occur at almost any location along the proposed pipeline corridor, in the unlikely event of a large oil spill. In that context, the ecological receptors considered in this qualitative ERA were treated generically. Thus, they were not intended to be an exact representation of the species present at the hypothetical spill location; rather they were intended to be representative of species that could be affected by an accidental oil spill affecting a watercourse or watercourses in Alberta or British Columbia.

A variety of organisms are found in the aquatic and shoreline environments along the proposed pipeline corridor. In addition to fish species, the rivers also support populations of aquatic and riparian vegetation, invertebrates, and wildlife. The ecological receptors assessed in the ERA are shown in Table 6.9 and described below.

TABLE 6.9 ECOLOGICAL RECEPTORS ASSESSED IN THE ERA

Aquatic Biota	Terrestrial Biota
Fish and Fish Eggs and Larvae In-Water Amphibians Aquatic Invertebrates Aquatic Vegetation	Mammals Birds Reptiles and Air-Breathing Amphibians Soil Invertebrates Shoreline Vegetation

6.1.3.1. Fish and Fish Eggs and Larvae

Indicator fish species for Alberta are defined in the report “Fisheries Alberta Technical Report for the Trans Mountain Pipeline ULC, Trans Mountain Expansion Project” prepared by TERA Environmental Consultants (2013) and include the following:

- Bull trout
- Arctic grayling
- Athabasca rainbow trout
- Northern pike
- Walleye
- Burbot.

Other species of management concern that could reasonably be encountered in watercourses along the Edmonton to Hinton segment include:

- Lake sturgeon
- Sauger
- Brown trout
- Brook trout
- Rainbow trout (introduced)
- Cutthroat trout (introduced)
- Mountain whitefish
- Yellow perch
- Mooneye
- Goldeye
- Spoonhead sculpin
- Northern redbelly dace.

Indicator fish species for British Columbia are defined in the report “Fisheries Technical Report for the Trans Mountain Pipeline ULC, Trans Mountain Expansion Project” by Triton Environmental Consultants (2013) and include the following:

- Chinook salmon
- Coho salmon
- Bull trout
- Dolly varden
- Rainbow trout / Steelhead

- Cutthroat trout (coastal and westslope subspecies).

Other listed species that could reasonably be encountered in watercourses along the British Columbia portion of the proposed pipeline corridor include:

- Green sturgeon
- White sturgeon
- Salish sucker
- Nootsack dace
- Eulachon
- Mountain sucker
- Cultus Lake sockeye salmon
- Interior Fraser coho salmon.

For the purposes of this qualitative ERA, fish will be addressed as an assemblage and will be represented by a generic salmonid species. This approach is reasonable because salmonids are among the more sensitive species to hydrocarbon exposure, and critical portions of their life cycle occur in fresh water. They are also among the species of highest management concern in both Alberta and British Columbia.

6.1.3.2. In-Water Amphibians

Amphibians, such as salamanders, frogs and toads, are likely present in the rivers, streams, ponds and wetlands along the proposed pipeline corridor, but their abundance would depend on the presence of surface water, breeding habitat, and prey items (*e.g.,* insects). Some species of salamanders do not breed in water, but instead may lay eggs in damp places on land. The following species are likely to be found along ports or all of the proposed pipeline corridor in Alberta and British Columbia:

- Long-toed salamander
- Wood frog
- Columbia spotted frog
- Boreal chorus frog
- Western toad
- North Pacific tree frog
- Red legged frog
- Great Basin spadefoot toad.

Many amphibian species are considered to be species at risk or sensitive species within their distributional ranges. For the purposes of the ERA, it is assumed that amphibian species may be present, and that they spend all or some of their life cycle in or around freshwater streams and rivers. Representing the aquatic portion of their life cycle, amphibian eggs and larvae are the most sensitive life stages. Owing to a general lack of toxicological information representing the effects of low-level hydrocarbon exposure on amphibian eggs, embryos and adults while in-water, these life stages will be assessed in conjunction with fish eggs and embryos, and fish generally.

6.1.3.3. Aquatic Invertebrates

The aquatic invertebrates prevalent along the pipeline corridor are likely typical of those found in freshwater streams. These include such species as mayflies, stoneflies, caddisflies, oligochaetes, chironomids, leeches, nematodes and beetles, freshwater bivalves, crustaceans and other benthic macro-invertebrates. The aquatic invertebrate community provides many important links in aquatic and terrestrial food webs, as well as providing a substantial food resource for many fish, amphibian, and bird species.

For the purposes of the ERA, aquatic invertebrates will be treated as a community. While individual species will vary in their sensitivity to hydrocarbon exposure, community metrics such as biomass, species richness and species diversity provide indicators of environmental effect and recovery.

6.1.3.4. Aquatic Vegetation

Along most stretches of the pipeline corridor, the aquatic vegetation (where present) will be assumed to consist of emergent and submerged plants, including riparian shrubs, sedges, grasses, rushes, submerged vascular plants, and non-vascular plants such as aquatic mosses and algae.

For the purposes of the ERA, aquatic vegetation will be treated as a community. While individual species will vary in their sensitivity to hydrocarbon exposure, community metrics such as biomass, species richness and species diversity, provide indicators of environmental effect and recovery.

6.1.3.5. Mammals

Since much of the proposed pipeline corridor is surrounded by forested land, a wide range of mammal species inhabit the area. Mammal species include large carnivores, such as grizzly, black bear and wolf; ungulates such as elk, deer and moose; and furbearer species such as marten, fisher, otter, mink, beaver and lynx. There are also numerous small mammals such as mice, voles, squirrels, rabbits and hares.

For the purposes of the ERA, individual species are selected as indicators of effects on mammals generally, and represent other mammal species that may be present and share similar habitat and dietary characteristics. Indicator species selected for their tendency to occupy habitat and use resources associated with rivers and streams include:

- Grizzly Bear
- Moose
- Muskrat
- River Otter.

6.1.3.6. Birds

Since much of the proposed pipeline corridor is surrounded by forested land, a wide range of bird species inhabit the area, including a number of songbirds, such as the olive-sided flycatcher and the wood warbler, and raptor species such as the northern goshawk, barred owl and western screech-owl. Waterfowl prevalent in the area include the Canada goose, mallard and trumpeter swan. Other waterbirds, such as black tern and common snipe, often use adjacent wetlands for breeding and nesting activity.

For the purposes of the ERA, individual species are selected as indicators of effects on birds generally, and represent other avian species that may be present and share similar habitat and dietary characteristics. Indicator species selected for their tendency to occupy habitat and use resources associated with rivers and streams include:

- Bald Eagle
- Canada Goose
- Great Blue Heron
- Mallard Duck
- Spotted Sandpiper
- Tree Swallow.

6.1.3.7. Reptiles and Air-Breathing Amphibians

Reptiles such as turtles and snakes, and amphibians such as toads are likely present in the rivers and streams, or in nearby terrestrial habitat along portions of the pipeline corridor. The degree to which turtles occupy aquatic habitat varies, but most turtles occupy aquatic habitat during at least part of their life cycle (*e.g.,* either as a primary habitat during summer or as hibernacula during winter). The most likely turtle encounter would be with the Western painted turtle in riparian habitat or backwater ponds of portions of the Thompson and lower Fraser River drainages. Turtle encounters are unlikely in Alberta due to their limited distribution.

For the purposes of the ERA, reptiles and air-breathing amphibians will be represented by the Western painted turtle.

6.1.3.8. Soil Invertebrates

Soils along the proposed pipeline corridor and in the riparian zones of watercourses potentially affected by spilled oil support communities of soil invertebrates. Representative types of soil invertebrates include, but are not limited to, nematodes, earthworms, insects and other arthropods including mites and spiders, and mollusks such as slugs and snails. The soil invertebrate community provides many important links in the terrestrial food web, particularly with respect to the processing of detritus, as well as providing a substantial food resource for many amphibians, reptiles, mammals and birds.

For the purposes of the ERA, soil invertebrates will be treated as a community. While individual species will vary in their sensitivity to hydrocarbon exposure, community metrics such as biomass, species richness and species diversity provide indicators of environmental effect and recovery.

6.1.3.9. Shoreline Vegetation

Along most river reaches, the shoreline vegetation consists of a mixture of forest trees, shrubs and sedges, with potential for emergent, floating or submerged aquatic plants, including both vascular and non-vascular plants and fungi in the riparian and aquatic environments. Locally, however, agricultural or urbanized land may extend to the river edge. Depending upon the particular river and reach, the riparian zone may be narrow and confined by steep valley walls, or may represent an extensive zone of high biological richness and diversity, inundated seasonally or less frequently by high river flows.

For the purposes of the ERA, the shoreline and riparian vegetation will be treated as a community. While individual species will vary in their sensitivity to hydrocarbon exposure, community metrics such as percent cover, dominant species composition, species richness and species diversity provide indicators of environmental effect and recovery.

6.1.4. Identification of Exposure Pathways

An exposure pathway describes the movement of a COPC from a source to an eventual point of contact or intake (exposure) by an ecological receptor. Identifying the potential exposure pathways involves consideration of several factors. The life history traits of each receptor (*e.g.,* habitat, diet), features of the affected environment (*e.g.,* habitat suitability), and the environmental fate and transport properties of the COPCs (including weathering properties) comprise but a few of the components taken into account. Table 6.10 provides a summary of potential exposure pathways for the Project resulting from hypothetical pipeline spills of diluted bitumen into the freshwater environment.

TABLE 6.10 POTENTIAL EXPOSURE PATHWAYS RESULTING FROM HYPOTHETICAL PIPELINE SPILLS INTO THE FRESHWATER ENVIRONMENT

Source	Exposure Pathways	Exposure Pathways Carried Forward?	Justification
Oiled upland soils and vegetation	• Direct contact • Ingestion • Inhalation of vapours	No	The area of upland soil affected by overland flow is expected to be very small and isolated in comparison with the area of aquatic and riparian habitat that is potentially affected. Further, upland soil was assumed to be remediated to Provincial Standards that are protective of all exposure pathways and receptors. Therefore, there will be no residual effects on receptors and this exposure pathway is not carried forward in the ERA.

TABLE 6.10 POTENTIAL EXPOSURE PATHWAYS RESULTING FROM HYPOTHETICAL PIPELINE SPILLS INTO THE FRESHWATER ENVIRONMENT

Source	Exposure Pathways	Exposure Pathways Carried Forward?	Justification
Oiled shoreline or riparian soils and vegetation	• Direct contact • Ingestion • Inhalation of vapours	Yes	Shorelines are expected to become oiled if down-river transport of oil slicks results in shoreline stranding. Such stranding becomes more likely to occur and to account for more mass of oil if a spill occurs during a high flow event and receding flows allow oil to become trapped over a broad riparian zone. Ecological receptors may directly contact and/or ingest oiled soils. Although ecological receptors may inhale hydrocarbon vapours, dilution in the outdoor air is expected to result in negligible effects; therefore, the vapour inhalation pathway will not be carried forward in the ERA.
Accumulation of hydrocarbon COPCs by terrestrial plants, soil invertebrates, reptiles, air-breathing amphibians, mammals and birds	• Ingestion of shoreline plants • Ingestion of terrestrial invertebrates • Ingestion of reptiles/air-breathing amphibians • Ingestion of bird/mammal prey	Yes	Following shoreline oiling, soil invertebrates, reptiles, air-breathing amphibians, mammals and birds, may accumulate hydrocarbon COPCs as a result of ingesting contaminated plant, invertebrate or animal foods.
River water	• Direct contact • Ingestion • Inhalation of vapours	Yes	River water will become contaminated with floating, dispersed, overwashed or dissolved hydrocarbon COPCs, if spilled oil enters the aquatic environment. Ecological receptors may come into direct contact with or be exposed to oil or oily water, or may ingest contaminated water. Although ecological receptors may inhale hydrocarbon vapours at the water surface, dilution in the outdoor air is expected to result in negligible effects; therefore, the vapour inhalation pathway will not be carried forward in the ERA.
River sediment	• Direct contact • Ingestion • Direct contact with pore water	Yes	Some river sediments may become contaminated by trapping droplets or globules of dispersed or overwashed oil, by adsorbing dissolved oil, or if oil becomes mixed with denser materials such as sand, gravel or suspended sediment, resulting in the physical sinking of oil. Ecological receptors may come into direct contact with oil in sediment, or may ingest contaminated sediments. In addition, ecological receptors such as fish eggs and embryos or benthic invertebrates may be exposed to sediment pore water that contains dissolved hydrocarbon COPCs.
Accumulation of hydrocarbon COPCs by aquatic plants, aquatic invertebrates, in-water amphibians, fish, mammals and birds	• Ingestion of aquatic plants • Ingestion of benthic invertebrates • Ingestion of in-water amphibians • Ingestion of fish	Yes	Following release of oil to a river, aquatic invertebrates, in-water amphibians, fish, mammals and birds may accumulate hydrocarbon COPCs as a result of ingesting contaminated plant, invertebrate or animal foods.

6.1.5. Conceptual Site Model

Figure 6.7 provides a schematic representation of the interactions between receptors and the COPCs in relevant exposure media, via various potential exposure pathways. The potential exposure pathways are designated by arrows leading from the contaminant source media to each receptor. Relevant pathways for each receptor are identified with an “X” in the compartments within the matrix.

Source of COPC	Exposure Media	Potential Exposure Pathways	Fish and In-Water Amphibians	Fish and Amphibian Eggs	Aquatic Invertebrates	Aquatic Vegetation	Shoreline and Riparian Vegetation	Soil Invertebrates	Grizzly Bear	Moose	Muskrat	River Otter	Bald Eagle	Canada Goose	Great Blue Heron	Mallard Duck	Spotted Sandpiper	Tree Swallow	Reptiles and Air-Breathing Amphibians
Oiled Shorelines	Shoreline Soil	Direct Contact				X	X	X	X	X	X	X	X	X	X	X	X		X
		Ingestion				X			X	X	X	X	X	X	X	X	X	X	X
	Bird/Mammal prey	Ingestion							X		X	X	X		X				
	Shoreline Plants	Ingestion				X			X	X	X			X		X	X		X
	Soil Invertebrates	Ingestion							X					X			X	X	X
River Water	River Water	Direct Contact	X			X			X	X	X	X	X	X	X	X	X	X	X
		Ingestion	X			X			X	X	X	X	X	X	X	X	X	X	X
	Fish	Ingestion	X						X		X	X	X		X		X		
River Sediment	Aquatic Plants	Ingestion								X	X					X	X		X
	Sediment	Direct Contact	X	X	X				X	X	X	X			X	X	X	X	X
		Ingestion	X		X				X	X	X	X	X		X	X	X	X	X
	Benthic Invertebrates	Ingestion	X								X	X				X	X	X	X
	Pore Water	Direct Contact		X	X														X
Submerged Oil	Submerged Oil	Direct Contact	X	X	X	X			X	X	X	X				X			X

Source → Receptors (VECs)

Notes:
X - a potentially complete exposure pathway.
[green box] No residual impacts. This media is assumed to be cleaned to Provincial Standards protective of all pathways.

FIGURE 6.7 CONCEPTUAL EXPOSURE MODEL FOR ECOLOGICAL RECEPTORS AND SELECTED INDICATORS

6.2. Exposure Assessment

The objectives of the Exposure Assessment are the following:

- To gather information to support predictions about the fate and transport of hypothetical pipeline releases of diluted bitumen into the freshwater environment along the proposed pipeline corridor.
- To gather information to qualitatively assess the ecological effects of COPC exposure resulting from hypothetical pipeline releases of diluted bitumen into the freshwater environment along the proposed pipeline corridor.

The qualitative ERA assesses both acute (short-term) and chronic (medium to long-term) risks to ecological receptors. The assessment of acute ecological risk focuses on the short-term effects of a pipeline release and the assessment of chronic risk begins after the acute exposure assessment.

6.2.1. Fate and Behaviour of Oil When Spilled in the Environment

Crude oils and refined petroleum products are complex mixtures of hydrocarbon compounds derived from naturally occurring geological formations. When released into the environment, various weathering processes work to break down the hydrocarbons into primarily carbon dioxide and water. The rate of these processes depends upon the type of oil (*i.e.,* the specific mixture of hydrocarbon compounds present), characteristics of the receiving environment (*e.g.,* location of the release, season, weather conditions, etc.), the volume spilled, and other factors.

Weathering, which results in changes to the chemical composition and physical characteristics of oil over time, occurs as a result of biological, chemical and physical processes. Upon being spilled, volatile hydrocarbons quickly (*i.e.,* on a time scale of minutes to days, depending upon the volatility of the compound and the environmental conditions) evaporate into the atmosphere, leaving heavier components of the crude oil mixture behind. As the crude oil weathers, its density and viscosity tend to increase. On a slower time scale (*i.e.,* days to weeks or longer), sunlight and microorganisms degrade hydrocarbons through photo-oxidation and biodegradation, which results in the gradual breakdown of larger molecules into smaller and simpler molecules that are themselves generally more amenable to further weathering.

If relatively fresh crude oil reaches water, some of the lighter hydrocarbon compounds that would otherwise evaporate may dissolve into the water, resulting in concentrations that may be toxic to aquatic organisms. In addition, physical processes such as dispersion (formation of oil droplets in water due to turbulent mixing), emulsification (formation of a water-in-oil suspension that may or may not be stable, and is denser than the crude oil alone), entrainment and overwashing (temporary submergence) of oil, sinking and sedimentation, and shoreline stranding, reduce the size of the surface oil slick and help the environment assimilate the spilled oil (National Research Council [NRC] 2003). Weathering rates are temperature and time dependent, increasing with increasing temperature (NRC 2003) and decreasing with time, as the remaining hydrocarbons are those that are less susceptible to weathering processes.

Because crude oils and petroleum products are composed of differing mixtures of hydrocarbon compounds, each have different physical properties (*e.g.,* viscosity, density, solubility) that affect their fate and transport once released into the environment (NRC 2003). For example, highly viscous oils (*i.e.,* those with a higher percentage of heavy fractions, or high asphaltene and resin content) tend to weather more slowly because they do not readily spread into thin oil slicks, and they contain a substantial number of chemical constituents that resist degradation.

The burial of pipelines typically slows the spread of oil from a release site. Depending on the rate of discharge from the pipeline (*e.g.,* a pin-hole leak versus a full-bore rupture) and the oil properties (*e.g.,* viscosity and pour point), oil may be forced to the surface through the pore spaces in soil. Frozen ground may limit the movement of oil from the spill site, and snow cover, if present, can also help to absorb or limit the spread of oil.

When a release is detected, emergency response preparedness and emergency response actions reduce the effects on the environment. The containment, recovery, and clean-up actions undertaken are specific to the affected receiving environment and include consideration of local sensitivities.

In the event of a full-bore rupture, the volume released would be made up of a dynamic (pressurized) and a static (gravity-based) drain-out volume. The dynamic release volume varies based on the volume of oil flowing through a pipeline, the time it takes to detect the loss of containment, and the time it takes to close the valves. The static release volume is based on the distance to the nearest pipeline valve, local topography, pipeline profile characteristics, and oil properties. The movement of oil would initially be dominated by the pressure differential as oil is forced out of the pipe by dynamic and static forces.

Oil spilled into the terrestrial environment undergoes physical, chemical and biological processes that weather the oil as it is transported away from the source (Figure 6.8). During the initial phase of a spill from a buried pipeline, oil can be forced to the surface, where it may flow over land. Portions of the oil may adhere to surface soil, debris and vegetation, pool in low lying areas, and/or infiltrate the soil. The rate of oil flow over land is a function of oil viscosity, ground and air temperature, slope of the terrain, and surface conditions (*e.g.,* roughness, vegetation type and cover, soil type, permeability, snow cover) (Owens 2002).

After the initial period when the dynamic and static pressures from the release site subside and the oil has spread out, hydrocarbon movement tends to slow. Oil in or on soil may sink downward under gravity and spread horizontally in the subsurface as a result of capillary forces. If the oil were to encounter an impermeable or semi-permeable soil structure (*e.g.,* bedrock, impermeable or frozen soil, water table), downward movement would halt or slow, and the oil would spread laterally. Unless the oil reached a watercourse (where further spreading would be likely), eventually the oil would stop moving and remain in local surface pools, be absorbed on vegetation and the litter layer, and be trapped in the void spaces within the soil structure. However, even when immobilized, hydrocarbons would remain subject to physical weathering and microbial biodegradation.

Oil spilled into the aquatic environment undergoes weathering processes similar to those described for the terrestrial environment, but they occur in a more dynamic system with a greater number of transport mechanisms (Figure 6.9). Upon entering a waterbody, oil spreads over the water surface forming an oil slick. Volatile hydrocarbons quickly evaporate into the atmosphere, and water-soluble components dissolve in the water at a rate that depends upon the turbulent energy present and the oil characteristics. Sunlight and microorganisms degrade hydrocarbon components through photo-oxidation and biodegradation. Physical processes (*e.g.,* wind, waves and currents causing turbulent dispersion) may result in the formation of water-in-oil emulsions (mousse), which may cause the formation of small oil droplets that disperse in the water column, and enhance the rate of dissolution of soluble constituents. Depending upon the density of the oil, droplets may coalesce and resurface, or may combine with suspended particulate matter and remain in the water column. With sufficient turbulent energy, oil globules may become temporarily overwashed or entrained into the water column. Weathering may also result in the formation of tar balls, which are persistent discrete globs of oil with a weathered rind of material (Foght 2006, NOAA 2010).

Oil in aquatic environments may be horizontally transported via advection and spreading, or locally concentrated by Langmuir circulation. Oil can become stranded on shorelines as oil slicks are horizontally transported and make contact with shore, or if a spill occurs while river flow is in flood stage and water levels recede. Physical processes may also vertically transport the oil by driving oil droplets into the water column (dispersion). Oil spilled into a river will eventually weather (primarily by evaporation), strand on a shoreline, dissolve or disperse into the water column, or become associated with mineral grains and sink to the bottom in a relatively quiescent zone of the river.

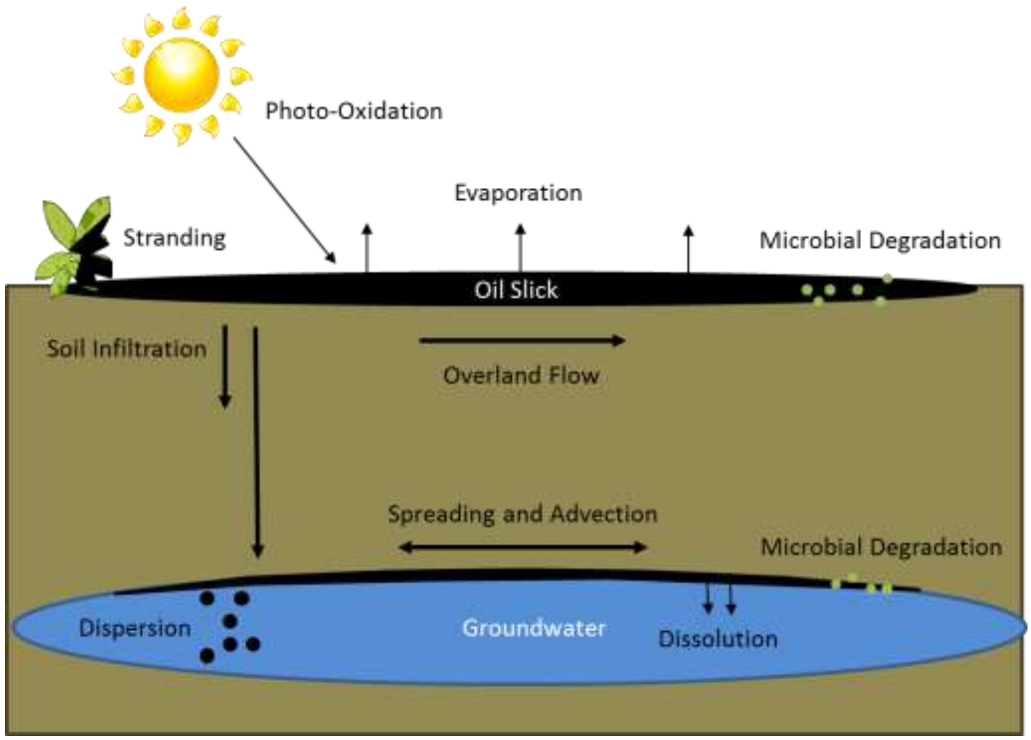


FIGURE 6.8 OIL SPILLS IN TERRESTRIAL ENVIRONMENTS

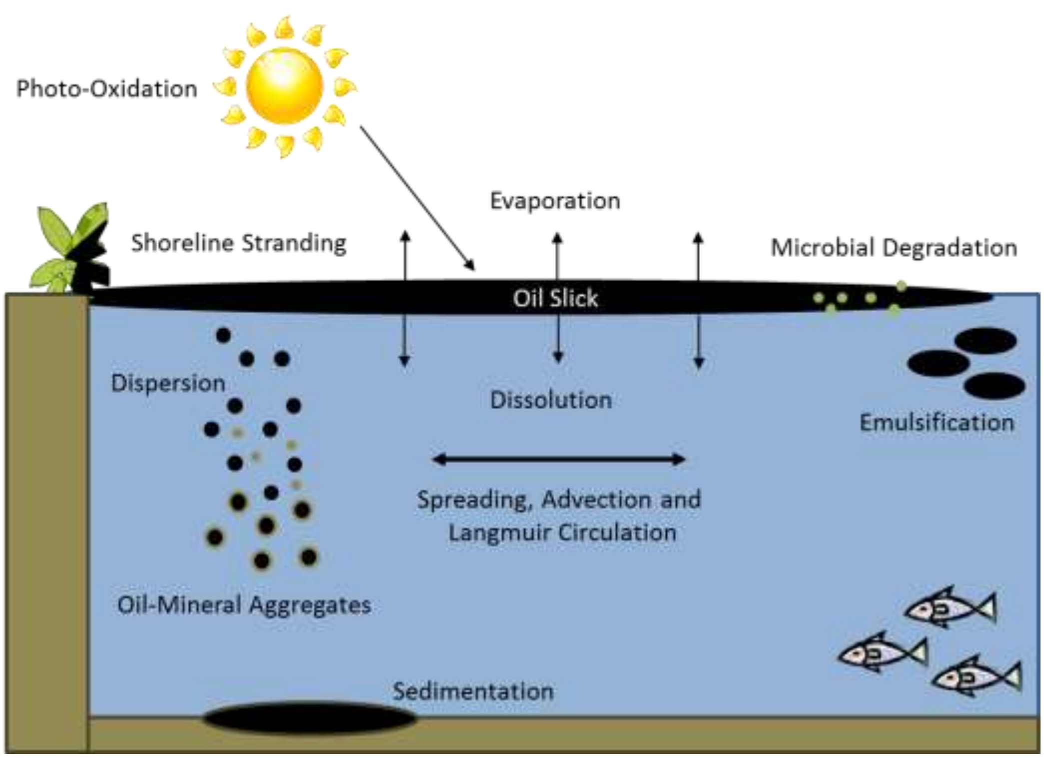


FIGURE 6.9 OIL SPILLS IN AQUATIC ENVIRONMENTS

6.2.1.1. Oil-Mineral Aggregate Formation

Vertical mixing can cause oil from a surface slick to disperse into the water column as suspended droplets. Once in the water column, under certain conditions, suspended material can coat the oil droplets, forming oil-mineral aggregates (OMA) (Danchuk 2009). The formation rate of OMA depends upon suspended sediment characteristics and concentrations (Delvigne 1987, 2002, Guyomarch *et al.* 1999, Payne *et al.* 1989), droplet size and number (Khelifa *et al.* 2005a), temperature (Khelifa *et al.* 2002), salinity (Khelifa *et al.* 2005b, Le Floch *et al.* 2002, Payne *et al.* 1989), mixing energy (Cloutier *et al.* 2002), and oil characteristics (Khelifa *et al.* 2002). OMA stabilizes within 24 to 48 hours (Payne *et al.* 2003, Hill *et al.* 2002), and once stable, it does not re-coalesce with the slick or adhere to surfaces (Danchuk 2009).

The formation of OMA can be detrimental to oil spill recovery efforts, particularly if it leads to sinking or sedimentation of oil that would otherwise float and be more readily captured. On the other hand, OMA formation has also been found to enhance biodegradation rates in the water column, reduce the amount of oil adhering to shorelines (Lee 2002), and can render oil droplets neutrally or nearly neutrally buoyant, resulting in subsurface transportation of oil away from the spill location (Lee *et al.* 2003). In addition, it has been found that physical dispersion, enhanced dissolution, and biodegradation of oil resulting from OMA formation, lowers the concentrations of oil components to which biota are exposed (Lee 2002). To determine whether OMA formation could be an important process in the fate of spilled oil, a number of key factors were evaluated. These factors included (Lee 2002):

- Mixing energy in the water column
- Temperature
- Oil characteristics
- Concentration, type and size distribution of suspended sediment
- Salinity.

During OMA formation, solid particles become associated with the outer surface of oil droplets in the water column. The oil droplet size associated with OMA formation ranges from approximately 0.2 to 4 µm, with a median value of about 0.6 to 1 µm (Khelifa *et al.* 2002). However, multiple droplet aggregates (where more than one droplet is present in a single OMA) and solid aggregates (elongated oil particles containing some mineral particles within the oil phase as well as on the outer surface) are also reported (Khelifa *et al.* 2002).

Mixing energy in the water column, oil characteristics (notably viscosity and density, which reflect the oil type, degree of weathering, and asphaltene/resin content) and temperature, all affect the tendency for oil droplets to form, and the size distribution of such droplets. OMA formation in light oils, which float on the water surface or rapidly re-surface and coalesce with floating oil, requires high mixing energy to maintain dispersed oil in the water column where OMA formation occurs. In contrast, relatively heavy oils can enter suspension in the water column at lower levels of mixing energy; however, they may also resist droplet formation due to associated higher viscosity. Similarly, viscosity increases at low temperatures, and again resistance to droplet formation can increase.

In addition to suitable oil droplet size, the potential for OMA formation increases with increasing sediment concentration (Ajijolaiya *et al.* 2006), decreasing sediment grain size (Ajijolaiya *et al.* 2006) and increasing organic content (Khelifa *et al.* 2008). Maximum OMA formation occurs when all droplets in suspension are coated by a film of sediment particles. As OMA classically takes the form of a monolayer of sediment particles coating an oil droplet, increased sediment concentrations, fine grained sediment particles and high organic content (although a secondary consideration after sediment grain size; Khelifa *et al.* 2008) have the potential to result in the greatest rates of OMA formation. Ajijolaiya *et al.* (2006) found that the amount of oil trapped in water was greater than one-half of the total oil for sediment mean diameters of 0.5 µm and 1 µm, approximately one-third for sediment mean diameters of 2 µm and 4 µm, and one-tenth for 16 µm. It was also determined that critical sediment concentrations for OMA formation increased linearly with increasing sediment sizes (Ajijolaiya *et al.* 2006).

Salinity also affects OMA formation because of its influence on surface chemistry. At low salinity, mineral particles and oil droplets are well dispersed because negative surface charges tend to counteract the van der Waals attraction forces (Huang and Elliot 1977). As salinity increases, attractive forces remain constant while the repelling negative surface charges tend to be neutralized. In a manner similar to the formation of flocculates when clay particles in river water enter brackish estuaries, OMA formation is also enhanced with increasing salinity, and inhibited in freshwater. Le Floch *et al.* (2002) found that some salinity is needed for OMA formation to occur. Below salinity levels of about 1 part per thousand (‰) (seawater having a salinity of 35‰, and freshwater typically having a salinity of less than 0.2‰), OMA formation is inhibited. Above salinity values of 2‰, OMA formation is no longer limited by a lack of salinity.

The foregoing considerations suggest that OMA formation involving diluted bitumen (which has high asphaltene and resin content) will be limited in inland waters, where the following conditions prevail:

- Salinity is low
- There is low to moderate total suspended solids concentrations or turbidity
- Oils are viscous, or as oils weather so that viscosity increases
- Temperatures are low.

Conversely, higher potential for OMA formation can be expected where:

- Salinity increases due to the presence of estuarine circulation
- Total suspended sediment concentrations are high
- Oil is fresh or only slightly weathered
- Temperatures are warm.

The formation of OMA does not dictate whether or not oil will sink. While the increased density of OMA will increase the density of the aggregate (relative to the oil droplet), OMA may remain positively or neutrally buoyant depending upon the characteristics of the oil and the ratio of oil to mineral in the aggregate (Le Floch *et al.* 2002). The formation of OMA is commonly regarded as beneficial for spilled oil, as it increases the natural dispersion of the oil, and promotes weathering and biodegradation processes (Lee 2002). In the estuarine environment, the density of the water increases with increasing salinity, so that OMA is more likely to remain suspended in the water column, and to disperse over a larger area, and may provide a net environmental benefit.

Danchuk (2009) evaluated the potential for OMA formation in the lower Mississippi River, a reach extending from Luling (river mile 119) to the Head of Passes (river mile 0). In this reach, the Mississippi River, although having mean annual flow about four times greater, shows marked similarities to the lower Fraser River with respect to channel dimensions, suspended sediment concentrations, the effects of tide and salinity from the nearby marine environment, and the presence of a delta.

In reviewing the fate of the DM 932 heavy fuel oil (No. 6 or Bunker “C” fuel) spill to the lower Mississippi River, Danchuk (2009) found that modelling of the potential OMA formation predicted that 0% to 36% of the oil could have been involved in this process. Salinity and availability of suspended sediments were both found to be limiting factors for OMA formation; suspended sediment would have had to reach 250 mg/L to not be a limiting factor. In a comparison with the known fate of oil from the DM 932 spill, OMA formation was estimated to remove only 2% to 5% of the spilled oil, suggesting that the models predicting OMA formation tended to over-estimate its role in the fate of spilled oil. However, including OMA formation in the spill evaluation also helped to explain the relatively low level of observed shoreline oiling. It was concluded that OMAs that formed would remain buoyant in the water column, reducing the potential for oil to beach and allowing some of the spilled oil to become dispersed into the Gulf of Mexico, beyond the Delta. These findings have considerable relevance to the likely fate of diluted bitumen, which is also a heavy oil, hypothetically spilled in the lower Fraser River.

6.2.2. Selected Case Studies

Previous studies of oil spills in similar environments provide a basis for evaluating the fate, transport and effects of hypothetical pipeline spills of diluted bitumen resulting from the Project. A literature review was conducted to identify and acquire information on simulated and actual oil spills in the freshwater environment. From the scientific literature in peer reviewed journals, government reports and technical documents, case studies of oil releases were selected using the following set of criteria:

- Occurred in a freshwater environment
- Located in a cold temperate zone or subarctic location
- Spilled oil had similar physical and chemical properties as the diluted bitumen assessed in the ERA.

For each case study, an effort was made to collect the following information:

- How much oil was spilled?
- What type of oil was spilled?
- How was the oil transported in the environment, and which factors contributed to spreading of the oil?
- What were the short-term and long-term environmental effects of the spilled oil?
- To what extent did the system recover from the oil spill, and what factors were important in achieving that recovery?

Table 6.11 summarizes the case studies evaluated in the ERA. While it was not possible to match all three of the desired criteria for each case study, each case study was considered to have relevance to the Project. A brief description of each case study, along with the fate and transport and environmental effects of the each spill, follows.

TABLE 6.11 CASE STUDIES SELECTED IN THE ASSESSMENT OF OIL SPILLS IN THE FRESHWATER ENVIRONMENT

Oil Spill	Location	Year	Release Platform	Oil Type	Volume (m^3)
Kalamazoo River	Michigan, USA	2010	Pipeline Full-bore Rupture	Diluted Bitumen	3,200
Wabamun Lake	Alberta, Canada	2005	Rail Accident	Bunker “C”	712
East Walker River	California/Nevada, USA	2000	Truck Accident	Bunker “C”	14
Pine River	British Columbia, Canada	2000	Pipeline Full-bore Rupture	Light Crude	985
Yellowstone River	Montana, USA	2011	Pipeline Full-bore Rupture	Light Crude	240
OSSA II	Bolivia, South America	2000	Pipeline Full-bore Rupture	Mixed Crude	4,611
DM 932	Louisiana, USA	2008	Barge Accident	Bunker “C”	1,070
Northern Gateway Project	Alberta/British Columbia, Canada	N/A (Oil Spill Simulations)	Pipeline Full-bore Ruptures	Diluted Bitumen, Synthetic Oil, Condensate	Various
Vancouver Airport Fuel Delivery Project	British Columbia, Canada	N/A (Oil Spill Simulations and Background Data Collection)	Various	Jet “A”	Various

6.2.2.1. Kalamazoo River Oil Spill

On July 25, 2010, Enbridge’s Line 6 pipeline ruptured in a wetland near Marshall, Michigan. Approximately 3,200 m^3 (843,444 US gallons) of heavy crude oil containing diluted bitumen was released over a period of about 17 hours. The pipeline contained two different batches of crude oil at the time of the spill, and it is estimated that the spilled oil comprised approximately 77% Cold Lake Winter Blend diluted bitumen and 23% Western Canadian Select crude oil (National Transportation Safety Board

[NTSB] 2012). Of this, approximately 1,300 m^3 (337,386 US gallons) reached Talmadge Creek and the Kalamazoo River (Enbridge 2013a).

The rupture, a longitudinal tear adjacent to a seam weld approximately 2 m long and up to 13.5 cm wide, occurred during the last stages of a planned shut-down (NTSB 2012). It was not immediately recognized as being a pipeline failure due to the transient conditions associated with the shutdown procedure, and an incorrect interpretation of data that led to the assumption that column separation had occurred. Upon discovery, response activities immediately commenced to remove free oil and prevent its transport downstream. However, recent heavy rainfall in the region (10 to 14.5 cm over the preceding three days) had increased flows and water levels, hindering response efforts (Enbridge 2011, NTSB 2012). As a consequence, approximately 3.2 km of Talmadge Creek and 60 km of the Kalamazoo River (as far as the Morrow Lake delta) were affected by the spill (NTSB 2012).

As part of the response to the spill, Enbridge prepared a Conceptual Site Model (CSM, Enbridge 2011, 2013b) that was reviewed and approved by the Michigan Department of Environmental Quality. The CSM provides the best available description of the conditions at the time of the spill, and the behaviour and fate of the spilled crude oil in the environment. Much of the information presented below originates from the CSM.

At the spill site, crude oil was released below grade level. The crude oil was forced from the pipeline under pressure into the surrounding soils and emerged to the ground surface. The released oil flowed overland through forested scrub-shrub wetland, following local topography, to Talmadge Creek (Enbridge 2013b). Despite the proximity of the oil spill location to Talmadge Creek, only about 40% of the spilled oil entered the aquatic environment, the remainder being recovered at the spill site, or in the wetland between the spill site and Talmadge Creek.

Talmadge Creek was flowing with higher than normal flow due to recent heavy rains. The crude oil flowed down Talmadge Creek to the confluence with the Kalamazoo River, and then into the Kalamazoo River. Due to the elevated water level, the crude oil affected floodplain areas on both sides of Talmadge Creek. The river was also high at the time of the spill and had overflowed its banks in many areas. As a result, oil entered the floodplain areas. As water levels in the river receded, much of the crude oil flowed with the flooding water back within the banks of the Kalamazoo River, although crude oil also became stranded in hydrologically isolated areas such as depressions, cavities, burrows, and other traps within the riparian zone (Enbridge 2013b). The average gradient of the Kalamazoo River ranges from 0.025% to 0.075%.

Upon entering the water, the density of the crude oil was slightly less than that of water, and therefore it floated, forming an oil slick that flowed downstream. In low sinuosity segments of the river, crude oil floated on top of the river and moved in slicks parallel to the main river channel. Floating crude oil tended to be carried through the low sinuosity segments (not stranded), and oiling of the floodplain areas was mostly along the edges of the straight sections of the river, or in backwater areas where eddy currents could direct flow. In high sinuosity segments of the river (*i.e.,* areas with more extensive floodplain), where flow had left the main channel, crude oil moved into the floodplain and was slowed and retained by vegetation. Slower flow encouraged collection of slicks in backwaters and eddies. Crude oil was subsequently trapped and stranded in low areas of the floodplain (Enbridge 2011).

High river flows entrained some of the oil into the water column (resulting in submerged oil) and transported it downstream. Dam spillways may have resulted in the formation of emulsions (mousse) that were also driven into the water column, or entrained further oil into the water column. Over time, weathering of the lighter components and interaction of the submerged oil with suspended sediments resulting in its sinking in the water column, and the sedimentation of some crude oil on the river bottom in quiescent or net-depositional areas of the riverbed once flows decreased (Enbridge 2011, 2013b).

As the crude oil interacted with water and air in the environment, the composition of the crude oil changed in predictable ways (Enbridge 2013b). Many compounds originating with the diluent are more volatile and more water soluble than compounds originating with the bitumen. Weathering therefore results in a selective reduction of contaminant mass and concentration in the bulk oil. Like any heavy crude oil, the diluted bitumen in highly weathered form can resemble asphalt or thick tar, and can attain a density that approaches or slightly exceeds that of water. The inclusion of mineral particles in the weathered oil further adds to the aggregate density, and promotes settlement and sinking of oil (Enbridge 2013b). Although the sediment within the bed of Talmadge Creek contained residual oil, extensive remediation efforts in 2011 removed most if not all of this oil (Enbridge 2013b). In the Kalamazoo River, as the unrecovered oil was transported downstream in the water column, a portion of it incorporated suspended sediments causing it to become entrained in the water column. Oil-sediment aggregates are subject to periodic burial and subsequent exposure, in response to hydrological conditions in the river. Oil was entrained with sediments and debris, incorporated into river bedload, and transported toward geomorphological traps in the riverbed. Such traps are commonly found as silt deposits associated with local features (backwaters and behind islands), or as deltaic deposits at the upstream end of headponds associated with dams on the river (Enbridge 2013b). As of June 2013, the USEPA (2013) estimated that approximately 680,000 litres (180,000 gallons) of submerged oil remained in the river bottom sediment and ordered the removal of the recoverable portion (approximately 45,000 to 68,000 litres or 12,000 to 18,000 gallons), principally in relation to the headponds of the Ceresco and Morrow dams. Removal of the remainder would result in substantial damage to the river; therefore, it was to be left in place and monitored (USEPA 2013). These volumes, however, are subject to great uncertainty, and may substantially overestimate the quantity of oil residual in sediments. Biological surveys carried out as early as the fall of 2010 and summer of 2011 rarely encountered oil deposits in the riverbed that would release sheen, and where such deposits were found, they were associated with silt deposits and not with gravel or cobble bottom areas (Enbridge 2011, Badra 2011, Walterhouse 2012).

The long-term environmental effects of the crude oil are still being assessed through water, soil and sediment sampling, biological diversity assessment, submerged oil assessment, erosion tours, and situational awareness (USEPA 2012). However, preliminary results show that since mid-2011, there have been no exceedences of organics in surface water (USEPA 2012). Metals (*i.e.,* nickel, vanadium, molybdenum, iron) were an ongoing concern as of the end of 2012; additional studies were being conducted to determine if elevated metal concentrations were the result of the oil spill or local background conditions (USEPA 2012).

As part of the Natural Resource Damage Assessment authorized under the *Oil Pollution Act*, the Kalamazoo River Oil Spill trustees have collected/are collecting data to assess environmental effects on behalf of the public. Data include the following (Winter *et al.* 2012):

- Extent of oiling
- Vegetation
- Erosion
- Fish
- Aquatic macroinvertebrates
- Mussels
- Chemistry (source oil, water, sediment, biota)
- Wildlife.

An important point with respect to the Enbridge Line 6B incident near Marshall, Michigan, is that no fish kills were observed in the spill area (Winter *et al.* 2012). Available results to date show that although the Talmadge Creek fish community was reduced and its habitat greatly diminished in 2010 due to oil spill recovery efforts (Wesley 2011), it experienced some recovery in 2011 (Winter *et al.* 2012). In the Kalamazoo River, some declines in fish community diversity and abundance were observed at some, but not all sites in 2010 (Wesley 2011, Winter *et al.* 2012).

The diversity and abundance of aquatic macroinvertebrates in Talmadge Creek and the Kalamazoo River were reduced in 2010 (Walterhouse 2011 in Walterhouse 2012). By 2011, diversity and abundance had improved, although abundance was still affected (Walterhouse 2012). In addition, clean-up activities in Talmadge Creek, which resulted in decreased vegetative cover, exposed more of the stream channel to sunlight and altered community composition (Walterhouse 2012).

A mussel shell survey was conducted by Badra (2011) in October 2010 to assess injury to mussels as a result of response activities (*e.g.,* crushing by boat traffic, habitat alterations, sedimentation). Results showed crushed and freshly dead shells within the spill area, but not in the reference area.

As part of the response, animal recovery efforts ran from July 2010 through October 2010. Table 6.14 summarizes the recovery effort as of May 2011. In total, 3,160 animals (*i.e.,* reptiles, crustaceans, amphibians, birds, mammals and fish) were collected (Enbridge 2011). Of the animals collected, three turtle species (13 individuals) were protected by Michigan law as either threatened (spotted turtle, *Clemmys guttata*) or special concern (Blanding's turtle, *Emys blandingii*; eastern box turtle, *Terrapene carolina carolina*) (Enbridge 2011).

TABLE 6.12 KALAMAZOO OIL SPILL WILDLIFE RECOVERY SUMMARY AS OF MAY 2011

Status	Reptiles	Crustaceans	Amphibians	Birds	Mammals	Fish	Total
Animals Collected Un-oiled	239	-	-	-	-	-	239
Oiled Animals Rescued	2,546	4	53	171	38	-	2,812
Oiled Animals Found Dead	15	3	-	25	25	42	109
Rescued Animals Released	2,119	2	50	144	23	-	2,338
Rescued Animals Live in Care	371	-	1	-	-	-	372
Turtle Hatchlings in Care	42	-	-	-	-	-	42

Source: Enbridge 2011

In July 2010 the Michigan Department of Community Health (2013) issued precautionary swimming and fishing advisories, and a "do not eat" guideline for fish in the river. In July 2012, most of the river was re-opened for recreational use and the fish consumption advisory in relation to the oil spill was lifted. Surface water samples were collected in 2010, 2011 and 2012, and fish tissue samples were collected in 2010 and 2011, with analysis for hydrocarbon constituents, particularly PAHs, as well as metals and other contaminants. Retrospective analysis (Michigan Department of Community Health 2013) found that trace metals of potential concern (nickel and vanadium) did not differ in fish tissues collected upstream and downstream of the spill site, and were below levels of concern. The PAHs were evaluated in the context of potential carcinogens (*i.e.,* as benzo(a)pyrene equivalents) and as non-carcinogenic compounds. Concentrations of the carcinogenic PAHs were actually higher in samples collected upstream of the spill location, but fish consumption guidelines were not considered necessary owing to the low overall concentrations detected. For non-carcinogenic PAHs, naphthalene and acenaphthene were detected in carp from the Ceresco headpond in 2010 at concentrations of 16.1 and 14.9 ppb, respectfully. These concentrations were well below a screening level of 2,300 ppb, and again no fish consumption guidelines were considered necessary (Michigan Department of Community Health 2013).

6.2.2.2. Wabamun Lake Train Derailment

On August 3, 2005, a CN freight train derailed near the Village of Whitewood Sands, Alberta, releasing approximately 712 m^3 of Bunker "C" fuel oil (Heavy Fuel Oil 7102, Hollebone *et al.* 2011) and 88 m^3 of pole treating oil (PTO) into the environment (Transportation Safety Board of Canada [TSBC] 2007, Hollebone *et al.* 2011). The Bunker "C" fuel oil (a high viscosity, heavy residual oil destined for use as an asphalt stock) had a density of approximately 0.99 at lake temperature (Fingas *et al.* 2006, Hollebone *et al.* 2011). It was still warm and relatively less viscous from loading, and flowed primarily south along the ground surface from the ruptured cars, along multiple flowpaths, to the north shore of Wabamun Lake. Oil that did not enter the water pooled in lower areas and saturated the soil. The pole treating oil, in contrast, appeared to have been held up near its point of release, and did not enter the lake in appreciable quantity (TSBC 2007, Hollebone *et al.* 2011). It is estimated that approximately 149.5 m^3 (*i.e.,* about 20% of the total spilled) entered the lake (Wernick *et al.* 2009).

Once in the water, the oil formed a thick (>1 cm) black slick that spread rapidly into the lake, but strong westerly winds and wave action the following week caused the slick to drift to the north, east, and southeast shorelines (Anderson 2006; TSBC 2007). Silvery sheens (0.05 µm) also rapidly covered the lake (Hollebone *et al.* 2011). The heavy Bunker product formed several types of aggregates including tar balls, larger tar "logs", submerged sheets, large lumps, tar balls that sometimes reformed into oil slicks, and a "slurry" composed of finely divided organic matter and small oil droplets (Fingas *et al.* 2006, Hollebone *et al.* 2011).These aggregates also exhibited a multitude of behaviours including submergence, neutral buoyancy, and resurfacing (Fingas *et al.* 2006). Laboratory analyses concluded that the variety of aggregates were formed as a result of uptake of a variety of extraneous materials contacted while flowing over land and in the water including sand, coal, grass, insects, and sediment (Fingas *et al.* 2006). In addition, it is thought that density changes that resulted in the resurfacing of oil were likely attributable to the loss of sediment or loss of heavily sedimented portions of the oil aggregates (Fingas *et al.* 2006).

No dispersions of oil in water were observed in the lake, and no mousse formation was reported in the three years following the spill (Hollebone *et al.* 2011). Rather, the oil formed tar balls and other aggregates, with density-dependent behaviour. Most of the tar balls remained in relatively shallow water, and particularly became associated with reed beds that represented almost 50% of the shoreline habitat (Sergy pers. comm. in Foght 2006).

Chemically, the Heavy Fuel Oil 7102 was primarily composed of saturated hydrocarbons. It also contained a high content of aromatic hydrocarbons (48%) and had high PAH content (6.04%). The PAHs were predominantly alkylated naphthalenes, with smaller amounts of alkylated phenanthrene and fluorene homologs. The oil contained relatively little 4-ring or 5-ring PAHs, and no benzene, toluene, ethylbenzene or xylenes (BTEX) were detected (Hollebone *et al.* 2011). As a result, the spilled oil did not exhibit rapid initial weathering due to evaporation of volatiles, and rapid dissolution of the relatively water soluble BTEX compounds into the surface water was not an issue. In the longer term, the HFO 7102 was observed to undergo weathering and biodegradation, but at a relatively slow rate due to the largely recalcitrant nature of the oil. The presentation of the oil in tar balls (with limited surface area and relatively high internal volume) is also likely to retard biodegradation. Tar balls having a relatively weathered outer "skin" and relatively fresh product inside have often been observed.

Notwithstanding the initial distribution of oil on the water surface and tar balls in near-shore areas, monitoring of water quality in the lake found few indications of hydrocarbon contamination. Overall, the water in the open water area of the lake was reported not to be contaminated with spilled hydrocarbons or associated metals (Anderson 2006). This is consistent with the absence of BTEX components from the spilled oil, and the relatively low solubility in water of PAHs. Similarly, sediments beneath the open water portions of Wabamun Lake were reported not to have been contaminated with petroleum hydrocarbons, and to be similar in quality to concentrations measured shortly before the spill, or in 2002 (Anderson 2006). Conversely, the Wabamun Watershed Management Council published a report stating that "some PAH readings in Wabamun Lake exceeded human health toxicity guidelines just after the CN oil spill but have since reduced below guidelines" (Aldridge undated). It is not clear where these PAH readings were taken, but it is reasonable to assume that samples taken in near-shore areas could have presented in this manner. Much of the oil became entrained in the abundant reed beds (*Schoenoplectus tabernaemontani)* in the eastern basin of the lake. As such, clean-up activities included cutting of the vegetation and vacuum removal of submerged tar balls entrained in the reed bed detritus (Wernick *et al.* 2009). A two year study was conducted to assess regrowth. The study found that exposure to the oil, which was spilled in the late growing season, did not cause large-scale changes to these emergent plant communities (Wernick *et al.* 2009). Physical factors such as clean-up activities and vegetation management appeared to be responsible for reduced regrowth observed at some locations. Overall, however, post-spill measures of productivity (vegetated transect length, total cover, and biomass) were within the variability of pre-spill data collected in 2001.

Although some dead fish were observed along the shoreline after the spill, these numbers were within the natural range expected and Alberta Sustainable Resource Development determined that the oil spill had no short-term effect on fish (TSBC 2007). Three months after the spill (November 2005), DeBruyn *et al.* (2007) assessed deformities in lake whitefish larvae *(Coregonus clupeaformis)* incubated *in situ* in shallow water habitat in areas of the lake that were considered to be either oil-exposed, or not exposed and suitable as reference locations. The lake had been subjected to PAH contamination from various sources prior to the oil spill (*e.g.,* coal mines, coal-fired power plants, marinas, recreational boat use) for many years. Other workers (Schindler *et al.* 2004) had reported that lake whitefish had not reproduced successfully in the lake for several years prior to the derailment. DeBruyn *et al.* (2007) found complete mortality of lake whitefish eggs at one exposure site and one reference site in the lake. High egg mortality (60% to 70%) was also observed at the remaining one exposure and one reference site. While overall rates of deformity were similar at these two sites, the deformities exhibited at the oil-exposed site were judged to be more severe than those at the reference site.

Wabamun Lake is one of nine lakes in Alberta that was found to support western grebe colonies in 2006 (Kemper *et al.* 2008). The Alberta population is estimated at between 10,000 and 11,000 birds, representing approximately 10% of the North American population. With between 100 and 500 nests, the Wabamun Lake colony is considered to be regionally important (Kemper *et al.* 2008). From 2001 to 2005, western grebes at Wabamun Lake nested in one main colony (Rich's Point), and the lowest reported number of nests was 243 in 2005. Following completion of nesting that year, the oil spill occurred, killing an estimated 333 western grebes (about 69% of the adult population). A wildlife recovery centre set up immediately after the spill recovered more than 530 oiled birds within five days after the spill; 156 were either dead or euthanized (TSBC 2007). The following summer, the release of submerged oil resulted in the oiling of additional waterfowl (TSBC 2007). In 2006, western grebes returned to nest at Rich's Point, and in addition formed a second colony at the Ascot Beach reed bed. Together, the two sites contained 456 nests in 2006 (Kemper *et al.* 2008).

6.2.2.3. East Walker River Oil Spill

On December 30, 2000, a tanker truck overturned on California State Route 182, resulting in the release of approximately 13.66 m^3 (3,608 gallons) of heavy fuel oil. The oil was described as comprising an equal mixture of desulfurized gas oil and PS 1500 Topped Crude (Reiter *et al.* 2002). In several publications, the oil is also described as a Bunker "C" fuel oil (No. 6 fuel oil). The oil was dense, tarry, and had to be warm in order for it to flow. The majority of the oil entered the East Walker River and formed an oil slick that flowed along the surface, visibly oiling approximately 16 km of river habitat (East Walker River Trustee Council [EWRTC] 2009).

The East Walker River is a steep gradient (1.26%), medium-sized stream located several kilometres below the Bridgeport Reservoir. Flows in the river are subject to regulation at the reservoir outlet. During the winter, the reservoir operates in storage mode, and therefore flows in the river are relatively low (a minimum flow of 20 cubic feet per second). During the spill response activity, a variance was obtained to allow flows of 10 to 15 cubic feet per second, although this resulted in the formation of anchor ice in the stream bed during cold periods, and may have caused secondary damage to fish, fish eggs, and benthic invertebrates. Fish species present below the reservoir include rainbow trout, mountain whitefish, Lahontan redside, Lahontan speckled dace, Tahoe and mountain sucker, tui chub, common carp, Paiute sculpin and brown trout (EWRTC 2009).

Low ambient temperatures, as well as the recalcitrant nature of the spilled oil, resulted in a low rate of weathering, and the formation of tar balls that settled on the riverbed (Higgins 2002). Degradation of the tar balls was delayed until the stream warmed up the following spring (Higgins 2002). Although visible oiling was limited to approximately 16 km of river, approximately 24 km of the river was judged to be affected by the spill (EWRTC 2009).

During the initial response, one Virginia Rail (*Rallus limicola*), two American Dippers (*Cinclus mexicanus*), one American mink (*Mustela vison*), six beavers (*Castor canadensis*), and approximately 21 fish, predominantly mountain whitefish (*Prosopium williamsoni*), were found dead within the first 16 km of the spill site (EWRTC 2009). In addition, one Common Merganser (*Mergus merganser*), one Great Blue Heron (*Ardea herodias*), one Bald Eagle (*Haliaeetus leucocephalus*) and an unspecified number of Canada geese (*Branta canadensis*) were observed alive but oiled (EWRTC 2009; Hampton *et al.* 2002). Owing to the low probability of finding dead wildlife, it was judged that nearly all of the birds and mammals that regularly came in contact with the water within the first 16 km of the spill zone were likely killed as a result of contacting the oil (EWRTC 2009).

Following the spill, river water sampling in January (one sample recording 4.9 µg TPAH/L and another recording 1.4 µg TPAH/L) revealed TPAH concentrations that were greater than the lethal toxicity thresholds for developmental effects on fish embryos. The remaining sample locations and dates showed concentrations lower than 1 µg/L. By May, 2001, the highest reported concentration in water was 0.035 µg TPAH/L (Higgins 2002).

For sediment, measured TPAH concentrations were greater than toxicity thresholds within three months after the spill, but were below levels of concern within five months. Hydrocarbon concentrations measured in sediment spiked upwards in March, 2001, possibly as a result of the residual oil in sediment becoming more fluid with increasing ambient temperatures (Higgins 2002). The highest reported sediment TPAH concentrations occurred in March, 2001, with values of 1.3 to 4.6 mg TPAH/kg sediment reported. By May, 2001, the highest reported concentration was 1.7 mg TPAH/kg, and most results were less than 0.1 mg TPAH/kg sediment.

Fish surveys conducted in 2001 by the California Department of Fish and Game and the Nevada Division of Wildlife showed a reduction of juvenile age classes and recruitment of rainbow trout (Hampton *et al.* 2002). However, as previously mentioned, the spill response required lower than normal water flows for safety and to slow downstream transport of the oil. The lower flows, in combination with exceptionally cold temperatures, resulted in the formation of anchor ice and a higher than normal winter fish kill (Hampton *et al.* 2002). Effects on the fish community, therefore, may have reflected either or both of the stresses imposed by oiling and lower than normal water levels with concomitant formation of anchor ice in the stream bed.

PAH concentrations were measured in fish tissues; concentrations were highest in suckers, which are bottom-feeding fish highly exposed to sediments (Higgins 2002). One sample reported a TPAH concentration in sucker (whole body) of 2.6 mg/kg, but all other samples reported values of less than 1 mg/kg. It was concluded that bioaccumulation factors (comparing concentrations in fish tissue to those in sediment) were indicative of low rates of uptake and retention of PAHs by fish in the East Walker river, in part due to the ability of fish to rapidly metabolize and excrete PAHs.

Benthic macroinvertebrates were surveyed by the California Department of Fish and Game to quantify the effects of the spill to aquatic biota. Results were interpreted as showing a 79% and 65% loss in abundance in January and March 2001, respectively, indicating that benthic invertebrates were affected by the spill (Hampton *et al.* 2002). However, the qualitative sampling methodology makes interpretation speculative at best, and decisions taken during data management (such as the exclusion of visibly “oiled” benthic invertebrates from the analysis on the assumption that they must have been dead at the time of collection) are questionable, considering that oiling of these organisms could have occurred as a consequence of the sampling event. Considering the cumulative number of taxa recovered, the cumulative number of Ephemeroptera, Trichoptera and Plecoptera (EPT taxa), the sensitive EPT index, and the Shannon Diversity, which show no compelling differences between upstream and downstream locations, it is difficult to interpret the results as showing impairment in the areas downstream of the spill. The benthic community would also have been subject to the same confounding influence of low stream flow and anchor ice formation as the fish community.

The East Walker River Trustee Council (2009) quantified the effects of the spill with respect to degree, duration and geographic area. The affected area was deemed to be limited to 24 km of stream, and the initial degree of injury was deemed to be 75% of resource services. The benthic community was considered to have recovered within one to two years of the accident. The Trustees estimated that full recovery of all resources from the spill would occur after five years.

6.2.2.4. Pine River Oil Spill

On August 1, 2000, a pipeline ruptured releasing approximately 985 m^3 of light crude oil, of which an estimated 450 m^3 entered into the Pine River approximately 110 km upstream of Chetwynd, British Columbia (BC MOE 2013b, Bustard and Miles 2011). The river was flowing at a low stage at the time of the spill (approximately 161 m^3/s measured at a station 160 km downstream, as compared to flow rates above 900 m^3/s during late spring and early summer). The Pine River has a gradient of approximately 0.225% in the first 40 km downstream from the spill location, becoming moderate (0.1%) farther downstream.

Clean-up efforts over 2 months recovered most of the oil; however, despite the effective recovery action, approximately 80 m^3 of the oil, with an uncertainty range of 48-113 m^3 remained unaccounted for (BC MOE 2013b, Goldberg 2011). Most of this unaccounted oil was considered likely to be located in river sediments, or trapped in woody debris dams within the river. Clean-up activities included the use of berms and removal of woody debris jams (BC MOE 2000a; Goldberg 2011). Oil that had "beaded" (become entrained) in the cold water escaped the first containment system placed 22 km downstream of the spill location, resulting in another berm being set up a further 30 km downstream (BC MOE 2000a).

An angling closure was implemented on the Pine River following the spill (BC MOE 2000b). Residents of the Pine River were advised by the District of Chetwynd not to use water directly from the river (BC MOE 2000a). Monitoring was implemented on the river, and it subsequently became necessary to temporarily close the water intake at the town of Chetwynd.

Acute effects included direct mortality to fish. Approximately 1,600 including but not limited to mountain whitefish, Arctic grayling, bull trout and rainbow trout, were collected along a 30 km stretch of the river (Bustard and Miles 2011, Goldberg 2011). The estimated numbers of dead fish varied widely, with values of 15,000 to 20,100 over a 30 km river reach (Alpine Environmental and EBA Engineering 2001 in Goldberg 2011) to 25,000 to 250,000 over a 50 km river reach (Bacante 2000 in Goldberg 2011). The killed fish represented approximately 50% to 70% of the fish in the first 30 km downstream from the spill site (Alpine Environmental and EBA Engineering 2001 in Bustard and Miles 2011).

The acute effects of spilled oil on fish in the river lasted only a short time, with water quality in the Pine River returning to pre-spill conditions less than three weeks after the spill (de Pennart *et al.* 2004). Fish were reported to be returning to the main stem of the river from smaller streams away from the main channel within two weeks of the spill (BC MOE 2000b). The Pine River downstream of the spill site functions primarily as rearing habitat for fish, with most spawning and juvenile habitat occurring in tributary streams (Bustard and Miles 2011).

Snorkel surveys were consulted to evaluate the effects of the spill and recovery of the fish community in the river, based on surveys taken both before and after the spill, within an approximately 50 km reach of river most likely to have been affected (Goldberg 2011). Fish were less abundant in 2000 than they had been in 1993 (164 vs. 259 observed fish/km). However, surveys completed in 2005, 2006 and 2007 showed recovery to levels equal to or greater than in 1993 (Goldberg 2011).

Owing to the deposition of hydrocarbons in the river sediments, effects on benthic invertebrates were investigated as a means of evaluating biological effects (de Pennart *et al.* 2004). Semi-permeable membrane devices were used to monitor very low concentrations of PAHs in the river water in 2000 and 2001. Values reported upstream of the spill site were approximately 0.01 µg/L as total alklylated PAH, of which a considerable portion was methylnaphthalene. Concentrations measured in water downstream of the spill location in 2000 were all less than 1 µg TPAH/L, averaging around 0.1 µg TPAH/L. Concentrations measured during 2001 were approximately one order of magnitude lower than concentrations measured in 2000 (de Pennart *et al.* 2004). The commonly accepted benchmark for effects of TPAH on sensitive life stages of fish is 1 µg TPAH/L. Hydrocarbon concentrations in sediments up to 26 km downstream of the spill steadily decreased between one and two years after the spill (de Pennart *et al.* 2004). Beyond this point, contamination not related to the spill appeared to be entering the river from side streams. The collection of benthic invertebrate samples in the Pine River in 2000 showed a depletion of all guilds downstream of the spill site. In 2001, benthic populations had partially recovered in the most affected areas. No relationship was observed between sediment hydrocarbon concentrations and benthic community structure in a subsequent survey during 2003, indicating a recovery of the system (de Pennart *et al.* 2004).

A golden eagle and a hooded merganser were found oiled after the spill; the eagle was successfully released but the hooded merganser died in the wildlife rehabilitation centre (BC MOE 2000b). No other birds or mammals were found by staff of the BC Ministry of Environment, Lands and Parks despite daily walkover of the river. There were, however, other reports that some beaver, otter and mink were affected (BC MOE 2000b).

Removal of oiled woody debris and log jams as part of the oil spill recovery effort was reported to result in substantial long-term effects on the Pine River and associated riparian and instream habitat (Bustard and Miles 2011). Replacement structures were constructed, but the river shifted course and bank erosion resulted in a straighter, wider and less complex river channel (Bustard and Miles 2011).

6.2.2.5. Yellowstone River Oil Spill

On July 1, 2011, flood conditions in the Yellowstone River resulted in the rupture of the ExxonMobil Silvertip Pipeline carrying medium sour crude oil near Laurel, Montana. Riverbed erosion had exposed the 12 inch pipeline beneath the crossing, and debris caught on the washed-out pipeline caused excessive stress, resulting in a clean break. The failure was detected at the pipeline control centre, and the line was shut down within 10 minutes (United States Department of Transportation [USDOT] 2012). Approximately 240 m^3 of crude oil (1,509 barrels) was released into the Yellowstone River (USDOT 2012). The affected reach of the Yellowstone River has an average gradient of 0.17%.

High flood flows carried the oil downstream and prevented it from settling on the river bottom. As water levels receded, oil settled in shallow areas and on flooded riverbanks. A pocket of emulsified oil was found approximately 130 km downstream (USEPA 2011b) but the majority of the oil spill effects were observed within 32 km of the spill location (USEPA 2011c).

The crude oil chemistry was measured on both fresh and weathered samples. The fresh oil was described as a medium weight sour crude (containing 2.94% sulphur, most likely as hydrogen sulphide). Volatile organic compounds such as benzene (142 mg/kg), toluene (1,060 mg/kg) and total xylenes (2,530 mg/kg) were present at levels expected in raw crude. Diesel range hydrocarbons were found at 369,000 mg/kg, and oil range hydrocarbons were found at 136,000 mg/kg. Total extractable hydrocarbon was 461,000 mg/kg. Metals analysis found only very low concentrations of iron, nickel and vanadium that were considered unlikely to pose any threat to human health or the environment (USEPA 2011a). Samples of slightly weathered oil collected four days after the release no longer contained detectable benzene, toluene or total xylenes, and all of the lighter aliphatic and semi-volatile constituents were reported to have been weathered (USEPA 2011a).

Surface water samples collected in the days after the spill showed that there were no petroleum-related compounds in the water, which was expected given the high flow conditions in the river (USEPA 2011d), and the rapid initial weathering of the oil. As of November 9, 2011, surface water samples from 164 locations and sediment samples from 146 locations were collected by the USEPA, Montana Department of Environmental Quality and ExxonMobil. With few exceptions, all samples were "non-detect" or below applicable (likely human health) standards or screening levels for petroleum hydrocarbons (Montana Department of Environmental Quality [MDEQ] 2013).

Operators of downstream public drinking water systems which drew water from the river were notified of the spill. Monitoring and testing of the water supply systems did not identify any exceedances of drinking water standards (USEPA 2011d). Similarly, while a precautionary fish consumption advisory was issued after the spill (Montana Fish, Wildlife and Parks 2011a), testing of fish tissue samples from the river did not identify any detection of petroleum hydrocarbon constituents in fish fillet, and only traces of hydrocarbons in organs of fish (Montana Fish, Wildlife and Parks 2011b).

The Montana Department of Environmental Quality described the oiling along the river as "varied and inconsistent". Crude oil effects were heaviest (as shoreline oiling or overbank oiling) immediately downstream of the spill site (MDEQ 2012). According to the USEPA (2011b), oiled wildlife observed or captured included 4 toads, 2 garter snakes, 2 yellow warblers, 1 Cooper's hawk, 6 Canada geese, 3 mallards, 6 common mergansers, 1 pelican, 1 great blue heron, 1 American robin, 2 bald eagles, an unknown raptor and 1 white-tailed deer. There were no reports of dead fish.

Clean-up activities ended on November 8, 2011 and the site was transitioned from emergency clean-up into long-term monitoring, assessment and reclamation (MDEQ 2012).

6.2.2.6. OSSA II Oil Spill

On January 30, 2000, an estimated 4,611 m^3 of mixed heavy crude oil and diluent (variously described as a kerosene range product, straight run condensate or straight run naphtha) was released from the OSSA II pipeline at the Rio Desaguadero river crossing in Bolivia (Lee *et al.* 2001, 2002, Owens and Henshaw 2002). Fresh oil collected from the pipeline had a relatively low density of approximately 0.8 g/mL, and a correspondingly low viscosity, due to the presence of the diluent (Lee *et al.* 2002). The spill occurred on the rising limb of a peak flood condition (with peak flows occurring on February 3, 2000, Owens and Henshaw 2002). Due to the very high river flow and water velocity conditions (on the order of 2.5 m/s or greater, Henshaw *et al.* 2001), oil was found up to 370 km downstream from the spill location. Altogether some 400 km of river bank, meander floodplain, irrigation ditch, and low-lying floodplains was oiled (Owens and Henshaw 2002). For the most part the surface oil was deposited in strips, generally 1 to 2 m wide and up to 2 to 3 cm thick. Many sections of river bank had a horizontal line of oil (a bathtub ring) indicating the water level at the time the oil was deposited or stranded (Owens and Henshaw 2002).

The Rio Desaguadero basin is described by Henshaw *et al.* (2001) as a high-altitude desert with elevations on the order of 3,750 m. Most of the annual rainfall occurs during the December to March summer period. The river originates at the regulated outlet of Lake Titicaca (elevation 3,815 m), and flows approximately 350 km to feed Lagos Uru-Uru and Poopó (elevation 3,685 m). The waters of the Rio Desaguadero are brackish, having a salinity of approximately 1.5‰ (Lee *et al.* 2002). Although the waters entering the river from Lake Titicaca have low suspended sediment concentration, there is a high suspended load input from the Rio Mauri tributary, a few kilometres upstream from the spill location. The actual suspended sediment load at the time of the oil spill appear to be unknown, but high water velocities, combined with a shallow riverbed created strong turbulence throughout the water column, and standing waves and boils were observed at the water surface.

High flows resulted in turbulent flow conditions, under which some of the oil would have been transported downstream on the surface, and some would have been entrained in the water column, likely as dispersed droplets (Lee *et al.* 2002). A budget of the fate of the oil indicated that the loss of oil due to evaporation, dissolution and other weathering and degradation processes was on the order of 60% of the total amount spilled (Douglas *et al.* 2002), leaving some 1,844 m^3 of weathered oil. Of this, some 1,236 to 1,723 m^3 could not be accounted for in a conventional mass balance. Residual concentrations of hydrocarbons in river sediments were generally not detectable (Henshaw *et al.* 2001). It was concluded, based on additional confirmatory research, that formation of OMAs likely dispersed a large amount of the spilled crude oil, and facilitated its dispersion and biodegradation (Lee *et al.* 2001, 2002).

Testing conducted after the spill using both water from the Rio Desaguadero and diluted seawater, and using suspended sediment derived from the river sediment, showed that OMA formed at all salinity levels tested, although in a salinity-dependent manner. Little OMA was formed below a salinity of approximately 0.3‰, however, OMA readily formed at higher salinity (Lee *et al.* 2001, 2002), with values of 20% to 70% of added oil participating in OMA formation in the laboratory tests. The residual oil also had a relatively high content of polar compounds, and this also may have promoted OMA formation (Henshaw *et al.* 2001). It was concluded that OMA formation occurred in the river immediately after the spill, and hypothesized that OMA formation was effecting in reducing the environmental effects of the spill by promoting widespread dispersion and dilution of the oil in the flood plains and enhancing the natural biodegradation rate of the oil (Lee *et al.* 2002).

The spilled oil appears to have had a total BTEX content of approximately 8,200 mg/kg oil, and a TPAH content of approximately 4,700 mg/kg oil (Douglas *et al.* 2002). The predominant PAHs were alkylated phenanthrenes, naphthalenes and chrysenes. The oil also appears to have weathered very rapidly after release so that river bank samples showed a nearly complete loss of light diluent fractions (including BTEX and the C8 to C15 boiling range). River bank samples were also strongly depleted in PAHs, with virtually all of the naphthalenes lost, as well as a large part of the phenanthrenes. Altogether from 50% to 70% of the total oil, and from 54% to 91% of the TPAH was lost from residual oil samples collected after the spill (Douglas *et al.* 2002). Evaporative loss was identified as the primary mechanism influencing degradation of the spilled oil, with as much as 45% of the oil mass potentially having evaporated. Solubilization and photodegradation were also identified as important loss mechanisms, however, biodegradation was judged not to have been very important as a process reducing the mass of non-dispersed oil (Douglas *et al.* 2002), however, dispersion via the formation of OMA was acknowledged as a factor in the overall mass balance of the oil.

Despite the relatively high BTEX and TPAH content of the fresh oil, biological effects of the oil spill appear to have been modest. Water and sediment samples collected from the river soon after the spill showed no detectable concentrations of hydrocarbons (Henshaw *et al.* 2001), except where oil was clearly deposited along strand lines. Following an initial assessment, and despite repetitive ground and aerial surveys throughout the entire region, very few (on the order of tens) oiled birds were reported in the first days following the spill (Wasson *et al.* 2000 in Owens and Henshaw 2002), and no fish, birds, or other animals were found dead or oiled as a result of the spill by clean-up crews or other field personnel (Henshaw *et al.* 2001, Owens and Henshaw 2002). Testing of the weathered oil showed that it was highly depleted in many of the chemical constituents typically associated with toxicity. Therefore, although there was a large and labour intensive recovery and remedial operation mounted, the short-term conclusion was that ecological damage from the spill was minimal (Henshaw *et al.* 2001).

6.2.2.7. DM 932 Oil Spill

On July 23, 2008, a chemical tanker collided with the DM 932 fuel barge on the Mississippi River in New Orleans, Louisiana. The DM 932, which was carrying a load of 1,587 m^3 of Bunker “C” (No. 6 fuel oil) was split in half by the impact. During subsequent salvage operations some of the oil on the barge was recovered, but it was estimated that approximately 1,070 m^3 of oil was spilled to the river. Most was released at the time of the impact, but the barge also leaked oil continuously over the following two week period (United States Fish & Wildlife Service [USFWS] 2009, Danchuk 2009).

The river was closed to vessel traffic on the day of the spill, from mile marker 98, to the mouth of the shipping channel at Southwest Pass Sea Buoy, a distance of more than 160 km. For the protection of human health there was air monitoring early in the spill, and downstream drinking water intakes were closed. By July 30, all drinking water intakes were reopened (USFWS 2009).

The fuel oil had nearly the same density as water, and although spilled oil was seen floating throughout the response area, it later became clear that some of the oil also sank. A silver sheen covered 90% of the river, reaching 20 to 25 km downstream from the barge within the first six hours (Danchuk 2009). Oil was recovered during routine dredging operations near the Head of Passes (at the mouth of the Delta) on July 28. Observations made during the barge salvage operations (after August 3) indicated that the oil initially sank (presumably by mixing with suspended sediment), then re-surfaced downstream when it encountered turbulent flow. The result was patchy surface oiling throughout the spill area, with unknown amounts or effects of submerged oil (USFWS 2009).

The river fell during the response operations, stranding oil in pools between the river and levees (known as the batture area), on vegetation in the battures, river banks, and structures in the river. Oil recovery efforts focused on these areas, although one of the greatest operational challenges was recovery of oil trapped in riprap on shorelines (USFWS 2009). Approximately 220 km of the shoreline was oiled to varying degrees (Danchuk 2009).

The high viscosity of the oil caused it to persist in the environment, rather than evaporate. The overall mass balance for the oil suggested that 11% was lost to evaporation, 86% of the oil was recovered from water, as oiled sediment, or as oiled debris, and 2.5% of the oil remained unaccounted for in the environment (Danchuk 2009). The oil interacted with suspended sediments forming OSA and small tar balls (Danchuk 2009).

Although the Mississippi River has high suspended sediment loads, and the oil was rich in resins and asphaltenes, formation of OMA may have been limited by a combination of the viscosity of the oil and the low level of turbulent energy in the river, as well as the low salinity in the surface water layer of the river. The Mississippi River at New Orleans can be characterized as a salt wedge estuary, with tidally influenced salt water moving in and out from the Gulf of Mexico at the bottom of the river, and fresher river water riding over the salt wedge to discharge at the mouth of the river. The salt wedge characteristic also has the potential to minimize contact between sinking oil and bed sediment, as sinking Bunker "C" oil, being less dense than the water of the salt wedge, would be expected to gather at the density interface between fresh and salt water. Danchuk (2009) concluded that OMA formation and subsequent oil dispersion could account for between 2% and 5% of the oil spilled from the DM 932 barge.

Recovery teams provided information on the distribution of stranded oil. Almost half of the affected shoreline habitat was described as scrub-shrub, and of this a large fraction was heavily oiled. The vegetation provided abundant opportunity for oil droplets and globules to become absorbed. Riprap also provided opportunities for trapping of oil due to the crevices between rocks. Mud and sand shorelines did not trap much oil, and oil did not penetrate into these substrates due to their water saturation (Danchuk 2009). On the surface of the river, lateral velocity vectors tended to move oil to the outside of bends where the velocities slow, and oil was retained on such shorelines. In addition, wind conditions from the south and southwest forced oil towards south-facing shorelines (Danchuk 2009).

Danchuk (2009) undertook detailed modelling of a range of crude oils in the lower Mississippi River. Oil fate and transport in this environment was described as follows: "As river velocities increase with flow rate, the time oil interacts with the shoreline is minimized. The oil slick elongates, tends to stay in the middle of the channel, and moves quickly past shorelines. However, if oil does reach the shoreline, it most likely will be retained due to the presence of vegetation at high flow rates; vegetation will retain oil for long periods of time due in part to the adhesiveness of the oil to organics, the large surface area exposed by leaves and stems, and the characteristic low elevation within vegetated areas behind the natural levees or rip rap. Thus, river geometry becomes an important factor as [a] way for oil to reach the shoreline. As current vectors change direction around the bend, oil parcels are moved towards the outside where velocities decrease and heavy oiling can result … At low and medium discharges, the shoreline type varies substantially down river. The presence of mud shorelines and sand bars, both with short re-flotation half-lives, encourage the distribution of oil to shift downstream over time. Re-flotation is a significant transport process in the Lower Mississippi River …".

Recorded observations of oiled wildlife were mostly (96%) birds, although some mammals and reptiles were also reported as oiled. No information is available about possible fish kills, if indeed such kills occurred. However, the characteristics of the oil (viscous, and lacking a large component of monoaromatic or low-boiling aliphatic constituents) make acute mortality of fish an unlikely scenario.

The first documented bird mortality was on July 29, a completely oiled wood duck found about 40 km downstream from the spill location. Dozens of oiled birds were seen in areas heavily affected, although most of these were wading birds that were capable of flying and could not be captured. The total number of oiled birds observed was 813. Wading birds were seen oiled most frequently (about twenty percent of these were oiled), but waterfowl had the highest rates of oiling (about forty percent being oiled). In addition, 26 mammals and 13 reptiles were observed oiled (USFWS 2009).

Most of the oil spill clean-up was complete by early October, 2008; only a small team remained as of early November 2008 to manage the final inspection and shoreline clean-up sign-off process (NOAA 2008).

6.2.2.8. Gainford Trials of Diluted Bitumen Behaviour on Marine Waters

In June 2012, Trans Mountain commissioned O'Brien's Response Management (now Witt O'Brien's) to organize a study on diluted bitumen (dilbit) products. The purpose of the requested study was to further the knowledge of dilbit in general and, more specifically, to investigate the behaviour of dilbit when spilled into a marine environment. The study findings are documented in a Technical Report (Witt O'Brien's *et al.* 2013).

The overall study goal was to better understand and assess oil behavior, weathering, and oil spill response (OSR) countermeasures for spilled dilbit crude in a controlled simulated condition similar to the potential receiving environment of Burrard Inlet. The objectives of the applied research were multifaceted. One objective was to better understand and characterize the changes in physical and chemical properties of dilbit in an estuarine simulated condition over a 10-day period. Another objective of the meso-scale trials was to determine efficiency and effectiveness of dispersant, in-situ burning, and shoreline cleaning agents as potential countermeasures for various stages of weathered oil. The third part of the study was to test various types of oil spill response equipment under similar weathering conditions and to assess their efficiencies over time. Air sampling and monitoring also was included with the objective of providing measured emission rates that could be used to ground-truth numerical estimates modeled for accidental release/hazard assessment.

Both Access Western Blend (AWB) and Cold Lake Winter Blend (CLWB) dilbits exhibited properties typical of a heavy, "conventional" crude oil. In no instance was any oil observed to have sunk after being allowed to spread on the water surface, under static or agitated conditions. Visual observations of the surface of the oil in the various tanks showed that a crust, or armoring, formed as the oil weathered. In some instances, especially noted under static conditions, the lighter components of the oil came out of solution and bubbles formed within the slick. These bubbles rose to the surface and, in places, became trapped under the crusted layer. Weathered oil densities approached, and in several instances, exceeded that of freshwater but not that used to represent Burrard Inlet brackish water. Visual observations were made of weathered oil overwashing within tanks with agitation; however, the weathered oil did not submerge or sink in the tanks.

Chemical analyses of the weathered oils and of the water column showed that concentrations of BTEX diminished rapidly within 48 hours and that TPH in the water column only exceeded the detection limit (2 mg/L) during the first 48 hours in tanks with moderate surface agitation, despite the artificial confinement imposed by tanks relative to what may be expected in an open, natural setting.

Countermeasures tested included dispersant application, burning, and shoreline cleaners. The visual observations of the dispersant test revealed that Corexit 9500 was marginally effective on 6 hour weathered oil and not particularly effective for more weathered Cold Lake Winter Blend dilbit. The early test burn (6 hour weathered CLWB dilbit) was effective with a sustained burn of 2 L of oil lasting for more than 2 minutes with approximately 70% of oil removed through burning. Additional burn testing showed approximately 50% of 24 hour weathered oil was removed, but only after sustained effort to ignite. The 72 hour weathered oil was not successfully ignited. Tests with Corexit 9580 found the cleaning agent to be effective on oils weathered up to five days. Test observations noted that the time oil weathers on water before being placed on the tile was less important than the time the weathered oil was exposed to air.

Some key conclusions were as follows ((Witt O'Brien's *et al.* 2013):

- There was no two-phase separation into bitumen and diluent
- Off-gassing of light-ends has safety implications for responders and the public during the initial hours of exposure to a release, as is the case for most oil spills
- Both AWB and CLWB dilbits remained floating on brackish water during the 10 days of weathering
- Both AWB and CLWB weathered dilbits surpassed viscosities of 10,000 cSt within 48 hours and exhibited strong tendencies to form a more continuous thick mat rather than a thin sheen on water which, with continued weathering and agitation, can be expected to produce tar balls.

6.2.2.9. Proposed Enbridge Northern Gateway Project

The Enbridge Northern Gateway Pipeline project proposes to build and operate two 1,175 km pipelines between Bruderheim, Alberta and a marine terminal at Kitimat, British Columbia. One pipeline will carry diluted bitumen or synthetic oil for export, and the other will import condensate to be used as a diluent.

As part of its application to the National Energy Board for approval to construct and operate the pipelines, Enbridge quantitatively assessed the risk of accidental releases along the pipeline corridor. In particular, the Technical Data Report, *Ecological and Human Health Risk Assessment for Pipeline Spills* (EHHRA; Stantec *et al.* 2012), assesses the acute and chronic risks to ecological receptors resulting from full-bore pipeline accident scenarios into four different rivers, representing a range of hydrological and geographic settings along the pipeline corridor.

The EHHRA evaluated hypothetical releases of three typical hydrocarbon products proposed to be carried by the twin pipelines (*i.e.,* diluted bitumen, synthetic oil and condensate). The focus of the EHHRA was to predict the range of potential effects based on direct releases to the aquatic environment in a total of four representative watercourses along the pipeline corridor. Scenarios were evaluated for a range of site-specific release volumes, and seasonal variations corresponding to flow rates (low and high), wind speeds and ambient temperatures.

The selected release locations considered in the EHHRA were based on the following criteria:

- Locations where Aboriginal peoples or the general public had expressed specific concerns about spills
- Locations where a spill could affect traditional use, other human uses or infrastructure (*e.g.,* potable water intakes or treatment facilities)
- Locations which reflect environmentally sensitive resources (*e.g.,* spawning grounds for salmon)
- Locations where the maximum volume of a spill could potentially enter a watercourse
- Locations which reflect a range of watercourse types
- Locations where there is limited access to the corridor, thereby increasing emergency response times

Based on these criteria, four representative watercourses were selected for site-specific modelling and assessment including:

- Chickadee Creek: a low gradient interior river tributary discharging to the Athabasca River (gradient 0.13%) located up-gradient from a populated centre within the Southern Alberta Uplands region
- Crooked River: a low gradient interior river with wetlands, entering a lake system within the Interior Plateau Region of British Columbia
- Morice River: a moderate gradient (0.165%) river system along the western boundary of the Interior Plateau Region of British Columbia
- Kitimat River near Hunter Creek: a high gradient (0.43%) coastal tributary discharging to a large watercourse with sensitive fisheries resources, downstream human occupation, and discharging to the Kitimat River estuary

The ERA component of the study evaluated potential short term (acute) effects as well as longer term (chronic effects) of hydrocarbon spills to these river systems. A total of 24 unique release scenarios were evaluated (3 hydrocarbon products, 4 river locations, 2 season variations). These analyses represent extreme spill scenarios based on the assumption of a full-bore rupture of a pipeline, with maximum draw-down of oil between valve locations being released to a nearby watercourse. Release volumes were specific to the release location. Hypothetical release volumes for the larger oil pipeline (carrying diluted bitumen or synthetic oil) ranged from 1,293 m^3 to 3,321 m^3. No credit was taken for possible mitigation of the spread of oil or recovery of spilled oil during the acute phase. The spill scenarios were therefore conservative with respect to both the physical extent of oiling and the hydrocarbon concentrations that could be present in the environment.

The ERA component of the report included separate assessments of the following:

- Acute (short term) effects on fish, other aquatic receptors and wildlife receptors, based on environmental fate and transport modelling of the spill event(s).
- Chronic (medium to long term) effects on the most sensitive aquatic receptors including the potential effects on developing fish embryos, such as salmonid eggs and spawning gravels, based on modelling of water and sediment quality following the initial spill event. Chronic risks to wildlife receptors were also evaluated, considering further modelling and distribution of hydrocarbons in water, sediment, fish, shoreline soils, vegetation, invertebrates and game animals.

The acute effects assessment utilized physical fate modelling to simulate the downstream transport of the spilled hydrocarbons over time, and of the partitioning of the products to various environmental media downstream of the release point including air, water, sediment and shoreline soil.

Acute effects for aquatic organisms were evaluated using two acute toxicity endpoints, assuming the toxicity resulting from exposure to dissolved aromatics is primarily due to the PAHs and substituted benzenes: the LC_{50} selected for average sensitivity species was 50 µg TPAH/L) and 5 µg TPAH/L for sensitive species (the 2.5^{th} percentile) (French McCay 2002).

A slick thickness of 10 µm was assumed as a threshold thickness for oiling mortality for wildlife, given the sizes of the water bodies evaluated and likely exposure times of animals such as muskrat, beaver, mink, otter, reptiles and waterfowl (French McCay 2009). Threshold effects for emergent vegetation was set at a slick thickness of >100 µm (French McCay 2009).

The chronic effects assessment evaluated a number of specific COPC including trace metals, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, alkylated PAH, pentachlorophenol and phenol, volatile organic compounds and alkylated mono aromatic hydrocarbons. Estimated exposure point concentrations (EPC) were calculated for various environmental media at time points of four weeks and one to two years following the end of the acute phase of each oil spill.

Potential risks were evaluated for a range of wildlife receptors including grizzly bear, mink, moose, muskrat, river otter, woodland caribou, bald eagle, belted kingfisher, Canada goose, herring gull, great blue heron, mallard, spotted sandpiper, tree swallow. Chronic effects to fish eggs and embryos were evaluated based on effect concentrations of 1 µg/L as total PAH (TPAH).

For the purposes of this discussion, the predicted effects from releases of diluted bitumen and synthetic oil were carried forward, as these are both relevant to the TMEP application.

Summary of Oil Spill Modelling Results from Enbridge Northern Gateway Project

The predicted mass balances for each release scenario are summarized in Table 6.12. Owing to the nature of the modelling, little of the oil remained on the surface of the water at the end of the model runs. Therefore, two cases stand out, both arising at Crooked River under high flow conditions. In these scenarios, high flow resulted in oil being advected downstream to Davie Lake, where it remained on the surface of the water for an extended period of time. Lakes or large reservoirs can act as “catchers” for spilled oil, and this accounts for the high percentage of the spilled oil remaining on the water surface in those scenarios.

Atmospheric losses of hydrocarbon ranged from 2.1% to 16.8% of the spilled oil, and are a function of the composition of the oil (*i.e.,* the amount of volatile hydrocarbons), as well as other fates of the oil that would prevent rapid evaporation of oil from the water surface. Examples of those other fates would include entrainment in the water column and sedimentation.

Dispersion of oil into the water column ranged from 0% to 80.1% of the spilled oil, and was a function of several factors including the viscosity of the oil (less viscous oil is more readily entrained and dispersed into the water column as small droplets that can remain submerged), as well as the amount of energy acting on the floating oil in the form of water turbulence, or wind shear. Thus, more oil is likely to become dispersed in the water column at high flow (*i.e.,* under more turbulent flow conditions), or in response to episodic or seasonal weather that has higher wind speeds.

Sedimentation of oil was also highly variable, ranging from 0% to 81.8% of the spilled oil. Any oil can become trapped in sediments under the right circumstances. However, sedimentation was an important fate for both the diluted bitumen and the synthetic oil, representing 25% to 50% of the spilled oil in most simulated cases. Factors that would normally lead to enhanced sedimentation of oil would include the initial dispersion of oil into the water and contact between oil droplets and suspended sediment or sand particles, as well as initial stranding of oil in contact with shoreline sediment, followed by remobilization of that oil by rising water levels, so that the oil/particulate aggregate re-enters the water column and has the potential to sink.

Stranding of oil accounted for 2.2% to 88.7% of the spilled oil. Stranding along shorelines is usually an important part of the mass balance for oil spilled in inland waterways. The diluted bitumen was more prone to stranding than the synthetic oil, in part due to its higher viscosity, which caused it to float on the surface until it encountered a shoreline, and upon contacting the shoreline having a tendency to form thicker coatings. In contrast, more of the synthetic oil tended to became entrained into the water column due to its lower viscosity, limiting the potential for the synthetic oil to strand.

Decay accounted for between 1.7% and 17.2% of the fate of the oil. This fate pathway was based on published microbial degradation rates for spilled crude oil fractions; however, under less than optimal conditions this pathway could also be a negligible fate pathway in the first few days following an oil spill.

To summarize the mass balance modelling results, dispersion into the water column can readily occur if an oil has low viscosity, and if the flow or wind conditions at the time of the spill generate high levels of turbulence. Flow conditions that would create turbulence include both high river slope, and high river flow rate. Once in the water column, hydrocarbons present in oil droplets may dissolve into the water, and the droplets themselves may re-surface, or sink, depending upon their state of weathering, and the potential for contact with mineral particles (silt, sand or gravel) that would increase the aggregate density so that it exceeded that of the water. This OMA would remain suspended in the water column or become part of the riverbed-load, coming to rest in areas with low water velocity. Sedimentation and shoreline stranding are both important fate pathways. Shoreline stranding is more likely to occur when oil remains floating on the surface of the river. However, in order to maintain mass balance, it is important to understand that when conditions are such that a particular oil fate is likely, other oil fates become diminished in importance.

TABLE 6.13 MASS BALANCE FATE OF SPILLED DILUTED BITUMEN AND SYNTHETIC OIL IN FOUR RIVERS, UNDER TWO FLOW CONDITIONS, BASED ON MODELLING CARRIED OUT FOR THE ENBRIDGE NORTHERN GATEWAY PROJECT

Scenario	Surface	Atmosphere	Water Column	Sediment	Ashore	Decay	Exits Last Grid
CA-DB-HQ	0.1%	3.8%	3.4%	15.5%	64.8%	7.8%	4.7%
CA-DB-LQ	0.0%	4.5%	0.0%	0.0%	88.7%	6.7%	0.0%
CR-DB-HQ	21.0%	3.9%	32.4%	4.1%	27.6%	11.1%	0.0%
CR-DB-LQ	0.0%	2.1%	0.0%	81.8%	11.2%	4.8%	0.0%
MR-DB-HQ	0.0%	2.1%	42.0%	23.0%	23.4%	9.5%	46.5%
MR-DB-LQ	0.0%	3.1%	3.9%	51.0%	35.1%	7.0%	0.8%
KR-DB-HQ	0.0%	4.2%	2.3%	15.8%	66.7%	10.7%	0.3%
KR-DB-LQ	0.0%	5.4%	0.2%	31.3%	54.9%	8.2%	0.0%
CA-SO-HQ	0.0%	4.4%	17.3%	52.1%	3.5%	1.7%	21.0%
CA-SO-LQ	0.0%	11.2%	14.1%	63.4%	6.4%	3.2%	1.8%
CR-SO-HQ	10.2%	8.4%	35.0%	33.2%	6.1%	7.5%	0.0%
CR-SO-LQ	0.0%	8.1%	80.1%	0.5%	2.2%	9.0%	0.0%
MR-SO-HQ	0.0%	3.3%	59.9%	26.7%	2.3%	7.8%	58.9%
MR-SO-LQ	0.0%	7.6%	52.3%	22.2%	8.6%	9.2%	52.4%
KR-SO-HQ	0.0%	5.7%	12.1%	49.1%	6.1%	5.6%	21.5%
KR-SO-LQ	0.0%	16.8%	5.7%	20.7%	16.7%	17.2%	22.8%

Chickadee Creek / Athabasca River = CA, Crooked River = CR, Morice River = MR, Kitimat River = KR
Diluted Bitumen = DB; Synthetic Oil = SO
High Flow = HQ; Low Flow = LQ

Source: Stantec *et al.* 2012

Acute Effects to Aquatic Receptors, Vegetation, Birds and Mammals

Acute effects to fish and other aquatic biota from spilled oil were summarized as the area of potential acute toxicity, represented by the summed area with various percent losses due to mortality where organisms are present. The percentage affected of each river section, as well as the distance down river where acute toxic effects could potentially occur, was provided for each hypothetical spill scenario. Acute effects assessments based on sensitive species presence are summarized in Table 6.13.

Effects on sensitive aquatic receptors, either as area affected or as percent of habitat present in the modelled reach, reflect river size, and oil type. Three of the four modelled rivers are rather small, with the Athabasca River being the largest. Large rivers have greater dilution flow, and as a result negative effects on fish and other aquatic life become less likely because the in-stream concentration of dissolved hydrocarbons is lower. The second factor is oil type. Two main considerations relate to oil type, namely the oil composition in terms of the availability of more water soluble hydrocarbons, and the oil viscosity, which affects the potential for the oil to become entrained into the water column as small droplets, accelerating the rate at which those hydrocarbons can dissolve into the water. Direct transfer of MAHs and other water soluble hydrocarbons from an oil slick to the water below is quite limited in the absence of water turbulence and oil entrainment, and oil floating on the water maximizes the opportunity for those hydrocarbons to evaporate instead of dissolving in the water. The conservative nature of the modelling completed also underscores that complete mortality of fish throughout an affected reach following an oil spill is unlikely, although localized mortality can be expected.

TABLE 6.14 ACUTE EFFECTS OF SPILLED OIL ON AQUATIC ECOLOGICAL RECEPTORS IN FOUR RIVERS, UNDER TWO FLOW CONDITIONS, BASED ON MODELLING CARRIED OUT FOR THE ENBRIDGE NORTHERN GATEWAY PROJECT

Scenario	Effects on Sensitive Aquatic Organisms		Effects on Aquatic Plants		Effects on Aquatic Wildlife	
	River Area (km²)	% Affected	Shoreline Length (km)	% Affected	River Area (km²)	% Affected
CA-DB-HQ	0.46	4.74	95.1	38.9	3.99	41.6
CA-DB-LQ	0.024	0.25	69.8	28.5	2.49	25.9
CR-DB-HQ	0.011	12.77	29.3	46	7.0	71
CR-DB-LQ	0.087	100	9.5	14.9	0.065	6.6
MR-DB-HQ	4.45	54.9	83.8	28.2	4.52	57.2
MR-DB-LQ	3.72	45.8	70.6	26.8	2.65	33.5
KR-DB-HQ	3.96	14.7	67.7	18.6	3.14	29
KR-DB-LQ	0.087	0.32	31.5	8.7	1.04	9.6
CA-SO-HQ	3.59	37.2	28.4	11.6	0.04	0.5
CA-SO-LQ	1.31	13.6	55.7	22.8	1.93	20.1
CR-SO-HQ	0.055	66.9	31.8	50	7.0	71
CR-SO-LQ	0.076	92.0	26.1	41.1	3.9	39.5
MR-SO-HQ	6.52	82.2	27.5	9.3	1.62	20.5
MR-SO-LQ	6.96	86.9	108	36.3	3.81	48.2
KR-SO-HQ	15.4	57.0	26.9	7.4	1.4	13
KR-SO-LQ	8.83	32.8	68.1	18.7	2.2	20.3

Chickadee Creek / Athabasca River = CA, Crooked River = CR, Morice River = MR, Kitimat River = KR
Diluted Bitumen = DB; Synthetic Oil = SO
High Flow = HQ; Low Flow = LQ

Source: Stantec *et al.* 2012

Effects on aquatic plants (if present) were forecast to occur and to affect between 7.4% and 50% of the reach. Similar values apply also to aquatic wildlife such as waterfowl and semi-aquatic mammals. These results underscore that while mortality of aquatic plants and wildlife receptors can be expected following an inland oil spill, complete population losses are unlikely to occur, and the survival of some of the potentially affected plants and animals will increase the rate of natural recovery.

Chronic Effects to Aquatic Receptors, Vegetation, Birds and Mammals

Chronic toxicological effects of spilled crude oil were assessed at locations downstream of the four hypothetical spill locations along the pipeline corridor. Ecological risks were based on trajectory modelling of the hydrocarbons in the watercourses as well as fate and weathering modelling to predict what hydrocarbon constituents would be likely to occur at specific areas and specific times after the hypothetical spill. To consider worst-case effects associated with these hypothetical spills, modelling did not take into account containment or removal of spilled hydrocarbons, except to a limited extent that would be associated with shoreline clean-up activities.

Hazard index (HI) and hazard quotient (HQ) values are used to evaluate the potential for negative effects on ecological receptors. Individual HI values are calculated by dividing the exposure point concentration or ingested dose of a particular substance by a specific toxicity reference value. The HI values therefore represent exposure to a unique substance or fraction of hydrocarbons. The HQ values are calculated as the sum of two or more HI values, where the toxicity of two or more individual substances can be considered additive. Since this assumption applies widely to hydrocarbon compounds, it is very common to express the toxicity of hydrocarbon mixtures in terms of HQ values.

Both oil type and river characteristics were found to affect the outcomes of hydrocarbon spills. In particular, the physical dimensions, flow rates, and other characteristics of the rivers where the hydrocarbon spills occur help to explain the outcomes. Chronic effects tended to be more severe in the smaller watercourses (*e.g.,* Chickadee Creek), and also in the slow-moving Crooked River, where organic soils and fine-grained sediments were predicted to trap and retain hydrocarbons. In contrast, little oil was predicted to become entrained into river gravels, and this oil was subject to weathering so that chronic effects were minimal.

Although oiling of shorelines was considered likely to cause acute effects on shoreline plant communities and soil invertebrates, following shoreline clean-up activities, it was predicted that many shoreline plants, particularly perennial plants and shrubs, would quickly regenerate from either surviving root stock or seed stock. Soil invertebrates would also be present in nearby unaffected soils, so that re-colonization of soils could proceed quickly as soils recovered from the chemical effects of oiling. Chronic effects on shoreline soils would also be limited to the areas oiled as the hydrocarbons moved downstream.

It was predicted that fish and benthic invertebrate communities would be subject to toxicity during the acute phase of the hydrocarbon spills. However, after the initial phase of the spill, the expected hydrocarbon concentrations in river water were predicted to decrease substantially, to levels that would not even cause chronic effects to fish or other aquatic life. Similarly, even with the deposition of hydrocarbons to sediment, the average predicted sediment pore water concentrations of hydrocarbons and TPAH were, for the most part, below concentrations likely to cause negative effects to developing fish eggs in the gravel. The primary exception to this generalization was observed in Chickadee Creek, where fine-grained sediments were predicted to create conditions leading to higher hydrocarbon concentrations in sediment pore water, with greater potential for effects on benthic invertebrates or fish eggs. However, it remains that for the gravels most likely to be used by salmonid fish as spawning habitats, the expected average TPAH concentrations in sediment pore water were predicted to quickly fall below benchmarks established to identify the potential for blue sac disease or mortality of developing eggs. As a result of natural weathering processes, it was concluded that conditions harmful to developing fish eggs in gravel substrates could occur for a period of weeks following a major river oil spill, but that concentrations of TPAH would rapidly decline to concentrations below such effects thresholds. The most likely predicted outcome, therefore, was that a portion of the reproductive capacity of a single year-class of fish could be lost, but that recovery would occur in subsequent years.

The wildlife receptors evaluated in the ERA were selected in part to focus on species likely to live in and around rivers, which would be highly exposed to the effects of hydrocarbon spills, and which are of importance to Aboriginal peoples. Comparison of species such as the muskrat and spotted sandpiper with other species having larger ranges and less emphasis on aquatic or riparian habitat (such as grizzly bear or bald eagle) underscored this aspect of the risk assessment study. While local populations of smaller animals such as muskrat or waterfowl could be subject to chronic effects caused by hydrocarbon spills, it is unlikely that individuals of larger and more widely-ranging species such as grizzly bear, bald eagle or ungulates would suffer serious harm from chronic exposure scenarios.

6.2.2.10. Proposed Vancouver Airport Fuel Delivery Project

In 2011, the Vancouver Airport Fuel Facilities Corporation submitted an environmental assessment for a proposed fuel delivery project. As part of the application, oil spill fate and transport modelling was completed for Jet “A” fuel that focussed on the lower Fraser River, between the Port Mann Bridge and the mouth of the Fraser River Delta. In addition, supplemental research was conducted on the characteristics of the Fraser River Delta, its value as migratory bird habitat, and in particular the role of “biofilm” as a food source for migrating Western Sandpiper. These documents are available through the British Columbia Environmental Assessment Office website.

6.2.2.11. Summary of Findings from the Case Studies

The selected case studies provide information on the actual or expected behaviour of diluted bitumen and other heavy oil products in freshwater environments that are relevant or informative to the range of freshwater environments in proximity to the Trans Mountain Expansion Project. It is important to distinguish, however, between the crude oils that will be transported by the proposed pipeline, and the bunker type products that were spilled in some case studies. The proposed pipeline’s tariff conditions require that crude oils shipped will have a density of 0.94 or lower, in addition to specifications for viscosity and other oil properties. Diluents are added to the bitumen to make it conform to the tariff specifications. A bunker type product would not conform to the tariff, and so the scenario of spilled crude oil or diluted bitumen sinking on contact with water is not plausible. Spilled diluted bitumen such as CLWB would initially float, like any other crude oil having a density of 0.94 or lower. Weathering over time would progressively increase the density of spilled CLWB until it approached a density of 1. Testing carried out by Witt O'Brien's *et al.* (2013) on behalf of Trans Mountain found that in some cases the density of weathered CLWB slightly exceeded 1.0, which would lead to sinking behaviour in fresh water. Interactions between the spilled oil and suspended or bed sediments could also increase the density of weathering CLWB, as it could for any crude oil, leading to oil sinking. Notwithstanding this potential for sinking behaviour, the primary fate of spilled diluted bitumen is expected to include weathering (including evaporative loss and dissolution into water) and shoreline stranding, with sinking expected to remain a minor loss pathway.

The case studies were also reviewed to obtain information on the recovery of aquatic and riparian ecosystems, and ecological receptors, following actual oil spills. The review is presented in Appendix C. Notwithstanding that some high profile and extensively researched oil spills, such as the Exxon Valdez oil spill (EVOS) incident, provide evidence for long-term negative effects, delayed recovery, or a failure to recover from a major oil spill on the part of some ecological receptors, the vast majority of oil spills to freshwater environments provide evidence of ecosystem recovery, often in a relatively short period of time. Two key factors serve to differentiate freshwater oil spills from marine spills such as the EVOS. The first is the volume of oil spilled, with the case study oil spills all involving much smaller volumes of oil than were spilled as a result of the EVOS. The second is a relatively intensive level of oil spill clean-up activity being brought to bear on a freshwater ecosystem that is usually well defined. While there are examples of oil spill recovery efforts that cause unintended negative consequences, such as the destabilization of the river channel of the Pine River caused by removal of logjams that had trapped oil, the purpose and objective of oil spill clean-up activity is to recover spilled oil, and to hasten ecosystem recovery, taking a net environmental benefit approach.

Biological effects of oil spills to freshwater environments vary widely in relation to the characteristics of spilled oil, the physical dimensions and other characteristics of the receiving waters, season, and other factors. Based upon the information reviewed in the case studies, these effects are summarized below, according to the general receptor groups.

Aquatic Vegetation

Rivers may not always support important populations of aquatic plants. However, where they occur, floating aquatic plants would be expected to be killed if contacted by an oil slick. Submerged aquatic plants would be less vulnerable, as they would be exposed primarily to dissolved hydrocarbons, and are not considered likely to fall within the most sensitive groups of aquatic biota to such exposure. Emergent aquatic plants would generally be quite tolerant of moderate exposure to floating oil (such that a portion of the stem was oiled). Slow moving rivers with soft sediments, as well as backwaters and riparian wetland areas, are all high value habitats for aquatic plants, and such plants are important as habitat and as a source of food for many wildlife species. Other river types, however, may support very limited aquatic plant populations. Rivers draining mountainous areas in western Canada, where snow and glacial melt water dominates the hydrology, typically fall into this second group. High water levels and flow rates during the summer months may cause erosion and scour in gravel/cobble riverbeds which would damage delicate aquatic plant tissues. High turbidity levels also limit light penetration into the water column, further limiting the habitat quality for aquatic plants. As a result, aquatic plants are not expected to be an important part of the ecological structure of most of the larger rivers crossed or paralleled by the proposed pipeline corridor.

Aquatic Invertebrates

Aquatic invertebrates are evaluated as a group, and as such exhibit a broad range of sensitivity to hydrocarbon exposure. Sensitive species such as stoneflies, mayflies and caddisflies would be expected to respond to dissolved hydrocarbon exposure at levels similar to sensitive fish species, while others are expected to be more tolerant. The case studies show that benthic invertebrate communities are affected by oil spills, but that they recover quickly. Effects on biomass and diversity are observed. A study of unionid clams in the Kalamazoo River also provided evidence of mortality associated with both the oil spill and recovery efforts, although the clam communities did not appear to be extirpated by the spill. With the exception of a few long-lived species such as bivalves, most benthic invertebrates have annual life cycles, and are well adapted for population recovery following natural or anthropogenic losses. Benthic communities typically recover within one or two years. Examples are provided by the Kalamazoo, Pine, and East Walker river oil spills.

Fish and Fish Eggs and Larvae

Few, if any, of the case studies provide direct evidence for effects on fish eggs in spawning gravels. Mortality of adult fish, however, is commonly but not always observed in association with inland oil spills. Factors that mitigate against fish kills include oil type (*i.e.,* the availability of more water-soluble constituents of the oil, and density/viscosity relationships that facilitate or impede the formation of oil droplets); the turbulence of the receiving environment (which helps to determine the extent to which oil droplets form and accelerate the dissolution of light hydrocarbons into the water); and the volume of water flowing in the receiving environment, relative to the volume of spilled oil (which may limit the maximum dissolved hydrocarbon concentration that can be achieved). High levels of fish mortality were observed in the Pine River spill example, where a light crude oil was spilled into a relatively small, turbulent river. Some mortality was also observed in the East Walker and Kalamazoo River spills, although effects of flow regulation and cold winter weather were also implicated at the East Walker River.

In-Water Amphibians

Little information is provided by the case studies with respect to amphibians. However, it is assumed that in-water amphibians, as eggs, juveniles or adults, will have sensitivity similar to that exhibited by sensitive fish and benthic invertebrate species.

Shoreline and Riparian Vegetation

Shoreline and riparian vegetation are expected to be affected only in cases where rivers are in flood condition at the time of an oil spill, such that the riparian areas are overwashed by oil. Oiling of vegetation is expected to result in the death of annual plants, as well as the death of contacted foliage of perennials, shrubs and trees. Where contact is only with the stems of plants, particularly trees and shrubs, effects are usually minimal. As discussed elsewhere, areas subject to heavy oiling, such as the initial overland flowpath from a spill site to the aquatic environment, may require aggressive remedial actions, so that all habitat is initially destroyed, then reconstructed and seeded with appropriate native seed mixes. Outside of these areas, recovery is usually allowed to proceed via natural attenuation following appropriate oil spill clean-up procedures to remove the most visible oiling. Annual plant communities typically recover from moderate oiling within one or two years. Shrubs and trees in riparian habitat are generally not killed as a result of oil exposure, or removed during remediation activities. The Kalamazoo River oil spill provides a good example.

Soil Invertebrates

Little information is provided by the case studies with respect to soil invertebrate communities. However, the assessment provided above for shoreline and riparian vegetation is believed to also be applicable to soil invertebrates.

Mammalian Wildlife

Relatively few mammals are usually found dead following inland oil spills. The case studies suggest that tens, rather than hundreds, are typically found. In part, this reflects the generally low sensitivity and/or exposure of many mammalian wildlife species. However it may also reflect the low probability of finding all dead animals. . The species most likely to be affected are those that actively swim in water (*e.g.,* muskrat, beaver, mink and otter), as opposed to those that occasionally visit streams and rivers or occupy riparian habitat, (*e.g.,* bears, raccoons or ungulates). Mortality may be caused by loss of insulative function in oiled fur, leading to hypothermia; or to ingestion of oil while trying to clean the fur, leading to haemorrhaging of the digestive tract; or to a combination of such stressors, but tends to be associated with the acute phase of the spill.

Avian Wildlife

Like mammals, few dead birds are usually found following inland oil spills considering their known sensitivity to oiling. Again, the case studies suggest tens, to a few hundred mortalities in most cases, although the actual numbers are likely to be higher due to the low probability of finding the dead birds. Among inland bird species, waterfowl appear to be the most sensitive, due to their high level of exposure to oil slicks on the surface of the water. Wading birds, shorebirds and birds that live around the water generally have lower exposure, although some birds such as dippers which bob in and out of the water to take invertebrates, tadpoles and small fish may be an exception. As was observed for grebes following the Wabamun Lake oil spill, affected populations may appear to rebound quickly because of immigration of birds from other unaffected areas.

Reptiles and Air-Breathing Amphibians

The Kalamazoo oil spill case study indicates that amphibians and reptiles (particularly turtles) may be particularly exposed to spilled oil (a large majority of the oiled wildlife that were captured, treated and released following that spill were reptiles, particularly turtles). Most of these animals were subsequently released alive. Turtles would have low sensitivity to external oiling, as they lack fur or feathers, and are cold-blooded. Similarly, as they have no grooming behaviour, their exposure to oil ingestion may also be lower than that of birds and mammals. The areas along the proposed pipeline corridor that would have the highest potential to support reptiles and amphibians would be found in the lower Fraser River valley. The abundance and diversity of reptiles and amphibians in the higher-elevation areas of British Columbia and most of the Alberta portion of the pipeline corridor is expected to be low.

6.3. Hazard Assessment

The purpose of the Hazard Assessment is to assess the fate and transport of oil spilled in the environment, to consider the pathways by which ecological receptors are exposed to (and hence potentially affected by) spilled oil and its constituents, and to identify the spatial extent, magnitude, and duration of potential negative effects associated with acute (short-term) and chronic (long-term) exposure of ecological receptors. The Hazard Assessment forms the basis for evaluating the effects of exposure to pipeline spills of diluted bitumen in the freshwater environment.

6.3.1. Ecological Effects of Spilled Oil

The ERA assesses both acute and chronic risks to ecological receptors resulting from hypothetical pipeline releases to the freshwater environment. The assessment of acute ecological risk focuses on the short-term effects of a pipeline release (*i.e.,* exposure to fresh or unweathered oil and its constituents). During this period, the hydrocarbons would be relatively unweathered, large volumes would be transported downstream in the receiving river or stream, and more volatile hydrocarbons would be available to evaporate to the atmosphere, or to dissolve in water. The assessment of chronic risk (*i.e.,* chronic toxic effects) begins after the acute exposure assessment and addresses the secondary fate of more weathered hydrocarbons, as well as the long-term risks to ecological receptors, including those that are higher-level consumers (*e.g.,* bears, piscivorous birds) that may be chronically exposed to residual hydrocarbons present in shoreline soils, sediment and biota.

There is no evidence that petroleum hydrocarbons, including PAHs, biomagnify up food chains (Environment Canada and Health Canada 2011). After ingestion by vertebrates much of the total ingested hydrocarbon has low bioavailability, and simply passes through the digestive tract. Absorbed petroleum hydrocarbons may be metabolized, or modified into a more readily excretable form; therefore, they do not tend to accumulate in tissues. Petroleum hydrocarbons are also not readily absorbed into and accumulated by plant tissues. The net result is that consumption of either plants or prey animals does not tend to constitute the major component of exposure to petroleum hydrocarbons for aquatic biota.

However, some invertebrates (*e.g.,* molluscs) lack enzyme systems capable of rapidly metabolizing PAHs and it is assumed that hydrocarbons can be accumulated by these animals.

Under the right conditions, spilled oil can become sequestered in the environment, so that weathering occurs very slowly over a long period of time (potentially decades). Sequestered oil is that which has become isolated from the environment, so that normal weathering processes are limited. While such oil can exhibit toxicity similar to that of freshly spilled oil, should it be disturbed and released back into the environment, it is generally considered to have been isolated from the environment and therefore harmless while sequestered. Sequestration of oil occurred on some beaches in Prince William Sound following the Exxon Valdez oil spill, at sites where it was possible for the oil to deeply penetrate into the interstitial spaces; however, sequestration did not play a substantial role in the overall mass balance of oil.

6.3.1.1. Aquatic Biota

Aquatic biota are here conceptualized as including aquatic plants, benthic invertebrates, fish and the aquatic life stages of amphibians.

Exposure of aquatic biota to hydrocarbons is considered to be primarily due to hydrocarbons present in dissolved form. Hydrocarbons are hydrophobic and partition strongly between water and other available non-polar media, including sediment organic matter and living organisms. Uptake of hydrocarbons from water by living organisms is considered to be regulated primarily by equilibrium exchange processes between water and lipids, and to take place 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 disrupt cellular and tissue function (French McCay 2009), and may or may not be metabolized.

Three primary mechanisms of toxicity have been identified for fish and fish eggs exposed to hydrocarbons. These can be broadly summarized as including non-polar narcosis, blue sac disease (BSD) and phototoxicity. Due to similar habitats and behaviours, it is expected that amphibian in-water stages (*i.e.,* eggs, juveniles) would experience toxic effects similar to those experienced by aquatic receptors (*e.g.,* fish and fish eggs).

Non-polar narcosis is a toxic modality whereby hydrocarbons are reversibly accumulated by organisms principally from the dissolved phase in water, and come to reside in the lipid pool of the receptor organism. The toxic potential of individual hydrocarbon compounds is normalized on a µmol/g lipid basis, so that they can be considered additive in their toxic action. At some critical concentration (C^*_L) the presence of the hydrocarbon contaminants causes a negative effect on metabolic functioning at some target lipid site within the organism, resulting in an expression of toxicity. As outlined by Di Toro *et al.* (2000) a species sensitivity distribution has been defined for a broad range of aquatic biota, from algae and protozoa to fish and amphibians. While relatively few of the indicator fish species for Alberta and British Columbia are represented in the species sensitivity distribution, it is known that salmonid fish (including rainbow trout) are among the more sensitive species. For the purposes of this qualitative ERA, the 5th percentile species in the species sensitivity distribution will be taken as the appropriate benchmark to assure protection of the freshwater aquatic community, including fish, with respect to hydrocarbon exposure following a hypothetical spill of diluted bitumen. The chemical constituents of crude oil that contribute most to its acute toxicity include monoaromatic compounds (*e.g.,* BTEX), as well as other low molecular weight hydrocarbons (*e.g.,* VOCs) and some of the lighter PAHs such as napthalenes. Because these components weather rapidly, acute toxicity of spilled oil to fish and other aquatic life tends to be confined to the first hours or days following a spill.

Blue sac disease (BSD) refers to a suite of morphological abnormalities of fish embryos that may be associated with chemical, physical or thermal shock. Common symptoms include ocular, yolk sac, and pericardial edema, hemorrhaging, circulatory abnormalities, and spinal and craniofacial deformities (Fallahtafti *et al.* 2011). Yolk sac and/or pericardial edema appear to be the most sensitive morphological indicators of embryonic fish exposure to crude oil (Marty *et al.* 1997, Carls *et al.* 1999). However, the development of symptoms associated with BSD does not necessarily result in mortality of fish embryos.

The effects of PAH may range in severity from a complete cessation of embryo development and death before feeding begins, to minor reductions in growth (Hodson *et al.* 2011). Several studies have linked BSD in the early life stages of fish with crude oil exposure and/or exposure to PAHs, particularly 3- and 4-ring PAHs such as phenanthrenes and fluoranthenes. Many of these studies were initiated as a consequence of the 1989 EVOS in Prince William Sound, Alaska. However, there has been considerable controversy regarding the sensitivity of fish eggs and embryos to PAH exposure. While a total PAH concentration in water of 1 µg/L has often been cited as a threshold for onset of blue sac disease induction, the range of concentrations leading to effects appears to range from 1 to 100 µg TPAH/L, depending upon the suite of PAH compounds present, the specific exposure conditions, the receptor species, and the life stage of the receptor species.

Phototoxicity occurs when PAHs present in biological tissues are exposed to natural light including ultraviolet (UV) light, and a resulting reaction enhances the toxicity of PAHs in the tissues, potentially causing mortality or other harm to fish and other aquatic organisms (Logan 2007). The PAHs known to be involved with phototoxic responses are the three- to five-ring PAHs and similar heterocyclic compounds. Hodson *et al.* (2011) noted that UV photomodification of PAHs can create oxygenated derivatives such as quinones and anthroquinones, which are more water soluble but also more reactive and more toxic than the parent compounds. Hodson *et al.* (2011) identified anthracene, fluoranthene and pyrene as substances of particular concern. For most benthic species, exposure to light may be minimal, and therefore this mode of action is not a major source of concern. Likewise, for the toxicity benchmarks used here to evaluate negative effects on fish eggs, the damage to developing embryos occurs relatively early in the incubation period, while eggs (particularly salmonid eggs) are buried in spawning gravels and not exposed to light. Barron *et al.* (2003) tested juvenile pink salmon using weathered Alaska North Slope crude oil (a rich source of PAHs) to determine if it would be phototoxic under conditions of short-term exposure to high levels of oil that may occur during a spill. However, the responses observed were typical of the acute narcotic toxicity of petroleum, and there was no indication of photo-enhanced toxicity. It was concluded that pink salmon are at less risk from photo-enhanced toxicity than early life stages of several other (marine) species. Therefore, although the potential for photo-enhancement of PAH toxicity exists and has been demonstrated in laboratory studies, it is not considered to be of sufficient importance in the natural environment to merit special consideration. This conclusion is similar to that of McDonald and Chapman (2002) who questioned the ecological relevance of PAH phototoxicity, suggesting that it should not be used for environmental management decisions unless its ecological relevance is firmly established, and then only as part of a weight of evidence determination. Over time, hydrocarbon mixtures lose low molecular weight components due to volatilization, dissolution and biodegradation, some of the key processes involved in weathering. As weathering proceeds, the total abundance of all hydrocarbons is reduced, but the lighter hydrocarbons tend to be lost more rapidly. The result is a shift in the total hydrocarbon distribution towards heavier residual hydrocarbons, with a corresponding reduction in the total hydrocarbon concentration or mass remaining in the environment. Similar to other hydrocarbons, as weathering proceeds the total abundance of all PAH compounds is reduced, although some PAHs (notably high molecular weight PAHs, or those that have higher degrees of alkylation) weather more slowly than others. The result can be an apparent increase in the concentration of these PAHs in residual oil, while at the same time the total mass of hydrocarbons or PAHs (and therefore the toxic burden imposed on the environment) is decreasing. Studies that have used oiled gravel packed into columns to generate dissolved PAHs for toxicity studies typically find that the weathering process results in a rapid depletion of water soluble PAHs, so that the potential for toxic effects on fish, fish eggs or embryos persists for only a few months.

6.3.1.2. Terrestrial Biota

Terrestrial biota were conceptualized as including shoreline and riparian vegetation, soil invertebrates, air-breathing life stages of amphibians, reptiles, birds and mammals. The acute effects of oil spills on terrestrial biota are those arising from direct contact with unweathered or slightly weathered crude oil, as well as ingestion or inhalation of hydrocarbons during this initial period of time (*i.e.,* hours to weeks) following an oil spill event. Chronic effects of oil spills on terrestrial biota include effects due to longer term (*i.e.,* weeks to months) exposure to chemical constituents of the spilled oil (such as PAHs), due to ingestion of contaminated surface water, soil, plants, or animal food types. Oiling of wildlife can result in decreased survival and reproductive success through a number of different mechanisms, including loss of waterproofing and insulating characteristics of feathers or fur, toxicity resulting from the transfer of oil from feathers to eggs during incubation or shoreline oiling of reptile eggs, toxicity through the skin, ingestion of toxins via grooming or feeding, and reduced mobility (NRC 2003, French McCay 2009).

In Canada, emphasis has been placed on exposure pathways based on direct contact between contaminated soils and both plant roots and soil invertebrates. This emphasis is based on the need to preserve the principal ecological functions performed by the soil resources and the low bioaccumulation rates of petroleum hydrocarbons, that would tend to limit exposure to birds and mammals. The Canada-Wide Standard for Petroleum Hydrocarbons in soil (CCME 2008) provides benchmark values for the protection of soil invertebrates and plants exposed to hydrocarbons. To develop these benchmark values protective of plants and soil invertebrates, available toxicity data were standardized at a 25-percent effect level (*e.g.,* the concentration of petroleum hydrocarbons that results in a 25% reduction in invertebrate survival or plant growth). The 25th percentile of the species sensitivity distribution for test results was then used as the guideline for agricultural or residential land use. The Tier 1 guidelines are intended to be generally applicable and to apply to both weathered and fresh hydrocarbons; in general the guidelines were developed using fresh hydrocarbons including but not limited to gasoline and crude oil, and it is acknowledged that the toxicity of hydrocarbon mixtures may decrease as weathering progresses. The Canada-Wide Standard guidelines for hydrocarbons in soil (taking the lower of the values for fine or coarse-grained agricultural soil for the agricultural/residential land use) are as follows: F1, 210 mg/kg dry soil; F2, 150 mg/kg dry soil; F3, 300 mg/kg dry soil; F4, 2,800 mg/kg dry soil.

Plants with emergent parts extending out of the water surface would be affected by floating oil entering their habitats. Based on observations of oil spills affecting wetlands (French *et al.* 1996, French McCay 2009), oil coating on leaves during the growing season would affect growth and survival of emergent plants, whereas oiling of stems and stubble during the dormant winter period does not appear to affect subsequent vegetative growth. The threshold amount of floating oil where reduced growth or lethal effects on growing vegetation could occur is about 100 g/m^2 (0.1 mm, heavy black or brown oil, French McCay 2009). Annual plants, or parts of plants, are likely to be killed outright following oiling of foliage. Perennial plants and shrubs may be damaged but are less likely to be killed outright, and may quickly regenerate from surviving root structures. Trees are unlikely to be negatively affected by oiling of trunks or branches. It is possible that clearing of trees could occur as part of clean-up activities on heavily oiled areas of land, such as the overland flowpath before oil contacts an aquatic environment. Clearing of trees from the riparian zone more generally is not a likely outcome, as trees are rarely killed in this context. Their importance as a key component of the ecosystem, in addition to the services they provide in stabilizing soil, shading watercourses, and providing food and shelter and habitat for other ecological receptors is such that there would rarely be a net environmental benefit to removing trees, and alternative, less intrusive means for soil remediation would be employed.

Potential environmental effects on wildlife in the spill-affected area are evaluated based on probability of encounter with floating and/or shoreline oil and the amount of oil likely accumulated on an individual animal. Jenssen and Ekker (1991a,b) studied eiders exposed to oil on their feathers at varying doses, finding that metabolism was affected following exposure to more than 20 mL of crude oil. However, their review of the literature revealed that a dose of an order of magnitude more oil (200 to 500 mL) is required for substantial and potentially lethal effects. Following French McCay (2009), 350 ml is assumed to be a lethal dose for many wildlife species in this ERA. Assuming a swimming animal has a width of 15 cm, it would need to swim through 230 m of oil of 10 µm thickness, or 2.3 km of oil at 1 µm thickness, to obtain a dose of 350 mL. This distance spent in oil need not be in a straight line. If an animal swims 10 m/min (0.17 m/sec), 230 m would be covered in 23 min (or 2.3 km would be covered in about 3.8 hours). Thus, a slick thickness of 10 µm is assumed as a threshold thickness for oiling mortality, given the sizes of the water bodies involved and likely exposure times of animals such as muskrat, beaver, mink, otter, reptiles and waterfowl within them (French McCay 2009).

Animals oiled above a threshold lethal dose would presumably die, given the remoteness of many of the areas considered, and the low probability that timely capture and rehabilitation would be possible. The likelihood of encounter with oil would be different for each wildlife type depending on its behaviour.

Terrestrial mammals and birds that do not feed in aquatic habitats would likely avoid or not contact oil, with the exception of those attracted to carrion (*e.g.,* bears, foxes, coyotes, wolverines, bald eagles). Scavengers and wildlife that obtain part of their diet from aquatic habitats (*e.g.,* otter, mink and moose) would have a moderate to high probability of becoming oiled. The acute environmental effects of an oil spill on wildlife (*i.e.,* air-breathing vertebrates such as birds, mammals, reptiles and adult amphibians) are evaluated based on the probability of encounter with floating and/or stranded oil, and the amount of oil likely to accumulate on an individual animal.

Dose response studies have been carried out to determine oral-based toxicity reference values (TRVs), doses of oil below which negative effects are not expected to occur. TRVs for ecological risk assessment are generally based on either the lowest observed negative effects level (LOAEL) or the no observed negative effects level (NOAEL). LOAELs used for TRV derivation are usually based on long-term growth or survival, or sub-lethal reproductive effects determined from chronic exposure studies because these endpoints are relevant to the maintenance of wildlife populations. The LOAEL represents a threshold dose at which negative outcomes are likely to become evident.

Cattle will voluntarily ingest large doses of petroleum substances (Coppock *et al.* 1996). In such acute poisoning cases the lung is the target organ. Chemical pneumonia results when droplets of oil are inhaled. Another cause of chemical pneumonia is aspiration of hydrocarbons during vomiting, regurgitation, or eructation. Lung lesions have been reported following the voluntary ingestion of petroleum by cattle. Such lesions have been reported in cattle given 20 to 60 mL crude oil/kg body weight, and in sheep after a 1-day exposure to water contaminated with natural gas condensate, which also caused reddening and hemorrhage in the digestive tract. Kidneys can also be target organs of petroleum hydrocarbon toxicosis (Coppock *et al.* 1996).

CCME (2008) derives a value for the toxicity of petroleum hydrocarbons (with a focus on fresh crude oil) to livestock in which the lowest documented effects dose is 2.1 g fresh crude/kg body weight/day. This is divided by an uncertainty factor of 10 to obtain a daily threshold effects dose of 210 mg/kg body weight/day, which is then used to estimate the allowable concentration of whole fresh crude oil ingested in livestock drinking water. However, it is noted that the value for weathered crude oil could be 3.7 times higher, due to the lower toxicity of weathered crude oil (CCME 2008). A value of approximately 0.78 g/kg body weight/day could then be an appropriate toxicity reference value for chronic ingestion of weathered crude oil.

Other studies evaluating the toxicity of fresh or weathered crude oil to mammals are presented in Table 6.15. These studies include cattle, rats, and ferrets and therefore represent herbivores, omnivores, and carnivores. The results from these studies are highly consistent with respect to the dose ranges that have been shown to have negative effects on mammals. Based on the available information, it is concluded that mammals are generally quite tolerant of exposure to unweathered or weathered crude oil. Negative effects are considered unlikely at dose levels less than 0.5 g/kg body weight/day.

Among birds, the Alcids (a family of web-footed diving birds that includes auks, murres and puffins) are considered to be the most vulnerable to oil exposure, due to their tendency to form large flocks and spend much time floating on offshore waters. However, this group is notably absent from inland waters. Among waterfowl, populations of dabbling ducks are generally less exposed because (with some exceptions) they tend not to form large breeding colonies. Therefore, while individual adult mortality and effects on eggs are likely to occur, they are less likely to have high magnitude consequences at the population level due to the tendency for populations to be dispersed. Direct mortality rates for shorebirds are generally low because they spend less time in the water. Raptors become oiled primarily via consumption of oiled prey or carrion. Wading birds generally experience low mortality because they wade in shallow, sheltered waters to feed. However, plumage can become contaminated due to wading through oiled vegetation or exposure to oil slicks, and indirect effects can occur due to loss of prey, resulting in starvation or shifting to alternative foraging sites (Hugenin *et al.* 1996). Oil exposure of adult birds can cause reproductive effects on birds (*e.g.,* oiling of eggs, as well as nest disturbance caused by shoreline clean-up operations.

Chronic low levels of oil pollution may have negative effects on aquatic bird populations. Small amounts of oil applied to the external surface of bird eggs were found to produce toxic effects (Leighton 1993). Single oral doses of oil have been demonstrated to cause lipid pneumonia, gastrointestinal irritation, and fatty livers. Pathological responses of birds examined after fatal exposure to Bunker "C" fuel oil include enteritis, hepatic fatty changes, and renal tubular nephrosis (Szaro *et al.* 1978).

Other studies evaluating the toxicity of fresh or weathered crude oil to birds are presented in Table 6.16. These studies focus on mallard, a common dabbling duck, which would be highly exposed to hydrocarbons in the event of a spill. Based on the available information, it is concluded that birds are generally quite tolerant of exposure to unweathered or weathered crude oil. The lowest reported negative effects on a reproductive endpoint are identified at a dose of approximately 0.2 g/kg body weight/day.

Reptiles are considered to have similar sensitivity to birds with respect to dietary exposure to hydrocarbons. Turtle eggs are assumed to be laid in riparian zone soils, but will likely be located above flood stage, and therefore are not likely to be laid in soils that are contaminated with hydrocarbon residues. In this context, turtle eggs are not likely to be more exposed to hydrocarbon residues than are bird eggs, which may be subject to external oiling through contact with oily residues on the feathers of parent birds.

Because petroleum hydrocarbons do not biomagnify up food chains (Environment Canada and Health Canada 2011), consumption of plants and/or other animals does not tend to constitute the major component of exposure to petroleum hydrocarbons for wildlife. Instead, toxic effects in birds, mammals, reptiles, and adult amphibians primarily results from direct ingestion (*e.g.,* from grooming, preening, or ingestion of contaminated water, soil or sediment).

TABLE 6.15 TOXICOLOGICAL BENCHMARKS FOR MAMMALIAN ECOLOGICAL RECEPTORS EXPOSED TO CRUDE OIL

Study Design	Effects	Results	Reference
Domestic cattle (8/group) were administered single oral doses of Pembina Cardium crude oil at 16.7, 33.4 and 67.4 g/kg body weight. Cattle were sacrificed at days 7 or 30 for pathological and histological examination, as well as measurement of a suite of enzyme activities.	No cattle died as a result of being dosed with crude oil. Cattle treated with 16.7 mg/kg body weight showed minimal signs of intoxication; cattle treated with higher doses exhibited tremors, nystagmus, regurgitation and vomiting, myoclonic seizures, depression, locomotor abnormalities, and pulmonary distress. On day 7, cattle in exposed groups showed alteration in enzyme activities in liver, kidney, and lung tissues. Cattle sacrificed on day 30 showed few statistically significant differences from control animals, and reduced differences in cytochrome P-450 activity.	Acute toxicity greater than 67.4 g/kg body weight.	Khan *et al.* (1996)
Sprague-Dawley rats were given doses of 0.25, 0.50 or 1.25 mL/kg Pembina Cardium crude oil, or 1.25 mL/kg commercial diesel fuel, on days 1, 3, 5 and 8 of the study, and were sacrificed on day 10. Tissue and blood samples were tested for a suite of enzyme activities, hematology and blood chemistry, and pathological examination.	No rats died as a result of being dosed with crude oil or diesel fuel, and there was no sign of distress or intoxication in the exposed animals. Dose-dependent changes were observed in levels of a suite of enzyme indicators (including EROD). The only statistically significant systemic change was a small increase in the liver somatic index of rats exposed to the highest dose of crude oil or diesel fuel.	No sign of distress or intoxication in rats exposed to crude oil at up to 1.25 mL/kg body weight.	Khan *et al.* (2001)
The toxicity of naturally weathered Exxon Valdez crude oil was tested in a battery of acute and subchronic tests using European ferrets. Young adult male and female ferrets were administered oil at a dose of 0.5, 1.0 or 5.0 g/kg body weight once daily for three days. Prior to the study and at termination, blood samples were taken for chemistry and enzyme testing, and the animals were weighed. At study termination (day 5) the animals were subject to gross necropsy examination and selected tissues were taken for histological examination.	No mortality of ferrets occurred as a consequence of being administered crude oil. No grossly observable signs of toxicity were noted. No effects on mean body weight were detected. No grossly observable signs of toxicity were noted during postmortem examination of the ferrets. Microscopic examination of tissues did not reveal lesions considered to be related to oil exposure. Significantly lower mean spleen to body weight ratios and raw spleen weights were noted in all female treatment groups. No other organ weight differences were noted. With the exception of lower mean serum albumin concentrations in the 5 g/kg female dose group, no significant differences among clinical chemistry parameters were noted. No significant differences in the hematological parameters were noted in any group.	Subacute toxicity of crude oil to European ferrets is >5 g/kg body weight/day.	Stubblefield *et al.* (1995a)

TABLE 6.16 TOXICOLOGICAL BENCHMARKS FOR AVIAN ECOLOGICAL RECEPTORS EXPOSED TO CRUDE OIL

Study Design	Effects	Results	Reference
The toxicity of naturally weathered Exxon Valdez crude oil was tested in a battery of acute and subchronic tests using mallard ducks. Adult ducks were tested with an acute oral dose of 5 g/kg body weight and observed for up to 14 days following testing (acute oral toxicity). Five-day old ducklings were tested by feeding them a diet containing weathered crude oil at a concentration of 50 g/kg diet (subacute dietary toxicity) for five days, followed by a 3-day observation period on uncontaminated rations; food avoidance was tested using ducklings offered diet containing 0, 1.25, 2.5, 5, 10 and 20 g/kg diet for five days, followed by a 3-day observation period on uncontaminated rations; and ducks (16 weeks old) were fed a diet containing 0, 10, 30 or 100 g/kg weathered crude oil for 14 days.	No adult ducks died following single doses of 5 g/kg body weight; no grossly observable signs of toxicity were noted, and there were no significant effects on feed consumption or body weight. No treatment related abnormalities were noted on postmortem examination. No mortality or observable sign of toxicity was noted in ducklings fed crude oil in their diet at 50 g/kg body weight. Food consumption was not affected, and no significant differences in body weight or growth were noted. Post-mortem examination showed no evidence of systemic toxicity. Ducklings did not avoid food containing crude oil at up to 20 g/kg. No significant differences in body weight or growth were found, and no consistent grossly observable lesions were noted in postmortem examination. No mortalities or grossly observable signs of toxicity were noted in 14-day exposure to dietary concentrations of up to 100 g/kg diet. No significant treatment-related differences in clinical blood chemistry were noted between treatment and control birds. No consistent or substantive differences were noted among the histological appearance of the kidney, thymus, brain or bone marrow of high dose birds when compared to control birds. Spleens and livers of high dose birds were found to show some minor changes when compared to control birds.	Weathered Exxon Valdez crude oil presented little potential for acute toxicity to wildlife species from oral ingestion. Lethal concentrations and no-observed negative effect levels were greater than the maximum tested doses (>5 g/kg body weight in the oral study, and >50 g/kg diet in the subacute dietary tests). LD_{50} values for refined hydrocarbon products were reported to range from 7 to 20 mL/kg body weight.	Stubblefield *et al.* (1995a) Hartung and Hunt (1966) as cited by Stubblefield *et al.* (1995a).
A one-generation reproductive toxicity study and a direct eggshell application toxicity study were conducted using naturally weathered crude oil obtained following the Exxon Valdez oil spill. Mallard ducks, 16 weeks of age, were exposed to dietary concentrations of 0, 0.2, 2 and 20 g/kg diet for 22 weeks. Eggs laid between weeks 12 and 22 of exposure were incubated and hatched. Mallard eggs were also treated with either weathered crude oil or Vaseline (a non-toxic control) to determine the extent of coverage causing reduced viability.	No deaths of ducks occurred that were attributed to crude oil exposure. All surviving birds appeared healthy throughout the study, and no signs of toxicity were noted. No statistically significant differences in growth of birds or food consumption were noted. Consumption of diets containing crude oil at 20 g/kg feed resulted in changes in clinical chemistry parameters (*i.e.,* serum phosphorus, total protein, albumin, bilirubin and calcium), reductions in eggshell thickness and strength (although the viability of embryos was not affected), and suggested liver and spleen weight changes. No significant effects were noted at dietary concentrations of 0.2 or 2 g/kg feed. Long-term ingestion of weathered crude oil at dietary concentrations of 20 g/kg feed may result in reduced egg fitness. Application of weathered crude oil to areas of up to 33% of the shell area had no appreciable effect on embryo survival, suggesting that not only is it substantially less toxic than unweathered crude oil, but that is not as effective as a shell sealant as Vaseline, which caused effects when 17% or greater of the egg shell was covered.	Weathered crude oil is substantially less toxic to mallard ducks than unweathered crude oil. Ingestion of a diet containing weathered crude oil at 20 g/kg caused reductions in eggshell thickness and strength, which could result in reduced hatching success of ducklings.	Stubblefield *et al.* (1995b)
Fresh South Louisiana crude oil was fed to mallard ducklings at concentrations of 0.025, 0.25, 2.5 and 5% of diet from hatching to 8 weeks of age.	Growth was depressed in birds receiving a diet containing 5% oil but there was no oil-related mortality. Diets containing as low as 0.25% oil caused behavioural response. Liver hypertrophy and splenic atrophy were evident in birds fed 2.5% or 5% oil. Some biochemical effects were noted, and tubular inflammation and degeneration in the kidney were noted in birds fed the 5% diet. High concentrations of oil in the diet impaired development of the wings and flight feathers and caused stunting.	Exposure to fresh crude oil over an 8 week period caused impaired development of mallard ducklings at a dose of 0.824 g/kg body weight/day.	Szaro *et al.* (1978)

TABLE 6.16 TOXICOLOGICAL BENCHMARKS FOR AVIAN ECOLOGICAL RECEPTORS EXPOSED TO CRUDE OIL

Study Design	Effects	Results	Reference
Fresh South Louisiana crude oil was fed to mallard ducks at concentrations of 0.25 and 2.5% of diet for 26 weeks.	No birds died during the study, nor were body weights significantly depressed. Oviduct weight was greatly reduced on necropsy in ducks on the 2.5% diet, and was also significantly reduced in ducks on the 0.25% diet. Egg production was lower in ducks fed oil in the diet; however, the hatchability of eggs was not significantly different, and there was no effect on eggshell thickness. No significant effects were observed on liver weight, although spleen weight was reduced on the 2.5% diet.	Exposure to fresh crude oil over a 26 week period resulted in reduced egg production. The reduction was about 14% in ducks fed 0.25% oil in diet, and was accompanied by reduced oviduct weight. The 0.25% diet equates to a dose of approximately 0.2 g/kg body weight/day.	Coon and Dieter (1981)

6.3.1.3. Effects of Oiling

Terrestrial Wildlife

The acute environmental effects of an oil spill on wildlife (*i.e.,* air-breathing vertebrates such as birds, mammals, reptiles, and adult amphibians) are evaluated based on the probability of encounter with floating and/or stranded oil, and the amount of oil likely to accumulate on an individual animal.

Oiling of wildlife can result in decreased survival and reproductive success through a number of different mechanisms, including loss of waterproofing and insulating characteristics of feathers or fur, toxicity resulting from the transfer of oil from feathers to eggs during incubation or shoreline oiling of reptile eggs, toxicity through the skin, ingestion of toxins via grooming or feeding, and reduced mobility (NRC 2003, French McCay 2009).

The likelihood of oiling is proportional to the amount of time an animal spends on the water or shorelines. For example, wading birds, semi-aquatic mammals (*e.g.,* mink, muskrats) and turtles spend much of their time in shallow water and shoreline habitats, resulting in high likelihoods of being oiled in the event of a spill. In contrast, terrestrial wildlife such as songbirds, terrestrial mammals (*e.g.,* fox, deer) and some reptiles, spend almost all of their time on land and are unlikely to be exposed to oil.

Survival rates depend on the amount of oiling that occurs; the greater the amount of oiling, the less likely an animal will survive. Jenssen and Ekker (1991a,b) studied eiders exposed to oil on their feathers at varying doses, finding that metabolism was affected above 20 mL of (crude) oil. However, their review of the literature revealed that a dose of an order of magnitude more (200-500 mL; average of 350 mL) was required for substantial and potentially lethal effects.

Shoreline and Aquatic Vegetation

Plants with emergent parts extending out of the water surface would be affected by floating oil entering their habitats. Based on observations of oil spills affecting wetlands (French *et al.* 1996, French McCay 2009), oil coating on leaves during the growing season would affect growth and survival of emergent plants, whereas oiling of stems and stubble during the dormant winter period does not appear to affect subsequent vegetative growth. Similarly, trees are unlikely to be negatively affected by oiling of trunks or branches. The threshold thickness of floating oil where reduced growth or lethal effects on growing vegetation could occur is approximately 1 mm (French McCay 2009).

Aquatic Wildlife

Submerged oil may settle to the bottom of a waterbody and smother benthic resources (*i.e.,* fish eggs, benthic invertebrates), resulting in reduced survival. Based on numerous studies reported in French McCay (2009), intertidal invertebrates are more sensitive to oiling than intertidal macrophytes, and the threshold thickness of oiling where lethal effects could occur is approximately 0.1 mm (based on the definition of oil “coat” by Owens and Sergy 1994).

6.4. Risk Characterization

The Risk Characterization section qualitatively assesses the extent and nature of the risk of oil spills along the proposed pipeline corridor, based on the information presented in the Problem Formulation, Exposure Assessment and Hazard Assessment sections of the ERA, and with reference to the case studies.

Information obtained from selected case studies (see the Exposure Assessment) was used to predict the fate and transport of diluted bitumen spilled in the freshwater environment along the proposed pipeline corridor. Predictions were made for the full range of watercourses crossed during both high and low flow periods.

The predictions with respect to fate and transport were then used in combination with the information obtained from the Exposure Assessment and the Hazard Assessment to evaluate the likely environmental effects of spilled CLWB on ecological receptors living in affected environments.

Acute effects of oil spills are evaluated following an assumption of no mitigation. This is not to say that effective oil spill response efforts would not be mounted. Rather it is a conservative assumption that reflects the fact that spills could occur at remote locations, and that substantial environmental effects could occur within 24 hours of a large oil spill occurring. Chronic effects of oil spills are evaluated following an assumption that shoreline clean-up and assessment techniques (SCAT) and other remedial measures would be applied in the days and weeks following a spill, and until additional efforts would cause more harm than good, based on net environmental benefit analysis. For the purposes of the ERA, it is assumed that remedial efforts remove most visible oil from shorelines and riparian zone soils, although a residual hydrocarbon loading on soils of up to 1 kg/m^2 might be expected. The chronic assessments also assume that sunken oil, if any, is not recovered from the riverbed.

At each hypothetical spill location, a credible worst-case spill volume was estimated based on a full-bore rupture scenario, with the leak being detected at the control centre and the line being shut down within 15 minutes (Lind pers. comm.). The spill volumes for these full-bore rupture scenarios include the drain-down volume for oil present in the proposed pipeline between nearby topographic high points; therefore, the spill volumes are site-specific. A secondary estimate was also made of the volume of oil that might be released due to a less serious accident, such as a third-party strike of the line with heavy equipment causing a puncture with nominal 5 cm (2 in) diameter. In this scenario, the ability of the control room to detect changes in flow and pressure is more limited, and drain-down of the line can still occur. As a result, the estimated spill volumes for the contractor damage were 65% of the volume for the full-bore rupture scenario. This was considered to be similar enough to the spill volume for a full-bore rupture that the difference would be immaterial for this qualitative assessment of ecological consequences. The risk assessment scenarios in the following sections are therefore based on the credible worst-case spill volumes for full-bore rupture. Table 6.17 provides a summary of the estimated full-bore rupture and contractor damage spill volumes for the four identified hypothetical spill scenario locations.

TABLE 6.17 ESTIMATED SPILL VOLUMES FOR FULL-BORE RUPTURE AND CONTRACTOR DAMAGE TO THE PIPELINE

Reference Kilometre (RK) Based on Line V6	Credible Worst-Case Spill Volume for Full-bore Rupture	Credible Worst-Case Spill Volume for 5 cm Puncture
RK 309.0	2,700 m^3	1,755 m^3
RK 766.0	1,400 m^3	910 m^3
RK 1072.8	1,300 m^3	845 m^3
RK 1167.5	1,250 m^3	812.5 m^3

6.4.1. Tributary to the Athabasca River near Hinton, Alberta at RK 309.0

The hypothetical spill scenario involves a release of 2,700 m^3 of CLWB at RK 309.0. Details of the local environment can be found in Section 6.1.2.1. The spilled oil would flow overland a short distance before entering Trail Creek, a tributary to the Athabasca River. Trail Creek is a first-order watercourse that does not represent fish habitat in its upper reaches, but likely does support fish in its lower (higher order) reaches, prior to entering the Athabasca River. The Athabasca River at this location is 100 to 300 m wide, with a gentle meander and cobble-gravel banks and riverbed. Flows are strongly seasonal, ranging from approximately 500 m^3/s in June (during freshet), to 32.5 m^3/s at low flow in March.

This spill example is evaluated with particular reference to four cases for comparison: the Kalamazoo River oil spill, since that oil spill involved a similar form of diluted bitumen; the Yellowstone River oil spill, as that river has similar gradients to the Athabasca River near Hinton; the modelling conducted by Enbridge for the Athabasca River near Whitecourt, Alberta, as this is a nearby reach of the Athabasca River with very similar characteristics; and the modelling conducted by Enbridge for the Morice River, as that river also has similar overall gradients to the Athabasca River.

Three sets of environmental conditions are considered for this spill example. These are:

- A winter condition between December and March, with ice cover on the river and snow cover on the land. Air temperatures are assumed to be below freezing, and the river flow is in the low range (50 m^3/s or less).
- A summer condition between June and August, with air temperatures of 15ºC to 25ºC. The river is in freshet, with flow greater than 500 m^3/s.
- A spring or fall condition between April and June, or September and November. The river flow is moderate, at approximately 200 m^3/s, and the air temperatures are cool, between 0ºC and 15ºC.

6.4.1.1. Winter Conditions

Under winter conditions, snow in the gully acts to absorb spilled CLWB, and although the gully bottom surrounding Trail Creek is heavily oiled, only a small amount of the CLWB reaches the Athabasca River. Water flow in the creek is negligible due to its small size and winter conditions. The low temperatures also help to limit the flow of CLWB as its viscosity increases as it cools. Some CLWB reaches the Athabasca River and spreads out on the ice, but the density of the oil is less than that of water, so relatively little penetrates cracks in the ice, and down-river transport of the CLWB is negligible. Owing to winter conditions, many of the ecological receptors that could potentially be exposed are absent or dormant.

Table 6.18 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 309.0 during winter. Due to winter conditions, overland flow of the oil is slowed, and some of the oil is absorbed into the snowpack. Following local terrain, crude oil would reach the creek, and then follow the thalweg of the creek down to the Athabasca River, where it would likely pool on the surface of the river ice. During winter conditions, most migratory birds would be at their wintering grounds, so acute effects on raptors, waterfowl, wading and shorebirds are unlikely to be of high magnitude. Similarly, some mammals such as bears would be hibernating, although others such as moose, muskrat and river otter remain active year-round. Due to the limited spatial extent of physical oiling, effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would likewise be limited in spatial extent. However, oil spill recovery effects on the overland flowpath and affected areas of Trail Creek would be substantial, likely requiring extensive excavation causing destruction of habitat, followed by reconstruction and habitat restoration. Depending upon the receptor group, this process of restoration and recovery could take anywhere from 18 months to five years.

TABLE 6.18 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent of Effects	Effect Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Aquatic vegetation is not contacted by spilled oil.	Low. Aquatic vegetation is not actively growing at the time of the spill, and ice cover prevents contact between the spilled oil and aquatic vegetation. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek.	Spilled CLWB is prevented from entering, or is recovered from the frozen river surface, without materially affecting aquatic vegetation.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of Trail Creek and the river. Effects on the benthic community of the tributary are substantial, affecting the entire tributary as a result of oil spill recovery activities. Effects on the benthic community of the river are Low, because most of the spilled oil is recovered.	High although localized in Trail Creek. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek. Low in the Athabasca River.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the benthic invertebrate community begins about 18 months after the spill, and is effectively complete after 30 months. Recovery of the benthic community in the Athabasca River is complete within 6 months of the spill.
Fish and Fish Eggs	Few fish are present in the tributary, because of winter low flow conditions. Fish are present in the river, and salmonid eggs may be present in pockets of suitable habitat in the river bed downstream from the oil spill location. However, effects on fish and fish eggs are Low, because most of the spilled oil is recovered.	Low, because the fish habitat present in Trail Creek is minimal during the winter because of low flow conditions, and very little oil contacts the river water. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins about 18 months after the spill, and is effectively complete after 30 months. Recovery of fish habitat in the Athabasca River is complete within 6 months of the spill.
In-water Amphibians	Juvenile amphibians are not present in the winter season. Adult amphibians may be overwintering in the sediments of Trail Creek, which is wholly affected, or in low energy areas of the Athabasca River, which is minimally affected.	Low, because overwintering amphibians will be buried in stream sediments, and are unlikely to be directly contacted by the spilled oil. However, oil spill recovery activities result in the physical destruction, and then reconstruction of aquatic habitat in Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 18 months after the spill, and is effectively complete after 30 months. Recovery of amphibian habitat in the Athabasca River is complete within 6 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River, but annual plants are not present except as seeds, and perennial plants, shrubs and trees are in a dormant state. Little if any shoreline habitat of the Athabasca River is affected.	Low, because the plants are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near Trail Creek.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River, but soil invertebrates are in a dormant state. Little if any shoreline habitat of the Athabasca River is affected.	Low, because the soil invertebrates are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near Trail Creek.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	Not likely to be directly affected as they hibernate during winter.	Low, because the probability of a grizzly bear den being located within the overland flow path or proximal to Trail Creek is small. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Moose	Potentially affected but localized, as Trail Creek could provide sheltering habitat during cold periods. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range and oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Muskrat	Potentially affected but localized, as the lower reaches of Trail Creek could provide suitable habitat, and muskrat remain active through the winter. However, effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting Trail Creek. Disturbance caused by oil spill recovery activities would also eliminate their habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
River Otter	Potentially affected but localized, as otters remain active through the winter. Most otter habitat would be present around openings in the river ice, where access to fish is present. Effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near Trail Creek or its confluence with the Athabasca River. Disturbance caused by oil spill recovery activities would also eliminate their habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Birds			
Bald Eagle	Not likely to be affected as the winter range is generally south of the pipeline corridor in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Not likely to be affected as the winter range is generally south of the pipeline corridor in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Not likely to be affected as the winter range is generally south of the pipeline corridor in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	Not likely to be affected as the winter range is generally south of the pipeline corridor in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Not likely to be affected as the winter range is generally south of the pipeline corridor in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Not likely to be affected as the winter range is generally south of the pipeline corridor in Alberta.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Western painted turtle range is not likely to extend to the Athabasca River. Adult amphibians could potentially be overwintering in the sediments of Trail Creek, which is wholly affected, or in quiescent areas of the Athabasca River, which is minimally affected.	Low, because overwintering amphibians will be buried in stream sediments, and are unlikely to be directly contacted by the spilled oil. However, disturbance caused by oil spill recovery activities would also eliminate their habitat.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 18 months after the spill, and is effectively complete after about five years. Recovery of habitat in the Athabasca River is complete within 6 months.

6.4.1.2. Summer Conditions

Under summer season conditions, the spilled CLWB flows overland to the gully, resulting in oiled ground-level vegetation, some absorption of oil on vegetation and the soil litter layer, and some penetration of soil. Most of the spilled CLWB, however, enters Trail Creek and flows rapidly towards the Athabasca River.

Table 6.19 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 309.0 during summer. The short-term loading of oil to the creek is large (approximately 2,500 m^3 over a period of several hours), in comparison with the water flow rate (<0.1 m^3/s), and so the aquatic habitat in the tributary is severely affected, and oil overflows the banks of the creek, causing oiling of the riparian habitat. About half of the spilled oil reaches the Athabasca River which is at or near flood stage, entering on the south shoreline, and is advected downstream by the quickly moving water. Because the oil is unweathered, and has low viscosity and density less than that of the water, it spreads across the water surface, and is susceptible to entrainment in the water column due to turbulent flow conditions. Floating oil is trapped along shorelines, in particular where river flow is above the banks and vegetation is flooded. Unweathered oil that is entrained into the water column in the early stages enhances the dissolution of BTEX and other light-end hydrocarbons into the water column. Over time, much of the entrained oil re-surfaces, although some also undergoes interactions with suspended sediment to become neutrally buoyant or denser than the water, resulting in submergence and sinking, respectively. As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of this oil becomes submerged and sinks in quiescent areas such as eddy zones behind islands and in backwaters. Although the water of the Athabasca River is somewhat turbid, the suspended sediment load is not particularly high and the water has no appreciable salinity; thus OMA formation is not a dominant factor in the fate of the spilled oil. Most of the spilled oil has weathered, largely due to evaporation, and stranded along shoreline and in riparian zones within 35 to 50 km of the spill location. A small amount of oil is advected farther downstream as dissolved and entrained oil droplets, or as OMA that moves with bedload until becoming deposited in quiescent areas, potentially up to 100 km downstream.

6.4.1.3. Spring or Fall Conditions

Under spring and fall conditions, the spilled CLWB flows overland to the gully, resulting in oiled ground-level vegetation, some absorption of oil on vegetation and the soil litter layer, and some penetration of soil. Most of the spilled CLWB, however, enters Trail Creek and flows rapidly towards the Athabasca River.

Table 6.20 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 309.0 during spring or fall. The short-term loading of oil to Trail Creek is large (approximately 2,500 m^3 over a period of several hours), in comparison with the water flow rate (<0.1 m^3/s), and so the aquatic habitat in the tributary is severely affected, and oil overflows the banks of Trail Creek, causing oiling of the riparian habitat. About half of the spilled oil reaches the Athabasca River which is flowing normally, within its banks. The oil enters the river on the south shoreline, and is advected downstream by the moving water. Because the oil is unweathered, and has low viscosity and density less than that of the water, it spreads across the water surface. Floating oil is trapped along shorelines, particularly on gravel and cobble exposures, but does not penetrate these deeply due to the shallow slope of the shorelines and the presence of the water table at or near the surface. In the spring, water levels are generally rising with the onset of freshet, so stranded oil is likely to be re-floated and/or dispersed. In the fall, water levels are generally falling, so stranded oils is likely to remain stranded and continue weathering until winder, unless recovered by oil spill clean-up crews. The river flow is slower and less turbulent in spring and fall than under summer conditions, and owing to the cooler temperatures, the turbulence of the river flow is less likely to entrain droplets of the oil in the water. As a result, the concentrations of BTEX and other light-end hydrocarbons in the water column are lower, but the surface slick tends to be thicker. As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of the oil becomes submerged and/or sinks in quiescent areas such as eddy zones behind islands and in backwaters. Although the water of the Athabasca River is somewhat turbid, the suspended sediment load is not particularly high, little oil is entrained in the water column, and the water has no appreciable salinity; thus OMA formation is not an important factor in the fate of the spilled oil. Most of the spilled oil has weathered, largely due to evaporation, or stranded along shoreline within 25 km of the spill location. A small amount of oil is advected farther downstream.

6.4.1.4. Environmental Effects Summary for Spill Scenarios at RK 309.0

A hypothetical spill scenario has been developed to describe the likely fate and behaviour of CLWB spilled as a result of a pipeline rupture near RK 309.0. Potential environmental effects likely to accrue to ecological receptors as a result of such hypothetical spills have been outlined in Table 6.18 through Table 6.20.

For Trail Creek and the Athabasca River in winter (Table 6.18), snow and ice conditions are likely to be such that much of the spilled CLWB is held up before reaching the river, and the presence of ice on the river prevents a large amount of oil from entering the water. Under these circumstances, the environmental effects of spilled oil may be minimized, because most of the oil is recoverable. Oil spill recovery efforts would still result in environmental effects along the overland flowpath, and in Trail Creek, but effects on the Athabasca River would be reduced or avoided. Many of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* migratory birds). The spatial extent of oil spill effects would therefore be limited to the overland flowpath, and the lower portion of Trail Creek, on the order of several hundred metres, where the primary environmental effects would be those associated with oil spill recovery efforts. Recovery of the terrestrial environment and Trail Creek would take approximately 18 months to five years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer.

For Trail Creek and the Athabasca River in summer (Table 6.19), flows in Trail Creek are seasonally low, but flow in the Athabasca River is peaking, due to snow melt in its mountain headwaters. Most of the spilled oil reaches and is rapidly advected downstream in the Athabasca River. Effect magnitude on the overland flowpath and riparian areas of Trail Creek is high but localized, and is addressed by physical remediation and re-seeding of affected areas. Effects on aquatic receptors, including vegetation, invertebrates, fish and amphibians, are high but localized in Trail Creek, and generally medium to low in the Athabasca River. Medium effects are observed within the first 10 km downstream from Trail Creek, and low magnitude effects are observed between 10 and 35 to 50 km downstream. Most of this oil becomes stranded along shorelines, and in riparian areas where vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flowpath and along Trail Creek, but medium to low along the Athabasca River due to the patchy distribution of the oil. Whereas the overland flowpath and Trail Creek are subject to intensive oil spill clean-up which is initially destructive to habitat, areas riparian to the Athabasca River are remediated with less intrusive methods, and a greater emphasis on natural attenuation of spilled oil residues at low levels. Environmental effects on mammal populations are greatest for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 50 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 6.19 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Submerged, floating and emergent aquatic vegetation in Trail Creek is likely to be killed by the flow of oil at the time of the spill, or by oil spill recovery efforts following the spill. Very little aquatic vegetation is present in the Athabasca River because of the high summer flows and cobble-gravel nature of most of the river bed. Effects are therefore likely to be limited to Trail Creek.	High in Trail Creek, as a result of clean-up activities which would result in the physical destruction, and then reconstruction of aquatic habitat. Low in the Athabasca River, because of the scarcity of aquatic vegetation generally.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the aquatic plant community begins about 12 months after the spill, and is effectively complete after 5 years. Recovery of the aquatic plant community in the Athabasca River is complete within one year of the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of Trail Creek and the river. Effects on the benthic community of the creek are substantial, affecting the entire creek as a result of oil spill recovery activities. Effects on the benthic community of the river range from moderate, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations near the confluence with the tributary, to Low, in downstream areas.	High in Trail Creek, with direct effects of oiling and hydrocarbon exposure as well as oil spill recovery activities resulting in the physical destruction, and then reconstruction of aquatic habitat in the creek. Medium to Low in the Athabasca River, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the benthic invertebrate community begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of the benthic community in the river is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer to recover fully.
Fish and Fish Eggs	The lower reaches of Trail Creek may provide rearing habitat for various fish species, and such fish would likely be killed as a result of high dissolved hydrocarbon concentrations at the time of the spill. Turbulent flow in the Athabasca River further enhances dispersion and dissolution of hydrocarbons in the reaches below the confluence, so that fish mortality is likely within 10 km of the spill location, but unlikely with increasing distance.	High in Trail Creek, because of the confined nature of the habitat and the lack of dilution water, as well as the physical effects of oil spill clean-up on fish habitat in the tributary. Medium in the first 10 km of the river, and Low in more distant reaches, because of the rapid weathering of oil. The high summer flow of the river also provides abundant dilution water, which limits the dissolved concentrations.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of fish habitat in the Athabasca River is complete within 12 months of the spill.
In-water Amphibians	Both adult and juvenile amphibians are likely present in Trail Creek during the summer season, and could be killed. Adult amphibians in shoreline habitat as well as in quiescent areas of the Athabasca River could be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration, likely within the first 10 km, but potentially up to 35 to 50 km downstream.	High in Trail Creek, which likely provides good breeding and rearing habitat for amphibians. High in shoreline habitat of the Athabasca River within 10 km of the spill site, and Medium in areas up to 35 to 50 km downstream, because of the more patchy spatial distribution of stranded oil, and decreased dissolved hydrocarbon concentrations.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of amphibian habitat in the Athabasca River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Similar effects are observed in the riparian areas of the Athabasca River, where high river flows cause flooding and terrestrial vegetation is contacted by oil.	High on the overland flow path and in Trail Creek, as a result of direct effects of oil on vegetation, and as a result of oil spill recovery efforts which result in physical destruction of habitat. Medium to Low in the riparian areas of the Athabasca River, because of the patchy distribution of oil, and with increasing distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the Athabasca River requires about two years, once visible oil has been recovered.
Soil Invertebrates	Soils are oiled along the overland flow path to Trail Creek, and along the creek to the river. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Effects on soil invertebrates are lower in riparian zones of the Athabasca River, in part because of the patchy nature of deposition. The heaviest oiling is noted in the first 10 km downstream from the spill location, but some oiling of riparian areas is observed as far as 35 to 50 km downstream.	High on the overland flow path and in Trail Creek, as a result of direct effects of oil on soil invertebrates, and as a result of oil spill recovery efforts which result in physical destruction of habitat. Medium to Low in the riparian areas of the Athabasca River, because of the patchy distribution of oil, and with increasing distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the Athabasca River requires about two years, once visible oil has been recovered.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 35 to 50 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of "hazing" affected areas, temporarily reducing utilization of this habitat by bears.
Moose	Oiling of individual moose could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 35 to 50 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil with vegetation or as a result of grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of "hazing" affected areas, temporarily reducing utilization of this habitat by moose.
Muskrat	Any muskrat present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Muskrat present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 35 to 50 km.	Effects on muskrat would be High, including mortality of individuals inhabiting Trail Creek and up to 35 to 50 km downstream in the river. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Muskrat populations recover as a result of re-colonization of affected areas from adjacent unaffected areas, likely within 5 years.
River Otter	Any otters present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Otters present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 35 to 50 km.	Effects on otter would be High, including mortality of individuals inhabiting Trail Creek and up to 35 to 50 km downstream in the river. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Otter populations recover as a result of re-colonization of affected areas from adjacent unaffected areas, likely within 5 to 10 years.
Birds			
Bald Eagle	Bald eagle would be present during summer, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 35 to 50 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 35 to 50 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 35 to 50 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 35 to 50 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.

TABLE 6.19 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	**Magnitude**	**Time to Recovery**
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 35 to 50 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 35 to 50 km from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult amphibians could be present in Trail Creek, or in riparian habitat or backwater areas along the Athabasca River. Such animals could be exposed to spilled oil for a distance of up to 35 to 50 km from the spill location.	High to Medium. Amphibians present in Trail Creek could be smothered by spilled oil or die from exposure to volatile hydrocarbons. Amphibians along the shoreline of the Athabasca River would be less exposed, and effect magnitude would decline with decreasing exposure. The risk of acute lethality would be greatest in the first 10 km downstream from Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 24 months. Recovery of habitat in the Athabasca River is complete within 12 months of the spill.

TABLE 6.20 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Spring and Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Submerged, floating and emergent aquatic vegetation in Trail Creek is likely to be killed by the flow of oil at the time of the spill, or by subsequent oil spill recovery efforts. Very little aquatic vegetation is present in the Athabasca River, because of the high summer flows and cobble-gravel nature of most of the river bed. Effects are therefore likely to be limited to Trail Creek.	High in the creek, because clean-up activities would result in the physical destruction and subsequent reconstruction of aquatic habitat. Low in the Athabasca River, because of the general scarcity of aquatic vegetation.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the aquatic plant community begins about 12 months after the spill, and is effectively complete after 5 years. Recovery of the aquatic plant community in the Athabasca River is complete within one year of the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of Trail Creek and the river. Effects on the benthic community of the tributary are substantial, affecting the entire creek as a result of oil spill recovery activities. Effects on the benthic community of the river range from moderate, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations near the confluence with the creek, to Low, in downstream areas.	High in Trail Creek, with direct effects of oiling and hydrocarbon exposure as well as oil spill recovery activities resulting in the physical destruction, and then reconstruction of aquatic habitat in the creek. Medium to Low in the Athabasca River, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of the benthic invertebrate community begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of the benthic community in the river is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer.
Fish and Fish Eggs	The lower reaches of Trail Creek may provide spawning habitat for various fish species, with most species spawning either in the spring or the fall. Such fish, and their eggs and larvae, would likely be killed as a result of high dissolved hydrocarbon concentrations during the spill. Flow in the Athabasca River is less turbulent than in the summer, but the lower flow also reduces the dilution potential. Fish mortality, as well as effects on eggs in spawning habitat, is likely to occur within 10 km of the spill location.	High in Trail Creek, because of the confined nature of the habitat and the lack of dilution water, as well as the physical effects of oil spill clean-up on fish habitat in the tributary. Moderate in the first 10 km of the Athabasca River, and Low in more distant reaches of the river, because of weathering of oil which causes more water soluble fractions to evaporate.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of fish habitat in the Athabasca River is complete within 12 months of the spill.
In-water Amphibians	Both adult amphibians and their eggs or larvae are likely present in Trail Creek during the spring season, and would be killed. Adults and juveniles could be present in the fall. Amphibians in shoreline habitat, as well as in quiescent areas of the Athabasca River, could be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration.	High in Trail Creek, which likely provides good breeding and rearing habitat for amphibians. Moderate in shoreline habitat of the Athabasca River within 10 km of the spill site, and Low in areas between 10 and 25 km downstream, because of the limited contact of oil with riparian habitat.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 2 years. Recovery of amphibian habitat in the Athabasca River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Lesser effects are observed in the riparian areas of the river, because flow is within the banks, and oil contact with the riparian areas is minimal.	High along the overland flow path and in Trail Creek, because of direct effects of oil on vegetation, and because of oil spill recovery efforts which result in physical destruction of habitat. Low in the riparian areas of the Athabasca River, because of minimal contact between spilled oil and riparian habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the shoreline areas of the Athabasca River requires about one year, once visible oil has been recovered.
Soil Invertebrates	Soils are oiled along the overland flow path to Trail Creek, and along the creek to the Athabasca River. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Lesser effects are observed in the riparian areas of the Athabasca River, because flow is within the banks of the river, and oil contact with the riparian areas is minimal.	High along the overland flow path and in Trail Creek, because of direct effects of oil on soil invertebrates, and because of oil spill recovery efforts which result in physical destruction of habitat. Low in the riparian areas of the Athabasca River, because of minimal contact between spilled oil and riparian habitat.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the shoreline areas of the Athabasca River requires about one years, once visible oil has been recovered.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during spring or fall is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of "hazing" affected areas, temporarily reducing utilization of this habitat by bears.
Moose	Oiling of individual moose could occur if they forage within Trail Creek, or along the shoreline of the Athabasca River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during spring or fall is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path and areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of "hazing" affected areas, temporarily reducing utilization of this habitat by moose.
Muskrat	Any muskrat present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Muskrat present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 25 km.	Effects on muskrat would be High, including mortality of individuals inhabiting Trail Creek and up to 25 km downstream. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Muskrat populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
River Otter	Any otters present in Trail Creek are likely to be killed by direct contact with spilled oil, or inhalation of vapours at the water surface. Otters present in the Athabasca River are also likely to become oiled and die throughout the affected reach of 25 km.	Effects on otter would be High, including mortality of individuals inhabiting Trail Creek and up to 25 km downstream. Disturbance caused by oil spill recovery activities would also eliminate their habitat in Trail Creek.	Areas around Trail Creek are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Otter populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
Birds			
Bald Eagle	Bald eagle would be present during spring and fall, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs during the spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. Oiled birds could also transfer oil to eggs during the spring, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs during the spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs during the spring, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.

TABLE 6.20 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE ATHABASCA RIVER NEAR HINTON, ALBERTA

Athabasca River, Spring and Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs during the spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 25 km from the spill location.	Medium. Neither partial oiling of feathers nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult amphibians could be present in Trail Creek, or in riparian habitat or backwater areas along the Athabasca River. Such animals could be exposed to spilled oil for a distance of up to 25 km from the spill location.	High to Medium. Amphibians present in Trail Creek could be smothered by spilled oil, or die from exposure to volatile hydrocarbons. Amphibians along the shorelines of the Athabasca River would be less exposed, and effect magnitude would decline with decreasing exposure. The risk of mortality would be greatest in the first 10 km downstream from Trail Creek.	Trail Creek is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of amphibian habitat begins about 12 months after the spill, and is effectively complete after 24 months. Recovery of habitat in the Athabasca River is complete within 12 months of the spill.

For Trail Creek and the Athabasca River in spring and fall (Table 6.20), flows in Trail Creek are potentially high, but flow in the Athabasca River is at an intermediate level, typically rising in the spring due to the onset of freshet, or falling in the fall, as freshet recedes. Most of the spilled oil reaches and is advected downstream in the Athabasca River. Effect magnitude on the overland flowpath and riparian areas of Trail Creek is high but localized, and is addressed by physical remediation and re-seeding of affected areas. Effects on aquatic receptors, including vegetation, invertebrates, fish and amphibians, are high but localized in Trail Creek, and generally medium to low in the Athabasca River. Medium effects are observed within the first 10 km downstream from Trail Creek, and low magnitude effects are observed between 10 and 25 km downstream. Most of the oil becomes stranded along shorelines, but there is little contact with riparian areas due to the moderate water level in the river. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flowpath and along Trail Creek, but low along the Athabasca River due to the low level of exposure. The overland flowpath and Trail Creek are subject to intensive oil spill clean-up which is initially destructive to habitat. Environmental effects on mammal populations are greatest for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 25 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the spring and fall could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

6.4.2. North Thompson River near Darfield, British Columbia at RK 766.0

The hypothetical spill scenario involves a release of 1,400 m^3 of CLWB at RK 766.0. Details of the local environment can be found in Section 6.1.2.2. Like the Athabasca River, the North Thompson River has a flow regime that is driven by glacial meltwater, with a strong mid-summer freshet. However, the North Thompson River experiences considerably higher summer flows than the Athabasca River, while having lower average gradient. The hypothetical spill location is within approximately 120 m of the river bank, just west and upgradient of the Southern Yellowhead Highway. Overland flow would cause oil to move towards the highway and potentially along a roadside ditch until encountering a culvert that would allow passage beneath the highway. Emerging on the east side of the highway, the oil would follow local drainage pathways to the river. Some holdup of spilled oil in pools and low areas between the spill site and the river is possible, but the overall proximity is such that most of the spilled oil (*i.e.,* 1,000 m^3 or greater) is assumed to reach the river. The North Thompson River at this location is approximately 300 m wide in unconstrained channel areas, although the hypothetical spill location is near the downstream end of a large island that causes the river to divide. Scour marks on the island and on nearby riparian habitat indicate that flood flows can extend over the island and a considerable distance across the intervale. Flows are strongly seasonal ranging from approximately 1,300 m^3/s in June (during freshet, with peak flow potentially up to 2,000 m^3/s), to low flows between December and March that are potentially less than 100 m^3/s.

This spill example is evaluated with particular reference to four cases for comparison: the Kalamazoo River oil spill, since that oil spill involved a similar form of diluted bitumen, and the gradient of the Kalamazoo River is most similar to that of the North Thompson River; the modelling conducted by Enbridge for the Morice and Athabasca Rivers; and the Yellowstone River oil spill.

Three sets of environmental conditions are considered for this spill example. These are:

- A winter condition between December and March, with ice cover on the river and snow cover on the land. Air temperatures are assumed to be below the freezing mark, and the river flow is in the low range (100 m^3/s or less).

- A summer condition between June and August, with air temperatures in the warm range (15 ºC to 25ºC). The river is in freshet, with flow greater than 1,250 m^3/s.
- A spring or fall condition between April and June, or September and November. The river flow is in a moderate range, at around 500 m^3/s, and the air temperatures are cool, between the freezing point and 15ºC.

6.4.2.1. Winter Conditions

Under winter conditions, snow on the ground and in roadside ditches acts to absorb spilled CLWB; however, although the hills around the Kamploops region are noted for high snowfall, winter temperatures are not particularly cold. Therefore, although the North Thompson River can be ice covered for several months of the year, it responds quickly to snow melt or rain events, and the ice cover may not be reliable. Low temperatures also help to limit the flow of CLWB as its viscosity increases as it cools. Most of the spilled CLWB (approximately 1,000 m^3) reaches the North Thompson River and spreads out on the ice. Open water patches in the ice allow some of the oil to become entrained in the river, and it moves downstream beneath the ice but still floats as its density is initially around 0.94. Owing to winter conditions, many of the ecological receptors that could potentially be exposed are absent, or dormant.

Table 6.21 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 766.0 during the winter. Due to winter conditions, overland flow of the oil is slowed, and some of the oil is absorbed into the snowpack. Following local terrain, crude oil would reach the roadside ditch on the west side of the Southern Yellowhead Highway, then move along the ditch until encountering a culvert. Emerging on the east side of the highway, the oil would follow local drainages to the river. During winter conditions, most migratory birds would be at their wintering grounds, so acute effects on raptors, waterfowl, wading and shorebirds are unlikely to be of high magnitude. Similarly, some mammals such as bears would be hibernating, although others such as moose, muskrat and river otter remain active year-round. Due to the limited spatial extent of physical oiling, effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would likewise be limited in spatial extent. However, oil spill recovery effects on the overland flowpath would be substantial, likely requiring extensive excavation causing destruction of habitat, followed by reconstruction and restoration of the terrestrial habitat. Depending upon the receptor group, this process of restoration and recovery could take anywhere from 18 months to five years.

6.4.2.2. Summer Conditions

Under summer conditions, the spilled CLWB flows overland to the west side of the Southern Yellowhead Highway, moves along the ditch until encountering a culvert, and emerges on the east side of the highway. The oil then follows local drainages to the North Thompson River. Some oil is held up in low areas, or absorbed onto vegetation and the soil litter layer, and some penetrates or is absorbed by soil. Most (approximately 1,300 m^3) of the spilled CLWB is likely to reach the North Thompson River over a period of several hours.

TABLE 6.21 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BRITISH COLUMBIA

North Thompson River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Aquatic vegetation is not contacted by spilled oil.	Low. Aquatic vegetation is not actively growing at the time of the spill, and ice cover prevents contact between the spilled oil and aquatic vegetation.	Spilled CLWB is prevented from entering, or is recovered from the river surface, without materially affecting aquatic vegetation.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the river. Effects on the benthic community of the river are Low, because most of the spilled oil is recovered.	Low, although localized areas of Medium effect magnitude may be present.	Recovery of the benthic community in the North Thompson River is complete within 6 months of the spill.
Fish and Fish Eggs	Fish are present in the river, and salmonid eggs may be present in pockets of suitable habitat in the river bed downstream from the oil spill location. However, effects on fish and fish eggs are Low, because most of the spilled oil is recovered.	Low, because very little oil contacts the river water.	Recovery of fish habitat in the North Thompson River is complete within 6 months of the spill.
In-water Amphibians	Juvenile amphibians are not present in the winter season. Adult amphibians are unlikely to be wintering in the river sediments, although presence of individuals in protected locations is possible.	Low, because overwintering amphibians will be buried in sediments in protected locations, and are unlikely to be directly contacted by the spilled oil.	Recovery of amphibian habitat in the North Thompson River is complete within 6 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the North Thompson River, but annual plants are not present except as seeds, and perennial plants, shrubs and trees are in a dormant state. Little if any shoreline habitat of the North Thompson River is affected.	Low, because plants are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat along the overland flow path and in some limited shoreline areas.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to the North Thompson River, but soil invertebrates are in a dormant state. Little if any shoreline habitat of the North Thompson River is affected.	Low, because the soil invertebrates are in a dormant state at the time of the spill. However, oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat along the overland flow path and in some limited shoreline areas.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	Not likely to be directly affected as they hibernate during winter.	Low, because the probability of a grizzly bear den being located within the overland flow path is very small. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Moose	Potentially affected. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, and oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Muskrat	Potentially affected, as muskrat remain active through the winter. However, effects on more than a few individual animals are unlikely.	Low, because muskrat populations will be limited along the main stem of the North Thompson River, with occupancy mainly in protected areas such as tributaries where exposure to oil is unlikely.	Recovery of this habitat is complete within 6 months of the spill.
River Otter	Potentially affected, as otters remain active through the winter. Most otter habitat would be present around openings in the river ice, where access to fish is present. Effects on more than a few individual animals are unlikely.	Low, because populations will be limited along the main stem of the North Thompson River, with occupancy mainly in protected areas such as tributary mouths with open water, where exposure to oil is unlikely.	Recovery of this habitat is complete within 6 months of the spill.
Birds			
Bald Eagle	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia, although individual birds may overwinter in areas with open water.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Western painted turtle habitat extends into the North Thompson River. Adult turtles and amphibians could potentially be overwintering in the sediments of protected areas such as backwaters and tributaries, but these will be minimally affected.	Low, because overwintering turtles and amphibians will be buried in stream or pool and pond sediments, and are unlikely to be directly contacted by the spilled oil.	Recovery of turtle habitat in the North Thompson River is complete within 6 months of the spill.

Table 6.22 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 766.0 during the summer. The river is at or near flood stage, and as the oil enters on the western shoreline it is advected downstream by the quickly moving water. Because the oil is unweathered, and has low viscosity and density less than that of the water, it spreads across the water surface. Oil is trapped along shorelines, and in particular where river flow is above the banks and vegetation is flooded. Due to the high water, however, the river flow is turbulent, and in the early stages of the spill the turbulence of the river flow is sufficient to entrain droplets of the oil in the water, enhancing the dissolution of BTEX and other light-end hydrocarbons into the water column, although much of this oil also re-surfaces. As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of the oil becomes submerged and/or sinks in quiescent areas such as eddy zones behind islands and in backwaters. Although the water of the North Thompson River is somewhat turbid, the suspended sediment load is not particularly high and the water has no appreciable salinity; thus OMA formation is not a significant factor in the fate of the spilled oil. Most of the spilled oil has weathered, largely due to evaporation, or stranded along shoreline and in riparian zones within 60 km of the spill location. A small amount of oil is advected farther downstream primarily as submerged oil, and some traces of oil are subsequently found in silty sediment deposits at the upstream end of Kamloops Lake, below the confluence of the North and South Thompson Rivers.

6.4.2.3. Spring or Fall Conditions

Under spring or fall conditions, the spilled CLWB flows overland to the west side of the Southern Yellowhead Highway, moves along the ditch until encountering a culvert, and emerges on the east side of the highway. The oil then follows local drainages to the North Thompson River. Some oil is held up in low areas, or absorbed onto vegetation and the soil litter layer, and some penetrates or is absorbed by soil. Most (approximately 1,300 m^3) of the spilled CLWB is likely to reach the North Thompson River over a period of several hours.

Table 6.23 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 766.0 during the winter. The river is flowing normally, and confined within its banks. As the oil enters on the western shoreline it is advected downstream by the moving water. Because the oil is unweathered, and has low viscosity and density less than that of the water, it spreads across the water surface. Floating oil is trapped along shorelines, particularly on gravel and cobble exposures, but does not penetrate these deeply due to the shallow slope of the shorelines and the presence of the water table at or near the surface. Due to the low gradient of the river and the moderate water flow, the turbulence in the river is rarely sufficient to entrain droplets of the oil in the water. As a result the concentrations of BTEX and other light-end hydrocarbons in the water column are lower, but the surface slick tends to be thicker. As the oil is transported downstream and weathers, it becomes more viscous and dense. Interactions between floating oil and shoreline sediments result in adhesion of sand and small gravel particles to oil globules, and some of the oil becomes submerged and sinks in quiescent areas such as eddy zones behind islands and in backwaters. As described for the Athabasca River, water levels are generally rising in the spring, and falling in the fall, and thus will influence the fate of oil that strands on shorelines. Although the water of the North Thompson River is somewhat turbid, the suspended sediment load is not particularly high and the water has no appreciable salinity; thus OMA formation is not a significant factor in the fate of the spilled oil. Most of the spilled oil has weathered, largely due to evaporation, or stranded along shoreline and in riparian zones within 25 km of the spill location. A small amount of oil is advected farther downstream primarily as submerged oil, but does not extend to the confluence of the South and North Thompson rivers.

6.4.2.4. Environmental Effects Summary for Spill Scenarios at RK 766.0

A hypothetical spill scenario has been developed to describe the likely fate and behaviour of CLWB spilled as a result of a pipeline rupture near RK 766.0. Potential environmental effects likely to accrue to ecological receptors as a result of such hypothetical spills have been outlined in Table 6.21 through Table 6.23.

For the North Thompson River in winter (Table 6.21), snow and ice conditions are less reliable than those at the Athabasca River, due to generally milder winter conditions. However, conditions are still likely to be such that much of the spilled CLWB is held up before reaching the river, and the presence of ice on the river prevents a large amount of oil from entering the water. Under these circumstances, the environmental effects of spilled oil may be minimized, because most of the oil is recoverable. Oil spill recovery efforts would still result in environmental effects along the overland flowpath, but effects on the North Thompson River would be reduced. Many of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* migratory birds), although some birds such as bald eagle may be present through the winter where open water occurs. The spatial extent of high magnitude oil spill effects would therefore be limited to the overland flowpath, where the primary environmental effects would be those associated with oil spill recovery efforts. Oil spill effect magnitudes for aquatic receptors in the North Thompson River would be low to medium, depending upon how much oil entered the river. Effect magnitudes on shoreline and riparian vegetation and soil invertebrates would be low, due partly to winter dormancy, and particularly to the low level of exposure given low winter water levels. Effect magnitudes for mammals and birds would generally be low due to lack of exposure for migratory birds or hibernating mammals, but also to the low level of exposure within the North Thompson River. Recovery of the terrestrial environment would take approximately 18 months to five years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer.

For the North Thompson River in summer (Table 6.22), flow in the river is peaking, due to snow melt in its mountain headwaters. Most of the spilled oil reaches and is rapidly advected downstream in the North Thompson River. Effect magnitude on the overland flowpath is high but localized, and is addressed by physical remediation and re-seeding of affected areas. Effects on aquatic receptors, including vegetation, aquatic invertebrates, fish and amphibians are generally medium to low, except for amphibians which may be affected in breeding habitats riparian to the river, if these areas are subject to heavy oiling. High turbulence in the river water tends to increase the dissolution of hydrocarbons into the river water, but the high flow rate of the river provides dilution, and widespread mortality of fish in the North Thompson River is unlikely. Much of the spilled oil becomes stranded along shorelines, and in riparian areas where vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flowpath, but medium to low along the North Thompson River due to the patchy distribution of the oil. Whereas the overland flowpath is subject to intensive oil spill clean-up which is initially destructive to habitat, areas riparian to the river are remediated with less intrusive methods, and a greater emphasis on natural attenuation of spilled oil residues at low levels. Environmental effects on mammal populations are high for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 60 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend for up to 60 km downstream. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

TABLE 6.22 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BRITISH COLUMBIA

North Thompson River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Very little aquatic vegetation is present in the North Thompson River, because of the high summer flows, turbid water, and cobble-gravel nature of most of the river bed.	Low, because of the general scarcity of aquatic vegetation.	Not Applicable
Aquatic Invertebrates	Turbulent flow in the North Thompson River enhances dispersion and dissolution of hydrocarbons so effects on aquatic invertebrates are likely within 10 km of the spill location. Effects range from Medium, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations near spill location, to Low in downstream areas.	Medium to low, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected, but these are localized, and tend to be silty sediments, rather than gravel/cobble areas.	Recovery of the benthic community is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer to recover fully.
Fish and Fish Eggs	Turbulent flow in the North Thompson River enhances dispersion and dissolution of hydrocarbons so that fish mortality is likely within 10 km of the spill location. However, as the oil spreads across the surface of the river, and the dissolved hydrocarbons are diluted by the full flow of the river, lethal exposures to fish become unlikely.	Medium in the first 10 km of the river, and Low in more distant reaches of the river, as a result of the rapid weathering of oil which causes more water soluble fractions to evaporate. The high summer flow of the North Thompson River also provides abundant dilution water, which limits the dissolved concentrations in the river.	Recovery of fish habitat in the North Thompson River is complete within 12 months of the spill; the fish community is restored by immigration from nearby unaffected areas and tributaries.
In-water Amphibians	Adult amphibians in shoreline habitat as well as in quiescent areas of the North Thompson River would be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration. Effects are most likely within 10 km of the spill site, but remain possible up to 60 km from the spill site.	High in shoreline habitat of the North Thompson River within 10 km of the spill site, and Medium in areas up to 60 km downstream, as a result of the more patchy spatial distribution of stranded oil, and decreased dissolved hydrocarbon concentrations.	Recovery of amphibian habitat in the North Thompson River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the North Thompson River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Similar effects are observed in the riparian areas of the river, where high river flows cause flooding and terrestrial vegetation is contacted by oil.	High along the overland flow path, but Medium to Low in the riparian areas of the North Thompson River, as a result of the patchy distribution of oil, and decreasing with distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the North Thompson River requires about two years, once visible oil has been recovered.
Soil Invertebrates	Soils are oiled along the overland flow path to the river. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Effects on soil invertebrates are lower in riparian zones of the North Thompson River, in part because of the patchy nature of deposition. The heaviest oiling is noted in the first 10 km downstream from the spill location, but some oiling of riparian areas is observed as far as 60 km downstream.	Medium to Low in the riparian areas of the North Thompson River, as a result of the patchy distribution of oil, and with increasing distance from the spill site. In these areas, most oil spill recovery efforts have Low magnitude effect on habitat quality because of efforts to avoid physical damage to habitat, and to allow natural attenuation after recovery of visible oil.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Natural attenuation in the riparian areas of the North Thompson River requires about two years, once visible oil has been recovered.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage along the shoreline of the North Thompson River up to 60 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. Recovery of river riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of "hazing" affected areas, temporarily reducing utilization of this habitat by bears.
Moose	Oiling of individual moose could occur if they forage along the shoreline of the North Thompson River up to 60 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. Recovery of river riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Oil spill response activities could have the beneficial side effect of "hazing" affected areas, temporarily reducing utilization of this habitat by moose.
Muskrat	Muskrat present in the North Thompson River are also likely to become oiled and die throughout the affected reach of up to 60 km.	Effects on muskrat would be High, including mortality of individuals up to 60 km downstream.	Recovery of river and riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Muskrat populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
River Otter	Otters present in the North Thompson River are likely to become oiled and die, throughout the affected reach of up to 60 km.	Effects on otter would be High, including mortality of individuals up to 60 km downstream.	Recovery of river and riparian habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Otter populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
Birds			
Bald Eagle	Bald eagle would be present during summer, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in riparian habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 60 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult turtles and amphibians could be present in riparian habitat or backwater areas along the North Thompson River. Such animals could be exposed to spilled oil for a distance of up to 60 km from the spill location.	High to Medium. Effect magnitude would decline with distance downstream and decreasing exposure. The risk of acute lethality would be greatest in the first 10 km downstream from spill location.	Recovery of turtle habitat in the North Thompson River is complete within 12 months of the spill.

TABLE 6.23 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE NORTH THOMPSON RIVER NEAR DARFIELD, BRITISH COLUMBIA

North Thompson River, Spring and Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	Very little aquatic vegetation is present in the North Thompson River, as a result of the high summer flows, turbid water, and cobble-gravel nature of most of the river bed.	Low, as a result of the scarcity of aquatic vegetation generally.	Not Applicable
Aquatic Invertebrates	Spring and fall flows in the North Thompson River are less turbulent than in summer, limiting the dispersion and dissolution of hydrocarbons in the reaches below the spill site, so that most aquatic invertebrate mortality is limited to areas within the first 5 km. Effects on the benthic community range from Medium, as more sensitive species are killed by direct contact with oil droplets or by dissolved hydrocarbon concentrations within 5 km of the spill location, to Low, in downstream areas.	Medium to low, depending upon exposure to dissolved hydrocarbons and oil droplets in the water column. Effects on the benthic community would be patchy, reflecting the hydrology of the river. Areas of oil accumulation in sediment would be most affected, but these are localized, and tend to be silty sediments, rather than gravel/cobble areas.	Recovery of the benthic community is largely complete within 12 months of the spill, although isolated areas such as eddies and backwaters, where silty sediments potentially trap sunken oil, would take longer to recover fully.
Fish and Fish Eggs	Spring and fall flows in the North Thompson River are less turbulent than in summer, limiting the dispersion and dissolution of hydrocarbons in the reaches below the spill site, so that most fish mortality is limited to areas within the first 5 km. As the oil spreads across the surface of the river, and the dissolved hydrocarbons are diluted by the full flow of the river, lethal exposures to fish become less likely.	Medium in the first 5 km of the river, and Low in more distant reaches of the river, as a result of the rapid weathering of oil which causes more water soluble fractions to evaporate. The North Thompson River provides abundant dilution water, which limits the dissolved concentrations in the river.	Recovery of fish habitat in the North Thompson River is complete within 12 months of the spill; the fish community is restored by immigration from nearby unaffected areas and tributaries.
In-water Amphibians	Adult amphibians or amphibian eggs and larvae (in spring) in shoreline habitat as well as in quiescent areas of the North Thompson River would be killed if contacted by oil, or by exposure to dissolved hydrocarbons at high enough concentration. This would be most likely within 10 km of the spill site, although effects could be observed up to 25 km downstream.	High in shoreline habitat of the North Thompson River within 10 km of the spill site, and Medium in areas up to 25 km downstream, as a result of the more patchy spatial distribution of stranded oil, and decreased dissolved hydrocarbon concentrations.	Recovery of amphibian habitat in the North Thompson River is complete within 12 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the North Thompson River. Actively growing annual and perennial ground level vegetation is killed, but shrubs and trees are not. Riparian areas of the river are not affected, as the river is flowing within its normal banks.	High on the overland flow path, as a result of aggressive clean-up activities on land, but Low to unaffected in riparian areas of the North Thompson River.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Riparian areas along the river are essentially unaffected.
Soil Invertebrates	Soils are oiled along the overland flow path to the river. Oiling and oil spill recovery efforts result in the destruction of the soil invertebrate community in these areas. Riparian areas of the river are not affected, as the river is flowing within its normal banks.	High on the overland flow path, as a result of aggressive clean-up activities on land, but Low to unaffected in riparian areas of the North Thompson River.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 12 months after the spill, and is effectively complete after about 5 years. Riparian areas along the river are essentially unaffected.
Mammals			
Grizzly Bear	Oiling of individual bears could occur if they forage along the shoreline of the North Thompson River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a grizzly bear during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. River riparian habitat is minimally affected. Oil spill response activities focusing on shoreline areas could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by bears.
Moose	Oiling of individual moose could occur if they forage along the shoreline of the North Thompson River up to 25 km downstream from the spill location in the days and weeks following the spill.	Medium. Partial oiling of the fur of a moose during summer is not likely to result in a breakdown of thermoregulation. Ingestion of slightly to highly weathered oil following grooming activity may cause temporary irritation of the digestive system, but is not likely to cause death.	The overland flow path is heavily disturbed by clean-up activities in the first year following the oil spill, but represents a very small area of habitat. River riparian habitat is minimally affected. Oil spill response activities focusing on shoreline areas could have the beneficial side effect of “hazing” affected areas, temporarily reducing utilization of this habitat by moose.
Muskrat	Muskrat present in the North Thompson River are likely to become oiled and die, throughout the affected reach of up to 25 km.	Effects on muskrat would be substantial, including mortality of individuals up to 25 km downstream.	Recovery of shoreline habitat begins about 12 months after the spill, and is effectively complete after 2 years. Muskrat populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
River Otter	Otters present in the North Thompson River are likely to become oiled and die, throughout the affected reach of up to 25 km.	Effects on otter would be substantial, including mortality of individuals up to 25 km downstream.	Recovery of shoreline habitat begins about 12 months after the spill, and is effectively complete after 2 years. Otter populations recover as a result of recolonization of affected areas from adjacent unaffected areas.
Birds			
Bald Eagle	Bald eagle would be present during spring and fall, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil on shoreline habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Mallard Duck	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 25 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in shoreline habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 25 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One year for physical effects of oil exposure, and one to two years for effects on habitat utilization, if clean-up activities result in temporary avoidance of habitat as a result ofdisturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 25 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Turtles and adult amphibians could be present in shoreline habitat or backwater areas along the North Thompson River. Such animals could be exposed to spilled oil for a distance of up to 25 km from the spill location.	High to Medium. Turtles and adult amphibians along the shorelines of the river would be less exposed, and effect magnitude would decline, with distance downstream. The risk of mortality would be greatest in the first 10 km downstream from spill location.	Recovery of turtle and amphibian habitat in the North Thompson River is complete within 12 months of the spill.

For the North Thompson River in spring and fall (Table 6.23), flow in the river is at an intermediate level, typically rising in the spring due to the onset of freshet, or falling in the fall, as freshet recedes. Most of the spilled oil reaches and is advected downstream in the North Thompson River. Effect magnitude on the overland flowpath is high but localized, and is addressed by physical remediation and re-seeding of affected areas. Effects on aquatic receptors, including aquatic vegetation, invertebrates, fish and amphibians, are generally medium to low in the North Thompson River, except for effects on amphibians in spring, which could be high if oil enters habitat where amphibian eggs or larvae are present. Medium effects are observed within the first 10 km downstream from Trail Creek, and low magnitude effects are observed between 10 and 25 km downstream. Most of the oil becomes stranded along shorelines, but there is little contact with riparian areas due to the moderate water level in the river. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flowpath, but low along the North Thompson River due to the low level of exposure. The overland flowpath is subject to intensive oil spill clean-up which is initially destructive to habitat. Environmental effects on mammal populations are greatest for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 25 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the spring and fall could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

6.4.3. Fraser River near Hope, British Columbia at RK 1072.8

The hypothetical spill scenario involves a release of 1,300 m^3 of CLWB at RK 1072.8. Details of the local environment can be found in Section 6.1.2.3. The hypothetical spill location is on the east side of the Fraser River, approximately 25 km southwest of Hope and 6 km east of Agassiz, British Columbia. At this location, the Fraser River is a large river entering the coastal lowlands, but still occupies a broad intervale with mountains on either side. The river is wide, having a main channel width of approximately 350 m, but is meandering and braided, with large islands and gravel bars that are overwashed during periods of high flow. Flow remains strongly seasonal, with freshet in June driven by meltwater in the mountainous terrain to the east and north, tailing off until the end of the year. Low flows are observed in January, February and March, as snow accumulates in the mountains. The water of the lower Fraser River has high turbidity. Winter low flow periods measured at Hope have monthly mean flows of 500 to 2,000 m^3/s. Peak flow in June averages almost 7,000 m^3/s, with maximum recorded monthly mean discharge of 10,800 m^3/s.

The hypothetical spill location is just east of the eastbound lane of Highway 1, on a hillslope adjacent to a gully, approximately 500 m from a small side channel of the Fraser River. Crude oil emerging from the ground would rapidly flow downhill into the gully. The gully is the lower portion of a watercourse originating on the mountain side to the east of the highway and river. Water flows in the gully are highly variable, driven by local precipitation and snowmelt events, and the boulder/cobble substrates clearly show that episodic high flow rates are common. Due to the steep gradient and flashy nature of flows, the watercourse in the gully is not likely to provide fish habitat. The gully passes beneath the two divided lanes of Highway 1, and outwashes to a small side channel of the Fraser River. At low water levels, this channel is stranded, although water remains in pools. Moving downstream, the side channel remains confined to the shoreline for a distance of approximately 6.1 km before emerging from the protection of an island and complex of gravel bars to enter the main stem of the river, approximately 1.5 km upstream from the Agassiz Rosedale (Highway 9) Bridge. From this point, oil could spread across the width of the Fraser River, and would be transported downstream with the flowing water.

Three environmental conditions were considered for this spill example:

- A winter condition between December and March. Air temperatures are assumed to be around the freezing mark, but snow cover is not guaranteed, and the river is ice-free. The river flow is in a low range (around 2,000 m^3/s).
- A summer condition between June and August, with air temperatures 15°C to 25°C. The river is in freshet, with flow greater than 6,000 m^3/s, and potentially approaching 12,000 m^3/s.
- A spring or fall condition between April and June, or September and November. The river flow is in a moderate range, at around 5,000 m^3/s, and the air temperatures are cool, between 0°C and 15°C.

This spill example is evaluated with particular reference to four cases for comparison: the Kalamazoo River oil spill, since that oil spill involved a similar form of diluted bitumen, and the gradient of the Kalamazoo River is most similar to that of the lower Fraser River; the modelling conducted by Enbridge for the Athabasca River near Whitecourt, Alberta; the Yellowstone River oil spill; the DM 932 oil spill; and the Wabamun Lake train derailment.

6.4.3.1. Winter Conditions

Under winter conditions, at this low elevation (no more than 50 masl), it is unlikely that sufficient (if any) snowpack would be present to influence the behaviour of the spilled CLWB. Owing to the frequently wet winter weather, however, it is likely that water is flowing rapidly down the gully towards the Fraser River. As a result of these factors, virtually all (1,250 m^3) of the spilled CLWB reaches the side channel of the Fraser River within a few hours of the rupture event. Although the river stage is low, and waters of the Fraser River are not actively flowing in this portion of the river channel, the flow of water from the gully and other similar tributaries acts to transport spilled oil farther downstream, towards the main channel 6.1 km distant.

Frequent contact with sand and gravel bars acts to hold up some of the spilled oil, and it is possible that emergency responders could trap and recover much of the spilled oil before it entered the main channel of the Fraser River, which is ice free. Failing this, oil entering the main channel, now somewhat weathered, would be advected downstream initially following the left (south) bank of the river, before emerging and dispersing across the river channel between 4 and 7 km downstream of the Agassiz Rosedale Bridge. The river is at low flow, and has a low gradient, so the currents are weak and have low turbulence. Floating oil or slicks may be carried 30 to 50 km downstream from the point where it entered the main river channel, and globules or tar balls may be recovered up to 100 km downstream.

The spilled oil floats until it strands on gravel or sand bars, or other shorelines. As it weathers, it becomes more viscous and thicker, but strands before its density approaches or exceeds that of the water. Little oil is entrained in the water column due to the low turbulence. Although the river has relatively high turbidity, turbidity is at a seasonally low level due to low water flow. There is no appreciable salinity to the water, so OMA formation is limited by the low levels of suspended oil droplets, low suspended sediment concentration, and absence of salinity. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand and gravel particles as the oil weathers, so that the weathered oil-mineral mixture may sink if it is subsequently eroded or flooded before it can be recovered. Owing to winter conditions, many of the ecological receptors that could potentially be exposed are absent, or dormant.

Table 6.24 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 1072.8 during the winter. Due to winter conditions, a considerable portion of the oil is retained in the side channel of the river, and does not reach the main channel. During winter conditions, most migratory birds would be at their wintering grounds, although it is likely that bald eagles and some waterfowl may be overwintering, particularly in sheltered habitat areas like the side channel. Similarly, some mammals such as bears would be hibernating, although others such as moose, muskrat and river otter remain active year-round. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would likewise be limited in spatial extent. The gully does not provide fish habitat. The side channel of the Fraser River would provide fish habitat, and it is likely that, considering the large volume of spilled CLWB and the small amount of water present or flowing in the side channel, acute toxicity to fish would be observed. The main stem of the Fraser River, however, is not likely to experience fish kills due to the large volume of flowing water, the low turbulence and limited potential for oil droplet formation, and the partially weathered condition of the oil by the time it reaches the main channel. Oil spill recovery effects on the side channel of the Fraser River would be substantial. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to five years.

6.4.3.2. Summer Conditions

Under summer conditions, it is assumed that water flow in the gully is low, and that as the oil moves down the gully, it displaces and overflows the water, causing accumulation and penetration of oil into the boulder and cobble outwash materials. This process results in some hold-up of oil that could otherwise reach the Fraser River. As a result, approximately 1,200 m^3 of CLWB reaches the river, which is in flood condition. Water is flowing freely along the side channel, and most of the sand and gravel bars are submerged. The oil is rapidly transported to the confluence with the main river channel, and is swept downstream with oil and sheens being observed as far as 100 km downriver, approaching the greater Vancouver area.

As the river is flowing at a high stage, flows frequently wash over islands or riparian areas, with oil contacting vegetation and shoreline soils. Air and water temperatures are relatively warm, so the oil weathers quickly. The side channel is quiescent, but turbulent flow is encountered as the oil enters the main river channel, and some oil is entrained into the water column, locally enhancing concentrations of dissolved hydrocarbons at this point. The viscosity of the oil increases as it weathers, so most of the oil remains on the surface, in patchy slicks and sheens, until it strands on shorelines, often coating vegetation.

The river is turbulent and has high turbidity at this time of year. The turbulent flow tends to entrain oil droplets into the water column in the upper reaches of the spill-affected area, but there is no appreciable salinity to the water, so OMA formation is limited. Most of the oil becomes stranded on shorelines and vegetation, so as water levels drop, this oil remains stranded and little remains in the riverbed as sunken oil. The presence of residual oil in riparian areas leads to exposure for ecological receptors occupying terrestrial and shoreline habitat.

Table 6.25 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 1072.8 during the summer. Due to the summer conditions, the oil is rapidly advected as much as 100 km downstream, with oil becoming stranded on shorelines and coating shoreline vegetation. During summer conditions, most migratory birds would be present, and breeding. Similarly, mammals such as bears, moose, muskrat and river otter would be present and active. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would likewise be limited in spatial extent. The gully does not provide fish habitat. The side channel of the Fraser River would provide fish habitat, and it is possible that fish mortality might be observed in the side channel. The main stem of the Fraser River, however, is not likely to experience fish kills due to the large volume of flowing water, notwithstanding the turbulence and potential for oil droplet formation. Oil spill recovery effects would be greatest on riparian and shoreline habitat. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to five years.

6.4.3.3. Spring or Fall Conditions

Under spring and fall conditions, it is assumed that water would be flowing down the gully, and that the spilled oil would quickly moves down the gully, displacing water and overflowing on the boulder and cobble substrates, with some accumulation and penetration of oil into the outwash materials. This process results in some hold-up of oil that could otherwise reach the Fraser River. Approximately 1,200 m^3 of CLWB reaches the river, which is flowing normally, within its banks, between 2,000 and 4,000 m^3/s. Some river water is flowing slowly along the side channel, but most of the sand and gravel bars remain visible. The oil flows along the side channel to the confluence with the main river channel, and is subsequently transported downstream with oil and sheens being observed as far as 60 km downriver.

As the river is flowing at a moderate stage, flows the river banks, islands and gravel bars provide abundant solid substrate that oil can adhere to. Oiling, however, is principally confined to sand and gravel shorelines, and little riparian habitat is oiled. Flow in the side channel is quiescent, but more turbulent flow is encountered as the oil enters the main river channel, and some oil is entrained into the water column, locally enhancing concentrations of dissolved hydrocarbons at this point. The viscosity of the oil increases as it weathers, so most of the oil remains on the surface, in patchy slicks and sheens, until it strands on shorelines.

The river has moderate turbulence and turbidity at this time of year. The turbulent flow tends to entrain some droplets of relatively unweathered oil into the water column in the upper reaches of the spill-affected area, but there is no appreciable salinity to the water, so OMA formation is limited. Most of the oil becomes stranded on shorelines. In the springtime, water levels tend to be steadily rising, so some of this oil may re-float, and some (if it has mixed with sand and gravel) may remain submerged or sink. In the fall, water levels tend to be steadily falling, so stranded oil will generally remain stranded and exposed to weathering on the shoreline through the winter months. This results in different exposure pathways for ecological receptors in spring and fall.

Table 6.26 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 1072.8 during the spring or fall. Due to the river flow condition, the oil is advected as much as 60 km downstream, with much of the oil becoming stranded on shorelines and gravel bars. As described for the Athabasca River, water levels are generally rising in the spring and falling in the fall, and this will influence the fate of oil that strands on shorelines. During the spring and fall conditions, many migratory birds would be present. Similarly, mammals such as bears, moose, muskrat and river otter would be present and active. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations. Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would likewise be limited in spatial extent. The gully does not provide fish habitat. The side channel of the Fraser River would provide fish habitat, and it is possible that fish mortality might be observed in the side channel. The main stem of the Fraser River, however, is not likely to experience fish kills due to the large volume of flowing water, notwithstanding the turbulence and potential for oil droplet formation. Oil spill recovery effects would be greatest on shoreline habitat. The potential for sunken oil is greatest in spring, as weathered oil that has contacted sand and gravel may be remobilized with rising waters and transported downriver as part of the bedload. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to five years.

TABLE 6.24 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE FRASER RIVER NEAR HOPE, BRITISH COLUMBIA

Fraser River, Winter Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	The small side channel of the Fraser River is assumed to be ice-free, but river water levels are low. The aquatic habitat is mostly small interconnecting pools, with flow provided mainly from tributaries. The side channel, extending some 6 km before entering the main Fraser River, supports some aquatic vegetation, but this is senescent in winter.	High. Aquatic vegetation is not actively growing at the time of the spill. However, oil spill recovery activities result in damage to, and then reconstruction of aquatic habitat in the side channel.	Oil spill recovery efforts in the side channel result in extensive disturbance of this habitat, but erosion and deposition of sediment during and after the summer high flow period effectively restore this habitat, so that effects persist for 6 to 18 months.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the side channel and the main Fraser River. Effects on the benthic community of the side channel (6 km) are substantial, affecting the entire channel as a result of initial toxicity as well as oil spill recovery activities. Effects on the benthic community of the main Fraser River are Low, because most of the spilled oil is recovered.	High although localized in the side channel. However, oil spill recovery activities result in damage to, and then reconstruction of aquatic habitat in the gully and side channel. Low in the main Fraser River, because of the partially weathered nature of the oil, and large size of the river.	The gully and side channel are heavily disturbed by clean-up activities in the first months following the oil spill. Recovery of the benthic invertebrate community begins between 6 and 18 months after the spill, and is effectively complete after 30 months. Recovery of the benthic community in the main Fraser River channel is complete within 6 months of the spill.
Fish and Fish Eggs	Few fish are present in the side channel, because of winter low flow conditions; however such fish, or eggs, would likely be killed throughout the 6 km reach. Fish are present in the main Fraser River. It is not a major migratory period for salmon or eulachon, although steelhead could be migrating up the river during the winter period. Mortality of fish in the main Fraser River is unlikely because of weathering of the oil and the large volume of water flowing in the river.	High although localized in the side channel. However, oil spill recovery activities result in damage to, and then reconstruction of aquatic habitat in the side channel.	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins between 6 and 18 months after the spill, and is effectively complete after 30 months. Recovery of fish habitat in the main Fraser River is complete within 6 months of the spill.
In-water Amphibians	Juvenile amphibians are not present in the winter season. Adult amphibians may be overwintering in the sediments of the side channel, which is wholly affected, or in quiescent areas of the main Fraser River where they are minimally affected.	Medium, because overwintering amphibians will be buried in stream sediments, and are unlikely to be directly contacted by the spilled oil. Oil spill recovery efforts, however, would result in damage to and then reconstruction of habitat in the side channel.	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of fish habitat begins between 6 and 18 months after the spill, and is effectively complete after 30 months. Recovery of fish habitat in the main Fraser River is complete within 6 months of the spill.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path, in the gully leading to the side channel, and potentially in places along the side channel to the main Fraser River, but annual plants are not present except as seeds. Perennial plants, shrubs and trees are in a dormant state. Little if any shoreline habitat of the Fraser River is affected because of low winter water levels.	High along the overland flow path, but Low elsewhere because the plants are in a dormant state at the time of the spill, and water levels are low during the winter. However, oil spill recovery activities result in damage to and then reconstruction of terrestrial habitat near the spill location.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path, in the gully leading to the side channel, and potentially in places along the side channel to the Fraser River. Little if any shoreline habitat of the main Fraser River is affected because of low winter water levels.	High along the overland flow path, but Low elsewhere even though soil invertebrates may remain active during the mild winter conditions. Water levels are low during the winter, so contact with riparian areas of the river is minimal. Oil spill recovery activities result in damage to and then reconstruction of terrestrial habitat near the spill location.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons), some of which may be winter-active in the lower mainland of British Columbia, even if grizzly bear are not present. A small number of individual animals might come into contact with spilled oil in the overland flow path, the gully, the side channel, or stranded along shorelines of the main Fraser River channel.	Low, because mild winter conditions reduce the probability that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Moose	Moose or other ungulates are potentially affected, as the gully and forested riparian areas of the side channel and river could provide sheltering habitat during cold periods. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Muskrat	Muskrat are potentially affected, as the side channel could provide suitable habitat, and muskrat remain active through the winter. However, effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
River Otter	Otters are potentially affected, as they remain active through the winter. Effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the gully and side channel are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial and aquatic habitat begins about 18 months after the spill, and is effectively complete after about 5 years.
Birds			
Bald Eagle	Winter range of bald eagle could extend to the hypothetical spill location. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick.	Low. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard Duck	Not likely to be affected as the winter range is generally south of the pipeline corridor in British Columbia.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Not likely to be affected as the winter range is south of the pipeline corridor in British Columbia.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Not likely to be affected as the winter range is south of the pipeline corridor in British Columbia.	Low, because of lack of exposure.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. A variety of amphibian species could be present in the side channel. Pools in the side channel could provide overwintering habitat for both turtles and amphibians, but these would be dormant and likely buried in sediments under winter conditions.	Low, because overwintering turtles and amphibians will be buried in sediments of the side channel, and are unlikely to be directly contacted by the spilled oil. Oil spill recovery activities, however, have the potential to disturb and possibly kill these animals.	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of turtle and amphibian habitat begins about 18 months after the spill, and is effectively complete after 30 months.

TABLE 6.25 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER NEAR HOPE, BRITISH COLUMBIA

Fraser River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Aquatic Receptors			
Aquatic Vegetation	The side channel of the Fraser River is flooded with water from the main river, and islands, sandbars, and some riparian habitat are inundated. Aquatic vegetation in the side channel has little exposure to floating oil, and generally low sensitivity to dissolved hydrocarbon constituents. Little of the oil sinks in this area.	Low. Aquatic vegetation is not directly exposed to the spilled oil, and oil spill recovery activities focus on riparian habitat, where oil has stranded.	Spilled CLWB enters the side channel of the Fraser River, moving along it quite rapidly because of the high river flow. Oil spill recovery efforts result in little disturbance of this habitat. Recovery is generally complete within 6 months.
Aquatic Invertebrates	The side channel of the Fraser River is flooded with water from the main river, and islands, sandbars, and some riparian habitat are inundated. Aquatic invertebrates in the side channel have little exposure to floating oil, and exhibit a range of sensitivity to dissolved hydrocarbon constituents. Little of the oil sinks in this area. Some sensitive species are locally affected.	Low. Aquatic invertebrates are not directly exposed to the spilled oil, and oil spill recovery activities focus on riparian habitat, where oil has stranded.	Spilled CLWB enters the side channel of the Fraser River, moving along it quite rapidly because of the high river flow. Oil spill recovery efforts result in little disturbance of this habitat. Recovery is generally complete within 6 months.
Fish and Fish Eggs	Fish, including potentially inward migrating salmon, could be present in the side channel. Eulachon are not likely to use spawning habitat this far up the Fraser River. Mortality of fish is possible in the side channel, because of its small dimensions and turbulent flow, with unweathered CLWB forming droplets in suspension in the river water. The same process will continue in the main Fraser River, but mortality of fish here is unlikely because of the high flow rate, and progressive weathering of the oil.	High although fish mortality is localized in the side channel.	Acutely lethal conditions persist for only about one day. Oil spill recovery efforts result in little disturbance of this aquatic habitat. Recovery is generally complete within 6 months.
In-water Amphibians	Amphibians may be spawning or juvenile amphibians may be present, but likely in protected areas not exposed to the high river flows. Turtles may be present and may be breeding, but also in more protected areas. Direct mortality is unlikely for turtles, although some limited mortality of amphibians in the side channel, or riparian areas of the main Fraser River is possible.	Low to Medium, because amphibians and turtles are likely to occupy protected areas, not exposed to the main flow of the Fraser River.	Spilled CLWB enters the side channel of the Fraser River, moving along it quite rapidly because of the high river flow. Oil spill recovery efforts result in little disturbance of this habitat. Recovery is generally complete within 6 months.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	Shoreline and riparian vegetation is oiled along the overland flow path to the gully and side channel, and in riparian areas of the side channel and main Fraser River. Annual plants contacted by the spilled oil are likely to be killed. Leaves of perennial plants, shrubs and trees will also be killed, but these plants are likely to survive and regenerate. Effects extend throughout the riparian areas of the side channel, and where oil accumulates in riparian areas of the main Fraser River, up to 100 km downstream.	High. The combination of direct contact with spilled oil, as well as oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near the spill location. Effects on riparian habitat are patchy, but can extend up to 100 km downstream.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to the side channel, and in riparian areas of the side channel and main Fraser River. Soil invertebrate communities may be affected by residual hydrocarbon concentrations. Effects extend throughout the riparian areas of the side channel, and where oil accumulates in riparian areas of the main Fraser River, up to 100 km downstream.	Medium, because residual hydrocarbon concentrations in soil are generally patchy, and recolonization from adjacent minimally affected areas proceeds rapidly.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivore/carnivores (such as raccoons). A small number of individual animals might come into contact with spilled oil in the overland flow path, the gully, the side channel, or stranded along shorelines of the main Fraser River channel.	Low, because partially oiled animals would not be likely to die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Moose	Moose or other ungulates are potentially affected, as the gully and forested riparian areas of the river could provide sheltering and feeding habitat. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Muskrat	Muskrat are potentially affected, as the side channel could provide suitable habitat. Muskrat in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur, and mortality is possible.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about five years.
River Otter	River otter are potentially affected, as the side channel could provide suitable habitat. Otters in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur, and mortality is possible.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Birds			
Bald Eagle	Bald eagle would be present during summer, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oiling in riparian habitat up to 100 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil on shoreline habitat. Oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oiling in shallow water or riparian habitat up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard Duck	Nesting mallards or other waterfowl could be exposed to oiling in riparian habitat up to 100 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in shoreline habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oiling in shallow water or riparian habitat up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 100 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 6.25 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER NEAR HOPE, BRITISH COLUMBIA

Fraser River, Summer Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Reptiles and air-breathing Amphibians	Adult turtles and amphibians could be present in riparian habitat or backwater areas along the Fraser River. Such animals could be exposed to spilled oil for a distance of up to 100 km from the spill location.	High to Medium. Turtles and amphibians along the shorelines of the river would be less exposed, and effect magnitude would decline with distance downstream and decreasing exposure. The risk of mortality would be greatest in the first 6 km (*i.e.*, the side channel).	The side channel is heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of turtle and amphibian habitat begins about 18 months after the spill, and is effectively complete after 30 months.

TABLE 6.26 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER NEAR HOPE, BRITISH COLUMBIA

Fraser River, Spring or Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
AQUATIC RECEPTORS			
Aquatic Vegetation	The side channel of the Fraser River is somewhat isolated from the main Fraser River because of intermediate water levels. Islands and sandbars are present and visible. Little if any riparian habitat is inundated. Aquatic vegetation in the side channel has little exposure to floating oil, and generally low sensitivity to dissolved hydrocarbon constituents. Little of the oil sinks in this area.	Medium. Some aquatic vegetation is contacted by the spilled oil. Oil spill recovery efforts in the side channel result in damage to the habitat. Oil exiting the side channel to enter the main channel is carried up to 60 km downstream, but little aquatic plant habitat is present in the main channel.	Spilled CLWB enters the side channel of the Fraser River, moving along it and entering the main channel. Because more of the oil is retained in the side channel, more habitat disturbance results from recovery efforts. Recovery is generally complete within 12 to 24 months.
Aquatic Invertebrates	The side channel of the Fraser River is somewhat isolated from the main Fraser River because of intermediate water levels. Islands and sandbars are present and visible. Little if any riparian habitat is inundated. Aquatic invertebrates in the side channel have moderate exposure to dissolved hydrocarbon constituents. Little of the oil sinks in this area.	Medium. Some aquatic invertebrates are killed by exposure to dissolved hydrocarbons in the side channel. Oil spill recovery efforts in the side channel result in damage to the habitat. Oil exiting the side channel to enter the main channel is carried up to 60 km downstream, but flow in the river is such that acute toxicity to aquatic invertebrates is unlikely. Some oil sinks and is deposited to sediment in areas of low flow and silty sediment. This aquatic invertebrate habitat remains compromised.	Spilled CLWB enters the side channel of the Fraser River, moving along it and entering the main channel. Because more of the oil is retained in the side channel, more habitat disturbance results from recovery efforts. Efforts to recover sunken oil from backwater areas of silty sediments take longer, but the natural flow regime of the river tends to periodically erode and resuspend sediment in these areas. Recovery is generally complete within 12 to 24 months.
Fish and Fish Eggs	Fish, including potentially inward migrating salmon in the fall, could be present in the side channel. Eulachon are not likely to use spring spawning habitat this far up the Fraser River. Mortality of fish is possible in the side channel, because of its small dimensions, but flow characteristics have low turbulence, so droplet formation is limited. Flow is more turbulent in the main Fraser River, but the oil is somewhat weathered by the time it leaves the side channel, and the flow volume is still large, limiting the potential for fish mortality.	Medium, and localized in the side channel.	Acutely lethal conditions persist for only about one day. Oil spill recovery efforts result in disturbance of this aquatic habitat. Recovery is generally complete within 12 to 24 months.
In-water Amphibians	Amphibians may be spawning in the spring, but likely in protected areas not exposed to the high summer river flows. Turtles may be present and may be breeding, but also in more protected areas. Direct mortality is unlikely for turtles, although some limited mortality of amphibians in the side channel, or riparian areas of the main Fraser River is possible.	Low to Medium, because amphibians and turtles are likely to occupy protected areas, not exposed to the main flow of the Fraser River.	Spilled CLWB enters the side channel of the Fraser River, moving along it with river flow. Oil spill recovery efforts result in disturbance of this habitat. Recovery is generally complete within 12 to 24 months.
TERRESTRIAL RECEPTORS			
Shoreline and Riparian Vegetation	Some shoreline and riparian vegetation is oiled along the overland flow path to the side channel, but little riparian habitat along the side channel or main Fraser River is contacted by oil, because of intermediate water levels. Annual plants contacted by the spilled oil are likely to be killed. Leaves of perennial plants, shrubs and trees will also be killed, but these plants are likely to survive and regenerate. Effects are largely confined to the overland flow path and the area where the oil enters the side channel.	Low. The combination of direct contact with spilled oil, as well as oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near the spill location. Effects on riparian habitat of the side channel and main Fraser River are minimal.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Soil Invertebrates	Soils are oiled along the overland flow path to the side channel. Riparian areas of the side channel and main Fraser River are minimally affected.	Low. The combination of direct contact with spilled oil, as well as oil spill recovery activities result in the physical destruction, and then reconstruction of terrestrial habitat near the spill location. Effects on riparian habitat of the side channel and main Fraser River are minimal.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivore/carnivores (such as raccoons). A small number of individual animals might come into contact with spilled oil in the overland flow path, the gully, the side channel, or stranded along shorelines of the main Fraser River channel.	Low, because partially oiled animals would not be likely to die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Moose	Moose or other ungulates are potentially affected, as the gully and forested riparian areas of the river could provide sheltering and feeding habitat. Moose tend to be solitary, so effects of external oiling on more than a few individual animals are unlikely.	Low, because moose have a large home range, oil spill recovery activity would quickly cause them to leave the area. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Muskrat	Muskrat are potentially affected, as the side channel could provide suitable habitat. Muskrat in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur up to 60 km downstream, and mortality is possible.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
River Otter	River otter are potentially affected, as the side channel could provide suitable habitat. Otters in this habitat could be heavily oiled, causing death. However, effects on more than a few individual animals are unlikely. Mortality becomes less likely as the oil slick spreads on the main Fraser River, although oiling of individual animals may still occur up to 60 km downstream, and mortality is possible.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy a den near the side channel, and possibly extending into the main Fraser River channel. Disturbance caused by oil spill recovery activities could also temporarily eliminate their habitat.	The overland flow path and areas around the spill location are heavily disturbed by clean-up activities in the first year following the oil spill. Recovery of terrestrial habitat begins between 12 and 24 months after the spill, and is effectively complete after about 5 years.
Birds			
Bald Eagle	Bald eagle would be present during spring and fall, and would likely contact spilled oil while taking fish at the water surface, or as a result of feeding on fish killed by the oil spill. These birds would be partially oiled, and would be further exposed to oil while preening to remove oil from feathers. Such effects could be seen up to 100 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed bald eagles, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	Nesting geese or other waterfowl could be exposed to oil in slicks or stranded on shorelines up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil on shoreline habitat. Oiled birds could also transfer oil to eggs in spring, resulting in embryo mortality. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	Herons and other wading birds could be exposed to oil in slicks or stranded on shorelines up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs in spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard Duck	Nesting mallards or other waterfowl could be exposed to oil in slicks or stranded on shorelines up to 60 km downstream from the spill location.	High to Medium, depending upon the level of exposure to floating oil, or stranded oil in shoreline habitat. High mortality is likely to be observed in oiled ducks. Surviving lightly oiled birds could also transfer oil to eggs, resulting in embryo mortality in spring. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Sandpipers and other shorebirds could be exposed to oil stranded on shorelines up to 60 km downstream from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs in spring, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment in spring, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 6.26 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER NEAR HOPE, BRITISH COLUMBIA

Fraser River, Spring or Fall Season	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Time to Recovery
Tree Swallow	Tree swallows nest in cavities in trees located near the water, and forage over water. Tree swallows may also dip onto the water take emerging insects or drink, or bathe in shallow water pools. These birds could be affected up to 60 km from the spill location.	Medium. Neither partial oiling of feathers, nor incidental oil ingestion is likely to be sufficient to kill exposed birds, but oiled birds may transfer oil to eggs, killing the embryos and resulting in reduced reproductive success. Clean-up activities could also lead to nest abandonment, if nest locations are close to areas of high activity.	One to two years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	Adult turtles and amphibians could be present in riparian habitat or backwater areas along the Fraser River. Such animals could be exposed to spilled oil for a distance of up to 60 km from the spill location.	High to Medium. Turtles and amphibians along the shorelines of the river would be less exposed, and effect magnitude would decline with distance downstream and decreasing exposure. The risk of mortality would be greatest in the first 6 km (*i.e.,* the side channel).	Spilled CLWB enters the side channel of the Fraser River, moving along it and entering the main channel. Because more of the oil is retained in the side channel, more habitat disturbance results from recovery efforts. Recovery is generally complete within 12 to 24 months.

6.4.3.4. Environmental Effects Summary for Spill Scenarios at RK 1072.8

A hypothetical spill scenario has been developed to describe the likely fate and behaviour of CLWB spilled as a result of a pipeline rupture near RK 1072.8. Potential environmental effects likely to accrue to ecological receptors as a result of such hypothetical spills have been outlined in Table 6.24 through Table 6.26.

For the Fraser River in winter (Table 6.24), it is assumed that both the side channel and the main river channel will be ice free and most of the spilled oil is initially distributed along the side channel, a distance of approximately 6 km. Oil spill recovery efforts would result in environmental effects along the overland flowpath, and in the side channel to the Fraser River. Some of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* some migratory birds), although birds such as bald eagle and potentially some waterfowl could be present through the winter due to the ice free conditions. High magnitude oil spill effects would therefore occur along the overland flowpath, where environmental effects associated with oil spill recovery efforts would follow the oil spill effects, and in the gully leading to the river, and in the side channel of the Fraser River, where heavy oiling of the water surface and shorelines would occur, due to the small dimensions of the channel. Oil spill effect magnitudes for aquatic receptors in the side channel would be high to medium, taking into consideration both oil effects and oil spill recovery effects. Mortality of fish in the main channel of the Fraser River is unlikely, due to weathering of the oil that would occur before it reached the main channel, as well as to the large flow volume in the river. Effect magnitudes on shoreline and riparian vegetation and soil invertebrates would be low, due partly to winter dormancy, and particularly to the low level of exposure given low winter water levels. Effect magnitudes for mammals and birds would generally be low due to lack of exposure for migratory birds or hibernating mammals, however, higher effect magnitudes would be seen for semi-aquatic mammals in the side channel and Fraser River due to oiling of fur. Higher effect magnitudes could also be seen for wintering birds such as ducks, depending upon the numbers present. Recovery of the terrestrial environment would take approximately 18 months to five years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer. For the Fraser River in summer (Table 6.25), flow in the river is peaking, due to snow melt in its mountain headwaters. Most of the spilled oil reaches the side channel, and is advected downstream to the confluence with the main Fraser River. Effect magnitude on the overland flowpath and in the gully leading to the side channel is high but localized, and is addressed by physical remediation and re-seeding of affected areas. Effects on aquatic receptors are variable. Effects on aquatic vegetation are of low magnitude as the spilled oil largely floats on the surface of the side channel, so vegetation has little direct exposure. Similarly effects on benthic invertebrates are generally low. There is potential for effects on fish and amphibians in the side channel, due to expected high dissolved hydrocarbon concentrations. Widespread mortality of fish in the main Fraser River is unlikely though. Much of the spilled oil becomes stranded along shorelines, and in riparian areas where vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flowpath, and along the side channel, becoming medium to low along the main Fraser River channel up to 100 km downstream, due to the patchy distribution of the oil. Whereas the overland flowpath is subject to intensive oil spill clean-up which is initially destructive to habitat, areas riparian to the Fraser river are remediated with less intrusive methods, and a greater emphasis on natural attenuation of spilled oil residues at low levels. Environmental effects on mammal populations are high for truly semi-aquatic species such as muskrat, beaver, otter and mink in the side channel, and it is assumed that some of these animals could also be sufficiently oiled to cause death in areas downstream in the main Fraser River channel. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend for up to 100 km downstream. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

For the Fraser River in spring and fall (Table 6.26), flow is at an intermediate level, typically rising in the spring due to the onset of freshet, or falling in the fall, as freshet recedes. Most of the spilled oil reaches and is advected downstream in the side channel and enters the main Fraser River. Effect magnitude on the overland flowpath and in the gully leading to the side channel is high but localized, and is addressed by physical remediation and re-seeding of affected areas. Effects on aquatic receptors, including aquatic vegetation, invertebrates, fish and amphibians, are generally medium to low in the side channel, and low in the Fraser River, except for effects on amphibians in spring, which could be high if oil enters habitat where amphibian eggs or larvae are present. Effects farther downstream in the main Fraser River are generally low, due to increasing dilution and dispersion of the oil. Effects on shoreline and riparian vegetation and soil invertebrates are high on the overland flowpath, but low along the Fraser River due to the low level of exposure. The overland flowpath is subject to intensive oil spill clean-up which is initially destructive to habitat. Environmental effects on mammal populations are greatest for truly semi-aquatic species such as muskrat, beaver, otter and mink, for which it is assumed that mortality could occur throughout a river reach of up to 60 km. For mammals that are larger or that are less adapted to the aquatic environment, such as bears, raccoons and moose, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the spring and fall could be as short as 12 months for some receptors, or up to five years where effects occur at the population level.

6.4.4. Fraser River and Delta near the Port Mann Bridge at RK 1167.5

The hypothetical spill scenario involves a release of 1,250 m^3 of CLWB at RK 1167.5. Details of the local environment can be found in Section 6.1.2.4. The hypothetical spill location for all of the stochastic model simulations was located adjacent to railway yards on the south side of the Fraser River, a short distance downstream from the Port Mann Bridge. At this location, the pipeline is within a few hundred metres of the river, and it is likely that culverts and other drainage systems would rapidly transport virtually all of the spilled oil from the spill location to the river. For this reason, there was assumed to be no hold-up of spilled crude oil on land, although it is possible that by blocking such culverts or ditches as an early emergency response action, a considerable amount of oil could be prevented from reaching the water. The Fraser River at this location is about 450 m wide, with a gentle meander and a sand bed. Shorelines are highly developed with wharves, pilings, log booms and rip-rap. Flows are strongly seasonal, ranging from approximately 7,000 to 12,000 m^3/s in June (during freshet), to 2,000 m^3/s or lower during winter.

This spill example is evaluated with particular reference to four cases for comparison: the Kalamazoo River oil spill, since that oil spill involved a similar form of diluted bitumen; the DM 932 spill in the lower Mississippi River, since that involved a heavy oil, and a large river/estuary system with high suspended sediment load. Consideration is also given to information that was developed during the Gainford experimental study (Witt O'Brien's *et al.* 2013) and as part of the proposed Vancouver Airport Fuel Delivery Project (VAFFC 2012a).

Three sets of environmental conditions are considered for this spill example. These are:

- A winter condition between December and March. Air temperatures are assumed to be around the freezing mark, but snow cover is not guaranteed, and the river is ice-free. The river flow is in the low range (around 2,000 m^3/s).
- A summer condition between June and August, with air temperatures in the warm range (15°C to 25°C). The river is in freshet, with flow greater than 6,000 m^3/s, and potentially approaching 12,000 m^3/s.
- A spring or fall condition between April and June, or September and November. The river flow is in a moderate range, at around 5,000 m^3/s, and the air temperatures are cool, between the freezing point and 15°C.

The ecological receptors considered previously for other hypothetical spill locations will also be considered in relation to potential crude oil spills affecting the Fraser River Delta. It is noted, however, that the potential for finding freshwater turtles and amphibians decreases as the river water becomes brackish. Two species of sea turtle (Pacific green turtle and Pacific leatherback turtle) are reported from British Columbia waters, but reproduce in more southerly areas, and would have a very low probability of being encountered in the Fraser River Delta. During the regulatory review of the proposed Vancouver Airport Fuel Delivery Project, which would have resulted in the construction of a marine terminal to receive imported aviation fuel near the mouth of the Fraser River, federal authorities expressed particular interest in the potential environmental effects of spilled aviation fuel on the Fraser River Estuary, and specifically the environmental effects of spilled fuel on biofilm and migratory birds. As a result, the proponents undertook investigations into the characteristics of the biofilm, conducted oil spill fate modeling to evaluate interactions between spilled aviation fuel and ecological receptors, and conducted investigations into the presence of western sandpiper in the Delta, as well as the feeding behaviour of the sandpipers, which are uniquely reliant upon the biofilm as a source of nutrition while migrating. These studies were reported by the proponents (VAFFC 2012a, b) and underwent regulatory review (Environment Canada 2012). Based on consultation with regulatory authorities carried out for the Trans Mountain Project, as well as consideration of concerns raised during the Vancouver Airport Fuel Delivery Project, consideration is also given here to two ecological receptors not specifically considered elsewhere, namely: biofilm, and Western sandpiper (*Calidris mauri*).

Biofilm (also sometimes referred to as microphytobenthos) is the name given to an assemblage of algal cells, rotifers, protozoans, bacteria and detritus found as a thin layer on the surface of mudflats. Forming a thin layer, biofilm is easily disturbed, although it may potentially help to stabilize the sediment surface from gentle wave action. Studies carried out in early 2012 described two types of organic films on the mudflat at Roberts Bank: a rusty-coloured organic film interpreted as diatoms, and a grey organic floc layer interpreted as extracellular polysaccharide material. Both types of films were observed on cleared plots within as little as 24 hours after clearing (VAFFC 2012a). The principal algal components of the biofilm were found to be pennate diatoms, including *Navicula* spp. And *Pleurosigma* spp. The biofilm and underlying mud also support benthic invertebrate species such as polychaete worms and small crustaceans.

The western sandpiper is a small shorebird, approximately 15 to 17 cm inches in length, with a wingspan of approximately 25 to 35 cm. It has white undersides, a long bill with a little droop at the end, long legs and slightly webbed feet. In the summer, its crown and upper back are a rusty brown. It has a black line on its rump that runs to its tail. In the winter, its crown and upper back are gray. Males and females look alike, but the female is a little larger and has a slightly longer bill (Natureworks 2013). The Western sandpiper nests on tundra in eastern Siberia and Alaska, and summers in the southern United States. Being one of the most abundant shorebirds in North America, its importance in the context of the Fraser River Delta is that during migration in spring. Roberts Bank can host over one million Western sandpiper over a 15 day period (Kuwae *et al.* 2008). During this stopover, the sandpipers feed heavily on biofilm, representing approximately 50% (±18%) of their caloric requirement, with the balance being provided by small invertebrates (Kuwae *et al.* 2008). While Western sandpiper can be found throughout the mudflat areas of Sturgeon and Roberts Banks and Boundary Bay, an area south of Brunswick Point appears to be particularly important as a congregating and feeding area (VAFFC 2012a).

6.4.4.1. Winter Condition

This spill condition is evaluated with primary reference to stochastic spill modeling results representing the months of November, December, January, February and March from EBA (2013). Spill summary information is presented in Appendix B. In winter conditions, at this low elevation and proximity to the ocean, it is unlikely that snowpack would be present to influence the behaviour of the spilled CLWB. It is assumed that culverts and ditching are present close to the pipeline, and that this drainage system quickly and effectively conveys virtually all of the spilled oil directly to the river over a period of several hours. Although the river stage is low, transit times for the spilled oil to reach the river mouth are short, on the order of one to two days, depending upon the tidal state at the time of spill initiation.

Frequent contact with shorelines acts to hold up some of the spilled oil, and it is possible that emergency responders could trap and recover some of the spilled oil, particularly in the main channel, before it reached the mouth of the Fraser River. Failing this, oil entering the main channel would be advected downstream. Most of the spilled oil remains confined to the main river channel, although a small amount enters the north channel but generally strands within a short distance.

The probability of oil presence on the surface of the river exceeds 90% between the Port Mann Bridge and a point downstream of Annacis Island. There is about a 50% probability of oil on the surface of the water reaching the islands and marshes near Port Guichon, and about a 5% to 10% probability of oil on the surface of the water exiting from the mouth of the river, into the Strait of Georgia. This represents a small amount of spilled crude oil, and the probability of oil stranding on Roberts Bank or other mudflats is low. As will be seen in other seasonal simulations, oil leaving via the main river channel tends to be swept out into the Strait of Georgia, and little if any strands in the immediate vicinity of the Delta.

The probability of shoreline oiling is high (generally 60% to 100% between the Port Mann Bridge and the upstream end of Annacis Island, and 60% to 90% along the west and south shorelines of Annacis Island), although lower on the south shoreline of the Fraser River in this area. Lower probability of shoreline oiling (20% to 60%) generally prevails between the middle of Annacis Island and the George Massey Tunnel. Beyond the George Massey Tunnel, the probability of shoreline oiling falls and is generally less than 10%, with most occurring along the main river channel. Some oil is also entrained into the river channels around the islands and marshes near Ladner and Port Guichon, but the probability of oil stranding in these areas is relatively low.

Mass balance plots (Appendix B) show that a large fraction of the spilled crude oil (>80%) has stranded along river shorelines within three days of spill initiation. About 11% of the crude oil has evaporated, and <5% remains on the surface of the water. Small amounts of the oil (generally <1%) also sink, undergo biodegradation, or dissolve into the water. Formation of OMA and dispersion of oil into the water are not predicted to occur to any meaningful extent (each representing <0.1% of the spilled oil).

Weathering CLWB is not likely to achieve a density greater than that of brackish water within 10 days of being spilled (Witt O'Brien's *et al.* 2013). The spilled oil therefore floats until it strands on shorelines. As it weathers, it becomes more viscous and thicker, but strands before its density approaches or exceeds that of the water. Little oil is entrained in the water column due to the viscosity of the oil and the relatively low turbulence of the river flow. Although the river has relatively high turbidity, turbidity is at a seasonally low level due to low water flow. The water is brackish, so OMA formation is limited primarily by the low levels of suspended oil droplets, and low suspended sediment concentrations. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand particles as the oil weathers, so that the weathered oil-sand mixture may sink if it is subsequently eroded or flooded before it can be recovered. Owing to winter conditions, many of the ecological receptors that could potentially be exposed are absent, or dormant.

Table 6.27 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 1167.5 during the winter. In the upper reaches, the river channel is bordered by rip-rap, rock, and beach (Harper 2013), although as noted by Danchuk (2009), the river stage may substantially alter the characteristics of exposed shorelines. At low river flows, little shoreline vegetation or rip-rap would be exposed to flowing water or oil, and most of the exposed shoreline would be sandy or muddy. The lower river reaches and Delta have a greater amount of fringing marsh (Harper 2013), with relatively less artificial shoreline. During winter conditions, most migratory birds would be at their wintering grounds, although the Delta is noted as high quality wintering habitat for raptors, waterfowl, and many shorebirds, particularly in sheltered habitat areas like side channels and wetland. It is less likely that large mammals (such as bear or moose) would be present in this predominantly urban landscape, however, other wildlife species such as raccoons, foxes, deer, otter and muskrat would be present and active year-round. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations.

TABLE 6.27 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BRITISH COLUMBIA

Fraser River Delta, Winter Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	Effect Magnitude	Time to Recovery
Aquatic Receptors			
Biofilm	Biofilm of variable quality will be present wherever sediments are exposed and remain moist at low tide, along the Fraser River channels and on the Banks and mudflats, but particularly in more protected areas and on more stable substrates. Biofilm will not be present on the river bed, generally, as a result of poor light penetration and the shifting sand nature of the river bed. The probability of shoreline oiling in the river is greatest along the south shore between the Port Mann Bridge and Annacis Island, becoming medium in the vicinity of the island, medium to low between the downstream end of Annacis Island and the George Massey Tunnel, and low downstream of the George Massey Tunnel. Sturgeon Bank, Roberts Bank, and the mudflats of Boundary Bay are not significantly exposed to oiling.	Variable, with a High effect magnitude in areas along the river shorelines where oiling is heavy; becoming Low downstream of the George Massey tunnel, and Negligible on the Banks and Boundary Bay.	Short. Biofilm has been observed to re-form within 24 hours following removal from mudflats (VAFFC 2012a), and it is likely that once shoreline clean-up has taken place, biofilm will readily regenerate.
Aquatic Vegetation	Aquatic vegetation is not expected to be a significant component in the main stem of the river, and will be senescent during the winter months in wetland areas that would otherwise be more productive.	Medium to Low. Aquatic vegetation is not actively growing at the time of the spill. However, oil spill recovery activities may result in some damage to oiled shorelines in the lower part of the river. The probability of shoreline oiling decreases substantially below the George Massey Tunnel.	Oil spill recovery efforts along the river channel and in wetland areas result in some disturbance of this habitat, but erosion and deposition of sediment during and after the summer high flow period effectively restore this habitat, so that effects persist for 6 to 18 months.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the main Fraser River, and in wetland and side-channel areas. Effects on the benthic community are low, however, as a result of the small amount of spilled hydrocarbon that becomes dissolved in the river water, and the large river flow.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the benthic community are minor, and rapidly reversible.
Fish and Fish Eggs	Fish are present in the main Fraser River, but it is not a major migratory period for salmon or eulachon, although steelhead could be migrating up the river during the winter period. Mortality of fish in the main Fraser River is unlikely as a result of the large volume of water flowing in the river and the low probability of oil droplet formation.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the fish community are minor, and rapidly reversible.
In-water Amphibians	Juvenile amphibians are not present in winter conditions. Adult amphibians may be overwintering in the sediments of the protected areas in the upstream portion of the river, but are minimally affected. The presence of amphibians becomes less likely as the river becomes more brackish, downstream.	Low, as a result of the low numbers expected to be present in this habitat, and the overwintering dormancy of any animals that may be present.	Short. Effects on amphibians are minor, and rapidly reversible.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	The overland flowpath comprises industrial lands, ditches and culverts. Little if any shoreline riparian habitat of the Fraser River is affected, as a result of low winter water flow rates. Water levels in the Delta and on the Banks remain within normal tidal ranges, so shoreline vegetation is not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low for shoreline communities along the river and in the Delta, as a result of lack of exposure to oiling.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils or vegetation communities of the river and Delta.
Soil Invertebrates	The overland flowpath comprises industrial lands, ditches and culverts. Little if any shoreline habitat of the Fraser River is affected, as a result of low winter water flow rates. Water levels in the Delta and on the Banks remain within normal tidal ranges, so shoreline soil invertebrate communities are not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low for shoreline communities along the river and in the Delta, as a result of lack of exposure to oiling.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils or invertebrate communities of the river and Delta.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons and foxes), some of which may be winter-active in the lower mainland of British Columbia, even if grizzly bear are not present. A small number of individual animals might come into contact with spilled oil in the overland flowpath, or stranded along shorelines of the Fraser River and Delta.	Low, because mild winter conditions reduce the probability that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils or invertebrate communities of the river and Delta.
Moose	It is unlikely that moose would be exposed, but other ungulates such as deer could use habitat along the river or in the Delta. Effects of external oiling on more than a few individual animals are unlikely.	Low, because soil spill clean-up activities will largely be confined to SCAT, and disturbance of habitat where deer or other ungulates are present is likely to be short-term and intermittent.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. No material effects on other shoreline soils and terrestrial habitats of the river and Delta.
Muskrat	Muskrat are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the main Fraser River channel or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual muskrat causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
River Otter	Otters are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy habitat in the main Fraser River channel, or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual otters causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
Birds			
Bald Eagle	Bald eagle, as well as many other raptors, are present year-round. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel.	Low. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	The Fraser River Delta provides important wintering habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel. Geese are likely to spend much of their time foraging in farmland on Westham Island and near Ladner.	Generally Low, as a result of low level of exposure, although individual birds could die if more heavily oiled.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	The Fraser River Delta provides important wintering habitat for herons. Individual birds could become oiled while foraging in shallow water or along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel. Herons also utilize terrestrial habitat and often hunt for voles in farmland during winter.	Generally Low, as a result of low level of exposure, although individual birds could die if more heavily oiled.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 6.27 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING WINTER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BRITISH COLUMBIA

Fraser River Delta, Winter Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	Effect Magnitude	Time to Recovery
Mallard	The Fraser River Delta provides important wintering habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and much lower in side channels and sloughs near Ladner. Likewise, the probability of shoreline oiling decreases substantially downstream of the George Massey Tunnel. Ducks and swans generally would have greater exposure to oil than geese, as a result of their more aquatic habits.	Generally Medium to High. Oil presence on the water surface and stranded along shorelines is most likely in the main river channel, and Low elsewhere, including side channels and sloughs, and in the more marine environment of Roberts and Sturgeon Banks. Individuals and groups of birds could die (giving a High effect magnitude) if heavily oiled in the main river channel. Mortality is less likely elsewhere as a result of lower exposure.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Not likely to be affected as the winter range is south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Western Sandpiper	Not likely to be affected as the winter range is south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	Not Applicable as a result of low probability of shoreline oiling in the Banks.
Tree Swallow	Not likely to be affected as the winter range is south of the pipeline corridor in British Columbia.	Low, as a result of lack of exposure.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the Western painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. The presence of turtles and amphibians becomes less likely as the waters of the estuary become more brackish.	Low, as a result of lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would be limited in spatial extent. The Fraser River provides fish habitat and is a major migration route for Pacific salmon, but winter conditions are not the primary season for such migrations. The main stem of the Fraser River is not likely to experience fish kills due to the large volume of flowing water, the low turbulence and limited potential for oil droplet formation, as indicated by the very small fraction of the spilled CLWB predicted to become dissolved in the water.

Oil spill recovery effects on the main channel of the Fraser River, and in marsh areas near Ladner and Port Guichon, would likely be substantial, leading to physical habitat disturbance. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 18 months to five years.

6.4.4.2. Summer Condition

This spill condition is evaluated with primary reference to stochastic spill modeling results representing the months of May, June and July from EBA (2013). Spill summary information is presented in Appendix B. In summer conditions, it is assumed that the river is at or near peak flow due to the freshet. It is assumed that culverts and ditching are present close to the pipeline, and that this drainage system quickly and effectively conveys virtually all of the spilled oil directly to the river over a period of several hours. Although the river stage is low, transit times for the spilled oil to reach the river mouth are short, on the order of one day. Tidal state is less important in summer than in winter, due to the high water level and flow rate which overwhelm the tidal influence in the upper part of the river.

Frequent contact with shorelines acts to hold up some of the spilled oil, but most of the oil would be rapidly advected downstream. Less of the oil is stranded along shorelines than under winter conditions, and more remains on the water surface, having been discharged into the Strait of Georgia. As in winter, most of the spilled oil is transported along the main river channel. Very little enters the north channel, and this oil generally strands within a short distance. Rather more oil, however, is transported into side channels near Ladner and Port Guichon, and most of this oil is likely to become stranded in the side channels, wetlands and sloughs.

The probability of oil presence on the surface of the river exceeds 90% between the Port Mann Bridge and a point downstream of the George Massey Tunnel. From there to the mouth of the river, the probability of oil on the surface is between 60% and 80%. There is about a 40% probability of oil on the surface of the water entering the side channels and marshes near Ladner and Port Guichon. Oil that reaches the mouth of the river is discharged into the Strait of Georgia with considerable momentum, so that it is likely to disperse to the north or south in the Strait and does not have a high probability of directly affecting the Sturgeon or Roberts Banks. It is more likely that this oil will affect shorelines on the opposite side of the Strait.

The probability of shoreline oiling is high (generally 60% to 100% along the south shore of the river between the Port Mann Bridge and the upstream end of Annacis Island), becoming moderate (40% to 60% along the west and south shorelines of Annacis Island, and along the north shoreline of the Fraser River from the lower end of Annacis Island to the George Massey Tunnel). Moderate probability of shoreline oiling (20% to 40%) generally prevails along the balance of the main channel, and low probability of oiling ((<10%) prevails in the side channels and wetlands near Ladner and Port Guichon. There is low probability of oiling shorelines along the Sturgeon and Roberts Banks, although some oiling occurs around Point Roberts.

Mass balance plots (Appendix B) show that less of the spilled crude oil (<60%) is likely to strand along river shorelines than during the winter. About 10% of the crude oil evaporates, and about 30% may remain on the surface of the water. Small amounts of the oil (generally <1%) also sink, undergo biodegradation, or dissolve into the water. Formation of OMA and dispersion of oil into the water are not predicted to occur to any meaningful extent (each representing <0.1% of the spilled oil).

Weathering CLWB is not likely to achieve a density greater than that of brackish water within 10 days of being spilled (Witt O'Brien's *et al.* 2013). The spilled oil therefore floats until it strands on shorelines. As it weathers, it becomes more viscous and thicker, but mostly strands before its density approaches or exceeds that of the water. Little oil is entrained in the water column due to the viscosity of the oil and the relatively low turbulence of the river flow. Although the river has relatively high turbidity, due to the high flow rate, and the water is brackish, OMA formation remains low due to the low abundance of suspended oil droplets. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand particles as the oil weathers, so that the weathered oil-sand mixture may sink if it is subsequently eroded or flooded before it can be recovered. In addition, there is a potential for reedbeds and salt marsh vegetation to trap floating or submerged oil being transported in the river if it enters the wetland habitats.

Table 6.28 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 1167.5 during the summer. In the upper reaches, the river channel is bordered by rip-rap, rock, and beach (Harper 2013), although as noted by Danchuk (2009), the river stage may substantially alter the characteristics of exposed shorelines. At high water levels, oil may enter and become trapped by rip-rap, or contact flooded riparian vegetation. The lower river reaches and Delta have a greater amount of fringing marsh (Harper 2013), with relatively less artificial shoreline. During summer conditions, most migrating birds (*e.g.,* Western sandpiper) would already be at their summer breeding grounds farther north, although the Delta is noted as high quality habitat for raptors, waterfowl, and shorebirds. It is less likely that large mammals (such as bear or moose) would be present in this predominantly urban landscape, however, other wildlife species such as raccoons, foxes, deer, otter and muskrat would be present and active year-round. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations.

Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would be limited in spatial extent. The Fraser River and Delta provide important fish habitat and the river is a major migration route for Pacific salmon, and some of these fish would be moving through the river during summer. The river is also an important migratory route for Eulachon in spring, with spawning occurring in the river between Chilliwack and Mission. Late spawning adults or fry could be moving down the river in summer. The main stem of the Fraser River, however, is not likely to experience fish kills due to the large volume of flowing water, the low turbulence and limited potential for oil droplet formation, as indicated by the very small fraction of the spilled CLWB that becomes dissolved in the water.

Oil spill recovery effects on the main channel of the Fraser River, and in marsh areas near Port Guichon, would likely be substantial, leading to physical habitat disturbance. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 12 months to five years.

6.4.4.3. Spring and Fall Condition

This spill condition is evaluated with primary reference to stochastic spill modeling results representing the months of April, August and September from EBA (2013). Spill summary information is presented in Appendix B. In spring and fall conditions, it is assumed that the river is on the rising or falling limbs of the freshet, but not at peak flow. It is assumed that culverts and ditching are present close to the pipeline, and that this drainage system quickly and effectively conveys virtually all of the spilled oil directly to the river over a period of several hours. Although the river stage is intermediate, transit times for the spilled oil to reach the river mouth are short, on the order of one or two days. The river is not flooding into riparian habitats, and is somewhat tidal, with flow reversal on high tides, as far upstream as the Port Mann Bridge.

TABLE 6.28 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BRITISH COLUMBIA

Fraser River Delta, Summer Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	Effect Magnitude	Reversibility and Time to Recovery
Aquatic Receptors			
Biofilm	Biofilm of variable quality will be present wherever sediments are exposed and remain moist at low tide, along the Fraser River channels and on the Banks and mudflats, but particularly in more protected areas and on more stable substrates. Biofilm will not be present on the river bed, generally, as a result of poor light penetration and the shifting sand nature of the river bed. In summer, with the river in freshet, the probability is high that oil will reach the river mouth and be discharged into the Strait of Georgia within 1 day of the spill. In the Strait, the oil is forced in a jet towards the open water and disperses, with very low probability (around 1%) of oil occurring on the water surface or stranding at Sturgeon or Roberts Banks. It is more likely that oil will disperse to the north and south in the Strait of Georgia, or cross the strait and strand along the shorelines of Gabriola, Valdes and Galiano Islands, although such oiling would be light and spatially discontinuous. The probability of shoreline oiling in the river is greatest along the south shore between the Port Mann Bridge and Annacis Island, becoming medium in the vicinity of the island, and medium to low between the downstream end of Annacis Island and the mouth of the river.	Variable, with a High effect magnitude in areas along the river shorelines where oiling is heavy; becoming Medium downstream of the George Massey tunnel, including areas of wetland near Ladner, Low along the shorelines of the Gulf Islands, and Negligible on Sturgeon and Roberts Banks and in Boundary Bay.	Short. Biofilm has been observed to re-form within 24 hours following removal from mudflats (VAFFC 2012a), and it is likely that once shoreline clean-up has taken place, biofilm will readily regenerate.
Aquatic Vegetation	Aquatic vegetation is not expected to be a significant component in the main stem of the river. Wetland vegetation will be actively growing during the summer, and both floating and emergent vegetation may be exposed to oiling while the river is in freshet. Effects are likely to occur in the wetlands near Ladner.	Medium to High. Emergent aquatic vegetation is likely to survive low to moderate oiling of stems. However, reed beds and salt marsh are likely to trap and retain floating oil. Oil spill recovery activities may result in damage to these areas in the lower part of the river.	Oil spill recovery efforts along the river channel and in wetland areas result in some disturbance of this habitat, but most of the aquatic vegetation regenerates from buried root systems, so that recovery is essentially complete in the year following the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the main Fraser River, and in wetland and side-channel areas. Effects on the benthic community are low, however, as a result of the small amount of spilled hydrocarbon that becomes dissolved in the river water, and the large river flow.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the benthic community are minor, and rapidly reversible.
Fish and Fish Eggs	Fish are present in the main Fraser River. Some salmonids may be migrating through the river, and late spawning eulachon or juvenile eulachon may be out-migrating. Mortality of fish in the Fraser River or Delta is unlikely as a result of the large volume of water flowing in the river, and the low level of entrainment of oil droplets into the water column.	Low in the Fraser River and Delta, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the fish community are minor, and rapidly reversible.
In-water Amphibians	Juvenile and adult amphibians may be present in the upstream portion of the river, but are minimally affected. The presence of amphibians becomes less likely as the river becomes more brackish, downstream.	Low, as a result of the low numbers expected to be present in the affected habitat.	Short. Effects on amphibians are minor, and rapidly reversible.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	The overland flowpath comprises industrial lands, ditches and culverts. High water levels caused by freshet result in oil entering and stranding in shoreline riparian habitat of the Fraser River. Water levels in the Delta are also high, causing flooding of marshlands with some oil stranding. Water levels on the Banks remain within normal tidal ranges, and oiling is minimal, so shoreline vegetation there is not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. High to Medium for shoreline riparian habitat along the river, with greater effect magnitude on the south side of the river, between the spill location and the upstream end of Annacis Island. Medium to Low for shoreline communities farther downstream and in the Delta, as a result of lower exposure to oiling. Low to Negligible on near the Sturgeon and Roberts Banks, and Negligible along shorelines of Gabriola, Valdes and Galiano Islands, and near Point Roberts, as oil that initially dispersed in the Strait of Georgia becomes stranded in the upper intertidal zone.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Recovery efforts in riparian areas that were moderately to heavily oiled cause some damage to annual vegetation, but this regenerates in subsequent years.
Soil Invertebrates	The overland flowpath comprises industrial lands, ditches and culverts. High water levels caused by freshet result in oil entering and stranding in shoreline riparian habitat of the Fraser River. Water levels in the Delta are also high, causing flooding of marshlands with some oil stranding. Water levels on the Banks remain within normal tidal ranges, and oiling is minimal, so shoreline vegetation there is not materially affected.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. High to Medium for shoreline riparian habitat along the river, with greater effect magnitude on the south side of the river, between the spill location and the upstream end of Annacis Island. Medium to Low for shoreline communities farther downstream and in the Delta, as a result of lower exposure to oiling. Low to Negligible on near the Sturgeon and Roberts Banks, and Negligible along shorelines of Gabriola, Valdes and Galiano Islands, and near Point Roberts, as oil that initially dispersed in the Strait of Georgia becomes stranded in the upper intertidal zone.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Riparian areas that were moderately to heavily oiled may experience some harm to soil invertebrate communities, but these recover in subsequent years after clean-up.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons and foxes), some of which will be present in the lower mainland of British Columbia, even if bears are not present. A small number of individual animals might come into contact with spilled oil in the overland flowpath, or stranded along shorelines of the Fraser River and Delta.	Low, because it is unlikely that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled riparian areas could cause disturbance of habitat use for several months.
Moose	It is unlikely that moose would be exposed, but other ungulates such as deer could use habitat along the river or in the Delta. Effects of external oiling on more than a few individual animals are unlikely.	Low, because soil spill clean-up activities will largely be confined to SCAT, and disturbance of habitat where deer or other ungulates are present is likely to be short-term and intermittent.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled riparian areas could cause disturbance of habitat use for several months.
Muskrat	Muskrat are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the main Fraser River channel or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual muskrat causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
River Otter	Otters are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy habitat in the main Fraser River channel, or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual otters causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
Birds			
Bald Eagle	Bald eagle, as well as many other raptors, are present year-round. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Low to Medium. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Geese are likely to nest close to water, and could be exposed to oil on the surface of the water, or stranded along shorelines.	Generally Low to Medium, depending on the level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 6.28 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SUMMER TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BRITISH COLUMBIA

Fraser River Delta, Summer Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent and Boundaries of Effects	Effect Magnitude	Reversibility and Time to Recovery
Great Blue Heron	The Fraser River Delta provides important foraging habitat for herons. Individual birds could become oiled while foraging in shallow water or along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Generally Low to Medium, as a result of low level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Mallard	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Ducks and swans generally would have greater exposure to oil than geese, as a result of their more aquatic habits.	Generally Medium to High, as individual birds could die if more heavily oiled. Oil presence on the water surface and stranded along shorelines is most likely in the main river channel, and lower elsewhere, including side channels and sloughs, and in the more marine environment of Roberts and Sturgeon Banks. Individuals and groups of birds could die if heavily oiled in the main river channel. Mortality is less likely elsewhere as a result of lower exposure. Oiling also extends out onto the Strait of Georgia, although it is patchy and discontinuous. This could result in negative effects including mortality to sea ducks, cormorants, and alcids. Disturbance caused by oil spill recovery activities could temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Shorebirds like the spotted sandpiper are likely to be present along the Fraser River channel, and throughout the Delta and Banks. They have a lower level of sensitivity to oiling than more aquatic birds such as ducks. Effects are likely to be related to the intensity of shoreline oiling, where there are shoreline types and/or adjacent upland habitats that are utilized by these birds.	Medium to low, depending upon the level of exposure. Exposure will be greatest along the main channel of the Fraser River, where mortality could occur in heavily oiled sections, and in the parts of the Delta. Negligible exposure is expected on Sturgeon and Roberts Banks, although low levels of exposure could be present on the shorelines of Gabriola, Valdes and Galiano Islands, as well as towards Point Roberts. Disturbance caused by oil spill recovery activities could temporarily disrupt habitat utilization, including nest abandonment during summer. Transfer of oil from feathers to eggs could also result in egg mortality.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Western Sandpiper	Not likely to be affected as they would be occupying summer breeding grounds far north of the Fraser River Delta.	Low, as a result of lack of exposure.	Not Applicable.
Tree Swallow	Tree swallows could be breeding along the Fraser River and around the Delta, and could be exposed to oil while dipping to the water. Direct mortality is unlikely, but oil could be transferred to eggs, causing mortality of developing embryos. Spatial extent is determined by the presence of oil on the water surface, principally affecting the main Fraser River channel for a period of several days.	Low to Medium, depending upon the level of exposure. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the Western painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. The presence of turtles and amphibians becomes less likely as the waters of the estuary become more brackish.	Low, as a result of low numbers present and lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

Frequent contact with shorelines acts to hold up some of the spilled oil, but most of the oil would be rapidly advected downstream. Less of the oil is stranded along shorelines than under winter conditions, and some remains on the water surface, having been discharged into the Strait of Georgia. As in winter and summer, most of the spilled oil is transported along the main river channel. Very little enters the north channel, and this oil generally strands within a short distance. Some oil, however, is transported into side channels near Ladner and Port Guichon, and may become stranded in the side channels, wetlands and sloughs.

The probability of oil presence on the surface of the river exceeds 90% between the Port Mann Bridge and a point approaching the George Massey Tunnel. From the George Massey Tunnel to the mouth of the river, the probability of oil on the surface is between 60% and 80%. There is about a 40% probability of oil on the surface of the water entering the side channels and marshes near Ladner and Port Guichon. Oil that reaches the mouth of the river is discharged into the Strait of Georgia with considerable momentum, so that it is likely to disperse to the north or south in the Strait and does not have a high probability of directly affecting the Sturgeon or Roberts Banks. It is more likely that this oil will affect shorelines on the opposite side of the Strait.

The probability of shoreline oiling is high (generally 60% to 100% along the south shore of the river between the Port Mann Bridge and the upstream end of Annacis Island), becoming moderate (40% to 60% along the west and south shorelines of Annacis Island, and along the north shoreline of the Fraser River from the lower end of Annacis Island to the George Massey Tunnel). Moderate probability of shoreline oiling (20% to 40%) generally prevails along the balance of the main channel, and low probability of oiling ((<10%) prevails in the side channels and wetlands near Ladner and Port Guichon. There is low probability of oiling shorelines along the Sturgeon and Roberts Banks, although some oiling occurs around Point Roberts.

Mass balance plots (Appendix B) show that rather more of the spilled crude oil (about 70%) is likely to strand along river shorelines than during the summer. About 10% of the crude oil evaporates, and about 20% may remain on the surface of the water. Small amounts of the oil (generally <1%) also sink, undergo biodegradation, or dissolve into the water. Formation of OMA and dispersion of oil into the water are not predicted to occur to any meaningful extent (each representing <0.1% of the spilled oil).

Weathering CLWB is not likely to achieve a density greater than that of brackish water within 10 days of being spilled (Witt O'Brien's *et al.* 2013). The spilled oil therefore floats until it strands on shorelines. As it weathers, it becomes more viscous and thicker, but mostly strands before its density approaches or exceeds that of the water. Little oil is entrained in the water column due to the viscosity of the oil and the relatively low turbulence of the river flow. Although the river has relatively high turbidity, due to the flow rate, and the water is brackish, OMA formation remains low due to the low abundance of suspended oil droplets. There is a risk that oil stranded on shorelines will acquire additional density as a result of adhering or intermixed sand particles as the oil weathers, so that the weathered oil-sand mixture may sink if it is subsequently eroded or flooded before it can be recovered, as could easily occur in the springtime. In addition, there is a potential for reedbeds and salt marsh vegetation to trap floating or submerged oil being transported in the river if it enters the wetland habitats.

Table 6.29 provides an evaluation of the likely spatial extent, magnitude, duration, and reversibility of environmental effects on each ecological receptor group that would be caused by an accidental spill of CLWB near RK 1167.5 during spring or fall conditions. In the upper reaches, the river channel is bordered by rip-rap, rock, and beach (Harper 2013), although as noted by Danchuk (2009), the river stage may substantially alter the characteristics of exposed shorelines. At high water levels, oil may enter and become trapped by rip-rap, or contact flooded riparian vegetation. The lower river reaches and Delta would have a greater amount of fringing marsh (Harper 2013), with relatively less artificial shoreline. During spring and fall conditions, migrating birds (*e.g.,* Western sandpiper) could be present, depending upon the exact timing of their migrations. The Delta is noted as high quality habitat for raptors, waterfowl, and shorebirds, and it is assumed that a large number of species would be present either as resident or migrating species. It is less likely that large mammals (such as bear or moose) would be present in this predominantly urban landscape, however, other wildlife species such as raccoons, foxes, deer, otter and muskrat would be present and active year-round. Effects on these wildlife receptors would likely be limited to a few individuals, rather than larger numbers that would affect the viability of regional populations.

Effects on fish and fish habitat, as well as benthic invertebrates and aquatic vegetation would be limited in spatial extent. The Fraser River and Delta provide important fish habitat and the river is a major migration route for Pacific salmon, and some of these fish would be moving through the river during spring and fall. The river is also an important migratory route for Eulachon in spring, with spawning occurring in the river between Chilliwack and Mission. The main stem of the Fraser River, however, is not likely to experience fish kills due to the large volume of flowing water, the low turbulence and limited potential for oil droplet formation, as indicated by the very small fraction of the spilled CLWB that becomes dissolved in the water.

Oil spill recovery effects on the main channel of the Fraser River, and in marsh areas near Port Guichon, would likely be substantial, leading to physical habitat disturbance. Depending upon the receptor group, the process of restoration and recovery could take anywhere from 12 months to five years.

6.4.4.4. Environmental Effects Summary for Spill Scenarios at RK 1167.5

A hypothetical spill scenario has been developed to describe the likely fate and behaviour of CLWB spilled as a result of a pipeline rupture near RK 1167.5. Potential environmental effects likely to accrue to ecological receptors as a result of such hypothetical spills have been outlined in Table 6.27 through Table 6.29.

For the Fraser River in winter (Table 6.27), it is assumed that the spill occurs close to the river bank, and is quickly transported into the river, which is ice free, by ditches and culverts adjacent to and associated with the rail yards. Oil spill recovery efforts would result in environmental effects along the overland flowpath, but as these areas are industrial lands the effects on ecological receptors are minimal. Most of the oil becomes stranded along shorelines of the main Fraser River channel, with very little entering side channels and wetland areas near Ladner and Westham Island, and very little leaving the river to enter the Strait of Georgia. As a result, the potential for oiling of Sturgeon and Roberts Banks is also very low.

Some of the relevant ecological receptors would be dormant (*e.g.,* plants, amphibians, reptiles, and mammals that hibernate) or absent (*e.g.,* some migratory birds), although birds such as bald eagle and waterfowl could be present around the river through the winter due to the ice free conditions. The Delta is also noteworthy as a wintering area for large numbers of birds. Mortality of fish in the main channel of the Fraser River is unlikely, due to the low level of oil droplet entrainment and hydrocarbon dissolution into the water, and the large volume of flowing water in the river, even in winter. Effect magnitudes on shoreline and riparian vegetation and soil invertebrates would be low, due to low water levels and lack of oiling of riparian habitats, as well as to winter dormancy. Effect magnitudes for mammals and birds would generally be low to medium due to lack of exposure for migratory birds or hibernating mammals. However, higher effect magnitudes would be seen for semi-aquatic mammals in the Fraser River due to oiling of fur. Higher effect magnitudes could also be seen for wintering birds such as ducks, depending upon the numbers present. Recovery of the various ecological receptors from oil spill effects would take approximately 12 months to five years, assuming that the spill occurs in January, and physical works associated with oil spill recovery are ongoing through until the late summer.

For the Fraser River in summer (Table 6.28), flow in the river is peaking, due to snow melt in its headwaters. Most of the spilled oil is transported along the main river channel, although some is diverted to the south near Ladner and enters the islands and wetlands between Ladner and Westham Island. Effect magnitude on the overland flowpath is low, due to the industrial nature of the lands. More of the oil that reaches the river is rapidly transported down the main channel, with less stranding along shorelines, and a larger fraction exiting the river mouth to enter the Strait of Georgia. In the Strait of Georgia, the oil is carried with the momentum of the freshwater plume so that it is transported offshore and disperses in the Strait. Some of this oil subsequently strands along the shorelines of Gabriola, Valdes and Galiano Islands, or at Point Roberts, but very little strands on Sturgeon or Roberts Bank, or in Boundary Bay.

TABLE 6.29 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BRITISH COLUMBIA

Fraser River Delta, Spring or Fall Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Duration
Aquatic Receptors			
Biofilm	Biofilm of variable quality will be present wherever sediments are exposed and remain moist at low tide, along the Fraser River channels and on the Banks and mudflats, but particularly in more protected areas and on more stable substrates. Biofilm will not be present on the river bed, generally, as a result of poor light penetration and the shifting sand nature of the river bed. In spring and fall, with the river at about average annual flow rate, the probability is high that oil will reach the river mouth and be discharged into the Strait of Georgia within 1 or 2 days of the spill. In the Strait, the oil is forced in a jet towards the open water and disperses, with very low probability (around 1%) of oil occurring on the water surface or stranding at Sturgeon or Roberts Banks. It is more likely that oil will disperse to the north and south in the Strait of Georgia, or cross the strait and strand along the shorelines of Gabriola, Valdes or Galiano Islands, although such oiling would be light and spatially discontinuous. The probability of shoreline oiling in the river is greatest along the south shore between the Port Mann Bridge and Annacis Island, becoming medium in the vicinity of the island, and medium to low between the downstream end of Annacis Island and the mouth of the river.	Variable, with a High effect magnitude in areas along the river shorelines where oiling is heavy; becoming Medium downstream of the George Massey tunnel, including areas of wetland near Ladner, Low along the shorelines of the Gulf Islands, and Negligible on Sturgeon and Roberts Banks and in Boundary Bay.	Short. Biofilm has been observed to re-form within 24 hours following removal from mudflats (VAFFC 2012a), and it is likely that once shoreline clean-up has taken place, biofilm will readily regenerate.
Aquatic Vegetation	Aquatic vegetation is not expected to be a significant component in the main stem of the river. Wetland vegetation will be actively growing during the spring, becoming senescent in fall. Both floating and emergent vegetation will be exposed to oiling. Effects are likely to occur in the wetlands near Ladner.	Medium to High. Emergent aquatic vegetation is likely to survive low to moderate oiling of stems. However, reed beds and salt marsh are likely to trap and retain floating oil. Oil spill recovery activities may result in damage to these areas in the lower part of the river.	Oil spill recovery efforts along the river channel and in wetland areas result in some disturbance of this habitat, but most of the aquatic vegetation regenerates from buried root systems, so that recovery is essentially complete in the year following the spill.
Aquatic Invertebrates	Aquatic invertebrates are present in the substrates of the main Fraser River, and in wetland and side-channel areas. Effects on the benthic community are low, however, as a result of the small amount of spilled hydrocarbon that becomes dissolved in the river water, and the large river flow.	Low in the main Fraser River and downstream areas, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the benthic community are minor, and rapidly reversible.
Fish and Fish Eggs	Fish are present in the main Fraser River. Some salmonids may be migrating through the river, and eulachon may be entering the river to spawn in spring. Mortality of fish in the Fraser River or Delta is unlikely as a result of the large volume of water flowing in the river, and the low level of entrainment of oil droplets into the water column.	Low in the Fraser River and Delta, as a result of the small amount of oil that becomes dissolved, and the large size of the river.	Short. Effects on the fish community are minor, and rapidly reversible.
In-water Amphibians	Juvenile and adult amphibians may be present in the upstream portion of the river, but are minimally affected. The presence of amphibians becomes less likely as the river becomes more brackish, downstream.	Low, as a result of the low numbers expected to be present in this habitat.	Short. Effects on amphibians are minor, and rapidly reversible.
Terrestrial Receptors			
Shoreline and Riparian Vegetation	The overland flowpath comprises industrial lands, ditches and culverts. Moderate water levels do not cause oil to enter or strand in riparian habitat.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low in riparian habitat of the river and Delta as a result of lack of oil entering or stranding in such habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors.
Soil Invertebrates	The overland flowpath comprises industrial lands, ditches and culverts. Moderate water levels do not cause oil to enter or strand in riparian habitat.	Low along the overland flowpath, as a result of the industrialized nature of the landscape. Low in riparian habitat of the river and Delta as a result of lack of oil entering or stranding in such habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors.
Mammals			
Grizzly Bear	The grizzly bear as a receptor is also intended to represent other omnivores and carnivores (such as raccoons and foxes), some of which will be present in the lower mainland of British Columbia, even if bears are not present. A small number of individual animals might come into contact with spilled oil in the overland flowpath, or stranded along shorelines of the Fraser River and Delta.	Low, because it is unlikely that partially oiled animals would die as a result of exposure. However, disturbance caused by oil spill recovery activities could cause an alteration of habitat use during the spring, summer and fall.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled shoreline areas could cause disturbance of habitat use for several months.
Moose	It is unlikely that moose would be exposed, but other ungulates such as deer could use habitat along the river or in the Delta. Effects of external oiling on more than a few individual animals are unlikely.	Low, because clean-up activities will largely be confined to SCAT, and disturbance of habitat where deer or other ungulates are present is likely to be short-term and intermittent.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Clean-up efforts in oiled shoreline areas could cause disturbance of habitat use for several months.
Muskrat	Muskrat are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on muskrat could be High, up to and including mortality of individuals inhabiting the main Fraser River channel or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual muskrat causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
River Otter	Otters are potentially affected, as they could be present along the river and in side channels and wetland areas downstream from the George Massey Tunnel. However, little of this habitat is predicted to be affected, and effects on more than a few individual animals are unlikely.	Localized effects on river otter could be High, up to and including mortality of individuals if they occupy habitat in the main Fraser River channel, or some side channels. Oil spill recovery activities and SCAT could also temporarily disturb their habitat.	Ditches and culverts of the overland flowpath are remediated and restored within weeks, with negligible effects on ecological receptors. Oiling of individual otters causes some mortality but such areas would be re-colonized within 12 to 24 months following shoreline clean-up.
Birds			
Bald Eagle	Bald eagle, as well as many other raptors, are present year-round. Individual birds could become oiled through feeding on dead fish or other carrion, or by taking fish from the water surface through an oil slick. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Low to Medium. Partial oiling of plumage is not likely to result in mortality. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Canada Goose	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Geese are likely to nest close to water, and could be exposed to oil in the surface of the water, or stranded along shorelines.	Generally Low to Medium, depending on the level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Great Blue Heron	The Fraser River Delta provides important foraging habitat for herons. Individual birds could become oiled while foraging in shallow water or along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner.	Generally Low to Medium, as a result of low level of exposure, although individual birds could die if more heavily oiled. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

TABLE 6.29 LIKELY ENVIRONMENTAL EFFECTS OF CLWB SPILL DURING SPRING OR FALL TO THE FRASER RIVER AND DELTA NEAR THE PORT MANN BRIDGE, BRITISH COLUMBIA

Fraser River Delta, Spring or Fall Conditions	LIKELY OIL SPILL EFFECTS		
	Spatial Extent	Magnitude	Duration
Mallard	The Fraser River Delta provides important breeding habitat for a wide range of geese, ducks and swans. Individual birds could become oiled while swimming through an oil slick, or foraging along shorelines. However, the probability of oil presence on the water surface is greatest in the main river channel, and lower in side channels and sloughs near Ladner. Ducks and swans generally would have greater exposure to oil than geese, as a result of their more aquatic habits.	Generally Medium to High, as individual birds could die if more heavily oiled. Oil presence on the water surface and stranded along shorelines is most likely in the main river channel, and lower elsewhere, including side channels and sloughs, and in the more marine environment of Roberts and Sturgeon Banks. Individuals and groups of birds could die if heavily oiled in the main river channel. Mortality is less likely elsewhere as a result of lower exposure. Oiling also extends out onto the Strait of Georgia, although it is patchy and discontinuous. This could result in negative effects including mortality to sea ducks, cormorants, and alcids. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Spotted Sandpiper	Shorebirds like the spotted sandpiper are likely to be present along the Fraser River channel, and throughout the Delta and Banks. They have a lower level of sensitivity to oiling than more aquatic birds such as ducks. Effects are likely to be related to the intensity of shoreline oiling, where there are shoreline types and/or adjacent upland habitats that are utilized by these birds.	Medium to Low, depending upon the level of exposure. Exposure will be greatest along the main channel of the Fraser River, where mortality could occur in heavily oiled sections, and in the parts of the Delta. Negligible exposure is expected on Sturgeon and Roberts Banks, although low levels of exposure could be present on the shorelines of Gabriola, Valdes and Galiano Islands, as well as towards Point Roberts. Disturbance caused by oil spill recovery activities could also temporarily disrupt habitat utilization, including nest abandonment during spring. Transfer of oil from feathers to eggs in spring could also result in egg mortality.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Western Sandpiper	Western sandpiper arrive at the Fraser River Delta in large numbers while migrating in spring and fall, feeding heavily on biofilm and benthic invertebrates on Roberts and Sturgeon Banks, and in Boundary Bay. These areas are predicted to have a very low level of exposure to floating or stranded crude oil.	Low, as a result of low level of exposure.	Six months or less
Tree Swallow	Tree swallows could be breeding along the Fraser River and around the Delta, and could be exposed to oil while dipping to the water. Direct mortality is unlikely, but oil could be transferred to eggs, causing mortality of developing embryos. Spatial extent is determined by the presence of oil on the water surface, principally affecting the main Fraser River channel for a period of several days.	Low to Medium, depending upon the level of exposure. Transfer of oil from feathers to eggs could also result in egg mortality.	One to 2 years, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.
Reptiles and air-breathing Amphibians	The only native turtle likely to be found along the Fraser River is the Western painted turtle, found in low numbers in parts of the Fraser Valley from Vancouver to Hope. The presence of turtles and amphibians becomes less likely as the waters of the estuary become more brackish.	Low, as a result of low numbers present and lack of exposure.	Six months to 1 year, if clean-up activities result in temporary avoidance of habitat use as a result of disturbance.

Effects on aquatic receptors are variable. Effects on aquatic vegetation are of medium magnitude as the spilled oil largely floats on the surface of the water, and oil that enters salt marsh or reedbed areas may become trapped there. Although the physical effects of this oil on the vegetation may be low to medium, oil spill recovery effects may be equally damaging to the vegetation, as well as affecting habitat utilization by wildlife species. Effects on benthic invertebrates and fish are generally low, due to the low level of dissolved hydrocarbons and low level of droplet formation, combined with the high water flow in the river. There is also low potential for effects on amphibians and reptiles, due to the limited distribution of turtles, and expected decline in habitat quality as the river becomes more brackish.

A considerable amount of the spilled oil becomes stranded along shorelines, and in riparian areas where terrestrial vegetation is oiled. Effects on shoreline and riparian vegetation and soil invertebrates are low on the overland flowpath, due to the industrial nature of the land, becoming medium to high along the main Fraser River channel, and medium in the Delta as the probability of shoreline oiling decreases. Areas riparian to the Fraser River are remediated with relatively non-intrusive methods, and an emphasis on natural attenuation of spilled oil residues at low levels. Environmental effects on mammal populations are potentially high for truly aquatic species such as muskrat, beaver, otter and mink, and it is assumed that some of these animals could be sufficiently oiled to cause death. For mammals that are larger or that are less adapted to the aquatic environment, such as raccoons, foxes and deer, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed and sensitive to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend along the entire river channel, as well as affecting portions of the Delta. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the summer could be as short as 12 months for some receptors, or up to five years where effects occur at the population level. Some of the spilled oil would be swept into the Strait of Georgia, and could affect other seabirds, such as alcids, on summer feeding grounds.

For the Fraser River in spring and fall (Table 6.29), flow is at an intermediate level, typically rising in the spring due to the onset of freshet, or falling in the fall, as freshet recedes. Most of the spilled oil would rapidly reach and enter the main Fraser River channel. Effect magnitude on the overland flowpath is low, due to the industrialized nature of the land. In the river, the spilled crude oil is confined to the normal channels, due to the moderate water levels, and is transported down to the river mouth within one or two days. As in summer, a considerable amount of the spilled oil is transported into the Strait of Georgia, where it disperses. Some of this oil subsequently strands along the shorelines of Gabriola, Valdes and Galiano Islands, or at Point Roberts, but very little strands on Sturgeon or Roberts Bank, or in Boundary Bay.

Effects on aquatic receptors are variable. Effects on aquatic vegetation are of medium magnitude as the spilled oil largely floats on the surface of the water, and oil that enters salt marsh or reedbed areas may become trapped there. Although the physical effects of this oil on the vegetation may be low to medium, oil spill recovery effects may be equally damaging to the vegetation, as well as affecting habitat utilization by wildlife species. Effects on benthic invertebrates and fish are generally low, due to the low level of dissolved hydrocarbons and low level of droplet formation, combined with the high water flow in the river. There is also low potential for effects on amphibians and reptiles, due to the limited distribution of turtles, and expected decline in habitat quality as the river becomes more brackish.

A considerable amount of the spilled oil becomes stranded along shorelines, but not in riparian areas, so effects on terrestrial plants and soil invertebrates are negligible. Environmental effects on mammal populations are potentially high for truly aquatic species such as muskrat, beaver, otter and mink, and it is assumed that some of these animals could be sufficiently oiled to cause death. For mammals that are larger or that are less adapted to the aquatic environment, such as raccoons, foxes and deer, effects are expected to be medium, and may arise from disturbance of habitat, as well as from oiling of fur, or ingestion of crude oil. For birds, guilds such as ducks and geese are considered to be most exposed and sensitive to spilled oil, and effects on these species could be high (including mortality) to medium, including reproductive effects caused by transfer of oil to eggs in spring, with resulting egg mortality, or effects on habitat quality caused by disturbance arising from oil spill response efforts. These effects could extend along the entire river channel, as well as affecting portions of the Delta. Other species, such as raptors, wading birds, shorebirds, and swallows could experience medium effect magnitudes, reflecting both oil exposure and disturbance of habitat following the oil spill. Recovery times for spills in the spring could be as short as 12 months for some receptors, or up to five years where effects occur at the population level. Some of the spilled oil would be swept into the Strait of Georgia, and could affect other seabirds, such as alcids.

Particular consideration was given in this scenario to Western sandpiper, which use the Sturgeon and Roberts Banks as a stopover and feeding area during spring and fall migrations. For short periods of time, hundreds of thousands of birds may congregate on the banks, feeding on biofilm and benthic invertebrates present in the mudflats. The stochastic analysis of oil spill fate and transport during winter, spring, summer and fall conditions (EBA 2013) has shown that the probability of oiling on Sturgeon and Roberts Banks is very low, either because the oil becomes stranded and does not exit from the Delta during periods of low flow, or because it is carried through and away from the Delta and into the Strait of Georgia by the momentum of the freshwater jet created by the Fraser River during periods of moderate or high flow. Once in the Strait of Georgia, the crude oil will continue to weather and disperse, and stranding does occur on the shorelines of Gabriola, Valdes and Galiano Islands and Point Roberts, but at low probability and intensity. The biofilm itself is not likely to be materially affected if weathered crude oil becomes stranded, and recovers quickly from disturbance. Therefore, neither the biofilm, nor Western sandpiper, are considered likely to be significantly affected in the event of a pipeline oil spill that results in crude oil entering the Fraser River near the Port Mann Bridge. In its review of the Vancouver Airport Fuel Delivery Project, Environment Canada agreed that the potential effects of a Jet A fuel spill on biofilm were unlikely to be high-magnitude and irreversible (Environment Canada 2012).

6.5. Certainty and Confidence in the Ecological Risk Assessment

This qualitative ecological risk assessment has been carried out using available information on the expected pipeline corridor in order to evaluate potential ecological consequences of hypothetical crude oil spills in the unlikely event of a full bore rupture event. Oil spill locations were selected using a risk-informed approach by considering large rivers that run parallel to the proposed new pipeline. All else being equal, the risk of a pipeline oil spill is cumulative, and depends upon the length of the pipeline. Therefore, a watershed that contains 100 km of pipeline has a proportionally greater risk of experiencing an oil spill accident than a watershed that contains 10 km of pipeline. The Athabasca River, North Thompson River and Fraser River all have relatively long reaches where the proposed pipeline corridor runs parallel to and in proximity to the rivers, and numerous small drainages that could convey spilled oil to the larger rivers. These rivers are also important to fish and wildlife, and are relied upon for traditional purposes and as sources of country food by Aboriginal peoples and others.

Oil spill volumes were based on an independent outflow analysis commissioned by Trans Mountain based on preliminary valve spacing to quantify the oil volume that would be released in the event of an incident. Modeling assumed a full-bore rupture with hole on the bottom of the pipe, which provided worst-case outflows for the purpose of the ERA. The potential spill volumes were estimated taking into consideration the expected response time for initiation and completion of valve closure upon detecting a leak, the distance between valve locations, and include both the volume of oil that would be released under pressure before the valves close, as well as the draindown volume for the line between valve locations. The volume of oil that could be released is therefore estimated with a high level of realism and confidence. Because the spill locations were selected to be in close proximity to a watercourse, the volume of oil that could enter a watercourse is conservatively estimated. If an oil spill were to take place at a greater distance from a watercourse, the volume reaching water could be substantially lower than has been assumed in this assessment.

The characteristics of spilled crude oil were based upon those of CLWB, a form of diluted bitumen that was selected for evaluation in the ERA because it is currently transported by Trans Mountain and is expected to remain a major product transported by the new pipeline. In addition, the diluent in CLWB is condensate (a light hydrocarbon mixture derived from natural gas liquids), which is volatile and relatively water-soluble. Due to the higher level of risk associated with inhalation of volatiles and/or exposure to dissolved hydrocarbons, CLWB was considered to be a conservative choice for the ERA, as opposed to heavy crude oil mixed with alternative diluents such as synthetic oil, which contain fewer volatile and less water soluble constituents. Meso-scale experimental tests using CLWB were carried out in order to better understand the behavior of CLWB when spilled onto water (Witt O'Brien's et al. 2013). A key finding of those tests was that the CLWB behaved on the water in much the same way as any other heavy (conventional) crude oil would. The chemical and physical characteristics and behavior of diluted bitumen on the surface of the water are therefore considered to be understood with a high level of confidence.

The potential fate and transport of spilled crude oil after entering a watercourse was evaluated taking into consideration the behavior of oil in actual spill events in similar types of watercourses, as well as modeling results for diluted bitumen and synthetic oil if spilled into similar types of watercourses. For the lower Fraser River and Delta, due to the complexity of the hydrodynamics of this ecosystem, stochastic oil spill modeling was undertaken to predict how far oil would be carried on the surface of the water during variable seasonal conditions, and the probability of oil stranding along river and wetland shorelines, as well as other fates of the spilled oil. This assessment is considered to have a moderate level of confidence. While the evaluation of oil fate and transport in this assessment is qualitative at the other hypothetical spill locations, that assessment is based on the fate and behavior of spilled oil in actual spill events, and is therefore also considered to have a moderate level of confidence.

The exposure of ecological receptors to oil is based upon the expected fate and transport of crude oil in the freshwater environment. Potential interactions between ecological receptors and spilled crude oil were evaluated in the context of winter, summer and spring or fall conditions. Under winter conditions, some ecological receptors will be absent from the local environment, or dormant, and may have little or no exposure to spilled oil. Under summer and spring or fall conditions, exposures were generally similar. There is no question that a large oil spill entering a watercourse will cause substantial negative environmental effects, including damage to vegetation, death of mammals and birds, and possibly death of fish and benthic invertebrates. The extent and magnitude of these negative effects will depend upon many factors including but not limited to: the type and volume of oil spilled; the proximity of the spill site to a watercourse; seasonal factors that may help to prevent oil from entering the water and affect stream flow rates and water levels; the size of the watercourse; seasonal factors that determine the presence or absence of ecological receptors; and the proximity of the ecological receptors to the spill site. Although not explicitly considered in this ERA, the specifics and effectiveness of spill clean-up, treatment and remediation activities will also determine the extent and magnitude of negative effects.

Section 6.4 has summarized, using tables, the Spatial Extent and Boundaries, Effect Magnitude, and Reversibility and Time to Recovery for hypothetical crude oil spills to the Athabasca River near Hinton, Alberta, the North Thompson River near Darfield, British Columbia, the Fraser River near Hope, British Columbia, and the Fraser River as it enters the Delta, for a suite of ecological receptors. This analysis is based upon effects that have been observed in actual oil spills, with an emphasis on heavy oils, and rivers with characteristics comparable to those that exist along the proposed pipeline corridor. This analysis is assigned a moderate level of confidence.

Taking all of these factors into consideration, it is clear that a crude oil spill into a freshwater environment could have substantial negative environmental effects that could be long-lasting if not effectively remediated. This confirms that the primary focus of the spill prevention and response activities must always be to reduce the probability of an oil spill to be as low as reasonably practical (ALARP), and to have adequate oil spill response plans and procedures in place.

7.0 SUMMARY AND CONCLUSIONS

The purpose of this ERA report is to evaluate the potential for ecological receptors (*e.g.,* fish, fish eggs, invertebrates, amphibians, reptiles, birds, mammals, and plants) to experience negative environmental effects as a result of exposure to crude oil released to the environment as a result of the Project. The following summary is based upon the assumption that an oil spill as a result of construction of the Trans Mountain Pipeline will be a low probability event.

Because of the nature of spills to land (*i.e.,* the limited spatial extent of environmental effects in the context of much larger habitat units) and the existence of legislative processes pertaining to environmental remediation following such spills, the ERA does not directly consider effects to terrestrial environments. Conversely, crude oil entering aquatic environments has the potential to spread or be advected rapidly downstream, and as a result has the potential to affect much more of the available habitat. Aquatic ecosystems are known to be sensitive to spilled oil, and therefore this ERA report focuses on spills that enter aquatic environments.

The proposed TMEP pipeline corridor crosses 474 defined watercourses between Edmonton, Alberta and Burnaby, British Columbia, and runs parallel to several large rivers for a considerable portion of its length. Where the pipeline runs parallel to a river, the potential for that river to be affected by oil in the unlikely event of an oil spill increases in proportion to the length of the pipeline corridor within the watershed, and the proximity of the corridor to the river. Based upon these and other criteria, hypothetical oil spill locations were selected in proximity to the Athabasca River near Hinton, Alberta; the North Thompson River near Darfield, British Columbia; the Fraser River near Hope, British Columbia; and the Fraser River near the Port Mann Bridge in greater Vancouver. This last location was selected to be as close as possible to the Fraser River Delta, in order to evaluate potential environmental effects of spilled oil on ecological receptors unique to the Delta, a tidal estuary.

Although the proposed TMEP pipeline will potentially carry a variety of crude oils, diluted bitumen is expected to comprise a large percentage of the oil shipped. For that reason, a sample of Cold Lake Winter Blend (CLWB) was procured and tested to provide information on the physical and chemical characteristics of a representative product. CLWB was selected because it is currently transported by Trans Mountain and is expected to remain a major product transported by the new pipeline. In addition, the diluent in CLWB is condensate (a light hydrocarbon mixture derived from natural gas liquids), which is volatile and relatively water-soluble. Due to the higher level of risk associated with inhalation of volatiles and/or exposure to dissolved hydrocarbons, CLWB was considered to be a conservative choice for the ERA, as opposed to heavy crude oil mixed with alternative diluents such as synthetic oil, which contain fewer volatile and less water soluble constituents.

A literature review was conducted to identify and acquire information on actual and modelled spills of heavy crude oils in the freshwater environment, and case studies were selected to inform predictions about the potential fate and transport and ecological effects of a diluted bitumen spill resulting from the Project. Actual spill case studies included the Kalamazoo River spill, East Walker River spill, Pine River spill, Wabamun Lake spill, Yellowstone River spill, OSSA II Pipeline spill, and the DM 932 barge spill, with crude oil types ranging from light crude oil to diluted bitumen and bunker type products. TMEP studies involving the behaviour of diluted bitumen on water in meso-scale experimental trials carried out at Gainford, Alberta (Witt O'Brien's *et al.* 2013) were also reviewed. Finally, modelling studies of oil spill fate and ecological effects conducted for the Enbridge Northern Gateway Project, representing a diluted bitumen and a synthetic crude oil, with hypothetical spill locations on the Athabasca, Crooked, Morice and Kitimat rivers in Alberta and British Columbia, and predictions of oil spill fate and ecological effects of Jet "A" fuel released to the lower Fraser River near Vancouver.

When crude oil is spilled, volatile components quickly evaporate, and more water-soluble components can dissolve into the water. The amount of hydrocarbon that will dissolve into the water depends upon a number of factors, including the availability of relatively water soluble hydrocarbons, the amount of mixing energy in the water column, and the viscosity of the oil. If there is sufficient mixing energy to entrain droplets of oil into the water column, then the rate of dissolution is increased in comparison to the case when oil is simply floating on the water surface. High oil viscosity increases the amount of mixing energy required. The resulting concentration of dissolved hydrocarbon also depends upon the amount of oil released, relative to the amount of water flowing in the river. Therefore, high potential for acute effects to aquatic organisms occurs when light oils containing a high percentage of MAH and other light hydrocarbons are released into streams or small rivers with high gradients leading to high energy mixing. Lower potential for such effects is observed as oils become more viscous, with lower percentages of MAH present, and as the level of turbulence decreases as river size increases, or river gradient decreases.

Once in the water column, oil droplets may be exposed to suspended sediments; if there is adequate contact, the particulate matter may adhere to the oil droplets and the resulting oil-mineral aggregate (OMA) may become neutrally to negatively buoyant and remain submerged or sink in the water column. Formation of substantial quantities of OMA requires high suspended sediment concentrations, and is enhanced by salinity, which is not normally present in freshwater ecosystems. Oil may also contact sand and gravel particles along shorelines, resulting in initial stranding of oil that may sink if it later re-enters the water column. In high flows, submerged oil is transported downstream and prevented from settling on the riverbed. In contrast, low flows have the potential to result in high levels of sedimentation of submerged oil, particularly in quiescent areas where silty sediments accumulate.

For spills in winter, direct environmental effects of spilled oil may depend upon the amount of snow and ice cover, as snow can absorb spilled oil, and ice cover on watercourses can prevent or limit contact between the oil and running water. Many ecological receptors are absent or dormant during the winter, and would not be exposed to the spilled oil. For such spills, there is a high potential to recover most of the spilled oil so that oil spill effects on ecological receptors can be minimal. Spills to rivers that are not ice covered in winter, however, would have environmental effects similar to the environmental effects of spills at other times of the year.

For the four locations considered in this study (the Athabasca River near Hinton, Alberta; the North Thompson River near Darfield, British Columbia; the Fraser River near Hope, British Columbia and the Fraser River as it enters the Delta, near Vancouver), seasonal flow regimes are such that high flows are observed during the summer, as snow and ice melt in the mountain headwater regions. Low flows are typically observed in winter, as water equivalents build up in snowpack. Spring and fall represent shoulder seasons when flows are intermediate. Using information from the actual spill events and modelling case studies, the likely behaviour of spilled heavy crude oil, and extent of oiling, was predicted for each river system. Stochastic modeling was used to predict the fate and transport of oil for the Fraser River Delta, due to the unique nature and complexity of this environment. For the other three spill examples, professional judgement was used, based upon the case studies.

From the predicted distribution of crude oil in the environment in each of the rivers, for winter, summer, and spring and fall seasons, interactions between spilled oil and ecological receptor groups were evaluated. Ecological receptor groups included aquatic biota (vegetation, benthic invertebrates, fish including eggs and larvae, and amphibians), terrestrial plant and soil invertebrate communities in riparian areas, mammals (with grizzly bear, moose, muskrat and river otter selected as representative types), birds (with bald eagle, Canada goose, great blue heron, mallard, spotted sandpiper and tree swallow selected as representative types) and reptiles (with the Western painted turtle selected as a representative) for the Delta oil spill scenario, two additional ecological receptors (biofilm and Western sandpiper) were evaluated.

For each river, season and ecological receptor type, the expected spatial extent, magnitude, duration and reversibility of negative environmental effects was evaluated, again with reference to case studies. The spatial extent of environmental effects was found to vary, depending upon the season and river characteristics, and both the spatial extent and magnitude of environmental effects was often rated as “high”. However, effect durations were typically less than five years, and often 12 to 24 months, and all rated negative environmental effects were considered to be “reversible”. Evidence from the case studies showed overwhelmingly that freshwater ecosystems can recover from oil spills, often within relatively short periods of time.

Taking all of these factors into consideration, it is clear that a crude oil spill into a freshwater environment could have substantial negative environmental effects that could be long-lasting if not effectively remediated. This confirms that the primary focus of spill prevention and response activities must always be to reduce the probability of an oil spill to be as low as reasonably practical (ALARP), and to have adequate oil spill response plans and procedures in place.

8.0 CLOSURE

This report has been prepared by Stantec Consulting Ltd. (Stantec) for the sole benefit of Trans Mountain Pipeline ULC (Trans Mountain). The report may not be relied upon by any other person or entity, other than for its intended purposes, without the express written consent of Stantec and Trans Mountain.

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The information provided in this report was compiled from existing documents and data provided by Trans Mountain and by applying currently accepted industry standard mitigation and prevention principles. This report represents the best professional judgement of Stantec personnel available at the time of its preparation. Stantec reserves the right to modify the contents of this report, in whole or in part, to reflect the any new information that becomes available. If any conditions become apparent that differ significantly from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

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9.2. Personal Communications

Stantec wishes to acknowledge those people identified in the Personal Communications for their assistance in supplying information and comments incorporated into this report.

Lind, A. Trans Mountain Expansion Project, Senior Pipeline Engineer, Calgary, Alberta.

Brown, C. A. Colpat Pipeline Consulting Inc., Edmonton, Alberta

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Appendix A: Laboratory Certificates

Your P.O. #: 806743-0-KMCA
Site Location: EHA & HHRA PROJECT
PO # 806743-0-KMCA

Attention: TAMMY SAUER
KINDER MORGAN CANADA
BOX 3198
SHERWOOD PARK, AB
CANADA T8A 2A6

Report Date: 2013/05/06
This report supersedes all previous reports with the same Maxxam job number

Job/Sample		Analysis Type	Well Name/Sample ID	Sample Point
B311691/	FP1881	Trace Sulphur	TRANSMOUNTAIN TERMINAL	AWB
B311691/	FP9840	Trace Sulphur	TRANSMOUNTAIN TERMINAL	CL
B311691/	GA9052	Trace Sulphur	KINDER MORGAN EDMONTON TERMINAL	AHS
B311691/	GB5489	Certificate of Analysis	TRANSMOUNTAIN TERMINAL	AWB
B311691/	GB5490	Certificate of Analysis	TRANSMOUNTAIN TERMINAL	CL
B311691/	GB5491	Certificate of Analysis	KINDER MORGAN EDMONTON TERMINAL	AHS
B311691/	GB6705	Certificate of Analysis	TRANSMOUNTAIN TERMINAL	AWB
B311691/	GB6706	Certificate of Analysis	TRANSMOUNTAIN TERMINAL	CL
B311691/	GB6707	Certificate of Analysis	KINDER MORGAN EDMONTON TERMINAL	AHS

The test Interfacial Tension (ASTM D971) was sent for analysis to Exova, 7217 Roper Rd., Edmonton, AB, Canada, T6B 3J4.
The test SAPA - Bitumen Samples (ASTM D4124) was sent for analysis to Alberta Innovates, 250 Karl Clark Rd, Edmonton, AB, Canada, T

Validated by :
Alex Urso
Senior Analyst

Report Distribution

0	Reports(B311691) TAMMY SAUER	KINDER MORGAN CANADA	BOX 3198	SHERWOOD PARK, CANADA

TRACE SULPHUR ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:FP1881
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	AWB
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Interval From / To	
Elevations (m) KB / GRD	
Sample Gathering Point	
Solution Gas	
Test Type / No. / Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d / Oil m3/d / Gas 1000m3/d	
Gauge Pressures kPa: Source / As Received	
Temperature °C: Source	
Temperature °C: As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/11
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	GS1

COMPOSITION

Component	Common Name	Boiling Pt. (°C)	Sulphur mole ppm	Sulphur mass ppm
Hydrogen Sulphide	H2S	-60.4	<0.5	<0.5
Carbonyl Sulphide	COS	-50	<0.5	<0.5
Methanethiol	Methyl mercaptan	6.2	3.3	0.9
Ethanethiol	Ethyl mercaptan	35	8.2	2.2
Dimethyl Sulphide	DMS	38	5.3	1.4
Carbon Disulphide	CS2	46.5	2.3	0.6
Iso-Propanethiol	Iso-propyl mercaptan	58	14.1	3.7
t-Butanethiol	tert-butyl mercaptan	64	5.4	1.4
Methyl Ethyl Sulphide	MES	67	8.7	2.3
n-Propanethiol	Propyl mercaptan	70	3.1	0.8
Unknown		36-69	1.5	<0.5
Thiophene/sec-Butanethiol	Thiophene/sec-Butyl mercaptan	84/90	9.0	2.4
Diethyl Sulphide	DES	92.1	1.2	<0.5
Iso-Butanethiol	Iso-butyl mercaptan	99	6.1	1.6
n-Butanethiol	Butyl mercaptan	98	1.0	<0.5
Unknown		71-97	2.7	0.7
Dimethyl Disulphide	DMDS	110	1.1	<0.5
n-Pentanethiol	Pentyl mercaptan	127	1.4	<0.5
Unknown		100-126	15.8	4.2
n-Hexanethiol	Hexyl mercaptan	151	5.0	1.3
Unknown		127-150	26.1	6.9
n-Heptanethiol	Heptyl mercaptan	177	14.1	3.7
Unknown		152-176	37.4	9.9
Total Sulphur				

Mercaptan Sulphur on Naphtha fraction (IBP 204°C) ASTM D3227 (mass%)
Naphtha IBP 204°C (volume %)
Elemental Sulphur (mass ppm)

PROPERTIES

Molecular Wt. (g/mole) Measured

Molecular Wt. (g/mole) Calculated

Onsite H2S: ppm(mole) / mole%

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

TRACE SULPHUR ANALYSIS

MaxxID	Client ID	Meter Number	Laboratory Number: B311691:FP9840
Operator Name: KINDER MORGAN CANADA		LSD	Well ID
Well Name: TRANSMOUNTAIN TERMINAL		Initials of Sampler: AL/PK	Sampling Company: MAXXAM ANALYTICS
Field or Area	Pool or Zone	Sample Point: CL	Container Identity: BLACK CAN
			Percent Full

Test Recovery

Test Type | No. | Multiple Recovery

Interval — From: To:

Elevations (m) — KB | GRD

Sample Gathering Point | Solution Gas

Well Fluid Status | Well Status Mode

Well Status Type | Well Type

Production Rates — Water m3/d | Oil m3/d | Gas 1000m3/d

Gauge Pressures kPa — Source | As Received

Temperature °C — Source | As Received: 23.0

Gas or Condensate Project | Licence No.

Date Sampled Start	Date Sampled End	Date Received	Date Reported	Date Reissued	Analyst
2013/02/14		2013/04/03	2013/04/25	2013/05/06	GS1

COMPOSITION

Component	Common Name	Boiling Pt. (°C)	Sulphur mole ppm	Sulphur mass ppm
Hydrogen Sulphide	H2S	-60.4	<0.5	<0.5
Carbonyl Sulphide	COS	-50	<0.5	<0.5
Methanethiol	Methyl mercaptan	6.2	3.0	<0.5
Ethanethiol	Ethyl mercaptan	35	8.6	1.1
Dimethyl Sulphide	DMS	38	13.8	1.7
Carbon Disulphide	CS2	46.5	3.3	<0.5
Iso-Propanethiol	Iso-propyl mercaptan	58	19.4	2.5
t-Butanethiol	tert-butyl mercaptan	64	3.3	<0.5
Methyl Ethyl Sulphide	MES	67	7.3	0.9
n-Propanethiol	Propyl mercaptan	70	<0.5	<0.5
Unknown		36-69	<0.5	<0.5
Thiophene/sec-Butanethiol	Thiophene/sec-Butyl mercaptan	84/90	22.6	2.9
Diethyl Sulphide	DES	92.1	3.3	<0.5
Iso-Butanethiol	Iso-butyl mercaptan	99	<0.5	<0.5
n-Butanethiol	Butyl mercaptan	98	4.2	0.5
Unknown		71-97	<0.5	<0.5
Dimethyl Disulphide	DMDS	110	<0.5	<0.5
n-Pentanethiol	Pentyl mercaptan	127	<0.5	<0.5
Unknown		100-126	31.9	4.0
n-Hexanethiol	Hexyl mercaptan	151	4.3	0.5
Unknown		127-150	111.5	14.2
n-Heptanethiol	Heptyl mercaptan	177	<0.5	<0.5
Unknown		152-176	154.3	19.6
Total Sulphur				

Mercaptan Sulphur on Naphtha fraction (IBP 204°C) ASTM D3227 (mass%)

Naphtha IBP 204°C (volume %)

Elemental Sulphur (mass ppm)

PROPERTIES

Molecular Wt. (g/mole) Measured

Molecular Wt. (g/mole) Calculated

Onsite H2S — ppm(mole) | mole%

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

TRACE SULPHUR ANALYSIS

Maxxam

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GA9052
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	KINDER MORGAN EDMONTON TERMINAL
Initials of Sampler	N/A
Sampling Company	KINDER MORGAN
Field or Area	EDMONTON
Pool or Zone	
Sample Point	AHS
Container Identity	RED CAN
Percent Full	
Test Recovery	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/03/31
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	GS1

COMPOSITION

Component	Common Name	Boiling Pt. (°C)	Sulphur mole ppm	Sulphur mass ppm
Hydrogen Sulphide	H2S	-60.4	<0.5	<0.5
Carbonyl Sulphide	COS	-50	0.5	<0.5
Methanethiol	Methyl mercaptan	6.2	2.1	0.5
Ethanethiol	Ethyl mercaptan	35	6.9	1.7
Dimethyl Sulphide	DMS	38	2.7	0.6
Carbon Disulphide	CS2	46.5	<0.5	<0.5
Iso-Propanethiol	Iso-propyl mercaptan	58	6.5	1.6
t-Butanethiol	tert-butyl mercaptan	64	1.0	<0.5
Methyl Ethyl Sulphide	MES	67	1.7	<0.5
n-Propanethiol	Propyl mercaptan	70	1.9	0.5
Unknown		36-69	<0.5	<0.5
Thiophene/sec-Butanethiol	Thiophene/sec-Butyl mercaptan	84/90	4.9	1.2
Diethyl Sulphide	DES	92.1	<0.5	<0.5
Iso-Butanethiol	Iso-butyl mercaptan	99	0.6	<0.5
n-Butanethiol	Butyl mercaptan	98	1.1	<0.5
Unknown		71-97	<0.5	<0.5
Dimethyl Disulphide	DMDS	110	1.2	<0.5
n-Pentanethiol	Pentyl mercaptan	127	<0.5	<0.5
Unknown		100-126	5.2	1.2
n-Hexanethiol	Hexyl mercaptan	151	2.6	0.6
Unknown		127-150	14.5	3.5
n-Heptanethiol	Heptyl mercaptan	177	<0.5	<0.5
Unknown		152-176	19.8	4.8
Total Sulphur				

Mercaptan Sulphur on Naphtha fraction (IBP 204°C) ASTM D3227 (mass%)
Naphtha IBP 204°C (volume %)
Elemental Sulphur (mass ppm)

** Information not supplied by client -- data derived from LSD information

PROPERTIES

Molecular Wt. (g/mole) Measured:

Molecular Wt. (g/mole) Calculated:

Onsite H2S: ppm(mole) / mole%

Results relate only to items tested

Remarks:

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5489
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	AWB
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Interval From: / To:	
Elevations (m) KB / GRD	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d / Oil m3/d / Gas 1000m3/d	
Gauge Pressures kPa: Source / As Received	
Temperature °C: Source	
Temperature °C: As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/11
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,HF ,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Industrial				
Interfacial Tension	35	dyne/cm		0.01
Metals				
Mercury (Hg)	10	ppb	ASTM D6722	1
Composition				
Saturates	30.2	mass%		0.1
Aromatics	18.9	mass%		0.1
Polars	42.6	mass%		0.1
Asphaltenes	8.3	mass%		0.1
Density Analysis				
Absolute Density @ 15 °C	921.5	kg/m3	ASTM D5002	0.1
Measured Relative Density @ 15 °C	0.9223	N/A	ASTM D5002	
API Gravity @ 15 °C	21.9	N/A		
Elements				
Dissolved Aluminum (Al)	<1	mg/kg	ASTM D5708A	1
Dissolved Barium (Ba)	<1	mg/kg	ASTM D5708A	1
Dissolved Beryllium (Be)	<1	mg/kg	ASTM D5708A	1
Dissolved Boron (B)	4	mg/kg	ASTM D5708A	1
Dissolved Cadmium (Cd)	<1	mg/kg	ASTM D5708A	1
Dissolved Calcium (Ca)	2	mg/kg	ASTM D5708A	1
Dissolved Chromium (Cr)	<1	mg/kg	ASTM D5708A	1
Dissolved Cobalt (Co)	<1	mg/kg	ASTM D5708A	1
Dissolved Copper (Cu)	<1	mg/kg	ASTM D5708A	1
Dissolved Iron (Fe)	1	mg/kg	ASTM D5708A	1
Dissolved Lead (Pb)	<1	mg/kg	ASTM D5708A	1
Dissolved Lithium (Li)	<1	mg/kg	ASTM D5708A	1
Dissolved Magnesium (Mg)	<1	mg/kg	ASTM D5708A	1
Dissolved Manganese (Mn)	<1	mg/kg	ASTM D5708A	1
Dissolved Molybdenum (Mo)	5	mg/kg	ASTM D5708A	1
Dissolved Nickel (Ni)	47.2	mg/kg	ASTM D5708A	0.5
Dissolved Phosphorus (P)	0.5	mg/kg	ASTM D5708A	0.5
Dissolved Potassium (K)	1	mg/kg	ASTM D5708A	1
Dissolved Silicon (Si)	1	mg/kg	ASTM D5708A	1

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

CERTIFICATE OF ANALYSIS

Maxxam

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5489
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	AWB
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Sample Gathering Point	
Solution Gas	
Test Type / No. / Multiple Recovery	
Interval From: / To:	
Elevations (m) KB / GRD	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d / Oil m3/d / Gas 1000m3/d	
Gauge Pressures kPa: Source / As Received	
Temperature °C: Source	
Temperature °C: As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/11
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,HF ,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Elements				
Dissolved Silver (Ag)	<1	mg/kg	ASTM D5708A	1
Dissolved Sodium (Na)	3	mg/kg	ASTM D5708A	1
Dissolved Strontium (Sr)	<1	mg/kg	ASTM D5708A	1
Dissolved Sulphur (S)	34500	mg/kg	ASTM D5708A	1
Dissolved Tin (Sn)	<1	mg/kg	ASTM D5708A	1
Dissolved Titanium (Ti)	<1	mg/kg	ASTM D5708A	1
Dissolved Vanadium (V)	136	mg/kg	ASTM D5708A	1
Dissolved Zinc (Zn)	<1	mg/kg	ASTM D5708A	1
Physical Properties				
Closed Cup Flash point	<-35	°C	ASTM D93	
Pour Point	-33	°C	ASTM D5853	
Simulated Dist ASTM D7169				
D7169 Distillation Initial Boiling Point	34.1	°C	ASTM D7169	
D7169 Distillation 1 % off	34.9	°C	ASTM D7169	
D7169 Distillation 2 % off	35.3	°C	ASTM D7169	
D7169 Distillation 3 % off	35.9	°C	ASTM D7169	
D7169 Distillation 4 % off	36.3	°C	ASTM D7169	
D7169 Distillation 5 % off	37.0	°C	ASTM D7169	
D7169 Distillation 6 % off	38.1	°C	ASTM D7169	
D7169 Distillation 7 % off	39.5	°C	ASTM D7169	
D7169 Distillation 8 % off	41.8	°C	ASTM D7169	
D7169 Distillation 9 % off	46.1	°C	ASTM D7169	
D7169 Distillation 10 % off	54.8	°C	ASTM D7169	
D7169 Distillation 11 % off	63.8	°C	ASTM D7169	
D7169 Distillation 12 % off	68.6	°C	ASTM D7169	
D7169 Distillation 13 % off	70.7	°C	ASTM D7169	
D7169 Distillation 14 % off	74.4	°C	ASTM D7169	
D7169 Distillation 15 % off	78.8	°C	ASTM D7169	
D7169 Distillation 16 % off	83.9	°C	ASTM D7169	
D7169 Distillation 17 % off	89.4	°C	ASTM D7169	
D7169 Distillation 18 % off	97.0	°C	ASTM D7169	
D7169 Distillation 19 % off	99.8	°C	ASTM D7169	
D7169 Distillation 20 % off	103.2	°C	ASTM D7169	
D7169 Distillation 21 % off	115.5	°C	ASTM D7169	
D7169 Distillation 22 % off	132.3	°C	ASTM D7169	
D7169 Distillation 23 % off	147.7	°C	ASTM D7169	

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5489
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	AWB
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/11
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,HF ,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Simulated Dist ASTM D7169				
D7169 Distillation 24 % off	165.1	°C	ASTM D7169	
D7169 Distillation 25 % off	186.6	°C	ASTM D7169	
D7169 Distillation 26 % off	211.0	°C	ASTM D7169	
D7169 Distillation 27 % off	231.3	°C	ASTM D7169	
D7169 Distillation 28 % off	249.1	°C	ASTM D7169	
D7169 Distillation 29 % off	263.2	°C	ASTM D7169	
D7169 Distillation 30 % off	276.0	°C	ASTM D7169	
D7169 Distillation 31 % off	288.0	°C	ASTM D7169	
D7169 Distillation 32 % off	298.3	°C	ASTM D7169	
D7169 Distillation 33 % off	307.5	°C	ASTM D7169	
D7169 Distillation 34 % off	316.4	°C	ASTM D7169	
D7169 Distillation 35 % off	325.1	°C	ASTM D7169	
D7169 Distillation 36 % off	333.5	°C	ASTM D7169	
D7169 Distillation 37 % off	342.0	°C	ASTM D7169	
D7169 Distillation 38 % off	349.9	°C	ASTM D7169	
D7169 Distillation 39 % off	357.5	°C	ASTM D7169	
D7169 Distillation 40 % off	365.2	°C	ASTM D7169	
D7169 Distillation 41 % off	372.7	°C	ASTM D7169	
D7169 Distillation 42 % off	380.4	°C	ASTM D7169	
D7169 Distillation 43 % off	388.2	°C	ASTM D7169	
D7169 Distillation 44 % off	395.9	°C	ASTM D7169	
D7169 Distillation 45 % off	403.4	°C	ASTM D7169	
D7169 Distillation 46 % off	410.8	°C	ASTM D7169	
D7169 Distillation 47 % off	417.5	°C	ASTM D7169	
D7169 Distillation 48 % off	423.8	°C	ASTM D7169	
D7169 Distillation 49 % off	430.2	°C	ASTM D7169	
D7169 Distillation 50 % off	436.8	°C	ASTM D7169	
D7169 Distillation 51 % off	443.8	°C	ASTM D7169	
D7169 Distillation 52 % off	450.9	°C	ASTM D7169	
D7169 Distillation 53 % off	457.9	°C	ASTM D7169	
D7169 Distillation 54 % off	465.1	°C	ASTM D7169	
D7169 Distillation 55 % off	472.4	°C	ASTM D7169	
D7169 Distillation 56 % off	479.9	°C	ASTM D7169	
D7169 Distillation 57 % off	487.7	°C	ASTM D7169	
D7169 Distillation 58 % off	495.6	°C	ASTM D7169	
D7169 Distillation 59 % off	503.0	°C	ASTM D7169	
D7169 Distillation 60 % off	510.6	°C	ASTM D7169	
D7169 Distillation 61 % off	518.6	°C	ASTM D7169	
D7169 Distillation 62 % off	526.9	°C	ASTM D7169	
D7169 Distillation 63 % off	535.4	°C	ASTM D7169	

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5489
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	AWB
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/11
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,HF ,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Simulated Dist ASTM D7169				
D7169 Distillation 64 % off	543.7	°C	ASTM D7169	
D7169 Distillation 65 % off	552.6	°C	ASTM D7169	
D7169 Distillation 66 % off	561.6	°C	ASTM D7169	
D7169 Distillation 67 % off	570.3	°C	ASTM D7169	
D7169 Distillation 68 % off	579.0	°C	ASTM D7169	
D7169 Distillation 69 % off	587.9	°C	ASTM D7169	
D7169 Distillation 70 % off	596.6	°C	ASTM D7169	
D7169 Distillation 71 % off	605.4	°C	ASTM D7169	
D7169 Distillation 72 % off	614.1	°C	ASTM D7169	
D7169 Distillation 73 % off	623.0	°C	ASTM D7169	
D7169 Distillation 74 % off	631.1	°C	ASTM D7169	
D7169 Distillation 75 % off	639.0	°C	ASTM D7169	
D7169 Distillation 76 % off	646.9	°C	ASTM D7169	
D7169 Distillation 77 % off	654.1	°C	ASTM D7169	
D7169 Distillation 78 % off	661.3	°C	ASTM D7169	
D7169 Distillation 79 % off	669.9	°C	ASTM D7169	
D7169 Distillation 80 % off	677.9	°C	ASTM D7169	
D7169 Distillation 81 % off	686.3	°C	ASTM D7169	
D7169 Distillation 82 % off	693.8	°C	ASTM D7169	
D7169 Distillation 83 % off	701.4	°C	ASTM D7169	
D7169 Distillation 84 % off	708.1	°C	ASTM D7169	
D7169 Distillation 85 % off	715.5	°C	ASTM D7169	
D7169 Distillation Residue @ 720°C	14.38	mass%	ASTM D7169	0.01
Viscosity Analysis				
Viscosity @ 30°C	112.5	cSt	ASTM D7042	0.01000
Viscosity @ 40°C	67.50	cSt	ASTM D7042	0.01000
Viscosity @ 50°C	43.76	cSt	ASTM D7042	0.01000

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

CERTIFICATE OF ANALYSIS

Maxxam

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5490
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	CL
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/14
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Industrial				
Interfacial Tension	42	dyne/cm		0.01
Metals				
Mercury (Hg)	21	ppb	ASTM D6722	1
Composition				
Saturates	31.8	mass%		0.1
Aromatics	20.3	mass%		0.1
Polars	39.8	mass%		0.1
Asphaltenes	8.0	mass%		0.1
Density Analysis				
Absolute Density @ 15 °C	926.0	kg/m3	ASTM D5002	0.1
Measured Relative Density @ 15 °C	0.9268	N/A	ASTM D5002	
API Gravity @ 15 °C	21.2	N/A		
Elements				
Dissolved Aluminum (Al)	<1	mg/kg	ASTM D5708A	1
Dissolved Barium (Ba)	<1	mg/kg	ASTM D5708A	1
Dissolved Beryllium (Be)	<1	mg/kg	ASTM D5708A	1
Dissolved Boron (B)	1	mg/kg	ASTM D5708A	1
Dissolved Cadmium (Cd)	<1	mg/kg	ASTM D5708A	1
Dissolved Calcium (Ca)	2	mg/kg	ASTM D5708A	1
Dissolved Chromium (Cr)	<1	mg/kg	ASTM D5708A	1
Dissolved Cobalt (Co)	<1	mg/kg	ASTM D5708A	1
Dissolved Copper (Cu)	<1	mg/kg	ASTM D5708A	1
Dissolved Iron (Fe)	3	mg/kg	ASTM D5708A	1
Dissolved Lead (Pb)	<1	mg/kg	ASTM D5708A	1
Dissolved Lithium (Li)	<1	mg/kg	ASTM D5708A	1
Dissolved Magnesium (Mg)	<1	mg/kg	ASTM D5708A	1
Dissolved Manganese (Mn)	<1	mg/kg	ASTM D5708A	1
Dissolved Molybdenum (Mo)	5	mg/kg	ASTM D5708A	1
Dissolved Nickel (Ni)	46.8	mg/kg	ASTM D5708A	0.5
Dissolved Phosphorus (P)	0.8	mg/kg	ASTM D5708A	0.5
Dissolved Potassium (K)	1	mg/kg	ASTM D5708A	1
Dissolved Silicon (Si)	2	mg/kg	ASTM D5708A	1

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5490
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	CL
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d	
Production Rates: Oil m3/d	
Production Rates: Gas 1000m3/d	
Gauge Pressures kPa: Source	
Gauge Pressures kPa: As Received	
Temperature °C: Source	
Temperature °C: As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/14
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Elements				
Dissolved Silver (Ag)	<1	mg/kg	ASTM D5708A	1
Dissolved Sodium (Na)	12	mg/kg	ASTM D5708A	1
Dissolved Strontium (Sr)	<1	mg/kg	ASTM D5708A	1
Dissolved Sulphur (S)	37100	mg/kg	ASTM D5708A	1
Dissolved Tin (Sn)	<1	mg/kg	ASTM D5708A	1
Dissolved Titanium (Ti)	1	mg/kg	ASTM D5708A	1
Dissolved Vanadium (V)	135	mg/kg	ASTM D5708A	1
Dissolved Zinc (Zn)	<1	mg/kg	ASTM D5708A	1
Physical Properties				
Closed Cup Flash point	<-35	°C	ASTM D93	
Pour Point	-33	°C	ASTM D5853	
Simulated Dist ASTM D7169				
D7169 Distillation Initial Boiling Point	35.0	°C	ASTM D7169	
D7169 Distillation 1 % off	35.3	°C	ASTM D7169	
D7169 Distillation 2 % off	36.2	°C	ASTM D7169	
D7169 Distillation 3 % off	37.9	°C	ASTM D7169	
D7169 Distillation 4 % off	41.0	°C	ASTM D7169	
D7169 Distillation 5 % off	49.1	°C	ASTM D7169	
D7169 Distillation 6 % off	62.2	°C	ASTM D7169	
D7169 Distillation 7 % off	69.3	°C	ASTM D7169	
D7169 Distillation 8 % off	72.9	°C	ASTM D7169	
D7169 Distillation 9 % off	82.3	°C	ASTM D7169	
D7169 Distillation 10 % off	91.9	°C	ASTM D7169	
D7169 Distillation 11 % off	100.0	°C	ASTM D7169	
D7169 Distillation 12 % off	107.7	°C	ASTM D7169	
D7169 Distillation 13 % off	120.1	°C	ASTM D7169	
D7169 Distillation 14 % off	135.5	°C	ASTM D7169	
D7169 Distillation 15 % off	149.6	°C	ASTM D7169	
D7169 Distillation 16 % off	165.2	°C	ASTM D7169	
D7169 Distillation 17 % off	183.7	°C	ASTM D7169	
D7169 Distillation 18 % off	201.9	°C	ASTM D7169	
D7169 Distillation 19 % off	217.2	°C	ASTM D7169	
D7169 Distillation 20 % off	229.6	°C	ASTM D7169	
D7169 Distillation 21 % off	241.3	°C	ASTM D7169	
D7169 Distillation 22 % off	251.9	°C	ASTM D7169	
D7169 Distillation 23 % off	261.4	°C	ASTM D7169	

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5490
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	CL
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/14
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Simulated Dist ASTM D7169				
D7169 Distillation 24 % off	270.3	°C	ASTM D7169	
D7169 Distillation 25 % off	279.6	°C	ASTM D7169	
D7169 Distillation 26 % off	288.4	°C	ASTM D7169	
D7169 Distillation 27 % off	296.4	°C	ASTM D7169	
D7169 Distillation 28 % off	304.1	°C	ASTM D7169	
D7169 Distillation 29 % off	311.6	°C	ASTM D7169	
D7169 Distillation 30 % off	318.8	°C	ASTM D7169	
D7169 Distillation 31 % off	326.3	°C	ASTM D7169	
D7169 Distillation 32 % off	333.6	°C	ASTM D7169	
D7169 Distillation 33 % off	341.0	°C	ASTM D7169	
D7169 Distillation 34 % off	348.1	°C	ASTM D7169	
D7169 Distillation 35 % off	355.1	°C	ASTM D7169	
D7169 Distillation 36 % off	362.2	°C	ASTM D7169	
D7169 Distillation 37 % off	369.3	°C	ASTM D7169	
D7169 Distillation 38 % off	376.6	°C	ASTM D7169	
D7169 Distillation 39 % off	384.0	°C	ASTM D7169	
D7169 Distillation 40 % off	391.4	°C	ASTM D7169	
D7169 Distillation 41 % off	398.9	°C	ASTM D7169	
D7169 Distillation 42 % off	406.2	°C	ASTM D7169	
D7169 Distillation 43 % off	413.2	°C	ASTM D7169	
D7169 Distillation 44 % off	419.6	°C	ASTM D7169	
D7169 Distillation 45 % off	425.8	°C	ASTM D7169	
D7169 Distillation 46 % off	432.2	°C	ASTM D7169	
D7169 Distillation 47 % off	439.0	°C	ASTM D7169	
D7169 Distillation 48 % off	445.9	°C	ASTM D7169	
D7169 Distillation 49 % off	452.8	°C	ASTM D7169	
D7169 Distillation 50 % off	459.7	°C	ASTM D7169	
D7169 Distillation 51 % off	466.8	°C	ASTM D7169	
D7169 Distillation 52 % off	474.0	°C	ASTM D7169	
D7169 Distillation 53 % off	481.2	°C	ASTM D7169	
D7169 Distillation 54 % off	488.8	°C	ASTM D7169	
D7169 Distillation 55 % off	496.5	°C	ASTM D7169	
D7169 Distillation 56 % off	503.5	°C	ASTM D7169	
D7169 Distillation 57 % off	510.8	°C	ASTM D7169	
D7169 Distillation 58 % off	518.5	°C	ASTM D7169	
D7169 Distillation 59 % off	526.5	°C	ASTM D7169	
D7169 Distillation 60 % off	534.7	°C	ASTM D7169	
D7169 Distillation 61 % off	542.7	°C	ASTM D7169	
D7169 Distillation 62 % off	551.2	°C	ASTM D7169	
D7169 Distillation 63 % off	559.9	°C	ASTM D7169	

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5490
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	CL
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Interval From: / To:	
Elevations (m) KB / GRD	
Sample Gathering Point	
Solution Gas	
Test Type / No. / Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d / Oil m3/d / Gas 1000m3/d	
Gauge Pressures kPa: Source / As Received	
Temperature °C: Source / As Received	23.0 (As Received)
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/14
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Simulated Dist ASTM D7169				
D7169 Distillation 64 % off	568.4	°C	ASTM D7169	
D7169 Distillation 65 % off	576.7	°C	ASTM D7169	
D7169 Distillation 66 % off	585.3	°C	ASTM D7169	
D7169 Distillation 67 % off	593.9	°C	ASTM D7169	
D7169 Distillation 68 % off	602.4	°C	ASTM D7169	
D7169 Distillation 69 % off	611.1	°C	ASTM D7169	
D7169 Distillation 70 % off	619.9	°C	ASTM D7169	
D7169 Distillation 71 % off	628.4	°C	ASTM D7169	
D7169 Distillation 72 % off	636.4	°C	ASTM D7169	
D7169 Distillation 73 % off	644.7	°C	ASTM D7169	
D7169 Distillation 74 % off	652.6	°C	ASTM D7169	
D7169 Distillation 75 % off	660.1	°C	ASTM D7169	
D7169 Distillation 76 % off	669.3	°C	ASTM D7169	
D7169 Distillation 77 % off	677.8	°C	ASTM D7169	
D7169 Distillation 78 % off	686.8	°C	ASTM D7169	
D7169 Distillation 79 % off	694.5	°C	ASTM D7169	
D7169 Distillation 80 % off	702.5	°C	ASTM D7169	
D7169 Distillation 81 % off	709.7	°C	ASTM D7169	
D7169 Distillation 82 % off	717.3	°C	ASTM D7169	
D7169 Distillation Residue @ 720°C	17.65	mass%	ASTM D7169	0.01
Viscosity Analysis				
Viscosity @ 30°C	105.9	cSt	ASTM D7042	0.01000
Viscosity @ 40°C	64.09	cSt	ASTM D7042	0.01000
Viscosity @ 60°C	28.63	cSt	ASTM D7042	0.01000

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5491
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	KINDER MORGAN EDMONTON TERMINAL
Initials of Sampler	N/A
Sampling Company	KINDER MORGAN
Field or Area	EDMONTON
Pool or Zone	
Sample Point	AHS
Container Identity	RED CAN
Percent Full	
Test Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d	
Production Rates: Oil m3/d	
Production Rates: Gas 1000m3/d	
Gauge Pressures kPa: Source	
Gauge Pressures kPa: As Received	
Temperature °C: Source	
Temperature °C: As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/03/31
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Industrial				
Interfacial Tension	74	dyne/cm		0.01
Metals				
Mercury (Hg)	7	ppb	ASTM D6722	1
Composition				
Saturates	31.2	mass%		0.1
Aromatics	25.2	mass%		0.1
Polars	35.4	mass%		0.1
Asphaltenes	8.2	mass%		0.1
Density Analysis				
Absolute Density @ 15 °C	935.4	kg/m3	ASTM D5002	0.1
Measured Relative Density @ 15 °C	0.9362	N/A	ASTM D5002	
API Gravity @ 15 °C	19.6	N/A		
Elements				
Dissolved Aluminum (Al)	13	mg/kg	ASTM D5708A	1
Dissolved Barium (Ba)	<1	mg/kg	ASTM D5708A	1
Dissolved Beryllium (Be)	<1	mg/kg	ASTM D5708A	1
Dissolved Boron (B)	2	mg/kg	ASTM D5708A	1
Dissolved Cadmium (Cd)	<1	mg/kg	ASTM D5708A	1
Dissolved Calcium (Ca)	7	mg/kg	ASTM D5708A	1
Dissolved Chromium (Cr)	<1	mg/kg	ASTM D5708A	1
Dissolved Cobalt (Co)	<1	mg/kg	ASTM D5708A	1
Dissolved Copper (Cu)	<1	mg/kg	ASTM D5708A	1
Dissolved Iron (Fe)	28	mg/kg	ASTM D5708A	1
Dissolved Lead (Pb)	<1	mg/kg	ASTM D5708A	1
Dissolved Lithium (Li)	<1	mg/kg	ASTM D5708A	1
Dissolved Magnesium (Mg)	<1	mg/kg	ASTM D5708A	1
Dissolved Manganese (Mn)	1	mg/kg	ASTM D5708A	1
Dissolved Molybdenum (Mo)	7	mg/kg	ASTM D5708A	1
Dissolved Nickel (Ni)	37.3	mg/kg	ASTM D5708A	0.5
Dissolved Phosphorus (P)	1.3	mg/kg	ASTM D5708A	0.5
Dissolved Potassium (K)	2	mg/kg	ASTM D5708A	1
Dissolved Silicon (Si)	10	mg/kg	ASTM D5708A	1

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5491
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	KINDER MORGAN EDMONTON TERMINAL
Initials of Sampler	N/A
Sampling Company	KINDER MORGAN
Field or Area	EDMONTON
Pool or Zone	
Sample Point	AHS
Container Identity	RED CAN
Percent Full	
Test Recovery	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/03/31
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Elements				
Dissolved Silver (Ag)	<1	mg/kg	ASTM D5708A	1
Dissolved Sodium (Na)	5	mg/kg	ASTM D5708A	1
Dissolved Strontium (Sr)	<1	mg/kg	ASTM D5708A	1
Dissolved Sulphur (S)	23600	mg/kg	ASTM D5708A	1
Dissolved Tin (Sn)	<1	mg/kg	ASTM D5708A	1
Dissolved Titanium (Ti)	4	mg/kg	ASTM D5708A	1
Dissolved Vanadium (V)	74	mg/kg	ASTM D5708A	1
Dissolved Zinc (Zn)	1	mg/kg	ASTM D5708A	1
Physical Properties				
Closed Cup Flash point	<-35	°C	ASTM D93	
Pour Point	-33	°C	ASTM D5853	
Simulated Dist ASTM D7169				
D7169 Distillation Initial Boiling Point	34.0	°C	ASTM D7169	
D7169 Distillation 1 % off	34.2	°C	ASTM D7169	
D7169 Distillation 2 % off	35.3	°C	ASTM D7169	
D7169 Distillation 3 % off	36.2	°C	ASTM D7169	
D7169 Distillation 4 % off	37.8	°C	ASTM D7169	
D7169 Distillation 5 % off	41.0	°C	ASTM D7169	
D7169 Distillation 6 % off	48.6	°C	ASTM D7169	
D7169 Distillation 7 % off	59.9	°C	ASTM D7169	
D7169 Distillation 8 % off	68.5	°C	ASTM D7169	
D7169 Distillation 9 % off	71.4	°C	ASTM D7169	
D7169 Distillation 10 % off	77.6	°C	ASTM D7169	
D7169 Distillation 11 % off	84.0	°C	ASTM D7169	
D7169 Distillation 12 % off	89.4	°C	ASTM D7169	
D7169 Distillation 13 % off	96.8	°C	ASTM D7169	
D7169 Distillation 14 % off	99.9	°C	ASTM D7169	
D7169 Distillation 15 % off	108.3	°C	ASTM D7169	
D7169 Distillation 16 % off	122.9	°C	ASTM D7169	
D7169 Distillation 17 % off	135.8	°C	ASTM D7169	
D7169 Distillation 18 % off	149.2	°C	ASTM D7169	
D7169 Distillation 19 % off	160.4	°C	ASTM D7169	
D7169 Distillation 20 % off	172.5	°C	ASTM D7169	
D7169 Distillation 21 % off	185.6	°C	ASTM D7169	
D7169 Distillation 22 % off	211.3	°C	ASTM D7169	
D7169 Distillation 23 % off	245.1	°C	ASTM D7169	

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5491
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	KINDER MORGAN EDMONTON TERMINAL
Initials of Sampler	N/A
Sampling Company	KINDER MORGAN
Field or Area	EDMONTON
Pool or Zone	
Sample Point	AHS
Container Identity	RED CAN
Percent Full	
Test Recovery	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/03/31
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Simulated Dist ASTM D7169				
D7169 Distillation 24 % off	271.0	°C	ASTM D7169	
D7169 Distillation 25 % off	293.9	°C	ASTM D7169	
D7169 Distillation 26 % off	312.9	°C	ASTM D7169	
D7169 Distillation 27 % off	330.1	°C	ASTM D7169	
D7169 Distillation 28 % off	345.6	°C	ASTM D7169	
D7169 Distillation 29 % off	358.3	°C	ASTM D7169	
D7169 Distillation 30 % off	369.6	°C	ASTM D7169	
D7169 Distillation 31 % off	379.6	°C	ASTM D7169	
D7169 Distillation 32 % off	388.5	°C	ASTM D7169	
D7169 Distillation 33 % off	396.4	°C	ASTM D7169	
D7169 Distillation 34 % off	403.6	°C	ASTM D7169	
D7169 Distillation 35 % off	410.2	°C	ASTM D7169	
D7169 Distillation 36 % off	415.9	°C	ASTM D7169	
D7169 Distillation 37 % off	421.2	°C	ASTM D7169	
D7169 Distillation 38 % off	426.1	°C	ASTM D7169	
D7169 Distillation 39 % off	430.9	°C	ASTM D7169	
D7169 Distillation 40 % off	435.9	°C	ASTM D7169	
D7169 Distillation 41 % off	440.7	°C	ASTM D7169	
D7169 Distillation 42 % off	445.5	°C	ASTM D7169	
D7169 Distillation 43 % off	450.1	°C	ASTM D7169	
D7169 Distillation 44 % off	454.4	°C	ASTM D7169	
D7169 Distillation 45 % off	458.6	°C	ASTM D7169	
D7169 Distillation 46 % off	462.8	°C	ASTM D7169	
D7169 Distillation 47 % off	466.9	°C	ASTM D7169	
D7169 Distillation 48 % off	471.0	°C	ASTM D7169	
D7169 Distillation 49 % off	475.0	°C	ASTM D7169	
D7169 Distillation 50 % off	479.0	°C	ASTM D7169	
D7169 Distillation 51 % off	483.0	°C	ASTM D7169	
D7169 Distillation 52 % off	487.1	°C	ASTM D7169	
D7169 Distillation 53 % off	491.1	°C	ASTM D7169	
D7169 Distillation 54 % off	495.2	°C	ASTM D7169	
D7169 Distillation 55 % off	499.0	°C	ASTM D7169	
D7169 Distillation 56 % off	502.8	°C	ASTM D7169	
D7169 Distillation 57 % off	506.6	°C	ASTM D7169	
D7169 Distillation 58 % off	510.4	°C	ASTM D7169	
D7169 Distillation 59 % off	514.4	°C	ASTM D7169	
D7169 Distillation 60 % off	518.4	°C	ASTM D7169	
D7169 Distillation 61 % off	522.5	°C	ASTM D7169	
D7169 Distillation 62 % off	526.7	°C	ASTM D7169	
D7169 Distillation 63 % off	531.0	°C	ASTM D7169	

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB5491
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	KINDER MORGAN EDMONTON TERMINAL
Initials of Sampler	N/A
Sampling Company	KINDER MORGAN
Field or Area	EDMONTON
Pool or Zone	
Sample Point	AHS
Container Identity	RED CAN
Percent Full	
Test Recovery	
Interval From: / To:	
Elevations (m) KB / GRD	
Sample Gathering Point	
Solution Gas	
Test Type / No. / Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d / Oil m3/d / Gas 1000m3/d	
Gauge Pressures kPa: Source / As Received	
Temperature °C: Source / As Received	/ 23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/03/31
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MS7,LG5,WH ,SK1,BC2,KL9,MN2

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Simulated Dist ASTM D7169				
D7169 Distillation 64 % off	535.2	°C	ASTM D7169	
D7169 Distillation 65 % off	539.4	°C	ASTM D7169	
D7169 Distillation 66 % off	543.6	°C	ASTM D7169	
D7169 Distillation 67 % off	548.1	°C	ASTM D7169	
D7169 Distillation 68 % off	552.7	°C	ASTM D7169	
D7169 Distillation 69 % off	557.4	°C	ASTM D7169	
D7169 Distillation 70 % off	562.1	°C	ASTM D7169	
D7169 Distillation 71 % off	566.8	°C	ASTM D7169	
D7169 Distillation 72 % off	571.3	°C	ASTM D7169	
D7169 Distillation 73 % off	576.0	°C	ASTM D7169	
D7169 Distillation 74 % off	581.0	°C	ASTM D7169	
D7169 Distillation 75 % off	586.1	°C	ASTM D7169	
D7169 Distillation 76 % off	591.3	°C	ASTM D7169	
D7169 Distillation 77 % off	596.5	°C	ASTM D7169	
D7169 Distillation 78 % off	601.9	°C	ASTM D7169	
D7169 Distillation 79 % off	607.7	°C	ASTM D7169	
D7169 Distillation 80 % off	613.4	°C	ASTM D7169	
D7169 Distillation 81 % off	619.6	°C	ASTM D7169	
D7169 Distillation 82 % off	625.9	°C	ASTM D7169	
D7169 Distillation 83 % off	632.0	°C	ASTM D7169	
D7169 Distillation 84 % off	638.6	°C	ASTM D7169	
D7169 Distillation 85 % off	645.6	°C	ASTM D7169	
D7169 Distillation 86 % off	652.6	°C	ASTM D7169	
D7169 Distillation 87 % off	659.7	°C	ASTM D7169	
D7169 Distillation 88 % off	668.9	°C	ASTM D7169	
D7169 Distillation 89 % off	678.1	°C	ASTM D7169	
D7169 Distillation 90 % off	688.4	°C	ASTM D7169	
D7169 Distillation 91 % off	698.2	°C	ASTM D7169	
D7169 Distillation 92 % off	708.1	°C	ASTM D7169	
D7169 Distillation 93 % off	719.4	°C	ASTM D7169	
D7169 Distillation Residue @ 720°C	6.95	mass%	ASTM D7169	0.01
Viscosity Analysis				
Viscosity @ 20°C	142.5	cSt	ASTM D7042	0.01000
Viscosity @ 30°C	79.26	cSt	ASTM D7042	0.01000
Viscosity @ 40°C	47.16	cSt	ASTM D7042	0.01000

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

Unable to perform Naphthenic Acid due to sample matrix.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB6705
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	AWB
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates: Water m3/d	
Production Rates: Oil m3/d	
Production Rates: Gas 1000m3/d	
Gauge Pressures kPa: Source	
Gauge Pressures kPa: As Received	
Temperature °C: Source	
Temperature °C: As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/11
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MM1

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Industrial				
Attachment	SEE BELOW	N/A		

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

See Attached Extended Condensate Analysis.

Maxxam

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB6706
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	TRANSMOUNTAIN TERMINAL
Initials of Sampler	AL/PK
Sampling Company	MAXXAM ANALYTICS
Field or Area	
Pool or Zone	
Sample Point	CL
Container Identity	BLACK CAN
Percent Full	
Test Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/02/14
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MM1

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Industrial				
Attachment	SEE BELOW	N/A		

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

See Attached Extended Condensate Analysis.

CERTIFICATE OF ANALYSIS

Field	Value
MaxxID	
Client ID	
Meter Number	
Laboratory Number	B311691:GB6707
Operator Name	KINDER MORGAN CANADA
LSD	
Well ID	
Well Name	KINDER MORGAN EDMONTON TERMINAL
Initials of Sampler	N/A
Sampling Company	KINDER MORGAN
Field or Area	EDMONTON
Pool or Zone	
Sample Point	AHS
Container Identity	RED CAN
Percent Full	
Test Recovery	
Interval From:	
Interval To:	
Elevations (m) KB	
Elevations (m) GRD	
Sample Gathering Point	
Solution Gas	
Test Type	
No.	
Multiple Recovery	
Well Fluid Status	
Well Status Mode	
Production Rates Water m3/d	
Production Rates Oil m3/d	
Production Rates Gas 1000m3/d	
Gauge Pressures kPa Source	
Gauge Pressures kPa As Received	
Temperature °C Source	
Temperature °C As Received	23.0
Well Status Type	
Well Type	
Gas or Condensate Project	
Licence No.	
Date Sampled Start	2013/03/31
Date Sampled End	
Date Received	2013/04/03
Date Reported	2013/04/25
Date Reissued	2013/05/06
Analyst	MM1

PARAMETER DESCRIPTION	Result	unit	Method	MDL
Industrial				
Attachment	SEE BELOW	N/A		

** Information not supplied by client -- data derived from LSD information

Results relate only to items tested

Remarks:

See Attached Extended Condensate Analysis.

Alberta Innovates - Technology Futures ~ Fuels & Lubricants
250 Karl Clark Road, Edmonton, Alberta, Canada T6N 1E4
Certified by the Standards Council of Canada as an Accredited Testing Organization complying with the requirements of ISO/IEC 17025 for specific tests registered with the Council

Report of Analysis

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Reported: 23-Apr-2013
Revision: 2013-1

Report To:	**Invoice To:**	
Maxxam Analytics Inc. 6744-50 St Edmonton, AB, T6B 3M9	Maxxam Analytics Inc. 500-1919 Minnesota CRT Mississauga, Ontario L5N 0C9	**Order Id: FL13_0581** **Contract #:** **Contract Name:** **PO#: B311691**
Attention: Victoria Martinek **E-mail:** **Fax:**	**Attention:** Victoria Martinek **E-mail:** **Fax:**	

Lab Sample Number	Client's Reference Matrix; Date Received	Test	Method	Analysis Parameter	Result	Notes
FL13_0581-001	GB5489-01 Misc; 11-Apr-2013					
		SAPA		Saturates	30.2	Mass %
				Aromatics	18.9	Mass %
				Polars	42.6	Mass %
				Asphaltenes	8.3	Mass %
FL13_0581-002	GB5490-01 Misc; 11-Apr-2013					
		SAPA		Saturates	31.8	Mass %
				Aromatics	20.3	Mass %
				Polars	39.8	Mass %
				Asphaltenes	8.0	Mass %
FL13_0581-003	GB5491-01 Misc; 11-Apr-2013					
		SAPA		Saturates	31.2	Mass %
				Aromatics	25.2	Mass %
				Polars	35.4	Mass %
				Asphaltenes	8.2	Mass %

Remarks and Notes

Results relate only to items tested.

Approved by: Trevor Lockyer

Trevor Lockyer
Upstream Analytical Coordinator

Contact Information

Portfolio Manager: Dan Wispinski
Phone: (780) 450-5108
Email: dan.wispinski@albertainnovates.ca

Maxxam

Success Through Science®

Your P.O. #: 806743-0-KMCA
PO # 806743-0-KMCA

Attention: TAMMY SAUER
KINDER MORGAN CANADA
BOX 3198
SHERWOOD PARK, AB
CANADA T8A 2A6

Report Date: 2013/05/31
This report supersedes all previous reports with the same Maxxam job number

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B327917
Received: 2013/04/10, 08:00

Sample Matrix: Soil
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Aromatic Fraction >C8-C10 in Soil (1)	3	2013/04/10	2013/05/31	CAL SOP-00256	CCME, RBCA
Total Cresols Calculation (1)	3	N/A	2013/04/17	CAL SOP-00164	EPA 8270D
CCME Hydrocarbons (F2-F4 in soil) (1)	3	2013/04/15	2013/04/20	AB SOP-00040 AB SOP-00036	CCME PHC-CWS
Aliphatic Fractions C6-C10 in Soil (1)	3	2013/04/10	2013/05/31	CAL SOP-00256	CCME, RBCA
BTEX/F1/Fractionation of C6-C10 in Soil (1)	3	2013/05/30	2013/05/31	CAL SOP-00256	CCME, RBCA
Aliphatic & Aromatic Fractions >C10-C50 (1)	3	2013/04/15	2013/04/20	CAL SOP-00184	CCME, RBCA
Alkylated PAH in soil by GC/MS (1,2)	3	2013/04/11	2013/05/10	AB SOP-00003 CAL SOP-00250	EPA 3540C/8270D
Benzo[a]pyrene Equivalency (1)	3	N/A	2013/04/17	AB SOP-00003	EPA 8270D
PAH in Soil by GC/MS (1)	3	2013/04/11	2013/04/12	AB SOP-00003 AB SOP-00036	EPA 3540C/8270D
Phenols (semivolatile) (1)	3	2013/04/11	2013/04/16	CAL SOP-00164	EPA 3510C, EPA 8270D
VOCs in Soil by HS GC/MS (Std List) (1)	3	2013/04/11	2013/04/11	AB SOP-00056	EPA 5021A/8260C

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Maxxam Calgary Environmental
(2) Alkylated PAH results are semiquantitative

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Kristopher Beaudet, B.Sc., P.Chem, Scientific Specialist
Email: KBeaudet@maxxam.ca
Phone# (780) 577-7100

==

Your P.O. #: 806743-0-KMCA
PO # 806743-0-KMCA

Attention: TAMMY SAUER
KINDER MORGAN CANADA
BOX 3198
SHERWOOD PARK, AB
CANADA T8A 2A6

Report Date: 2013/05/31
This report supersedes all previous reports with the same Maxxam job number

CERTIFICATE OF ANALYSIS

-2-

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 2

PETROLEUM HYDROCARBONS (CCME)

Maxxam ID		GC7584	GC7585	GC7586		
Sampling Date						
	UNITS	**GB5489**	**GB5490**	**GB5491**	**RDL**	**QC Batch**
Ext. Pet. Hydrocarbon						
F2 (C10-C16 Hydrocarbons)	mg/kg	50000	82000	36000	250	6738100
F3 (C16-C34 Hydrocarbons)	mg/kg	210000	260000	240000	1300	6738100
F4 (C34-C50 Hydrocarbons)	mg/kg	99000	110000	220000	1300	6738100
Reached Baseline at C50	mg/kg	No	No	No	N/A	6738100
Hydrocarbons						
>C10 - C12 Aliphatic	mg/kg	8100	16000	8600	130	6738108
>C10 - C12 Aromatic	mg/kg	2200	4100	3500	130	6738108
>C12 - C16 Aliphatic	mg/kg	24000	40000	15000	250	6738108
>C12 - C16 Aromatic	mg/kg	9100	22000	7200	250	6738108
>C16 - C21 Aliphatic	mg/kg	31000	46000	19000	250	6738108
>C16 - C21 Aromatic	mg/kg	33000	47000	22000	250	6738108
>C21 - C34 Aliphatic	mg/kg	48000	60000	70000	250	6738108
>C21 - C34 Aromatic	mg/kg	100000	120000	170000	250	6738108
>C34 Aliphatic (up to C50)	mg/kg	18000	23000	45000	250	6738108
>C34 Aromatic (up to C50)	mg/kg	65000	77000	170000	250	6738108
Surrogate Recovery (%)						
DECANE (sur)	%	96	98	113	N/A	6738108

N/A = Not Applicable
RDL = Reportable Detection Limit

Maxxam

Success Through Science®

KINDER MORGAN CANADA

Maxxam Job #: B327917
Report Date: 2013/05/31

Your P.O. #: 806743-0-KMCA

SEMIVOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		GC7584		GC7585		GC7586		
Sampling Date								
	UNITS	**GB5489**	**RDL**	**GB5490**	**RDL**	**GB5491**	**RDL**	**QC Batch**
Polycyclic Aromatics								
Acenaphthene	mg/kg	<4.2	4.2	12	4.5	<5.4	5.4	6728236
Benzo[a]pyrene equivalency	mg/kg	7.52	0.10	9.49	0.10	54.0	0.10	6726337
Acenaphthylene	mg/kg	<4.2	4.2	<4.5	4.5	<5.4	5.4	6728236
Acridine	mg/kg	15	8.3	39	8.9	13	11	6728236
Anthracene	mg/kg	<3.3	3.3	6.6	3.6	<4.3	4.3	6728236
Benzo(a)anthracene	mg/kg	<4.2	4.2	5.6 (1)	5.6	22	5.4	6728236
Benzo(b&j)fluoranthene	mg/kg	5.3	4.2	6.7	4.5	18	5.4	6728236
Benzo(k)fluoranthene	mg/kg	<4.2	4.2	<4.5	4.5	<5.4	5.4	6728236
Benzo(g,h,i)perylene	mg/kg	<4.2	4.2	4.8 (1)	4.8	81	5.4	6728236
Benzo(c)phenanthrene	mg/kg	<4.2	4.2	<4.5	4.5	<5.4	5.4	6728236
Benzo(a)pyrene	mg/kg	4.2	4.2	5.8	4.5	33	5.4	6728236
Benzo[e]pyrene	mg/kg	5.6	4.2	5.1	4.5	49	5.4	6728236
Chrysene	mg/kg	<4.2	4.2	8.6	4.5	24	5.4	6728236
Dibenz(a,h)anthracene	mg/kg	<4.2	4.2	<4.5	4.5	14	5.4	6728236
Fluoranthene	mg/kg	4.6	4.2	7.3	4.5	11	5.4	6728236
Fluorene	mg/kg	7.2	4.2	21	4.5	6.1	5.4	6728236
Indeno(1,2,3-cd)pyrene	mg/kg	<4.2	4.2	<4.5	4.5	16	5.4	6728236
2-Methylnaphthalene	mg/kg	72	4.2	80	4.5	25	5.4	6728236
Naphthalene	mg/kg	33	4.2	34	4.5	14	5.4	6728236
Phenanthrene	mg/kg	18	4.2	63	4.5	31	5.4	6728236
Perylene	mg/kg	12	4.2	9.0	4.5	22	5.4	6728236
Pyrene	mg/kg	9.7	4.2	<13 (1)	13	98	5.4	6728236
C3-fluorene	mg/kg	610	4.2	770	4.5	300	5.4	6803862
Quinoline	mg/kg	<8.3	8.3	<8.9	8.9	<11	11	6728236
Retene	mg/kg	27	4.2	43	4.5	15	5.4	6803862
C1-Naphthalene	mg/kg	250	4.2	160	4.5	46	5.4	6803862
C2-Naphthalene	mg/kg	460	4.2	600	4.5	140	5.4	6803862
C3-Naphthalene	mg/kg	310	4.2	780	4.5	180	5.4	6803862
C4-Naphthalene	mg/kg	410	4.2	810	4.5	210	5.4	6803862
Biphenyl	mg/kg	13	4.2	7.3	4.5	<5.4	5.4	6803862
C1-biphenyl	mg/kg	84	4.2	50	4.5	13	5.4	6803862
C2-biphenyl	mg/kg	83	4.2	84	4.5	19	5.4	6803862

RDL = Reportable Detection Limit
(1) Detection limits raised due to matrix interference.

SEMIVOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		GC7584		GC7585		GC7586		
Sampling Date								
	UNITS	**GB5489**	**RDL**	**GB5490**	**RDL**	**GB5491**	**RDL**	**QC Batch**
C1-fluorene	mg/kg	76	4.2	150	4.5	42	5.4	6803862
C2-fluorene	mg/kg	210	4.2	300	4.5	100	5.4	6803862
Dibenzothiophene	mg/kg	15	4.2	44	4.5	11	5.4	6803862
C1-dibenzothiophene	mg/kg	130	4.2	330	4.5	110	5.4	6803862
C2-dibenzothiophene	mg/kg	300	4.2	910	4.5	390	5.4	6803862
C3-dibenzothiophene	mg/kg	450	4.2	700	4.5	340	5.4	6803862
C4-dibenzothiophene	mg/kg	600	4.2	440	4.5	280	5.4	6803862
C1 phenanthrene/anthracene	mg/kg	160	4.2	310	4.5	170	5.4	6803862
C2 phenanthrene/anthracene	mg/kg	410	4.2	550	4.5	310	5.4	6803862
C3 phenanthrene/anthracene	mg/kg	790	4.2	660	4.5	340	5.4	6803862
C4 phenanthrene/anthracene	mg/kg	420	4.2	230	4.5	250	5.4	6803862
C1 fluoranthene/pyrene	mg/kg	100	4.2	75	4.5	250	5.4	6803862
C2 fluoranthene/pyrene	mg/kg	320	4.2	200	4.5	400	5.4	6803862
C3 fluoranthene/pyrene	mg/kg	740	4.2	340	4.5	760	5.4	6803862
C4 fluoranthene/pyrene	mg/kg	530	4.2	170	4.5	870	5.4	6803862
C1 benzo(a)anthracene/chrysene	mg/kg	110	4.2	59	4.5	350	5.4	6803862
C2 benzo(a)anthracene/chrysene	mg/kg	460	4.2	230	4.5	860	5.4	6803862
C3 benzo(a)anthracene/chrysene	mg/kg	260	4.2	110	4.5	450	5.4	6803862
C4 benzo(a)anthracene/chrysene	mg/kg	66	4.2	37	4.5	210	5.4	6803862
C1benzobjkfluoranthene/benzoapyrene	mg/kg	72	4.2	21	4.5	310	5.4	6803862
C2benzobjkfluoranthene/benzoapyrene	mg/kg	64	4.2	37	4.5	260	5.4	6803862
C1-Acenaphthene	mg/kg	<4.2	4.2	<4.5	4.5	<5.4	5.4	6803862
Phenols								
Cresols	mg/kg	<11	11	<16	16	<6.9	6.9	6727549
Phenol	mg/kg	<12 (1)	12	<8.1 (1)	8.1	<3.2 (1)	3.2	6730070
3 & 4-chlorophenol	mg/kg	<12 (1)	12	<21 (1)	21	<11 (1)	11	6730070
2,3,5,6-tetrachlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
2,3,4,6-tetrachlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
2,4,5-trichlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
2,4,6-trichlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
2,3,5-trichlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
2,3,4-trichlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
2,4-dichlorophenol	mg/kg	<3.1 (1)	3.1	<6.3 (1)	6.3	<3.1 (1)	3.1	6730070

RDL = Reportable Detection Limit
(1) Detection limits raised due to matrix interference.

SEMIVOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		GC7584		GC7585		GC7586		
Sampling Date								
	UNITS	**GB5489**	**RDL**	**GB5490**	**RDL**	**GB5491**	**RDL**	**QC Batch**
2,4-dimethylphenol	mg/kg	<23 (1)	23	29	4.3	<13 (1)	13	6730070
2,4-dinitrophenol	mg/kg	<50	50	<43	43	<46	46	6730070
2,6-dichlorophenol	mg/kg	<5.0	5.0	<8.5 (1)	8.5	<4.6	4.6	6730070
2-chlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
2-methylphenol	mg/kg	<5.0	5.0	<8.7 (1)	8.7	<4.6	4.6	6730070
2-nitrophenol	mg/kg	<50	50	<43	43	<46	46	6730070
3 & 4-methylphenol	mg/kg	<11 (1)	11	16 (1)	16	<6.9 (1)	6.9	6730070
4,6-dinitro-2-methylphenol	mg/kg	<50	50	<43	43	<46	46	6730070
4-chloro-3-methylphenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070
4-nitrophenol	mg/kg	<50	50	<43	43	<46	46	6730070
Pentachlorophenol	mg/kg	<5.0	5.0	<4.3	4.3	<4.6	4.6	6730070

RDL = Reportable Detection Limit
(1) Detection limits raised due to matrix interference.

Maxxam

Success Through Science®

KINDER MORGAN CANADA

Maxxam Job #: B327917
Report Date: 2013/05/31

Your P.O. #: 806743-0-KMCA

VOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		GC7584	GC7585	GC7586		
Sampling Date						
	UNITS	**GB5489**	**GB5490**	**GB5491**	**RDL**	**QC Batch**
Volatiles						
(C6-C10)	mg/kg	200000	120000	160000	6000	6859127
Calculated >C8-C10 Aromatics (-EX)	mg/kg	<6000	<6000	<6000	6000	6859501
Calculated Aliphatic >C8-C10	mg/kg	26000	20000	41000	6000	6858571
Calculated Aliphatic C6-C8	mg/kg	74000	55000	77000	6000	6858571
Benzene	mg/kg	2200	1800	940	2.5	6859127
Bromodichloromethane	mg/kg	<150	<150	<150	150	6729879
Toluene	mg/kg	4400	3900	2400	10	6859127
Bromoform	mg/kg	<250	<250	<250	250	6729879
Ethylbenzene	mg/kg	430	470	670	5.0	6859127
Bromomethane	mg/kg	<100	<100	<100	100	6729879
Xylenes (Total)	mg/kg	3500	3500	2600	20	6859127
Carbon tetrachloride	mg/kg	<100	<100	<100	100	6729879
m & p-Xylene	mg/kg	2800	2800	1900	20	6859127
Chlorobenzene	mg/kg	<100	<100	<100	100	6729879
o-Xylene	mg/kg	710	790	720	10	6859127
Chlorodibromomethane	mg/kg	<100	<100	<100	100	6729879
C6-C8	mg/kg	81000	61000	81000	6000	6859127
Chloroethane	mg/kg	<100	<100	<100	100	6729879
>C8-C10	mg/kg	26000	20000	41000	6000	6859127
Chloroform	mg/kg	<100	<100	<100	100	6729879
Aromatic >C8-C10	mg/kg	<6000	<6000	<6000	6000	6859127
Chloromethane	mg/kg	<150	<150	<150	150	6729879
1,2-dibromoethane	mg/kg	<100	<100	<100	100	6729879
F1 (C6-C10) - BTEX	mg/kg	190000	110000	160000	6000	6859127
1,2-dichlorobenzene	mg/kg	<100	<100	<100	100	6729879
1,3-dichlorobenzene	mg/kg	<100	<100	<100	100	6729879
1,4-dichlorobenzene	mg/kg	<100	<100	<100	100	6729879
1,1-dichloroethane	mg/kg	<100	<100	<100	100	6729879
1,2-dichloroethane	mg/kg	<100	<100	<100	100	6729879
1,1-dichloroethene	mg/kg	<100	<100	<100	100	6729879
cis-1,2-dichloroethene	mg/kg	<100	<100	<100	100	6729879
trans-1,2-dichloroethene	mg/kg	<100	<100	<100	100	6729879
Dichloromethane	mg/kg	<150	<150	<150	150	6729879

RDL = Reportable Detection Limit

VOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		GC7584	GC7585	GC7586		
Sampling Date						
	UNITS	**GB5489**	**GB5490**	**GB5491**	**RDL**	**QC Batch**
1,2-dichloropropane	mg/kg	<100	<100	<100	100	6729879
cis-1,3-dichloropropene	mg/kg	<100	<100	<100	100	6729879
trans-1,3-dichloropropene	mg/kg	<100	<100	<100	100	6729879
Methyl methacrylate	mg/kg	<200	<200	<200	200	6729879
Methyl-tert-butylether (MTBE)	mg/kg	<150	<150	<150	150	6729879
Styrene	mg/kg	<100	<100	<100	100	6729879
1,1,1,2-tetrachloroethane	mg/kg	<500	<500	<500	500	6729879
1,1,2,2-tetrachloroethane	mg/kg	<250	<250	<250	250	6729879
Tetrachloroethene	mg/kg	<100	<100	<100	100	6729879
1,2,3-trichlorobenzene	mg/kg	<200	<200	<200	200	6729879
1,2,4-trichlorobenzene	mg/kg	<200	<200	<200	200	6729879
1,3,5-trichlorobenzene	mg/kg	<200	<200	<200	200	6729879
1,1,1-trichloroethane	mg/kg	<100	<100	<100	100	6729879
1,1,2-trichloroethane	mg/kg	<100	<100	<100	100	6729879
Trichloroethene	mg/kg	<50	<50	<50	50	6729879
Trichlorofluoromethane	mg/kg	<100	<100	<100	100	6729879
1,2,4-trimethylbenzene	mg/kg	<2500	<2500	<2500	2500	6729879
1,3,5-trimethylbenzene	mg/kg	<2500	<2500	<2500	2500	6729879
Vinyl chloride	mg/kg	<50	<50	<50	50	6729879
Surrogate Recovery (%)						
1,4-Difluorobenzene (sur.)	%	97	97	95	N/A	6859127
4-BROMOFLUOROBENZENE (sur.)	%	107	106	106	N/A	6859127
D4-1,2-DICHLOROETHANE (sur.)	%	98	97	87	N/A	6859127
1,4-Difluorobenzene (sur.)	%	103	103	103	N/A	6729879
4-BROMOFLUOROBENZENE (sur.)	%	94	93	94	N/A	6729879
D4-1,2-DICHLOROETHANE (sur.)	%	87	85	87	N/A	6729879

N/A = Not Applicable
RDL = Reportable Detection Limit

General Comments

Due to the sample matrix ,sample required dilution ,detection limit was adjusted accordingly.

SEMIVOLATILE ORGANICS BY GC-MS (SOIL) Comments

Sample GC7584-02 PAH in Soil by GC/MS: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly. Sample diluted not extracted therefore no surrogate was added.

Sample GC7585-02 PAH in Soil by GC/MS: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly. Sample diluted not extracted therefore no surrogate was added.

Sample GC7586-02 PAH in Soil by GC/MS: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly. Sample diluted not extracted therefore no surrogate was added.

Sample GC7584-02 Alkylated PAH in soil by GC/MS: Due to the matrix, sample was diluted and not extracted, therefore no surrogate was added. Detection limit was adjusted accordingly.

Sample GC7585-02 Alkylated PAH in soil by GC/MS: Due to the matrix, sample was diluted and not extracted, therefore no surrogate was added. Detection limit was adjusted accordingly.

Sample GC7586-02 Alkylated PAH in soil by GC/MS: Due to the matrix, sample was diluted and not extracted, therefore no surrogate was added. Detection limit was adjusted accordingly.

Sample GC7584-01 Phenols (semivolatile): Due to the sample matrix sample was diluted not extracted, therefore no surrogate was added. Detection limit was adjusted accordingly.

Sample GC7585-01 Phenols (semivolatile): Due to the sample matrix sample was diluted not extracted, therefore no surrogate was added. Detection limit was adjusted accordingly.

Sample GC7586-01 Phenols (semivolatile): Due to the sample matrix sample was diluted not extracted, therefore no surrogate was added. Detection limit was adjusted accordingly.

VOLATILE ORGANICS BY GC-MS (SOIL) Comments

Sample GC7584-03 BTEX/F1/Fractionation of C6-C10 in Soil: Due to sample matrix, sample required dilution, detection limit was adjusted accordingly

Sample GC7585-03 BTEX/F1/Fractionation of C6-C10 in Soil: Due to sample matrix, sample required dilution, detection limit was adjusted accordingly

Sample GC7586-03 BTEX/F1/Fractionation of C6-C10 in Soil: Due to sample matrix, sample required dilution, detection limit was adjusted accordingly

Sample GC7584-03 VOCs in Soil by HS GC/MS (Std List): Due to sample matrix, sample required dilution, detection limit was adjusted accordingly.

Sample GC7585-03 VOCs in Soil by HS GC/MS (Std List): Due to sample matrix, sample required dilution, detection limit was adjusted accordingly.

Sample GC7586-03 VOCs in Soil by HS GC/MS (Std List): Due to sample matrix, sample required dilution, detection limit was adjusted accordingly.

Results relate only to the items tested.

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report

Maxxam Job Number: EB327917

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6728236 PM4	Matrix Spike	Acenaphthene	2013/04/11		84	%	50 - 130
		Acenaphthylene	2013/04/11		84	%	50 - 130
		Acridine	2013/04/11		73	%	50 - 130
		Anthracene	2013/04/11		78	%	50 - 130
		Benzo(a)anthracene	2013/04/11		97	%	50 - 130
		Benzo(b&j)fluoranthene	2013/04/11		101	%	50 - 130
		Benzo(k)fluoranthene	2013/04/11		87	%	50 - 130
		Benzo(g,h,i)perylene	2013/04/11		82	%	50 - 130
		Benzo(c)phenanthrene	2013/04/11		94	%	50 - 130
		Benzo(a)pyrene	2013/04/11		96	%	50 - 130
		Benzo[e]pyrene	2013/04/11		96	%	50 - 130
		Chrysene	2013/04/11		93	%	50 - 130
		Dibenz(a,h)anthracene	2013/04/11		82	%	50 - 130
		Fluoranthene	2013/04/11		92	%	50 - 130
		Fluorene	2013/04/11		85	%	50 - 130
		Indeno(1,2,3-cd)pyrene	2013/04/11		82	%	50 - 130
		2-Methylnaphthalene	2013/04/11		89	%	50 - 130
		Naphthalene	2013/04/11		82	%	50 - 130
		Phenanthrene	2013/04/11		85	%	50 - 130
		Perylene	2013/04/11		79	%	50 - 130
		Pyrene	2013/04/11		92	%	50 - 130
		Quinoline	2013/04/11		112	%	50 - 130
	Spiked Blank	Acenaphthene	2013/04/11		79	%	50 - 130
		Acenaphthylene	2013/04/11		74	%	50 - 130
		Acridine	2013/04/11		59	%	50 - 130
		Anthracene	2013/04/11		68	%	50 - 130
		Benzo(a)anthracene	2013/04/11		79	%	50 - 130
		Benzo(b&j)fluoranthene	2013/04/11		88	%	50 - 130
		Benzo(k)fluoranthene	2013/04/11		88	%	50 - 130
		Benzo(g,h,i)perylene	2013/04/11		77	%	50 - 130
		Benzo(c)phenanthrene	2013/04/11		82	%	50 - 130
		Benzo(a)pyrene	2013/04/11		79	%	50 - 130
		Benzo[e]pyrene	2013/04/11		86	%	50 - 130
		Chrysene	2013/04/11		85	%	50 - 130
		Dibenz(a,h)anthracene	2013/04/11		77	%	50 - 130
		Fluoranthene	2013/04/11		83	%	50 - 130
		Fluorene	2013/04/11		79	%	50 - 130
		Indeno(1,2,3-cd)pyrene	2013/04/11		74	%	50 - 130
		2-Methylnaphthalene	2013/04/11		82	%	50 - 130
		Naphthalene	2013/04/11		76	%	50 - 130
		Phenanthrene	2013/04/11		79	%	50 - 130
		Perylene	2013/04/11		74	%	50 - 130
		Pyrene	2013/04/11		81	%	50 - 130
		Quinoline	2013/04/11		111	%	50 - 130
	Method Blank	Acenaphthene	2013/04/11	<0.0050		mg/kg	
		Acenaphthylene	2013/04/11	<0.0050		mg/kg	
		Acridine	2013/04/11	<0.010		mg/kg	
		Anthracene	2013/04/11	<0.0040		mg/kg	
		Benzo(a)anthracene	2013/04/11	<0.0050		mg/kg	
		Benzo(b&j)fluoranthene	2013/04/11	<0.0050		mg/kg	
		Benzo(k)fluoranthene	2013/04/11	<0.0050		mg/kg	
		Benzo(g,h,i)perylene	2013/04/11	<0.0050		mg/kg	
		Benzo(c)phenanthrene	2013/04/11	<0.0050		mg/kg	
		Benzo(a)pyrene	2013/04/11	<0.0050		mg/kg	
		Benzo[e]pyrene	2013/04/11	<0.0050		mg/kg	

Maxxam

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report (Continued)

Maxxam Job Number: EB327917

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6728236 PM4	Method Blank	Chrysene	2013/04/11	<0.0050		mg/kg	
		Dibenz(a,h)anthracene	2013/04/11	<0.0050		mg/kg	
		Fluoranthene	2013/04/11	<0.0050		mg/kg	
		Fluorene	2013/04/11	<0.0050		mg/kg	
		Indeno(1,2,3-cd)pyrene	2013/04/11	<0.0050		mg/kg	
		2-Methylnaphthalene	2013/04/11	<0.0050		mg/kg	
		Naphthalene	2013/04/11	<0.0050		mg/kg	
		Phenanthrene	2013/04/11	<0.0050		mg/kg	
		Perylene	2013/04/11	<0.0050		mg/kg	
		Pyrene	2013/04/11	<0.0050		mg/kg	
		Quinoline	2013/04/11	<0.010		mg/kg	
	RPD	Acenaphthene	2013/04/11	NC		%	50
		Acenaphthylene	2013/04/11	NC		%	50
		Acridine	2013/04/11	NC		%	50
		Anthracene	2013/04/11	NC		%	50
		Benzo(a)anthracene	2013/04/11	NC		%	50
		Benzo(b&j)fluoranthene	2013/04/11	NC		%	50
		Benzo(k)fluoranthene	2013/04/11	NC		%	50
		Benzo(g,h,i)perylene	2013/04/11	NC		%	50
		Benzo(c)phenanthrene	2013/04/11	NC		%	50
		Benzo(a)pyrene	2013/04/11	NC		%	50
		Benzo[e]pyrene	2013/04/11	NC		%	50
		Chrysene	2013/04/11	NC		%	50
		Dibenz(a,h)anthracene	2013/04/11	NC		%	50
		Fluoranthene	2013/04/11	NC		%	50
		Fluorene	2013/04/11	NC		%	50
		Indeno(1,2,3-cd)pyrene	2013/04/11	NC		%	50
		2-Methylnaphthalene	2013/04/11	NC		%	50
		Naphthalene	2013/04/11	NC		%	50
		Phenanthrene	2013/04/11	NC		%	50
		Perylene	2013/04/11	NC		%	50
		Pyrene	2013/04/11	NC		%	50
		Quinoline	2013/04/11	NC		%	50
6729879 PK1	Matrix Spike	1,4-Difluorobenzene (sur.)	2013/04/11		104	%	60 - 140
		4-BROMOFLUOROBENZENE (sur.)	2013/04/11		98	%	60 - 140
		D4-1,2-DICHLOROETHANE (sur.)	2013/04/11		91	%	60 - 140
		Bromodichloromethane	2013/04/11		97	%	60 - 140
		Bromoform	2013/04/11		122	%	60 - 140
		Bromomethane	2013/04/11		93	%	60 - 140
		Carbon tetrachloride	2013/04/11		120	%	60 - 140
		Chlorobenzene	2013/04/11		104	%	60 - 140
		Chlorodibromomethane	2013/04/11		122	%	60 - 140
		Chloroethane	2013/04/11		78	%	60 - 140
		Chloroform	2013/04/11		96	%	60 - 140
		Chloromethane	2013/04/11		55 (1)	%	60 - 140
		1,2-dibromoethane	2013/04/11		97	%	60 - 140
		1,2-dichlorobenzene	2013/04/11		97	%	60 - 140
		1,3-dichlorobenzene	2013/04/11		96	%	60 - 140
		1,4-dichlorobenzene	2013/04/11		97	%	60 - 140
		1,1-dichloroethane	2013/04/11		89	%	60 - 140
		1,2-dichloroethane	2013/04/11		86	%	60 - 140
		1,1-dichloroethene	2013/04/11		97	%	60 - 140
		cis-1,2-dichloroethene	2013/04/11		89	%	60 - 140
		trans-1,2-dichloroethene	2013/04/11		95	%	60 - 140
		Dichloromethane	2013/04/11		98	%	60 - 140

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report (Continued)

Maxxam Job Number: EB327917

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6729879 PK1	Matrix Spike	1,2-dichloropropane	2013/04/11		87	%	60 - 140
		cis-1,3-dichloropropene	2013/04/11		87	%	60 - 140
		trans-1,3-dichloropropene	2013/04/11		83	%	60 - 140
		Methyl methacrylate	2013/04/11		101	%	60 - 140
		Methyl-tert-butylether (MTBE)	2013/04/11		87	%	60 - 140
		Styrene	2013/04/11		106	%	60 - 140
		1,1,1,2-tetrachloroethane	2013/04/11		119	%	60 - 140
		1,1,2,2-tetrachloroethane	2013/04/11		90	%	60 - 140
		Tetrachloroethene	2013/04/11		117	%	60 - 140
		1,2,3-trichlorobenzene	2013/04/11		99	%	60 - 140
		1,2,4-trichlorobenzene	2013/04/11		106	%	60 - 140
		1,3,5-trichlorobenzene	2013/04/11		103	%	60 - 140
		1,1,1-trichloroethane	2013/04/11		104	%	60 - 140
		1,1,2-trichloroethane	2013/04/11		90	%	60 - 140
		Trichloroethene	2013/04/11		99	%	60 - 140
		Trichlorofluoromethane	2013/04/11		94	%	60 - 140
		1,2,4-trimethylbenzene	2013/04/11		102	%	60 - 140
		1,3,5-trimethylbenzene	2013/04/11		105	%	60 - 140
		Vinyl chloride	2013/04/11		67	%	60 - 140
	Spiked Blank	1,4-Difluorobenzene (sur.)	2013/04/11		103	%	60 - 140
		4-BROMOFLUOROBENZENE (sur.)	2013/04/11		97	%	60 - 140
		D4-1,2-DICHLOROETHANE (sur.)	2013/04/11		94	%	60 - 140
		Bromodichloromethane	2013/04/11		100	%	60 - 140
		Bromoform	2013/04/11		132	%	60 - 140
		Bromomethane	2013/04/11		103	%	60 - 140
		Carbon tetrachloride	2013/04/11		116	%	60 - 140
		Chlorobenzene	2013/04/11		107	%	60 - 140
		Chlorodibromomethane	2013/04/11		121	%	60 - 140
		Chloroethane	2013/04/11		82	%	60 - 140
		Chloroform	2013/04/11		96	%	60 - 140
		Chloromethane	2013/04/11		60	%	60 - 140
		1,2-dibromoethane	2013/04/11		103	%	60 - 140
		1,2-dichlorobenzene	2013/04/11		101	%	60 - 140
		1,3-dichlorobenzene	2013/04/11		104	%	60 - 140
		1,4-dichlorobenzene	2013/04/11		99	%	60 - 140
		1,1-dichloroethane	2013/04/11		90	%	60 - 140
		1,2-dichloroethane	2013/04/11		92	%	60 - 140
		1,1-dichloroethene	2013/04/11		98	%	60 - 140
		cis-1,2-dichloroethene	2013/04/11		97	%	60 - 140
		trans-1,2-dichloroethene	2013/04/11		97	%	60 - 140
		Dichloromethane	2013/04/11		89	%	60 - 140
		1,2-dichloropropane	2013/04/11		94	%	60 - 140
		cis-1,3-dichloropropene	2013/04/11		95	%	60 - 140
		trans-1,3-dichloropropene	2013/04/11		92	%	60 - 140
		Methyl methacrylate	2013/04/11		107	%	60 - 140
		Methyl-tert-butylether (MTBE)	2013/04/11		91	%	60 - 140
		Styrene	2013/04/11		109	%	60 - 140
		1,1,1,2-tetrachloroethane	2013/04/11		123	%	60 - 140
		1,1,2,2-tetrachloroethane	2013/04/11		92	%	60 - 140
		Tetrachloroethene	2013/04/11		116	%	60 - 140
		1,2,3-trichlorobenzene	2013/04/11		107	%	60 - 140
		1,2,4-trichlorobenzene	2013/04/11		112	%	60 - 140
		1,3,5-trichlorobenzene	2013/04/11		108	%	60 - 140
		1,1,1-trichloroethane	2013/04/11		105	%	60 - 140
		1,1,2-trichloroethane	2013/04/11		95	%	60 - 140

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report (Continued)

Maxxam Job Number: EB327917

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6729879 PK1	Spiked Blank	Trichloroethene	2013/04/11		106	%	60 - 140
		Trichlorofluoromethane	2013/04/11		92	%	60 - 140
		1,2,4-trimethylbenzene	2013/04/11		106	%	60 - 140
		1,3,5-trimethylbenzene	2013/04/11		107	%	60 - 140
		Vinyl chloride	2013/04/11		76	%	60 - 140
	Method Blank	1,4-Difluorobenzene (sur.)	2013/04/11		104	%	60 - 140
		4-BROMOFLUOROBENZENE (sur.)	2013/04/11		94	%	60 - 140
		D4-1,2-DICHLOROETHANE (sur.)	2013/04/11		88	%	60 - 140
		Bromodichloromethane	2013/04/11	<0.030		mg/kg	
		Bromoform	2013/04/11	<0.050		mg/kg	
		Bromomethane	2013/04/11	<0.020		mg/kg	
		Carbon tetrachloride	2013/04/11	<0.020		mg/kg	
		Chlorobenzene	2013/04/11	<0.020		mg/kg	
		Chlorodibromomethane	2013/04/11	<0.020		mg/kg	
		Chloroethane	2013/04/11	<0.020		mg/kg	
		Chloroform	2013/04/11	<0.020		mg/kg	
		Chloromethane	2013/04/11	<0.030		mg/kg	
		1,2-dibromoethane	2013/04/11	<0.020		mg/kg	
		1,2-dichlorobenzene	2013/04/11	<0.020		mg/kg	
		1,3-dichlorobenzene	2013/04/11	<0.020		mg/kg	
		1,4-dichlorobenzene	2013/04/11	<0.020		mg/kg	
		1,1-dichloroethane	2013/04/11	<0.020		mg/kg	
		1,2-dichloroethane	2013/04/11	<0.020		mg/kg	
		1,1-dichloroethene	2013/04/11	<0.020		mg/kg	
		cis-1,2-dichloroethene	2013/04/11	<0.020		mg/kg	
		trans-1,2-dichloroethene	2013/04/11	<0.020		mg/kg	
		Dichloromethane	2013/04/11	<0.030		mg/kg	
		1,2-dichloropropane	2013/04/11	<0.020		mg/kg	
		cis-1,3-dichloropropene	2013/04/11	<0.020		mg/kg	
		trans-1,3-dichloropropene	2013/04/11	<0.020		mg/kg	
		Methyl methacrylate	2013/04/11	<0.040		mg/kg	
		Methyl-tert-butylether (MTBE)	2013/04/11	<0.030		mg/kg	
		Styrene	2013/04/11	<0.020		mg/kg	
		1,1,1,2-tetrachloroethane	2013/04/11	<0.10		mg/kg	
		1,1,2,2-tetrachloroethane	2013/04/11	<0.050		mg/kg	
		Tetrachloroethene	2013/04/11	<0.020		mg/kg	
		1,2,3-trichlorobenzene	2013/04/11	<0.040		mg/kg	
		1,2,4-trichlorobenzene	2013/04/11	<0.040		mg/kg	
		1,3,5-trichlorobenzene	2013/04/11	<0.040		mg/kg	
		1,1,1-trichloroethane	2013/04/11	<0.020		mg/kg	
		1,1,2-trichloroethane	2013/04/11	<0.020		mg/kg	
		Trichloroethene	2013/04/11	<0.010		mg/kg	
		Trichlorofluoromethane	2013/04/11	<0.020		mg/kg	
		1,2,4-trimethylbenzene	2013/04/11	<0.50		mg/kg	
		1,3,5-trimethylbenzene	2013/04/11	<0.50		mg/kg	
		Vinyl chloride	2013/04/11	<0.010		mg/kg	
	RPD	Bromodichloromethane	2013/04/11	NC		%	50
		Bromoform	2013/04/11	NC		%	50
		Bromomethane	2013/04/11	NC		%	50
		Chlorodibromomethane	2013/04/11	NC		%	50
		Chloroethane	2013/04/11	NC		%	50
		Chloromethane	2013/04/11	NC		%	50
		1,2-dichlorobenzene	2013/04/11	NC		%	50
		1,3-dichlorobenzene	2013/04/11	NC		%	50
		1,4-dichlorobenzene	2013/04/11	NC		%	50

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report (Continued)
Maxxam Job Number: EB327917

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6729879 PK1	RPD	1,1-dichloroethane	2013/04/11	NC		%	50
		1,1-dichloroethene	2013/04/11	NC		%	50
		cis-1,2-dichloroethene	2013/04/11	NC		%	50
		trans-1,2-dichloroethene	2013/04/11	NC		%	50
		Dichloromethane	2013/04/11	NC		%	50
		1,2-dichloropropane	2013/04/11	NC		%	50
		cis-1,3-dichloropropene	2013/04/11	NC		%	50
		trans-1,3-dichloropropene	2013/04/11	NC		%	50
		Methyl methacrylate	2013/04/11	NC		%	50
		Methyl-tert-butylether (MTBE)	2013/04/11	NC		%	50
		Styrene	2013/04/11	NC		%	50
		1,1,1,2-tetrachloroethane	2013/04/11	NC		%	50
		1,1,2,2-tetrachloroethane	2013/04/11	NC		%	50
		Tetrachloroethene	2013/04/11	NC		%	50
		1,2,3-trichlorobenzene	2013/04/11	NC		%	50
		1,2,4-trichlorobenzene	2013/04/11	NC		%	50
		1,3,5-trichlorobenzene	2013/04/11	NC		%	50
		1,1,1-trichloroethane	2013/04/11	NC		%	50
		1,1,2-trichloroethane	2013/04/11	NC		%	50
		Trichloroethene	2013/04/11	NC		%	50
		Trichlorofluoromethane	2013/04/11	NC		%	50
		1,2,4-trimethylbenzene	2013/04/11	NC		%	50
		1,3,5-trimethylbenzene	2013/04/11	NC		%	50
6730070 SJ1	Spiked Blank	Phenol	2013/04/15		65	%	30 - 130
		2,3,5,6-tetrachlorophenol	2013/04/15		62	%	30 - 130
		2,3,4,6-tetrachlorophenol	2013/04/15		66	%	30 - 130
		2,4,5-trichlorophenol	2013/04/15		67	%	30 - 130
		2,4,6-trichlorophenol	2013/04/15		63	%	30 - 130
		2,4-dichlorophenol	2013/04/15		64	%	30 - 130
		2,4-dimethylphenol	2013/04/15		65	%	30 - 130
		2,4-dinitrophenol	2013/04/15		35	%	30 - 130
		2,6-dichlorophenol	2013/04/15		70	%	30 - 130
		2-chlorophenol	2013/04/15		64	%	30 - 130
		2-methylphenol	2013/04/15		67	%	30 - 130
		2-nitrophenol	2013/04/15		60	%	30 - 130
		3 & 4-methylphenol	2013/04/15		69	%	30 - 130
		4,6-dinitro-2-methylphenol	2013/04/15		49	%	30 - 130
		4-chloro-3-methylphenol	2013/04/15		72	%	30 - 130
		4-nitrophenol	2013/04/15		58	%	30 - 130
		Pentachlorophenol	2013/04/15		63	%	30 - 130
	Method Blank	Phenol	2013/04/15	<0.0010		mg/kg	
		3 & 4-chlorophenol	2013/04/15	<0.0050		mg/kg	
		2,3,5,6-tetrachlorophenol	2013/04/15	<0.0050		mg/kg	
		2,3,4,6-tetrachlorophenol	2013/04/15	<0.0050		mg/kg	
		2,4,5-trichlorophenol	2013/04/15	<0.0050		mg/kg	
		2,4,6-trichlorophenol	2013/04/15	<0.0050		mg/kg	
		2,3,5-trichlorophenol	2013/04/15	<0.0050		mg/kg	
		2,3,4-trichlorophenol	2013/04/15	<0.0050		mg/kg	
		2,4-dichlorophenol	2013/04/15	<0.0010		mg/kg	
		2,4-dimethylphenol	2013/04/15	<0.0050		mg/kg	
		2,4-dinitrophenol	2013/04/15	<0.050		mg/kg	
		2,6-dichlorophenol	2013/04/15	<0.0050		mg/kg	
		2-chlorophenol	2013/04/15	<0.0050		mg/kg	
		2-methylphenol	2013/04/15	<0.0050		mg/kg	
		2-nitrophenol	2013/04/15	<0.050		mg/kg	

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report (Continued)

Maxxam Job Number: EB327917

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6730070 SJ1	Method Blank	3 & 4-methylphenol	2013/04/15	<0.0050		mg/kg	
		4,6-dinitro-2-methylphenol	2013/04/15	<0.050		mg/kg	
		4-chloro-3-methylphenol	2013/04/15	<0.0050		mg/kg	
		4-nitrophenol	2013/04/15	<0.050		mg/kg	
		Pentachlorophenol	2013/04/15	<0.0050		mg/kg	
	RPD [GC7586-01]	Phenol	2013/04/16	NC		%	50
		3 & 4-chlorophenol	2013/04/16	NC		%	50
		2,3,5,6-tetrachlorophenol	2013/04/16	NC		%	50
		2,3,4,6-tetrachlorophenol	2013/04/16	NC		%	50
		2,4,5-trichlorophenol	2013/04/16	NC		%	50
		2,4,6-trichlorophenol	2013/04/16	NC		%	50
		2,3,5-trichlorophenol	2013/04/16	NC		%	50
		2,3,4-trichlorophenol	2013/04/16	NC		%	50
		2,4-dichlorophenol	2013/04/16	NC		%	50
		2,4-dimethylphenol	2013/04/16	NC		%	50
		2,4-dinitrophenol	2013/04/16	NC		%	50
		2,6-dichlorophenol	2013/04/16	NC		%	50
		2-chlorophenol	2013/04/16	NC		%	50
		2-methylphenol	2013/04/16	NC		%	50
		2-nitrophenol	2013/04/16	NC		%	50
		3 & 4-methylphenol	2013/04/16	NC		%	50
		4,6-dinitro-2-methylphenol	2013/04/16	NC		%	50
		4-chloro-3-methylphenol	2013/04/16	NC		%	50
		4-nitrophenol	2013/04/16	NC		%	50
		Pentachlorophenol	2013/04/16	NC		%	50
6738100 NK3	Spiked Blank	F2 (C10-C16 Hydrocarbons)	2013/04/20		92	%	70 - 130
		F3 (C16-C34 Hydrocarbons)	2013/04/20		97	%	70 - 130
		F4 (C34-C50 Hydrocarbons)	2013/04/20		98	%	70 - 130
	Method Blank	F2 (C10-C16 Hydrocarbons)	2013/04/20	<10		mg/kg	
		F3 (C16-C34 Hydrocarbons)	2013/04/20	<50		mg/kg	
		F4 (C34-C50 Hydrocarbons)	2013/04/20	<50		mg/kg	
	RPD [GC7585-02]	F2 (C10-C16 Hydrocarbons)	2013/04/20	3.4		%	50
		F3 (C16-C34 Hydrocarbons)	2013/04/20	1.9		%	50
		F4 (C34-C50 Hydrocarbons)	2013/04/20	1.7		%	50
6738108 NK3	Spiked Blank	DECANE (sur)	2013/04/20		75	%	30 - 130
		>C10 - C12 Aliphatic	2013/04/20		125	%	60 - 130
		>C12 - C16 Aliphatic	2013/04/20		113	%	60 - 130
		>C12 - C16 Aromatic	2013/04/20		117	%	60 - 130
		>C16 - C21 Aliphatic	2013/04/20		110	%	60 - 130
		>C16 - C21 Aromatic	2013/04/20		118	%	60 - 130
		>C21 - C34 Aliphatic	2013/04/20		117	%	60 - 130
		>C21 - C34 Aromatic	2013/04/20		130	%	60 - 130
	Method Blank	DECANE (sur)	2013/04/20		92	%	30 - 130
		>C10 - C12 Aliphatic	2013/04/20	<5.0		mg/kg	
		>C10 - C12 Aromatic	2013/04/20	<10 (2)		mg/kg	
		>C12 - C16 Aliphatic	2013/04/20	<10		mg/kg	
		>C12 - C16 Aromatic	2013/04/20	<10		mg/kg	
		>C16 - C21 Aliphatic	2013/04/20	<10		mg/kg	
		>C16 - C21 Aromatic	2013/04/20	<10		mg/kg	
		>C21 - C34 Aliphatic	2013/04/20	<10		mg/kg	
		>C21 - C34 Aromatic	2013/04/20	<10		mg/kg	
		>C34 Aliphatic (up to C50)	2013/04/20	<10		mg/kg	
		>C34 Aromatic (up to C50)	2013/04/20	<10		mg/kg	
	RPD [GC7585-02]	>C10 - C12 Aliphatic	2013/04/20	2.6		%	50
		>C10 - C12 Aromatic	2013/04/20	25.7		%	50

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report (Continued)

Maxxam Job Number: EB327917

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6738108 NK3	RPD [GC7585-02]	>C12 - C16 Aliphatic	2013/04/20	1.4		%	50
		>C12 - C16 Aromatic	2013/04/20	15.6		%	50
		>C16 - C21 Aliphatic	2013/04/20	3.9		%	50
		>C16 - C21 Aromatic	2013/04/20	14.4		%	50
		>C21 - C34 Aliphatic	2013/04/20	2.4		%	50
		>C21 - C34 Aromatic	2013/04/20	18.1		%	50
		>C34 Aliphatic (up to C50)	2013/04/20	2.0		%	50
		>C34 Aromatic (up to C50)	2013/04/20	20.1		%	50
6803862 DM	Method Blank	C3-fluorene	2013/05/10	<0.0050		mg/kg	
		Retene	2013/05/10	<0.0050		mg/kg	
		C1-Naphthalene	2013/05/10	<0.0050		mg/kg	
		C2-Naphthalene	2013/05/10	<0.0050		mg/kg	
		C3-Naphthalene	2013/05/10	<0.0050		mg/kg	
		C4-Naphthalene	2013/05/10	<0.0050		mg/kg	
		Biphenyl	2013/05/10	<0.0050		mg/kg	
		C1-biphenyl	2013/05/10	<0.0050		mg/kg	
		C2-biphenyl	2013/05/10	<0.0050		mg/kg	
		C1-fluorene	2013/05/10	<0.0050		mg/kg	
		C2-fluorene	2013/05/10	<0.0050		mg/kg	
		Dibenzothiophene	2013/05/10	<0.0050		mg/kg	
		C1-dibenzothiophene	2013/05/10	<0.0050		mg/kg	
		C2-dibenzothiophene	2013/05/10	<0.0050		mg/kg	
		C3-dibenzothiophene	2013/05/10	<0.0050		mg/kg	
		C4-dibenzothiophene	2013/05/10	<0.0050		mg/kg	
		C1 phenanthrene/anthracene	2013/05/10	<0.0050		mg/kg	
		C2 phenanthrene/anthracene	2013/05/10	<0.0050		mg/kg	
		C3 phenanthrene/anthracene	2013/05/10	<0.0050		mg/kg	
		C4 phenanthrene/anthracene	2013/05/10	<0.0050		mg/kg	
		C1 fluoranthene/pyrene	2013/05/10	<0.0050		mg/kg	
		C2 fluoranthene/pyrene	2013/05/10	<0.0050		mg/kg	
		C3 fluoranthene/pyrene	2013/05/10	<0.0050		mg/kg	
		C4 fluoranthene/pyrene	2013/05/10	<0.0050		mg/kg	
		C1 benzo(a)anthracene/chrysene	2013/05/10	<0.0050		mg/kg	
		C2 benzo(a)anthracene/chrysene	2013/05/10	<0.0050		mg/kg	
		C3 benzo(a)anthracene/chrysene	2013/05/10	<0.0050		mg/kg	
		C4 benzo(a)anthracene/chrysene	2013/05/10	<0.0050		mg/kg	
		C1benzobjkfluoranthene/benzoapyrene	2013/05/10	<0.0050		mg/kg	
		C2benzobjkfluoranthene/benzoapyrene	2013/05/10	<0.0050		mg/kg	
		C1-Acenaphthene	2013/05/10	<0.0050		mg/kg	
6859127 RSA	Spiked Blank	1,4-Difluorobenzene (sur.)	2013/05/31		72	%	60 - 140
		4-BROMOFLUOROBENZENE (sur.)	2013/05/31		92	%	60 - 140
		D4-1,2-DICHLOROETHANE (sur.)	2013/05/31		96	%	60 - 140
		(C6-C10)	2013/05/31		130	%	60 - 140
		Benzene	2013/05/31		108	%	60 - 140
		Toluene	2013/05/31		110	%	60 - 140
		Ethylbenzene	2013/05/31		109	%	60 - 140
		m & p-Xylene	2013/05/31		113	%	60 - 140
		o-Xylene	2013/05/31		113	%	60 - 140
		C6-C8	2013/05/31		109	%	60 - 140
		>C8-C10	2013/05/31		108	%	60 - 140
		Aromatic >C8-C10	2013/05/31		77	%	60 - 140
	Method Blank	1,4-Difluorobenzene (sur.)	2013/05/30		83	%	60 - 140
		4-BROMOFLUOROBENZENE (sur.)	2013/05/30		97	%	60 - 140
		D4-1,2-DICHLOROETHANE (sur.)	2013/05/30		94	%	60 - 140
		(C6-C10)	2013/05/30	<12		mg/kg	

KINDER MORGAN CANADA
Attention: TAMMY SAUER
Client Project #:
P.O. #: 806743-0-KMCA
Site Location:

Quality Assurance Report (Continued)

Maxxam Job Number: EB327917

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6859127	RSA	Method Blank	Benzene	2013/05/30	<0.0050		mg/kg	
			Toluene	2013/05/30	<0.020		mg/kg	
			Ethylbenzene	2013/05/30	<0.010		mg/kg	
			Xylenes (Total)	2013/05/30	<0.040		mg/kg	
			m & p-Xylene	2013/05/30	<0.040		mg/kg	
			o-Xylene	2013/05/30	<0.020		mg/kg	
			C6-C8	2013/05/30	<12		mg/kg	
			>C8-C10	2013/05/30	<12		mg/kg	
			Aromatic >C8-C10	2013/05/30	<12		mg/kg	
			F1 (C6-C10) - BTEX	2013/05/30	<12		mg/kg	

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.
(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.
(2) Detection limit raised due to extraction interference.

Validation Signature Page

Maxxam Job #: B327917

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Kristopher Beaudet, B.Sc., P.Chem, Scientific Specialist

Veronica Falk, Scientific Specialist

===

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Your Project #: B327917 PRODUCTS
Your C.O.C. #: NA

Attention:
Calgary Customer Service
Maxxam Analytics
2021 41st Ave NE
Calgary, AB
T2E 6P2

Report Date: 2013/06/14

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B385868
Received: 2013/06/04, 08:57

Sample Matrix: Oil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
PAHs in Soil by HRMS (CARB429mod)	1	2013/06/07	2013/06/08	BRL SOP-00418	CARB429 MOD

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Marsela Wijaya, Project Manager Assistant
Email: MWijaya@maxxam.ca
Phone# (905) 817-5700

==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

RESULTS OF ANALYSES OF OIL

Maxxam ID		RT4983			
Sampling Date					
COC Number		NA			
	Units	GC7585-03 GB5490	EDL	RDL	QC Batch
Naphthalene	ng/g	30300	20000	910	3240038
2-Methylnaphthalene	ng/g	102000 (1)	28000	910	3240038
Acenaphthylene	ng/g	<14000	14000	910	3240038
Acenaphthene	ng/g	21700	5200	910	3240038
Fluorene	ng/g	25200	5900	910	3240038
Phenanthrene	ng/g	78300	23000	910	3240038
Anthracene	ng/g	<25000	25000	910	3240038
Fluoranthene	ng/g	<9700	9700	910	3240038
Pyrene	ng/g	10700	9100	910	3240038
Benzo(a)anthracene	ng/g	4070	3400	910	3240038
Chrysene	ng/g	10400	5400	910	3240038
Benzo(b)fluoranthene	ng/g	4670	1500	910	3240038
Benzo(k)fluoranthene	ng/g	<2800	2800	910	3240038
Benzo(e)pyrene	ng/g	6850	2200	910	3240038
Benzo(a)pyrene	ng/g	4420	3400	910	3240038
Perylene	ng/g	13300	1800	910	3240038
Indeno(1,2,3-cd)pyrene	ng/g	1880	1700	910	3240038
Dibenz(a,h)anthracene	ng/g	<1500	1500	910	3240038
Benzo(g,h,i)perylene	ng/g	3280	1700	910	3240038
1-Methylnaphthalene	ng/g	77800	31000	910	3240038
1-Methylphenanthrene	ng/g	79000	15000	910	3240038
2,6-Dimethylnaphthalene	ng/g	137000 (1)	10000	910	3240038
2,3,5-Trimethylnaphthalene	ng/g	171000	5000	910	3240038
Dibenzothiophene	ng/g	41800	1600	910	3240038
Surrogate Recovery (%)					
2,6-Dimethylnaphthalene-2H12	%	97	N/A	N/A	3240038
2-Methylnaphthalene-2H10	%	94	N/A	N/A	3240038
Acenaphthylene-2H8	%	84	N/A	N/A	3240038
Benz(a)anthracene-2H12	%	147	N/A	N/A	3240038
Benzo(a)pyrene-2H12	%	85	N/A	N/A	3240038
Benzo(b)fluoranthene-2H12	%	112	N/A	N/A	3240038

N/A = Not Applicable
RDL = Reportable Detection Limit
EDL = Estimated Detection Limit
QC Batch = Quality Control Batch
(1) EMCL - Exceeds Maximum Calibration Limit

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Maxxam Job #: B385868
Report Date: 2013/06/14

Maxxam Analytics
Client Project #: B327917 PRODUCTS

RESULTS OF ANALYSES OF OIL

Maxxam ID		RT4983			
Sampling Date					
COC Number		NA			
	Units	**GC7585-03 GB5490**	**EDL**	**RDL**	**QC Batch**
Benzo(g,h,i)perylene-2H12	%	69	N/A	N/A	3240038
Benzo(k)fluoranthene-2H12	%	92	N/A	N/A	3240038
Chrysene-2H12	%	108	N/A	N/A	3240038
Dibenzo(a,h)anthracene-2H14	%	65	N/A	N/A	3240038
Fluoranthene-2H10	%	95	N/A	N/A	3240038
Indeno(1,2,3-c,d)pyrene-2H12	%	81	N/A	N/A	3240038
Naphthalene-2H8	%	103	N/A	N/A	3240038
Perylene-2H12	%	86	N/A	N/A	3240038
Phenanthrene-2H10	%	76	N/A	N/A	3240038

N/A = Not Applicable
RDL = Reportable Detection Limit
EDL = Estimated Detection Limit
QC Batch = Quality Control Batch

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Test Summary

Maxxam ID RT4983
Sample ID GC7585-03 GB5490
Matrix Oil

Collected
Shipped
Received 2013/06/04

Test Description	Instrumentation	Batch	Extracted	Analyzed	Analyst
PAHs in Soil by HRMS (CARB429mod)	HRMS/MS	3240038	2013/06/07	2013/06/08	Branko Vrzic

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Package 1	7.7°C

Each temperature is the average of up to three cooler temperatures taken at receipt

GENERAL COMMENTS

Results relate only to the items tested.

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Maxxam Analytics
Attention: Calgary Customer Service
Client Project #: B327917 PRODUCTS
P.O. #:
Site Location:

Quality Assurance Report

Maxxam Job Number: GB385868

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	%Recovery	Units	QC Limits
3240038 BY	Spiked Blank	2,6-Dimethylnaphthalene-2H12	2013/06/08		91	%	50 - 150
		2-Methylnaphthalene-2H10	2013/06/08		91	%	50 - 150
		Acenaphthylene-2H8	2013/06/08		81	%	50 - 150
		Benz(a)anthracene-2H12	2013/06/08		72	%	50 - 150
		Benzo(a)pyrene-2H12	2013/06/08		66	%	50 - 150
		Benzo(b)fluoranthene-2H12	2013/06/08		99	%	50 - 150
		Benzo(g,h,i)perylene-2H12	2013/06/08		78	%	50 - 150
		Benzo(k)fluoranthene-2H12	2013/06/08		70	%	50 - 150
		Chrysene-2H12	2013/06/08		70	%	50 - 150
		Dibenzo(a,h)anthracene-2H14	2013/06/08		52	%	50 - 150
		Fluoranthene-2H10	2013/06/08		80	%	50 - 150
		Indeno(1,2,3-c,d)pyrene-2H12	2013/06/08		57	%	50 - 150
		Naphthalene-2H8	2013/06/08		91	%	50 - 150
		Perylene-2H12	2013/06/08		64	%	50 - 150
		Phenanthrene-2H10	2013/06/08		91	%	50 - 150
		Naphthalene	2013/06/08		81	%	60 - 140
		Acenaphthylene	2013/06/08		84	%	60 - 140
		Acenaphthene	2013/06/08		84	%	60 - 140
		Fluorene	2013/06/08		91	%	60 - 140
		Phenanthrene	2013/06/08		91	%	60 - 140
		Anthracene	2013/06/08		88	%	60 - 140
		Fluoranthene	2013/06/08		108	%	60 - 140
		Pyrene	2013/06/08		93	%	60 - 140
		Benzo(a)anthracene	2013/06/08		86	%	60 - 140
		Chrysene	2013/06/08		92	%	60 - 140
		Benzo(b)fluoranthene	2013/06/08		71	%	N/A
		Benzo(k)fluoranthene	2013/06/08		178 (1)	%	60 - 140
		Benzo(a)pyrene	2013/06/08		103	%	60 - 140
		Indeno(1,2,3-cd)pyrene	2013/06/08		91	%	60 - 140
		Dibenz(a,h)anthracene	2013/06/08		79	%	60 - 140
		Benzo(g,h,i)perylene	2013/06/08		85	%	60 - 140
	Method Blank	2,6-Dimethylnaphthalene-2H12	2013/06/12		89	%	50 - 150
		2-Methylnaphthalene-2H10	2013/06/12		102	%	50 - 150
		Acenaphthylene-2H8	2013/06/12		101	%	50 - 150
		Benz(a)anthracene-2H12	2013/06/12		71	%	50 - 150
		Benzo(a)pyrene-2H12	2013/06/12		44 (1)	%	50 - 150
		Benzo(b)fluoranthene-2H12	2013/06/12		85	%	50 - 150
		Benzo(g,h,i)perylene-2H12	2013/06/12		105	%	50 - 150
		Benzo(k)fluoranthene-2H12	2013/06/12		84	%	50 - 150
		Chrysene-2H12	2013/06/12		53	%	50 - 150
		Dibenzo(a,h)anthracene-2H14	2013/06/12		46 (1)	%	50 - 150
		Fluoranthene-2H10	2013/06/12		99	%	50 - 150
		Indeno(1,2,3-c,d)pyrene-2H12	2013/06/12		72	%	50 - 150
		Naphthalene-2H8	2013/06/12		111	%	50 - 150
		Perylene-2H12	2013/06/12		82	%	50 - 150
		Phenanthrene-2H10	2013/06/12		88	%	50 - 150
		Naphthalene	2013/06/12	<260		ng/g	
		2-Methylnaphthalene	2013/06/12	<170		ng/g	
		Acenaphthylene	2013/06/12	<150		ng/g	
		Acenaphthene	2013/06/12	<370		ng/g	
		Fluorene	2013/06/12	<99		ng/g	
		Phenanthrene	2013/06/12	<130		ng/g	
		Anthracene	2013/06/12	<140		ng/g	
		Fluoranthene	2013/06/12	<120		ng/g	
		Pyrene	2013/06/12	<110		ng/g	

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Attention: Calgary Customer Service
Client Project #: B327917 PRODUCTS
P.O. #:
Site Location:

Quality Assurance Report (Continued)

Maxxam Job Number: GB385868

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	%Recovery	Units	QC Limits
3240038 BY	Method Blank	Benzo(a)anthracene	2013/06/12	<570		ng/g	
		Chrysene	2013/06/12	<610		ng/g	
		Benzo(b)fluoranthene	2013/06/12	<160		ng/g	
		Benzo(k)fluoranthene	2013/06/12	<300		ng/g	
		Benzo(e)pyrene	2013/06/12	<450		ng/g	
		Benzo(a)pyrene	2013/06/12	<570		ng/g	
		Perylene	2013/06/12	<170		ng/g	
		Indeno(1,2,3-cd)pyrene	2013/06/12	<160		ng/g	
		Dibenz(a,h)anthracene	2013/06/12	<360		ng/g	
		Benzo(g,h,i)perylene	2013/06/12	141, RDL=500		ng/g	
		1-Methylnaphthalene	2013/06/12	<200		ng/g	
		1-Methylphenanthrene	2013/06/12	<91		ng/g	
		2,6-Dimethylnaphthalene	2013/06/12	<150		ng/g	
		2,3,5-Trimethylnaphthalene	2013/06/12	<200		ng/g	
		Dibenzothiophene	2013/06/12	<28		ng/g	

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.
(1) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

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Validation Signature Page

Maxxam Job #: B385868

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Owen Cosby, BSc.C.Chem, Supervisor, HRMS Services

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

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C30+ / C100 RECOMBINED LIQUID HYDROCARBON ANALYSIS

Laboratory Number	B311691 : GB6705
Operator Name	KINDER MORGAN CANADA
Well Name	TRANSMOUNTAIN TERMINAL
Well I.D.	N/A
Sample Point	AWB
Sample Point Maxx I.D.	N/A

Source Pressure	N/A	kPag
Source Temperature	N/A	°C

Prepared by: Monika Majerova

COMPOSITION

Component	Mole Fraction	Mass Fraction	Volume Fraction
N2	<0.0001	<0.0001	<0.0001
CO2	<0.0001	<0.0001	<0.0001
H2S	<0.0001	<0.0001	<0.0001
C1	<0.0001	<0.0001	<0.0001
C2	0.0001	<0.0001	0.0001
C3	0.0023	0.0005	0.0009
IC4	0.0045	0.0012	0.0020
NC4	0.0262	0.0070	0.0111
IC5	0.1532	0.0511	0.0755
NC5	0.1587	0.0530	0.0774
C6	0.1517	0.0604	0.0839
C7+	0.5033	0.8268	0.7492
TOTAL	1.0000	1.0000	1.0000

PROPERTIES

RESIDUE	RELATIVE DENSITY @ 15°C		RELATIVE MOLECULAR MASS		DATA SUMMARY		
	Observed	Calculated	Observed	Calculated	Mole Fraction	Mass Fraction	Volume Fraction
C5+		0.9280		222	0.9668	0.9912	0.9860
C6+		0.9829		293	0.6549	0.8872	0.8331
C7+		1.0186		355	0.5033	0.8268	0.7492
C10+		1.0889		629	0.2428	0.7058	0.5983
C12+		1.1032		698	0.2123	0.6855	0.5736
Total		0.9230		216	1.0000	1.0000	1.0000

Calculated Absolute Density Total Sample	923.8	kg/m^3 @ 15°C
Observed Absolute Density Total Sample	923.8	kg/m^3 @ 15°C
Gas Equivalency Factor	100.8	m^3 Gas / m^3 Liquid

Success Through Science

Maxxam Analytics Inc

C30+ / C100 RECOMBINED LIQUID HYDROCARBON ANALYSIS

Laboratory Number	B311691 : GB6705	
Operator Name	KINDER MORGAN CANADA	
Well Name	TRANSMOUNTAIN TERMINAL	
Well I.D.	N/A	
Sample Point	AWB	
Sample Point Maxx I.D.	N/A	
Source Pressure	N/A	kPag
Source Temperature	N/A	°C

Prepared by: Monika Majerova

Component	Boling Point (°C)	Mole Fraction	Mass Fraction	Volume Fraction
Nitrogen	-196	<0.0001	<0.0001	<0.0001
Carbon Dioxide	-79	<0.0001	<0.0001	<0.0001
Hydrogen Sulfide	-60	<0.0001	<0.0001	<0.0001
Methane	-162	<0.0001	<0.0001	<0.0001
Ethane	-90	0.0001	<0.0001	0.0001
Propane	-42	0.0023	0.0005	0.0009
Iso-Butane	-12	0.0045	0.0012	0.0020
n-Butane	0	0.0262	0.0070	0.0111
Iso-Pentane	28	0.1532	0.0511	0.0755
n-Pentane	36	0.1587	0.0530	0.0774
Hexanes	37-69	0.1517	0.0604	0.0839
Heptanes	70-98	0.1362	0.0574	0.0723
Octanes	99-126	0.0862	0.0422	0.0524
Nonanes	127-151	0.0380	0.0214	0.0262
Decanes	152-174	0.0190	0.0124	0.0156
Undecanes	175-196	0.0115	0.0078	0.0091
Dodecanes	197-216	0.0111	0.0083	0.0096
Tridecanes	217-236	0.0155	0.0126	0.0143
Tetradecanes	237-253	0.0139	0.0122	0.0137
Pentadecanes	254-271	0.0164	0.0156	0.0174
Hexadecanes	272-287	0.0137	0.0141	0.0155
Heptadecanes	288-302	0.0136	0.0149	0.0163
Octadecanes	303-317	0.0142	0.0165	0.0179
Nonadecanes	318-331	0.0116	0.0141	0.0152
Eicosanes	332-343	0.0134	0.0171	0.0183
Heneicosanes	344-357	0.0104	0.0140	0.0149
Docosanes	358-369	0.0116	0.0164	0.0173
Tricosanes	370-380	0.0111	0.0163	0.0172
Tetracosanes	381-391	0.0113	0.0173	0.0181
Pentacosanes	392-402	0.0090	0.0143	0.0149
Hexacosanes	403-412	0.0085	0.0141	0.0147
Heptacosanes	413-422	0.0090	0.0156	0.0161
Octacosanes	423-432	0.0087	0.0155	0.0160
Nonaconsanes	433-441	0.0082	0.0152	0.0156
Triacontanes+	442-449+	0.0010	0.4213	0.2906
Total		1.0000	1.0000	1.0000
Neo-Hexane	50	<0.0001	<0.0001	<0.0001
Methylcyclopentane	70	0.0274	0.0107	0.0130
Benzene	80	0.0094	0.0034	0.0035
Cyclohexane	81	0.0372	0.0145	0.0170
Methylcyclohexane	101	0.0309	0.0140	0.0167
Toluene	111	0.0103	0.0044	0.0046
Ethylbenzene	136	0.0003	0.0001	0.0001
M&P Xylene	139	0.0080	0.0039	0.0042
O-Xylene	144	0.0025	0.0012	0.0013
1,2,4-Trimethylbenzene	169	0.0005	0.0003	0.0003

Maxxam Analytics Inc

Success Through Science

C30+ / C100 RECOMBINED LIQUID HYDROCARBON ANALYSIS

Laboratory Number	B311691 : GB6706
Operator Name	KINDER MORGAN CANADA
Well Name	TRANSMOUNTAIN TERMINAL
Well I.D.	N/A
Sample Point	CL
Sample Point Maxx I.D.	N/A
Source Pressure	N/A kPag
Source Temperature	N/A °C

Prepared by: Monika Majerova

COMPOSITION

Component	Mole Fraction	Mass Fraction	Volume Fraction
N2	<0.0001	<0.0001	<0.0001
CO2	<0.0001	<0.0001	<0.0001
H2S	<0.0001	<0.0001	<0.0001
C1	<0.0001	<0.0001	<0.0001
C2	0.0002	<0.0001	<0.0001
C3	0.0021	0.0004	0.0007
IC4	0.0042	0.0010	0.0016
NC4	0.0222	0.0051	0.0081
IC5	0.1106	0.0316	0.0468
NC5	0.1198	0.0342	0.0502
C6	0.1258	0.0430	0.0599
C7+	0.6151	0.8847	0.8328
TOTAL	1.0000	1.0000	1.0000

PROPERTIES

RESIDUE	RELATIVE DENSITY @ 15°C		RELATIVE MOLECULAR MASS		DATA SUMMARY		
	Observed	Calculated	Observed	Calculated	Mole Fraction	Mass Fraction	Volume Fraction
C5+		0.9296		258	0.9713	0.9935	0.9896
C6+		0.9624		316	0.7409	0.9277	0.8926
C7+		0.9838		363	0.6151	0.8847	0.8327
C10+		1.0276		543	0.3642	0.7831	0.7056
C12+		1.0415		606	0.3144	0.7547	0.6709
Total		0.9259		252	1.0000	1.0000	1.0000

Calculated Absolute Density Total Sample	926.7	kg/m^3 @ 15°C
Observed Absolute Density Total Sample	926.7	kg/m^3 @ 15°C
Gas Equivalency Factor	86.6	m^3 Gas / m^3 Liquid

Success Through Science

Maxxam Analytics Inc

C30+ / C100 RECOMBINED LIQUID HYDROCARBON ANALYSIS

Laboratory Number B311691 : GB6706
Operator Name KINDER MORGAN CANADA
Well Name TRANSMOUNTAIN TERMINAL
Well I.D. N/A
Sample Point CL
Sample Point Maxx I.D. N/A

Source Pressure N/A kPag
Source Temperature N/A °C

Prepared by: Monika Majerova

Component	Boling Point (°C)	Mole Fraction	Mass Fraction	Volume Fraction
Nitrogen	-196	<0.0001	<0.0001	<0.0001
Carbon Dioxide	-79	<0.0001	<0.0001	<0.0001
Hydrogen Sulfide	-60	<0.0001	<0.0001	<0.0001
Methane	-162	<0.0001	<0.0001	<0.0001
Ethane	-90	0.0002	<0.0001	<0.0001
Propane	-42	0.0021	0.0004	0.0007
Iso-Butane	-12	0.0042	0.0010	0.0016
n-Butane	0	0.0222	0.0051	0.0081
Iso-Pentane	28	0.1106	0.0316	0.0468
n-Pentane	36	0.1198	0.0342	0.0502
Hexanes	37-69	0.1258	0.0430	0.0599
Heptanes	70-98	0.1182	0.0427	0.0541
Octanes	99-126	0.0834	0.0351	0.0438
Nonanes	127-151	0.0493	0.0238	0.0292
Decanes	152-174	0.0278	0.0156	0.0196
Undecanes	175-196	0.0220	0.0128	0.0150
Dodecanes	197-216	0.0228	0.0146	0.0168
Tridecanes	217-236	0.0254	0.0176	0.0201
Tetradecanes	237-253	0.0254	0.0191	0.0215
Pentadecanes	254-271	0.0281	0.0229	0.0255
Hexadecanes	272-287	0.0220	0.0194	0.0214
Heptadecanes	288-302	0.0202	0.0189	0.0207
Octadecanes	303-317	0.0204	0.0203	0.0221
Nonadecanes	318-331	0.0174	0.0182	0.0196
Eicosanes	332-343	0.0173	0.0189	0.0203
Heneicosanes	344-357	0.0136	0.0157	0.0168
Docosanes	358-369	0.0150	0.0182	0.0193
Tricosanes	370-380	0.0151	0.0190	0.0200
Tetracosanes	381-391	0.0134	0.0176	0.0185
Pentacosanes	392-402	0.0114	0.0156	0.0164
Hexacosanes	403-412	0.0103	0.0146	0.0152
Heptacosanes	413-422	0.0107	0.0158	0.0164
Octacosanes	423-432	0.0111	0.0170	0.0176
Nonaconsanes	433-441	0.0108	0.0172	0.0178
Triacontanes+	442-449+	0.0040	0.4342	0.3251
Total		1.0000	1.0000	1.0000
Neo-Hexane	50	<0.0001	<0.0001	<0.0001
Methylcyclopentane	70	0.0241	0.0080	0.0099
Benzene	80	0.0085	0.0026	0.0028
Cyclohexane	81	0.0300	0.0100	0.0118
Methylcyclohexane	101	0.0269	0.0105	0.0125
Toluene	111	0.0107	0.0039	0.0041
Ethylbenzene	136	0.0007	0.0003	0.0003
M&P Xylene	139	0.0094	0.0039	0.0042
O-Xylene	144	0.0038	0.0016	0.0017
1,2,4-Trimethylbenzene	169	0.0006	0.0003	0.0003

Success Through Science

Maxxam Analytics Inc

C30+ / C100 RECOMBINED LIQUID HYDROCARBON ANALYSIS

Laboratory Number B311691 : GB6707
Operator Name KINDER MORGAN CANADA
Well Name KINDER MORGAN EDMONTON TERMINAL
Well I.D. N/A
Sample Point AHS
Sample Point Maxx I.D. N/A

Source Pressure N/A kPag
Source Temperature N/A °C

Prepared by: Monika Majerova

COMPOSITION

Component	Mole Fraction	Mass Fraction	Volume Fraction
N2	<0.0001	<0.0001	<0.0001
CO2	<0.0001	<0.0001	<0.0001
H2S	<0.0001	<0.0001	<0.0001
C1	<0.0001	<0.0001	<0.0001
C2	0.0001	<0.0001	<0.0001
C3	0.0059	0.0007	0.0013
IC4	0.0143	0.0022	0.0037
NC4	0.0603	0.0094	0.0150
IC5	0.0841	0.0163	0.0244
NC5	0.1029	0.0199	0.0295
C6	0.1338	0.0309	0.0435
C7+	0.5986	0.9207	0.8826
TOTAL	1.0000	1.0000	1.0000

PROPERTIES

RESIDUE	RELATIVE DENSITY @ 15°C		RELATIVE MOLECULAR MASS		DATA SUMMARY		
	Observed	Calculated	Observed	Calculated	Mole Fraction	Mass Fraction	Volume Fraction
C5+		0.9445		401	0.9194	0.9877	0.9800
C6+		0.9629		485	0.7324	0.9516	0.9261
C7+		0.9776		575	0.5986	0.9207	0.8826
C10+		1.0097		976	0.3226	0.8428	0.7823
C12+		1.0196		1178	0.2596	0.8187	0.7525
Total		0.9371		374	1.0000	1.0000	1.0000

Calculated Absolute Density Total Sample	937.9	kg/m^3 @ 15°C
Observed Absolute Density Total Sample	937.9	kg/m^3 @ 15°C
Gas Equivalency Factor	59.3	m^3 Gas / m^3 Liquid

Success Through Science

Maxxam Analytics Inc

C30+ / C100 RECOMBINED LIQUID HYDROCARBON ANALYSIS

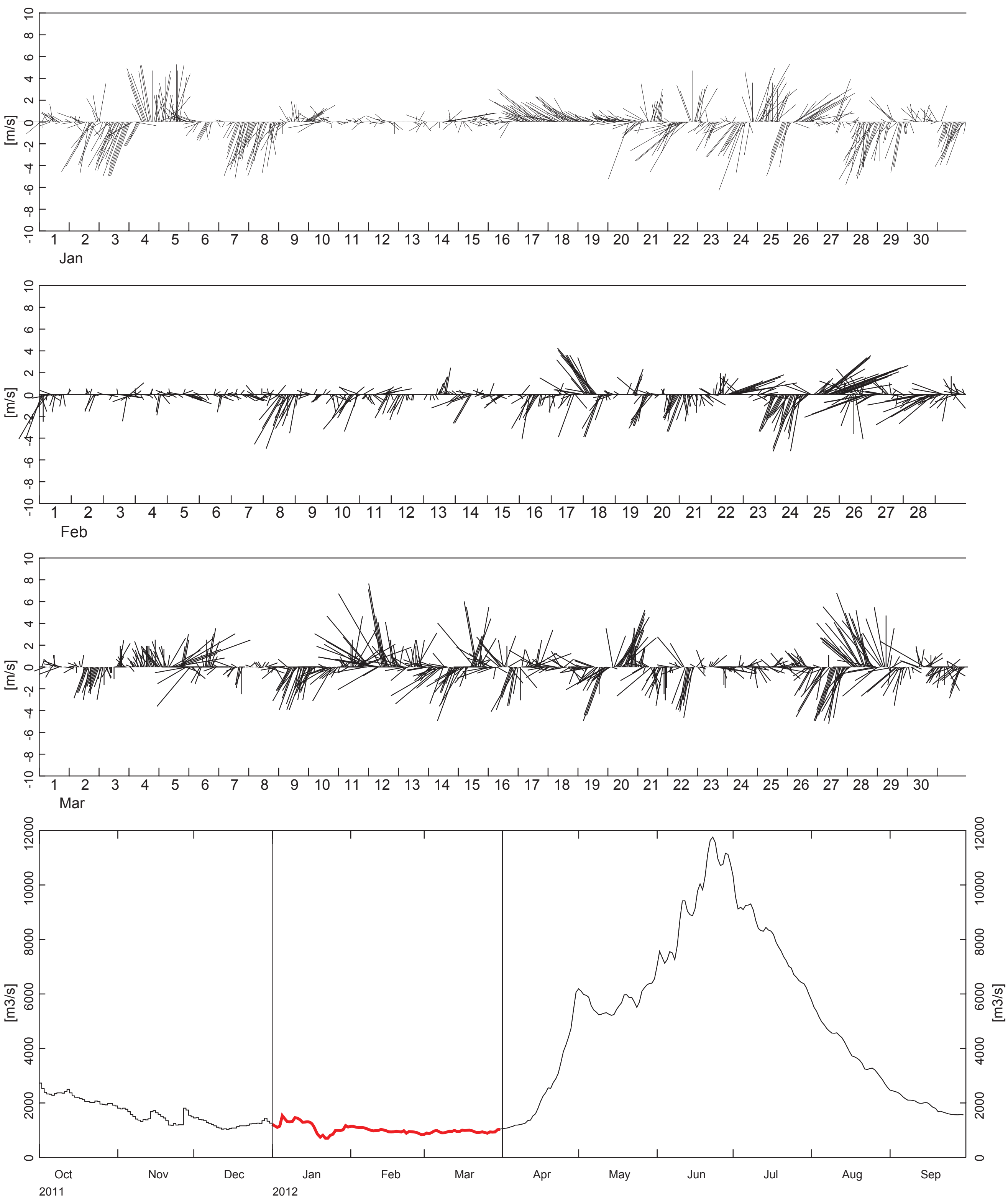
Laboratory Number B311691 : GB6707
Operator Name KINDER MORGAN CANADA
Well Name KINDER MORGAN EDMONTON TERMINAL
Well I.D. N/A
Sample Point AHS
Sample Point Maxx I.D. N/A

Source Pressure N/A kPag
Source Temperature N/A °C

Prepared by: Monika Majerova

Component	Boling Point (°C)	Mole Fraction	Mass Fraction	Volume Fraction
Nitrogen	-196	<0.0001	<0.0001	<0.0001
Carbon Dioxide	-79	<0.0001	<0.0001	<0.0001
Hydrogen Sulfide	-60	<0.0001	<0.0001	<0.0001
Methane	-162	<0.0001	<0.0001	<0.0001
Ethane	-90	0.0001	<0.0001	<0.0001
Propane	-42	0.0059	0.0007	0.0013
Iso-Butane	-12	0.0143	0.0022	0.0037
n-Butane	0	0.0603	0.0094	0.0150
Iso-Pentane	28	0.0841	0.0163	0.0244
n-Pentane	36	0.1029	0.0199	0.0295
Hexanes	37-69	0.1338	0.0309	0.0435
Heptanes	70-98	0.1226	0.0310	0.0406
Octanes	99-126	0.0949	0.0275	0.0353
Nonanes	127-151	0.0584	0.0194	0.0244
Decanes	152-174	0.0394	0.0148	0.0187
Undecanes	175-196	0.0236	0.0093	0.0110
Dodecanes	197-216	0.0089	0.0038	0.0045
Tridecanes	217-236	0.0081	0.0038	0.0044
Tetradecanes	237-253	0.0091	0.0046	0.0053
Pentadecanes	254-271	0.0103	0.0057	0.0064
Hexadecanes	272-287	0.0084	0.0050	0.0056
Heptadecanes	288-302	0.0080	0.0051	0.0056
Octadecanes	303-317	0.0085	0.0057	0.0063
Nonadecanes	318-331	0.0079	0.0056	0.0061
Eicosanes	332-343	0.0084	0.0062	0.0067
Heneicosanes	344-357	0.0083	0.0064	0.0070
Docosanes	358-369	0.0094	0.0077	0.0083
Tricosanes	370-380	0.0123	0.0105	0.0112
Tetracosanes	381-391	0.0121	0.0107	0.0114
Pentacosanes	392-402	0.0123	0.0113	0.0120
Hexacosanes	403-412	0.0120	0.0115	0.0121
Heptacosanes	413-422	0.0130	0.0131	0.0137
Octacosanes	423-432	0.0153	0.0159	0.0166
Nonaconsanes	433-441	0.0165	0.0178	0.0185
Triacontanes+	442-449+	0.0706	0.6682	0.5908
Total		1.0000	1.0000	1.0000
Neo-Hexane	50	<0.0001	<0.0001	<0.0001
Methylcyclopentane	70	0.0226	0.0051	0.0063
Benzene	80	0.0044	0.0009	0.0010
Cyclohexane	81	0.0166	0.0037	0.0045
Methylcyclohexane	101	0.0227	0.0060	0.0072
Toluene	111	0.0083	0.0021	0.0022
Ethylbenzene	136	0.0031	0.0009	0.0009
M&P Xylene	139	0.0063	0.0018	0.0019
O-Xylene	144	0.0025	0.0007	0.0007
1,2,4-Trimethylbenzene	169	0.0032	0.0010	0.0011

Appendix B: Results of the Stochastic Modeling



NOTES

- The wind stick represent winds at Pitt Meadows.
- The bottom graph represents the Fraser River discharge at Hope.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANS MOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

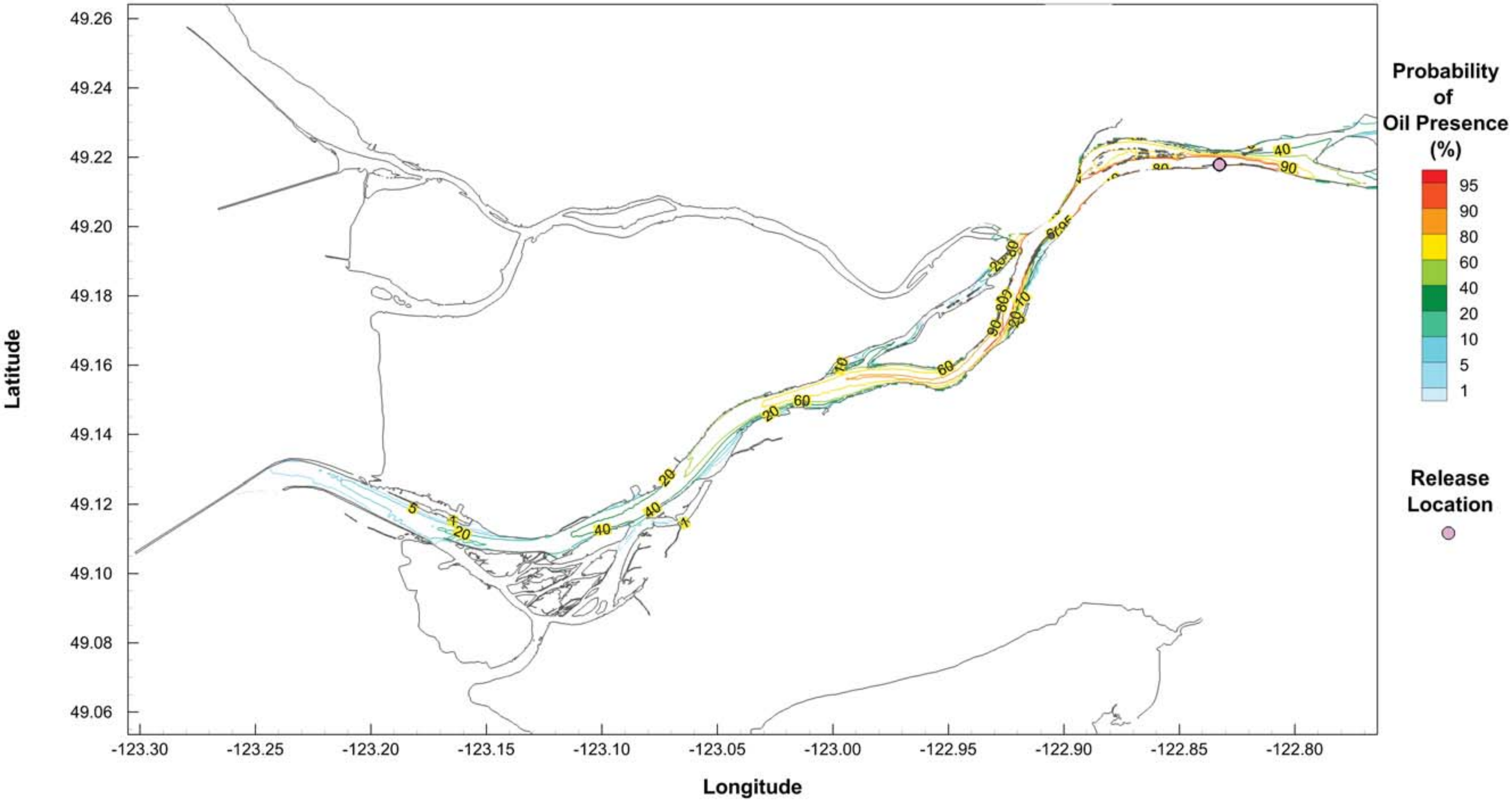
Environmental Conditions: Winter 2012 Site FR Stochastic Modelling

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

OFFICE	DATE
EBA-VANC	October 2013

Figure I.1-1

Thu Oct 24 16:57:55 2013:V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\Tsplot



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 toMarch 31 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

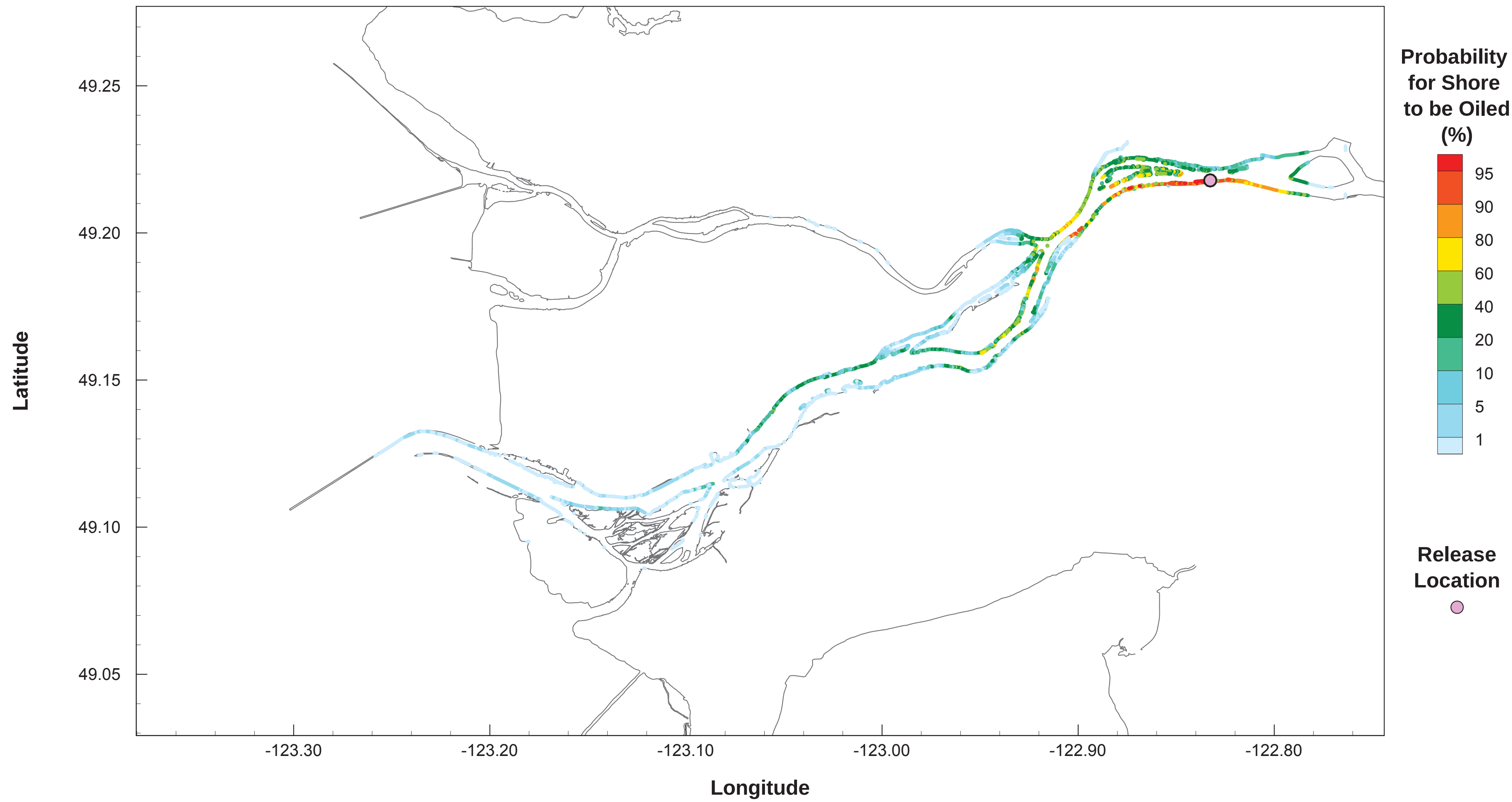
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Winter 2012, Site FR (1,250 m^3)
Probability of Oil Presence

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

OFFICE	DATE
EBA-VANC	October 29, 2013

Figure FR.1-2



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

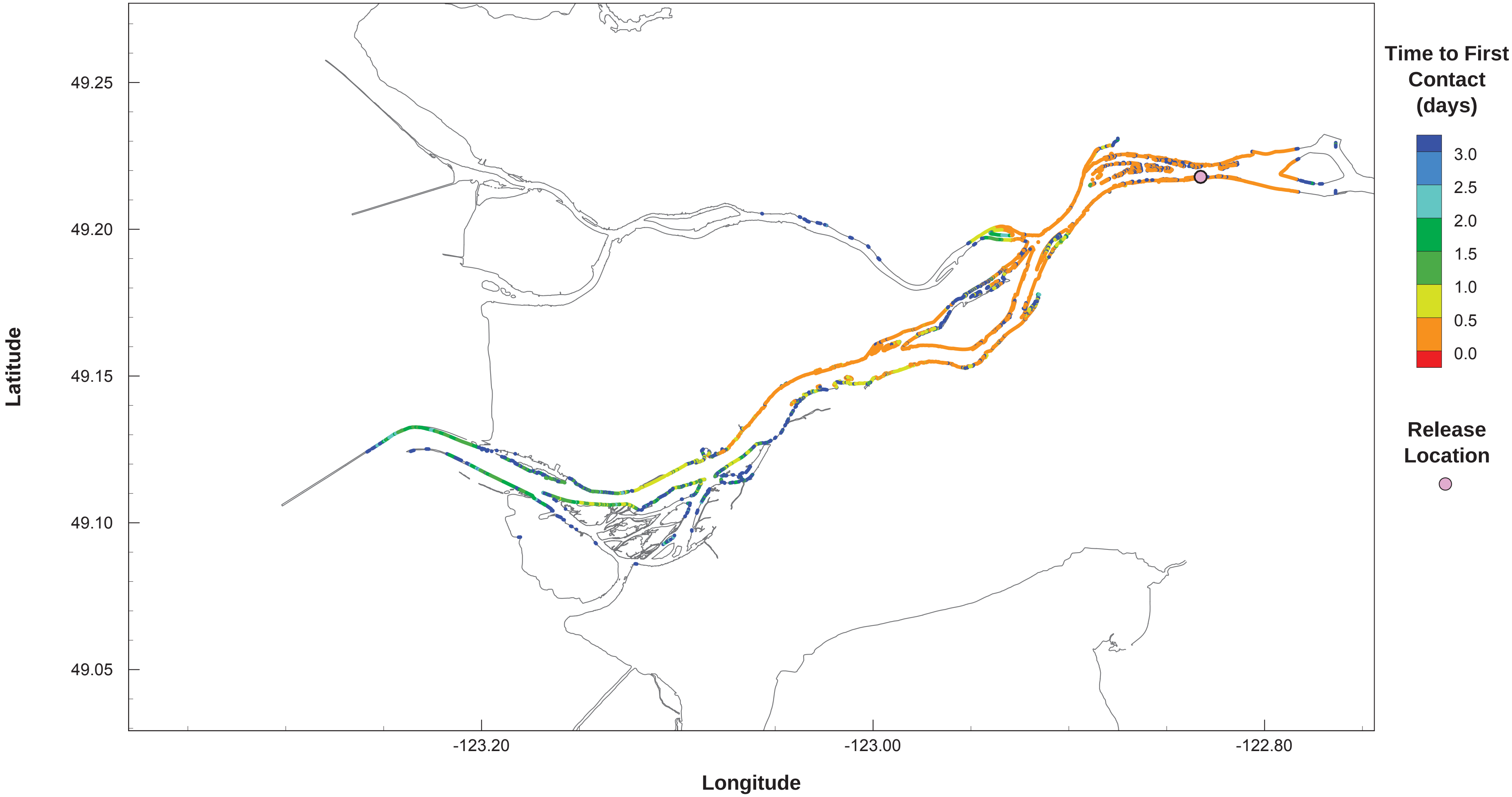
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Winter 2012, Site FR (1,250 m^3) Shoreline Oiled Probability

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.1-3



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.
- Time to first contact is the minimum time, over all simulations, for oil to reach a given shore segment.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Winter 2012, Site FR (1,250 m^3) Shoreline Time to First Contact

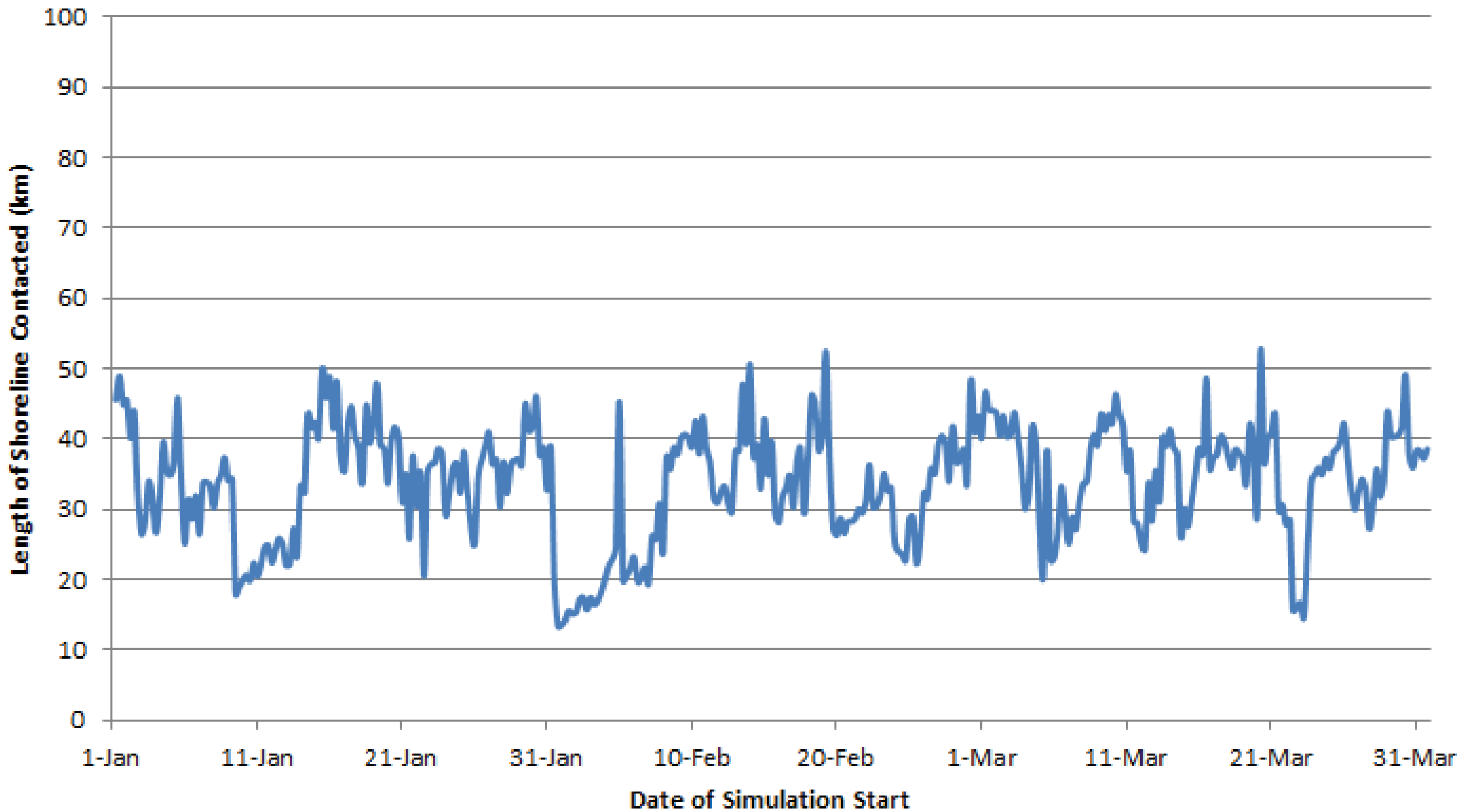
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.1-4

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Winter\Tecplot\04-shore_firstcontact.lay

24 Oct 2013 17:14:17



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

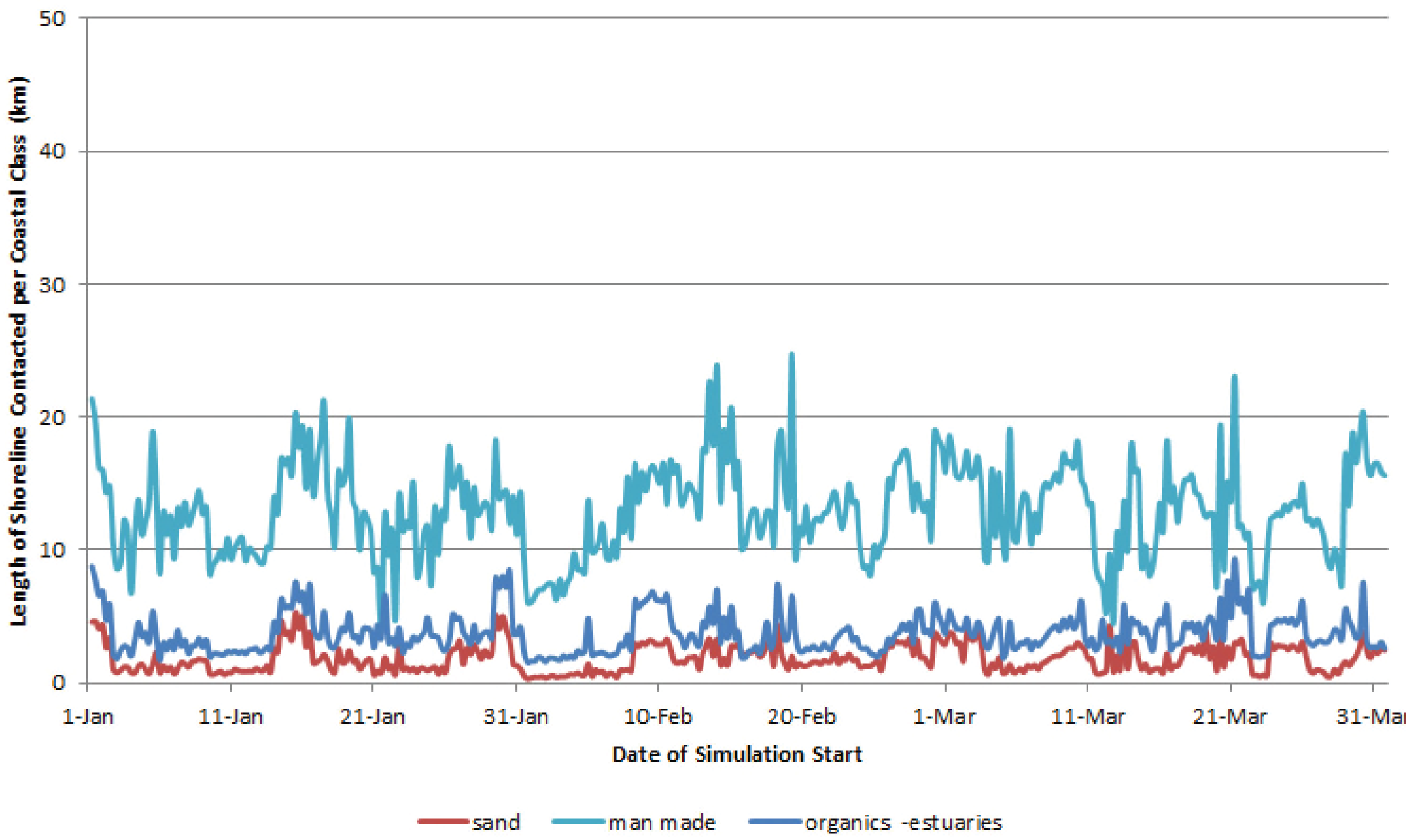
CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Winter 2012, Site FR (1,250 m^3)
Length of Shoreline Contacted

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	**Figure FR.1-5**
OFFICE	DATE				
EBA-VANC	October 24, 2013				



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

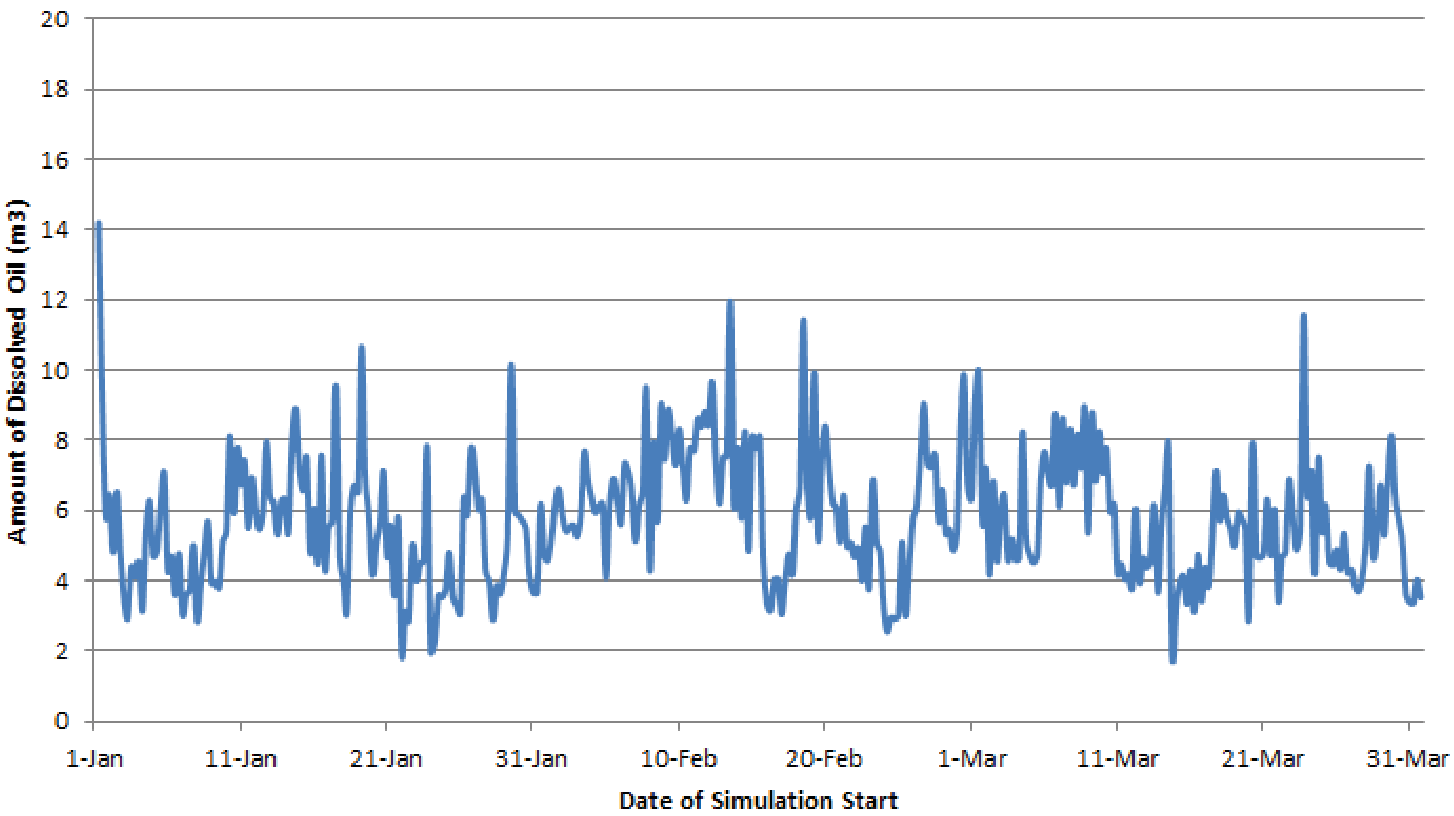
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation - Winter 2012 Site FR (1,250 m^3): Length of Shoreline Contacted Per Coastal Class

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.1-6



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

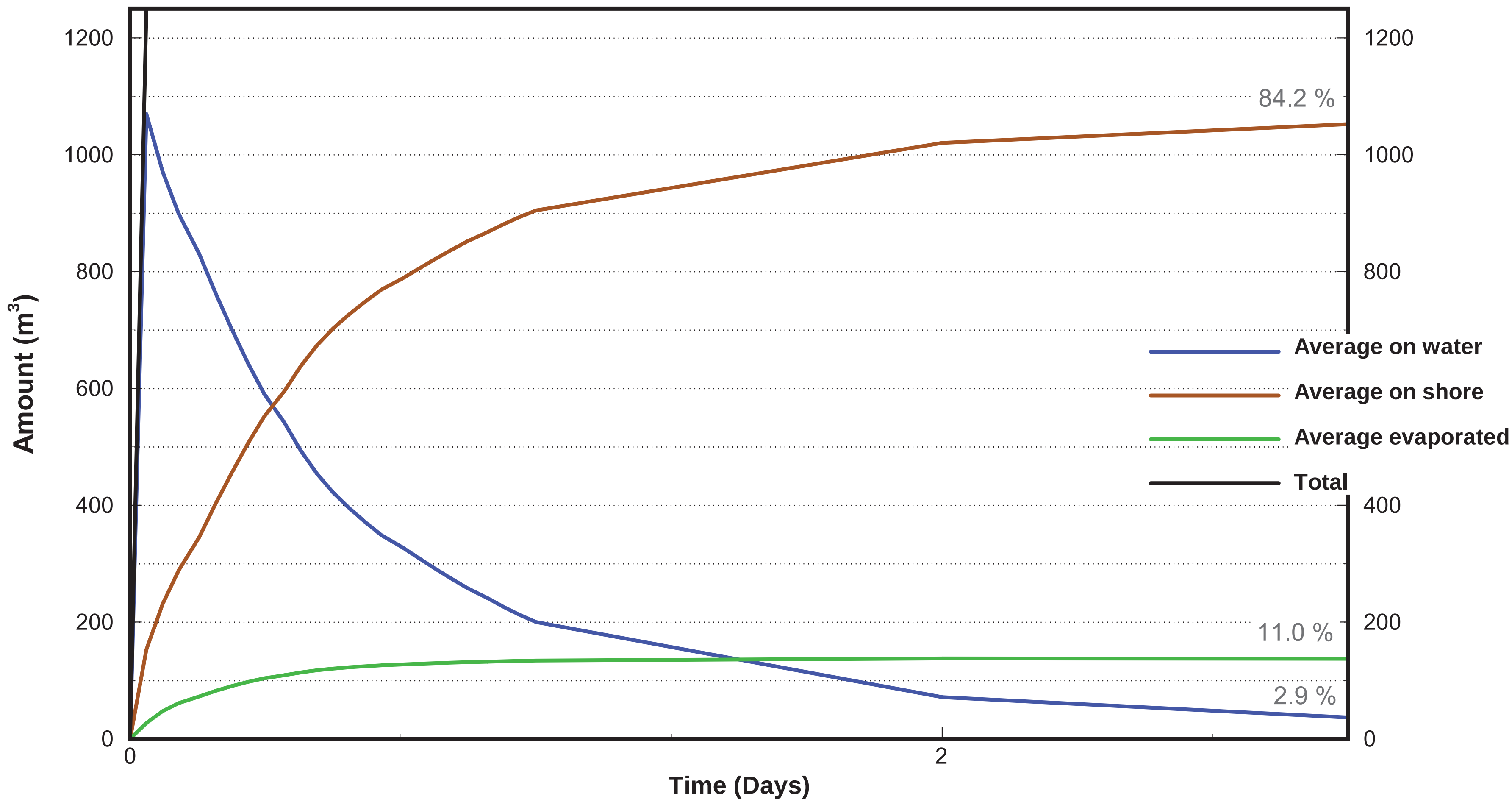
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Winter 2012, Site FR (1,250 m^3) Amount of Dissolved Oil

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.1-7



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.

- Tracking time for each spill was 3 days.

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

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

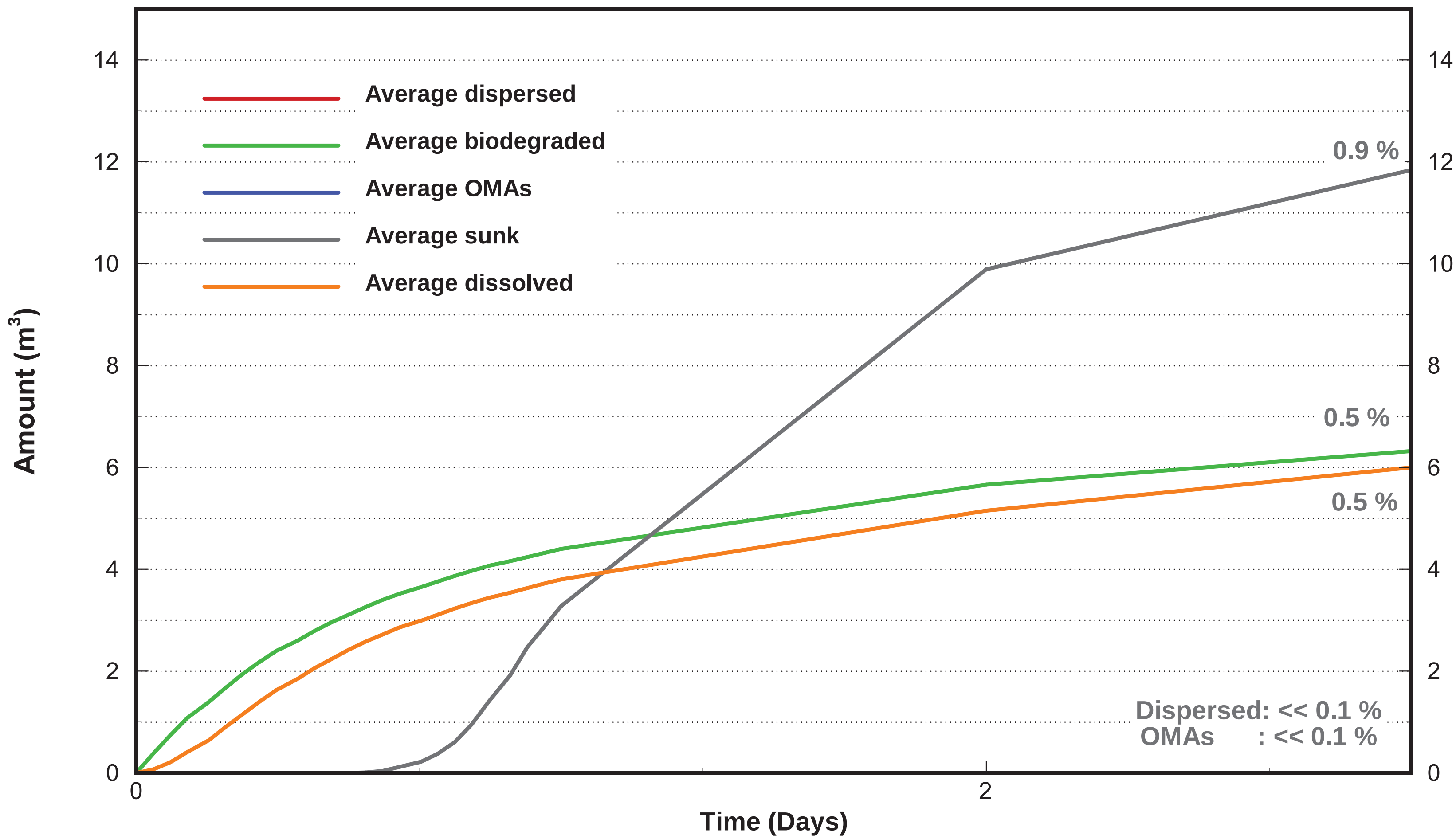
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Winter 2012, Site FR (1,250 m^3)
Major Components of the Mass Balance

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.1-8



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 3 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

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A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Winter 2012, Site FR (1,250 m^3)
Minor Components of the Mass Balance

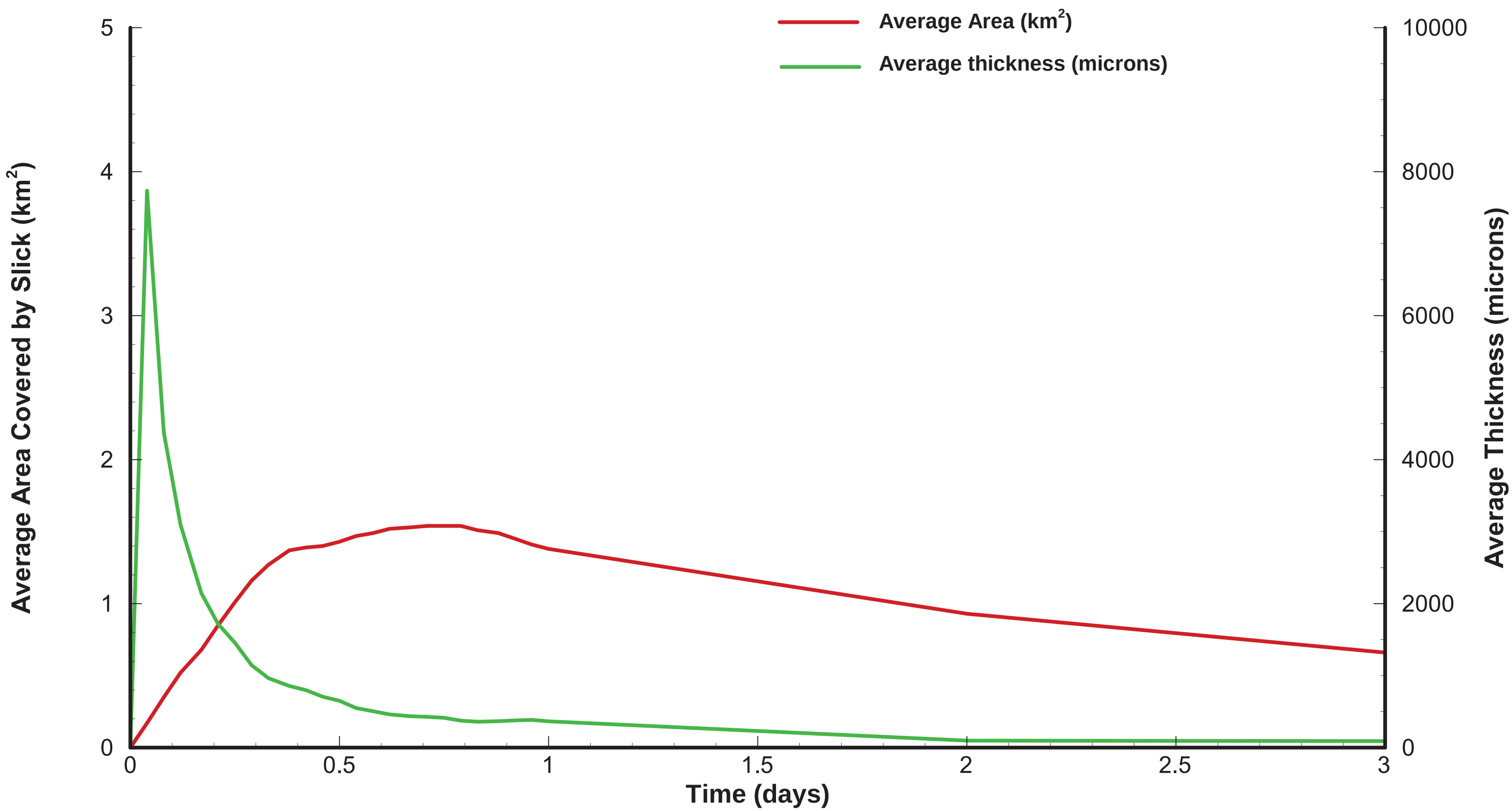
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.1-9

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Winter\Tecplot\09-statistics_MB_2.lay

24 Oct 2013 09:49:27



NOTES

- Statistical results based on independent spills occuring every 6 hours from January 01 00:00 to March 31 23:00, for a total of 364 independant spills.

- The average thickness is based on a full coverage of each grid cell that contains oil.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

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A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Winter 2012, Site FR (1,250 m^3)
Statistics on Area and Thickness

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	Figure FR.1-10
OFFICE	DATE				
EBA-VANC	October 24, 2013				

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Winter\Tecplot\10-statistics_thk.lay

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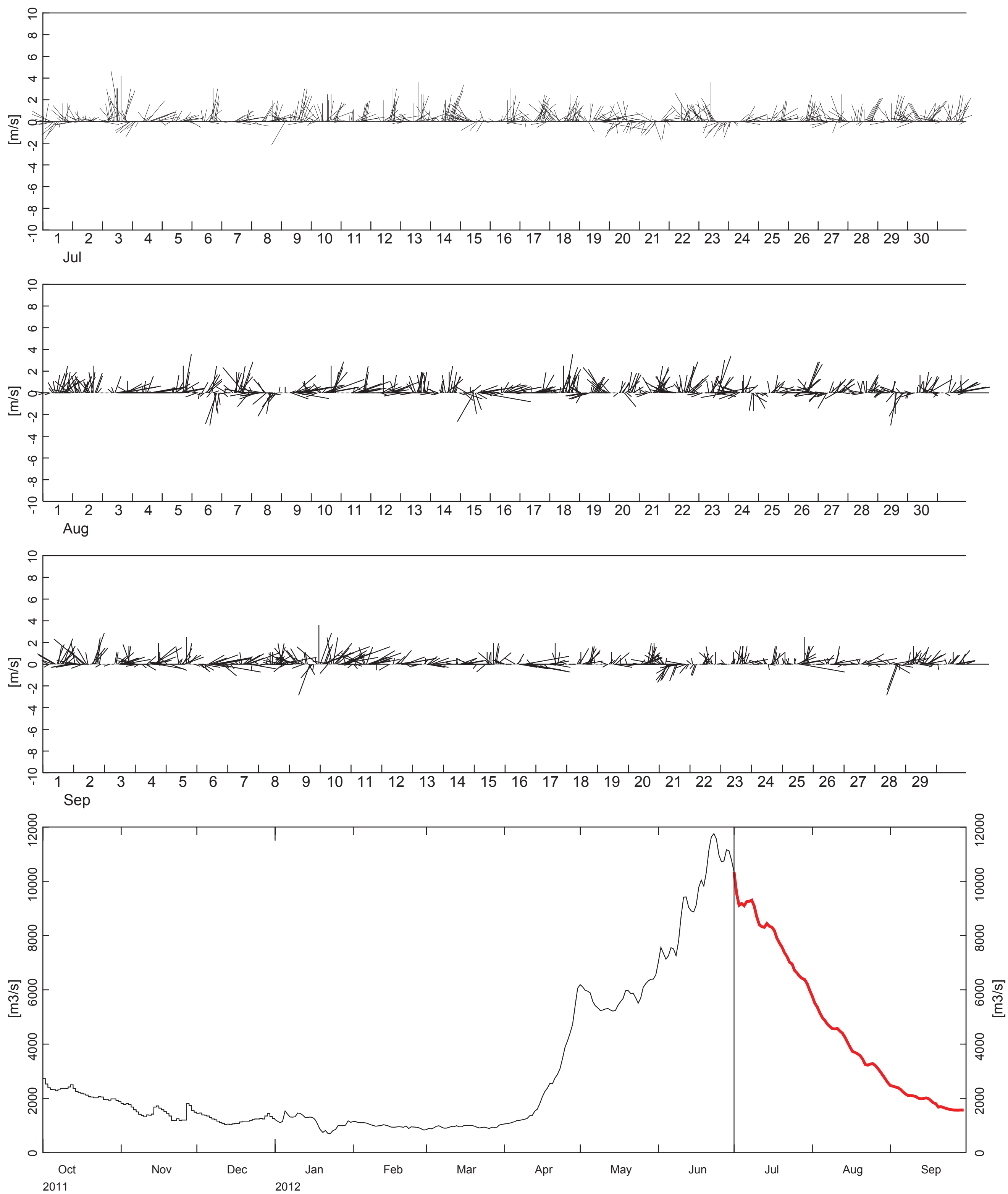


NOTES

- The wind stick represent winds at Pitt Meadows.
- The bottom graph represents the Fraser River discharge at Hope.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANS MOUNTAIN

eba A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

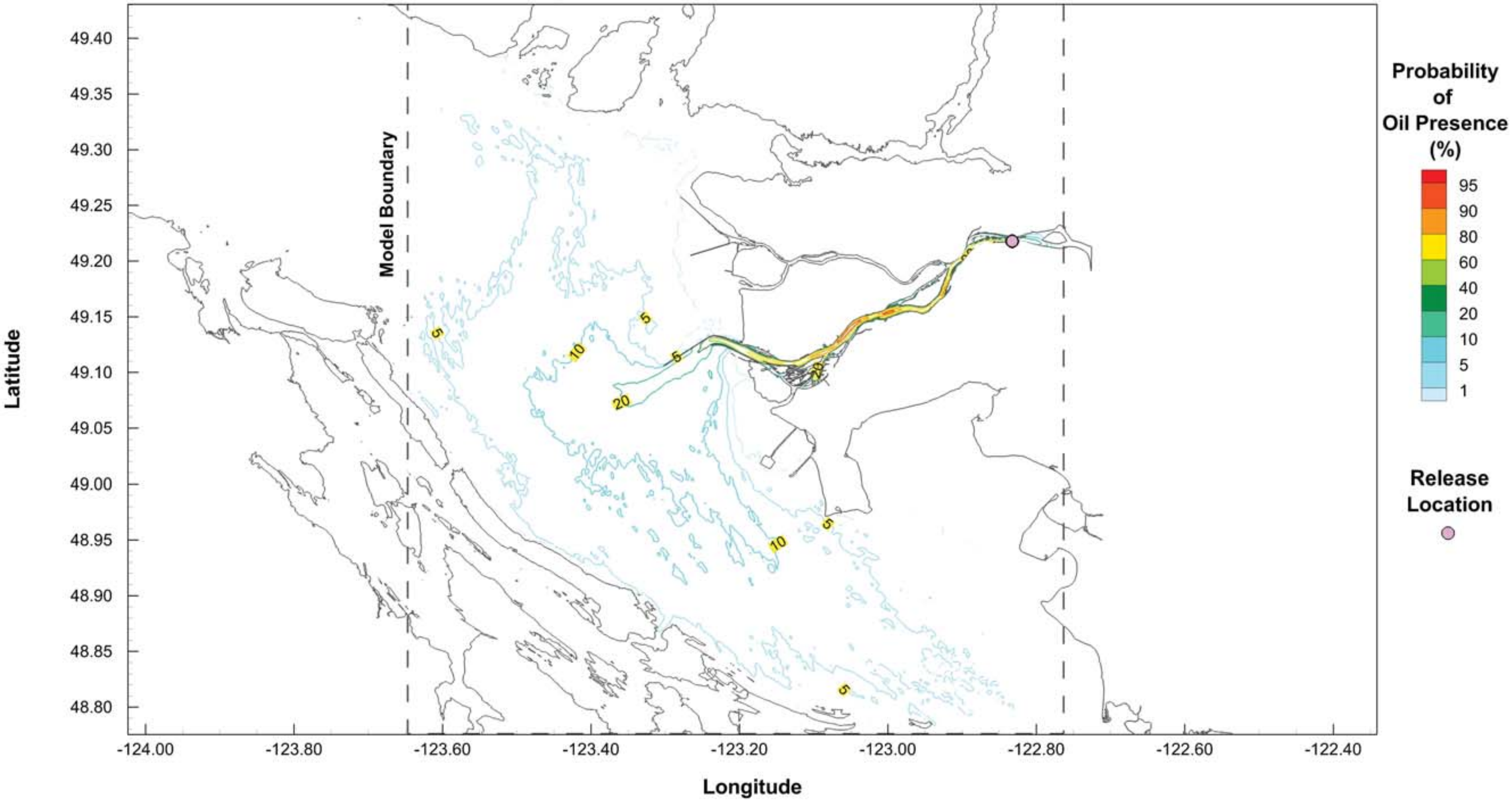
Environmental Conditions: Summer 2012 Site FR Stochastic Modelling

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

OFFICE	DATE
EBA-VANC	October 2013

Figure I.3-1

Thu Oct 24 16:56:54 2013:V:\V13203022 Trans Mountain\working\AH\02-SPILLCALC\Tsplot



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.
- Due to the fine scale grid resolution, a smoothing of the fine scale features was applied for better clarity.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

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A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Summer 2012, Site FR (1,250 m^3) Probability of Oil Presence

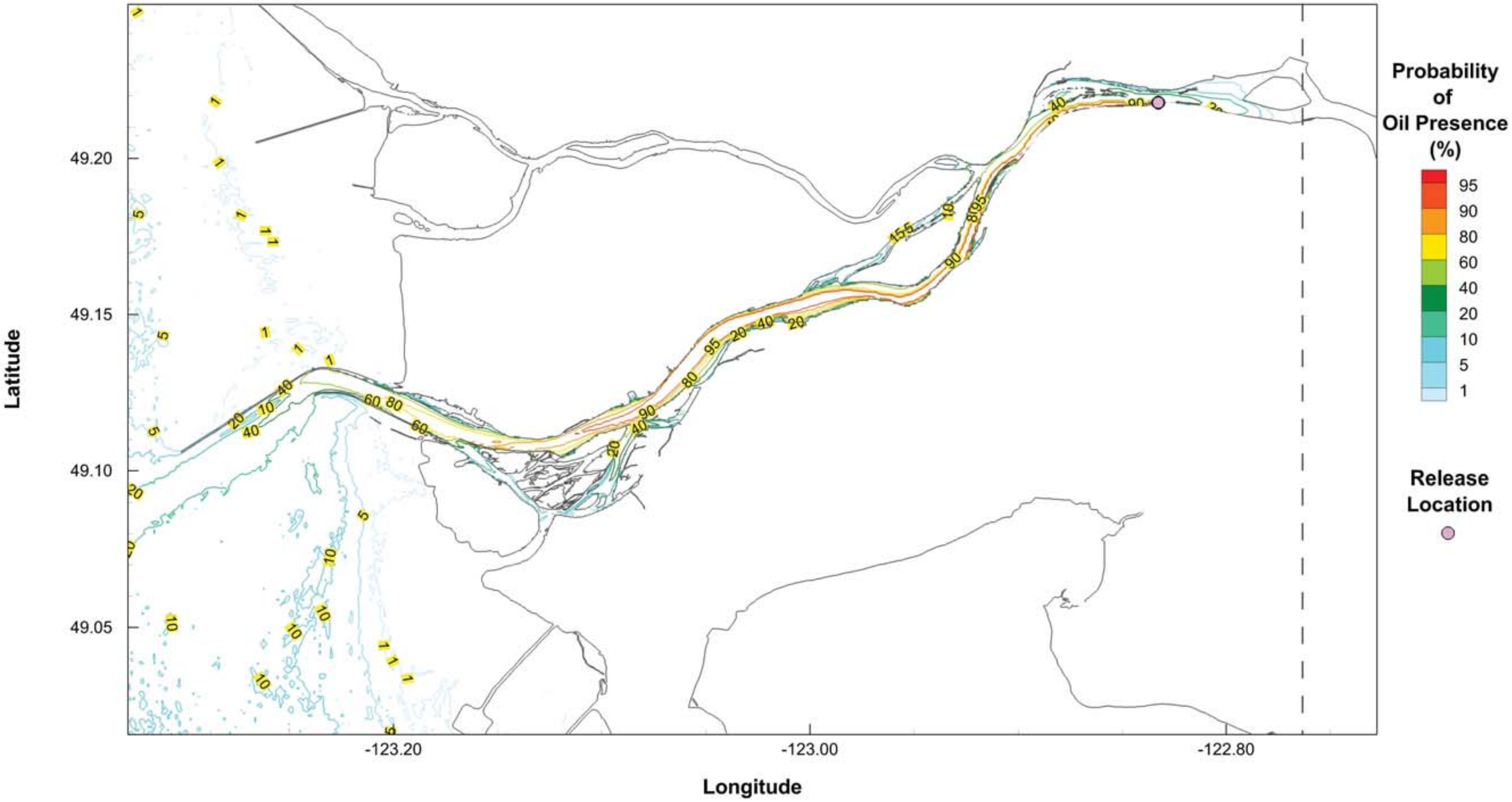
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 29, 2013

Figure FR.3-2

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Summer\Tecplot\02-stochastic_map_lines_smooth.lay

30 Oct 2013 10:36:32



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

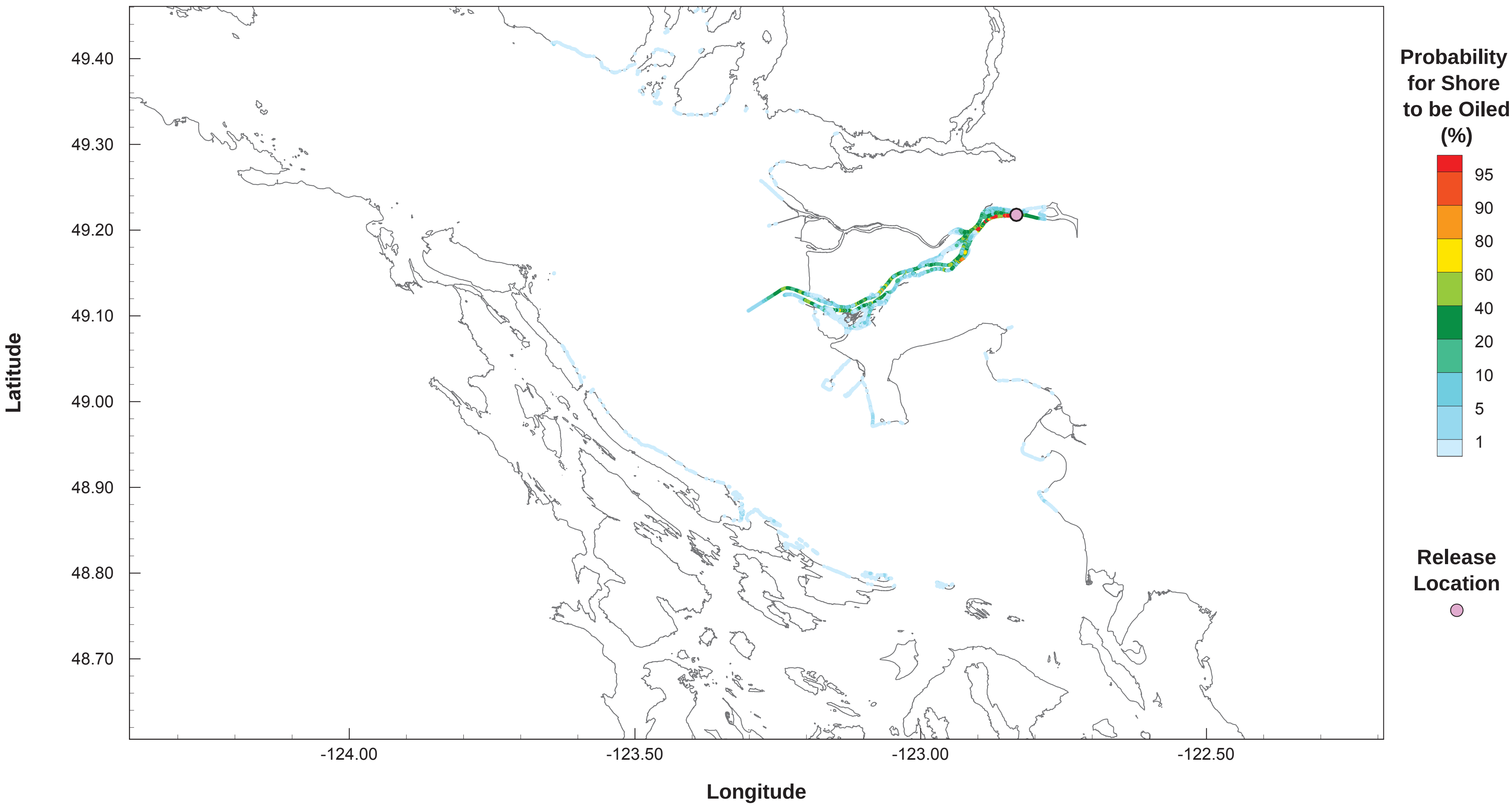
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site FR (1,250 m^3)
Probability of Oil Presence

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

OFFICE	DATE
EBA-VANC	October 29, 2013

Figure FR.3-2



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

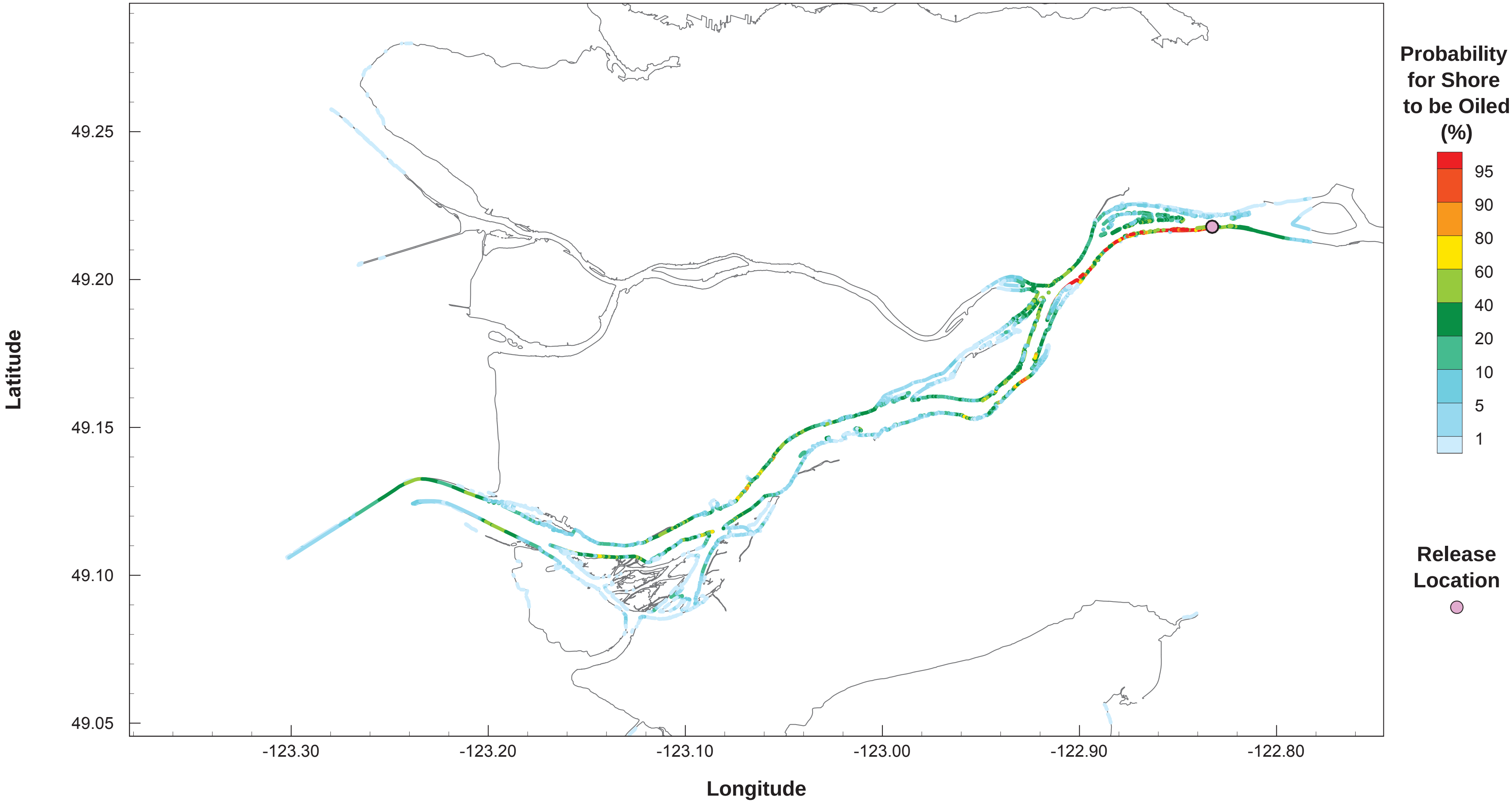
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Summer 2012, Site FR (1,250 m^3) Shoreline Oiled Probability

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

OFFICE	DATE
EBA-VANC	October 30, 2013

Figure FR.3-3



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site FR (1,250 m^3)
Shoreline Oiled Probability

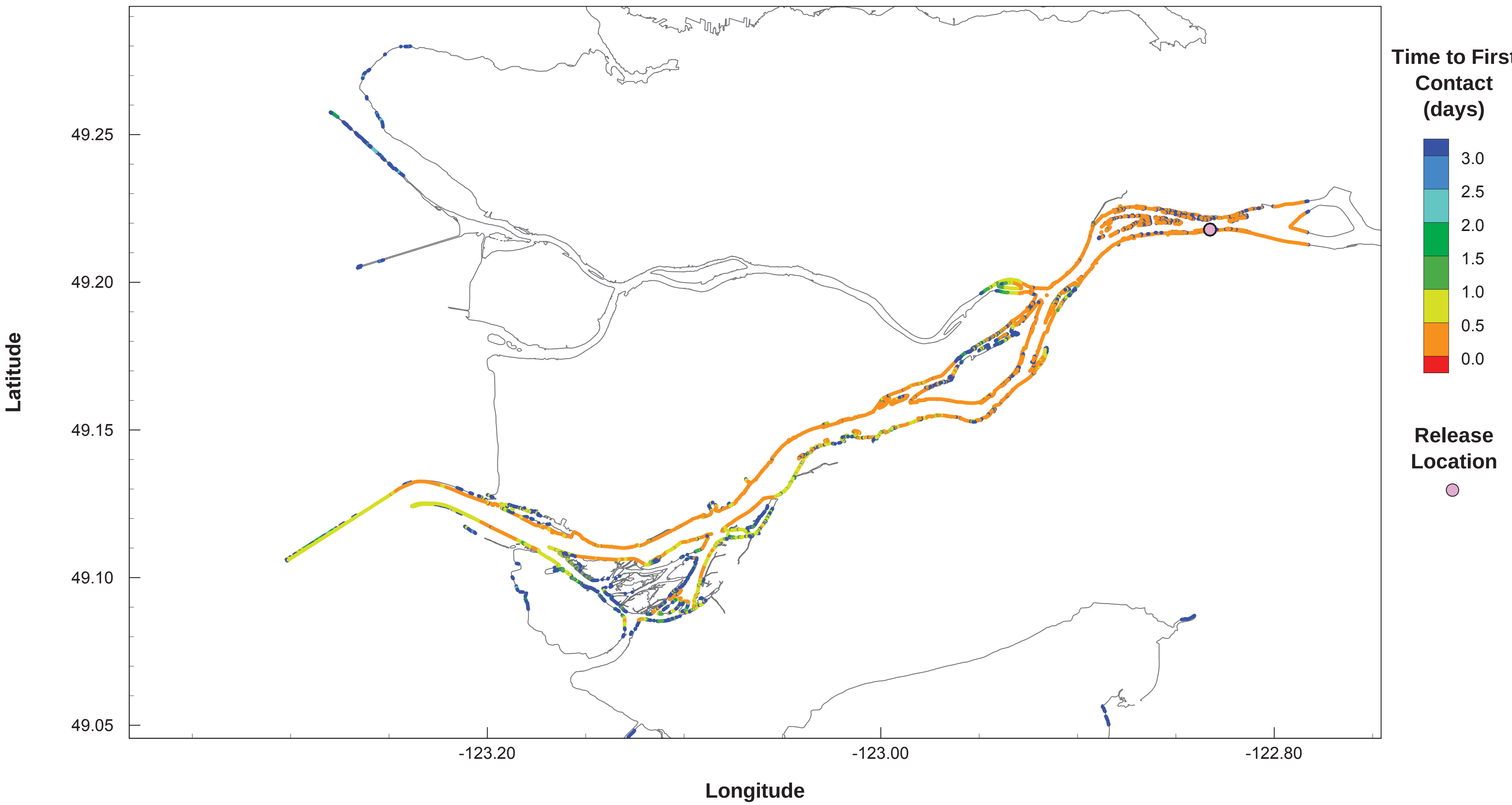
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.3-3

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Summer\Tecplot\03-shore_prob.lay

24 Oct 2013 12:13:39



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Time to first contact is the minimum time, over all simulations, for oil to reach a given shore segment.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

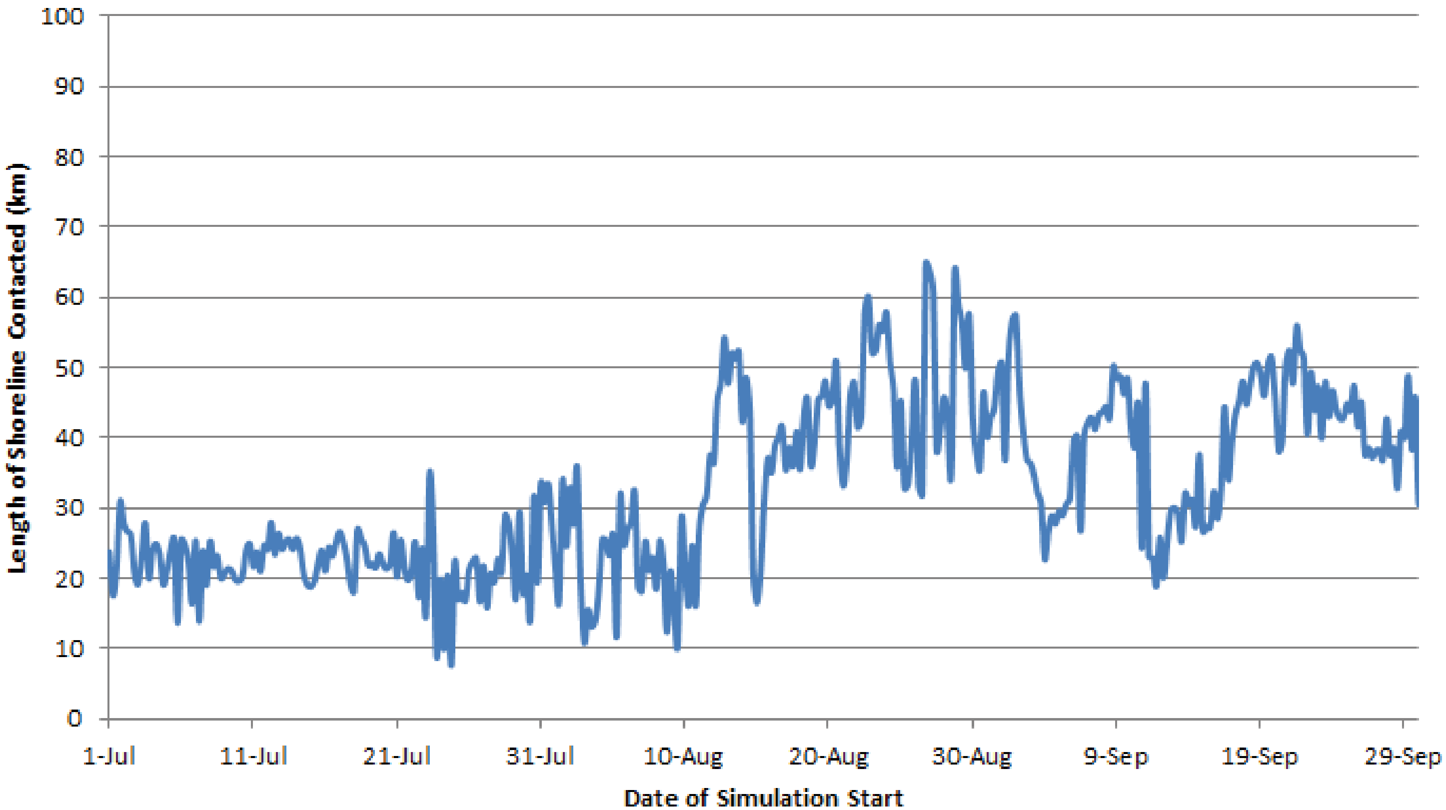
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Summer 2012, Site FR (1,250 m^3) Shoreline Time to First Contact

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.3-4



NOTES

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

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

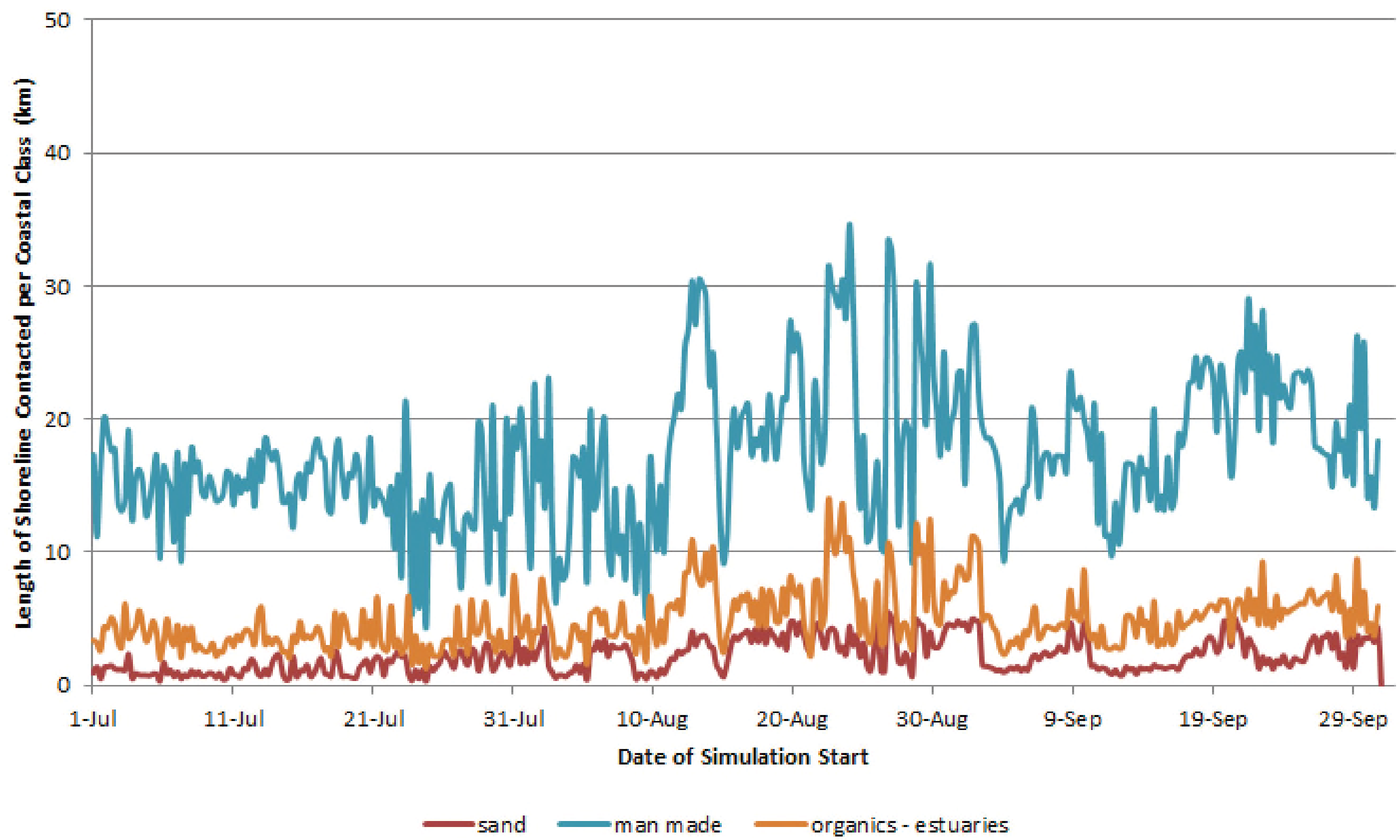
TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site FR (1,250 m^3)
Length of Shoreline Contacted

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	**Figure FR.3-5**
OFFICE	DATE				
EBA-VANC	October 24, 2013				



NOTES

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

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

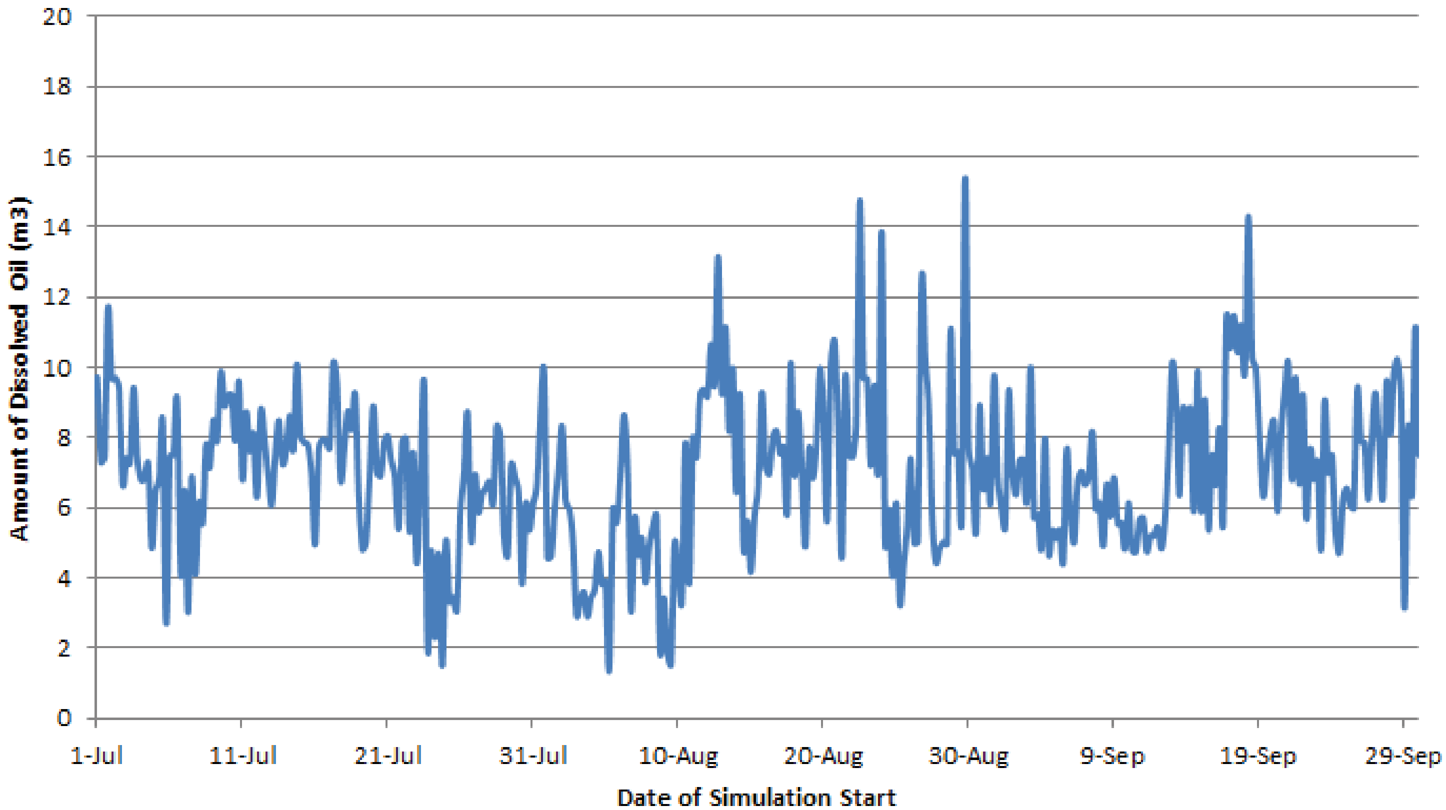
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation - Summer 2012 Site FR (1,250 m^3): Length of Shoreline Contacted Per Coastal Class

PROJECT NO.	DWN	CKD	APVD	REV	
V13203022	AH	JAS	-	0	Figure FR.3-6
OFFICE	DATE				
EBA-VANC	October 24, 2013				



NOTES

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

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

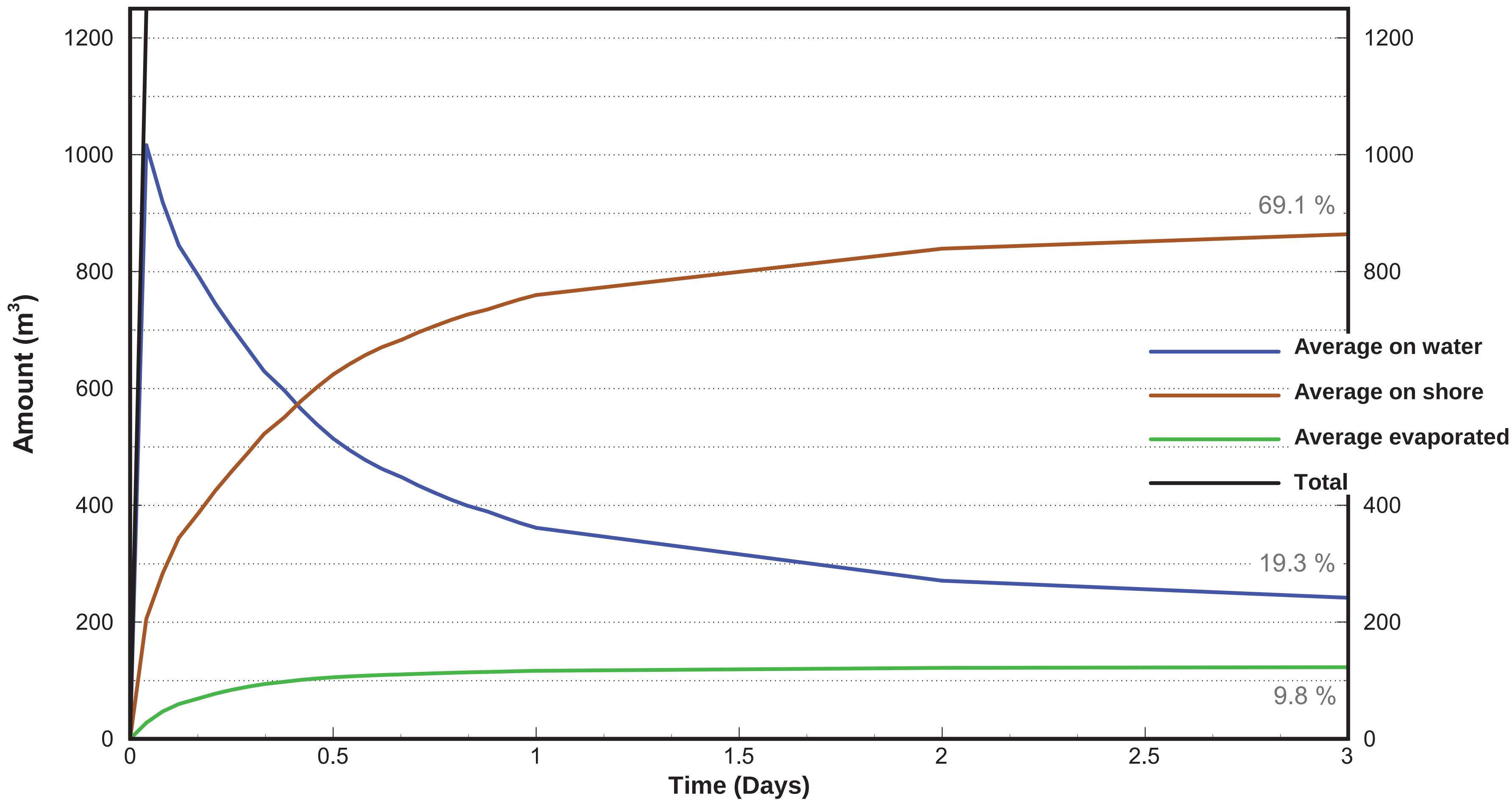
Stochastic Simulation Summer 2012, Site FR (1,250 m^3) Amount of Dissolved Oil

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.3-7

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Summer\Tecplot\07-dissolution_TS.lay 24 Oct 2013 12:14:34



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 3 days.
- The major components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site FR (1,250 m^3)
Major Components of the Mass Balance

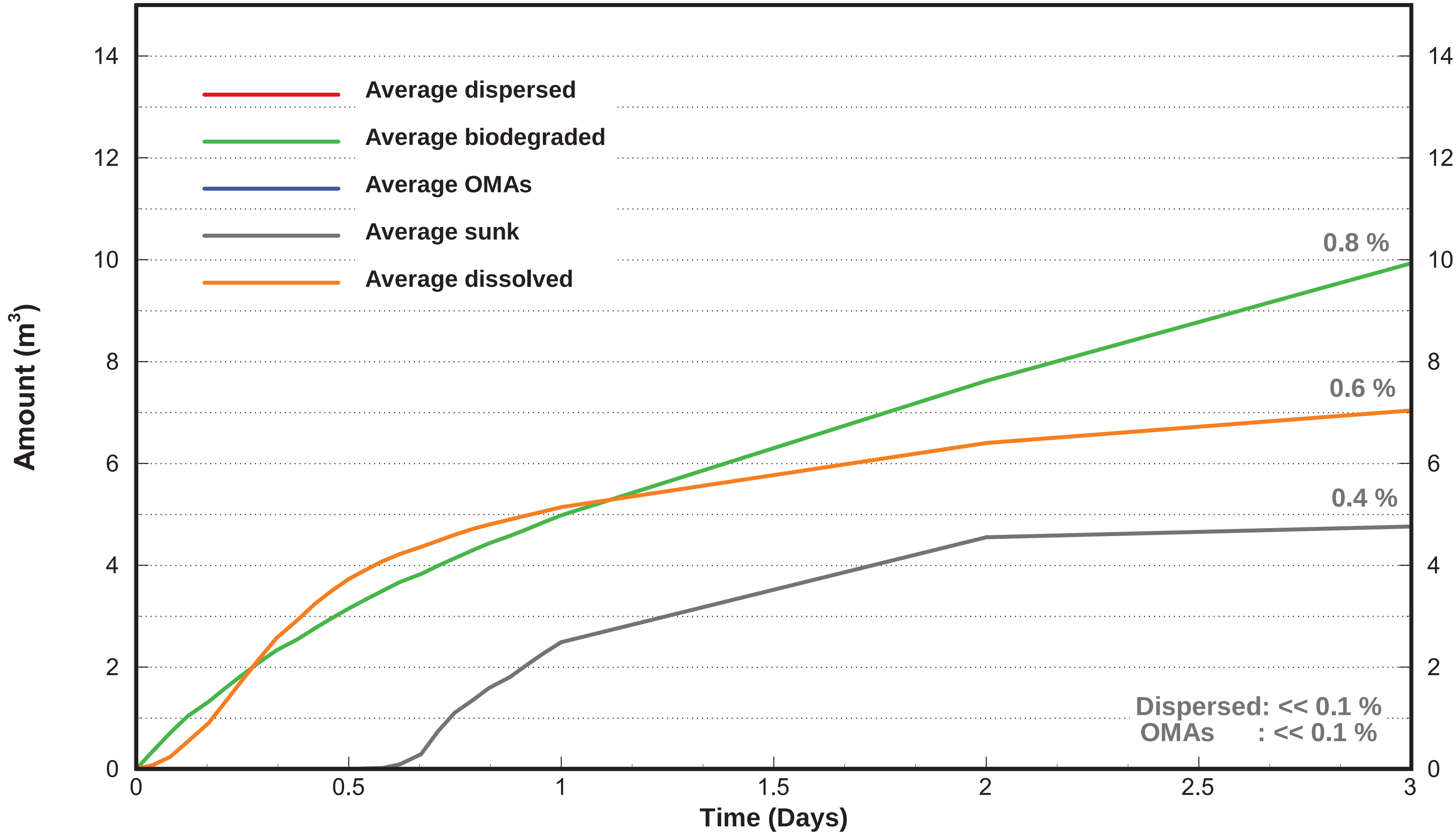
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.3-8

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Summer\Tecplot\08-statistics_MB_1.lay

24 Oct 2013 12:14:45



NOTES

- Statistical results based on independent spills occuring every 6 hours from July 01 00:00 to September 30 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 3 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

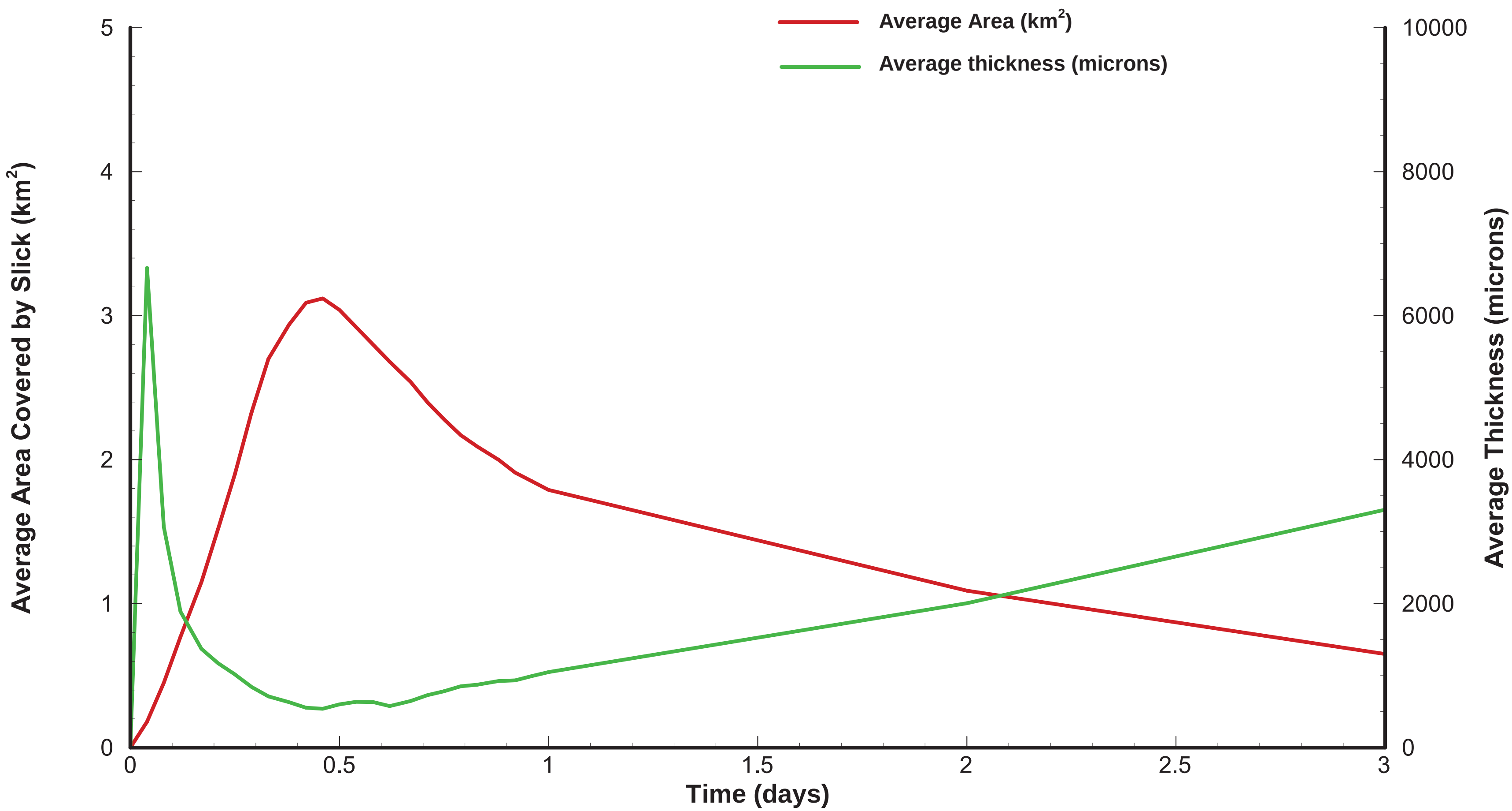
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site FR (1,250 m^3)
Minor Components of the Mass Balance

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.3-9



NOTES

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

- The average thickness is based on a full coverage of each grid cell that contains oil.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Summer 2012, Site FR (1,250 m^3)
Statistics on Area and Thickness

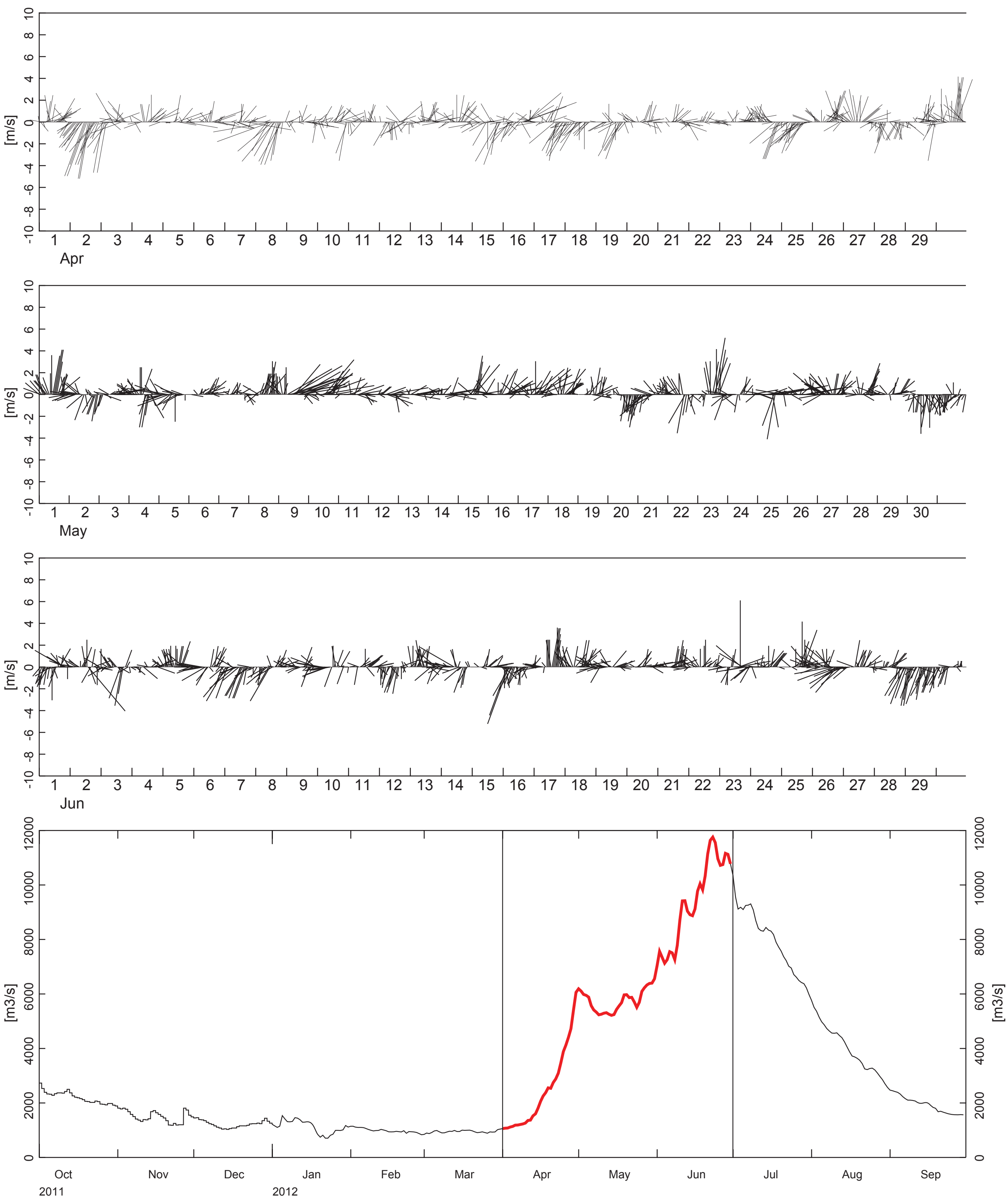
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.3-10

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Summer\Tecplot\10-statistics_thk.lay

24 Oct 2013 12:15:05



NOTES

- The wind stick represent winds at Pitt Meadows.
- The bottom graph represents the Fraser River discharge at Hope.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANS MOUNTAIN

A TETRA TECH COMPANY

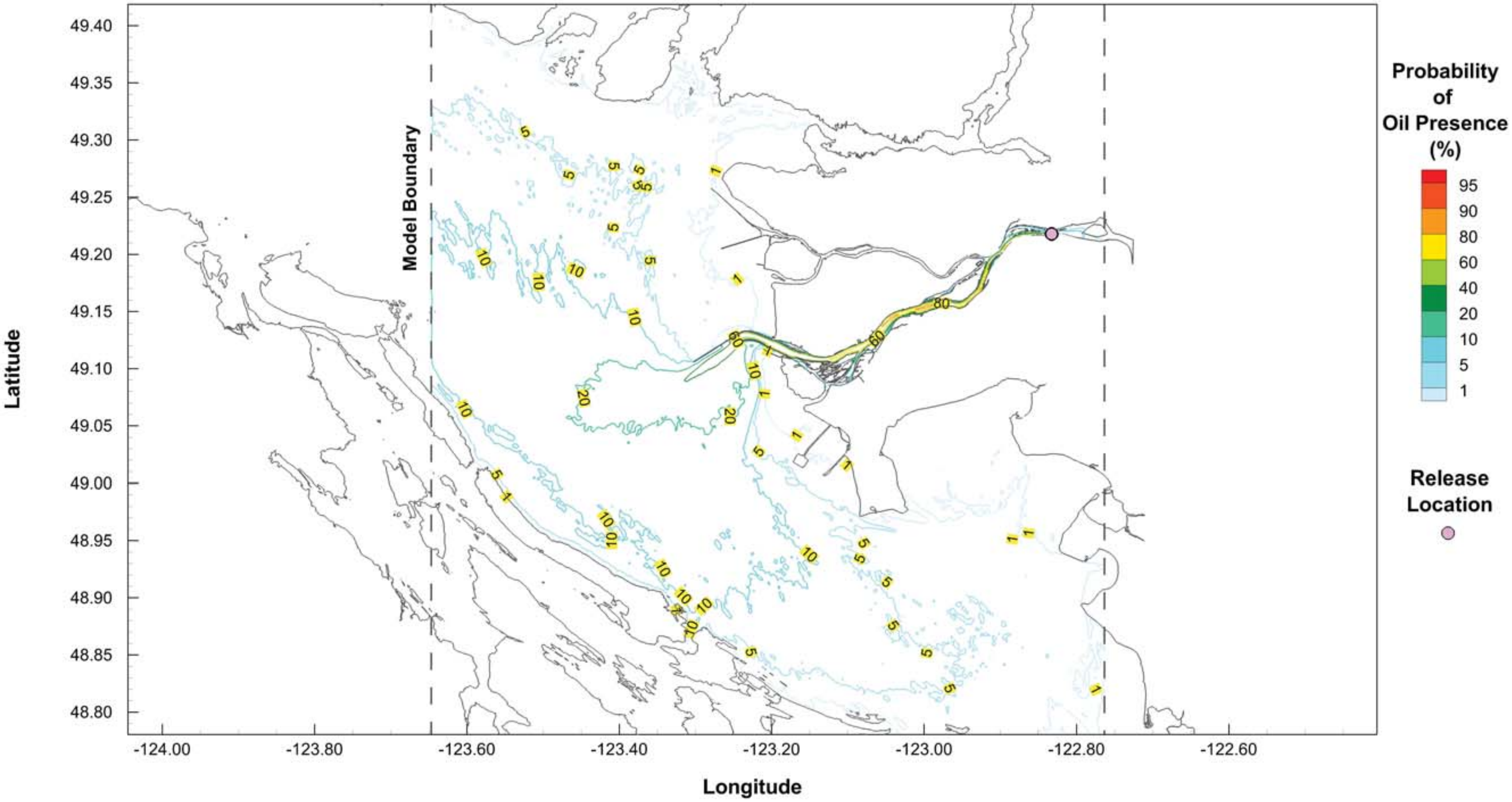
TRANS MOUNTAIN OIL SPILL STUDY

Environmental Conditions: Spring 2012 Site FR Stochastic Modelling

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

OFFICE	DATE
EBA-VANC	October 2013

Figure I.2-1



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.
- Due to the fine scale grid resolution, a smoothing of the fine scale features was applied for better clarity.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Probability of Oil Presence

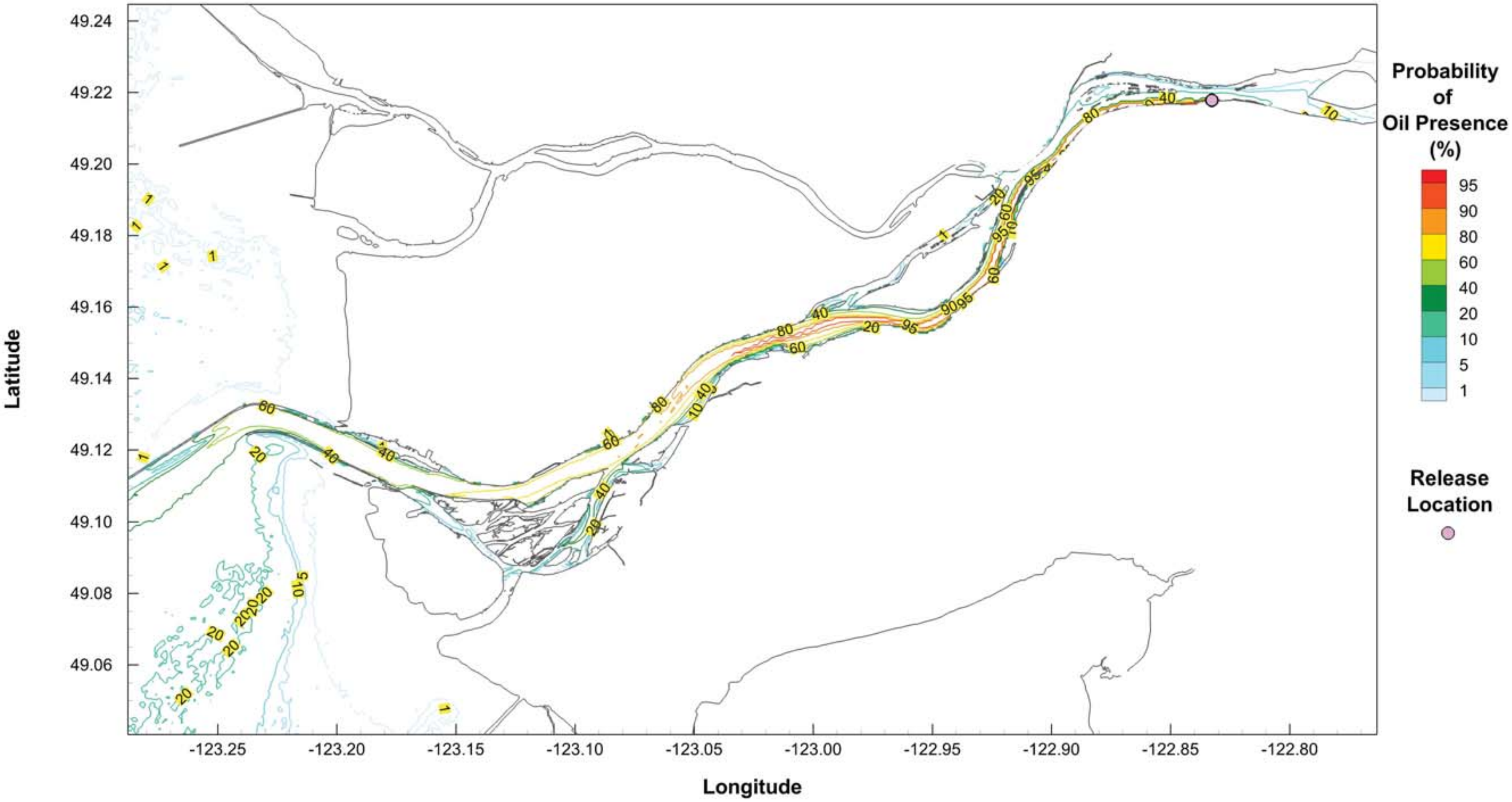
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 29, 2013

Figure FR.2-2

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Spring\Tecplot\02-stochastic_map_lines_smooth.lay

30 Oct 2013 10:51:14



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

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A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation Spring 2012, Site FR (1,250 m^3) Probability of Oil Presence

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

OFFICE	DATE
EBA-VANC	October 29, 2013

Figure FR.2-2

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Spring\Tecplot\02-stochastic_map_lines_zoom.lay

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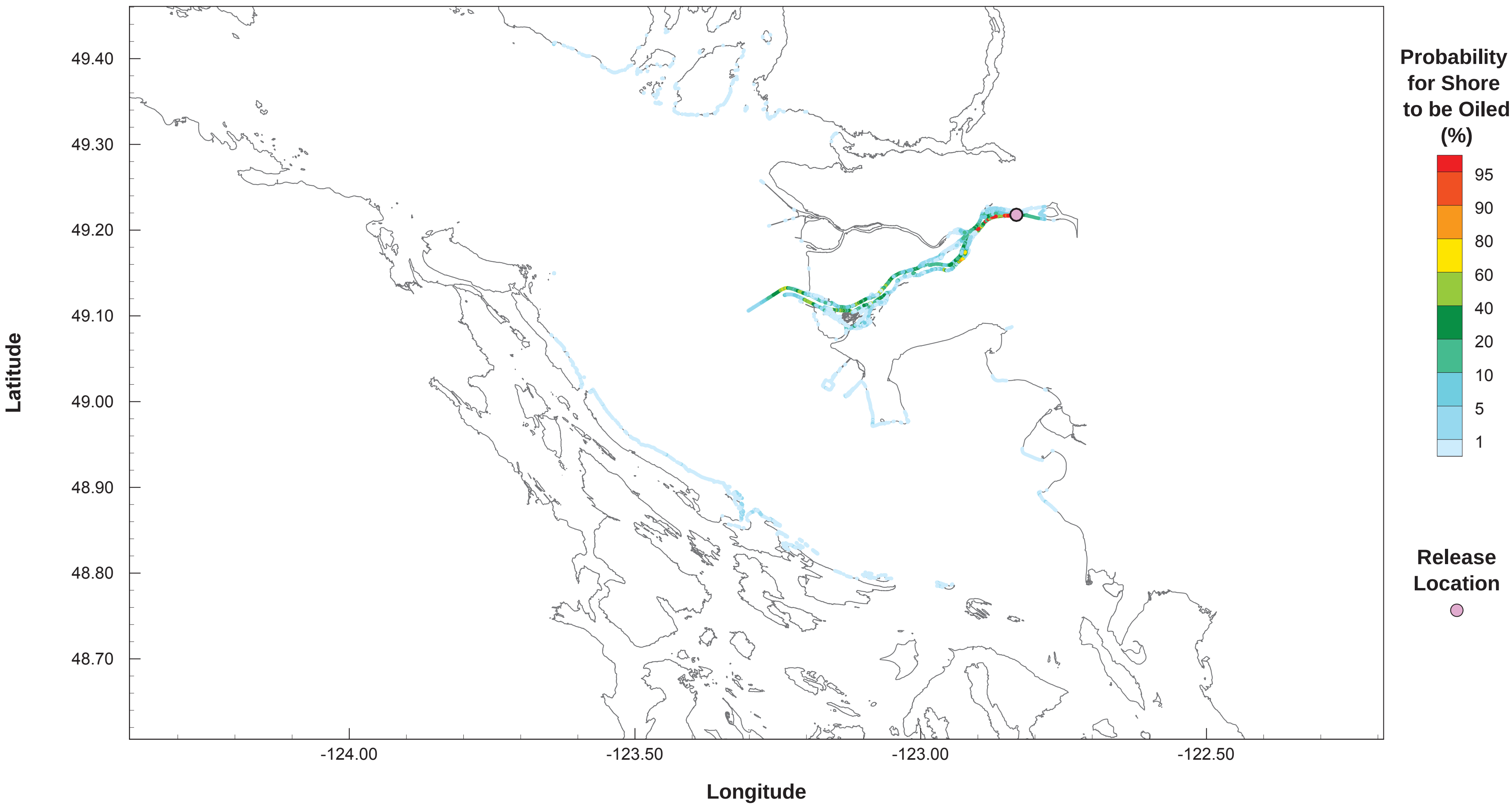


NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

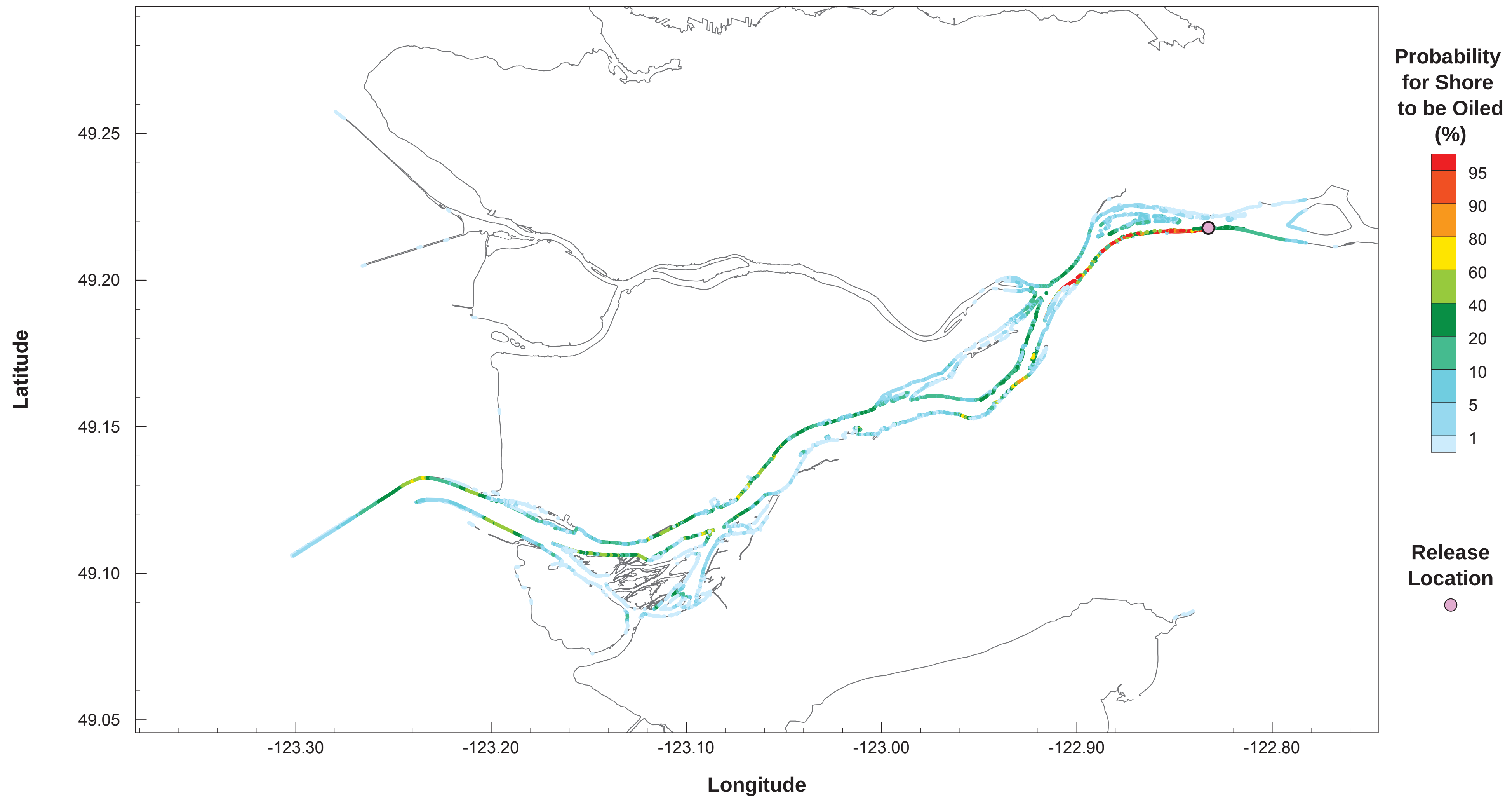
Stochastic Simulation Spring 2012, Site FR (1,250 m^3) Shoreline Oiled Probability

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

OFFICE	DATE
EBA-VANC	October 30, 2013

Figure FR.2-3

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Spring\Tecplot\03-shore_prob.lay 30 Oct 2013 09:11:03



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

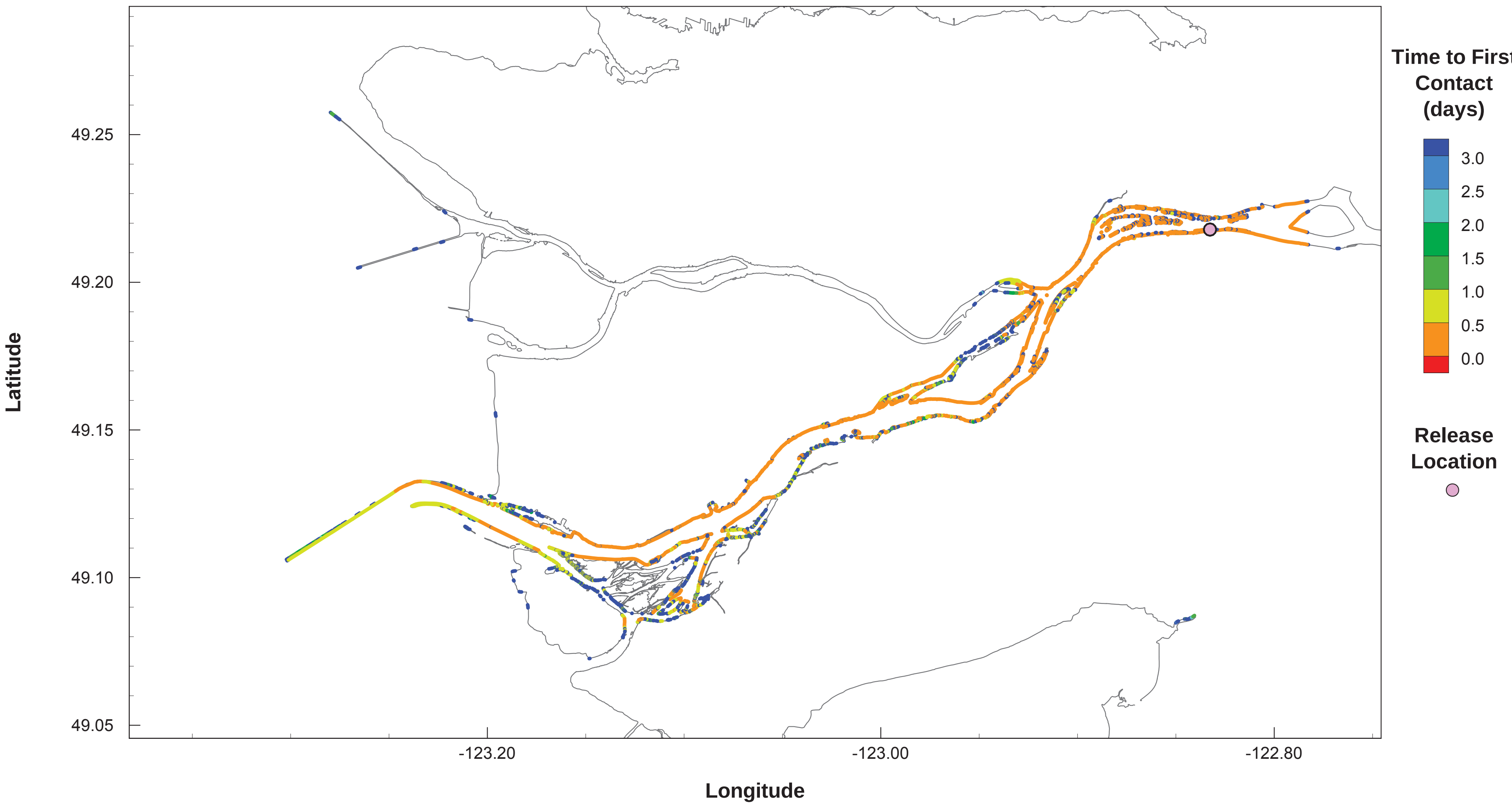
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Shoreline Oiled Probability

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-3



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.
- Time to first contact is the minimum time, over all simulations, for oil to reach a given shore segment.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Shoreline Time to First Contact

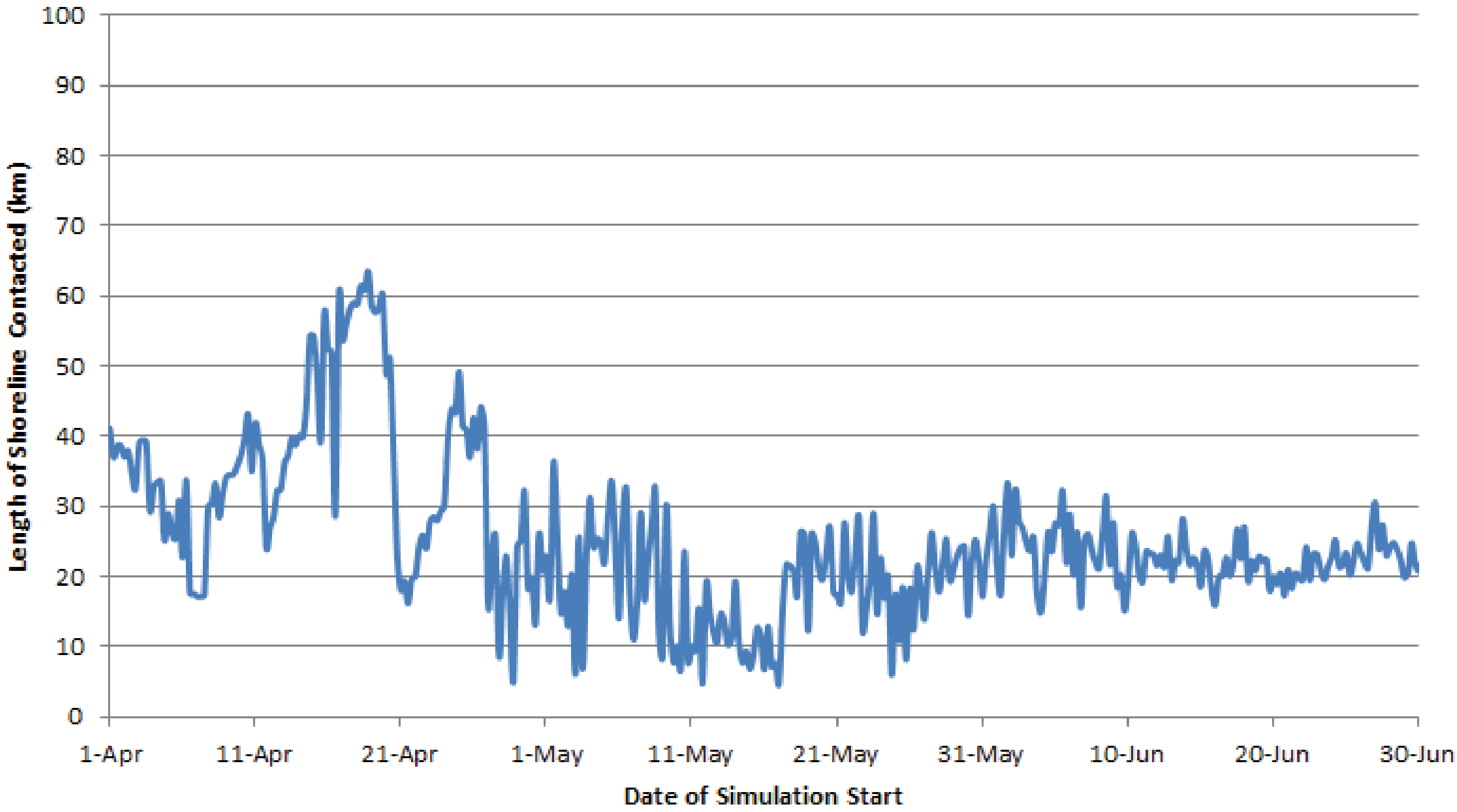
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-4

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Spring\Tecplot\04-shore_firstcontact.lay

24 Oct 2013 11:42:00



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

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TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Length of Shoreline Contacted

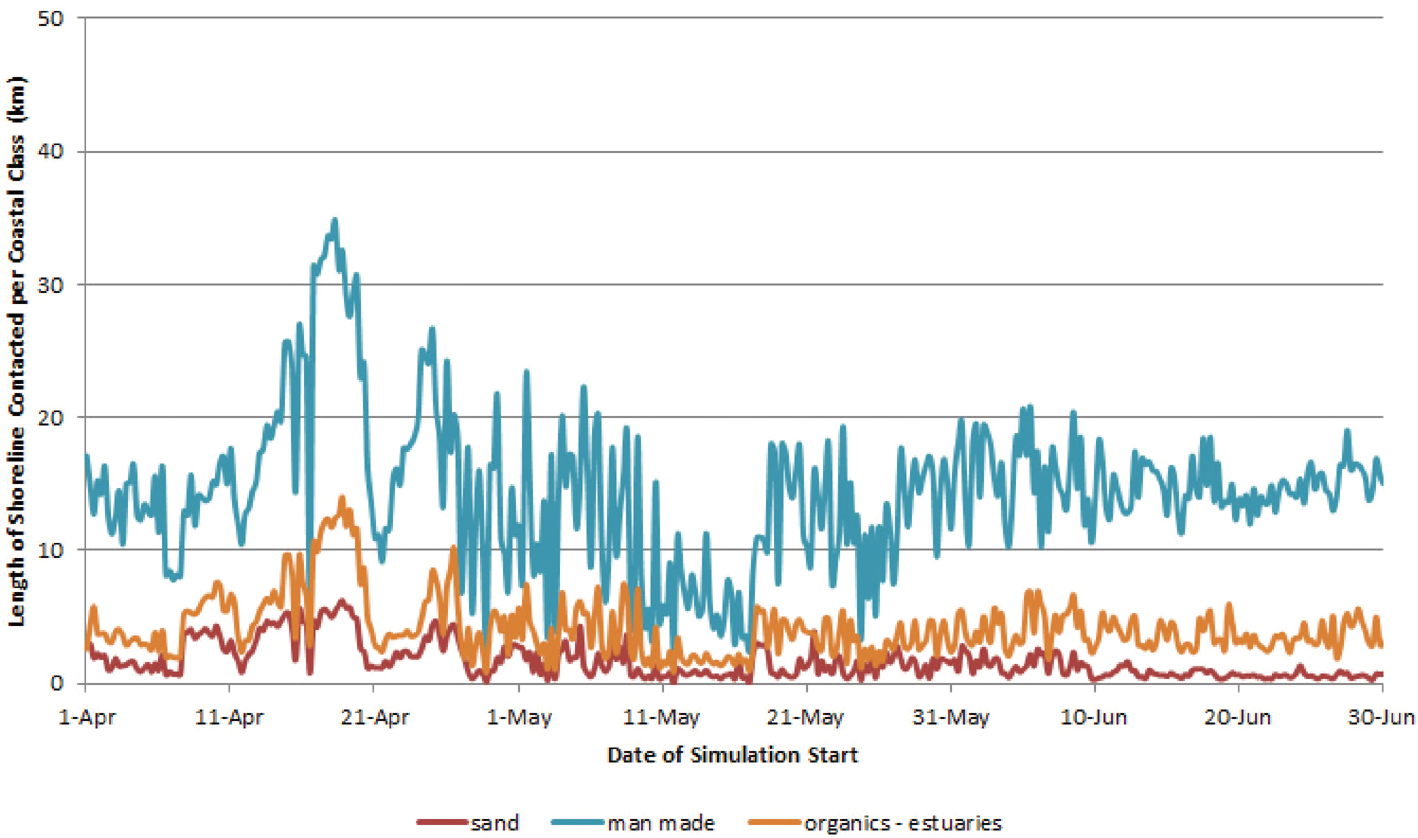
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-5

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Spring\Tecplot\05-shore_km.lay

24 Oct 2013 11:42:13



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

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A TETRA TECH COMPANY

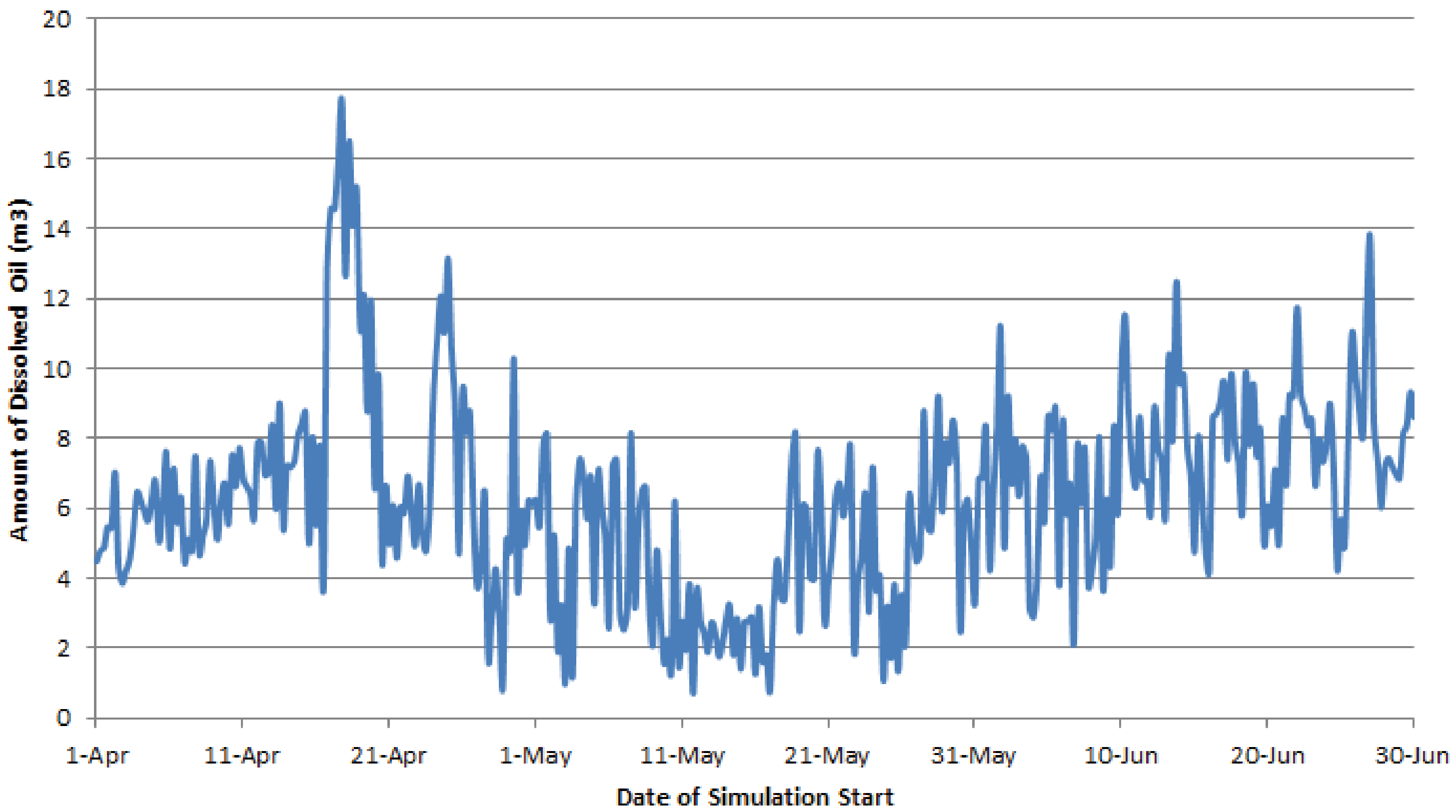
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation - Spring 2012 Site FR (1,250 m^3): Length of Shoreline Contacted Per Coastal Class

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-6



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

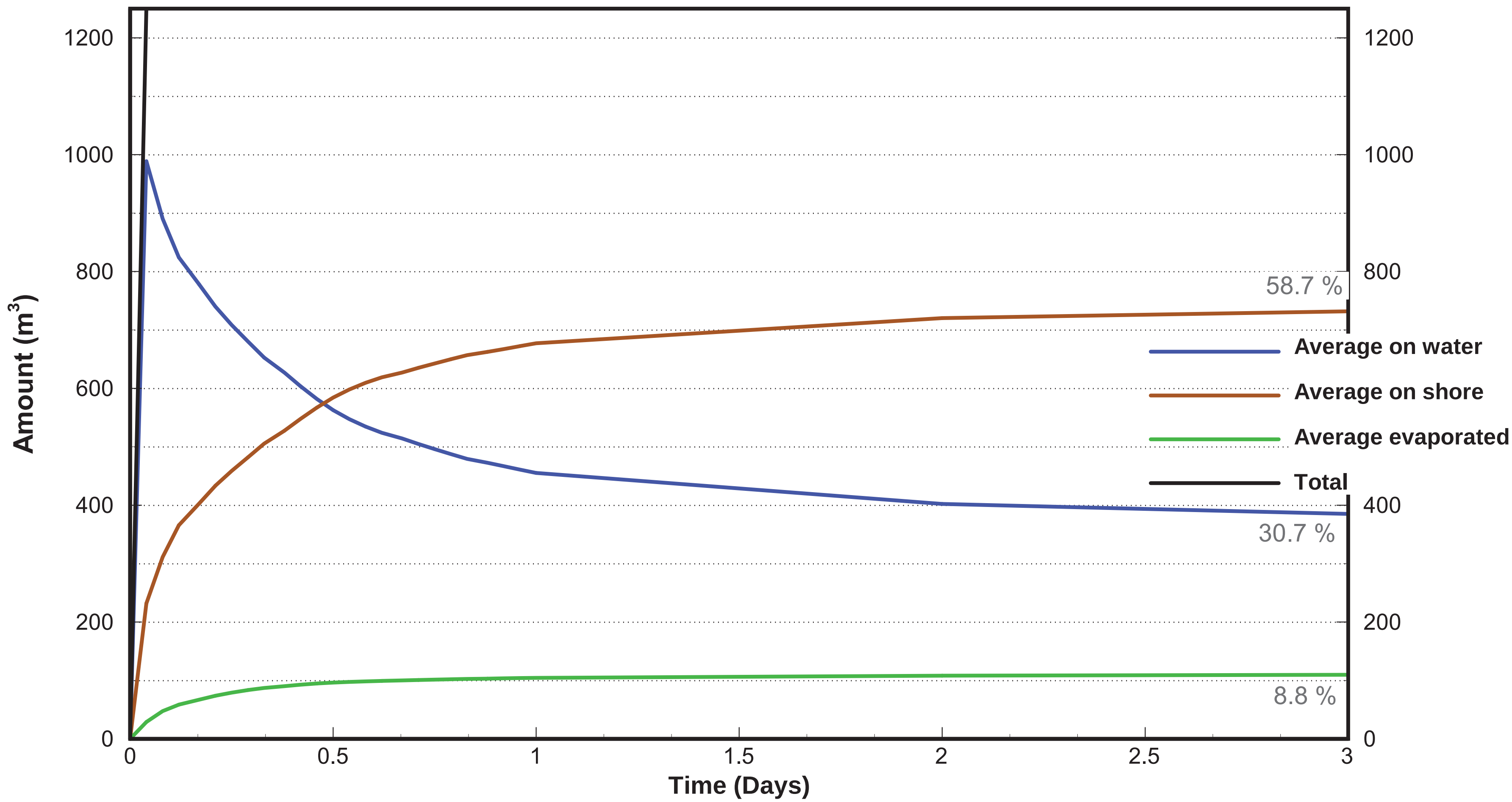
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Amount of Dissolved Oil

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-7



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 3 days.
- The major components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

A TETRA TECH COMPANY

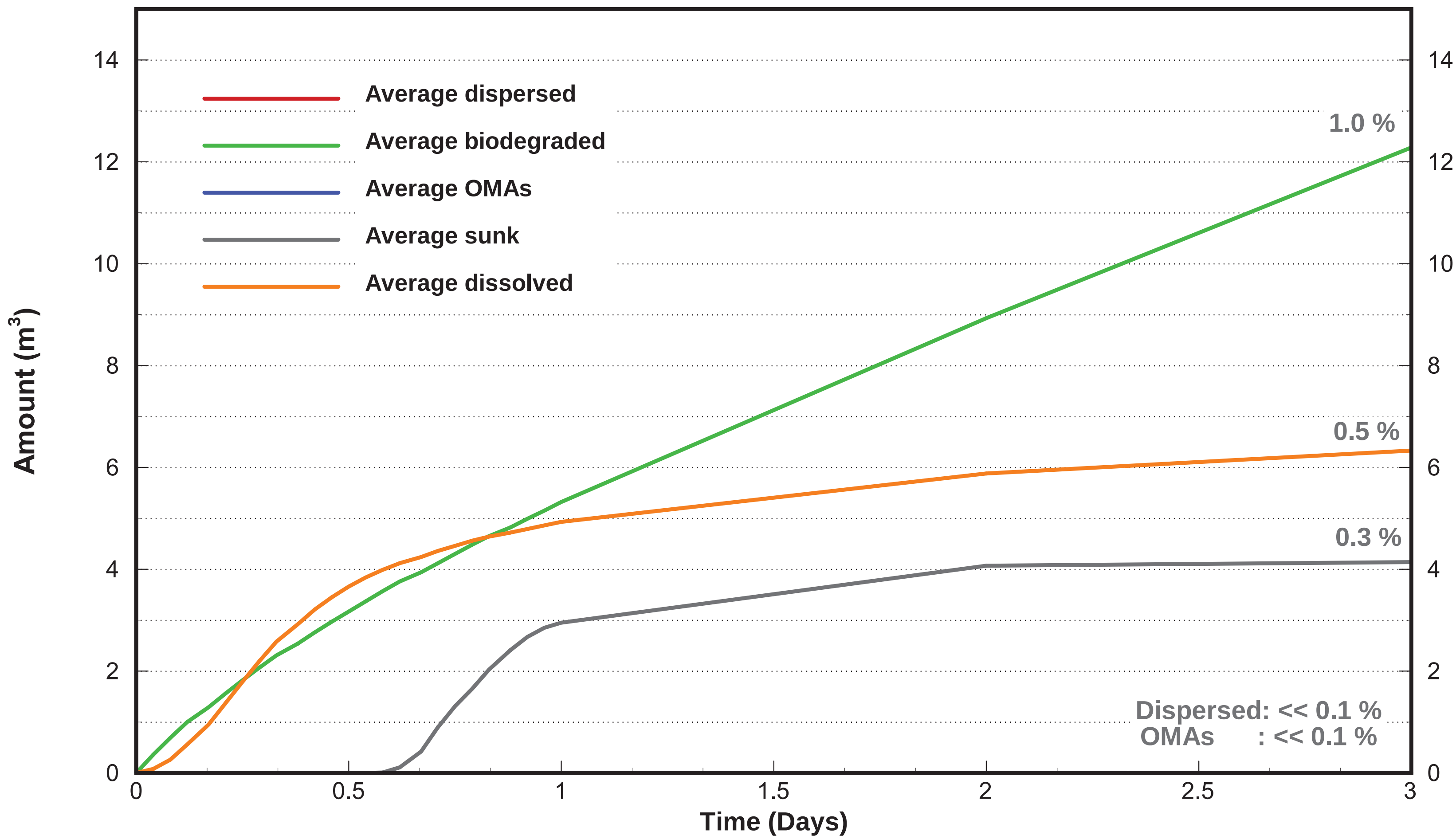
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Major Components of the Mass Balance

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-8



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.
- Tracking time for each spill was 3 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

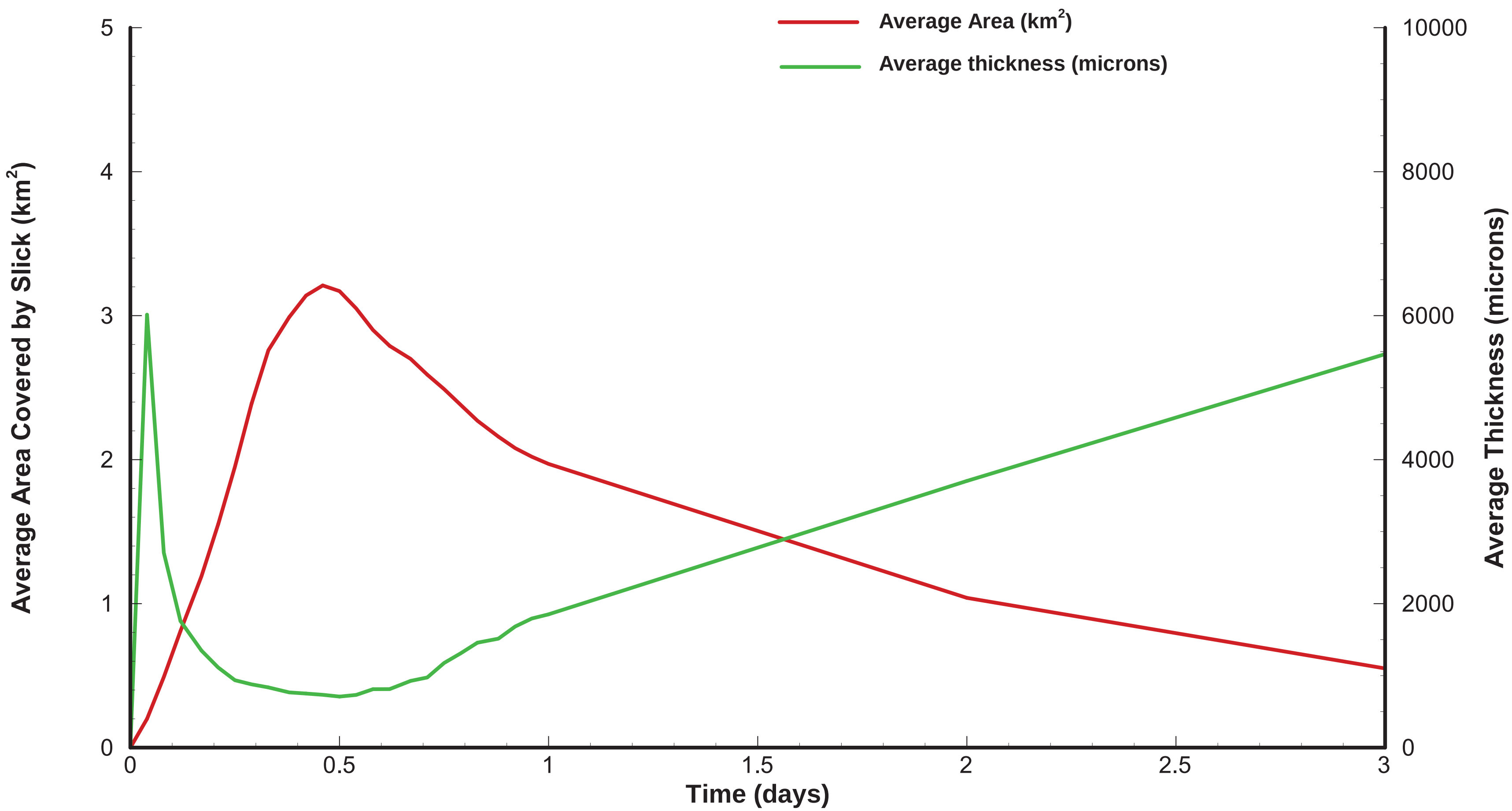
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Minor Components of the Mass Balance

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-9



NOTES

- Statistical results based on independent spills occuring every 6 hours from April 01 00:00 to June 30 23:00, for a total of 364 independant spills.

- The average thickness is based on a full coverage of each grid cell that contains oil.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

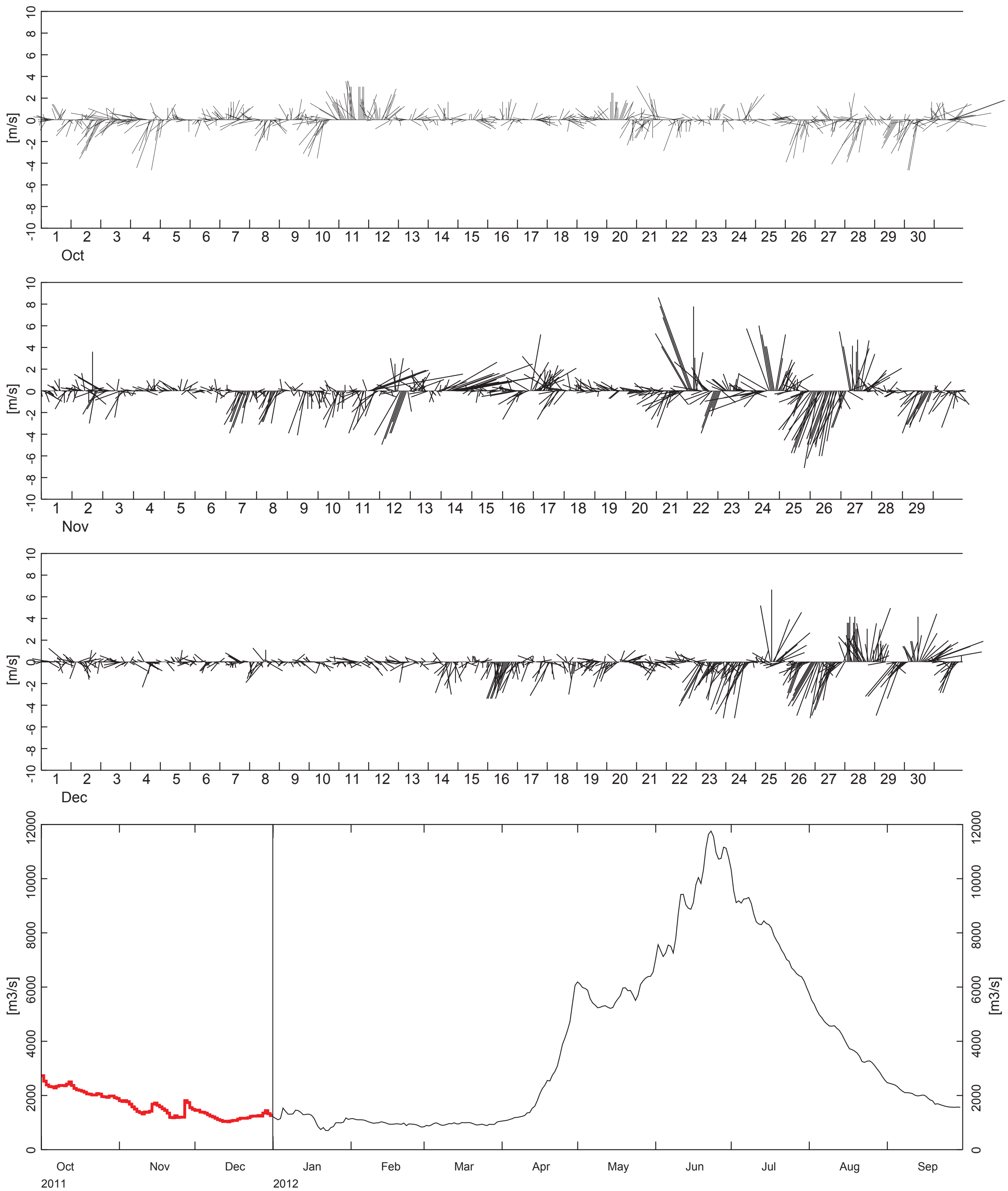
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Spring 2012, Site FR (1,250 m^3)
Statistics on Area and Thickness

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.2-10



NOTES

- The wind stick represent winds at Pitt Meadows.
- The bottom graph represents the Fraser River discharge at Hope.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANS MOUNTAIN

A TETRA TECH COMPANY

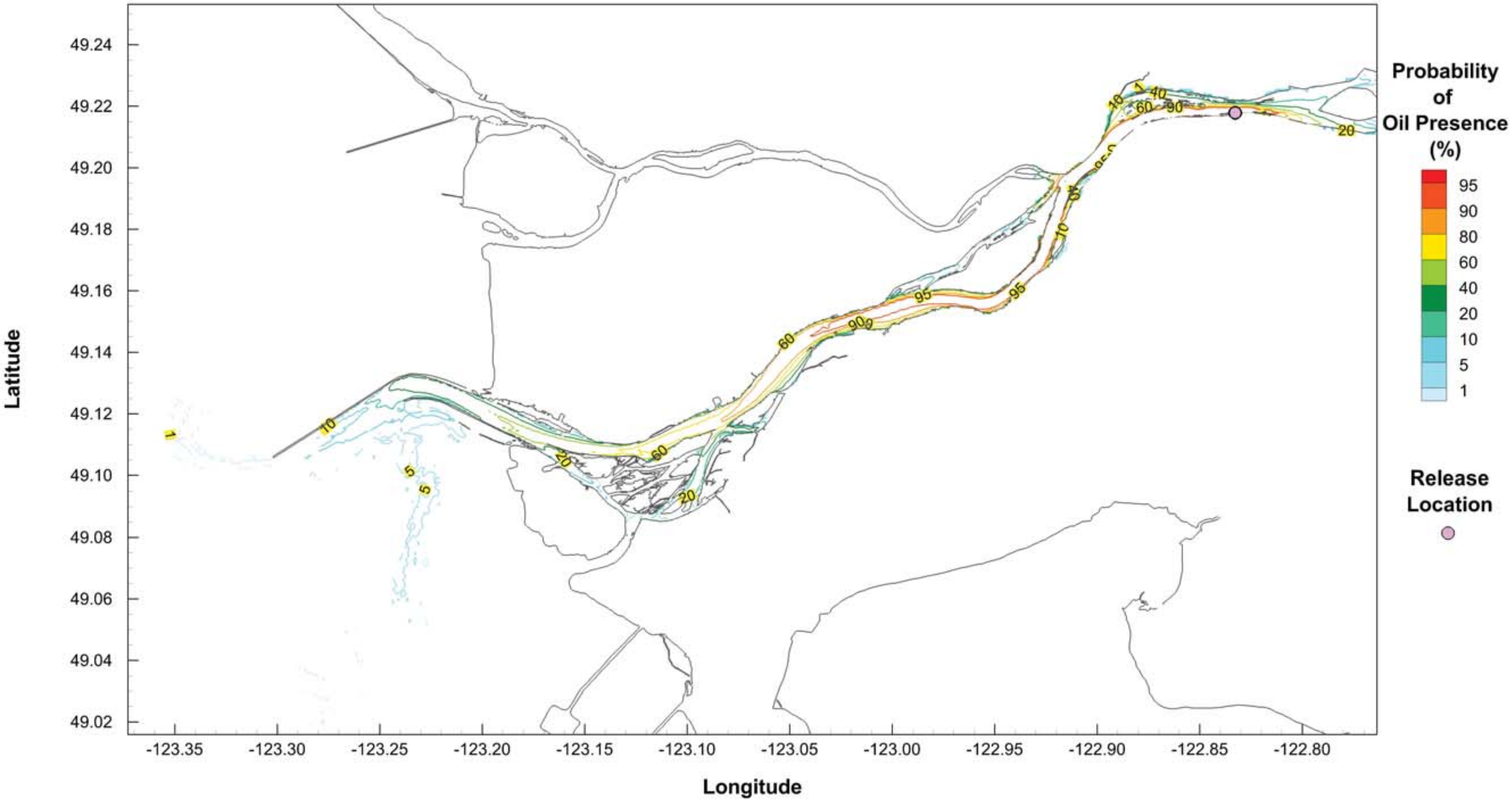
TRANS MOUNTAIN OIL SPILL STUDY

Environmental Conditions: Fall 2011 Site FR Stochastic Modelling

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

OFFICE	DATE
EBA-VANC	October 2013

Figure I.4-1



NOTES

- Statistical results based on independent spills occuring every 6 hours from October 01 00:00 to December 31 23:00.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Probability of Oil Presence

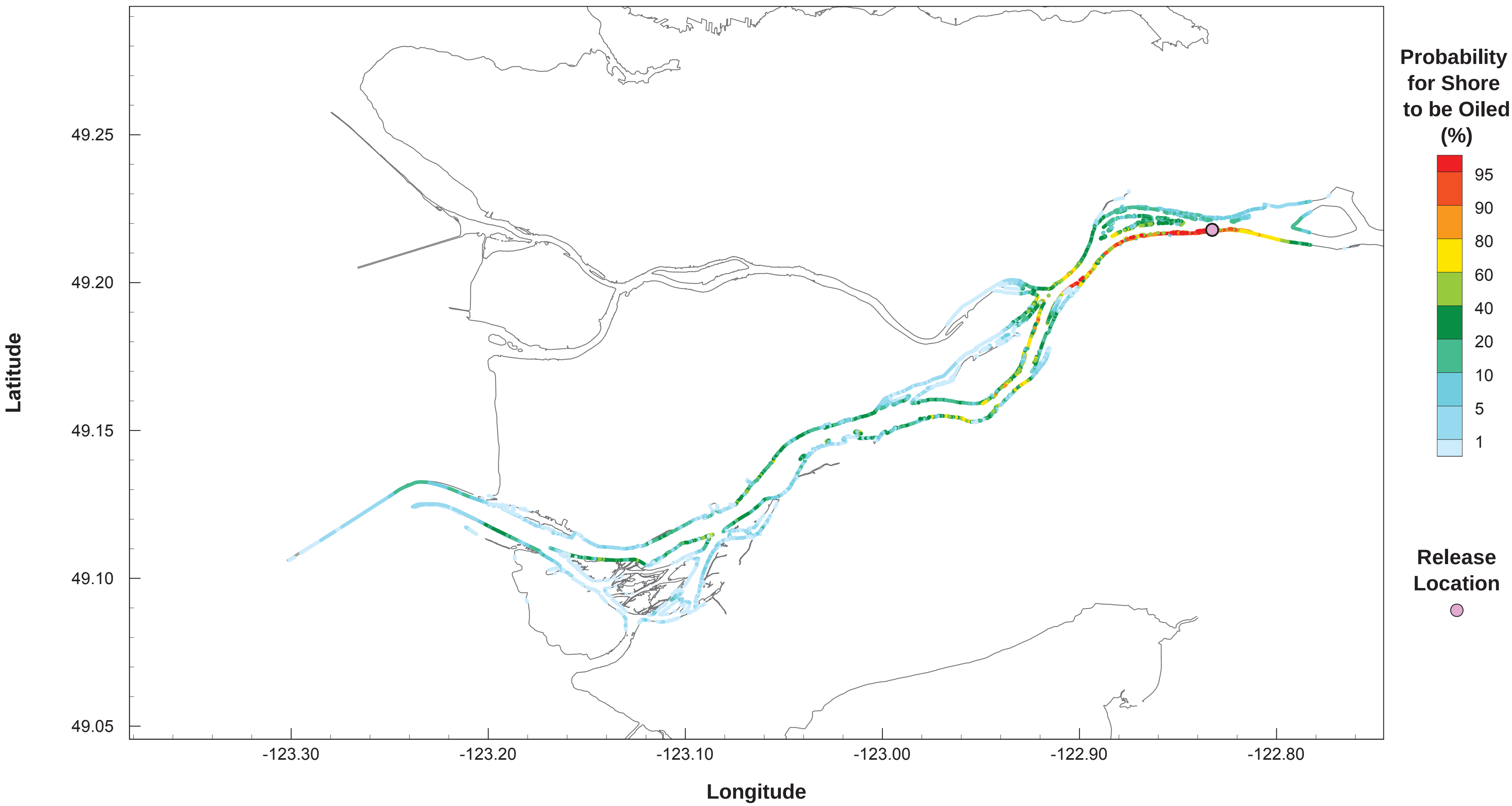
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE: EBA-VANC
DATE: November 6, 2013

Figure FR.4-2

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Fall\Tecplot\02-stochastic_map_lines_zoom.lay

06 Nov 2013 16:08:42



NOTES

- Statistical results based on independent spills occuring every 6 hours fromOctober 01 00:00 to December 31 23:00, for a total of 368 independant spills.
- Probability of oil presence is the percentage of simulations in which oil was present at a given location.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Shoreline Oiled Probability

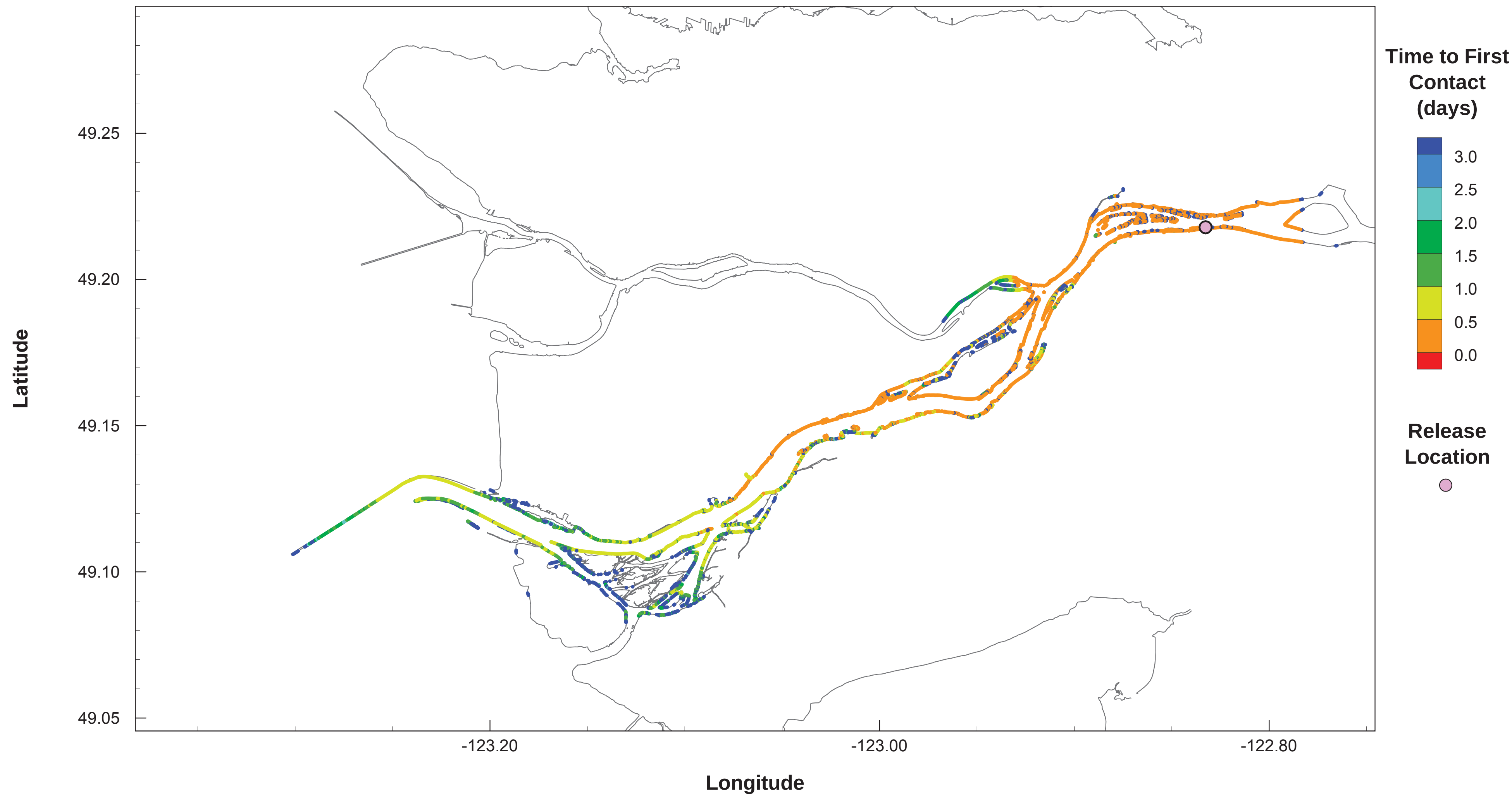
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.4-3

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Fall\Tecplot\03-shore_prob.lay

24 Oct 2013 14:16:00



NOTES

- Statistical results based on independent spills occuring every 6 hours fromOctober 01 00:00 to December 31 23:00, for a total of 368 independant spills.
- Time to first contact is the minimum time, over all simulations, for oil to reach a given shore segment.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Shoreline Time to First Contact

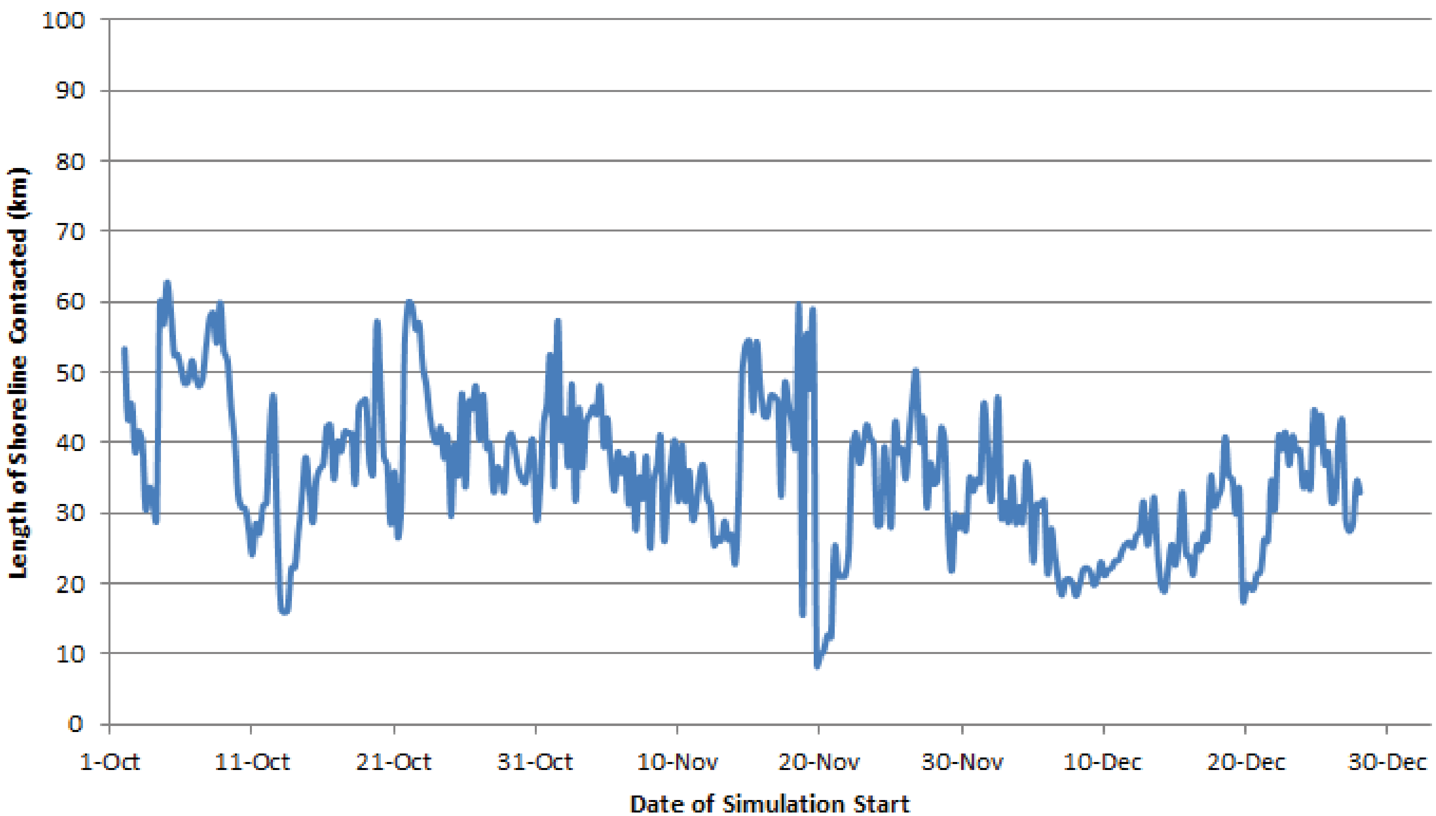
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	AH	JAS	-	0

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.4-4

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Fall\Tecplot\04-shore_firstcontact.lay

24 Oct 2013 14:15:42



NOTES

- Statistical results based on independent spills occuring every 6 hours fromOctober 01 00:00 to December 31 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

A TETRA TECH COMPANY

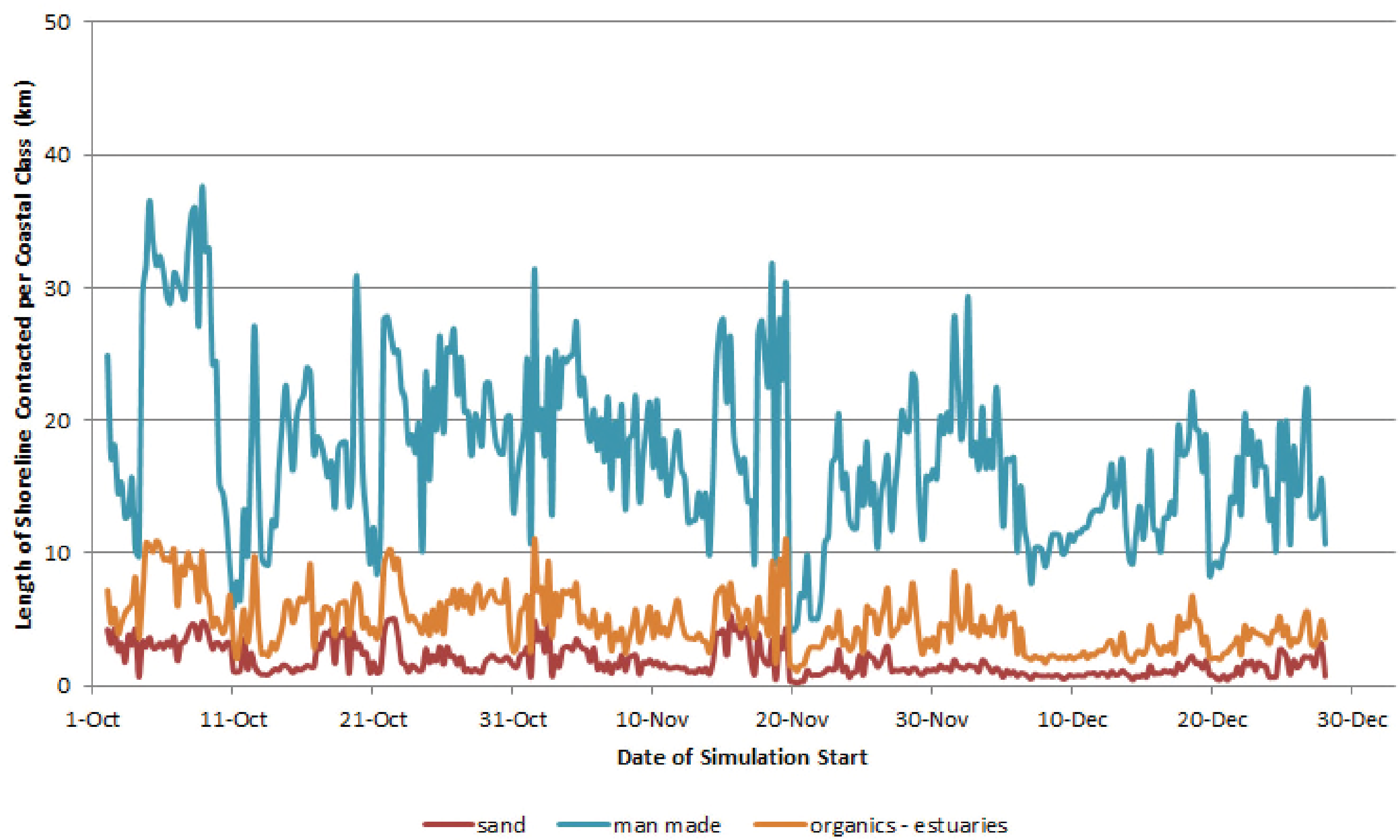
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Length of Shoreline Contacted

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

OFFICE	DATE
EBA-VANC	October 24, 2013

Figure FR.4-5



NOTES

- Statistical results based on independent spills occuring every 6 hours fromOctober 01 00:00 to December 31 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

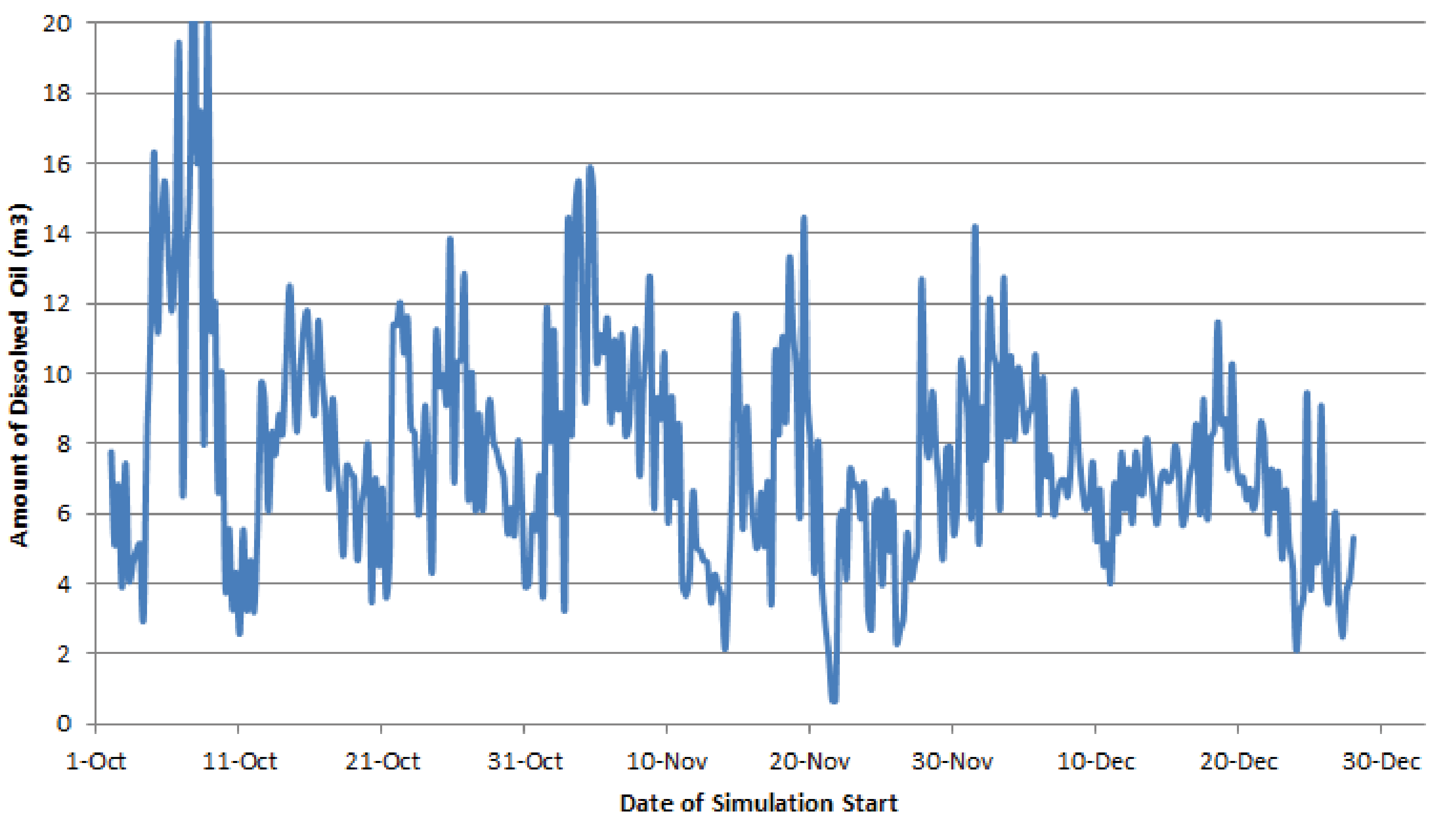
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation - Fall 2011
Site FR (1,250 m^3): Length of Shoreline Contacted Per Coastal Class

PROJECT NO.	DWN	CKD	APVD	REV
□13203022	□□	□□S	-	0

OFFICE	DATE
□□□-□□□□	October 2□, 2013

Figure FR.4-6



NOTES

- Statistical results based on independent spills occuring every 6 hours from October 01 00:00 to December 31 23:00, for a total of 368 independant spills.

- Tracking time for each spill was 3 days.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

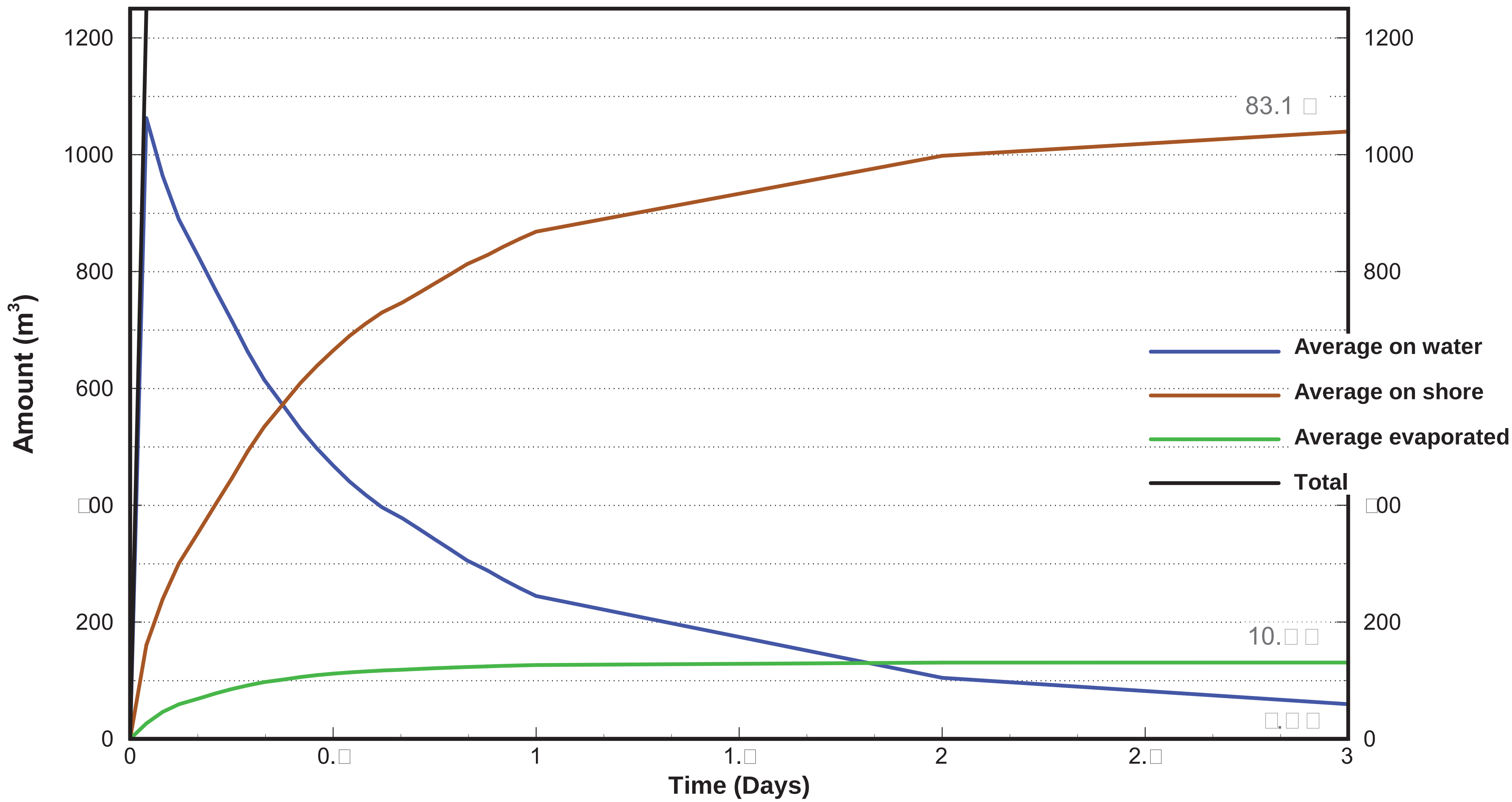
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Amount of Dissolved Oil

PROJECT NO.	DWN	CKD	APVD	REV
□13203022	□□	□□S	-	0

OFFICE	DATE
□□□-□□□□	October 2□, 2013

Figure FR.4-7



NOTES

- Statistical results based on independent spills occuring every 6 hours from October 01 00:00 to December 31 23:00, for a total of 368 independant spills.

- Tracking time for each spill was 3 days.

- The ma□or components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

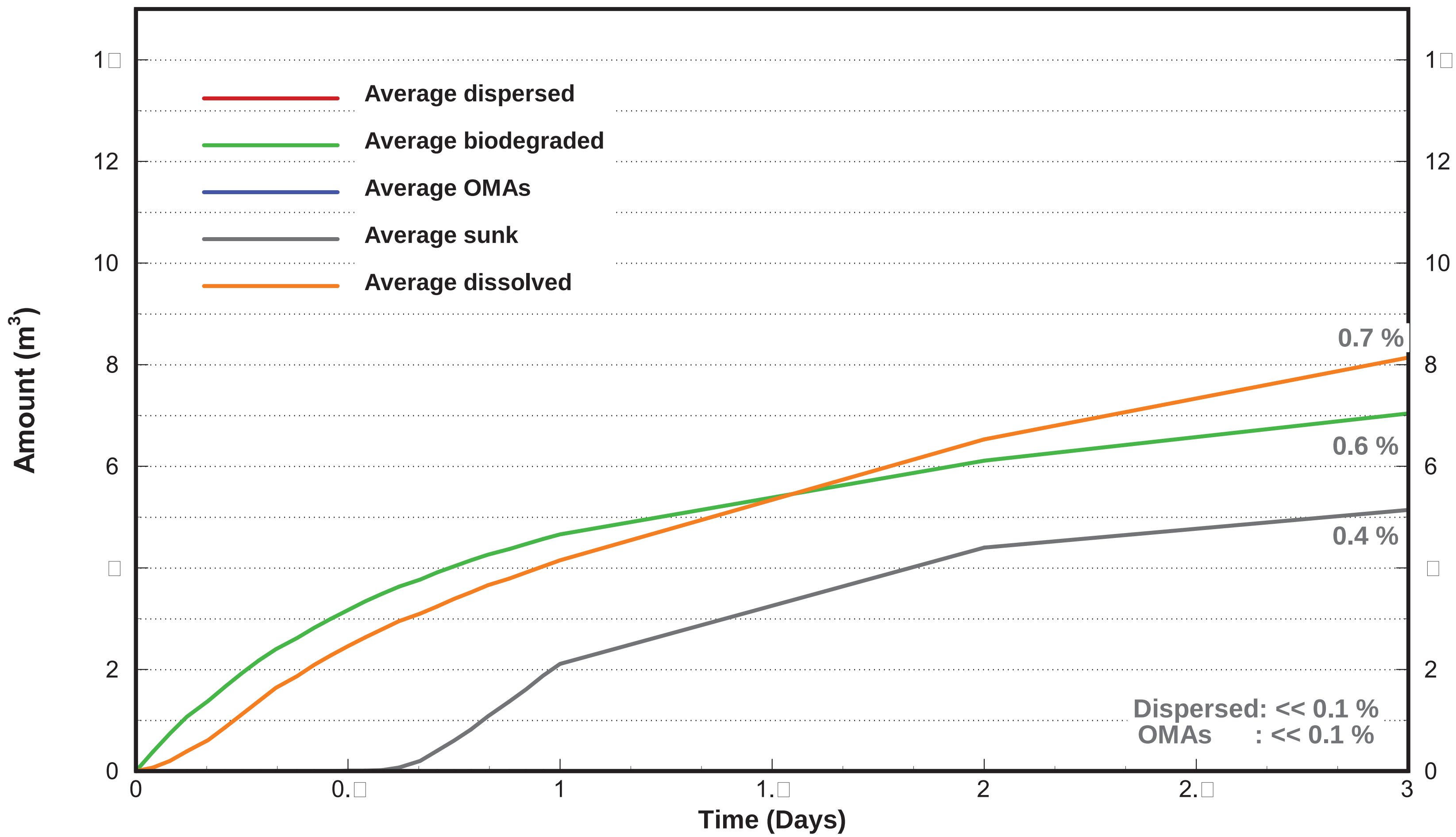
TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Major Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
□13203022	□□	□□S	-	0

OFFICE	DATE
□□□-□□□□	October 2□, 2013

Figure FR.4-8



NOTES

- Statistical results based on independent spills occuring every 6 hours from October 01 00:00 to December 31 23:00, for a total of 368 independant spills.
- Tracking time for each spill was 3 days.
- The minor components of the mass balance are shown above.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

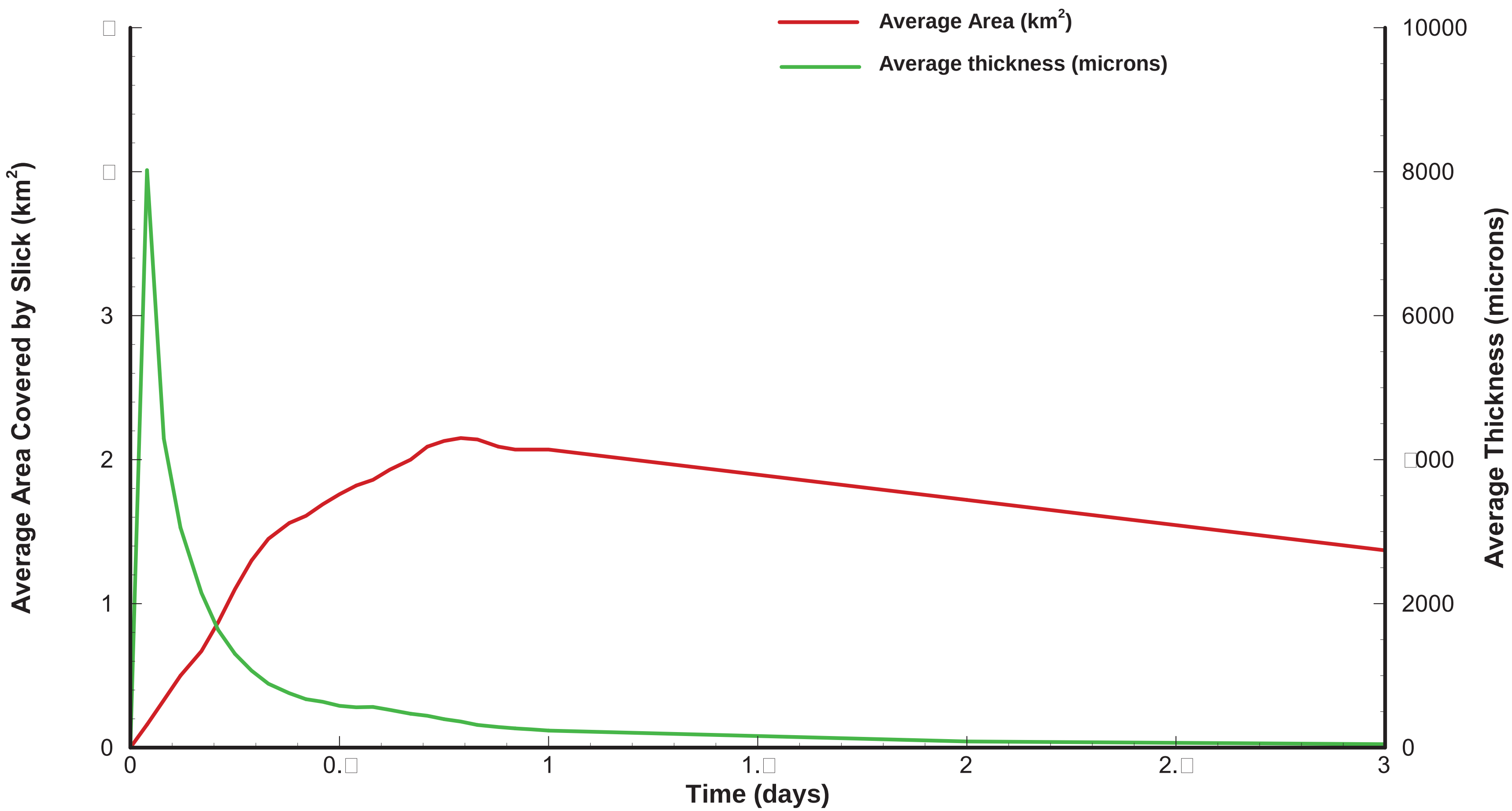
Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Minor Components of the Mass Balance

PROJECT NO.	DWN	CKD	APVD	REV
13203022		S	-	0

OFFICE	DATE
	October 2, 2013

Figure FR.4-9

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Fall\Tecplot\09-statistics_MB_2.lay
24 Oct 2013 14:14:25



NOTES

- Statistical results based on independent spills occuring every 6 hours fromOctober 01 00:00 to December 31 23:00, for a total of 368 independant spills.
- The average thickness is based on a full coverage of each grid cell that contains oil.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Stochastic Simulation
Fall 2011, Site FR (1,250 m^3)
Statistics on Area and Thickness

PROJECT NO.	DWN	CKD	APVD	REV
[illegible]13203022	[illegible]	[illegible]S	-	0

OFFICE	DATE
[illegible]	October 2[illegible], 2013

Figure FR.4-10

T:\TMEP\working\AH\02-SPILLCALC\560-Stochastic_Fraser\Results_Fall\Tecplot\10-statistics_thk.lay

24 Oct 2013 14:12:14

Appendix C: Recovery Assessment

C.1. Recovery Assessment

The objective of the Recovery Assessment is to assess the likelihood of recovery of ecosystem components or ecological receptors in the event of an accidental pipeline release of heavy crude oil as a result of the Project. The definition of recovery after an oil spill is subject to interpretation. Science and policy must be integrated to define desirable system endpoints. For the purposes of this report, the definition of recovery used is the return of the ecosystem component or ecological receptor to a state that "would have been" if the spill had not occurred.

Previous studies on the recovery of the freshwater environment after an oil spill provide a basis for evaluating the likelihood of recovery following a hypothetical pipeline spill resulting from the Project. Similar to the approach described in the Exposure Assessment (Section 6.2), a literature review was conducted to identify and acquire information on the recovery of the freshwater environment for simulated and actual oil spills. From the scientific literature in peer reviewed journals, government reports and technical documents, case studies of oil releases were selected using the following set of criteria:

- Occurred in a freshwater environment
- Located in a cold temperate zone or subarctic location
- Spilled oil had similar physical and chemical properties as the product assessed in the ERA

For each case study, an effort was made to collect the following information:

- Which ecological receptors were affected?
- What was the reported effect?
- Was recovery reported?
- If the ecological receptor recovered, what processes were involved?
- Were there obstacles or complicating factors that impeded recovery?
- Were there attempts to intervene to accelerate recovery?
- How long did the recovery take?

While it was not possible to match all three of the desired criteria for each case study, each case study was considered to have relevance to the Project (Table C.1). The Recovery Assessment is organized to evaluate recovery potential and timelines using the same ecosystem components and ecological receptors as for the Effects Assessment.

TABLE C.1 CASE STUDIES SELECTED IN THE ASSESSMENT OF THE RECOVERY OF THE FRESHWATER ENVIRONMENT AFTER AN OIL SPILL

Oil Spill	Location	Year	Release Platform	Oil Type	Volume (m^3)
Northern Gateway Project	Alberta/British Columbia, Canada	N/A (Oil Spill Simulations)	Pipeline Full-bore Ruptures	Diluted Bitumen, Synthetic Oil, Condensate	Various
Kalamazoo River	Michigan, USA	2010	Pipeline Full-bore Rupture	Diluted Bitumen	3,200
Wabamun Lake	Alberta, Canada	2005	Rail Accident	Bunker "C"	712
East Walker River	California/Nevada, USA	2000	Truck Accident	Bunker "C"	14
Pine River	British Columbia, Canada	2000	Pipeline Full-bore Rupture	Light Crude	985
Yellowstone River	Montana, USA	2011	Pipeline Full-bore Rupture	Light Crude	240
OSSA II	Bolivia, South America	2000	Pipeline Full-bore Rupture	Mixed Crude	4,611
DM 932	Louisiana, USA	2008	Barge Accident	Bunker "C"	1,070

C.1.1. Water Quality

After an oil spill in the aquatic environment, evaporation of the volatile components and dispersion of oil into the water column removes oil from the water surface. Once in the water column, oil has three general fates: first, hydrocarbons dissolve or are entrained in the water column to be diluted and degraded by microbial action; second, droplets dispersed by waves or turbulent conditions may coalesce into larger droplets and float back to the water surface; or third, dispersed oil droplets may accumulate suspended particulate matter in the water column becoming submerged oil, or sinking to the sediments.

Modelling conducted for the Enbridge Northern Gateway Project found that after the acute phase of a spill (days to 2 weeks), hydrocarbon concentrations in river water rapidly declined so that they would not be expected to cause acute or chronic effects to aquatic biota (Stantec *et al.* 2012). Water quality in larger rivers recovered faster than smaller rivers, which were more affected by chronic residual hydrocarbon concentrations. The highest chronic TPH concentration in river water (0.16 mg/L) was predicted for a release of synthetic oil into Crooked River under a high flow conditions at a distance of 3.9 km downstream from the spill location. Due to its higher viscosity and greater resistance to dispersion, spilled diluted bitumen resulted in lower predicted chronic hydrocarbon concentrations in river water than synthetic oil.

The Kalamazoo River oil spill in July 2010 released approximately 3,200 m^3 of heavy crude oil (primarily a CLWB) into the Kalamazoo River under turbulent conditions, which resulted in high rates of entrainment into the water column. Within two months of the spill thousands of surface water samples had been collected and analyzed. The majority of these samples showed non-detectable concentrations of hydrocarbon constituents. Only the following chemicals exceeded applicable human health-based guidelines (Michigan Department of Community Health [MDCH] 2013), and it was by no means certain that the spilled oil was the source of the detected chemicals:

- 1,2,4-Trimethylbenzene (2 out of 1,686 samples)
- Benzo(a)anthracene (1 out of 1,957 samples)
- Benzo(a)pyrene (2 out of 1,957 samples)
- Bis(2-ethylhexyl)phthalate (30 out of 1,671 samples)
- Chromium (25 out of 1,425 samples)
- Chrysene (1 out of 1,957 samples)
- Lead (2 out of 1,098 samples)
- n-Nitrosodi-n-propylamine (1 out of 1,671 samples).

Samples collected up to five months after the spill (*i.e.,* October through December 2010) were all below applicable guidelines (MDCH 2013). Two samples collected one year after the spill (May to August 2011) were above guidelines for benzo(a)pyrene; however, results indicate that overall water quality had recovered within five months after the spill.

Following the August 2005 Wabamun Lake oil spill, notwithstanding the initial distribution of oil on the water surface and tar balls in near-shore areas, monitoring of water quality in the lake found few indications of hydrocarbon contamination in the water column within six weeks. Overall, the water in the open water area of the lake was reported not to be contaminated with spilled hydrocarbons or heavy metals (Anderson 2006).

Immediately after the December 2000 release of Bunker “C” fuel oil into the East Walker River, water sampling revealed TPAH concentrations in the river that were greater than toxicity thresholds for developmental effects on fish embryos (one sample recording 4.9 μg/L and another recording 1.4 μg/L). However, within five months (May 2001), dissolved TPAH in the water column had decreased to near background concentrations; the highest reported concentration was 0.035 μg/L (Higgins 2002).

Following the August 2000 release of light crude oil into the Pine River, analytical results from surface water samples showed that water quality had returned to pre-spill conditions within three weeks after the spill (de Pennart *et al.* 2004). In addition, fish were reported to be returning to the main stem of the river within two weeks of the spill (BC MOE 2000b).

Surface water samples collected in the days following the July 2011 Yellowstone River spill showed there were no petroleum-related compounds remaining in the water (USEPA 2011a). These results were expected given the high flow conditions and rapid initial weathering of the oil. As of November 9, 2011, surface water samples from 164 locations were collected by the USEPA, Montana Department of Environmental Quality and ExxonMobil. With few exceptions, all samples were “non-detect” or below applicable water quality standards or screening levels for petroleum hydrocarbons (MDEQ 2013). In addition, operators of downstream public drinking water systems, which drew water from the river, were notified of the spill; however, monitoring and testing of the water supply systems did not identify any exceedances of drinking water standards (USEPA 2011d).

Water samples collected from the Rio Desaguadero after the January 2000 release of mixed heavy crude oil and diluent from the OSSA II pipeline showed no detectable concentrations of hydrocarbons within one month of the spill (Henshaw *et al.* 2001), indicating that water quality had recovered from the release.

Following the July 2008 collision of a chemical tanker with the DM 932 fuel barge, the Mississippi River was closed to vessel traffic. For the protection of human health, downstream drinking water intakes were closed; however, all drinking water intakes were reopened by July 30 (USFWS 2009), indicating that water quality was below applicable human health-based guidelines.

The evidence shows that water quality typically recovers within days to weeks following an oil spill to inland waters.

C.1.2. Sediment Quality

Hydrocarbons are hydrophobic and partition strongly between water and other available non-polar media, including sediment organic matter. Once dispersed in the water column, oil droplets may accumulate enough suspended particulate matter to become as dense as, or denser than water, becoming submerged oil. Sedimentation results when this oil settles out of the water column onto the riverbed, usually in quiescent areas of silty sediment. Contaminated sediments have the potential to negatively affect water quality in sediment pore water, which can affect benthic invertebrates, rooted aquatic plants, and developing fish eggs. Oil can also re-contaminate the water, if the sediment is disturbed.

Modelling results for the Enbridge Northern Gateway Project show that hydrocarbon concentrations in sediment vary greatly as a function of distance from the release; river size (small or low-gradient rivers generally experience greater oil sedimentation than larger or high-gradient rivers); sediment characteristics (high organic content and fine-grained sediments trap and retain more hydrocarbons); and oil type (diluted bitumen and synthetic oil were both predicted to have the potential to load heavily to sediments) (Stantec *et al.* 2012).

Modelling conducted by Stantec *et al.* (2012) was completed without taking credit for hydrocarbon containment or recovery during the acute phase of spill modelling, although removal of visible oil on shorelines was assumed during the chronic assessment of spills. The highest hydrocarbon concentrations in sediment were predicted for a release of diluted bitumen into Crooked River under low flow conditions. Very high loadings to sediment were forecast, with concentrations ranging from 430,000 mg/kg at 4 weeks to 270,000 mg/kg at one to two years post release (Stantec *et al.* 2012). The Crooked River represents an extreme case of slow flowing water and organic sediments, such that oil that sank to the sediments was retained, similar to the situation observed in Talmadge Creek following the Kalamazoo River oil spill. Such residual hydrocarbon contamination would require intensive remedial action. Importantly, however, deposition of hydrocarbons to sediment in other aquatic habitats (*e.g.,* flowing waters with gravel or cobble substrates) was estimated to be low, rarely exceeding toxicity thresholds for developing fish eggs and embryos, and recovering within weeks to a few months due to weathering out of more soluble hydrocarbon constituents.

Weathering of the crude oil released in the Kalamazoo River oil spill resulted in sedimentation of a portion of the released oil in both Talmadge Creek and the Kalamazoo River. In Talmadge Creek, extensive removal of sediment in 2011 removed most if not all of the oil (Enbridge 2013b). In the Kalamazoo River, as the unrecovered oil was transported downstream in the water column, a portion of it incorporated suspended sediments. This oil became part of the river bedload, and was transported toward geomorphological traps in the riverbed, such as silt deposits near in-stream dams (Enbridge 2013b). As of June 2013, the USEPA (2013) estimated that approximately 680,000 litres (180,000 gallons) of submerged oil remained in the river bottom sediment, although this estimate seems improbably large in light of other mass balance estimates of the fate of the spilled oil. Removal of the recoverable portion (approximately 45,000-68,000 litres or 12,000-18,000 gallons) was ordered, principally in relation to the headponds of the Ceresco and Morrow dams. Removal of the remainder was considered likely to result in substantial further damage to the river, so it was to be left in place and monitored (USEPA 2013).

Following the release of Bunker “C” fuel oil into Wabamun Lake in August 2005, the released oil formed tar balls and other aggregates instead of incorporating into the lakebed sediment. Consequently, sediments beneath the open water portions of Wabamun Lake were reported not to have been contaminated with petroleum hydrocarbons, and to be similar in quality to concentrations measured shortly before the spill, or in 2002 (Anderson 2006). In contrast, tarballs and more finely divided oil particles tended to accumulate in reedbeds, where presumably the natural water circulation of the lake was weakest.

Eleven days following the December 30, 2000, East Walker River oil spill, TPAH concentrations measured in sediments ranged from 0.034 to 0.26 mg/kg. Measured concentrations increased substantially in March 2001 (three months after the spill), ranging from 1.3 to 4.6 mg/kg, a phenomenon that was attributed to warming water temperatures and increasing mobilization of the Bunker “C” type oil, which solidified at low temperature. However, by May, 2001 (five months after the spill), measured concentrations ranged from 0.025 to 1.7 mg/kg, and were generally below levels of concern (Higgins 2002).

Clean-up efforts over two months recovered most of the oil released into the Pine River in August 2000, with approximately 450 m^3 removed from the river and 415 m^3 removed with contaminated soil. Despite the effective recovery action, approximately 80 m^3 of the oil, with an uncertainty range of 48 to 113 m^3 remained unaccounted for (BC MOE 2013b, Goldberg 2011). Most of this unaccounted oil was considered likely to be located in river sediments or trapped in woody debris dams within the river. Two years after the August 2000 oil spill in Pine River, although concentrations had decreased over time, hydrocarbons were still detectable in river sediments (de Pennart *et al.* 2004).

Within four months after the July 2011 release of light crude oil in Yellowstone River, sediment samples collected from 146 locations were collected by the USEPA, Montana Department of Environmental Quality and ExxonMobil. With few exceptions, all samples were “non-detect” or below applicable standards or screening levels for petroleum hydrocarbons (MDEQ 2013). These results were expected given the high flow conditions and rapid initial weathering of the oil.

Following the January 2000 release of mixed crude oils into the Rio Desaguadero, sediment samples collected within five months of the spill showed no detectable concentrations of hydrocarbons, except where oil was clearly deposited along strand lines (Henshaw *et al.* 2001). Upon release, high flows resulted in extremely turbulent flow conditions, under which some of the oil would have been transported downstream on the surface, and some would have been entrained in the water column, likely as dispersed droplets (Lee *et al.* 2002). A budget of the fate of the oil indicated that the loss of oil due to evaporation, dissolution and other weathering and degradation processes was on the order of 60% of the total amount spilled (Douglas *et al.* 2002), leaving approximately 1,844 m^3 of weathered oil to account for. Of this, some 1,236 to 1,723 m^3 could not be accounted for in a conventional mass balance. It was concluded, based on additional confirmatory research, that formation of OMAs likely dispersed a large amount of the spilled crude oil, and enhanced the biodegradation of this oil. The Rio Desaguadero is a brackish system, with very high suspended sediment loads. These factors would facilitate the formation of OMAs (Lee *et al.* 2001, 2002).

Information with respect to hydrocarbon concentrations in sediments after the DM 932 oil spill in July 2008 could not be located. However, five days after the spill occurred, routine dredging operations at the Head of Passes were halted upon the discovery of sunken oil in the dredged material (NOAA 2008, USFWS 2009). The high viscosity and low volatile content of the released oil (Bunker "C") caused it to persist in the environment, rather than evaporate. The overall mass balance for the oil suggested that 11% was lost to evaporation, 86% was recovered, and 2.5% of the oil remained unaccounted for in the environment (Danchuk 2009). It was determined that the oil likely interacted with suspended sediments to form OMA and small tar balls, which facilitated its dispersion and biodegradation (Danchuk 2009).

The evidence shows that oil can persist in aquatic sediments when deposited in slow moving areas of water, in silty sediments. Physical recovery of such oil is usually the preferred option. Formation of OMA can increase the density of oil droplets in the water, increasing the fraction that sinks, but OMA formation is not usually a major process in inland oil spills due to limiting low salinity values, or limiting suspended sediment concentrations, or both. OMA formation also has potential benefits as it maintains the dispersed characteristic of affected oil, and enhances rates of biodegradation. Relatively little oil appears to become entrained into riverbed gravels, and such oil remains subject to weathering as water passes through the gravels, so that recovery of lightly or moderately oiled substrates will occur over a period of weeks to months.

C.1.3. Soil Quality

As oil slicks come into contact with shorelines and floodplains, a portion of the oil may become stranded on shoreline soils. When oil comes into contact with soil, it interacts with the soil matrix in a number of ways, which can result in deleterious effects to soil biota. In addition to being toxic via direct contact with plants, invertebrates and microbes, the oil also has the potential to:

- Occupy the pore space between the soil particles, excluding air and water
- Coat soil particles and create a hydrophobic layer that prevents the absorption and retention of water
- Retard the exchange of air and water within the soil matrix, leaving the soil deficient in both of these components, along with the nutrients that would otherwise be leached into the soil from the surface
- Increase the carbon content of the soil and subsequently promote microbial growth that depletes oxygen and available nutrients.

Modelling results for the Enbridge Northern Gateway Project show that oiling of shorelines would likely result in acute effects to shoreline vegetation and soil invertebrates. After the acute phase of the spill (days to 2 weeks), it was assumed that visible oiling on shorelines would be cleaned-up, reducing the initial total hydrocarbon loading to shoreline soils to a maximum of 1,000 g/m^2. Results found that weathering of hydrocarbons resulted in decreasing TPH concentrations in shoreline soils after 1 to 2 years (Stantec *et al.* 2012).

Following the 2010 release of crude oil into Talmadge Creek and the Kalamazoo River, oil and visually affected soils were excavated from the source area and along riverbanks. Contaminated soils were removed, clean organic soils were backfilled into excavated areas, and soil erosion controls were implemented (Enbridge 2011). Although mat roads were used in sensitive areas, temporary roads and heavy equipment movement may have resulted in soil compaction (Enbridge 2011). In Talmadge Creek, soil confirmation samples were collected in the interim restoration areas: 19 out of 465 samples exceeded applicable criteria for VOCs, PAH, and TPH (Enbridge 2011). As of April 2013, residual oil still resided in overbank soil; however, acute toxicity studies concluded that the residual oil was nontoxic (Enbridge 2013a).

The August 2005 train derailment near Wabamun Lake resulted in the release of warm (from recent loading) Bunker "C" fuel oil from the tank cars onto lawns of cottages adjacent to Wabamun Lake. The oil flowed into the lake along many paths along a front approximately 0.5 km wide, picking up various materials (*e.g.,* grass, insects) along the way (Fingas *et al.* 2006). Soils along these flowpaths were subject to excavation and replacement with clean soil.

It was reported that the Bunker "C" fuel oil released from the DM 932 did not strand substantially along the mud and sand shorelines of Mississippi River, nor did the oil penetrate into these substrates due to their water saturation (Danchuk 2009). However, riprap along the shorelines provided opportunities for trapping of the oil due to the crevices between rocks, and oil droplets and globules to become absorbed to shoreline vegetation (Danchuk 2009).

No information was available with respect to the effects of the East Walker River; however, as a result of winter, low flow would have minimized contact between the oil and riparian soils.

The evidence shows that although weathering processes decrease hydrocarbon concentrations over time, hydrocarbon residues can persist in soils for years. Physical removal of oil saturated soils and replacement with clean fill is usually the preferred option; with surface removal of oily residues where oil has not penetrated deeply, also preferred. These physical remediation practices promote shorter recovery times for shoreline and riparian environments.

C.1.4. Aquatic Vegetation

A hydrocarbon spill into a water body may result in effects to aquatic vegetation. Hydrocarbons have the potential to affect aquatic vegetation by:

- Physically smothering plants
- Exposing them to acute or chronic toxicity
- Altering habitat.

Modelling results for the Enbridge Northern Gateway Project show that aquatic biota (*i.e.,* fish, amphibian, aquatic invertebrate and aquatic plant communities) are subject to toxicity during the acute phase of hydrocarbon spills. However, after the initial phase of the spill (a few days to 2 weeks), hydrocarbon concentrations in river water decrease to levels that would not be expected to cause chronic effects to aquatic life (Stantec *et al.* 2012). Chronic effects on aquatic plants were not directly assessed due to a lack of chronic toxicity information. Instead, it was assumed that while those portions of aquatic plants that can be directly exposed to hydrocarbons are susceptible to being killed (*i.e.,* an acute effect), below-ground roots and rhizomes would generally be capable of surviving and sending out new shoots. Aquatic plant communities would also be able to restore themselves from other nearby sources of seed or vegetative propagules.

The release of crude oil in the Kalamazoo River oil spill resulted in negative effects to aquatic vegetation, particularly in the impoundments (*i.e.,* Ceresco, Mill Pond Dam, and Morrow Lake) where submerged oil affected submerged vegetation (Enbridge 2013a). Clean-up activities included the cutting of submerged vegetation when the risk of oiled vegetation contaminating wildlife was greater than the value of the vegetation and there was no less destructive method to remove or reduce risk to acceptable levels (Enbridge 2013a). Vegetation was cut below the water surface and roots were left to allow regrowth.

As of June 2013, the USEPA (2013) estimated that approximately 680,000 litres (180,000 gallons) of submerged oil remained in the river bottom sediment and ordered the removal of the recoverable portion (approximately 45,000-68,000 litres or 12,000-18,000 gallons), principally in relation to the headponds of the Ceresco and Morrow dams. Removal of the remainder would result in substantial damage to the river; therefore, it was to be left in place and monitored (USEPA 2013). It is possible that the submerged oil left in situ is resulting in chronic effects to aquatic vegetation either through toxic effects or smothering.

Following the August 2005 Wabamun Lake train derailment, much of the Bunker "C" fuel oil became entrained in the abundant reed beds (*Schoenoplectus tabernaemontani)* in the eastern basin of the lake. As such, clean-up activities included cutting of the vegetation and vacuum removal of submerged tar balls entrained in the reed bed detritus (Wernick *et al.* 2009). A two year study was conducted to assess regrowth. The study found that exposure to the oil, which was spilled in the late growing season, did not cause large-scale changes to these emergent plant communities (Wernick *et al.* 2009). Physical factors such as clean-up activities and vegetation management appeared to be responsible for reduced regrowth observed at some locations. Overall, however, post-spill measures of productivity (vegetated transect length, total cover, and biomass) were within the variability of pre-spill data collected in 2001.

The evidence shows that while oil spills can result in acute toxic effects to aquatic vegetation, it is expected that below-ground roots and rhizomes would generally be capable of surviving and sending out new shoots once hydrocarbon concentrations in the water column decreased below effect thresholds (days to weeks). Aquatic plant communities would also recolonize from nearby sources of seed or vegetative propagules. Recovery of aquatic vegetation affected by submerged oil and hydrocarbons retained in sediments could take years to recover. However, physical recovery of such oil is usually the preferred option. Recovery of most aquatic plant communities can be expected within 1 to 2 years of a spill.

C.1.5. Aquatic Invertebrates

A hydrocarbon spill into a water body may result in acute (lethal) and chronic or sub-lethal effects on aquatic invertebrates. Aquatic invertebrates are critical components of aquatic ecosystems because of their role in converting non-living organic matter into energy resources accessible to other aquatic organisms. Hydrocarbons have the potential to affect aquatic invertebrates and the habitat upon which they depend, by:

- Physically smothering organisms
- Exposing them to acute or chronic toxicity
- Altering essential habitat.

Modelling results for the Enbridge Northern Gateway Project show that aquatic biota (*i.e.,* fish, amphibian, aquatic invertebrate and aquatic plant communities) are subject to toxicity during the acute phase of hydrocarbon spills. However, after the initial phase of the spill (a few days to 2 weeks), hydrocarbon concentrations in river water decrease to levels that would not be expected to cause chronic effects to fish or other aquatic life (Stantec *et al.* 2012).

The assessment of negative effects on aquatic biota included the assessment of benthic invertebrates, which were considered to be similar in sensitivity, or less sensitive than fish eggs and larvae. As described in Section C.1.6, the average predicted sediment pore water concentrations of hydrocarbons and TPAH were, for the most part, below concentrations likely to cause negative effects to developing fish eggs (and by extension aquatic invertebrates). The exception was in Chickadee Creek where fine-grained sediments were predicted to retain hydrocarbons and lead to higher hydrocarbon concentrations in sediment pore water. In most cases, however, and with particular reference to gravel bed habitats, it was concluded that although a portion of a single year-class of fish (and by extension, aquatic invertebrates) could be lost, recovery would occur in subsequent years (Stantec *et al.* 2012).

Available results show that although diversity and abundance of aquatic macroinvertebrates in Talmadge Creek and the Kalamazoo River were reduced as a result of the Kalamazoo River oil spill in July 2010 (Walterhouse 2011 in Walterhouse 2012), by 2011, they had improved, although abundance was still affected (Walterhouse 2012). Recovery in Talmadge Creek was attributable to physical remediation of the habitat, which involved removal of oiled substrates and reconstruction with clean materials. In the Kalamazoo River, overall condition at Station K2 (below the confluence of Talmadge Creek) was scored as “acceptable” shortly after the spill in 2010, but was rated “excellent” in 2011. Farther downstream, degradation was observed at some stations, but may have been attributable to siltation caused by increased rates of shoreline erosion as a result of recovery efforts, rather than to residual hydrocarbon contamination.

Following the December 2000 oil spill into the East Walker River, benthic macroinvertebrates were surveyed by the California Department of Fish and Game to quantify the effects of the spill to aquatic biota. Results purport to show a 79% and 65% loss in abundance in January and March 2001, respectively, indicating that benthic invertebrates were affected by the spill (Hampton *et al.* 2002). However, the qualitative sampling methodology makes interpretation speculative at best, and decisions taken during data management (such as the exclusion of visibly "oiled" benthic invertebrates from the analysis on the assumption that they must have been dead at the time of collection) are questionable, considering that oiling of these organisms could have occurred as a consequence of the sampling activity. Considering the cumulative number of taxa recovered, the cumulative number of Ephemeroptera, Trichoptera and Plecoptera (EPT taxa), the sensitive EPT index, and the Shannon Diversity, which show no compelling differences between upstream and downstream locations, it is difficult to interpret the results as showing impairment in the areas downstream of the spill. The benthic community would also have been subject to the same confounding influence of low stream flow and anchor ice formation as the fish community. Notwithstanding these issues, the East Walker River Trustee Council (EWRTC 2009) quantified the effects of the spill with respect to degree, duration and geographic area. The affected area was deemed to extend to 24 km of stream habitat, and the benthic community was considered to have recovered within one to two years of the accident.

Owing to the deposition of hydrocarbons in the river sediments resulting from the Pine river oil spill in August 2000, effects on benthic invertebrates were investigated as a means of evaluating biological effects (de Pennart *et al.* 2004). The collection of benthic invertebrate samples in the Pine River in 2000 showed a depletion of all guilds downstream of the spill site; however, in 2001, benthic populations had partially recovered in the most affected areas. No relationship was observed between sediment hydrocarbon concentrations and benthic community structure in a subsequent survey during 2003 indicated recovery of the system (de Pennart *et al.* 2004).

The evidence shows that while oil spills can result in acutely toxic effects to aquatic invertebrates, causing change in community structure, populations and communities start to recover within 1 year after a spill, and recovery within two years is not unusual.

C.1.6. Fish and Fish Eggs and Larvae

A hydrocarbon spill into a waterbody has a high potential to affect fish, fish eggs and larvae. Hydrocarbons may have lethal and non-lethal effects on aquatic biota, depending on the sensitivity of the species or life stage exposed, and the degree and duration of exposure. Hydrocarbons have the potential to affect fish species and the habitat upon which they depend, by:

- Altering essential habitat
- Physically smothering organisms
- Exposing them to acute or chronic toxicity.

Modelling results for the Enbridge Northern Gateway Project show that aquatic biota (*i.e.,* fish, amphibian, aquatic invertebrate and aquatic plant communities) are subject to toxicity during the acute phase of hydrocarbon spills. However, results show that after the initial phase of the spill (a few days to 2 weeks), hydrocarbon concentrations in river water decreased to levels that would not be expected to cause chronic effects to fish or other aquatic life (Stantec *et al.* 2012).

Similarly for aquatic biota exposed to sediment pore water (*i.e.,* fish eggs), the average predicted sediment pore water concentrations of hydrocarbons and TPAH were, for the most part, below concentrations likely to cause negative effects to developing fish eggs. The exception was in Chickadee Creek where fine-grained sediments were predicted to retain hydrocarbons and lead to higher hydrocarbon concentrations in sediment pore water. In most cases, however, and with particular reference to gravel bed habitats that would be of greatest relevance to spawning salmonid fish, it was concluded that although a portion of a single year-class of fish could be lost, recovery would occur in subsequent years (Stantec *et al.* 2012).

Available results for the Kalamazoo River oil spill show that although the Talmadge Creek fish community was reduced and its habitat greatly diminished due to oil spill recovery efforts (Wesley 2011) after the release in 2010, it experienced some recovery in 2011 (Winter *et al.* 2012). In the Kalamazoo River, some declines in fish community diversity and abundance were observed at some, but not all, sites in 2010 (Wesley 2011, Winter *et al.* 2012). No fish kills were observed in the spill area (Winter *et al.* 2012). In

July 2010 the Michigan Department of Community Health issued precautionary fishing advisories, and a "do not eat" guideline for fish in the river (MDCH 2013). In July 2012, most of the river was re-opened for recreational use and the fish consumption advisory in relation to the oil spill was lifted. Fish tissue samples were collected in 2010 and 2011, with analysis for hydrocarbon constituents, particularly PAHs, as well as metals and other contaminants. Retrospective analysis (MDCH 2013) found that trace metals of potential concern (*i.e.,* nickel and vanadium) did not differ in fish tissues collected upstream and downstream of the spill site, and were below levels of concern. The PAHs were evaluated in the context of potential carcinogens (*i.e.,* as benzo(a)pyrene equivalents) and as non-carcinogenic compounds. Concentrations of the carcinogenic PAHs were actually higher in samples collected upstream of the spill location, but fish consumption guidelines were not considered necessary owing to the low overall concentrations detected. For non-carcinogenic PAHs, naphthalene and acenaphthene were detected in carp from the Ceresco headpond in 2010 at concentrations of 16.1 and 14.9 ppb, respectively. These concentrations were well below the applicable screening level of 2,300 ppb, and again no fish consumption guidelines were considered necessary (MDCH 2013).

Although some dead fish were observed along the shoreline after the Wabamun Lake train derailment, these numbers were within the natural range expected and Alberta Sustainable Resource Development determined that the release of Bunker "C" fuel oil had no short-term effect on fish (TSBC 2007). Three months after the spill (November 2005), DeBruyn *et al.* (2007) assessed deformities in lake whitefish larvae incubated *in situ* in shallow water habitat in areas of the lake that were considered to be either oil-exposed, or not exposed and suitable as reference locations. The lake had been subjected to PAH contamination from various sources prior to the oil spill (*e.g.,* coal mines, coal-fired power plants, marinas, recreational boat use) for many years, and Schindler *et al.* 2004 reported that lake whitefish had not reproduced successfully in the lake for several years prior to the derailment. DeBruyn *et al.* (2007) found complete mortality of lake whitefish eggs at one exposure site, but also at one reference site in the lake. High egg mortality (60 to 70%) was also observed at the remaining exposure and reference sites. While overall rates of deformity were similar at these two sites, the deformities exhibited at the oil-exposed site were judged to be more severe than those at the reference site, indicating potential ongoing chronic effects resulting from the spill.

During the initial response following the December 2000 East Walker River oil spill, approximately 21 fish, predominantly mountain whitefish, were found dead within the first 16 km of the spill site (EWRTC 2009). Fish surveys conducted in 2001 by the California Department of Fish and Game and the Nevada Division of Wildlife showed a reduction of juvenile age classes and recruitment of rainbow trout (Hampton *et al.* 2002). However, the spill response required lower than normal water flows for safety and to slow downstream transport of the oil. The lower flows, in combination with exceptionally cold temperatures, resulted in the formation of anchor ice and a higher than normal winter fish kill (Hampton *et al.* 2002). Effects on the fish community, therefore, may have reflected either or both of the stresses imposed by oiling and lower than normal water levels with concomitant formation of anchor ice in the stream bed. PAH concentrations were measured in fish tissues collected three months after the spill (March 2001); concentrations were highest in suckers, which are bottom-feeding fish highly exposed to sediments (Higgins 2002). One sample reported a TPAH concentration in sucker (whole body) of 2.6 mg/kg, but all other samples reported values of less than 1 mg/kg. There were no fish survey data available with respect to the recovery of fish and fish eggs and larvae for the East Walker River oil spill. However, water and sediment samples collected within five months of the release were below aquatic toxicity thresholds, indicating that conditions were suitable for recovery of the fish community.

Acute effects of the August 2000 oil spill in Pine River included direct mortality to fish. Approximately 1,600 fish, including but not limited to mountain whitefish, Arctic grayling, bull trout and rainbow trout, were collected along a 30 km stretch of the river (Bustard and Miles 2011, Goldberg 2011). The estimated numbers of dead fish varied widely, with values of 15,000 to 20,100 over a 30 km river reach (Alpine Environmental and EBA Engineering 2001 in Goldberg 2011) to 25,000 to 250,000 over a 50 km river reach (Bacante 2000 in Goldberg 2011). However, the acute effects of spilled oil on fish in the river lasted only a very short time, as water quality in the Pine River had returned to pre-spill conditions less than three weeks after the spill (de Pennart *et al.* 2004) and fish were reported to be returning to the main stem of the river from smaller streams away from the main channel within two weeks of the spill (BC MOE 2000b).

Removal of oiled woody debris and log jams as part of the Pine River oil spill recovery effort was reported to result in substantial long-term effects on the Pine River and associated riparian and instream habitat (Bustard and Miles 2011). Replacement structures were constructed, but the river shifted course and bank erosion resulted in a straighter, wider and less complex river channel (Bustard and Miles 2011). Snorkel surveys were consulted to evaluate the effects of the spill and recovery of the fish community in the river, based on surveys taken both before and after the spill, within an approximately 50 km reach of river most likely to have been affected (Goldberg 2011). Fish were less abundant in 2000 than they had been in 1993 (164 vs. 259 observed fish/km). However, surveys completed in 2005, 2006 and 2007 showed recovery to levels equal to or greater than in 1993 (Goldberg 2011).

There were no reports of dead fish after the July 2011 oil spill in Yellowstone River. Although a precautionary fish consumption advisory was issued after the spill (Montana Fish, Wildlife and Parks 2011a), testing of fish tissue samples from the river did not identify any detection of petroleum hydrocarbon constituents in fish fillet, and only traces of hydrocarbons in organs of fish (Montana Fish, Wildlife and Parks 2011b). Water and sediment samples collected within four months of the spill showed that with few exceptions, all samples were “non-detect” or below applicable (likely human health) standards or screening levels for petroleum hydrocarbons (MDEQ 2013).

Following the January 2000 OSSA II pipeline rupture, no fish were found dead as a result of the spill (Henshaw *et al.* 2001). Testing of the weathered oil showed that it was highly depleted in many of the chemical constituents typically associated with toxicity. Additionally, water and sediment samples collected up to five months after the spill showed no detectable concentrations of hydrocarbons, except where oil was clearly deposited along strand lines (Henshaw *et al.* 2001). These results indicate that the spill of mixed crude oil did not substantially affect fish and fish eggs and larvae in the Rio Desaguadero.

No information is available about possible fish kills, if indeed such kills occurred after the release of Bunker “C” fuel oil from the DM 932 in July 2008. However, the characteristics of the oil (viscous, and lacking a large component of monoaromatic or low-boiling aliphatic constituents) make acute mortality of fish an unlikely scenario.

The evidence shows that recovery of fish and fish eggs and larvae could occur within a few years after a release. Water concentrations are likely to decrease below effects thresholds within days to weeks after a spill and relatively little oil appears to become entrained into riverbed gravels, where it would remain subject to weathering so that recovery would occur over a period of weeks to months. In contrast, oil can persist for long periods of time in silty sediments when deposited in slow moving areas of water. Although the uneven distribution of hydrocarbons in sediment could result in some areas where effects on developing fish eggs could occur, it is equally likely that areas with lower deposition would remain unaffected. As a result of natural weathering processes, concentrations of TPAH would decline to concentrations below effects thresholds. The most likely outcome, depending upon the type of oil spilled, and the characteristics of the receiving environment, is that a portion of the reproductive capacity of a single year-class of fish could be lost, but that recovery would occur in subsequent years.

C.1.7. In-Water Amphibians

A hydrocarbon spill into a waterbody has the potential to result in lethal and non-lethal effects on amphibian eggs and larvae. Many amphibian species are considered to be species at risk or sensitive species within their distributional ranges. Representing the aquatic portion of an amphibian life cycle, amphibian eggs and larvae are considered to be the most sensitive life stages.

Few oil spills document the effect of oil spills on in-water amphibians. However, modelling results for the Enbridge Northern Gateway Project show that aquatic biota, which included the assessment of amphibian communities, are subject to toxicity during the acute phase of hydrocarbon spills. However, after the initial phase of the spill (a few days to 2 weeks), hydrocarbon concentrations in river water decrease to levels that would not be expected to cause chronic effects to aquatic life (Stantec *et al.* 2012). The assessment of negative effects on aquatic biota included the assessment of amphibians because they were included in the species sensitivity distribution used to determine effects thresholds for sensitive species, and thus would to experience similar effects as fish, fish eggs and benthic invertebrates under acute or chronic exposure to hydrocarbons.

The evidence suggests that effects on and recovery of in-water amphibian populations would be similar to the timeframes for recovery of fish and fish eggs and larvae. After a release, hydrocarbon concentrations in the water column rapidly decrease below effects thresholds (days to weeks), and concentrations of TPAH in sediment pore water would rapidly decline to concentrations below effects thresholds. The most likely outcome, therefore, is that a portion of the reproductive capacity of a single year-class of amphibians could be lost, but that recovery would occur in subsequent years.

C.1.8. Shoreline and Riparian Vegetation

Direct contact of vegetation with spilled oil could result in physical smothering, habitat modification and toxicity to shoreline and riparian vegetation, which could lead to ecosystem changes, including loss of overall diversity, rare species and rare ecological communities. In addition, response and remediation activities can disrupt habitat and provide an opportunity for invasion by non-native or weedy species.

Modelling results for the Enbridge Northern Gateway Project show that oiling of shorelines causes acute and chronic effects to shoreline vegetation. However, following recovery of visible hydrocarbon contamination from oiled shorelines, it was concluded that moderately tolerant perennial or biennial vegetation will rapidly regenerate from surviving root systems (Stantec *et al.* 2012).

Following the 2010 release of crude oil into Talmadge Creek and the Kalamazoo River, clearing and grubbing of trees and vegetation was conducted, primarily in the heavily oiled section of Talmadge Creek, to allow completion of free-phase crude oil removal (Enbridge 2011). Although mat roads were used in sensitive areas, temporary roads and heavy equipment movement may have resulted in trampling of vegetation (Enbridge 2011). Disturbed areas were seeded and stabilized using native seed mixes (Enbridge 2011).

As part of the emergency response following the Pine River oil spill, oiled woody debris and log jams were removed. Replacement structures were constructed, but the river shifted course and bank erosion resulted in a straighter, wider and less complex river channel (Bustard and Miles 2011). In addition, the extensive use of heavy equipment in the river led to habitat disturbance and effects to riparian areas.

Four months after the January 2000 OSSA II oil spill, 10 oiled vegetation samples were collected and analyzed. Laboratory analyses determined that none of them contained toxic elements of petroleum (Comisión de Forraje 2000 in Henshaw *et al.* 2001).

Following the DM 932 oil spill, a large fraction of the scrub-shrub shoreline habitat was heavily oiled; shoreline vegetation provided abundant opportunity for oil droplets and globules to become absorbed. Riprap also provided opportunities for trapping of oil due to the crevices between rocks. Mud and sand shorelines did not trap much oil, and oil did not penetrate into these substrates due to their water saturation (Danchuk 2009).

The evidence suggests that recovery of shoreline and riparian vegetation from an oil spill and its associated response can take years. However, remediation measures including the removal of oiled soils and vegetation, and reseeding of excavated areas would promote recovery. Moderately tolerant perennial or biennial vegetation will rapidly regenerate from surviving root systems and indigenous plant species would recolonize from neighbouring populations not affected by the release.

C.1.9. Soil Invertebrates

As oil slicks come into contact with shorelines and floodplains, a portion of the oil may become stranded on shoreline soils and result in effects to soil invertebrates by:

- Physically smothering organisms
- Exposing them to acute or chronic toxicity
- Altering essential habitat.

Modelling results for the Enbridge Northern Gateway Project show that oiling of shorelines would likely result in acute effects to soil invertebrates. After the acute phase of the spill (days to 2 weeks), it was assumed that visible oiling on shorelines would be cleaned-up, reducing the initial total hydrocarbon loading to shoreline soils to a maximum of 1,000 g/m^2. Results showed that weathering of hydrocarbons resulted in decreased risks (about half) to soil invertebrates after one to two years (as compared to four weeks post-spill).

Following the 2010 release of crude oil into Talmadge Creek and the Kalamazoo River, oil and affected soils were excavated from the source area and along riverbanks (Enbridge 2011), which would have affected soil invertebrate populations. Clean organic soils were backfilled into excavated areas (Enbridge 2011).

Recovery of soil invertebrate populations would be similar to the recovery time for shoreline and riparian vegetation. Oil spills have the potential to chronically affect soil invertebrates through soil contamination; however, remediation measures including the removal of oiled soils, would promote recovery. Soil invertebrate populations would recolonize from neighbouring areas not affected by the release.

C.1.10. Mammalian Wildlife

Oil spills to the freshwater environment can result in lethal and sub-lethal effects to terrestrial and semi-aquatic mammals. These effects can result from oiling of fur (which reduces thermoregulatory capacity), inhalation of VOCs, dermal exposure, ingestion of hydrocarbons during preening, and chronic exposure from ingestion of contaminated food. Mammals may also experience habitat loss and a decline in food availability through decreased prey abundance.

Modelling results for the Enbridge Northern Gateway Project assessed the potential for acute environmental effects on terrestrial biota (*i.e.,* mammals, birds, reptiles and shoreline vegetation) based on the probability of encounter with floating oil and/or shoreline oil, and the amount of oil likely to be accumulated by an individual animal. Results showed that semi-aquatic mammals (such as muskrat, mink or otter) were likely to be negatively affected by oiling in the event of an accidental pipeline release. Potential chronic effects of oil exposure were assessed by comparing estimated daily ingestion doses from dietary exposure against chronic exposure benchmarks for the grizzly bear, mink, moose, muskrat, river otter and woodland caribou. Results showed that while populations of smaller mammals such as muskrat (which were highly exposed and have small home range) may be subject to chronic risks, it is unlikely that individuals of larger and more widely-ranging species such as grizzly bear or moose would suffer serious harm from chronic exposure. Effects on mammal populations were considered reversible with the effects on terrestrial biota persisting from months to years.

As part of the Kalamazoo River oil spill response, animal recovery efforts ran from July 2010 through October 2010. As of May 2011, a total of 3,160 animals (*i.e.,* reptiles, crustaceans, amphibians, birds, mammals and fish) were collected (Enbridge 2011). Of these, a total of 63 oiled mammals (mainly beaver and muskrat) were either rescued or found dead; 23 were cleaned and released, for a survival rate of 36.5% (Enbridge 2011).

Following the East Walker River oil spill, 1 American mink and 6 beaver were found dead within the first 16 km of the spill site (EWRTC 2009). Owing to the low probability of finding dead wildlife, it was judged that nearly all of the birds and mammals that regularly came in contact with the water within the first 16 km of the spill zone were likely killed as a result of contacting the oil (EWRTC 2009).

Following the Pine River oil spill in August 2000, there were reports that some beaver, otter and mink were affected by the spill (BC MOE 2000b). However, no mammals were found by staff of the BC Ministry of Environment, Lands and Parks despite daily walkover of the river (BC MOE 2000b).

According to the USEPA (2011a), oiled mammals observed or captured after the Yellowstone river oil spill consisted of 1 white-tailed deer.

No mammals were found dead or oiled as a result of the OSSA II oil spill, despite repetitive ground and aerial surveys throughout the entire region, (Henshaw *et al.* 2001). Testing of the weathered oil showed that it was highly depleted in many of the chemical constituents typically associated with toxicity. Therefore, although there was a large and labour intensive recovery and remedial operation mounted, the short-term conclusion was that ecological damage from the spill was minimal (Henshaw *et al.* 2001).

Following the DM 932 oil spill, 26 mammals were observed oiled (USFWS 2009). As of July 27, 2008, these numbers included 2 muskrats and 2 beavers (USFWS 2008).

The evidence suggests that while accurate counts of mammals killed by oil spills are unlikely to be obtained, relatively few dead mammals are usually observed. Consistent with the results of risk assessment models, those dead animals that are found are typically the semi-aquatic mammals that have the highest exposure, and the greatest potential to suffer as a result of hypothermia. Large mammals with more terrestrial habitat, such as bears and moose, are rarely if ever observed to be seriously harmed. It is concluded that individuals of more terrestrial species would be unlikely to suffer serious harm from acute or chronic exposure to oil spills in the aquatic environment. Individuals and populations of smaller semi-aquatic mammal species (*e.g.,* muskrat, beaver, otter and mink) would be more likely to experience negative effects. Recovery would likely occur within months to five years, depending upon the extent of the injuries, and the reproductive capacity of the affected population.

C.1.11. Avian Wildlife

Oil spills to the freshwater environment can result in lethal and sub-lethal effects to birds. These effects can result from contamination of feathers (which reduces thermoregulatory capacity), inhalation of VOCs, dermal exposure, ingestion of hydrocarbons during preening, chronic exposure from ingestion of contaminated food, and external oiling of bird eggs through contact with oily residues on the feathers of parent birds. Birds may also experience habitat loss and a decline in food availability through decreased prey abundance due to contamination.

Modelling results for the Enbridge Northern Gateway Project assessed acute potential environmental effects on terrestrial biota (*i.e.,* mammals, birds, reptiles and shoreline vegetation) based on the probability of encounter with floating oil and/or shoreline oil and the amount of oil likely accumulated on an individual. Results showed that terrestrial biota (including birds) were likely to be negatively affected in the event of an accidental pipeline release. Potential chronic effects were assessed by comparing estimated doses ingested with food against exposure benchmarks for the bald eagle, belted kingfisher, Canada goose, herring gull, great blue heron, mallard duck, spotted sandpiper and tree swallow. Results showed that while populations of smaller birds such as waterfowl may be subject to chronic risks, it is unlikely that individuals of larger and more widely-ranging species such as bald eagle would suffer serious harm from chronic exposure. Effects were considered reversible with the effects on terrestrial biota persisting from months to years.

As part of the Kalamazoo River oil spill response, animal recovery efforts ran from July 2010 through October 2010. As of May 2011, a total of 3,160 animals (*i.e.,* reptiles, crustaceans, amphibians, birds, mammals and fish) were collected (Enbridge 2011). Of these, a total of 196 oiled birds were either rescued or found dead; 144 were cleaned and released, for a survival rate of 73.5% (Enbridge 2011).

A wildlife recovery centre set up immediately after the Wabamun Lake train derailment recovered more than 530 oiled birds within five days after the spill; 156 were either dead or euthanized (TSBC 2007). The following summer, the release of submerged oil in the lake resulted in the oiling of additional waterfowl (TSBC 2007). Wabamun Lake is one of nine lakes in Alberta that was found to support western grebe colonies in 2006 (Kemper *et al.* 2008). The Alberta population is estimated at between 10,000 and 11,000 birds, representing approximately 10% of the North American population. With between 100 and 500 nests, the Wabamun Lake colony is considered to be regionally significant (Kemper *et al.* 2008). From 2001 to 2005, western grebes at Wabamun Lake nested in one main colony (Rich's Point), and the lowest reported number of nests was 243 in 2005, prior to the spill. The oil spill occurred following completion of nesting in 2005 and resulted in the mortality of an estimated 333 western grebes (about 69% of the adult population at Wabamun Lake). However, in 2006, western grebes returned to nest at Rich's Point, and formed a second colony at the Ascot Beach reed bed. Together, the two sites contained 456 nests in 2006 (Kemper *et al.* 2008), indicating that bird populations at Wabamun Lake had recovered from the effects of the spill.

During the initial response after the East Walker River oil spill, 1 Virginia rail and 2 American dippers were found dead within the first 16 km of the spill site (EWRTC 2009). In addition, 1 common merganser, 1 great blue heron, 1 bald eagle and an unspecified number of Canada geese were observed alive but oiled (EWRTC 2009, Hampton *et al.* 2002).

Following the Pine River oil spill, a golden eagle and a hooded merganser were found oiled; the eagle was successfully released but the hooded merganser died in the wildlife rehabilitation centre (BC MOE 2000b). No other birds were found by staff of the BC Ministry of Environment, Lands and Parks despite daily walkover of the river.

According to the USEPA (2011a), oiled birds observed or captured after the Yellowstone River oil spill included 2 yellow warblers, 1 Cooper's hawk, 6 Canada geese, 3 mallards, 6 common mergansers, 1 pelican, 1 great blue heron, 1 American robin, 2 bald eagles, and an unknown raptor.

After the OSSA II oil spill, despite repetitive ground and aerial surveys throughout the entire region, very few (on the order of tens) oiled birds were reported in the first days following the spill (Wasson *et al.* 2000 in Owens and Henshaw 2002). Testing of the weathered oil showed that it was highly depleted in many of the chemical constituents typically associated with toxicity. Therefore, although there was a large and labour intensive recovery and remedial operation mounted, the short-term conclusion was that ecological damage from the spill was minimal (Henshaw *et al.* 2001).

Following the July 2008 DM 932 oil spill, 96% of recorded observations of oiled wildlife were birds, although some mammals and reptiles were also reported as oiled. The first documented bird mortality was on July 29, when a completely oiled wood duck was found about 40 km downstream from the spill location. Dozens of oiled birds were seen in areas of heavy effects, although most of these were wading birds that were capable of flying and could not be captured. The total number of oiled birds observed was 813. Wading birds were seen oiled most frequently (about 20% of these were oiled), but waterfowl had the highest rates of oiling (about 40% being oiled) (USFWS 2009).

The evidence suggests that a wide variety of bird species would be exposed to oiling following a large oil spill to a river. While many birds would likely die undetected, the experience based on various oil spill response operations suggests that waterfowl are among the most exposed birds, and that many bird species (such as wading birds and raptors) are less exposed and can tolerate light to moderate oiling without becoming incapacitated. Recovery would likely occur within months to five years, depending upon the extent of the injuries, and the reproductive capacity of the affected population.

C.1.12. Reptiles and Air-Breathing Amphibians

Oil spills in the freshwater environment can result in lethal and sub-lethal effects to reptiles and air-breathing amphibians (*i.e.,* adult frogs, toads and salamanders). These effects can result from dermal exposure, chronic exposure from ingestion of contaminated food, and external oiling of reptile and salamander eggs by oil stranded on floodplains. Reptiles and air-breathing amphibians may also experience habitat loss and a decline in food availability through decreased prey abundance due to contamination.

Modelling results for the Enbridge Northern Gateway Project assessed acute potential environmental effects on terrestrial biota (*i.e.,* mammals, birds, reptiles and shoreline vegetation) based on the probability of encounter with floating oil and/or shoreline oil and the amount of oil likely accumulated on an individual animal. Results showed that terrestrial biota (including reptiles) were likely to be negatively affected in the event of an accidental pipeline release. Reptiles (*i.e.,* snakes and turtles) were considered to have similar sensitivity to birds with respect to both oiling and dietary exposure to hydrocarbons. Turtle eggs were assumed to be laid in riparian zone soils, but would likely be located above flood stage, and therefore are not likely to be laid in soils that are contaminated with hydrocarbon residues. In this context, turtle eggs were not thought likely to be more exposed to hydrocarbon residues than bird eggs, which may be subject to external oiling through contact with oily residues on the feathers of parent birds. As discussed in Section C.1.11, results showed that populations of smaller birds (and by extension, reptiles) may be subject to chronic risks. Effects were considered reversible with the effects persisting from months to years.

As part of the Kalamazoo River oil spill response, animal recovery efforts ran from July 2010 through October 2010. As of May 2011, a total of 3,160 animals (*i.e.,* reptiles, crustaceans, amphibians, birds, mammals and fish) were collected (Enbridge 2011). Of these, a total of 2,561 oiled reptiles and 53 oiled amphibians were either rescued or found dead. In addition, 239 unoiled reptiles were collected. Three of the turtle species collected (13 individuals) were protected by Michigan law as either threatened (spotted turtle, *Clemmys guttata*) or special concern (Blanding's turtle, *Emys blandingii*; eastern box turtle, *Terrapene carolina carolina*) (Enbridge 2011).

As of May 2011, 2,119 reptiles had been cleaned and released, and 371 rescued reptiles and 42 turtle hatchlings were live in care, for a survival rate of 97.5% (Enbridge 2011). As of May 2011, 50 amphibians had been cleaned and released and one toad was live in care, for a survival rate of 96.2% (Enbridge 2011).

According to the USEPA (2011a), oiled wildlife observed or captured after the Yellowstone River oil spill included 4 toads and 2 garter snakes.

Recorded observations of oiled wildlife after the DM 932 oil spill included reptiles (USFWS 2009). As of July 27, 2008, 2 oiled American alligators had been observed (USFWS 2008).

Following the OSSA II oil spill, despite repetitive ground and aerial surveys throughout the entire region, very few (on the order of tens) oiled birds were reported in the first days following the spill (Wasson *et al.* 2000 in Owens and Henshaw 2002), and no fish or other animals were found dead or oiled as a result of the spill by clean-up crews or other field personnel (Henshaw *et al.* 2001, Owens and Henshaw 2002). Testing of the weathered oil showed that it was highly depleted in many of the chemical constituents typically associated with toxicity. Therefore, although there was a large and labour intensive recovery and remedial operation mounted, the short-term conclusion was that ecological damage from the spill was minimal (Henshaw *et al.* 2001).

The evidence suggests that reptiles (particularly turtles) and air-breathing amphibians are moderately to highly exposed to oiling following oil spills. However, although amphibians are presumed to be highly sensitive as a result of having permeable and delicate epidermal tissue, the epidermis of reptiles is impermeable, and in the case or turtles, largely armoured. Therefore turtles would appear to have generally lower sensitivity to oil exposure than many birds or mammals. In the event of harm, recovery of amphibian populations would be fairly rapid (*i.e.,* one or two breeding cycles), due to their high reproductive potential. On the other hand, turtles tend to be long lived and have lower reproductive potential, so recovery from serious harm at the population level could take longer, potentially five years or more.



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.

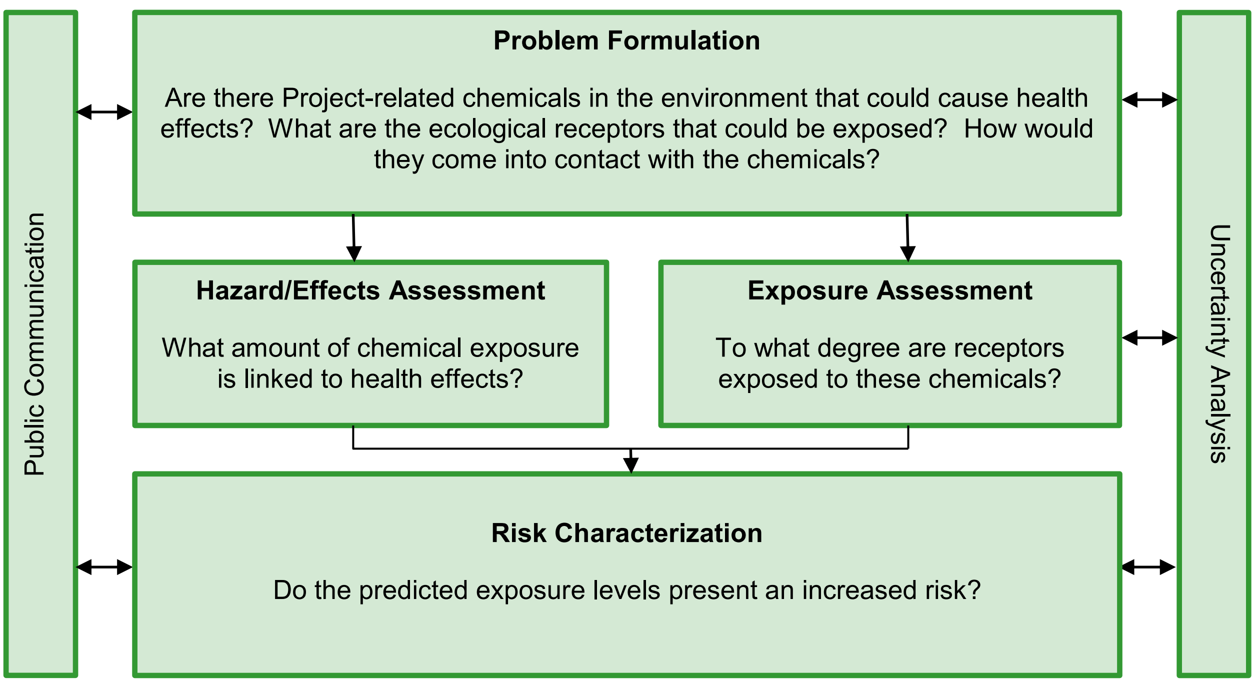

FIGURE 3.1 CONCEPTUAL DIAGRAM OF THE PQERA FRAMEWORK

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 Spring Summer Fall	Large break in loading arm (Credible Worst Case)	Total: 160 Released across boom: 32 (20%) Retained by boom: 128 (80%)	Cold Lake Winter Blend
2	Winter Spring Summer Fall	Leaking in loading arm	Total: 10 Released across boom: 0 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). 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

<table>
<tr><th rowspan="2">Species</th><th rowspan="2">Distribution and Seasonal Timing</th><th colspan="3">Conservation Status</th></tr>
<tr><th>SARA</th><th>BC</th><th>COSEWIC</th></tr>
<tr><td rowspan="4">Pelagic cormorant</td><td rowspan="4">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).
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).
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).</td><td colspan="3">P. p. pelagicus</td></tr>
<tr><td>No Status</td><td>Red</td><td>No Status</td></tr>
<tr><td colspan="3">P. p. resplendens</td></tr>
<tr><td>No Status</td><td>Yellow</td><td>No Status</td></tr>
<tr><td rowspan="4">Great blue heron</td><td rowspan="4">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).</td><td colspan="3">A. h. fannini</td></tr>
<tr><td>Special Concern Schedule 1</td><td>Blue</td><td>Special Concern</td></tr>
<tr><td colspan="3">A. h. herodias</td></tr>
<tr><td>No Status</td><td>Blue</td><td>No Status</td></tr>
<tr><td>Barrow's goldeneyes</td><td>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).</td><td>No Status</td><td>Yellow</td><td>No Status</td></tr>
<tr><td>Bald eagle</td><td>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).
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.</td><td>No Status</td><td>Yellow</td><td>Not At Risk</td></tr>
<tr><td>Glaucous-winged gulls</td><td>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).</td><td>No Status</td><td>Yellow</td><td>No Status</td></tr>
<tr><td>Spotted sandpiper</td><td>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).</td><td>No Status</td><td>Yellow</td><td>No Status</td></tr>
</table>

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. 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). 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. • 0 - <10 • 10 - <50 • 50 - <90 • 90 – 100	Marine Fish and Supporting Habitat Marine Birds and Supporting Habitat 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. • 0 - <10 • 10 - <50 • 50 - <90 • 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 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 Low exposure, sand Low exposure, rip rap Low exposure, wood bulkheads High exposure, rock High exposure, sand 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. • 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. • 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 Low exposure, pebble veneer over sand High exposure, cobble/boulder veneer over rock High exposure, cobble/boulder	• These shorelines comprise low-sloping, well compacted substrates, often with underlying fine-grained sediment which limit oil penetration. • 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 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 Rockfish Conservation Areas Eulachon Critical Habitat Dungeness Crab Important Habitat 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. • 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. • 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. • Auks are highly sensitive to crude oil exposure as well as being highly exposed in open water areas. • 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 (km²)	Affected Surface Water (by Surface Water Oiling Probabilities)					
			Area According to Sensitivity Factor (km²)			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 (km² or km*)	Affected Surface Water (by Surface Water Oiling Probabilities)					
			Area or Length According to Sensitivity Factor (km² 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 (km²) 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

This report has been prepared by Stantec Consulting Ltd. (Stantec) for the sole benefit of Trans Mountain Pipeline ULC (Trans Mountain). The report may not be relied upon by any other person or entity, other than for its intended purposes, without the express written consent of Stantec and Trans Mountain.

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The information provided in this report was compiled from existing documents and data provided by Trans Mountain and by applying currently accepted industry standard mitigation and prevention principles. This report represents the best professional judgement of Stantec personnel available at the time of its preparation. Stantec reserves the right to modify the contents of this report, in whole or in part, to reflect the any new information that becomes available. If any conditions become apparent that differ significantly from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

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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

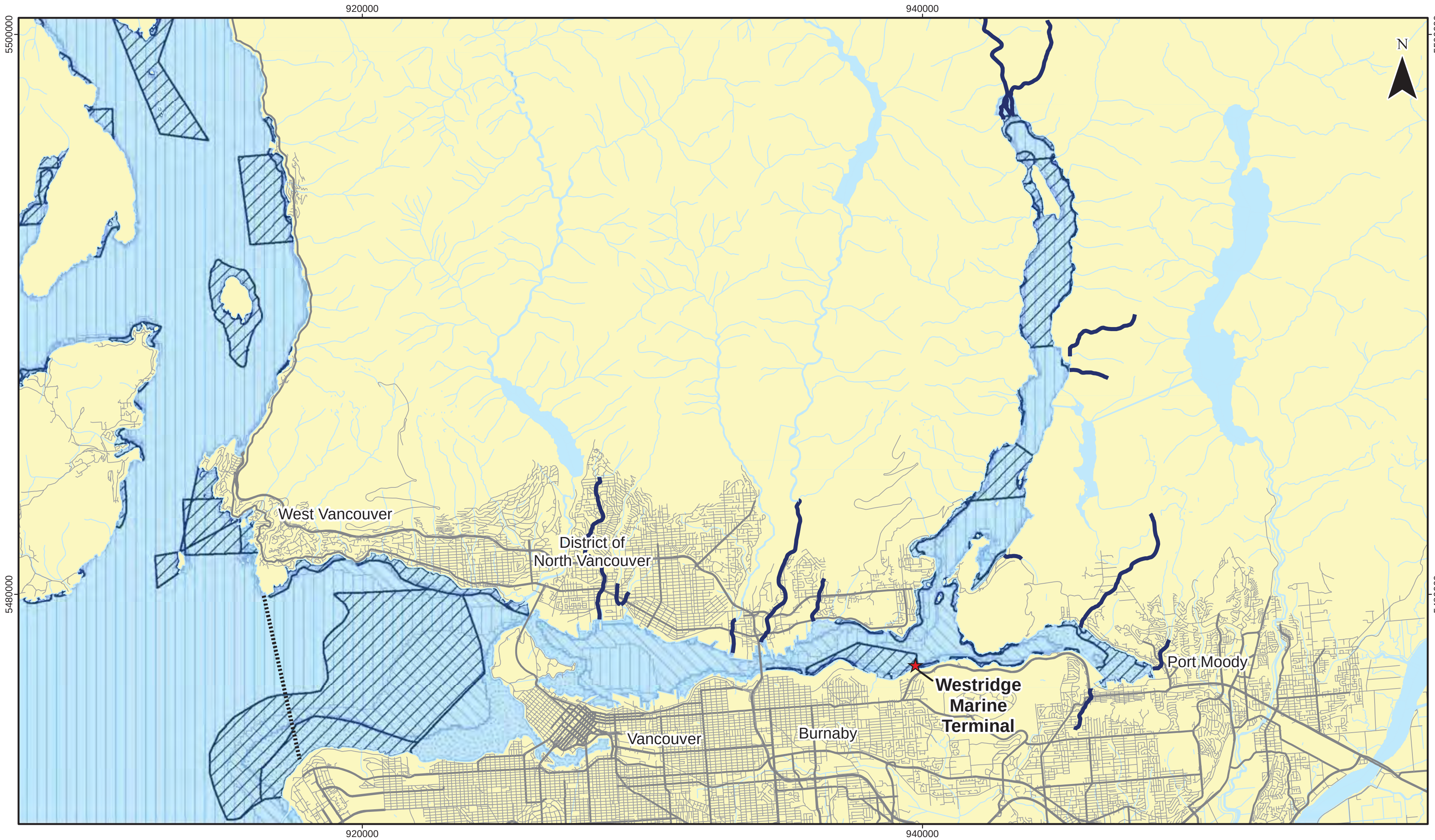
★ Westridge Marine Terminal
Regional Study Area Boundary
Land of British Columbia
Waterbody
Protected Area
Aboriginal Reserve

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
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

Salmon-bearing Streams

Biological Risk Factor - Fish

1 Low

2 Medium

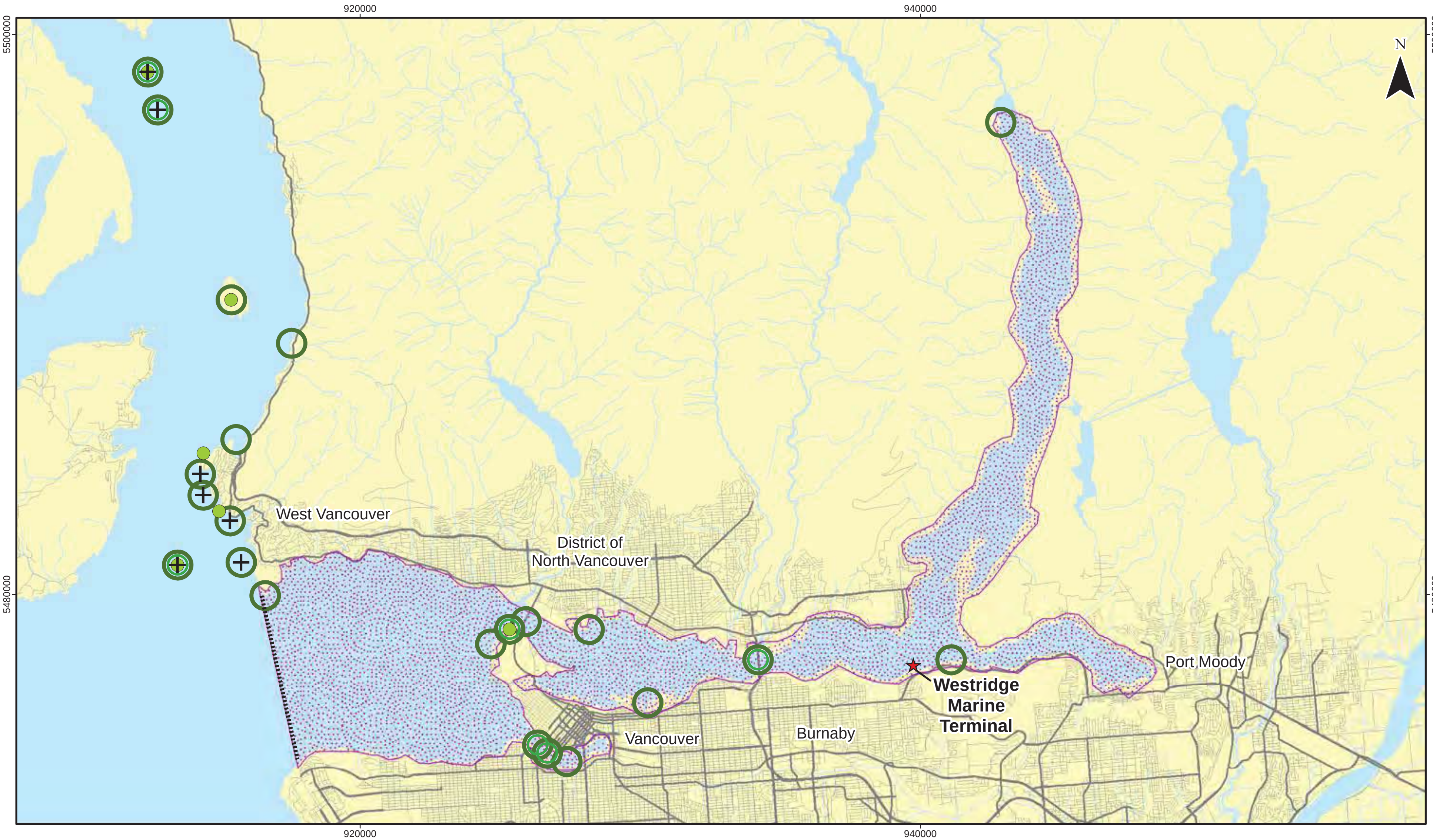
3 High

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

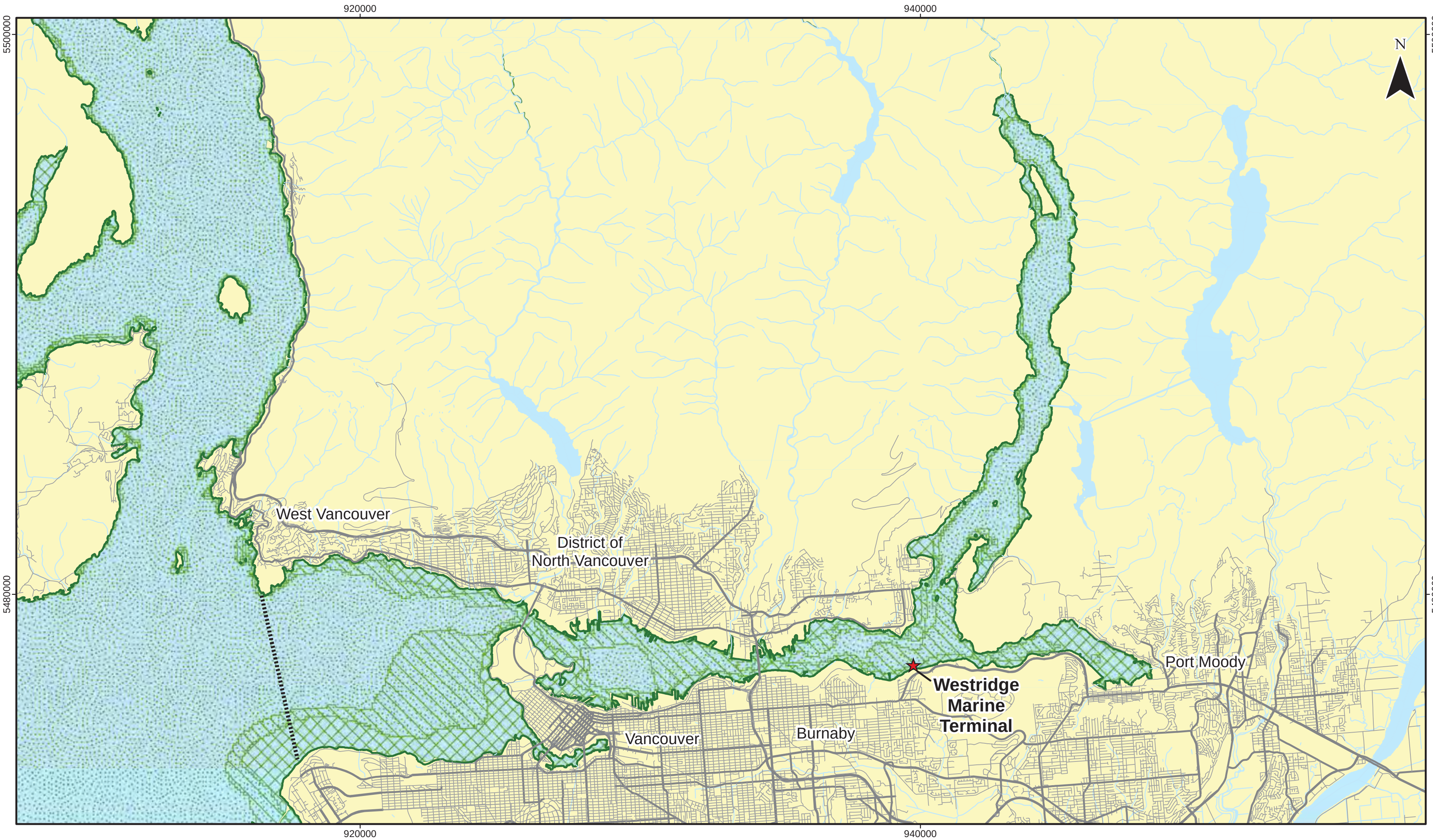
- ★ Westridge Marine Terminal
- Regional Study Area Boundary
- Land of British Columbia
- Waterbody
- + Black Oystercatcher Breeding Areas
- Pigeon Guillemot Colony
- Pelagic Cormorant Colony
- Glaucous-winged Gull Colony
- Important Bird Area

TRANS MOUNTAIN

MAP NUMBER		PAGE
123110494_063		SHEET 1 OF 1
DATE	TERA REF.	REVISION
Nov 2013	REF	A
SCALE	PAGE SIZE	DISCIPLINE
1:200,000	8.5 x 11	ERA
DRAWN	CHECKED	DESIGN
HW	AS, PM	MS, HW

FIGURE: A.3

BIOLOGICAL SENSITIVITY FACTORS FOR MARINE BIRDS AND BIRD HABITAT



Stantec

km
0 1.5 3 4.5 6
ALL LOCATIONS APPROXIMATE

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

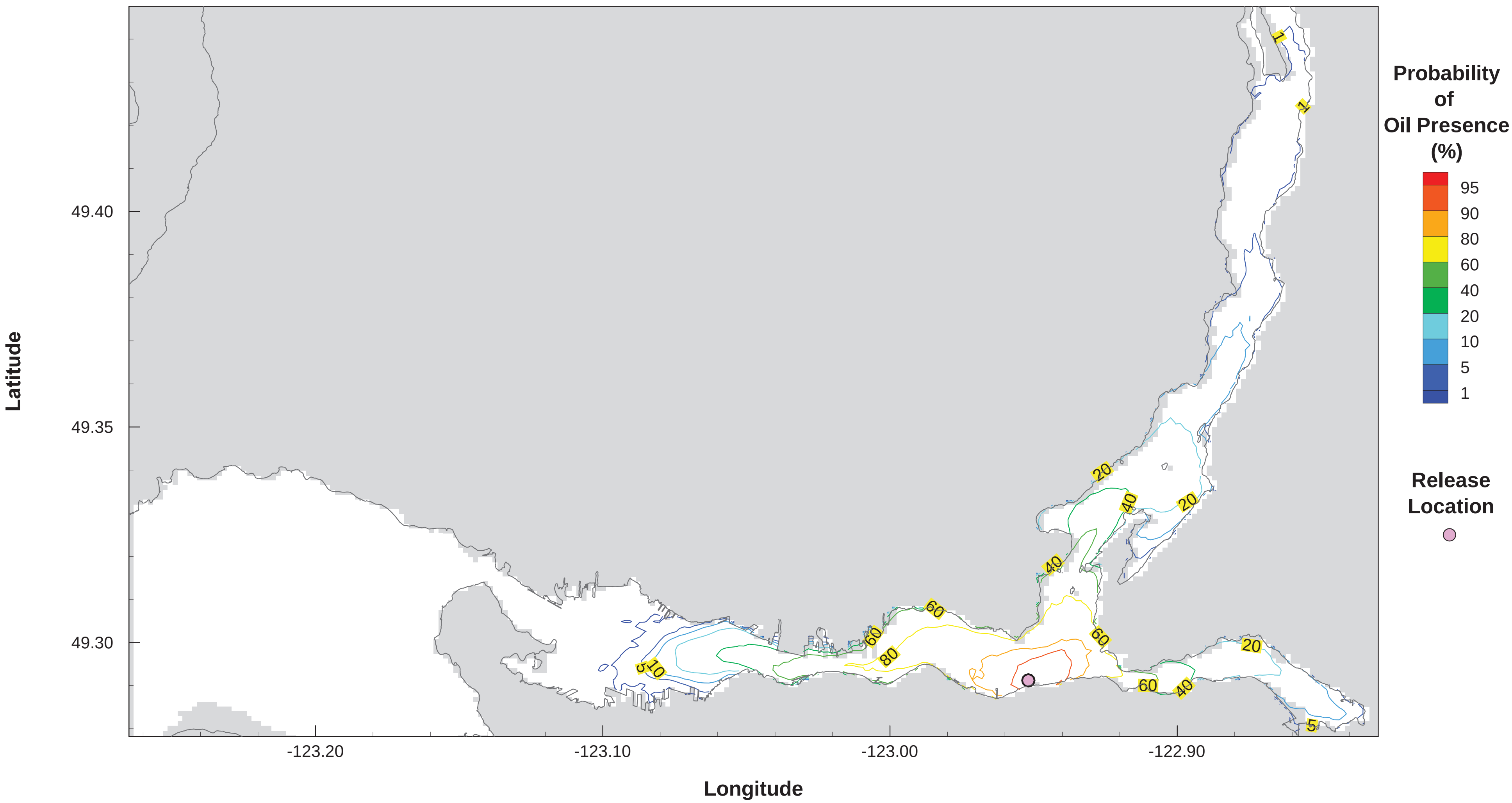
Biological Risk Factor - Mammals
1 Low
2 Medium
3 High
4 Very High

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
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

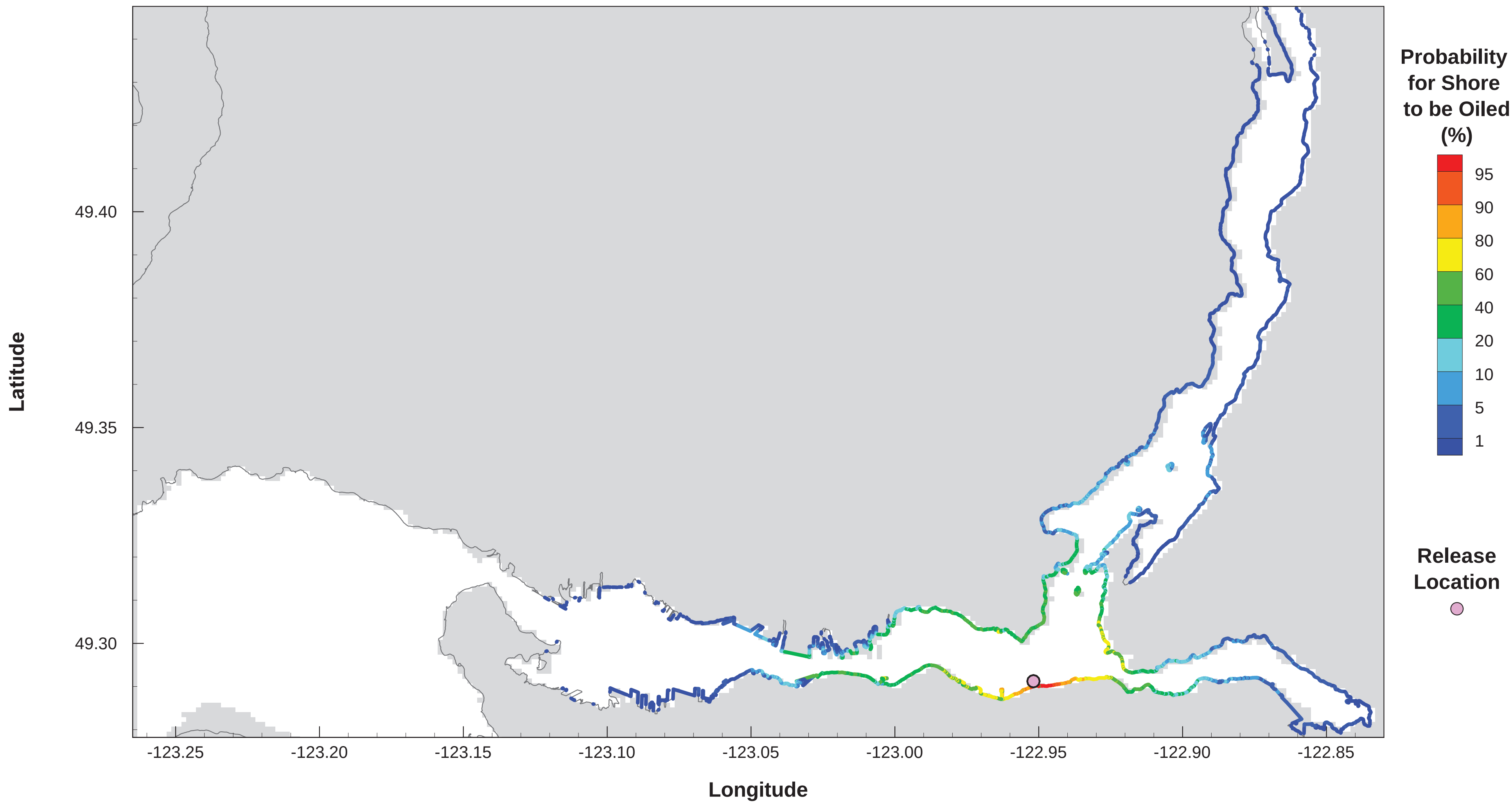
TRANS MOUNTAIN OIL SPILL STUDY

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



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STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

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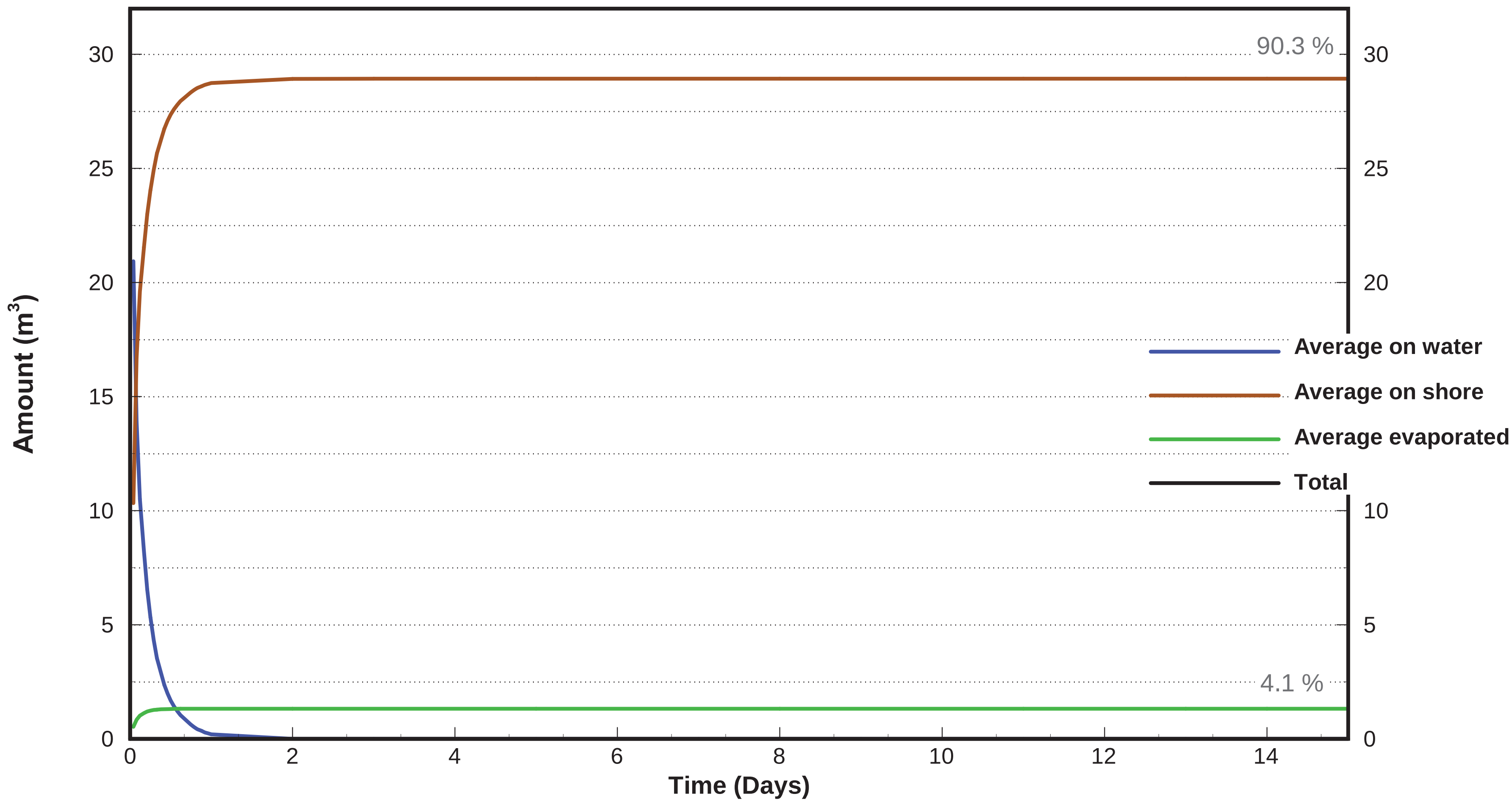
TRANS MOUNTAIN OIL SPILL STUDY

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



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
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

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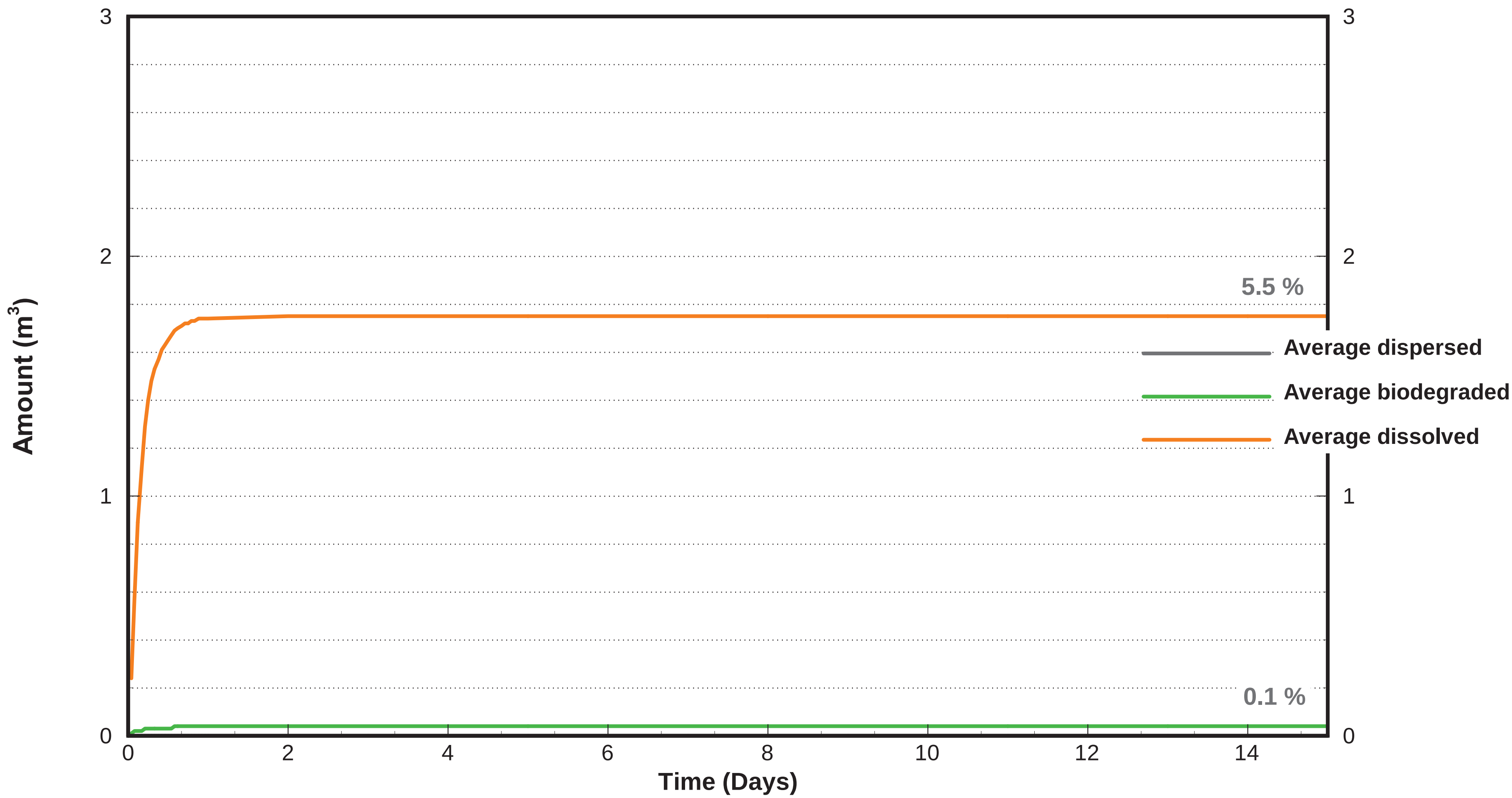
TRANS MOUNTAIN OIL SPILL STUDY

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

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

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

EBA
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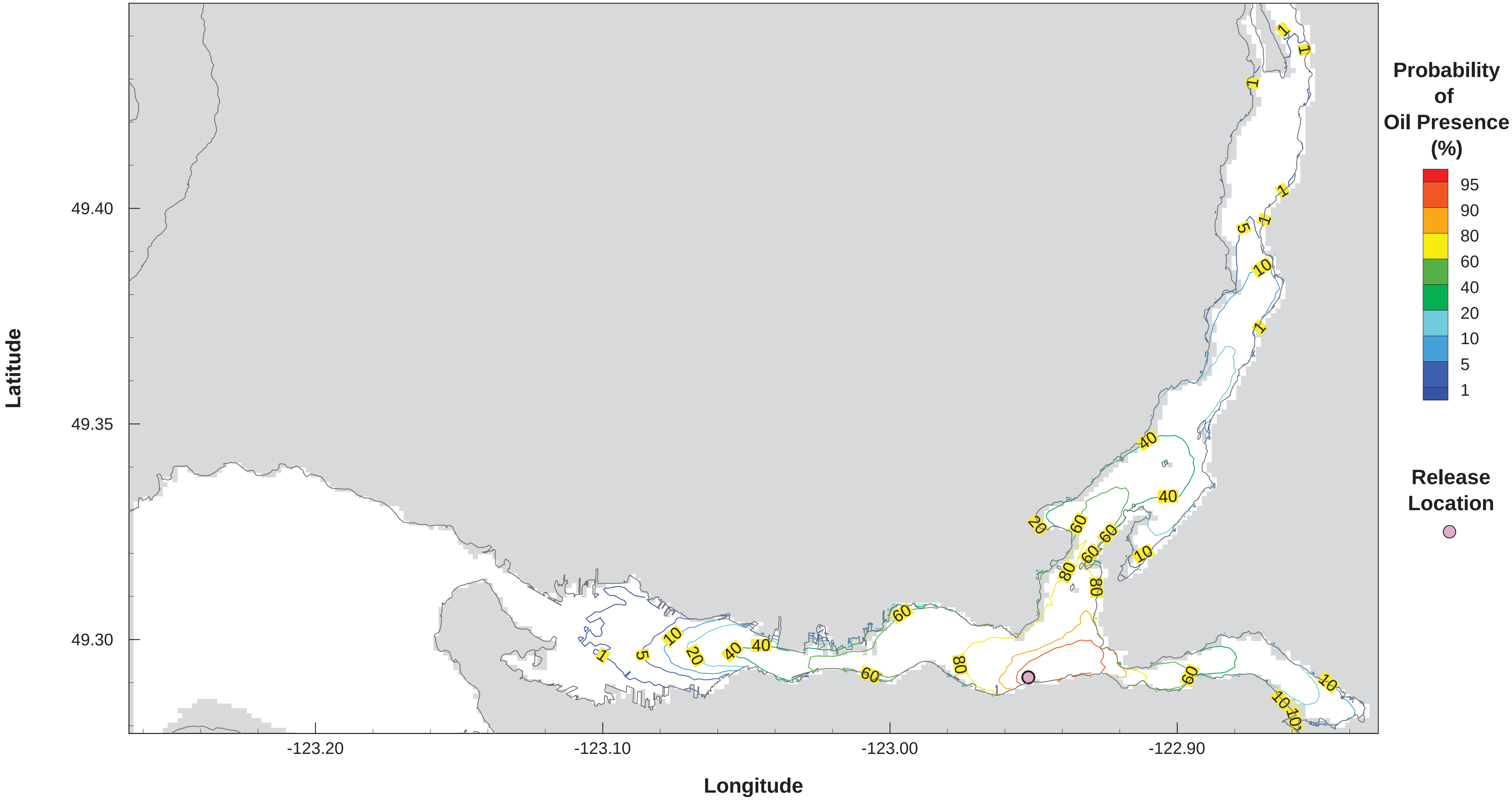
TRANS MOUNTAIN OIL SPILL STUDY

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
ISSUED FOR REVIEW

CLIENT
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TRANS MOUNTAIN OIL SPILL STUDY

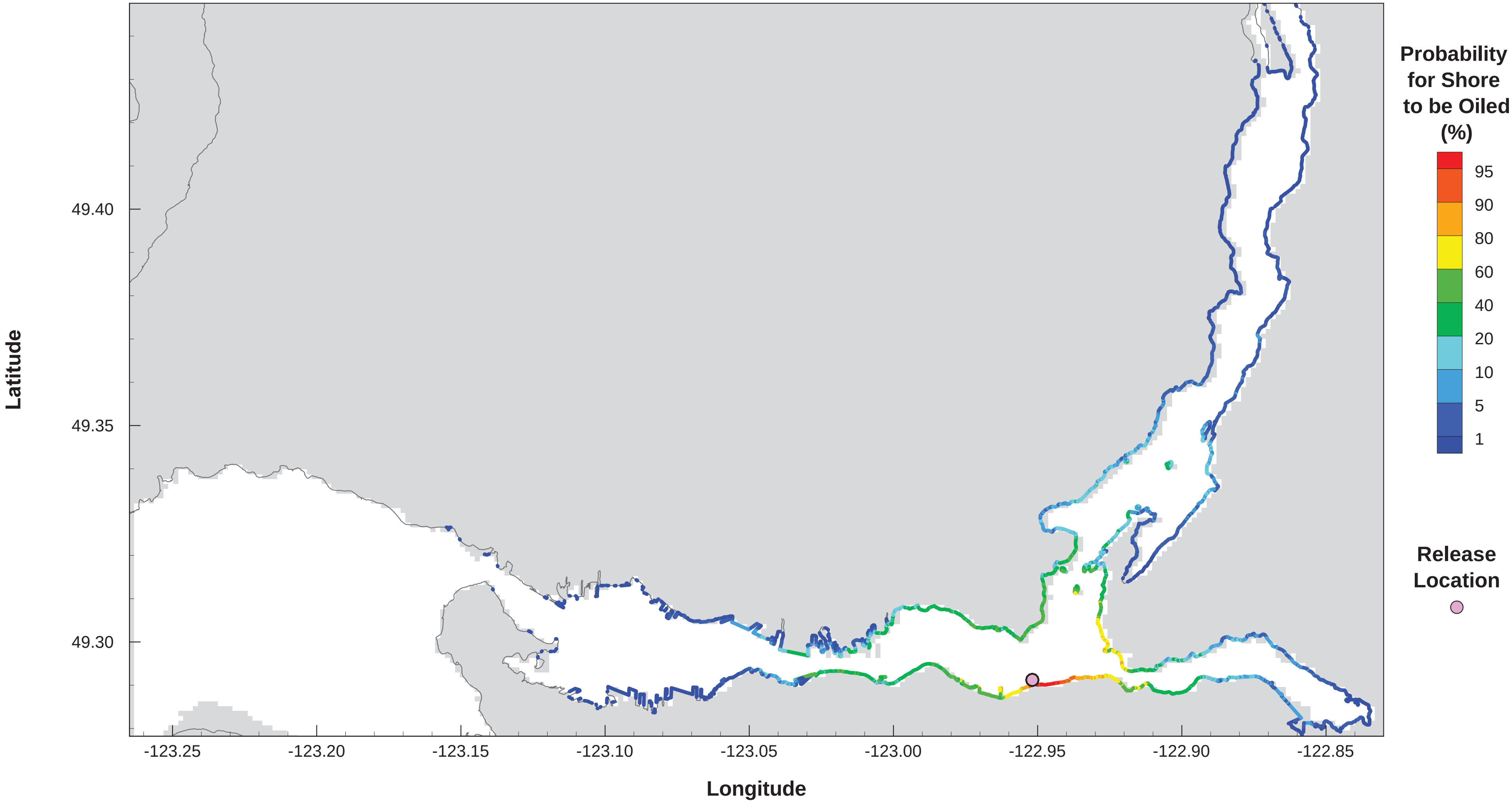
Stochastic Simulation Spring 2012, Site A Probability of Oil Presence

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

OFFICE: EBA-VANC

DATE: August 21, 2013

Figure A.2-3



NOTES

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STATUS
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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

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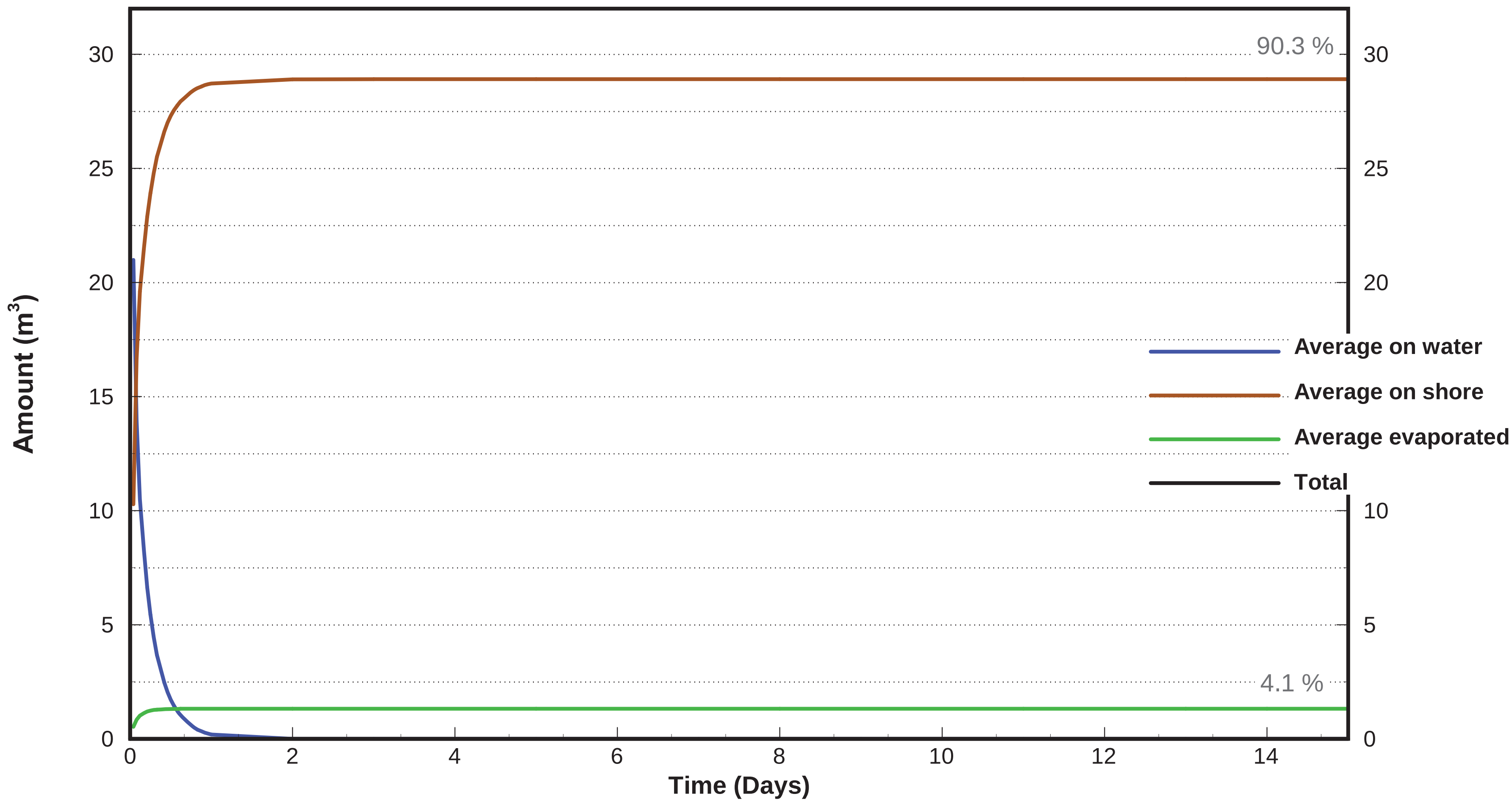
26 Aug 2013 11:44:31



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
ISSUED FOR REVIEW

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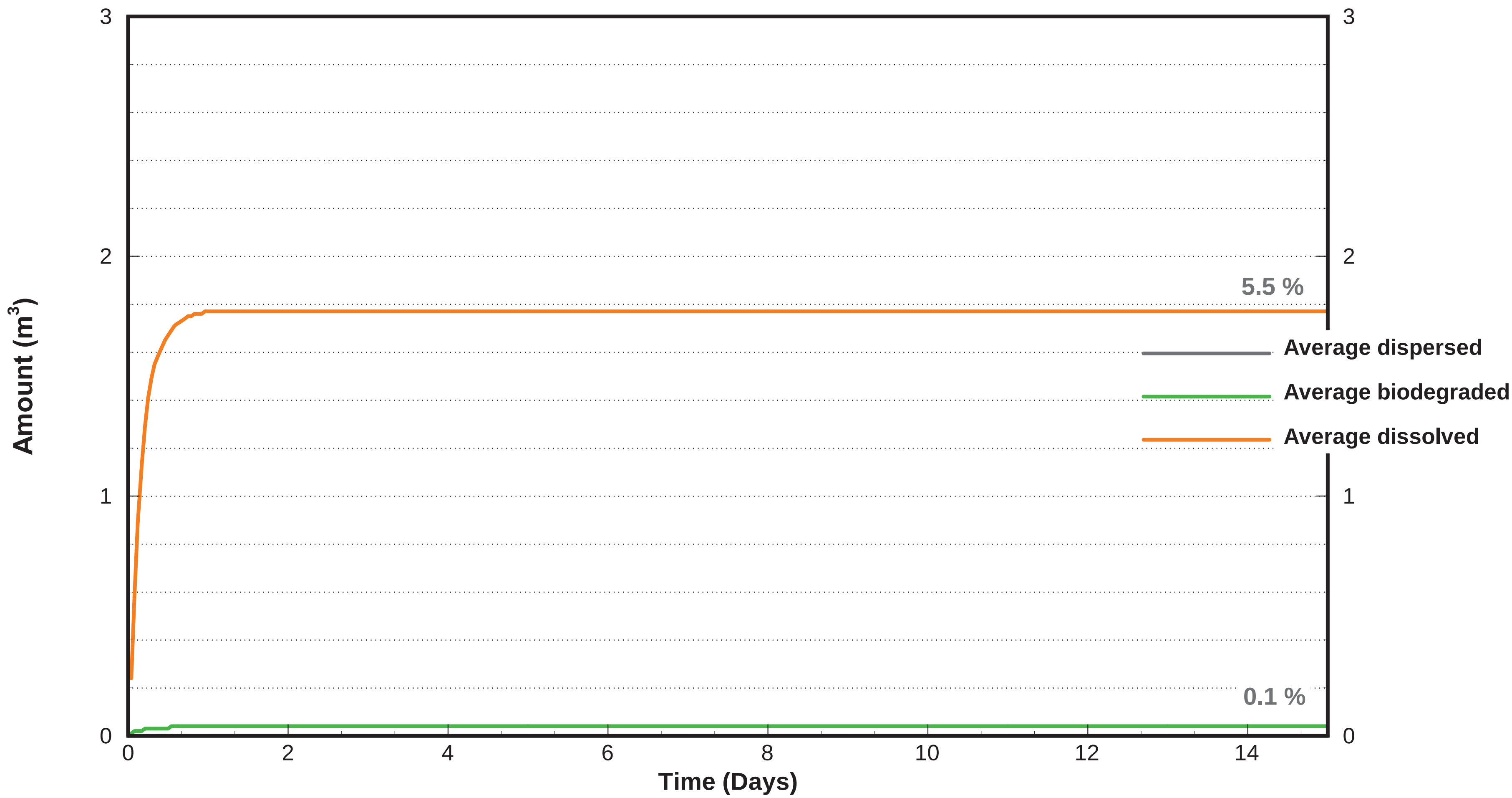
TRANS MOUNTAIN OIL SPILL STUDY

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

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STATUS
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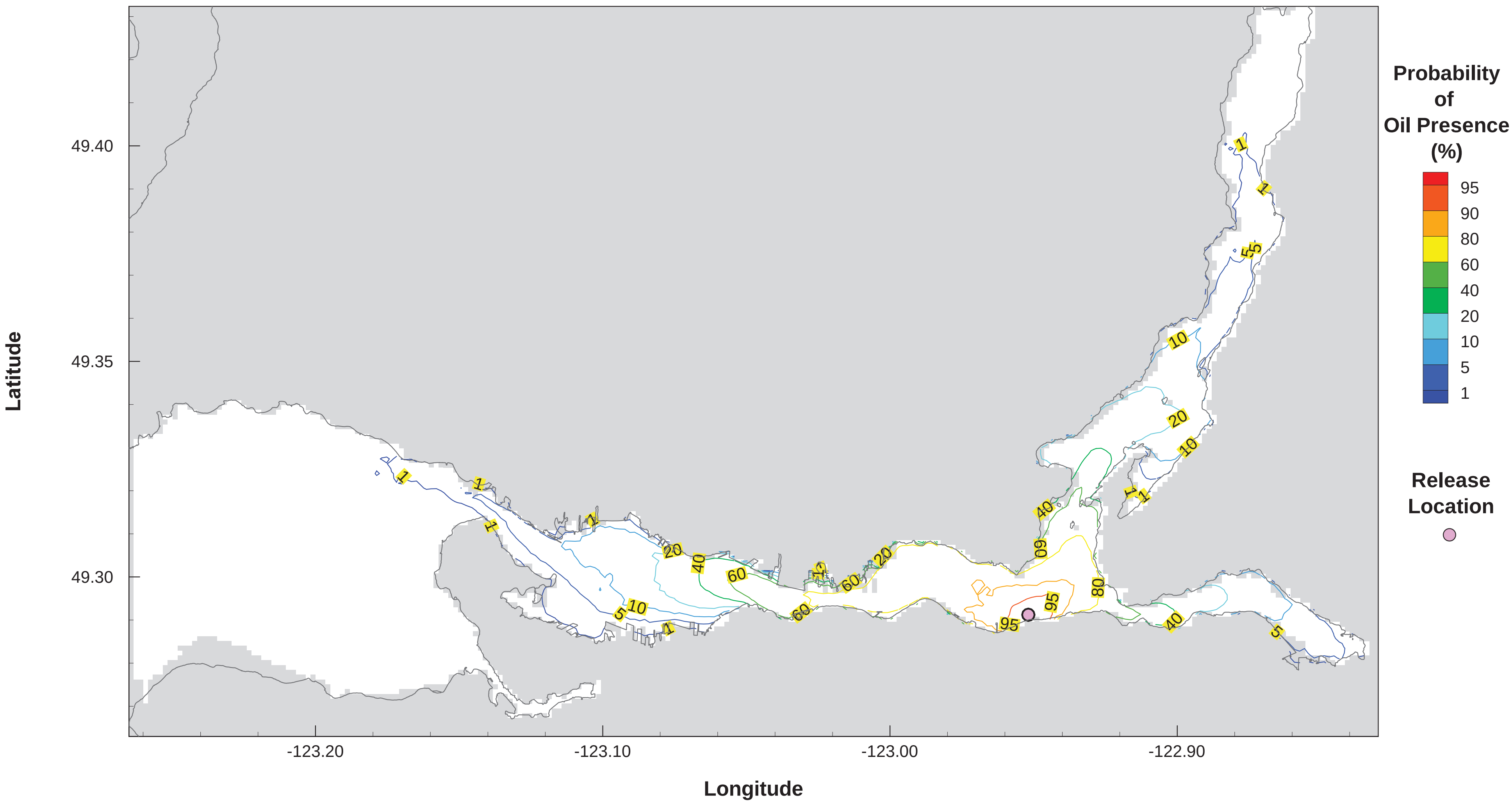
TRANS MOUNTAIN OIL SPILL STUDY

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
ISSUED FOR REVIEW

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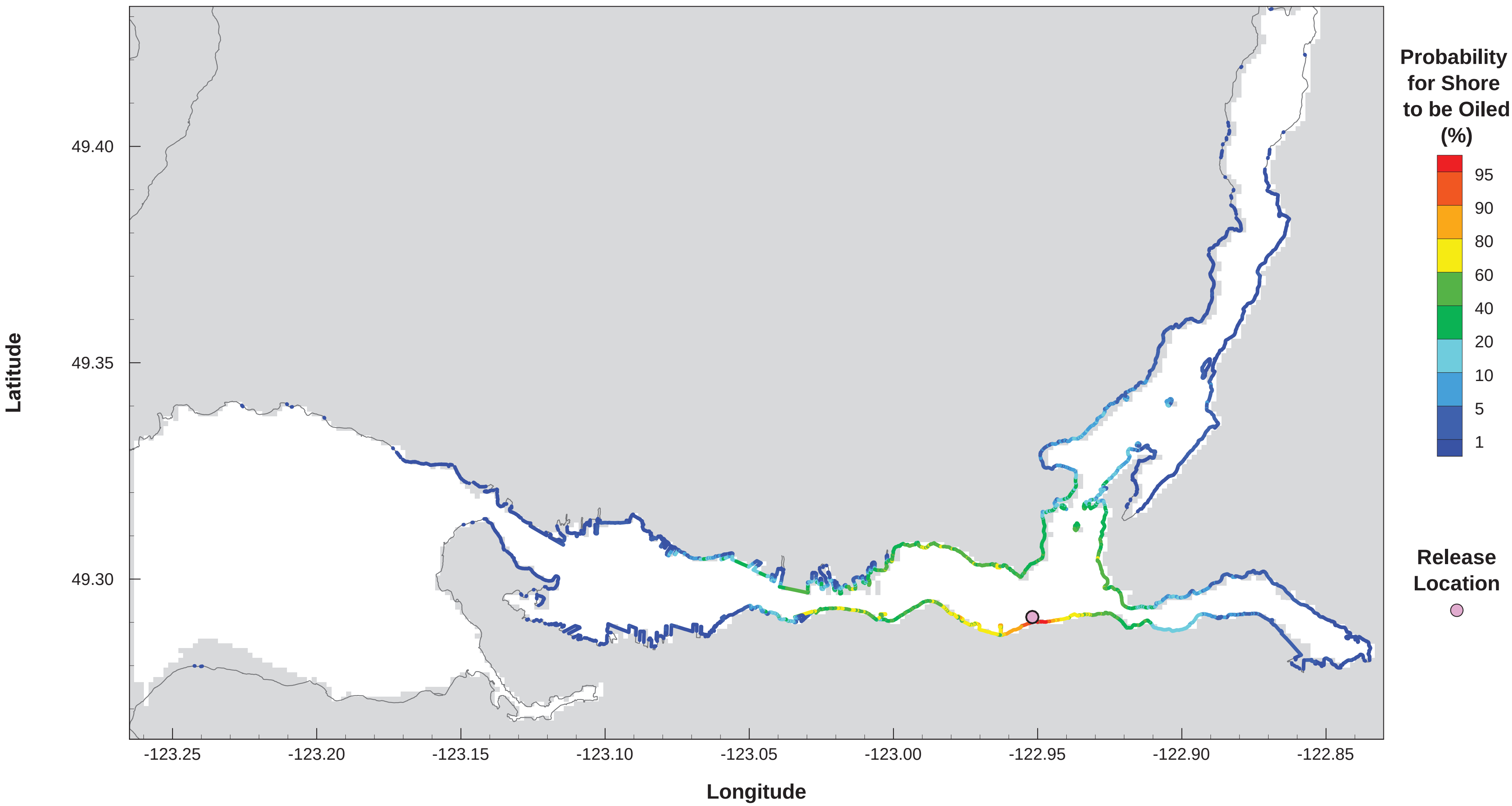
TRANS MOUNTAIN OIL SPILL STUDY

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

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STATUS
ISSUED FOR REVIEW

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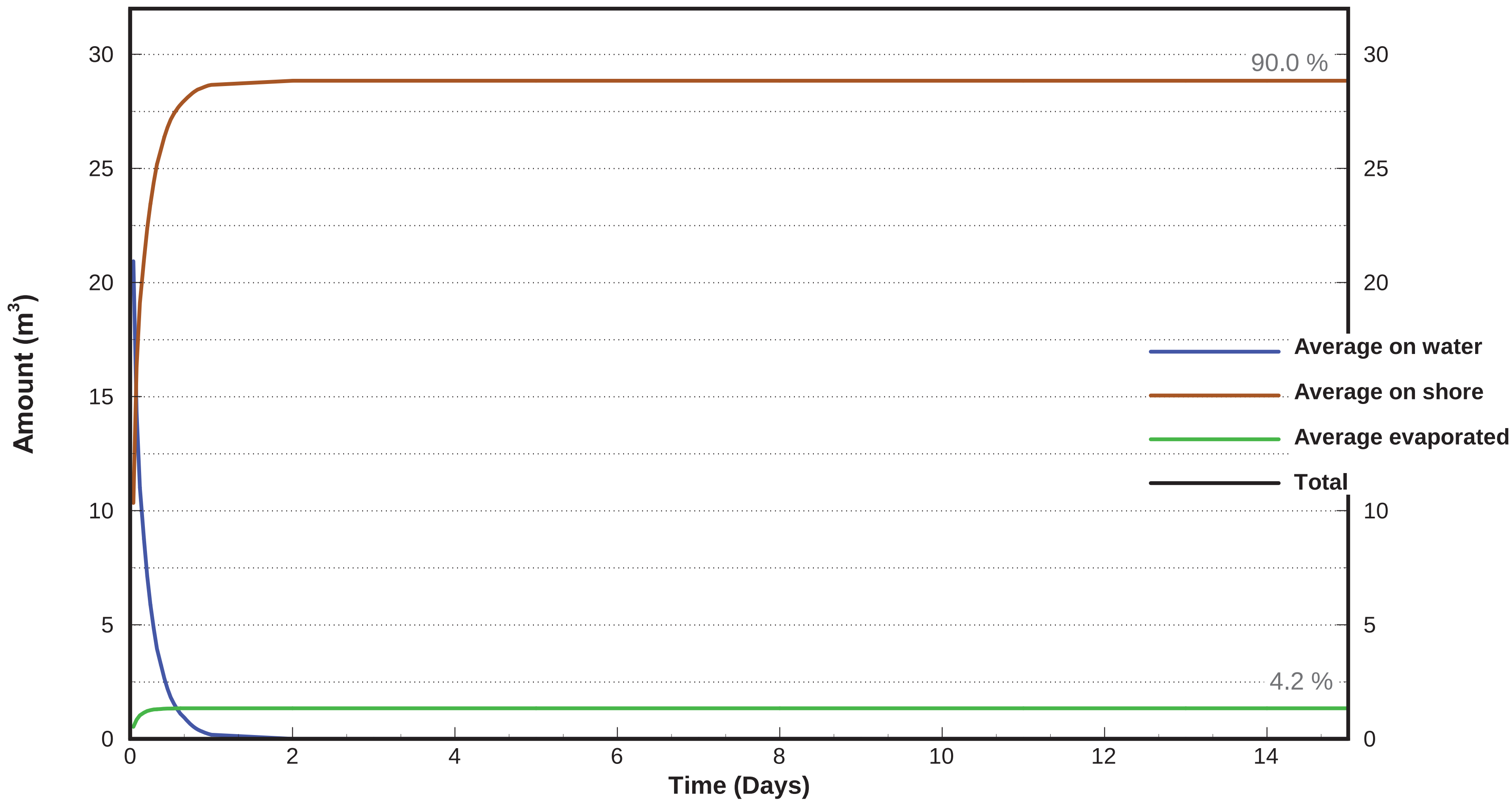
TRANS MOUNTAIN OIL SPILL STUDY

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

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- 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

CLIENT

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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

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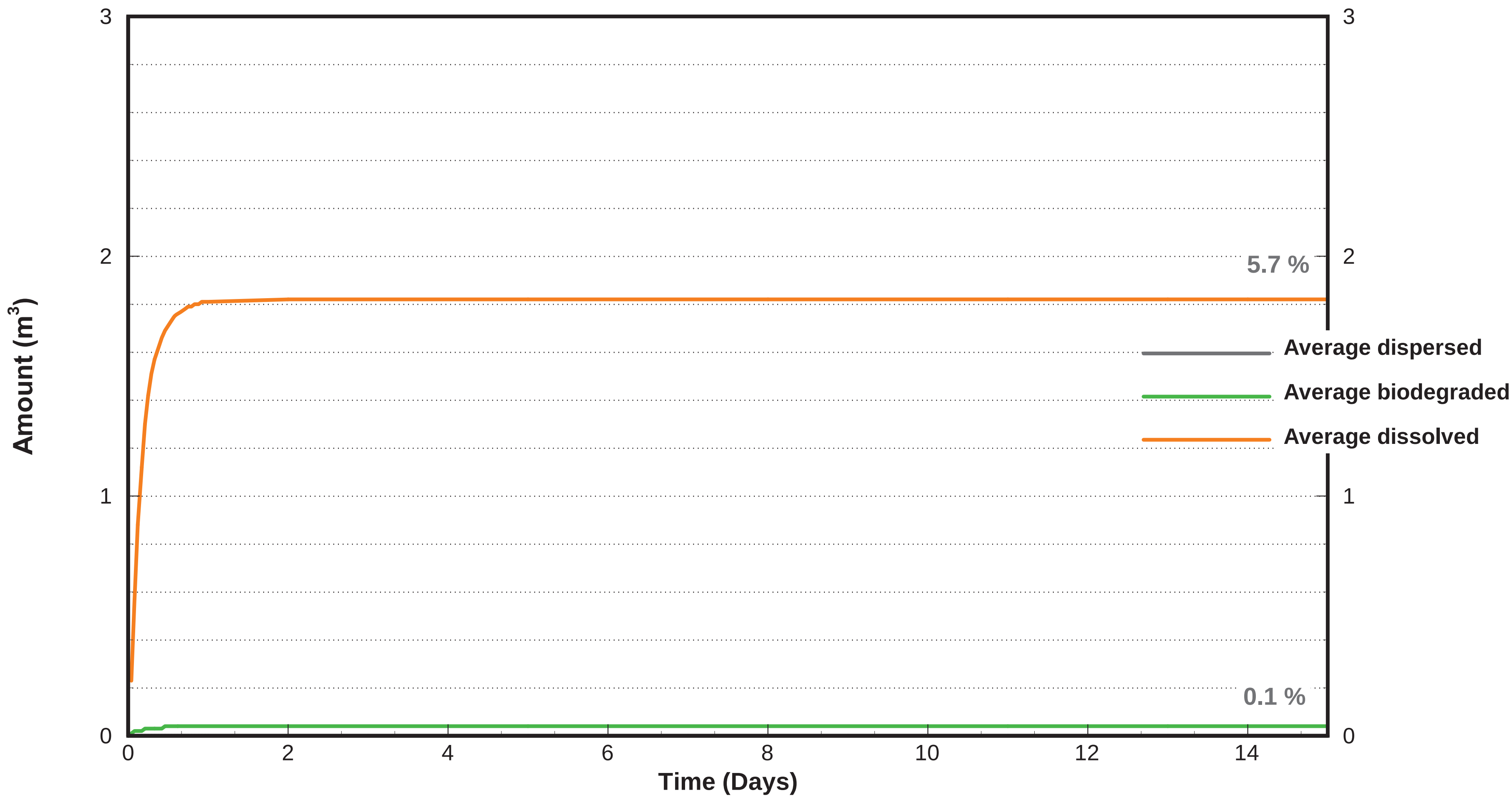
16 Oct 2013 14:38:37



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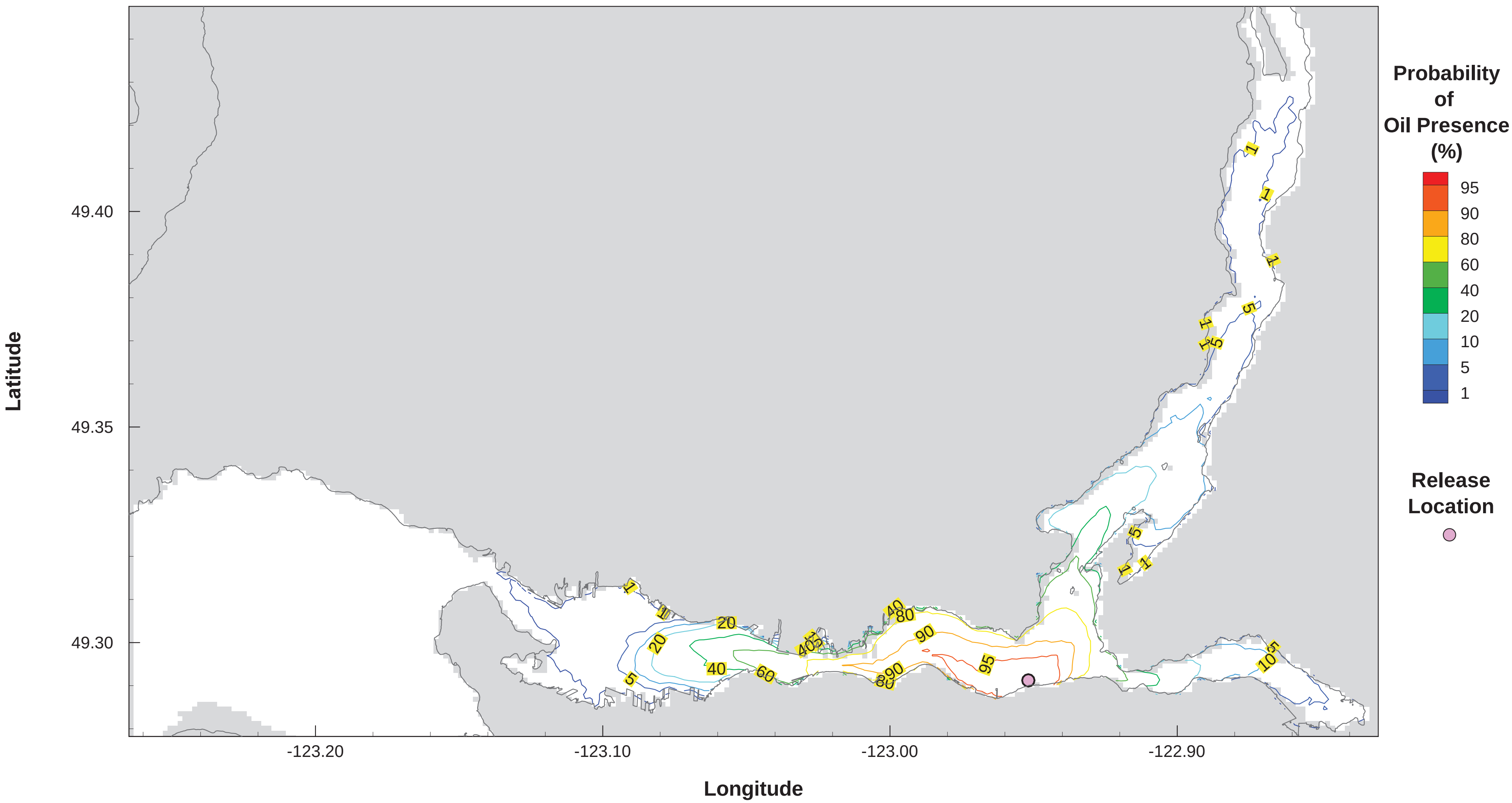
TRANS MOUNTAIN OIL SPILL STUDY

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

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

OFFICE	DATE
EBA-VANC	October 16, 2013

Figure A.3-10



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

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

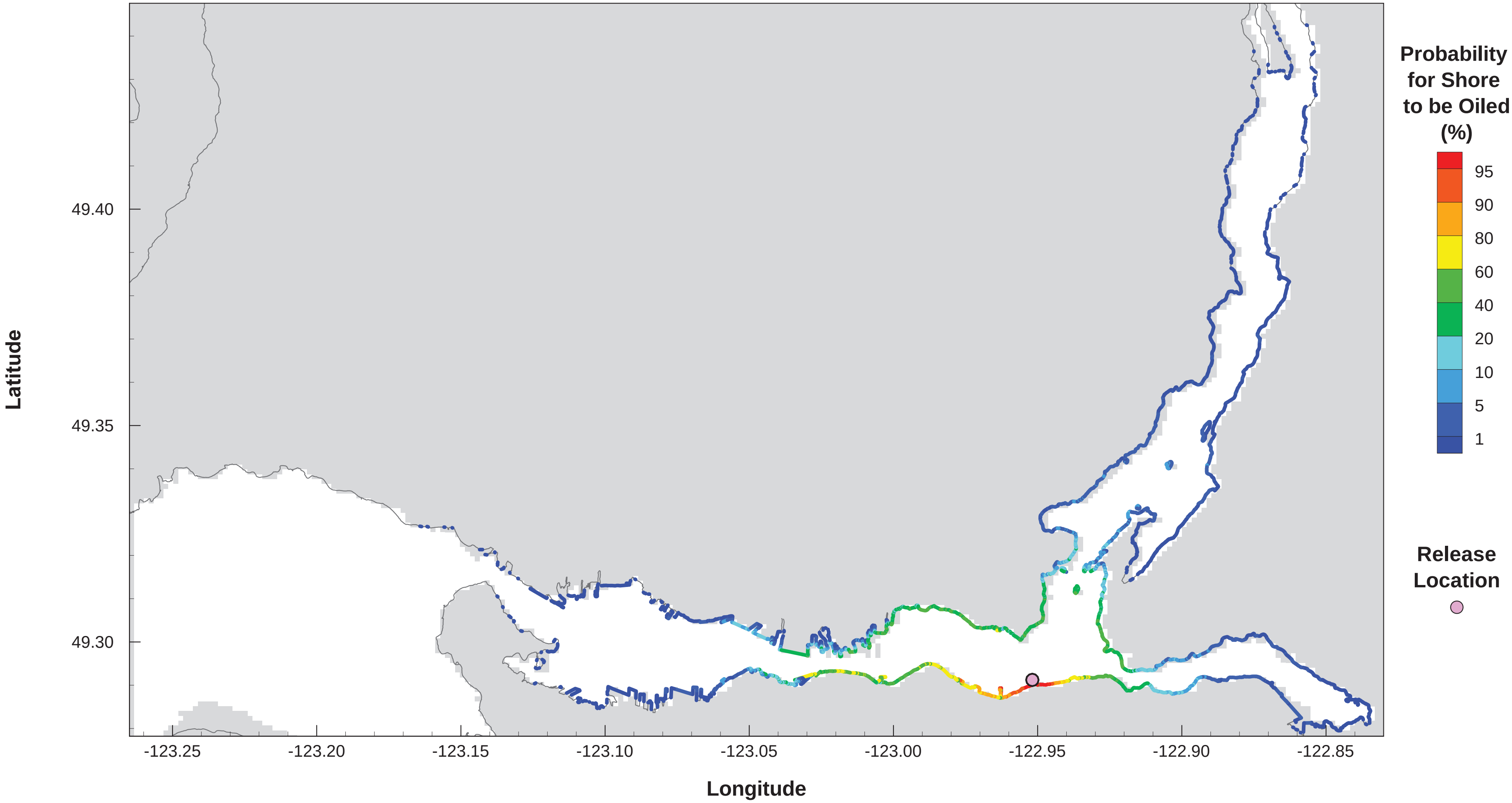
TRANS MOUNTAIN OIL SPILL STUDY

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



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

CLIENT
TRANSMOUNTAIN

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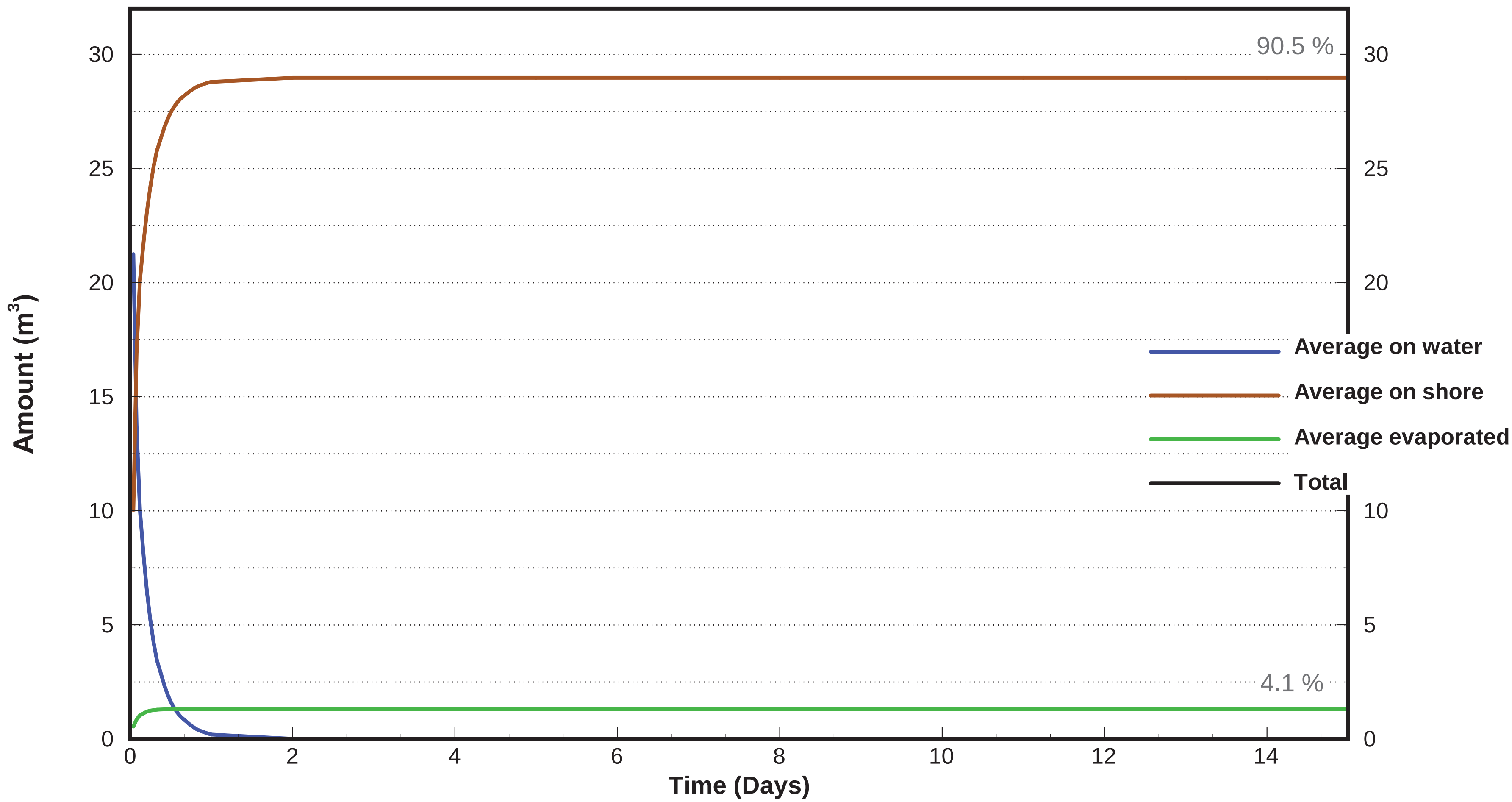
TRANS MOUNTAIN OIL SPILL STUDY

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



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

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

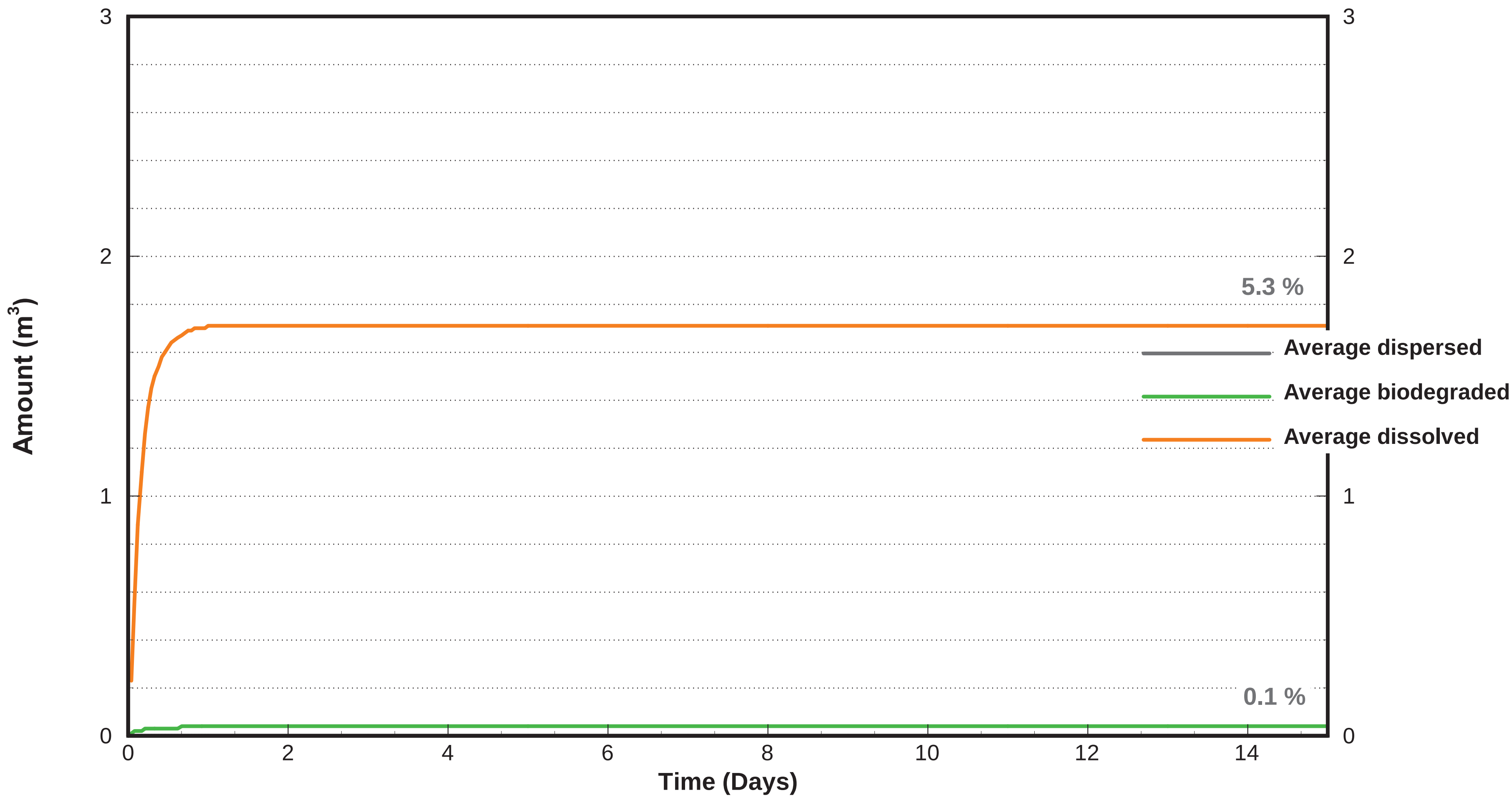
TRANS MOUNTAIN OIL SPILL STUDY

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

CLIENT
TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

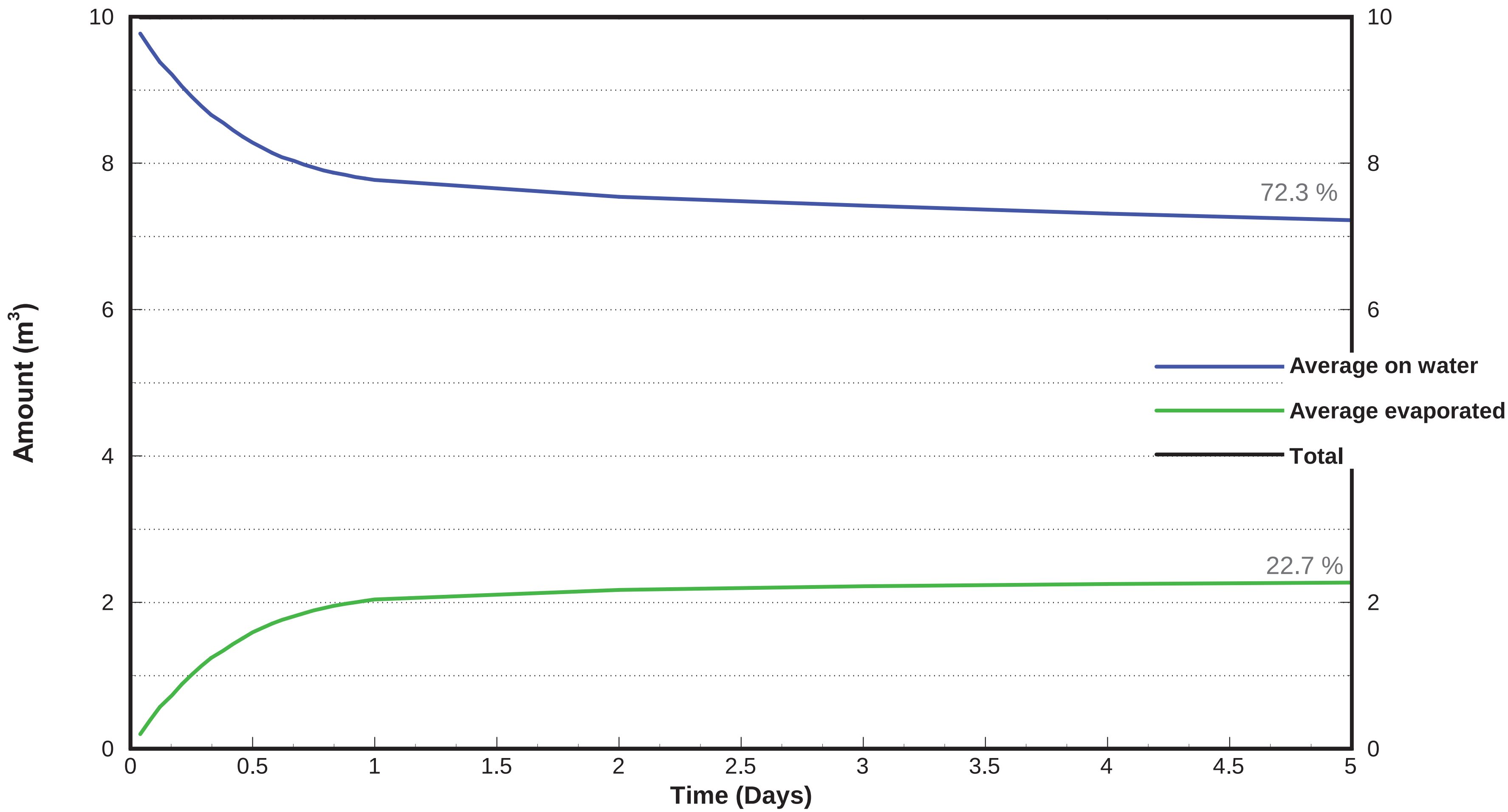
Stochastic Simulation
Fall 2011, Site A
Minor Components of the Mass Balance

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

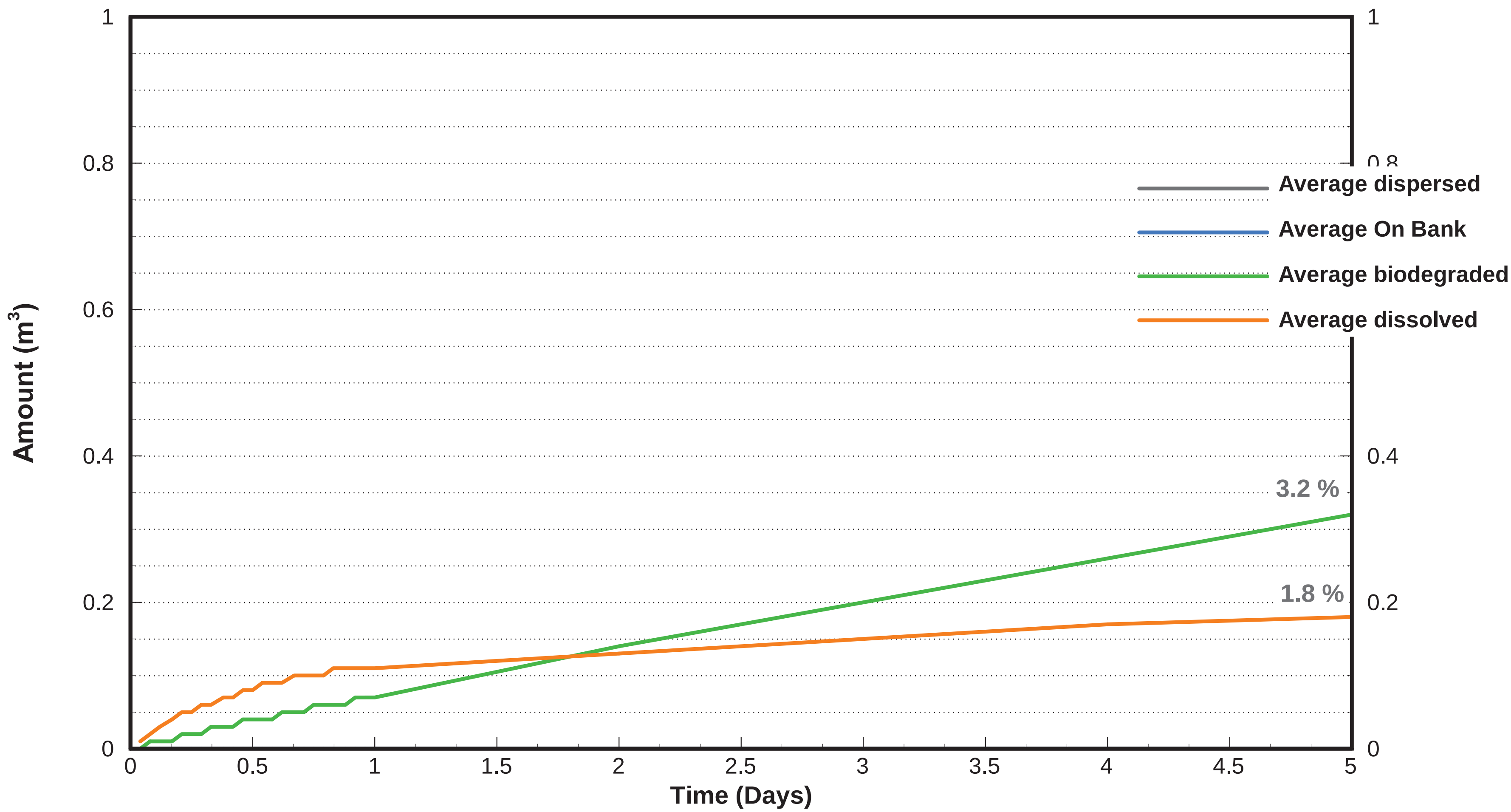
EBA A TETRA TECH COMPANY

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	Figure A.1-2
V13203022	AH	JAS	-	0	
OFFICE	DATE				
EBA-VANC	October 23, 2013				

T:\TMEP\working\AH\02-SPILLCALC\512-Stochastic_Westridge_10m3_Boom\Results_Winter\Tecplot\08-statistics_MB_1.lay 21 Oct 2013 15:20:11



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

CLIENT
TRANSMOUNTAIN

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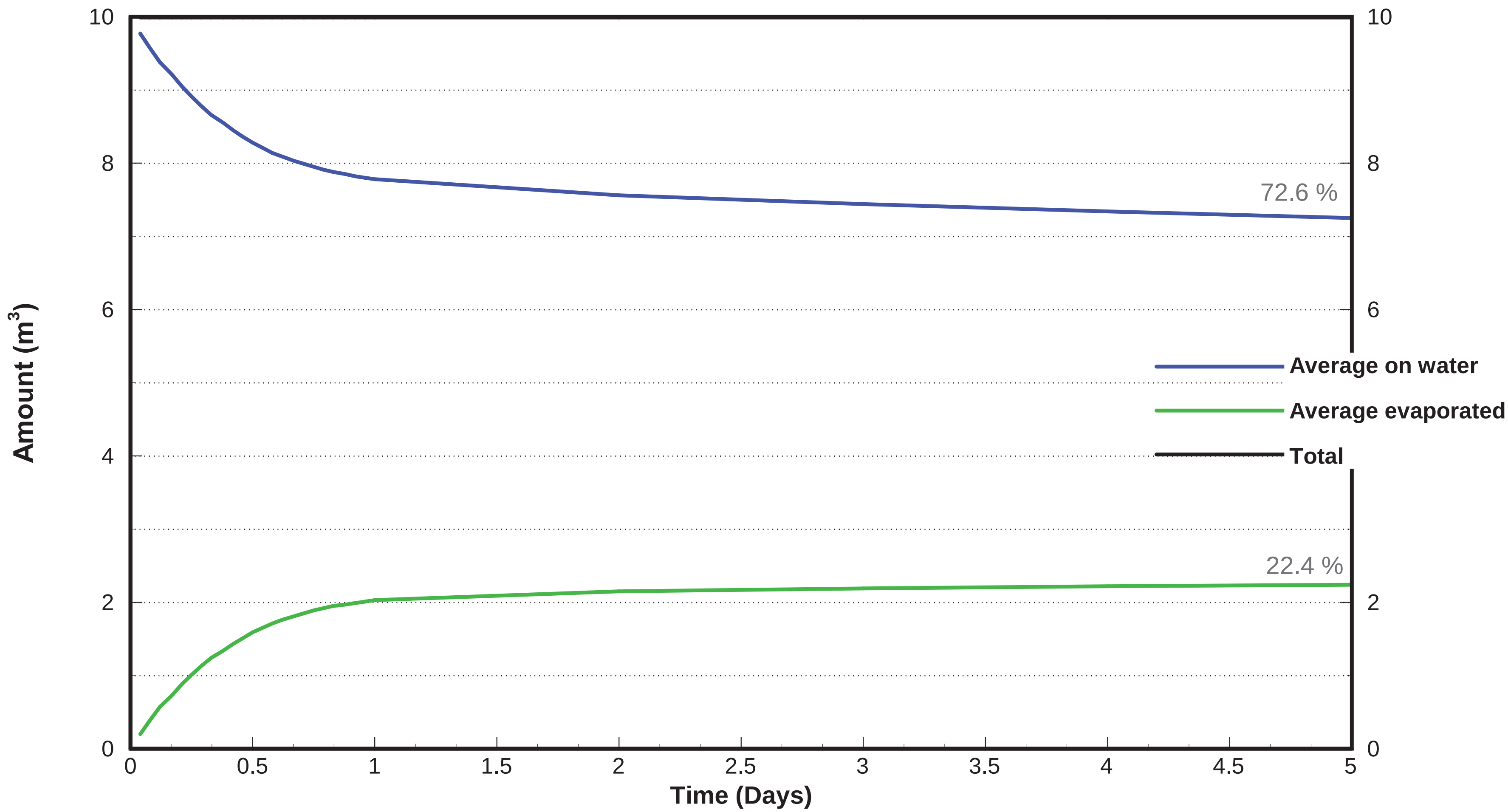
TRANS MOUNTAIN OIL SPILL STUDY

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



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

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

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

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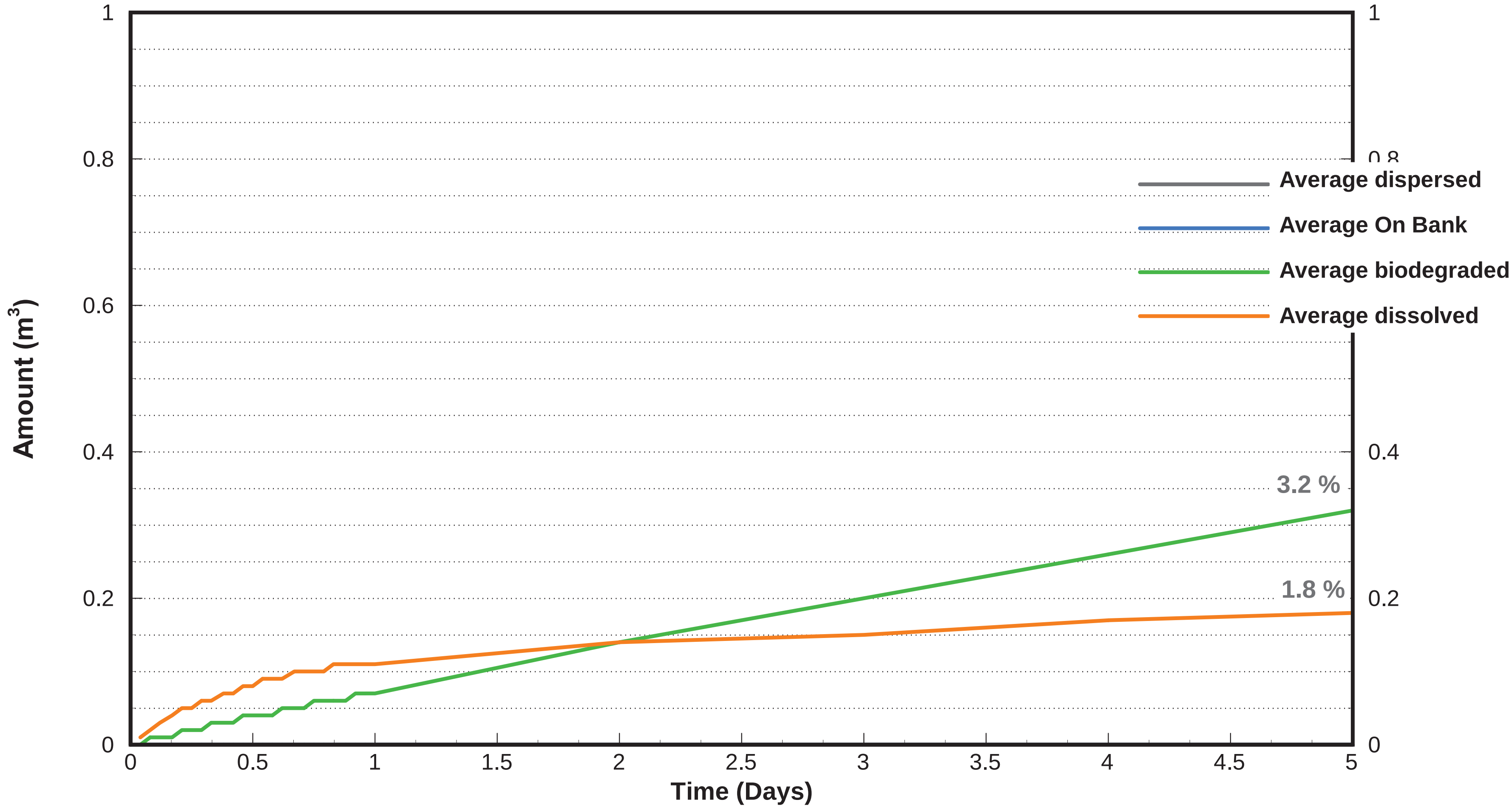


NOTES

- 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

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

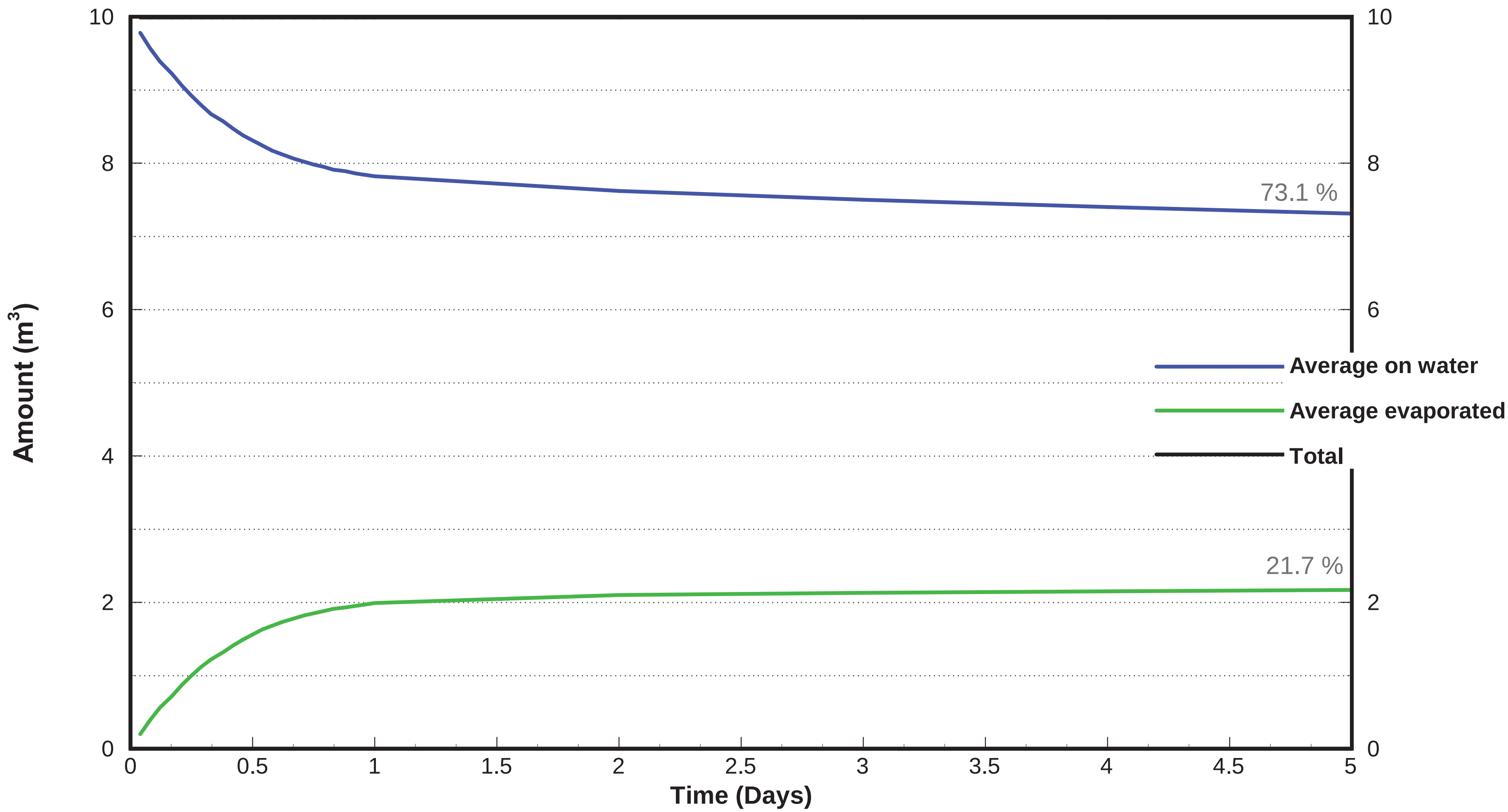
TRANS MOUNTAIN OIL SPILL STUDY

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



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

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

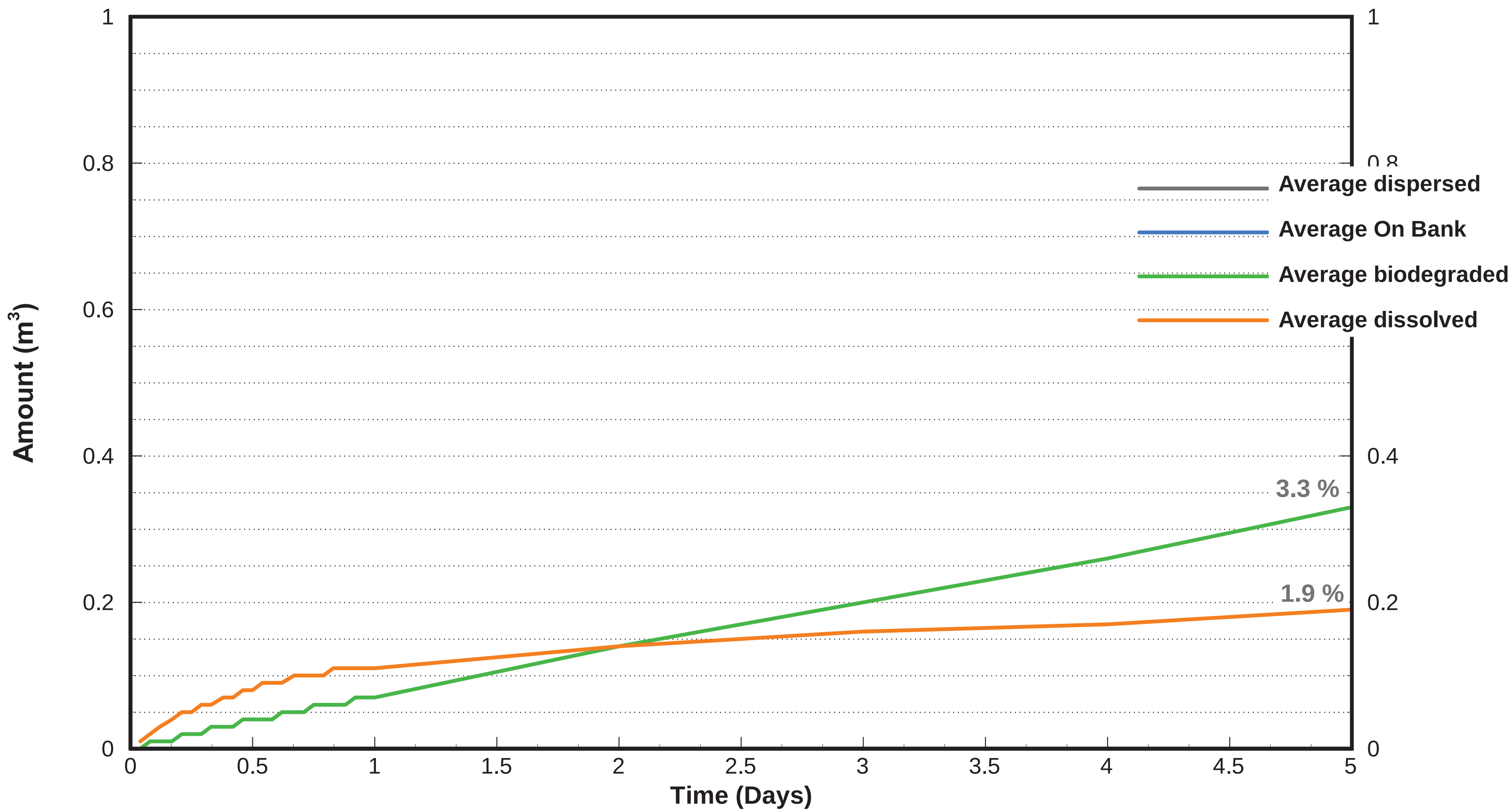
TRANS MOUNTAIN OIL SPILL STUDY

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



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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CLIENT
TRANSMOUNTAIN

EBA A TETRA TECH COMPANY

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

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

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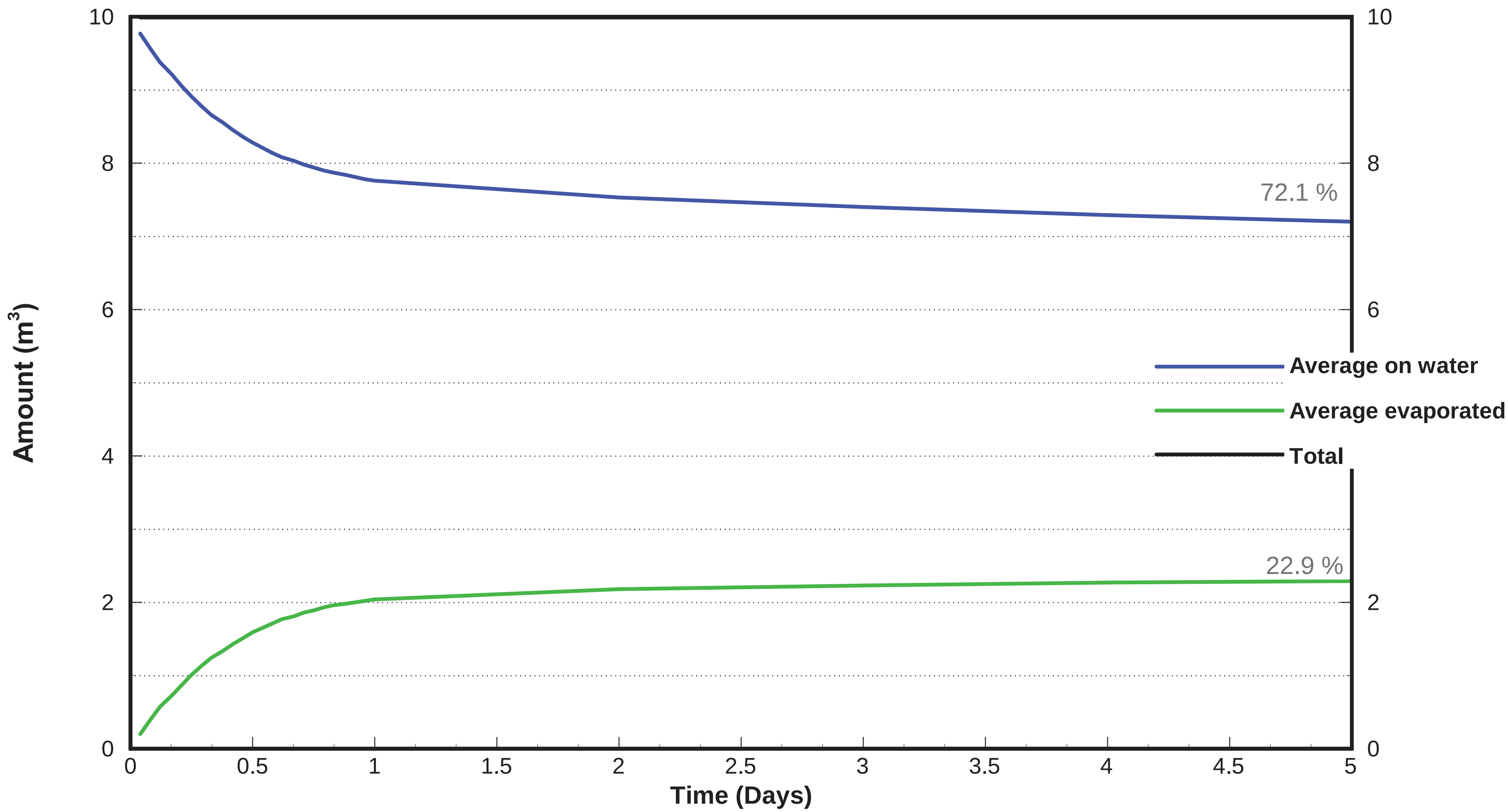

NOTES

- 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.

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

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

T:\TMEP\working\AH\02-SPILLCALC\512-Stochastic_Westridge_10m3_Boom\Results_Fall\Tecplot\08-statistics_MB_1.lay

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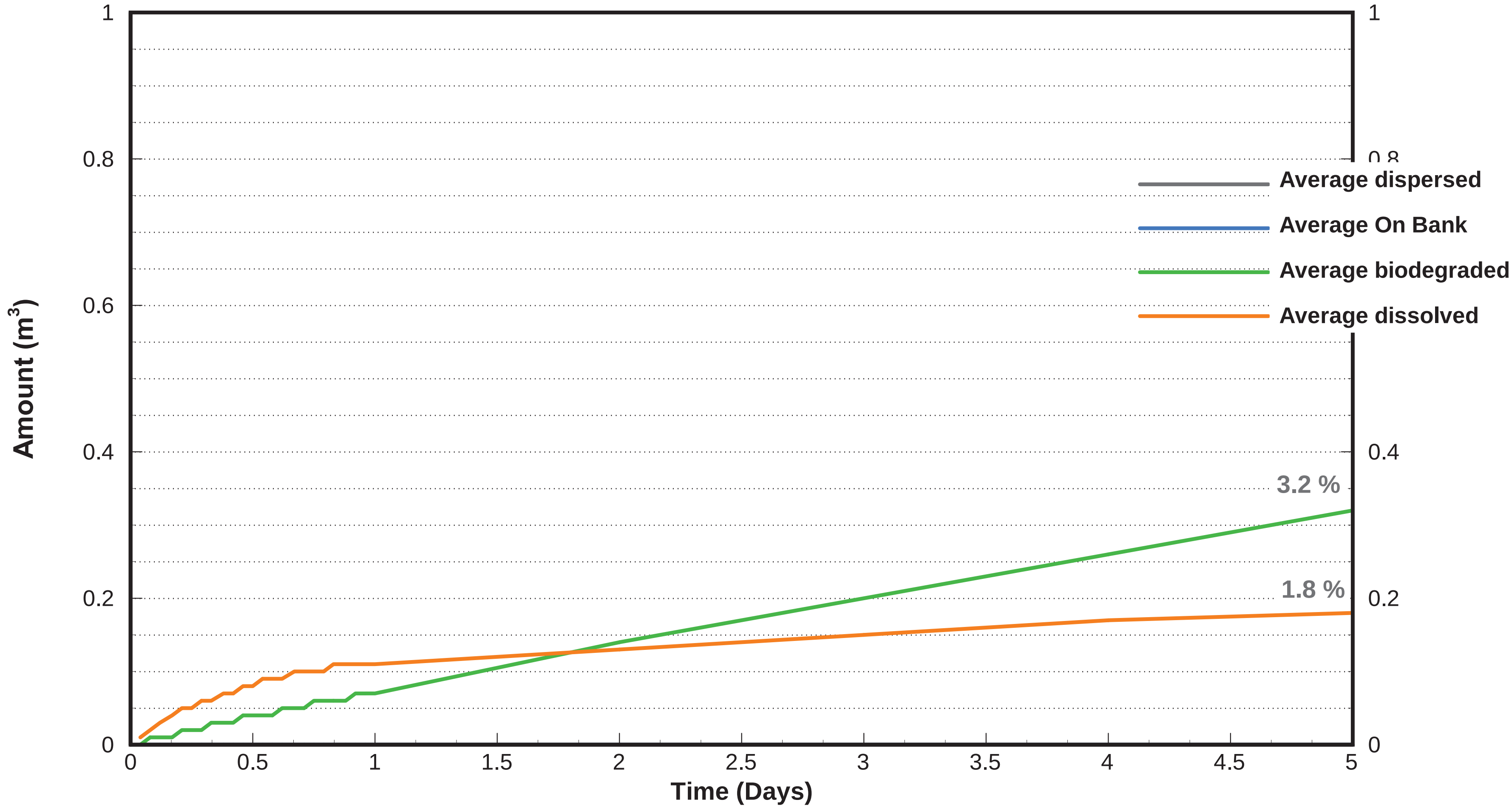

NOTES

- 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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CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

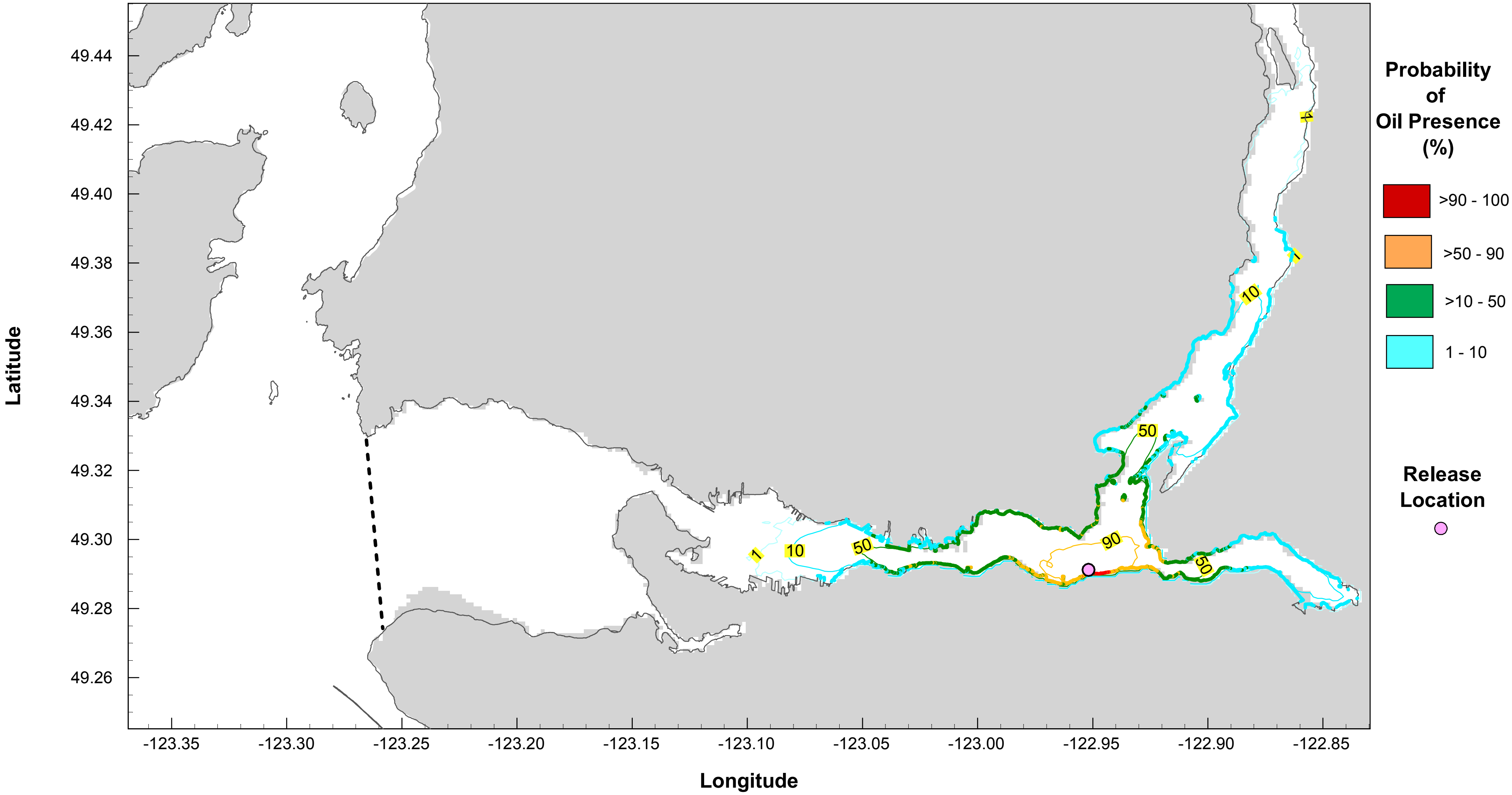
Stochastic Simulation
Fall 2011, Site A (10 m^3)
Minor Components of the Mass Balance

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

OFFICE	DATE
EBA-VANC	October 23, 2013

Figure A.4-3

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.

STATUS
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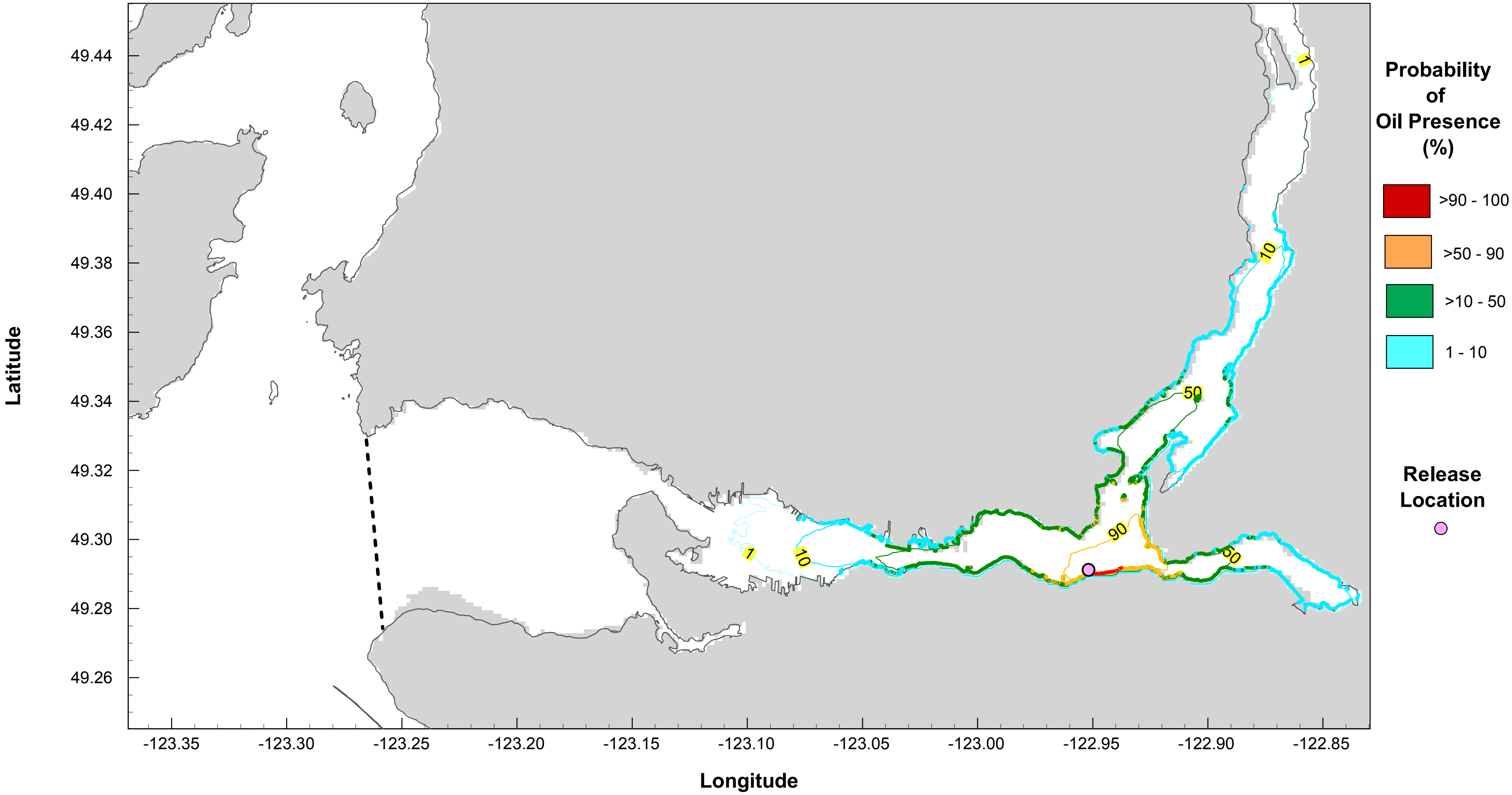
TRANS MOUNTAIN OIL SPILL STUDY

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.

STATUS
ISSUED FOR USE

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

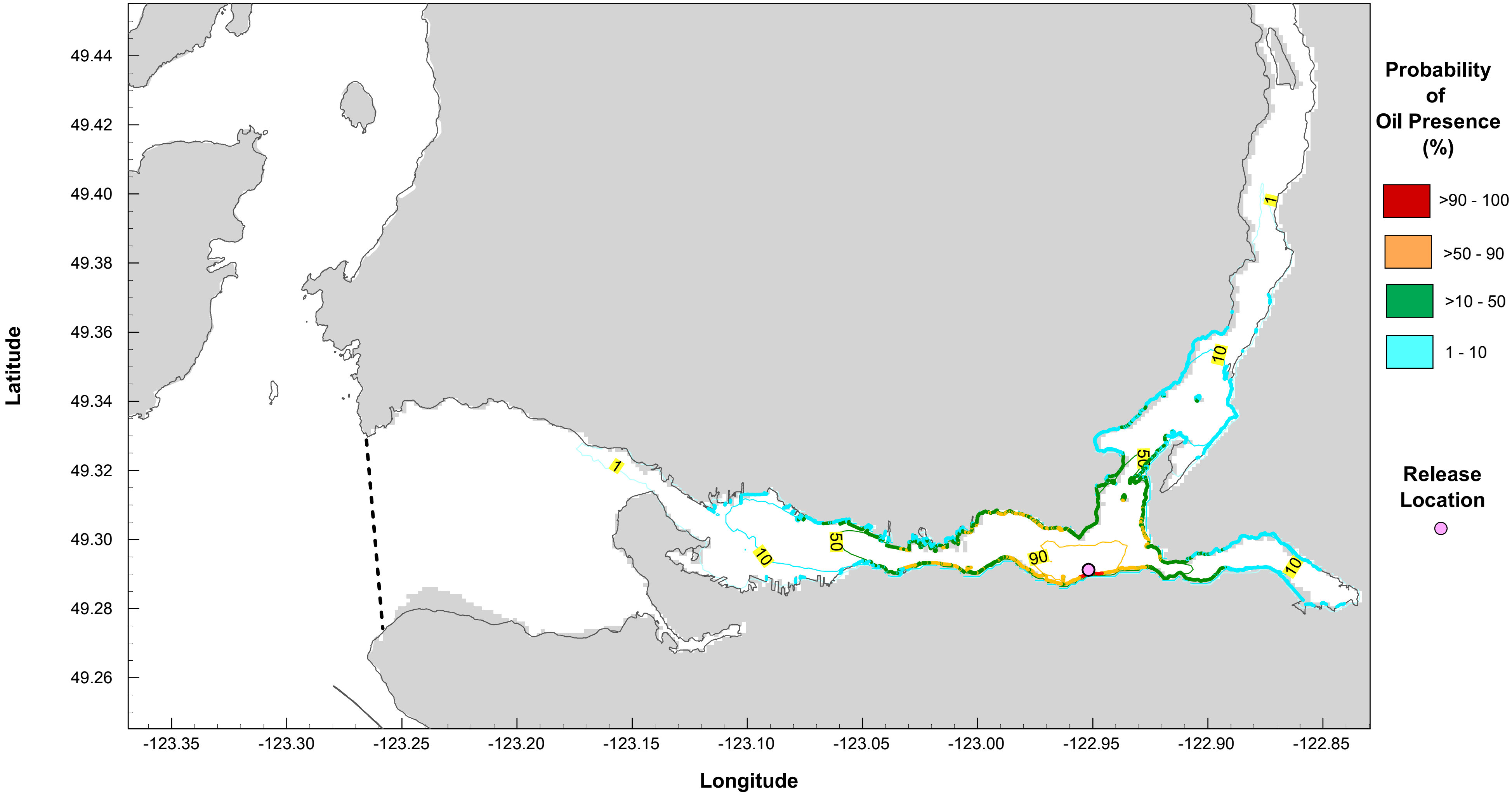
TRANS MOUNTAIN OIL SPILL STUDY

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



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.

STATUS
ISSUED FOR USE

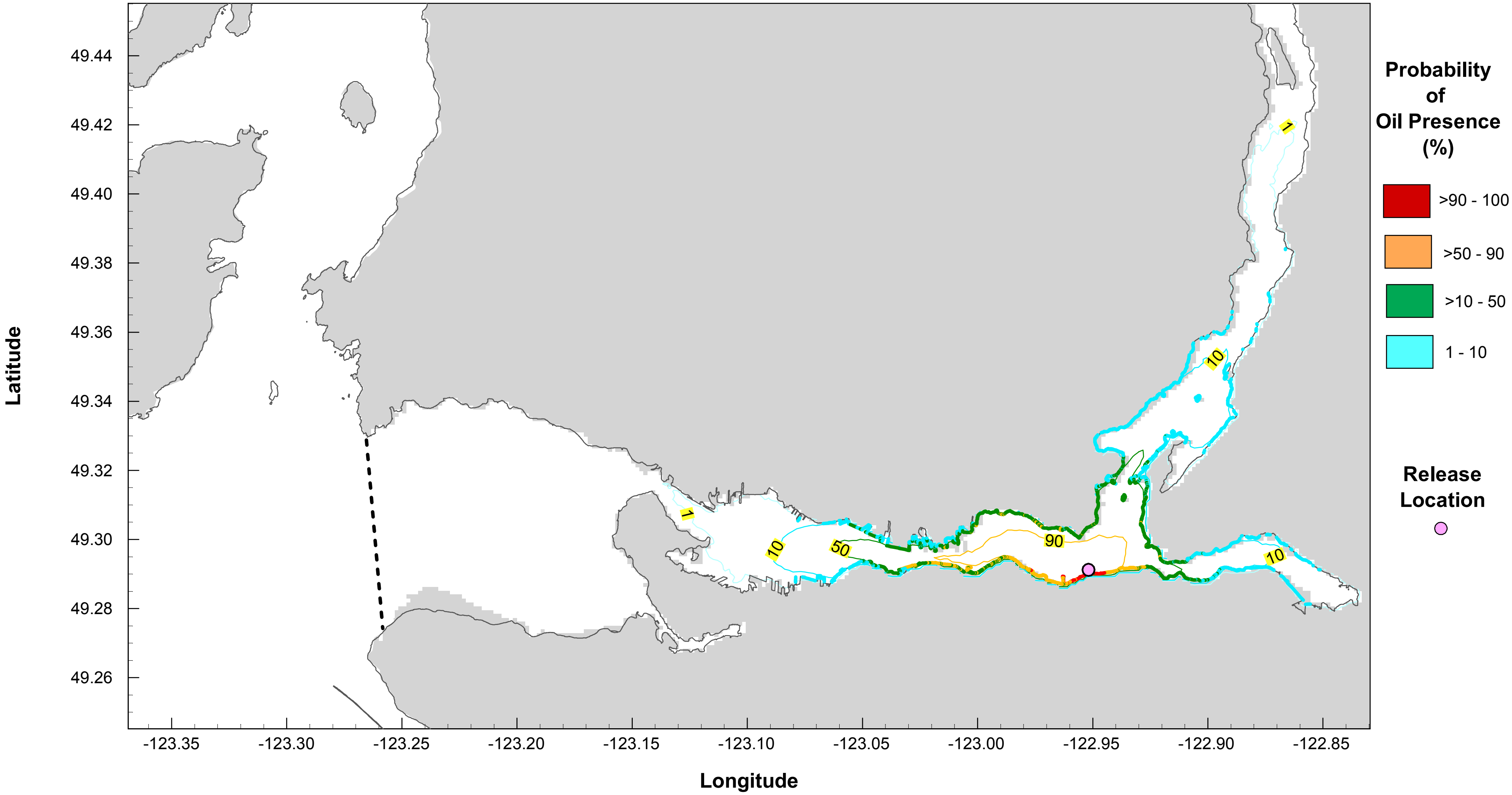
CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

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	Figure D.3
OFFICE	DATE				
EBA-VANC	December 9, 2013				



NOTES

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STATUS
ISSUED FOR USE

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

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

QUALITATIVE HUMAN HEALTH RISK ASSESSMENT OF WESTRIDGE MARINE TERMINAL SPILLS TECHNICAL REPORT FOR THE TRANS MOUNTAIN PIPELINE ULC TRANS MOUNTAIN EXPANSION PROJECT

December 2013

REP-NEB-TERA-00033

Prepared for:

TRANSMOUNTAIN

Trans Mountain Pipeline ULC

Kinder Morgan Canada Inc.
Suite 2700, 300 – 5th Avenue S.W.
Calgary, Alberta T2P 5J2
Ph: 403-514-6400

Prepared by:

intrinsik

Intrinsik Environmental Sciences Inc.
Suite 1060, 736 - 8th Avenue S.W.
Calgary, Alberta T2P 1H4
Ph: 403-237-0275

EXECUTIVE SUMMARY

This report outlines the methods that were used, the findings that emerged and the conclusions that were reached as part of a preliminary qualitative human health risk assessment (QHHRA) of two simulated scenarios involving oil spills during tanker loading at the Westridge Marine Terminal:

1) A credible worst case (CWC) oil spill scenario of 160 m^3 in which 80% of the spilled oil was assumed to be contained with the boom at the berth and 20% of the spilled oil escaped the boom and entered the Burrard Inlet; and,
2) A smaller 10 m^3 spill scenario, totally contained within the boom.

The QHHRA focused on the potential health effects that could occur among people present in the area surrounding the Westridge Marine Terminal, whether on shore or on the water in pleasure craft or other boats.

The QHHRA focused on the acute inhalation exposures to hydrocarbons vapours emitted from the surface of the oil slick that people could experience during the early stages of the oil spill. No other relevant exposure pathways by which people in the area could be exposed to the hydrocarbons were identified.

The QHHRA revealed some prospect for people's health to be affected from acute inhalation exposure to the hydrocarbon vapours under the CWC simulated spill scenario. Based on the types of chemicals that might be encountered, the potential health effects experienced by these people would likely be dominated by irritation of the eyes and/or breathing passages, possibly accompanied by symptoms consistent with central nervous system (CNS) involvement, such as nausea, headache, light headedness and/or dizziness. The effects could range from barely noticeable to quite noticeable, depending on the actual exposure circumstances and the sensitivity of the individuals exposed.

The QHHRA revealed no obvious prospect for people's health to be affected from acute inhalation exposure to the hydrocarbon vapours under the smaller simulated oil spill scenario.

The QHHRA provided no indication that health effects would be experienced by people living in communities along the Burrard Inlet under either of the simulated oil spill scenarios.

A more focused and detailed human health risk assessment (HHRA) will be completed and submitted to the National Energy Board (NEB) in early 2014.

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DEFINITIONS AND ACRONYM LIST

Definition/Acronym	Full Name
bbl/d	barrel(s) per day
BC	British Columbia
BTEX	Benzene, toluene, ethylbenzene and xylenes
CLWB	Cold Lake Winter Blend
CNS	Central nervous system
COPC	Chemical(s) of potential concern
CPCN	Certificate of Public Convenience and Necessity
CWC	Credible worst-case
EBA	EBA Engineering Consultants Ltd., a Tetra Tech Company
ESA	Environmental and Socio-economic Assessment
FHA	Fraser Health Authority
FVRD	Fraser Valley Regional District
HHRA	Human health risk assessment
Intrinsik	Intrinsik Environmental Sciences Inc.
km	kilometre(s)
KMC	Kinder Morgan Canada Inc.
m^3	cubic metre(s)
m^3/d	cubic metre(s) per day
NEB	National Energy Board
NEB Act	*National Enegry Board Act*
PAH	Polycyclic aromatic hydrocarbon
PPE	Personal protection equipment
QHHRA	Qualitative human health risk assessment
SLHHRA	Screening level human health risk assessment
the Project	The Trans Mountain Expansion Project
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain pipeline
Trans Mountain	Trans Mountain Pipeline ULC
TMPL system	Trans Mountain pipeline system
WCMRC	Western Canada Marine Response Corporation

1.0 INTRODUCTION

This technical report describes a preliminary qualitative human health risk assessment (QHHRA) that was completed in order to identify and understand the nature and extent of the potential human health effects that could occur in the event of an oil spill during tanker loading at the Westridge Marine Terminal that forms part of the Trans Mountain Expansion Project (the Project). Two hypothetical spill scenarios were examined:

1) A scenario corresponding to credible worst-case (CWC) conditions involving a simulated spill of 160 m^3 of Cold Lake Winter Blend (CLWB) diluted bitumen while loading a tanker at berth; and,
2) A smaller simulated spill of 10 m^3 of CLWB while loading a tanker at berth.

The QHHRA encompassed a preliminary qualitative examination of the potential health effects that might be experienced under each spill scenario by members of the general public who might be present in the area at the time of the spill. The assessment was conducted as a screening-level exercise to understand the overall likelihood, nature and extent to which people's health might be affected under each spill scenario, with the findings used to determine if potential health risks exist, and if so, the need for further, more detailed investigation of these risks.

This report outlines the methods that were followed, the results that emerged and the conclusions that were reached as part of the preliminary QHHRA.

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, government agencies (*e.g.*, regulators and municipalities), stakeholders, and the general public. Information on the Project is also available at www.transmountain.com.

1.2 Objectives

The primary objectives of the QHHRA were to:

- Identify and understand the potential health effects that might be experienced by people under each of the simulated oil spill scenarios examined, with an emphasis on the effects that could potentially occur from short-term exposure to the chemical vapours that might be released from the surface of the oil slick formed during the early stages of the incident before the arrival of first reposinders and the implementation of emergency and spill response measures.

- Address the information requirements outlined in Guide A.2 of the NEB *Filing Manual* for completion of an Environmental and Socio-economic Assessment (ESA) in support of a facilities application (NEB 2013a).

- Address information requirements outlined in NEB's (2013b) *Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project* (September 10, 2013).

- Address concerns expressed by Aboriginal communities and stakeholders, including the public and regulatory authorities at the federal, provincial and regional levels, over the potential health effects of accidents and malfunctions associated with the Project. These concerns included the possible effects of oil spills on people's health.

- Provide information to Trans Mountain, the Project team and spill response authorities on the nature, extent and likelihood of occurrence of potential human health effects that could result from oil spills under the simulated spill scenarios in order to help inform emergency response preparedness and planning and other programs aimed at the protection of public health and safety.

2.0 CONSULTATION

Trans Mountain and its consultants have conducted a number of 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, Aboriginal engagement and landowner relations 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 corridor. 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 assessment of human health risks in Volume 5A and Volume 5B:

- Potential human health effects associated with the inhalation of chemical emissions from a pipeline spill.
- Potential human health effects that could occur if an accidental oil spill was to happen on water as a result of the Project.
- Potential human health effects of a pipeline spill on Aboriginal health.

In addition, concerns related to the potential effects of spills on traditional activities were also raised and detailed information on pipeline spills is provided in Volume 7.

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 Volume 5A and Volume 5B summarizes the consultation and engagement activities that have focused on identifying and assessing potential issues and concerns related to the QHHRA which may be affected by the Project. Information collected through the public consultation, Aboriginal engagement and landowner relations programs for the Project was considered in the development of this technical report, and the assessment of human health in Volume 5A and Volume 5B.

2.2 Regulatory Consultation

The human health risk assessment (HHRA) team met with federal, provincial and regional regulatory authorities to discuss the overall scope and nature of the planned work. The consultative activities are shown in Table 2.1.

TABLE 2.1

SUMMARY OF CONSULTATION ACTIVITIES RELATED TO THE HUMAN HEALTH RISK ASSESSMENT

Stakeholder Group / Agency Name	Name and Title of Contact	Method of Contact	Date of Consultation Activity	Reason For Engagement	Issues / Concerns	Commitments / Follow-up Actions / Comments
FEDERAL CONSULTATION						
Health Canada (BC Region)	Dr. Carl Alleyne, BC Regional Environmental Assessment Coordinator Dr. Gladis Lemus, BC Regional Manager	Meeting	January 28, 2013	Project introduction. Discussion of the planned HHRA methodology.	Health Canada advised that they will be directing particular attention to Aboriginal health. Health Canada expressed an interest in knowing the potential health effects associated with any accidents and malfunctions. Health Canada will be interested in knowing the potential short-term as well as long-term health effects associated with the Project, with consideration given to all relevant exposure pathways.	None
PROVINCIAL CONSULTATION - ALBERTA						
Alberta Health	Dr. Karina Thomas, Environmental Health Scientist, Health Protection Branch Dr. James Talbot, Chief Medical Officer of Health for Alberta	Meeting	February 4, 2013	Project introduction. Discussion of the planned HHRA methodology.	No specific issues / concern regarding the planned HHRA methodology were identified.	Alberta Health requested that the HHRA team keep them informed of progress as the HHRA is completed.
LOCAL CONSULTATION - BRITISH COLUMBIA						
Fraser Health Authority (FHA)	Dr. Paul Van Buynder, Chief Medical Health Officer Dr. Nadine Loewen, Medical Health Officer Dr. Goran Krstic, Human Health Risk Assessment Specialist, Health Protection Tim Shum, Regional Director	Meeting	January 28, 2013	Project introduction. Discussion of the planned HHRA methodology.	FHA and VCHA expressed an interest in knowing whether any long-term monitoring of health is planned. FHA and VCHA expressed an interest in knowing the historical effects of the Legacy Line. FHA and VCHA expressed an interest in knowing the potential health effects associated with a spill to an urban environment. FHA and VCHA is interested in knowing the potential short-term as well as long-term health effects associated with the Project, with consideration given to all relevant exposure pathways.	None
Vancouver Coastal Health Authority (VCHA)	Dr. Patricia Daly, Chief Medical Health Officer Dr. James Lu, Medical Health Officer, Richmond Public Health Dr. Richard Taki, Regional Director, Health Protection					

Stakeholder Group / Agency Name	Name and Title of Contact	Method of Contact	Date of Consultation Activity	Reason For Engagement	Issues / Concerns	Commitments / Follow-up Actions / Comments
Fraser Valley Regional District (FVRD)	Alison Stewart, Senior Planner, Strategic Planning and Initiatives	Telephone call	March 20, 2013	Project introduction. Discussion of the planned HHRA methodology.	FVRD expressed an interest in knowing the potential effects of the Project on air quality, and subsequently human health, in the FVRD. From a health perspective, Ms. Stewart indicated that the FVRD would be taking their direction from FHA.	None

3.0 METHODS

3.1 Overall Approach

The approach followed for the preliminary QHHRA differed from that routinely adopted for the assessment of the potential health risks associated with chemical exposures, including the screening level human health risk assessment (SLHHRA) of the routine pipeline and facilities operations that also forms part of the Trans Mountain Application for Approval (see Volume 5D, Screening Level Human Health Risk Assessment of Pipeline and Facilities Technical Report). Unlike routine operations, which consist of planned activities for which chemical exposures and any associated health risks can be anticipated and assessed on the basis of known or reasonably well-defined exposure scenarios, spills represent low probability, unpredictable events for which the exposures and risks must necessarily be forecast on the basis of strictly hypothetical scenarios. Accordingly, rather than following a conventional HHRA paradigm with an emphasis on quantifying the potential risks involved, the present assessment was designed to provide a preliminary indication of the prospect for people's health to be affected under different hypothetical spill scenarios, together with an indication of the types of health effects, if any, that might be experienced, with both elements addressed from a qualitative perspective at a screening level. The results of this preliminary qualitative assessment were then used to determine the need for a more comprehensive assessment to better determine the prospect for people's health to be affected and to better define the nature and extent of any health effects that they might experience.

The preliminary QHHRA examined the likelihood and extent to which people's health potentially could potentially be affected under each of the two simulated spill scenarios of interest. Consideration was not given to the probability of occurrence of either spill scenario nor to the various design, engineering, maintenance and inspection, and other preventative programs that Trans Mountain will have in place to reduce the likelihood of a spill occurring during tanker loading at the Westridge Marine Terminal, details of which are provided elsewhere (Volume 7, Section 2.0). Instead, the assessment was conducted based on the premise that the spill(s) had occurred despite these programs existing.

The overall approach followed for the QHHRA included consideration of the following:

- the type and volume of oil spilled;
- the types of chemicals contained in the spilled oil to which people could be exposed;
- the extent to which people could be exposed based on predictions of how the spilled oil and the chemicals would likely behave in the environment;
- the manner and pathways by which people might be exposed to the chemicals;
- the types of health effects known to be caused by the chemicals as a function of the amount and duration of exposure;
- the responsiveness and sensitivity of the people who could potentially be exposed to the chemicals; and,
- the emergency response measures that will be taken by Trans Mountain and other spill response authorities to limit people's exposure to the chemicals in the event of a spill.

Details with respect to each of the above items are presented in the sections that follow.

3.2 Spill Scenario Selection

Descriptions of each of the two simulated spill scenarios that were examined and the basis of their selection are presented below. Additional details surrounding each scenario can be found in Volume 7, Section 8.1. Each scenario involved a spill during tanker loading at the Westridge Marine Terminal, with the principal differences between the scenarios being:

- The CWC 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 CWC 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 and risk assessment 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..

- A smaller release of 10 m^3 was also evaluated, consistent with the NEB's letter of September 10, 2013 *Filing Requirements Related to the Potential Environmental and Socio-Economic Effects of Increased Marine Shipping Activities, Trans Mountain Expansion Project*. This smaller release was assumed to result from a loading arm leak, and be totally contained within the boom placed around all tankers during loading.

EBA completed stochastic oil spill modeling for the hypothetical scenarios to describe the expected fate and behaviour of the spilled oil (EBA Tetra Tech 2013). Modelling results were used to derive estimates of the chemical exposures that people might experience under each scenario. The modelling accounted for a number of different parameters affecting the fate and movement of the oil slick, including time of year, weather patterns, ocean currents and tides, and wave action. As the modelling evolved, further parameters such as the thickness of the oil slick, the time the oil would be expected to remain on the water surface, the time to first contact with the shoreline, and the extent of shoreline oiling were added to refine the CWC spill scenario. Consideration also was given to the manner in which the spilled oil and its chemical constituents would partition between the water column and the air in order to develop estimates of the air-borne concentrations that could occur as a function of elapsed time, with these concentrations serving as proxies for the chemical exposures that people might potentially experience. The key steps in the selection process are outlined below. Full details concerning the spill modelling can be found in EBA Tetra Tech (2013).

3.2.1 CWC Simulated Oil Spill Scenario

The modelling proceeded step-wise.

As a first step, approximately 720 stochastic model simulations were completed for each of four seasons: winter (January–March), spring (April–June), summer (July–September) and fall (October–December). The combined simulations for any given season tracked the behaviour and fate of the spilled oil over a 15-day period, beginning from moment the spill occurred. Each simulation comprised a three-hour snapshot of the movement of the oil slick, with the movement forecast on the basis of weather, ocean currents and tide data drawn from records compiled for 2011 and 2012. The mass balance of the spilled oil also was forecast, with the distribution of the hydrocarbon components of the oil between the ocean water column, the overlying air and the shoreline determined for each three-hour interval. The series of approximately 2,900 simulations served to represent the behaviour and fate of the spilled oil as a function of time across the four seasons of the year.

As a second step, one of the 2,900 independent model simulations from the stochastic dataset was selected for more comprehensive deterministic modelling in order to compute the fate of the individual chemical components of the spilled oil. The simulation chosen ultimately served to represent the circumstances under which people could potentially be exposed to the chemical components of the spilled oil, with a focus on exposures that could be experienced under circumstances corresponding to credible worst-case conditions. The selection process proceeded as follows:

a) First, consideration was given to the four seasons that were modeled stochastically. Selection centered on the summer season as warmer water and air temperatures facilitate more rapid dissolution and volatilization of lighter hydrocarbons into water and air, respectively. At the same time, generally lower wind speeds during the summer months result in less wave action (and hence, less vertical mixing of the water column and higher concentrations of dissolved hydrocarbons in the surface water layer) as well as less dilution of any hydrocarbon vapours released from the surface of the oil slick into the air. These factors will contribute to greater opportunity for people to be exposed to the hydrocarbon components of the spilled oil during the summer months compared to other seasons of the year. In addition, people are more likely to be outdoors and possibly in the neighbourhood of the Westridge Marine Terminal during the summer months compared to other seasons, again contributing to a greater potential for people to be exposed to the hydrocarbon components during the summer in the event that an oil spill was to occur. Thus, a simulation chosen from the summer season was considered best fit-for-purpose in terms of representing conditions corresponding to credible worst-case exposure circumstances.

b) Second, consideration was given to the predicted length of shoreline oiled since oil spill effects on shorelines are among the more obvious and profound environmental effects of spills (both with respect to people and organisms). The median length of shoreline oiled was identified as a selection criterion in order to balance the need to address the potential effects that could be experienced by:

- aquatic organisms, for which effects are primarily driven by the amount of oil remaining in water;
- terrestrial organisms, for which effects are primarily driven by the length of shoreline oiled; and,
- people who might be on the water close to the oil slick itself and potentially at risk of exposure versus people who might be on-shore at or near the oiled shoreline at the time of the spill.

The median length of shoreline oiled as a result of the spill was determined based on the 736 summer stochastic simulations. The specific simulations resulting in a length of oiled shoreline corresponding to this median value were then identified and examined. Twenty simulations meeting this criterion were identified. The following additional criteria were then factored into the selection of the single simulation to be used for deterministic modelling:

- the maximum thickness of the oil modelled on water during the simulation;
- the time elapsed to first contact with the shoreline;
- the exposure duration for the oil on water; and,
- the distribution of total hydrocarbons between water, shore and air (*i.e.*, the mass balance).

c) As the third step of the selection process, each of the 20 stochastic simulations was ranked (high, moderate or low) according to how well the final four selection criteria were satisfied. Higher weighting was given to those simulations that demonstrated greater thickness of the oil reaching the shoreline, shorter time to first contact with the shoreline, longer exposure time on water, and higher percentage of hydrocarbons in air. On this basis, the list was narrowed to two simulations.

d) As the final step of the selection process, visual examination of the outputs for these two simulations and the outputs for the entire summer season stochastic modelling revealed one of the simulations to be more representative of the movement of the oil slick. This simulation was chosen for the more detailed deterministic modelling, with these modelling results serving as inputs to the QHHRA. More specifically, the modelling results consisted of hour-by-hour estimates of the concentrations of hydrocarbon vapours at progressively increasing distances from the oil slick that people in the area might encounter.

3.2.2 Smaller Simulated Oil Spill Scenario

The simulated oil spill modelling that was completed for the smaller oil spill scenario resembled that performed for the CWC spill scenario, except that fewer steps were involved since no need existed for determining the extent of shoreline oiling since the smaller spill scenario assumed that all of the spilled oil would be contained within the boom at the berth.

Reliance was placed on the results of the deterministic modelling of the same stochastic simulation selected for use in the CWC spill scenario, with the model outputs again consisting of hour-by-hour estimates of the airborne concentrations of the hydrocarbon vapours at progressively increasing distances from the oil slick that people in the area might encounter over a 15-day period beginning from the time the spill started. These predicted concentrations served as proxies of the acute inhalation exposures that the people might experience during the early stages of the smaller oil spill, before the arrival of first responders and the implementation of spill isolation, containment, recovery and other emergency response measures.

3.3 Exposure Scenario and Pathway Selection

The QHHRA focused on the potential health effects that could occur among people either on-shore or in pleasure craft or other boats in the neighbourhood of the Westridge Marine Terminal from inhalation exposure to the hydrocarbon vapours released from the surface of the spilled oil, with a specific focus on exposures that could be received on a short-term (or acute) basis during the early stages of the oil spill. The choice of this exposure scenario was based on the following:

- In the event of a spill into the Burrard Inlet, emergency response measures will be taken by Trans Mountain, Coast Guard authorities, the Western Canada Marine Response Corporation (WCMRC) and other spill response agencies to protect people's health, the marine environment, and the coastal shoreline. Details of the emergency response measures are discussed elsewhere (see Volume 7, Section 4), and will include securing the area as well as the isolation, surveillance, monitoring, containment, and clean-up and recovery of the spilled oil. Local, provincial and federal authorities responsible for the protection of public health, fisheries, and the marine environment and resources will be notified so that additional resources can be deployed and any further needed protective measures can be implemented. Other response measures would include notifying the public to avoid the spill area, restricting access to the spill area, and possibly evacuating people from the area if public health and safety was deemed to be threatened. The exact emergency response measures taken will be dictated, in part, by the circumstances and real-time events surrounding the spill, including the size, behaviour and immediate hazards presented by the oil slick. The measures will serve not only to limit any opportunities for exposure of the general public to chemical vapours released from the spilled oil in the short-term, but also will act to preclude any reasonable opportunity for people to be exposed on a longer-term basis either by inhalation or other exposure pathways such as physical contact with the chemicals.

- If warranted, local, provincial and/or federal authorities can implement controls or issue advisories to protect public health. Examples of such controls include closure of commercial and recreational fisheries, beach closures, forced evacuation of people off-shore and/or on-shore if public health and safety is threatened, and the issuance of fish, shellfish or other seafood consumption advisories. These measures further reduce the potential opportunities for exposure of people to the chemicals released during a spill through either inhalation or other pathways on both a short-term and long-term basis.

- The potential exists for people located downwind of the oil to be exposed to chemical vapours released from the surface of the slick during the early stages of the incident because some time will elapse between the first reporting of a spill, the arrival of first responders and the implementation of the emergency response measures. Exposure to the vapours would be via inhalation on a short-term basis, with the likelihood of exposure declining as responders arrive on scene and emergency response measures are taken. It is expected that the WCMRC and other first responders will arrive on-scene within as little as one hour after receiving notification.

- Direct physical contact with the spilled oil was considered unlikely, especially in the case of the smaller oil spill in which the oil slick will be completely contained within the boom. The actions taken by first responders will include securing the area, restricting access, and containing the oil slick. Appropriate regulatory authorities will be immediately notified and the public will be advised to avoid the area. In the case of the CWC spill scenario, in which oiling of the shoreline is possible based on the simulated oil spill modelling, beach and shoreline closures will be announced, if conditions warrant. These actions will limit any exposure of the general public to the spilled oil through physical contact with the chemicals.

- In some cases, exposure of people might reasonably be expected to be self-limiting owing to the irritant properties of a number of the hydrocarbon components of the spilled oil as well as the odours that might be noticed. Both of these properties would provide warning of the presence of the chemicals such that people could quickly take action to remove themselves from the source, thereby limiting the amount and duration of any exposure that might be experienced.

3.4 Receptor Selection

The selection of the human receptors to be assessed as part of the QHHRA was based on consideration of the following:

- Emergency response measures will be taken by Trans Mountain, Coast Guard authorities, the WCMRC and other spill response agencies to protect people's health, the marine environment, and the coastal shoreline. It is expected that response personnel arriving at the scene will be trained in emergency preparedness and response, will be equipped with appropriate personal protective equipment (PPE), will be trained and prepared for such situations, and will take appropriate precautions to avoid physical contact with the oil slick itself as well as to limit exposure to any chemical vapours that might be present. These measures will act to limit any chemical exposures and corresponding health effects that might be experienced by first responders and other response personnel. Accordingly, these people were not included among the human receptors selected for assessment.

- It was considered reasonable to assume that members of the general public could potentially be in the neighbourhood of the Westridge Marine Terminal at the time of the oil spill, and might remain in the area unaware of the spill during its early stages before emergency responders arrive on scene and emergency response measures are implemented. These people could include individuals on the water in pleasure craft or other boats, residents living in communities downwind of the Marine Terminal, and bystanders located on or near the shoreline while frequenting the area for work, recreation or other purposes. Given that opportunity exists for these people to be exposed to hydrocarbon vapours originating from the spilled oil, they were chosen as the human receptors to be assessed.

It was recognized that the general public includes sub-populations who may be especially responsive to chemical exposures, including young children, the elderly and people with compromised health. The QHHRA necessarily allowed for the fact that the human receptors to be assessed, being bystanders found in the area at the time of the spill, could include these types of individuals.

3.5 Selection of Chemicals of Potential Concern

The nature and extent to which people's health might be affected by exposure to the chemical vapours released during the oil spill will be governed, in part, by the characteristics of the oil itself as well as by the properties of the hydrocarbon components of the oil, particularly the ease with which the components can volatilize from the surface of the oil slick. For the purposes of the assessment, Cold Lake Winter Blend (CLWB) diluted bitumen was chosen to represent the type of oil spilled. The selection of the CLWB was based, in part, on the following:

- CLWB is currently, and is expected to remain, a major product carried by the TMEP. Accordingly, in the unlikely event of a spill occurring, there is a strong possibility the spilled product will be CLWB.

- The diluent in CLWB is a liquid condensate that is rich in light-end hydrocarbons that are volatile or semi-volatile in nature. These hydrocarbon components could potentially be released as vapours from the surface of the oil slick, which would then disperse in a downwind direction, possibly reaching human receptors who could inhale them.

The choice of the actual chemicals to be examined as part of the preliminary QHHRA (hereafter referred to as the chemicals of potential concern or COPC) followed a step-wise process, which is described in detail in Screening Level Human Health Risk Assessment of Pipeline and Facilities, Volume 5D. Briefly, the steps included:

- First, the results of a bulk liquid analysis of the CLWB that identified the chemical components present in the diluted bitumen were examined.
- Second, the physical properties and characteristics of the chemical components were reviewed, notably those properties, such as vapour pressure and Henry's Law Constant, that determine their tendency to partition into air and provide an indication of the ease with which they might volatilize from the surface of the oil slick.
- Third, a series of pseudo-components of the spilled oil identified by EBA Tetra Tech as part of the spill simulation modelling and comprised of aliphatic and aromatic hydrocarbons, some of which were grouped according to carbon chain length, was reviewed, with "surrogate" chemicals or chemical groups assigned to represent those pseudo-components that would be expected to volatilize from the surface of the oil slick during the early stages of the oil spill.

The COPC consisted principally of lighter-end, volatile and semi-volatile hydrocarbons (C_1 to C_{16}), including both aliphatic and aromatic constituents. The latter constituents included BTEX (benzene, toluene, ethylbenzene and xylenes), alkyl substituted benzenes, and polycyclic aromatic hydrocarbons (PAHs), including naphthalene. Trace amounts of sulphur-containing chemicals made up the remainder of the COPC. A listing of the COPC, along with a summary of the health effects associated with acute exposures for these COPC, is provided in Table 3.1.

3.6 Health Effects Characterization

The potential health effects that people in the area might experience from acute inhalation exposure to the hydrocarbon vapours released from the surface of the oil slick during the initial stages of the oil spill were characterized on a qualitative basis for each of the two simulated spill scenarios examined. The characterization was reliant on preliminary modelled predictions of the COPC concentrations that might be encountered by people at varying distances from the oil slick that were derived from the deterministic spill simulation modelling completed by EBA Tetra Tech (2013). The model outputs consisted of hour-by-hour predictions of the maximum concentrations of the COPC that people might encounter as the incident evolved. These preliminary modelled estimates served as proxies for the acute inhalation exposures that the general public, including residents and bystanders in the area, might experience during the early stages of the incident before the arrival of first responders and the implementation of emergency response measures. These exposure estimates were then qualitatively compared to exposures associated with health effects in humans and/or other animal species for each of the COPC to gauge the nature and extent to which people's health could be affected. The intent was to obtain a preliminary indication of whether or not the potential exposures that could be received under each of the simulated spill scenarios would be expected to cause health effects, and if so, what types of symptoms could potentially be experienced by people in the area. For the purposes of the preliminary QHHRA, the health effects of interest were those known to be associated with acute exposure to the COPC, with these effects shown in Table 3.1.

TABLE 3.1

LIST OF COPC EXAMINED AS PART OF THE QHHRA

Chemicals of Potential Concern	CLWB Pseudo-Components and Other Analytes[1]	Health Effects Associated with Acute Over-Exposure
Aliphatic C_1-C_4	Iso-Butane, n-Butane, Propane	Neurological effects
Aliphatic C_5-C_8	iso-Pentane; n-Pentane, Aliphatic C_6-C_8	Possible cognitive performance deficits
Aromatic C_9-C_{16}	Aromatics >C_8-C_{10}; Aromatics >C_{10}-C_{12}; Aromatics >C_{12}-C_{16}, Naphthalene	Eye irritation
Benzene	Benzene	Hematological/immunological effects.
Ethanethiol group	Ethanethiol Iso-Propanethiol; Thiophene/sec-Butanethiol; n-Butanethiol; n-Hexanethiol	Respiratory irritation, odour perception.
Ethylbenzene	Ethylbenzene	Effects on auditory function.
Toluene	Toluene	Irritation of the eyes and throat CNS effects, including headache, dizziness and feeling of intoxication.
Trimethylbenzenes	1,2,4-Trimethylbenzene	Neurological effects, including impaired balance. Effects on respiratory function.
Xylenes	Xylenes	Irritation of the eyes, nose and throat. CNS effects, including fatigue, headache, dizziness and light headedness.

Notes:
1 Consist of hydrocarbon components identified by EBA Tetra Tech (2013), which were represented by the COPC shown in the opposite column.

4.0 RESULTS

4.1 CWC Simulated Oil Spill Scenario

The preliminary QHHRA of the CWC simulated spill scenario revealed some prospect for people's health to be affected from acute inhalation exposure to the chemical vapours that could be released from the oil slick during the early stages of this spill scenario. Based on the health effects that can follow acute exposure to the COPC, the potential symptoms that could be experienced by people in the area would likely be dominated by irritation of the eyes and/or breathing passages, possibly accompanied by symptoms consistent with central nervous system (CNS) involvement, such as nausea, headache, light headedness and/or dizziness. In this regard, a number of the COPC are capable of acting as irritants and CNS depressants (see Table 3.1). The effects could range from barely noticeable to quite noticeable, depending on the actual exposure circumstances and the sensitivity of the individuals exposed. Based on the modelled exposure estimates for this spill scenario, which showed the concentrations of the COPC to decline relatively quickly with elapsed time, the opportunity for people's health to be affected would be rather limited. Odours could be apparent, dominated by a hydrocarbon-like smell, with some potential for other distinct odours due to the presence of sulphur-containing chemicals in the vapour mix. The odours themselves could contribute to discomfort, irritability and anxiety.

Effects would be confined to bystanders in pleasure craft or other boats close to the spill area, and possibly to people on the shoreline immediately adjacent to the Westridge Marine Terminal. There is no indication that people living in communities along the Burrard Inlet, including Westridge and Capitol Hill would be affected.

The exact nature and severity of any health effects will depend on several factors, including:

- The circumstances surrounding the spill, including the time of year and the meteorological conditions in effect at the time. These circumstances will affect the extent to which chemical vapours are released from the surface of the spilled oil and the manner in which these vapours disperse. For the purposes of the QHHRA, the potential exposures to the COPC that people in the area could experience were based on estimates derived using the deterministic spill simulation modelling that captured seasonal and weather conditions favouring the volatilization of the hydrocarbons from the oil slick.

- The person's whereabouts in relation to the spill, including their distance from the oil slick and their orientation to the slick with respect to wind direction. The preliminary modelled estimates of the exposures that could be received revealed that exposures would be highest at distances closest to the slick, declining with increasing distance. The prospect for health effects to occur as well as the severity of any effects will follow the same pattern. The prospect for people's health to be affected also will be greatest downwind of the oil slick, where the maximum concentrations of the COPC will be encountered.

- The timeliness of emergency response measures. Measures taken to either remove the hazard from the general public (e.g., spill isolation, containment) or to remove the general public from the hazard (e.g., securing the spill area, restricting access, notifying the public to avoid the area, evacuation of people from the area) will reduce exposure and the probability of any associated health effects. The sooner these measures can be implemented, the lower the likelihood of any effects. Prompt measures taken by Trans Mountain, the Coast Guard authorities, the WCMRC and other spill response agencies will act to reduce the potential for health effects.

- A person's sensitivity to chemical exposures. The manner and extent to which people in the area may respond to the COPC exposures will depend, in part, on their age, health status and other characteristics, with the young, the elderly and people with compromised health possibly showing heightened sensitivity.

4.2 Smaller Simulated Oil Spill Scenario

The preliminary QHHRA for this spill scenario revealed no obvious prospect for people's health to be affected from acute inhalation exposure to the chemical vapours released from the surface of the oil slick. The preliminary modelled estimates of the exposures to the COPC that the general public might potentially experience appeared to fall below the levels known to be associated with health effects. The absence of health effects is attributable to both the small size of the spill and the fact that the oil slick will remain within the boomed area where access will be restricted. Under these circumstances, little opportunity, if any, exists for people in the area to be exposed, whether on shore or on the water in boats.

Odours could be noticeable depending on the person's keenness of smell and their proximity to the oil slick. In all likelihood, the odours would be dominated by a hydrocarbon-like smell, with some potential for other distinct odours to be noticed due to the presence of sulphur-containing chemicals in the vapour mix. The odours themselves could contribute to discomfort, irritability and anxiety.

5.0 DISCUSSION

The QHHRA was completed in order to obtain an understanding of potential effects to people's health from exposure to the hydrocarbon vapours emitted from the surface of the oil slick under two simulated oil spill scenarios involving the loading of a tanker at the Westridge Marine Terminal: a credible worst-case spill scenario (*i.e.*, 160 m^3) which assumed that some of the spilled oil would escape the boom at the berth and entering the Burrard Inlet, and a smaller spill scenario (*i.e.*, 10 m^3), with all of the spilled oil assumed to be contained within the boom. For each scenario, hour-by-hour predictions of the airborne concentrations of the COPC at progressively increasing distances from the oil slick were derived on the basis of spill simulation modelling, with the predicted concentrations serving as proxies for the acute inhalation exposures that might be experienced by people located in the neighbourhood of the terminal, whether on the water in boats or on shore during the early stages of the spill before the arrival of first responders and the implementation of emergency response measures. The principal findings of the QHHRA were:

- There was no indication that the health of people residing in communities located along the Burrard Inlet would be affected by exposure to the COPC under either of the two simulated oil spill scenarios examined.
- Similarly, no obvious prospect for the health of people in the area to be affected by exposure to the COPC emitted from the surface of the oil slick under the small spill scenario was shown to exist.
- Some potential for people's health to be affected by exposure to the COPC under the CWC spill scenario was revealed by the assessment, with the effects likely to be dominated by irritation of the eyes and/or breathing passages, with or without CNS effects, including fatigue, headache and/or dizziness. The effects could range from barely noticeable to quite noticeable depending on the person's actual exposure circumstances. The people at risk would include bystanders located relatively close to the oil spill, either on the water in pleasure craft or other boats near the berth or on-shore adjacent to the Terminal.

Interpretation of the latter findings must necessarily consider the following:

- The QHHRA did not consider the probability of occurrence of either of the oil spill scenarios. Both scenarios represented simulations only. The QHHRA simply assumed that the spill had occurred, without allowance for the fact that spill prevention programs will be in place to guard against the occurrence of oil spills.
- Consistent with a screening-level approach, a number of conservative elements were incorporated into the QHHRA as a means to avoid overlooking or understating any potential health effects that might occur under either of the spill scenarios. For example, estimates of the exposures that people in the area might experience were derived on the basis of spill simulation modelling which provided hour-by-hour predictions of the airborne concentrations of the COPC at progressively increasing distances from the oil slick. The specific model simulation used to predict the concentrations was deliberately selected to capture conditions with respect to the time of year, weather, ocean currents and tides and other influences that would contribute to rapid and near complete volatilization of the COPC from the oil slick to which the people could be exposed. As a further example, the proxy exposures that were used to gauge whether or not people's health might be affected were based on the maximum predicted concentrations of the COPCs that the people might encounter on an hour-by-hour basis during the early stages of the spill. Because of the conservatism involved, the actual prospect for people's health to be affected could much lower than that revealed by the QHHRA.
- The prospect for people's health to be affected is limited to a relatively narrow window of time, in part, because: i) first responders will arrive on scene within as little as one hour after receiving notification of the spill and will begin to take emergency response actions aimed at isolating, containing and recovering the spilled oil as well as ensuring the health and safety of the public; and, ii) the spill simulation modelling revealed that the concentrations of the COPC will decline relatively quickly with elapsed time.

Notwithstanding the above items, the QHHRA revealed that some potential exists for people's health to be affected under the CWC simulated spill scenario. This potential will be explored in a more focused and detailed HHRA. The results of this more detailed assessment will be used to inform emergency response and preparedness and other programs intended to protect public health and safety.

6.0 SUMMARY

This report outlines the methods that were used, the findings that emerged and the conclusions that were reached as part of a preliminary QHHRA of two simulated scenarios involving oil spills during tanker loading operations at the Westridge Marine Terminal:

1) A CWC oil spill scenario of 160 m^3 in which 80% of the spilled oil was assumed to be contained with the boom at the berth and 20% of the spilled oil escaped the boom and entered the Burrard Inlet; and,
2) A smaller 10 m^3 spill scenario, totally contained within the boom.

The QHHRA focused on the potential health effects that could occur among people present in the area surrounding the Westridge Marine Terminal, whether on shore or the water in pleasure craft or other boats.

The QHHRA focused on the acute inhalation exposures to hydrocarbons vapours emitted from the surface of the oil slick that people could experience during the early stages of the oil spill. No other relevant exposure pathways by which people in the area could be exposed to the hydrocarbons were identified.

The QHHRA revealed some prospect for people's health to be affected from acute inhalation exposure to the hydrocarbon vapours under the CWC simulated spill scenario. Based on the types of chemicals that might be encountered, the potential health effects experienced by these people would likely be dominated by irritation of the eyes and/or breathing passages, possibly accompanied by symptoms consistent with central nervous system involvement, such as nausea, headache, light headedness and/or dizziness. The effects could range from barely noticeable to quite noticeable depending on the actual exposure circumstances and sensitivity of the individual.

The QHHRA revealed no obvious prospect for people's health to be affected from acute inhalation exposure to the hydrocarbon vapours under the smaller simulated oil spill scenario.

The QHHRA provided no indication that health effects would be experienced by people living in communities along the Burrard Inlet under either of the simulated oil spill scenarios.

A more focused and detailed HHRA will be completed and submitted to the NEB in early 2014.

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8.0 REFERENCES

8.1 Literature Cited

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