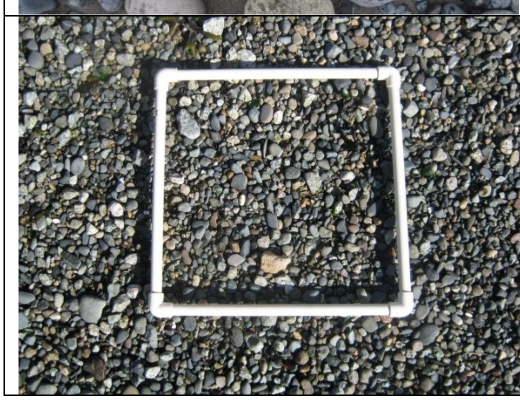
Surface	Subsurface	Description
		A. Plot 306D, a low energy site, upper intertidal zone
		B. Plot 320B, low energy site, upper intertidal zone.
		C. Plot 610B, a moderate energy site, upper intertidal zone (near Jordan River).
		D. Plot 312C showing a location where both surface and subsurface are *moderately* permeable.

Figure A-2. Examples of plot photos of surface and subsurface sediments.

Discussion

This modest field program examined approximately 54 km of shoreline that is included within the BC ShoreZone dataset (57 shore units). The intention of the program was to provide a level of confidence in the approximations used in estimating oil retention from spill models. In particular we wanted to make the case that ShoreZone mapping was an appropriate tool to support modeling of oil retention. The survey examined actual ground conditions in comparison to the ShoreZone mapping data (collected between 1980 and 2007).

Table A-6 Permeability Comparisons of Surface and Subsurface

Permeability		Observations	
Surface	**Subsurface**	**No**	**%**
low	low	184	68%
moderate	low	66	24%
moderate	moderate	17	6%
high	low	1	0%
high	high	2	1%
	TOTALS:	***270***	***100%***

Table A-7 Summary of Low-Energy Plots

Permeability			
Surface	**Subsurface**	**No**	**%**
moderate	low	49	82%
moderate	moderate	9	15%
high	high	2	3%
	Totals:	*60*	*100%*

The ground verification showed about a 60% match between aerial interpretation/classification and ground interpretation/classification (Harney et al 2008; Harper and Morris 2007). This is similar to previous verification studies of ShoreZone and resulted in more detailed mapping rules after 2007. But the ShoreZone datasets used in this project pre-dated the refined mapping rules. When the data comparisons are examined in terms of initial oil retention, the comparison of aerial and ground data indicate a 80 to 85% agreement (Tables A-3, A-4). That is, for most of the shoreline examined, the ShoreZone mapping data appears to correctly predict the permeability of shore sediment observed during this ground survey.

A secondary objective of the field survey was to test the hypothesis that *low-energy gravel beaches (pebble, cobble, boulder) are usually only a thin veneer of gravel over sand*. This is an assumption that was used in the modeling and has important implications to the permeability of these beaches and ultimately to oil retention from a spill. *Impermeable* substrates will have lower retention than *permeable* shorelines, which may act like a “sponge” to retain oil. Shoreline substrate and permeability were observed at 270 plots where both surface and immediate subsurface sediments were photographed (Fig. A-2). Of the 60 plots with *low-wave exposures* and *moderate* to *high* permeability (pebbles, cobbles, boulders), over 80% had impermeable sediment (mud, sand granules) in the immediate subsurface (Table A-7). These data support the assumption that most low energy shorelines will have limited penetration into subsurface sediments and that most oil retention will occur as surface slick on the beach surface.

References

Berry, H.D., Harper, J.R., Mumford Jr., T.F., Bookheim, B.E., Sewell, A.T., & Tamayo, L.J. (2001). The Washington State ShoreZone Inventory User's Manual. Olympia, WA: DNR Nearshore Habitat Program.

Harney, J.N., J.R. Harper and M.C. Morris 2008. Report on the ShoreZone Ground Verification Study Conducted in Sitka, Alaska (May 2008) (ver. 5). Prepared by Coastal & Ocean Resources Inc., Victoria, BC for Prepared for: NOAA National Marine Fisheries Service and Nature Conservancy (Juneau, Alaska) 62p.

Harper, J.R., and Morris, M.C. 2008. BC ShoreZone Field Verification Project. Report prepared for BC Ministry of Environment 39 p.

Howes, D.E. 2001. BC Biophysical Shore-Zone Mapping System— A Systematic Approach to Characterize Coastal Habitats in the Pacific Northwest. Proceedings of the 2001 Puget Sound – Georgia Basin Conference, Seattle.

APPENDIX B

Fraser River Addendum

Table B-1 Fraser River Shore Types

2009 Shore Type	Code	% Occurrence	SSS ShoreType	Code	% Occurrence
Rip Rap	RR	35%	Rip rap	LE_RR	35%
Artificial Marsh	AM	2%	Marsh	LE_M	51%
Fringing Marsh	FM	49%	Marsh	LE_M	
Beach	B	5%	Sand beach or mudflat	LE_S	7%
Mudflat	MF	2%	Sand beach or mudflat	LE_S	
Impermeable	IM	7%	Rock	LE_R	7%

Note: 204 km of South Arm mapped downstream of the Port Mann Bridge.

A previous shore-typing scheme was utilized for most of the shoreline below Annacis Island. This shore-typing scheme mapped six shore types (Table B-1). The equivalent four shore types for the Salish Sea Shoreline Shore Types are also identified in Table B-1.

Intertidal widths were estimated from satellite imagery and the FREMP on-line atlas ortho-photographs.

The South Arm of the Fraser River was assumed to be an entirely *Protected* wave exposure environment and all shore types in the river assumed to be *low energy* shore types.

Once the SSS Shore types were assigned, the same procedures were used to estimate the potential oil retention should a slick reach the shoreline.

Log booms within the river presented a special challenge as there is little documentation of oil retention on log booms. The total area of log-booms was estimated from a satellite image. Log booms are uniformly 20 m in width and we digitized a line segment along the centre axis of each log boom. The area of the log boom is calculated as the length of the line segment times the average width (20m). Some oil would coat the outer boom sticks of the boom and some would likely be carried under the boom and re-emerge within the boom. We assumed an average coverage of 20% of the total boom area and would receive a uniform coating of 1 cm. A single square metre of boom would have a retention of 2 L/m^2.

APPENDIX D

BURRARD INLET SPILLCALC VALIDATION

EBA Engineering Consultants Ltd. operating as EBA, A Tetra Tech Company
Oceanic Plaza, 9th Floor, 1066 West Hastings Street
Vancouver, BC V6E 3X2 CANADA
p. 604.685.0275 f. 604.684.6241

TECHNICAL MEMO

ISSUED FOR USE

TO:	Bikramjit Kanjilal	**DATE:**	July 31, 2013
C:	Jim Stronach, Aurelien Hospital	**MEMO NO.:**	N/A
FROM:	Daniel Potts	**EBA FILE:**	V13203022

SUBJECT: SPILLCALC Validation against Westridge Hydrocarbon Accidental Release, Burrard Inlet, 2007

1.0 DOCUMENT OBJECTIVE

This technical memo describes the validation of SPILLCALC against the 2007 spill in Burrard Inlet at Kinder Morgan's Westridge Terminal.

2.0 INTRODUCTION

At 12:32 p.m. on 24 July 2007, a backhoe accidentally ruptured a pipeline carrying crude oil in Burnaby, BC. Approximately 224 m^3 of oil escaped the pipeline, some of which entered city storm sewers and was released into Burrard Inlet near Kinder Morgan's Westridge Terminal.

EBA used SPILLCALC to hindcast the trajectory of the released oil as a validation of the model. Predictions made by SPILLCALC were compared against observations reported in the Environmental Impact Statement (EIS; Stantec, 2010) as well as archived news articles available online.

3.0 MODEL INPUTS

SPILLCALC relies on surface currents computed by H3D. EBA implemented H3D in a nested configuration, with a 125-m resolution model of Burrard Inlet nested within a 975-m resolution model of the Strait of Georgia. Inputs to these models are summarized below.

3.1 Strait of Georgia H3D Implementation

The model bathymetry was the same as that used for the stochastic and deterministic simulations for Trans Mountain, described in the main report: Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project" (EBA, 2013). Fraser River daily flows were included, with median monthly temperatures and clay concentrations; no other rivers were included in the Strait of Georgia model. Water elevation boundary conditions were derived from tidal harmonic constants. Temperature and salinity boundary conditions were derived from ROMS 2012 data. Temperature and salinity initial conditions were taken from existing H3D model output for 1 July 2012. Wind and other meteorological inputs were taken

from Vancouver Airport data and Halibut Banks buoy data. The model was run from 1 July 2007 to 30 August 2007.

3.2 Burrard Inlet H3D Implementation

The model bathymetry was the same as that used for the stochastic and deterministic simulations for Trans Mountain, described in the main report: Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project" (EBA, 2013). No river inflows were included. Water elevation, temperature and salinity boundary conditions were provided by the Strait of Georgia model. Temperature and salinity initial conditions were duplicated from the 2011 H3D inputs, which correspond to late August or early September. Wind data were derived from Calmet outputs. Other meteorological inputs were taken from Vancouver Airport data and Halibut Banks buoy data. The model was run from 1 July 2007 to 30 August 2007. Surface currents were archived every 15 minutes.

3.3 SPILLCALC Implementation

In addition to surface currents, SPILLCALC requires wind data; the properties, volume, timing and location of the oil release; and shore oil retention properties.

- The wind input was the same as that used for the Burrard Inlet H3D model.
- Oil properties were derived from information in Table 1.1 of the EIS. The oil was represented by eleven pseudo-components, whose properties were based on the corresponding Cold Lake Blend pseudo-components. The densities of each pseudo-component were decreased by 1.7% to force the overall density to match that given in Table 1.1 (925 kg/m^3). According to Table 1.1, volatiles made up 15.9% of the mass of the oil released. Based on the adjusted densities of the pseudo-components, this corresponds to 21.3% by volume.
- Table 2.3 of the EIS reports that 5.636 m^3 of oil was estimated to have been released to Burrard Inlet, excluding recovered oil and volatilization. Since volatile pseudo-components made up 21.3% of the oil volume, the release volume input to SPILLCALC was (5.636 m^3)/(100% - 21.3%) = 7.16 m^3.
- Emergency responders contained and ultimately recovered most of the oil that entered the sewers, using booms, vacuum trucks and skimmers. According to Table 2.1 of the EIS, the first report of oil coming out of the sewer was at 1:35 p.m. on 24 July (one hour after the rupture), and the first booms were deployed at 2:15 p.m. By 4:40 p.m. on 26 July most of the oil was removed from inside the boomed area. In the intervening time, small amounts of oil escaped from the boomed area as a result of wave action. Therefore, the oil release in SPILLCALC was assumed to occur at a steady rate over a period of 51 hours, from 1:35 p.m. on 24 July to 16:35 p.m. on 26 July.
- The location of the sewer outflow was estimated based on a photo in a news article (CBC, 2007). The estimated coordinates of the outflow were 49° 17.306' N, 122° 57.507' W. This point is at the foot of Cliff Avenue, about 600 m downhill from the site of the pipeline rupture.
- The oil retention properties of the shoreline were as described in the main report: Modelling the Fate and Behaviour of Marine Oil Spills for the Trans Mountain Expansion Project" (EBA, 2013). In the region of interest, oil retention capacities ranged from 70 to 2900 L/m.

The SPILLCALC model was run from the start of the oil release until no oil remained on the water surface.

4.0 RESULTS

The model ran for about 85 hours, terminating at 3:00 a.m. on Saturday 28 July 2007, at which time there was no oil remaining on the water surface. At the end of the simulation, 76.1% of the oil volume was on shore, 22.2% had evaporated and 1.7% had dissolved – see the simulation mass balance in Figure 4.1. The evaporated fraction included the 21.3% volume of volatiles plus 0.9% from the heavier pseudo-components. Aside from a small dissolved fraction, all the remaining oil reached and was retained on the shore.

The SPILLCALC predictions were validated against observations in the EIS and new reports, as follows.

4.1 Validation of Shore Impacts

Figure 4.2 shows the SPILLCALC prediction of oil retained on shore. The maximum predicted oil retention on shore was 69 L/m, adjacent to the release location. At the same location, the shore retention capacity is 1245 L/m. Nowhere was the shore capacity exceeded; therefore, all oil that reached shore was 100% retained. SPILLCALC does not simulate re-suspension of beached oil.

Figure 4.3, reproduced from the EIS, summarizes the observations of shore impacts. The observations are qualitative, categorizing the oil impacts as heavy, moderate, light, very light, or none in each surveyed shore segment. These categories are illustrated with sample photos in the EIS, but are not quantitatively defined. Therefore, only a qualitative comparison of Figures 4.2 and 4.3 can be made. Overall, the two figures show good general agreement:

- The heaviest observed shore oiling was adjacent to the spill site, from the Chevron refinery to Barnet Marine Park. The heaviest predicted shore oiling was in the same area, although perhaps more localized to the release point.
- Moderate oiling was observed on the shore near the Dollarton Highway beginning near the Second Narrows and extending to Cates Park. SPILLCALC also predicted oiling along this shoreline.
- Light oiling was observed along the south shore at the Second Narrows. SPILLCALC also predicted oiling along this shoreline.
- Very light oiling was observed in Belcarra Bay. SPILLCALC also predicted oiling in the bay.
- No oil was observed in Port Moody; neither did SPILLCALC predict any oil impact there.

There were also some differences between the observed and predicted shore impacts:

- No shore oiling was observed south of Belcarra Bay; however, SPILLCALC predicted oiling there.
- No shore oiling was observed north of Cates Park and around Deep Cove; however, SPILLCALC predicted oiling there.

The oiling predicted south of Belcarra Bay is likely due to the uncertainty in the timing of the oil escape(s) from under the containment booms. The predicted oiling occurred midday on Thursday 26 July, from oil

released that morning. If much oil did not escape from the booms that morning, the shoreline oiling would not be predicted.

The oiling predicted around Deep Cove is patchy, with many unoiled sections. It is possible that the predicted slight degree of oiling actually occurred and escaped detection. Alternately, the model may have incorrectly predicted the oil trajectory due to uncertainty in the release timing or errors in prediction of local wind or currents around Deep Cove. Note that tar balls and sheen were observed on the water in this area (see next section) despite the lack of shore impacts.

4.2 Validation of Slick Motion

The time history of the slick motion was validated against descriptive reports of oil observations in the EIS and in archived news items. Section 2.1.1.1 of the EIS, titled "Oil Dispersion Throughout Burrard Inlet," provided several notes useful for this validation. The "pie plates" referred to in the EIS texts are tar balls, which are also predicted by SPILLCALC.

- 'The greatest concentration of oil was reported east of Second Narrows and west of Port Moody. Oil in this area initially consisted of pie plates and sheen, with sheen noticeably increasing on July 29…. Mousse first appeared on July 30. By August 2 only a few patches of sheen and mousse remained outside of the spill site." (EIS, page 2-5)
    - The greatest predicted concentrations of oil were in the same locations; predictions agreed with observations. The predicted lifespan of oil on water is underestimated by the model due to complete stranding of the oil on shore. In reality, oil on shore can be re-suspended and continue to move, but this mechanism is not supported in the model.
- "The westward movement of oil consisted of intermittent pie plates between First Narrows Bridge and Second Narrows Bridge, with the most westerly observation being a patch of sheen about 1 km east of First Narrows. By August 2, there were no further signs of oil west of the Second Narrows Bridge…" (EIS, page 2-5)
    - SPILLCALC predicted some oil passing west of the Second Narrows Bridge predawn on 27 July. All of this oil either struck the north shore or moved back east by midafternoon with the change of tides. Predictions agreed with observations.
- "The eastward movement of oil into Port Moody began July 29 and was followed by sheen reports…. The last reports of mousse and sheen in Port Moody were on August 1…." (EIS, page 2-5)
    - The model stopped before 29 July and predicted no oil going to Port Moody. The absence of oil observations at Port Moody before 29 July agrees with model predictions.
- "Throughout the surveys there were reports of scattered pie plates and sheen in the Deep Cove area of Indian Arm and about 1 km further north. This oil was most evident on July 27 and decreased steadily thereafter." (EIS, page 2-6)
    - SPILLCALC predicted oil entering Indian Arm on the afternoon of 26 July. By 6:00 a.m. on 27 July most of this oil had hit shore, with the remainder also hitting shore within another 12 hours. The prediction is slightly early but the location matches observations.

- "Late Thursday night, 'turkey-platter-sized globs' of oil coated boats and docks on the shore in Belcarra Bay." (Vancouver Sun, 2007)
    - The model predicted oil entering Belcarra Bay midafternoon Thursday 26 July. All the oil either struck shore or exited by 9:00 p.m. The predicted oil movement agrees with observations, except a slight difference in timing, which can be attributed to the uncertainty in the oil release timing.

Overall, the oil movement predicted by SPILLCALC agrees with recorded observations, apart from some slight differences in timing, and the early termination of the model due to oil stranding on shore.

5.0 CONCLUSIONS

The predictions made by SPILLCALC of oil motion and shore impacts during the 2007 spill in Burrard Inlet were compared with recorded observations. The general movement of the oil, the locations of heavily affected shorelines and the extent of the affected area are in agreement. Some differences appear in the timing of the oil motion and the lifespan of oil on water. These differences are mainly attributed to uncertainty in the timing of the release and to the permanence of oil on shore in SPILLCALC.

6.0 LIMITATIONS OF REPORT

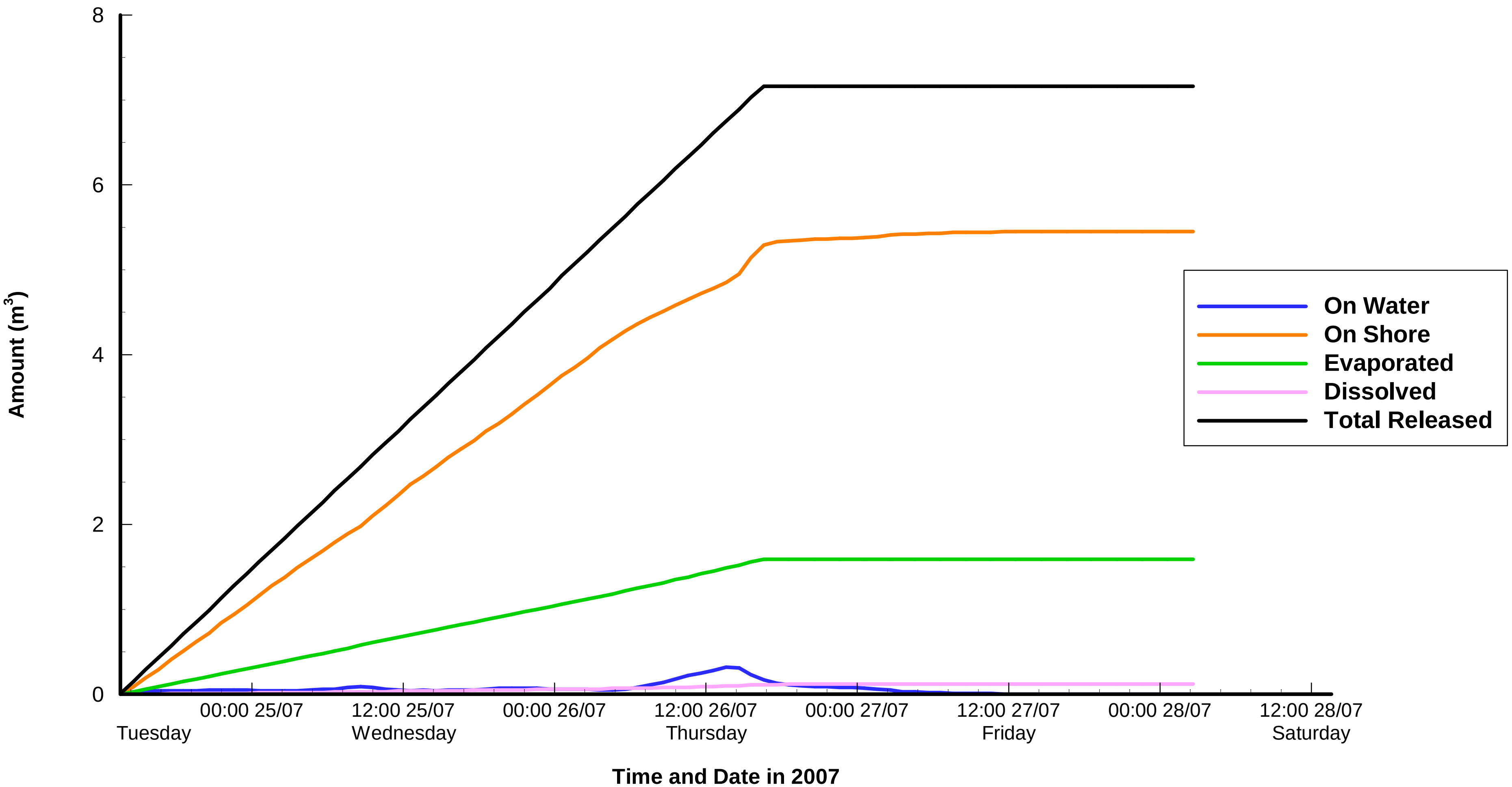
This report and its contents are intended for the sole use of Trans Mountain and their agents. EBA Engineering Consultants Ltd. does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Trans Mountain, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement. EBA's General Conditions are attached to this memo.

REFERENCES

CBC, 2007. Cleanup continues on B.C. oil spill. http://www.cbc.ca/news/canada/british-columbia/story/2007/07/24/bc-oilspill.html Dated 24 July 2007; accessed 30 July 2013.

Stantec, 2010. Environmental Impact Statement: Divisions B and D: Sewers, Foreshore, and Marine Environment – Westridge Hydrocarbon Accidental Release. May 2010.

Vancouver Sun, 2007. Beaches closed as 'big black globs' of oil spread north. http://www.canada.com/vancouversun/news/story.html?id=e819bd23-bfb6-4427-9a9a-ddb2010f5049&k=79641 Dated 28 July 2007; accessed 31 July 2013.



NOTES

Simulation Parameters:
Tracking time: up to 10 days
Release time: 13:35 24-Jul-2007
Release volume: 7.16 m3

Mass Balance After Simulation (m3):

On Water:	0.00	(0.0%)
On Shore:	5.45	(76.1%)
Evaporated:	1.59	(22.2%)
Dissolved:	0.12	(1.7%)
Total:	7.16	(100%)

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

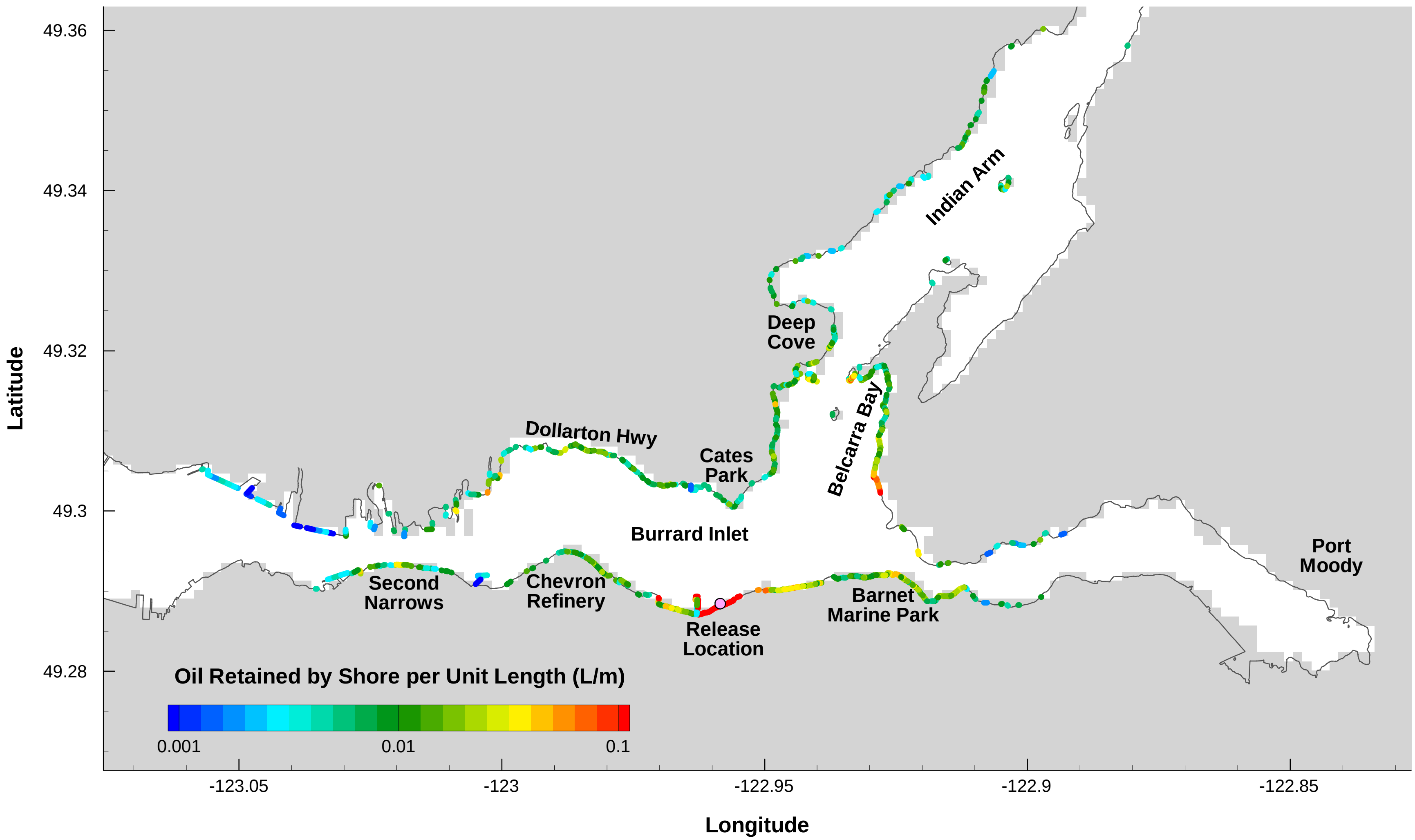
TRANS MOUNTAIN OIL SPILL STUDY

Oil Mass Balance Summer, Site D

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

OFFICE	DATE
EBA-VANC	July 31, 2013

Figure 4.1



NOTES

Maximum predicted oil retention on shore was 69 L/m adjacent to the release location. The total volume of oil retained on shore was 5.45 m3.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

eba
A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Simulated Shoreline Oiling: Westridge Hydrocarbon Accidental Release

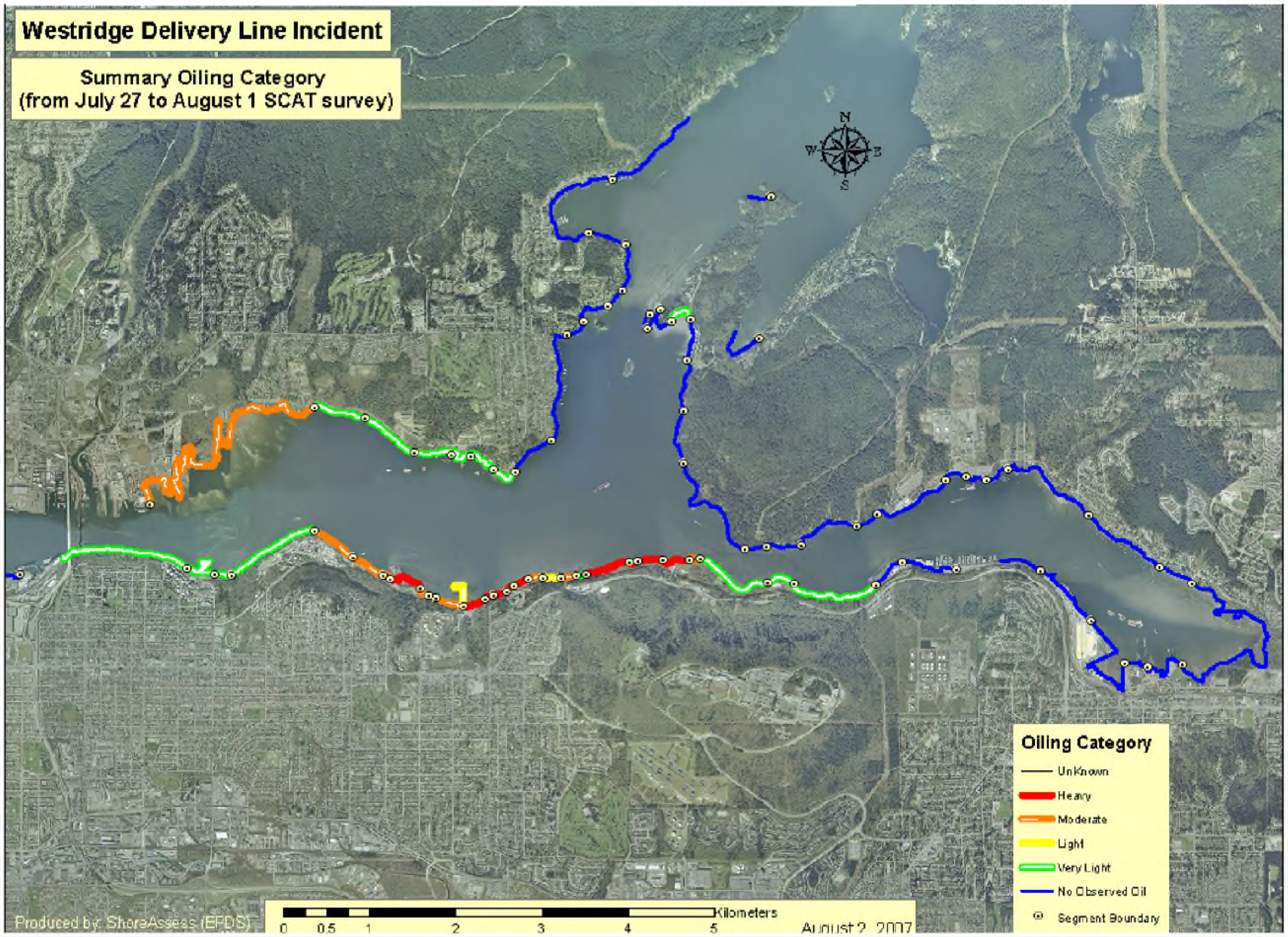
PROJECT NO.	DWN	CKD	APVD	REV
V13203022	DP	JAS	JAS	0

OFFICE	DATE
EBA-VANC	July 30, 2013

Figure 4.2

C:\Users\daniel.potts\Documents\Local_work\KinderMorgan\99-Reports\05-Final Report\BI_validation_2007\figures\sources\shoreline_oiling\shore_oiling_figure.lay

31 Jul 2013 13:37:40



Jacques Whitford AXYS Ltd.
4370 Dominion Street
Burnaby, British Columbia
V5G 4L7
Tel. (604) 436 3014
Fax. (604) 436 3752

KINDER MORGAN

SUMMARY OILING CATEGORY

PROJECTION	UTM - ZONE 10	DRAWN BY	SS
DATUM	NAD 83	CHECKED BY	
DATE	23-Oct-07	FIGURE NO.	3.3

NOTES

Reproduced from "Environmental Impact Statement: Divisoins B and D: Sewers, Foreshore and Marine Environment - Westridge Hydrocarbon Accidental Release" by Stantec (formerly Jacques Whitford AXYS), May 2010.

STATUS
ISSUED FOR REVIEW

CLIENT

TRANSMOUNTAIN

A TETRA TECH COMPANY

TRANS MOUNTAIN OIL SPILL STUDY

Shore Oiling Summary Map from Stantec EIS

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

OFFICE	DATE
EBA-VANC	July 30, 2013

Figure 4.3

APPENDIX E

STOCHASTIC MODELLING RESULTS

APPENDIX F
EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

DESIGN REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This Design Report pertains to a specific site, a specific development, and a specific scope of work. The Design Report may include plans, drawings, profiles and other support documents that collectively constitute the Design Report. The Report and all supporting documents are intended for the sole use of EBA’s Client. EBA does not accept any responsibility for the accuracy of any of the data, analyses or other contents of the Design Report when it is used or relied upon by any party other than EBA’s Client, unless authorized in writing by EBA. Any unauthorized use of the Design Report is at the sole risk of the user.

All reports, plans, and data generated by EBA during the performance of the work and other documents prepared by EBA are considered its professional work product and shall remain the copyright property of EBA.

2.0 ALTERNATIVE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. EBA’s instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless so stipulated in the Design Report, EBA was not retained to investigate, address or consider, and has not investigated, addressed or considered any environmental or regulatory issues associated with the project specific design.

4.0 CALCULATIONS AND DESIGNS

EBA has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, EBA’s client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by EBA’s Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of EBA.

5.0 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design has been completed. It is incumbent upon EBA’s Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by EBA, it will be included in the Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for the Design Report.

6.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.