

Table IR2020-1.1-A1: Summary of supporting documents

Project	Supporting document name	Location
Onsite offsetting	Moffatt and Nichol. 2020. Onsite Offsetting – Marsh and Eelgrass: Roberts Bank Terminal Project Modeling Report. Produced for Port of Vancouver. 37pp. Contained within Moffatt and Nichol 2020a as Appendix B.	Appendix IR2020-1.1-A1
	Moffatt and Nichol. 2020a. Roberts Bank Terminal 2 Onsite Habitat Offsetting Design Report. Produced for Port of Vancouver. 138 pp.	Appendix IR2020-1.1-A2
South Arm Jetty Tidal Marsh Project	Vancouver Fraser Port Authority. 2018. Land Tenure Application & Management Plan for Land Tenure Application – South Arm Jetty Tidal Marsh. 51 pp.	Appendix IR2020-1.1-A3
	Stantec. 2014. Archeological Overview Assessment – South Arm Jetty Tidal Marsh Project, Richmond, BC. 31 pp.	Appendix IR2020-1.1-A4
	Stantec. 2015. South Arm Jetty Tidal Marsh Preliminary Field Reconnaissance. Prepared for Port Metro Vancouver. 7 pp.	Appendix IR2020-1.1-A5
	Moffatt and Nichol. 2020d. Supplemental Hydrodynamic and Salinity Analysis by Incorporating Phase 2 Breaching into the South Arm Jetty Tidal Marsh Project. 9 pp.	Appendix IR2020-1.1-A6
	Moffatt and Nichol. 2020c. Habitat Enhancement Program – South Arm Jetty Tidal Marsh Coastal Processes and Salinity Modeling. Produced for Port of Vancouver. 69 pp. Contained within Moffatt and Nichol 2020b as Appendix D.	Appendix IR2020-1.1-A7
	Moffatt and Nichol. 2020b. South Arm Jetty Tidal Marsh Design Report. Produced for Port of Vancouver. 172 pp.	Appendix IR2020-1.1-A8
	Hemmera. 2018a. Existing Ecological Conditions – Proposed South Arm Jetty Tidal Marsh Project. Prepared for Vancouver Fraser Port Authority. 62 pp.	Appendix IR2020-1.1-A9
	Golder and Associates. 2014. Geotechnical Assessment – Phase 2 Habitat Enhancement: South Arm Jetty Tidal Marsh, Richmond, BC. 16 pp. Contained within Moffatt and Nichol 2020b as Appendix A.	Appendix IR2020-1.1-A10
South Causeway Eelgrass Project	Moffatt and Nichol. 2012. T2 Habitat Offsetting Engineering Support – Updated Hydrodynamic Model of Roberts Bank. 7 pp. Contained within Moffatt and Nichol 2020e as Appendix A.	Appendix IR2020-1.1-A11
	Moffatt and Nichol. 2020e. Tsawwassen Eelgrass Project Design Report. Produced for Port of Vancouver. 52 pp.	Appendix IR2020-1.1-A12
	Hemmera. 2015. Existing Ecological Conditions – Proposed Tsawwassen Eelgrass Enhancement Project. Prepared for Port Metro Vancouver – Habitat Enhancement Program. 74 pp.	Appendix IR2020-1.1-A13
	Hemmera. 2020. Tsawwassen Eelgrass Project Existing Ecological Conditions Update Assessment. Prepared for Vancouver Fraser Port Authority. 13pp.	Appendix IR2020-1.1-A14
	Golder and Associates. 2017. Geotechnical Assessment – Habitat Enhancement: Tsawwassen Eelgrass Project, Tsawwassen,	Appendix IR2020-1.1-A15

Project	Supporting document name	Location
	BC. 11 pp. Contained within Moffatt and Nichol 2020e as Appendix B.	
Westham Island Canoe Pass Tidal Marsh Project	Vancouver Fraser Port Authority. 2014. Land Tenure Application & Management Plan – Westham Island / Canoe Pass Tidal Marsh Habitat Banking Project. 11 pp.	Appendix IR2020-1.1-A16
	Stantec. 2013. Preliminary Field Reconnaissance of the Proposed Cane Pass/Westham Island Habitat Banking Development. 2 pp.	Appendix IR2020-1.1-A17
	Moffatt and Nichol. 2020g. Salinity Impacts for the Westham Island/Canoe Passage Tidal Marsh Project. Prepared for Vancouver Fraser Port Authority. 3pp. Contained within Moffatt and Nichol 2020f as Appendix E.	Appendix IR2020-1.1-A18
	Moffatt and Nichol. 2020f. Westham Island Canoe Pass Tidal Marsh Project Design Report. Produced for Port of Vancouver. 68 pp.	Appendix IR2020-1.1-A19
	Hemmera. 2014b. Ecological Conditions at Proposed Westham Island Tidal Marsh Project. Prepared for Port Metro Vancouver. 42 pp.	Appendix IR2020-1.1-A20
	Golder and Associates. 2013. Geotechnical Assessment – Phase 1 Habitat Compensation: Westham Island, Delta, BC. 10 pp. Contained within Moffatt and Nichol 2020f as Appendix A.	Appendix IR2020-1.1-A21
Tilbury Island Peninsula Enhancement Project	Northwest Hydraulic Consultants. 2021a. Tilbury Island Peninsula Enhancement Project Design Brief for Habitat Offsetting. Prepared for the Vancouver Port Authority. 47 pp.	Appendix IR2020-1.1-A22
	AECOM. 2020a. Existing Ecological Conditions Report: Tilbury Island Peninsula Enhancement Project. Prepared for Vancouver Fraser Port Authority.	Appendix IR2020-1.1-A23
Semiahmoo Bay-Little Campbell River Enhancement Project	Northwest Hydraulic Consultants. 2021b. Semiahmoo Bay – Little Campbell River Enhancement Project Design Brief for Habitat Offsetting. Prepared for Vancouver Fraser Port Authority. 49 pp.	Appendix IR2020-1.1-A24
	AECOM. 2020b. Existing Ecological Conditions Report: Semiahmoo Bay-Little Campbell River Enhancement Project. Prepared for Vancouver Fraser Port Authority.	Appendix IR2020-1.1-A25
Finn Slough Enhancement Project	Moffatt & Nichol. 2021. Finn Slough Enhancement Project Design Report. Produced for the Port of Vancouver. 53 pp.	Appendix IR2020-1.1-A26

Appendix IR2020-1.1-A1

**Onsite Offsetting – Marsh and Eelgrass:
Roberts Bank Terminal Project Modeling
Report**

Document Verification

Client	Vancouver Fraser Port Authority
Project name	RBT2 On Site Offsetting – Marsh and Eelgrass
Document title	Modeling Report
Date	August 13, 2020
Project number	9117-O

Revision	Description	Issued by	Date	Checked
A	Draft	E. Omranian	May 29, 2020	M. Jorgensen
0	Final	M. Jorgensen	Aug 13, 2020	A. Alcorn

Produced by:

Moffatt & Nichol, Vancouver
Suite 301 - 777 West Broadway
Vancouver BC V5Z 4J7 Canada
T +1-604-707-9004
www.moffattnichol.com

Table of Contents

Document Verification	i
Executive Summary	v
Disclaimer	vi
Glossary	vii
1. Introduction	1
2. Site Description	2
3. Hydrographic Conditions	4
3.1. Water Levels	4
3.1.1. Astronomical Tides	4
3.1.2. Extreme Water Levels	4
3.2. Winds	5
4. Numerical Modelling Development	10
4.1. Model Description	10
4.2. Model Grid and Bathymetry	11
4.3. SW Model Calibration	14
4.4. HD Model Calibration	16
5. Design Criteria for Onsite Habitat Features	19
5.1. Peak Tidal Currents	19
5.2. Permissible Bed Shear Stress	21
5.3. Biological Design Criteria	24
5.3.1. Eelgrass Salinity Range	24
5.3.2. Intertidal Marsh Salinity Range	26
5.3.3. Intertidal Marsh Elevation Range	27
5.3.4. Intertidal Marsh Wave Tolerance	28
5.3.5. Rock Berm Stone Size	29
5.3.6. Rock Berm Crest Elevation	30
5.3.7. Marsh Channel Dimensions	31
6. Conclusions	35
7. References	36

List of Figures

Figure 2-1: Roberts Bank Terminal 2 (eelgrass, intertidal marsh, rocky reef) location.....	2
Figure 2-2: Example of existing marsh.....	3
Figure 3-1: Annual wind rose at sandheads.....	6
Figure 3-2: Wind-wave model data output locations.....	7
Figure 3-3: Significant wave height under 50 knots wind.....	8
Figure 3-4: Peak wave period under 50 knots wind.....	9
Figure 4-1: Meteocean data stations.....	10
Figure 4-2: Model domain for the spectral wave and hydrodynamic models.....	12
Figure 4-3: Unstructured grid elements near RBT2.....	12
Figure 4-4: Overall model bathymetry.....	13
Figure 4-5: Model bathymetry near RBT2 with onsite marshes.....	13
Figure 4-6: Selected winter storm event for wave calibration.....	14
Figure 4-7: Measured vs modelled H_s at Halibut Bank.....	15
Figure 4-8: Measured vs modelled T_p at Halibut Bank.....	15
Figure 4-9: Measured vs modelled water levels at DFO tide gauges.....	17
Figure 4-10: Measured vs modelled tidal constituents at DFO tide gauges.....	18
Figure 4-11: Measured vs modelled flow split.....	18
Figure 5-1: Pre-project peak currents.....	20
Figure 5-2: Post-project peak currents.....	21
Figure 5-3: Difference of peak currents between pre- and post-project conditions.....	21
Figure 5-4: Pre-project bed shear stress.....	24
Figure 5-5: Post-project bed shear stress.....	24
Figure 5-6: Salinities associated with a high slack tide.....	25
Figure 5-7: Salinities associated with an ebb tide.....	26
Figure 5-8: Wave height tolerance for marsh species, Douglass (2004).....	29
Figure 5-9: Rock berm crest elevation and details (van der Meer-1991).....	31
Figure 5-10: Equilibrium cross-section area versus tidal prism data.....	32
Figure 5-11: Cross-sectional area vs. peak discharge for sheltered tidal channels (friedrichs,1995).....	33
Figure 5-12: Width-to-depth ratio for tidal channels (adopted from hughes 2011).....	34

List of Tables

Table 3-1: Tidal datums for Tsawwassen (CHS, 2005).....	4
Table 3-2: Extreme high water levels estimated at RBT2 (Worley Parsons, 2014).....	4
Table 3-3: Extreme wind speeds at Sandheads (Worley Parsons, 2014).....	5
Table 3-4: Detailed wave characteristics for data-point locations	7
Table 3-5: Detailed normal tide Peak wave period for data-point locations	8
Table 5-1: Depth-average tidal Current velocities for existing and proposed conditions.....	20
Table 5-2: Unified soil classification system (abbreviated).....	22
Table 5-3: Typical permissible shear stress, reproduced from FHWA (2005).....	23
Table 5-4: Salinity ranges for existing and proposed eelgrass zones.....	25
Table 5-5: Salinity ranges for existing and proposed tidal marsh zones.....	26
Table 5-6: Project and regional marsh habitat salinity tolerance.....	27
Table 5-7: Project and regional marsh habitat elevation ranges	28
Table 5-8: Gradation of rock sizes in each class of riprap	30

Executive Summary

This report summarizes the design criteria for intertidal marsh and subtidal eelgrass zones as well as using hydraulic engineering manual to design a rock containment berm at northern side of Roberts Bank Terminal 2 (RBT2) site. Hydrodynamic modeling results (M&N 2020) are used to study and better understand the overall condition of the project's site.

A discussion of the existing site conditions is provided in Chapter 2. By characterizing the existing site conditions the design concept was developed.

A summary of metocean data utilized for the study including water levels, wind, and waves provided in Chapter 3.

Subsequently, the numerical modeling details are indicated in Chapter 4 and the criteria used to support the design of the site are discussed in Chapter 5. The Project design criteria also include a description of the functional, physical and biological criteria as well as the applied engineering standards using the Coastal Engineering Manual (CEM) developed by U.S. Army Corp of Engineers.

Overall conclusions are summarized in Chapter 6.

Findings and Conclusions

1. Post-project current speeds around the peripheral boundaries and RBT2 project areas are equal to or less than pre-project values.
2. The proposed marsh and eelgrass habitat meets the outline design criteria.
3. The salinity range in the area proposed for new eelgrass plantings is within the optimal range for eelgrass.
4. The salinity range estimated for the proposed intertidal marsh zone along the northern side of RBT2 is within the optimal range for select salt-tolerant species.
5. Based on the salinity tolerance parameters; Saltgrass, pickleweed, and Arrowgrass species may be candidate marsh vegetation for the onsite marsh habitat. The preferred elevation range for these species is 3.6 to 5.0 m Chart Datum (CD).
6. The freeboard of the rock berm is estimated to be 1.1 m above Higher High Water-Mean Tide (HHW-MT) with a crest width of 5 m. This corresponds to a crest elevation of about +5.2 m CD.
7. The suggested marsh channel dimensions range from a 5 m wide and 0.7 m deep channel to a 10 m wide and 1.4 m deep channel.

Disclaimer

Moffatt & Nichol devoted effort consistent with (i) the level of diligence ordinarily exercised by competent professionals practicing in the area under the same or similar circumstances, and (ii) the time and budget available for its work, to ensure that the data contained in this report is accurate as of the date of its preparation. This study is based on estimates, assumptions and other information developed by Moffatt & Nichol from its independent research effort, general knowledge of the industry, and information provided by and consultations with the client and the client's representatives. No responsibility is assumed for inaccuracies in reporting by the Client, the Client's agents and representatives, or any third-party data source used in preparing or presenting this study. Moffatt & Nichol assumes no duty to update the information contained herein unless it is separately retained to do so pursuant to a written agreement signed by Moffatt & Nichol and the Client.

Moffatt & Nichol's findings represent its professional judgment. Neither Moffatt & Nichol nor its respective affiliates, makes any warranty, expressed or implied, with respect to any information or methods disclosed in this document. Any recipient of this document other than the Client, by their acceptance or use of this document, releases Moffatt & Nichol and its affiliates from any liability for direct, indirect, consequential or special loss or damage whether arising in contract, warranty (express or implied), tort or otherwise, and irrespective of fault, negligence and strict liability.

This report may not be used in conjunction with any public or private offering of securities, debt, equity, or other similar purpose where it may be relied upon to any degree by any person other than the Client. This study may not be used for purposes other than those for which it was prepared or for which prior written consent has been obtained from Moffatt & Nichol.

Possession of this study does not carry with it the right of publication or the right to use the name of "Moffatt & Nichol" in any manner without the prior written consent of Moffatt & Nichol. No party may abstract, excerpt or summarise this report without the prior written consent of Moffatt & Nichol. Moffatt & Nichol has served solely in the capacity of consultant and has not rendered any expert opinions in connection with the subject matter hereof. Any changes made to the study, or any use of the study not specifically identified in the agreement between the Client and Moffatt & Nichol or otherwise expressly approved in writing by Moffatt & Nichol, shall be at the sole risk of the party making such changes or adopting such use.

This document was prepared solely for the use by the Client. No party may rely on this report except the Client or a party so authorised by Moffatt & Nichol in writing (including, without limitation, in the form of a reliance letter). Any party who is entitled to rely on this document may do so only on the document in its entirety and not on any excerpt or summary. Entitlement to rely upon this document is conditioned upon the entitled party accepting full responsibility and not holding Moffatt & Nichol liable in any way for any impacts on the forecasts or the earnings from the project resulting from changes in "external" factors such as changes in government policy, in the pricing of commodities and materials, price levels generally, competitive alternatives to the project, the behaviour of consumers or competitors and changes in the owners' policies affecting the operation of their projects.

This document may include "forward-looking statements". These statements relate to Moffatt & Nichol's expectations, beliefs, intentions or strategies regarding the future. These statements may be identified by the use of words like "anticipate," "believe," "estimate," "expect," "intend," "may," "plan," "project," "will," "should," "seek," and similar expressions. The forward-looking statements reflect Moffatt & Nichol's views and assumptions with respect to future events as of the date of this study and are subject to future economic conditions, and other risks and uncertainties. Actual and future results and trends could differ materially from those set forth in such statements due to various factors, including, without limitation, those discussed in this study. These factors are beyond Moffatt & Nichol's ability to control or predict. Accordingly, Moffatt & Nichol makes no warranty or representation that any of the projected values or results contained in this study will actually be achieved.

This study is qualified in its entirety by, and should be considered in light of, these limitations, conditions and considerations.

Glossary

CD	Chart Datum
CHS	Canadian Hydrographic Service
cm	Centimetres
DHI	Danish Hydraulic Institute
HD	Hydrodynamic
GD	Geodetic Datum
HA	Hectare
HHW-LT	Higher High Water - Large Tide
HHW-MT	Higher High Water - Mean Tide
H _s	Significant Wave Height
kg	Kilogram
m	metre
m	Metres
M&N	Moffatt & Nichol
m/s	Metres per second
mm	Millimetres
N	Newtons
N/m ²	Newton per square metre
NAD83	North American Vertical Datum of 1983
OOF	Onsite Offset Feature
PAR	Photosynthetically Active Radiation
PI	Plasticity Index
ppt	Parts per thousand
psu	Practical salinity unit
RBT2	Roberts Bank Terminal 2
SI	Système International
SW	Spectral Wave
T _p	Peak Wave Period
US	United States
USCS	Unified Soil Classification System
UTM	Universal Transverse Mercator
VFPA	Vancouver Fraser Port Authority

1. Introduction

The Roberts Bank Terminal 2 (RBT2) On Site Offsetting project (Project) consists of an intertidal marsh site and a subtidal eelgrass zone located north of the proposed RBT2 terminal and southwest of the existing Deltaport Terminal, British Columbia. In general, the Project involves converting lower-value subtidal areas into higher value eelgrass habitat through the construction of rock containment berms followed by placement of sand fill material and transplanting of eelgrass.

This report provides the criteria that have been considered in developing the design for the Project. A discussion of the existing site conditions is provided in Section 2. By characterizing the existing site conditions the design concept was developed.

Hydrographic conditions including water levels, wind, and waves discussed in Section 3.

Subsequently, the numerical modeling details are included in Chapter 4 and the criteria used to support the design of the site are discussed in Section 5. The Project design criteria also include a description of the functional, physical and biological criteria as well as the applied engineering standards. Conclusions are summarized in Chapter 6.

2. Site Description

On site offset features for the RBT2 Project consist of an eelgrass bed and an intertidal marsh zone located along the RBT2 causeway adjacent to the existing Westshore/Deltaport Terminals and to the north of RBT2 (Figure 2-1).



FIGURE 2-1: ROBERTS BANK TERMINAL 2 (EELGRASS, INTERTIDAL MARSH, ROCKY REEF) LOCATION

The Onsite Offset Features (OOF) involve creation of eelgrass beds by placement of sand fill between constructed containment berms. The eelgrass zone will be located at west-side of the existing Deltaport terminal adjacent to existing eelgrass colonies. The containment berms are comprised of quarry run rock and quarry screenings orientated along the north side of the proposed intertidal marsh zone, adjacent to the proposed RBT2. The site boundaries are constrained by property boundaries, existing habitat, and footprint of the proposed RBT2 terminal.

The proposed intertidal marsh zone will be placed along the north-side of RBT2 and protected and contained by a rock berm. The rock berm will serve to reduce vulnerability of intertidal marsh against wave action coming from west and contain the fill material. An example photo of existing marsh near the proposed site is shown in Figure 2-2.



FIGURE 2-2: EXAMPLE OF EXISTING MARSH

3. Hydrographic Conditions

3.1. Water Levels

3.1.1. Astronomical Tides

Total water level consists of astronomical and meteorological tide components. Astronomical tides refer to the tidal levels which result from gravitational effects, e.g. of the Earth, Sun and Moon, without any atmospheric influences.

Table 3-1 summarizes tidal datums at Tsawwassen based on the Canadian Hydrographic Service *Nautical Chart 3492* (CHS, 2005).

- Higher High Water Large Tide (HHW-LT): The average of the highest high waters, one from each of 19 years of predictions.
- Higher High Water Mean Tide (HHW-MT): The average from all the higher high waters from 19 years of predictions.
- Mean Water Level (MLW): The average of all hourly water levels over the available period of record.
- Lower Low Water Mean Tide (LLW-MT): The average of all the lower low waters from 19 years of predictions.
- Lower Low Water Large Tide (LLW-LT): The average of the lowest low waters, one from each of 19 years of predictions.

TABLE 3-1: TIDAL DATUMS FOR TSAWWASSEN (CHS, 2005)

Location	Elevation above Chart Datum (m, CD)				
	Large Tide		Mean Tide		Mean Water Level
	HHW	LLW	HHW	LLW	
Tsawwassen	4.8	0.1	4.1	1.2	3.0

3.1.2. Extreme Water Levels

The second component of total water level, meteorological tides (or residual), refer to changes in expected astronomical tides caused by local meteorological conditions. The positive value of residual is commonly called storm surge as the water surface is elevated due to the passage of a low-pressure storm system. Extreme value estimates are summarized in Table 3-2.

TABLE 3-2: EXTREME HIGH WATER LEVELS ESTIMATED AT RBT2 (WORLEY PARSONS, 2014)

Description	Return Period (Years)				
	2	5	10	50	100
Extreme High Water Level (m, CD)	5.02	5.15	5.22	5.35	5.39

3.2. Winds

Wind data for Sandheads is archived in the Environment Canada National Climate Data and Information network. A total of 24 years of data between 1995 and 2018 was analyzed. Figure 3-1 presents the annual wind rose and shows the prevailing wind direction is from the east. Stronger winds are aligned northwesterly or east/southeasterly, which reflects the open water orientation of the Strait of Georgia. The largest recorded wind speed was approximately 50 knots.

Table 3-3 summarizes wind speed extremes. The 50-year and 100-year return period omni-directional winds are 50 and 51 knots.

TABLE 3-3. EXTREME WIND SPEEDS AT SANDHEADS (WORLEY PARSONS, 2014)

Wind Direction	Return Period (Year)							
	1	2	5	10	25	30	50	100
Omni-Directional (knots)	40	42	44	46	48	49	50	51
SE-S (knots)	38	40	43	45	47	48	49	51
NW-W (knots)	36	39	42	44	47	48	49	51

M&N conducted a wind-wave analysis using MIKE-21 Spectral Wave (SW) model to estimate the exposure of the marsh and eelgrass zones to wave action. Figure 3-2 shows the location of output points.

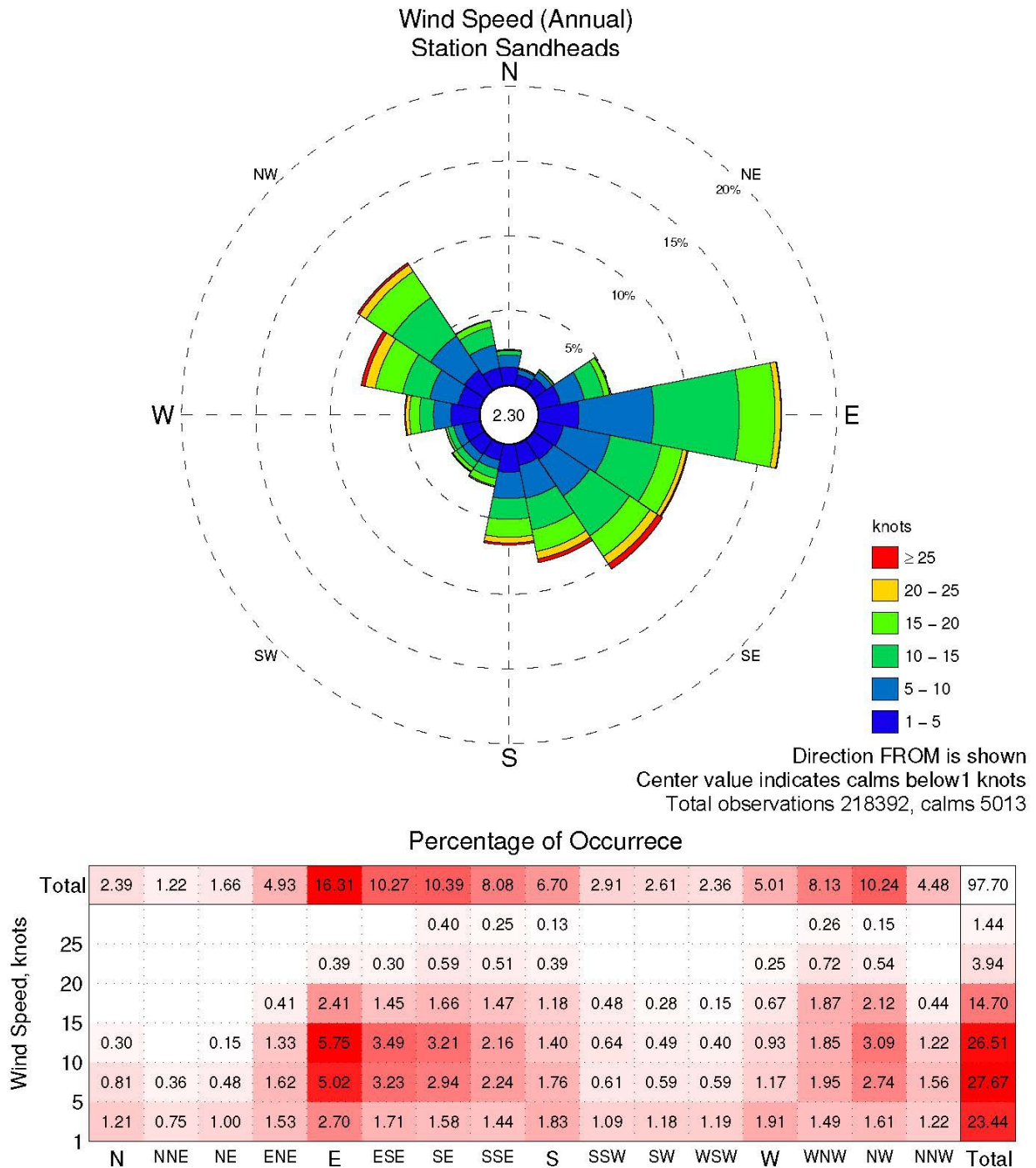


FIGURE 3-1: ANNUAL WIND ROSE AT SANDHEADS

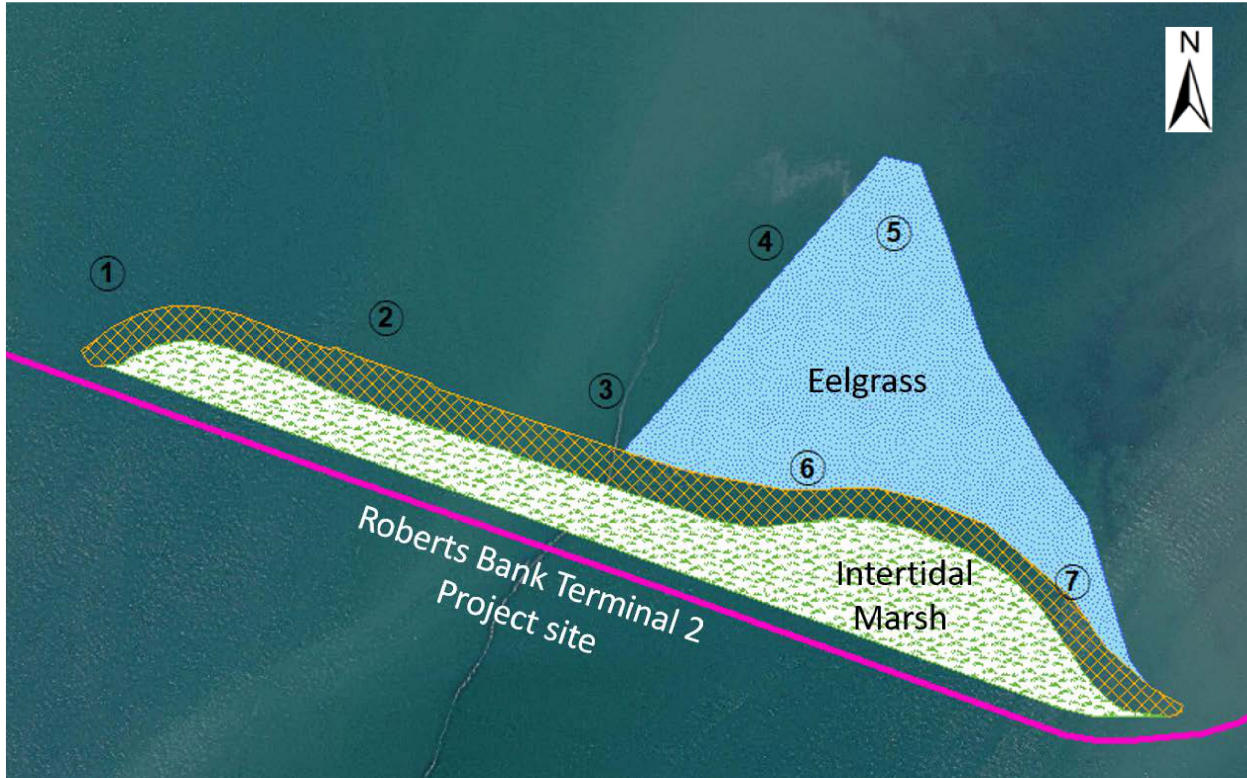


FIGURE 3-2: WIND-WAVE MODEL DATA OUTPUT LOCATIONS

Table 3-4 lists the significant wave height for the 7 selected locations (Figure 3-2). Comparing all locations, it is clear that Point 1 is the most exposed location. These values were obtained from a normal high tide without sea-level rise (SLR).

TABLE 3-4: SIGNIFICANT WAVE HEIGHT FOR SELECTED LOCATIONS

WSPD (knots)	Significant Wave Height (m)						
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
5	0.21	0.19	0.19	0.20	0.19	0.19	0.19
10	0.29	0.27	0.27	0.28	0.27	0.27	0.27
15	0.42	0.40	0.39	0.39	0.39	0.38	0.37
20	0.54	0.51	0.50	0.51	0.50	0.50	0.47
25	0.68	0.63	0.62	0.65	0.63	0.61	0.59
30	0.84	0.78	0.76	0.79	0.78	0.75	0.72
35	1.00	0.94	0.92	0.95	0.93	0.91	0.86
40	1.17	1.11	1.08	1.10	1.08	1.07	1.01
45	1.35	1.28	1.25	1.26	1.24	1.23	1.16
50	1.53	1.45	1.42	1.42	1.40	1.40	1.31
55	1.70	1.63	1.59	1.57	1.55	1.57	1.46

Similarly, Table 3-5 lists the corresponding peak wave period. For the design wind speed of 50 knots (e.g. 50-year return period), the peak wave period is around 4.1 seconds in the marsh area.

TABLE 3-5: PEAK WAVE PERIOD FOR SELECTED LOCATIONS

WSPD (knots)	Peak Wave Period (s)						
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
10	2.7	2.7	2.7	2.7	2.7	2.7	2.7
15	2.9	2.8	2.8	2.8	2.7	2.8	2.7
20	3.0	2.9	2.9	2.9	2.9	2.9	2.9
25	3.2	3.2	3.1	3.1	3.1	3.1	3.1
30	3.4	3.3	3.3	3.3	3.3	3.3	3.3
35	3.6	3.5	3.5	3.6	3.5	3.5	3.5
40	3.8	3.7	3.7	3.7	3.7	3.7	3.6
45	4.0	3.9	3.9	3.9	3.9	3.9	3.9
50	4.1	4.1	4.0	4.1	4.1	4.0	4.0
55	4.3	4.2	4.2	4.2	4.2	4.2	4.1

Figure 3-3 and Figure 3-4 present examples of significant wave height variations and peak wave period under 50 knots wind.

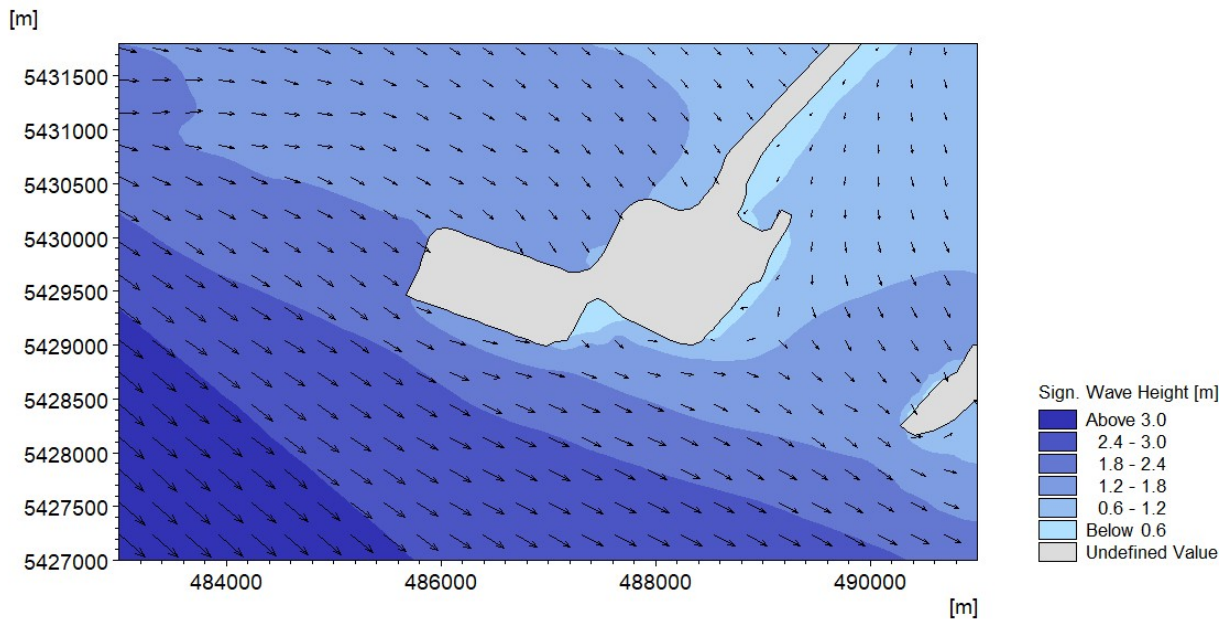


FIGURE 3-3: SIGNIFICANT WAVE HEIGHT UNDER 50 KNOTS WIND

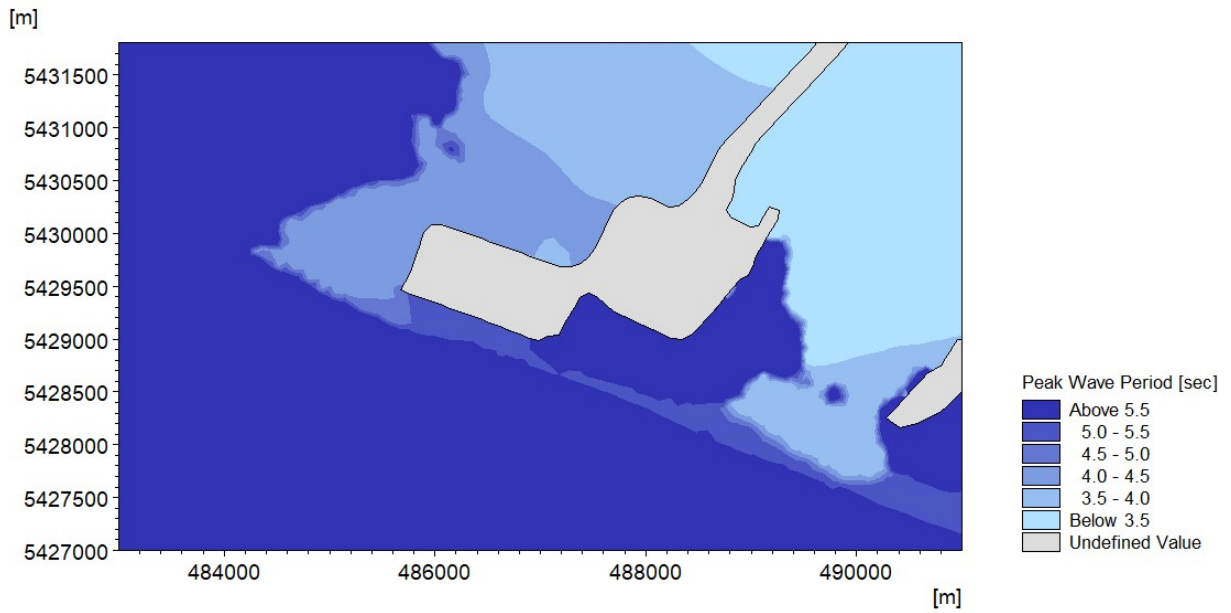


FIGURE 3-4: PEAK WAVE PERIOD UNDER 50 KNOTS WIND

4. Numerical Modelling Development

The Danish Hydraulic Institute MIKE-21 two-dimensional Spectral Wave (SW) and Hydrodynamic (HD) models were developed for the Lower Fraser River and Strait of Georgia to carry out the relevant analyses and to determine engineering requirements for the proposed marsh. Both models were calibrated to ensure that wave and hydrodynamic processes were adequately reproduced. Figure 4-1 depicts the locations of the meteocean data stations used in the model development.

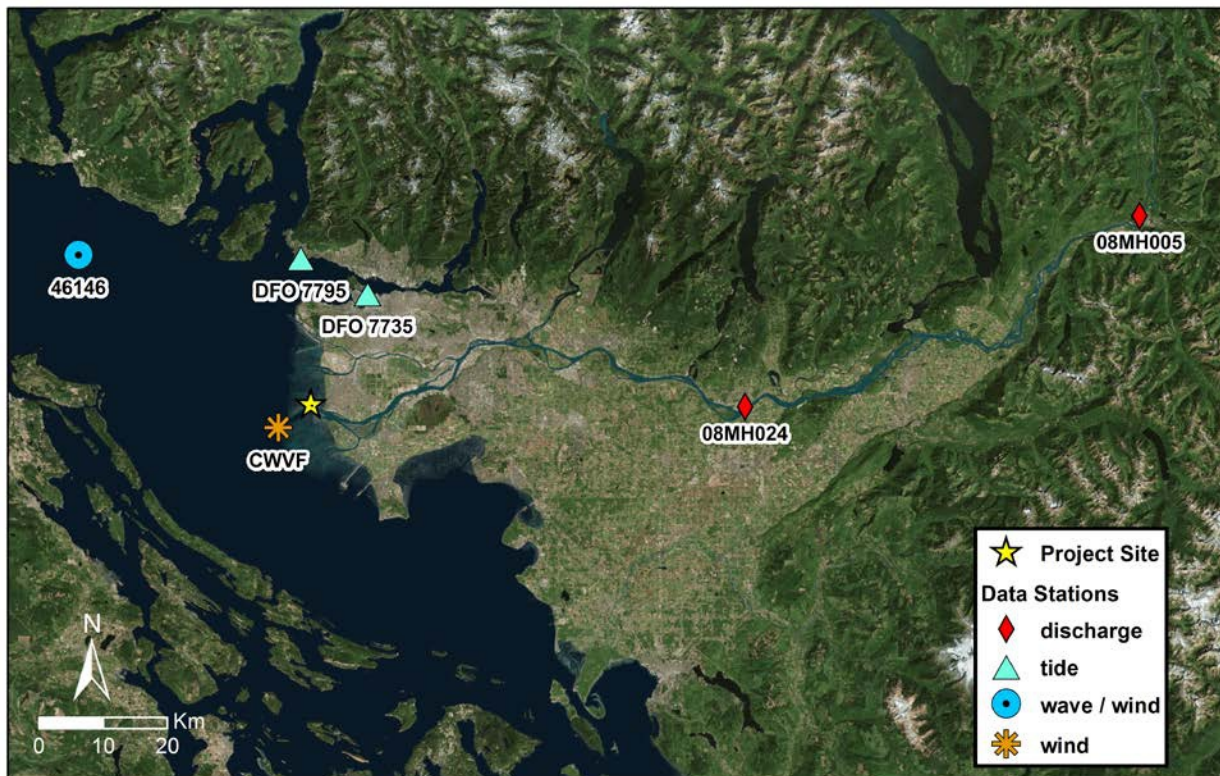


FIGURE 4-1: METEOCEAN DATA STATIONS

4.1. Model Description

MIKE-21 is a modelling system developed by the Danish Hydraulic Institute (DHI) Water and Environment. It was selected for the project because of the flexibility and computational efficiency with its unstructured grid configuration. The unstructured grid makes it possible to resolve both large and small-scale flow and wave processes effectively. Finer resolution grid elements are used in the vicinity of the project area while coarser grid elements are used away from the areas of interest.

The SW model solves the wave action conservation equations and simulates the growth, decay, and transformation of wind-generated seas and long-period swells in offshore and coastal areas. The SW considers important physical processes, including wave growth by action of winds, shoaling and refraction due to depth variations, diffraction and reflection near structures, wave breaking in the surf zone, wave dissipation (including bottom friction, white capping, and wave-wave interaction), and

some non-linear wave-current interactions. Although the model considers wave shoaling due to seabed changes and wave breaking where the water depth can't sustain the incident wave height, it should be noted that the focus of the study is on the design wave condition, which is occurred when the water level is high.

The HD model solves the depth-averaged shallow water equations and simulates water level variations and flows in response to a variety of forcing functions. It has been applied extensively worldwide within oceanographic, coastal, and estuarine environments.

4.2. Model Grid and Bathymetry

For computational efficiency and accuracy purposes, different model grids were developed for the SW and HD model. To accurately reproduce wave processes such as growth and propagation to RBT2, the computational domain for the SW model covers the Strait of Georgia Basin, extended around Texada Island to the northwest and connected with Strait of Juan de Fuca to the south (orange polygon in Figure 4-2); while a smaller domain for the HD model (pink polygon in Figure 4-2) to resolve the complex circulation processes in the Fraser River Delta. The HD domain extends inland to Mission as the freshwater discharge source.

Figure 4-3 shows the unstructured grid configuration (e.g. variable element resolutions) near RBT2. The finest element resolution around the proposed marsh area is approximately 25 m, while the coarsest grid element is about 650 to 700 m in the Strait of Georgia.

Bathymetry (or seabed elevations) for the majority of model domain was extracted from the C-Map Software of DHI, incorporating Jeppesen Norway's electronic database of global nautical charts (DHI, 2008). Figure 4-4 shows the average water depth in the Strait of Georgia is approximately 150 meters. The maximum depth can reach 400 meters, just south of Texada Island.

Bathymetry in the shallow mudflats surrounding the project area was based on Stantec's LiDAR survey conducted in July 2013 (Stantec, 2013). The LiDAR coverage included Roberts Bank and Sturgeon Bank. At the proposed onsite marshes, the design elevation was based on the preliminary concept drawing (M&N, 2020). Figure 4-5 presents the model bathymetry near RBT2, with onsite marshes. Vertical datum reference is Chart Datum (CD).

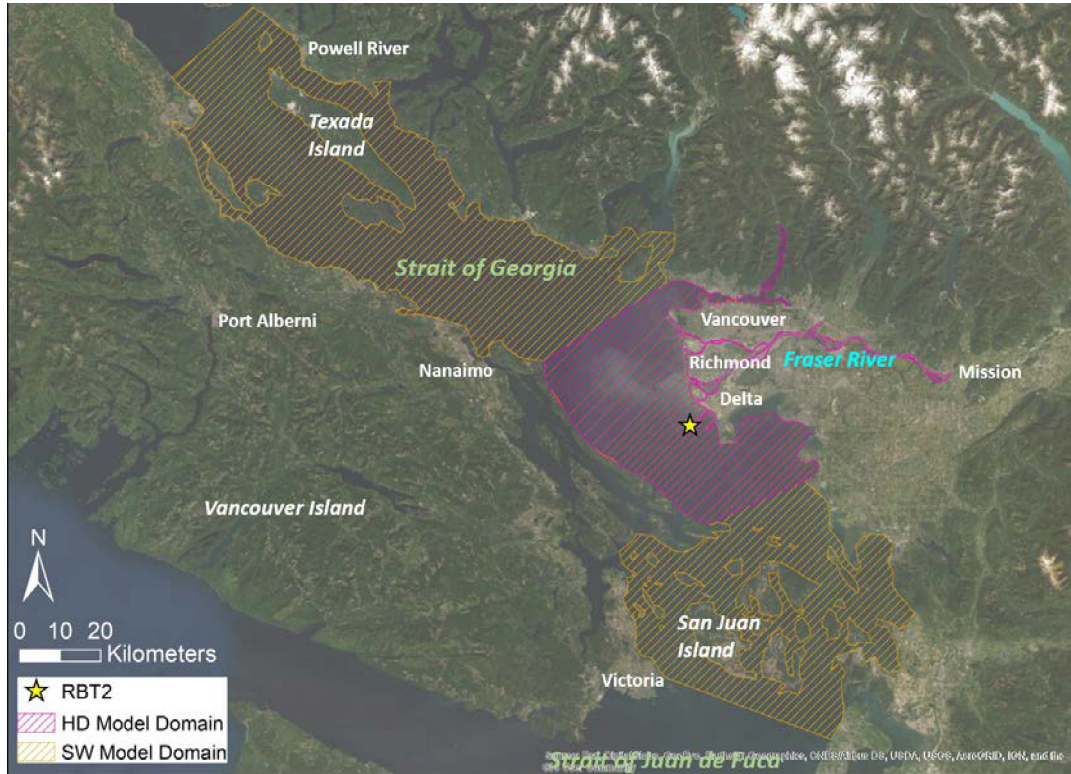


FIGURE 4-2: MODEL DOMAIN FOR THE SPECTRAL WAVE AND HYDRODYNAMIC MODELS

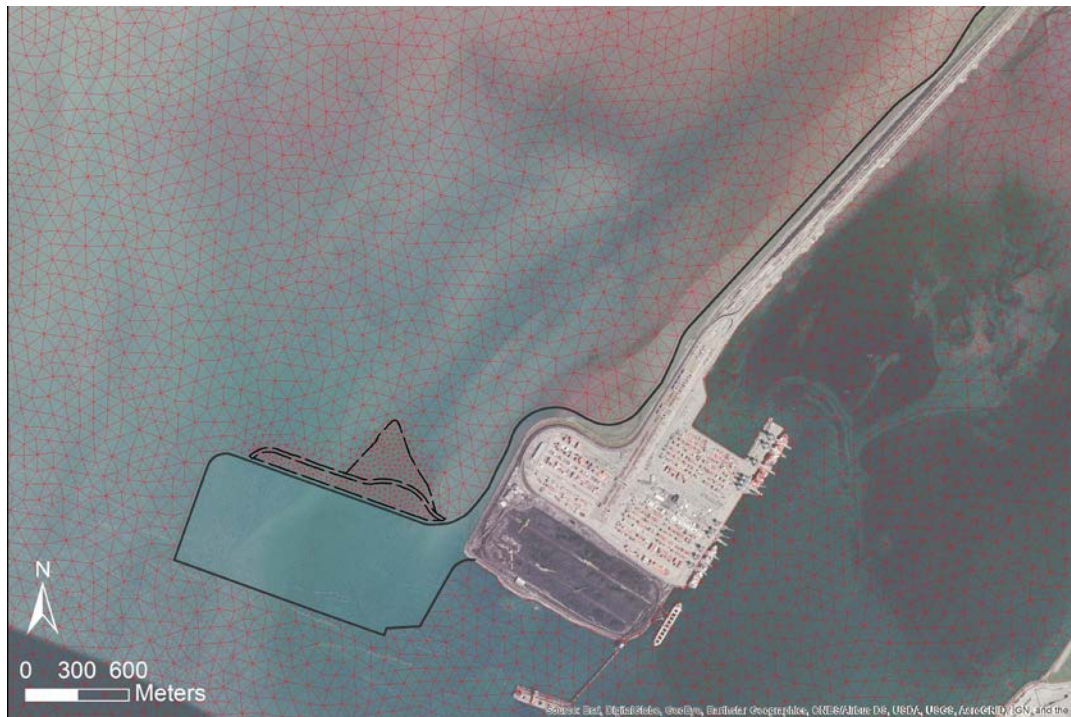


FIGURE 4-3: UNSTRUCTURED GRID ELEMENTS NEAR RBT2

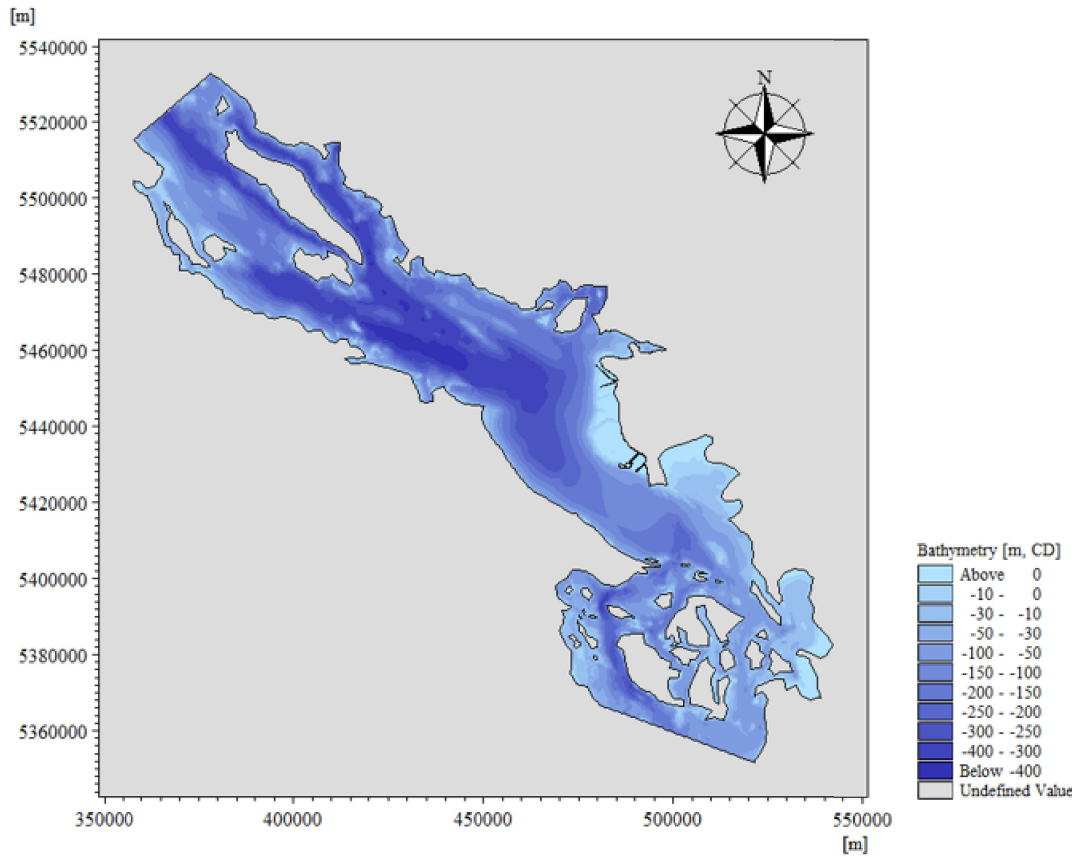


FIGURE 4-4: OVERALL MODEL BATHYMETRY

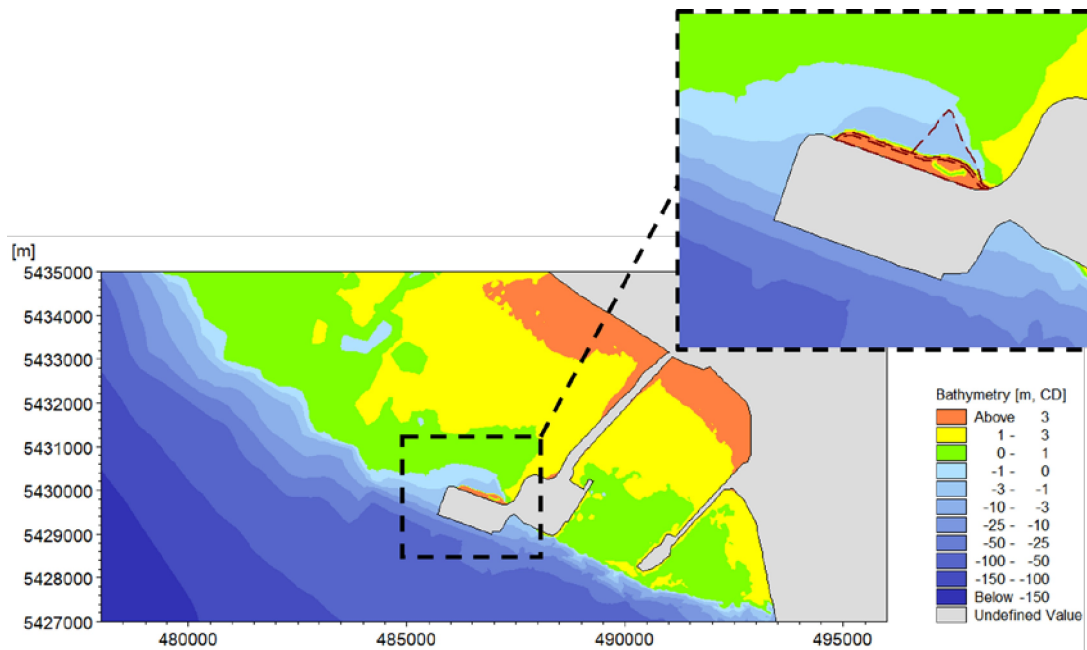


FIGURE 4-5: MODEL BATHYMETRY NEAR RBT2 WITH ONSITE MARSHES

4.3. SW Model Calibration

Typically, outputs from any numerical model need to be verified with field measurements, in order to show the model can reasonably reproduce the processes or environment of interest. This procedure is called model calibration.

The SW model was calibrated against hourly wave records at DFO Halibut Bank station (C46146, Figure 4-1), which include observations of significant wave height (H_s) and peak wave period (T_p) from 1996 to 2017.

A winter storm which occurred in Strait of Georgia in December 2001 was selected for SW model calibration because the storm had lasted more than 12 hours. Figure 4-6 shows the selected storm had retained wind speeds up to 40 knots (or 20 m/s) at Halibut Bank with predominant northwest-southeast directions.

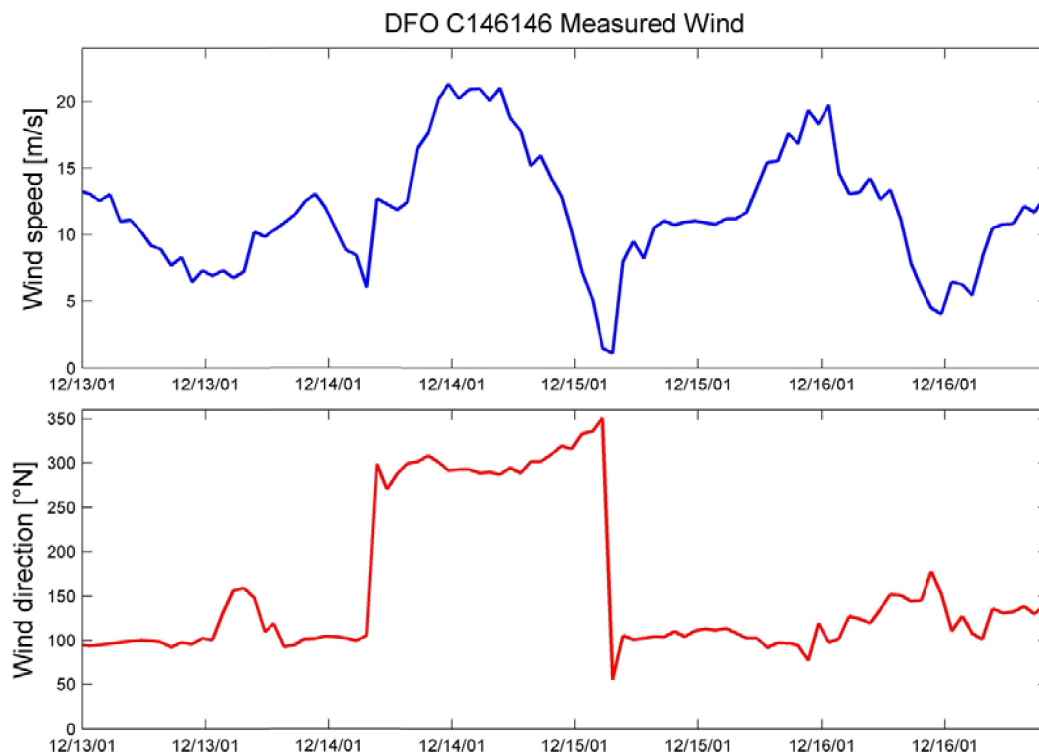


FIGURE 4-6: SELECTED WINTER STORM EVENT FOR WAVE CALIBRATION

Wave calibration was achieved by adjusting wave dissipation coefficients as well as spectral properties. In order to quantify the agreement between measured and model data, the following statistical parameters were determined.

- Root Mean Square Error (RMSE): $\varepsilon_{RMS} = \sqrt{(x - y)^2}$
- Mean Absolute Error (MAE, m): $MAE = |x - y|$

- Model Prediction Capability Index (d):
$$d = 1 - \frac{\overline{(x - y)^2}}{(|x - \bar{x}| + |y - \bar{x}|)^2}$$

Where, x and y represent the measured and modelled data, respectively. A comparison between measured and modelled wave statistical parameters is presented in Figure 4-7 and Figure 4-8, and shows that the model is in reasonable agreement with the measurements.

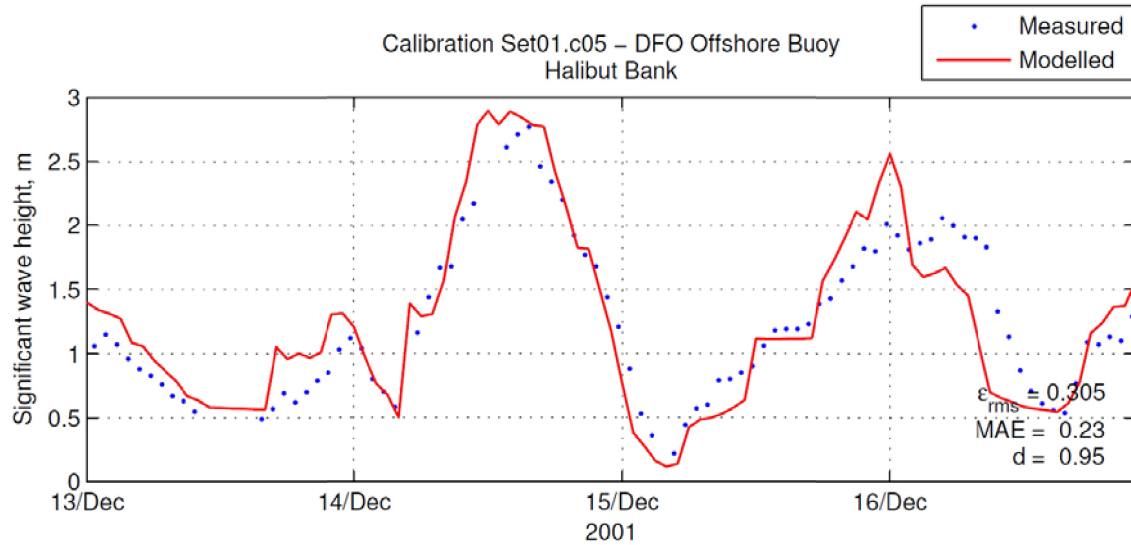


FIGURE 4-7: MEASURED VS MODELLED H_s AT HALIBUT BANK

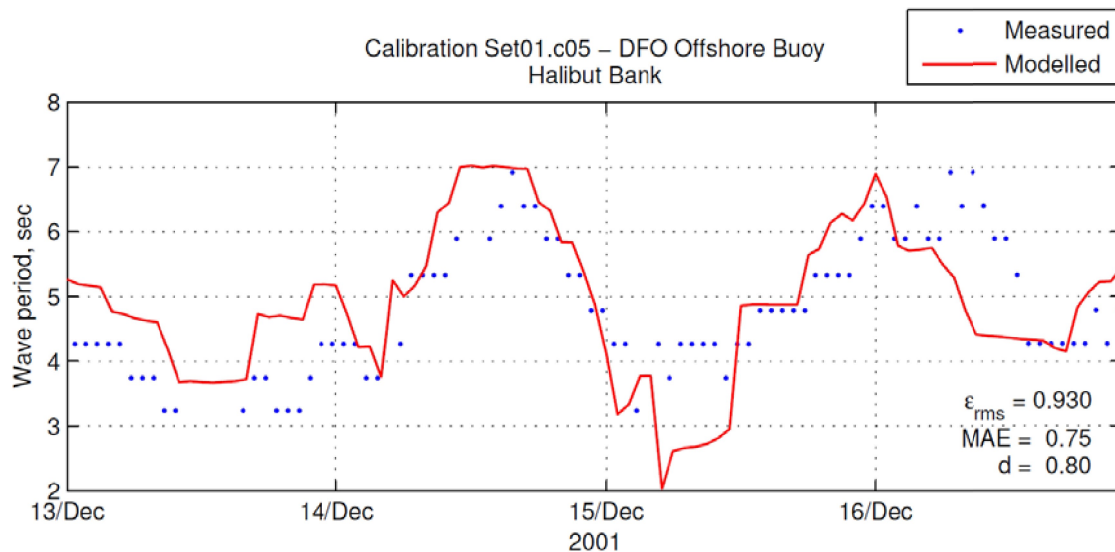


FIGURE 4-8: MEASURED VS MODELLED T_p AT HALIBUT BANK

4.4. HD Model Calibration

The HD model was calibrated against water levels and flow split. Modelled water levels were compared with tides measured at two DFO tide gauges, namely Point Atkinson and Vancouver, labelled as DFO7795 and DFO7735 in Figure 4-1. Modelled flow split was compared to measurements as reported by North Hydraulic Consultants (NHC, 2006).

The HD model was forced with astronomical tides and tidal currents, derived from the tidal constituent global database developed from TOPEX/Poseidon altimetry data (Egbert & Erofeeva, 2010), along its offshore tidal boundaries. In addition, Fraser River discharge measured at Mission (station 08MH024 in Figure 4-1) was used as the inland freshwater boundary.

A two-month simulation period was conducted between June 1 and July 31, 2012, in order to capture the higher-than-average discharges observed during the 2012 freshet season. A graphical comparison between measured and modelled water levels is provided in Figure 4-9 and shows that the HD model closely reproduces observed water level variations. Model prediction capability indices (d) of 0.99 (1.0 being perfect prediction) corroborate the accuracy of the modelled water levels at both tide gauges.

In addition, a comparison between the measured and modelled tidal constituents (i.e. the astronomical components of the tides) at both tide gauges was made. Figure 4-10 shows that the model adequately captures the amplitude of these constituents, with the M2 component amplitude being overpredicted by less than 7% and 3%, and the K1 component being overpredicted by 16% and 15%, respectively.

To confirm that the model correctly distributes flow into the North, Middle and South Arm of the Fraser river, modelled flow splits were also calculated. Flow split data collected by Public Works and Government Services Canada (PWGSC) from May 2005 to January 2006, was processed and reported by NHC in 2006. The blue and red boxes in Figure 4-11 indicate the measured and modelled flow splits, respectively. Overall, the model reproduces closely the flow distribution in the North, Middle and South Arm, with differences less than 1%. A slightly larger difference of 3% is found near Steveston.

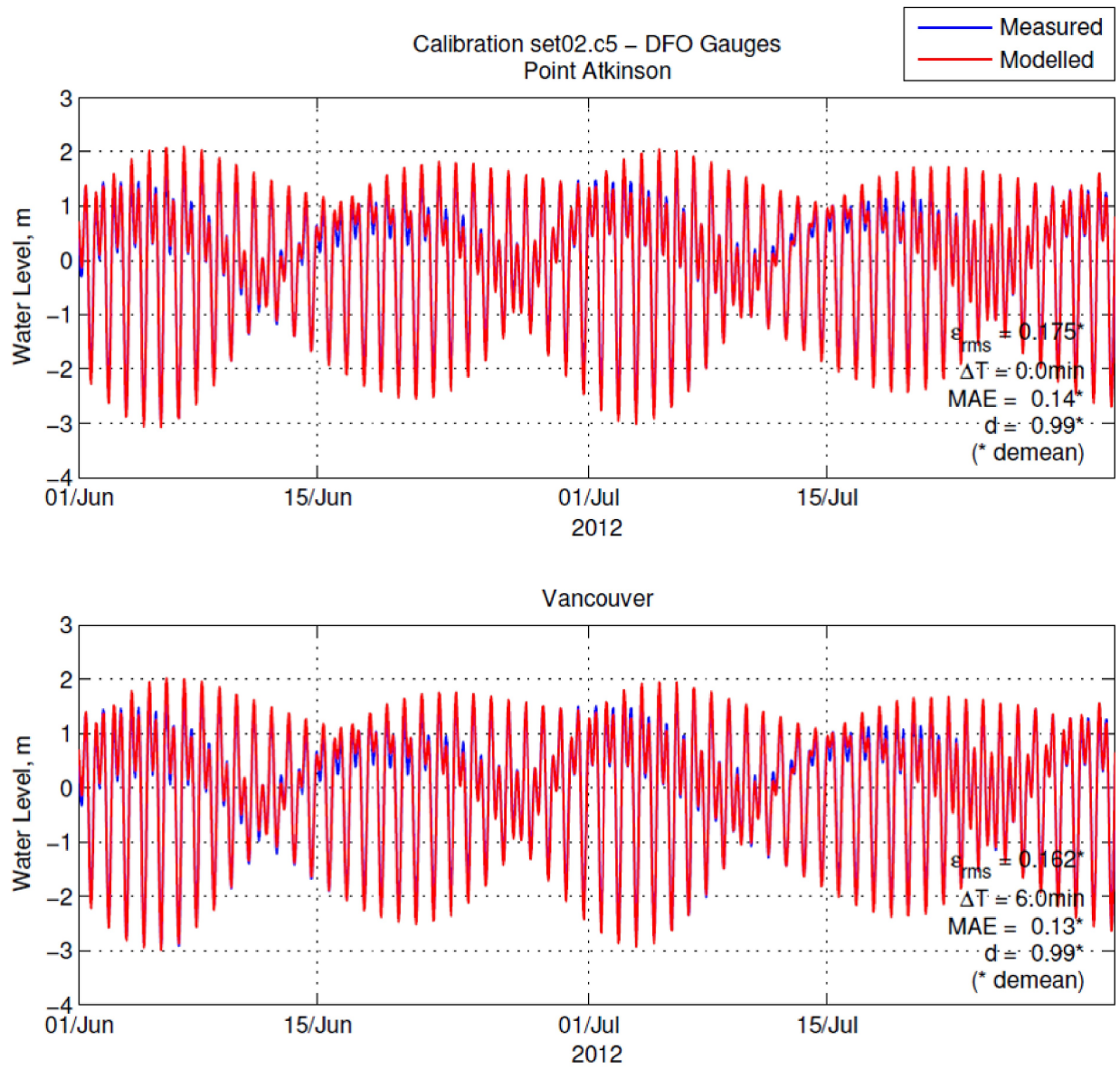


FIGURE 4-9: MEASURED VS MODELLED WATER LEVELS AT DFO TIDE GAUGES

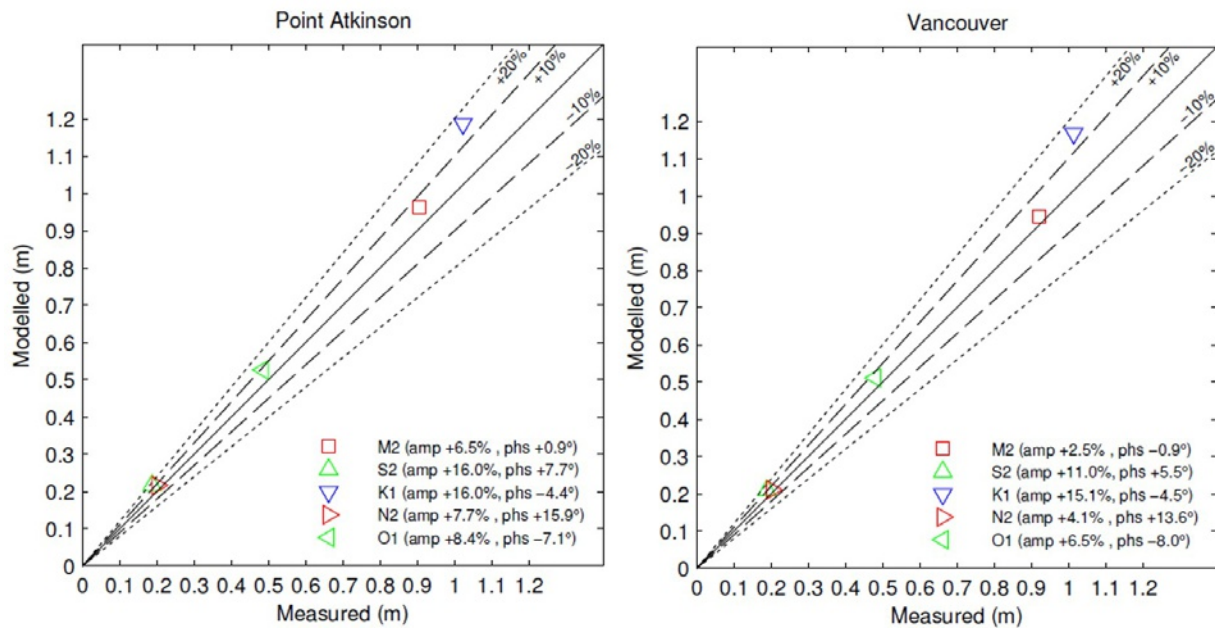


FIGURE 4-10: MEASURED VS MODELLED TIDAL CONSTITUENTS AT DFO TIDE GAUGES

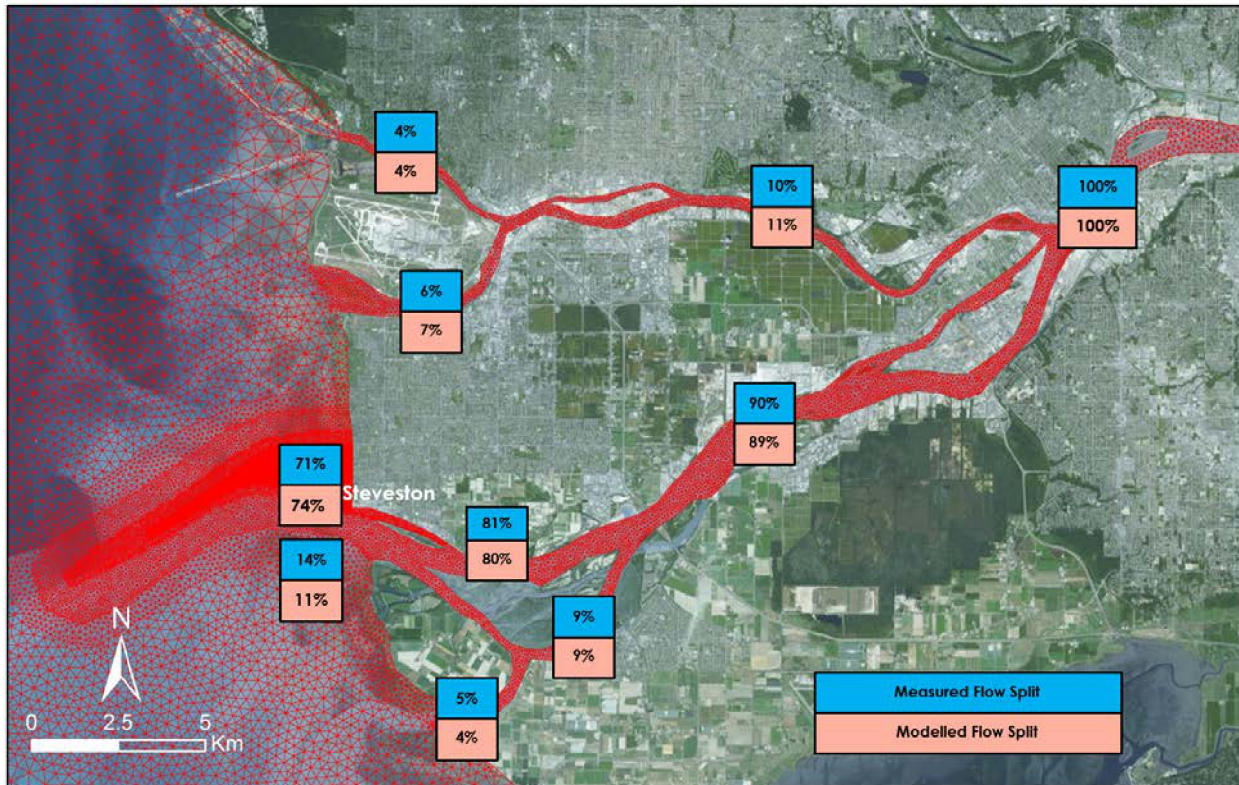


FIGURE 4-11: MEASURED VS MODELLED FLOW SPLIT

5. Design Criteria for Onsite Habitat Features

Onsite Offset Features for the RBT2 project include intertidal marsh, subtidal eelgrass, and rock berms. This section describes the design criteria that apply to these. This includes a description of the physical and biological design criteria as well as applicable engineering standards.

Horizontal datum is NAD83 UTM Zone 10N. The vertical datum is Canadian Hydrographic Service (CHS) Chart Datum (CD). All drawings are presented in SI (metric) units.

The following guidelines, codes, and standards are applicable:

- British Columbia Building Code 2018 (BCBC'18); and
- Coastal Engineering Manual (CEM, US Army Corps of Engineers, 2002).

5.1. Peak Tidal Currents

Sediment mobilized by waves and tidal currents may either bury plants, expose roots and rhizomes or during heavy storms even uproot entire plants. Moderate current speeds tend to enhance eelgrass growth. The maximum current that eelgrass can withstand depends to some extent on the sediment type. The optimal range for eelgrass reported in the literature varies considerably, a conservative range would be 2 to 120 cm s⁻¹. The habitat is usually patchy (sub-optimal) at the higher velocities.

A recent study using a flume determined that the critical orbital velocity threshold for eelgrass growing in sand was 12 cm s⁻¹ and in mud 4 cm s⁻¹, greater velocities resulted in increased sediment resuspension and therefore increased turbidity reducing the amount of photosynthetically active radiation (PAR) that reaches the plants. The roots and rhizomes of eelgrass growing in mud started to be uprooted around 15 cm s⁻¹, while the eelgrass growing in sand could withstand that velocity. Eelgrass establishes best on a fairly level seabed, it would be best to minimize any slopes (Durance C., 2014).

The MIKE-21 HD model was used to evaluate the changes to the tidal hydrodynamics due to the incorporation of the proposed intertidal marsh and eelgrass beds. The pre- and post-project peak current speeds within the existing and proposed intertidal marsh and subtidal eelgrass zones are shown graphically in Figure 5-1 and Figure 5-2. Additionally, Figure 5-3 shows the difference of peak currents between the pre- and post-project conditions. Table 5-1 provides depth-averaged current speeds for both the intertidal marsh and subtidal eelgrass zones.

Result shows that the post-project speeds at the project boundaries are equal or less than the existing values and within the acceptable range to predict bedform impacts. Consequently the construction of the intertidal marsh and eelgrass beds will have negligible impact to the tidal currents in the existing intertidal marsh and eelgrass zones with peak post-project current speeds of approximately 0.4 m/s. At the northwest corner of the RBT2, the area with the highest current speed (ranges 1 – 1.2 m/s) reduces at the post-project phase and still remains within the acceptable range defined for optimal eelgrass/marsh zone maximum current speed.

The overall evaluation indicates that post project current speeds are equal or less than pre-project values and construction of the new plan meet all the requirements and design criteria.

TABLE 5-1: DEPTH-AVERAGED CURRENT SPEED FOR EXISTING AND PROPOSED CONDITIONS

Description	Tidal Currents			
	Existing		Proposed	
	Intertidal Marsh	Eelgrass	Intertidal Marsh	Eelgrass
Current Speed Range (m/s)	Below 0.4	0.4 – 0.6	Below 0.1	Below 0.4

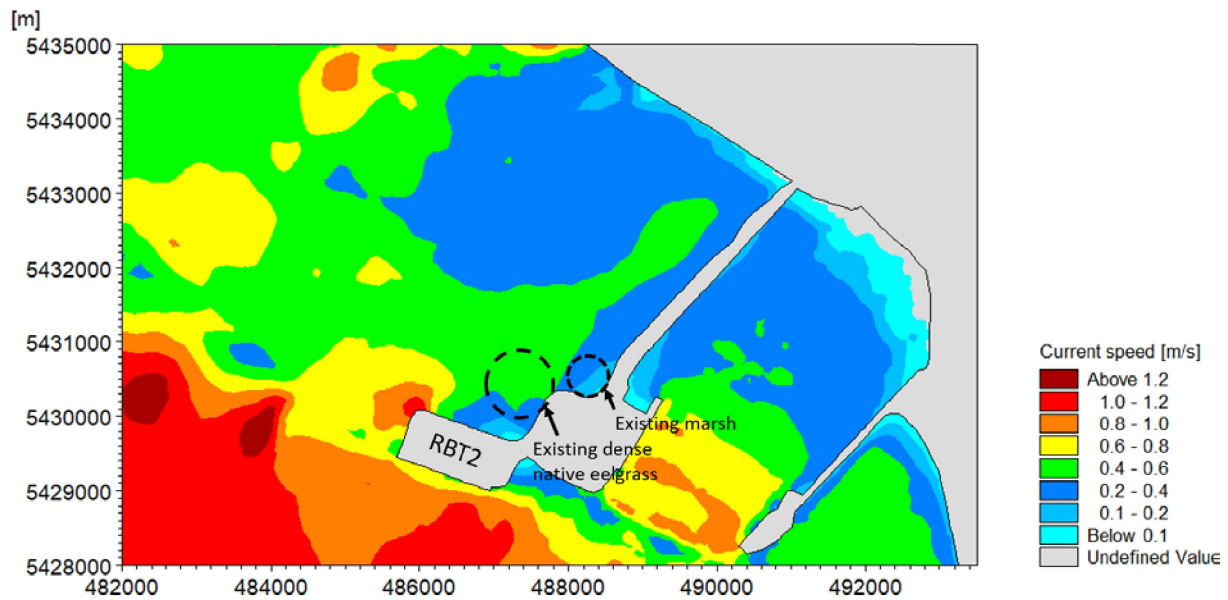


FIGURE 5-1: PRE-PROJECT PEAK CURRENTS

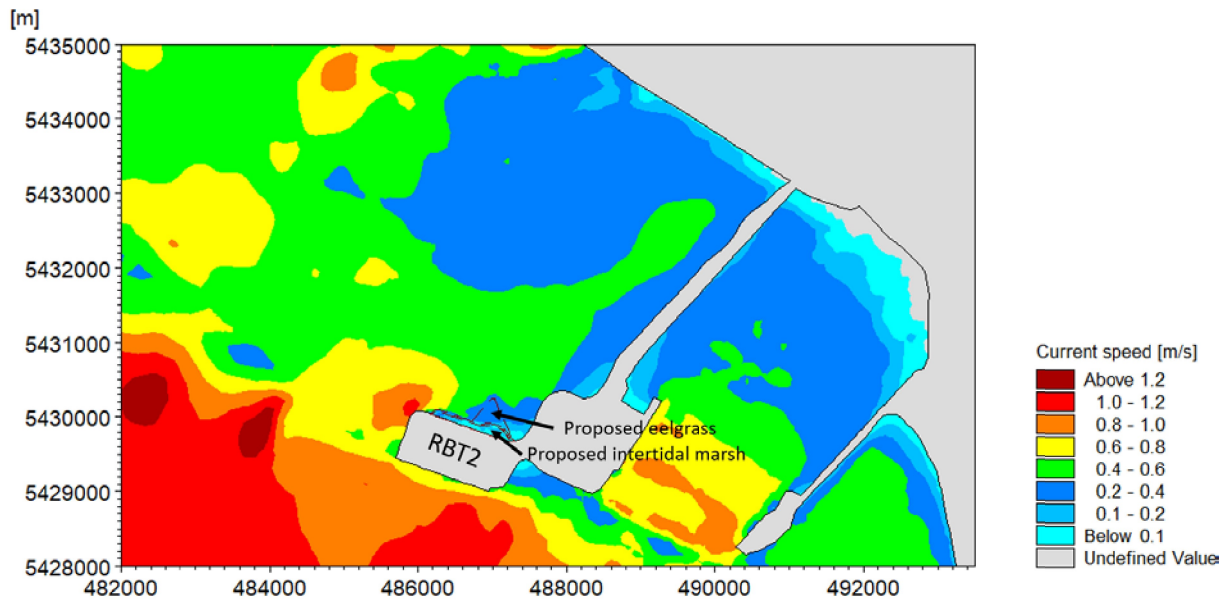


FIGURE 5-2: POST-PROJECT PEAK CURRENTS

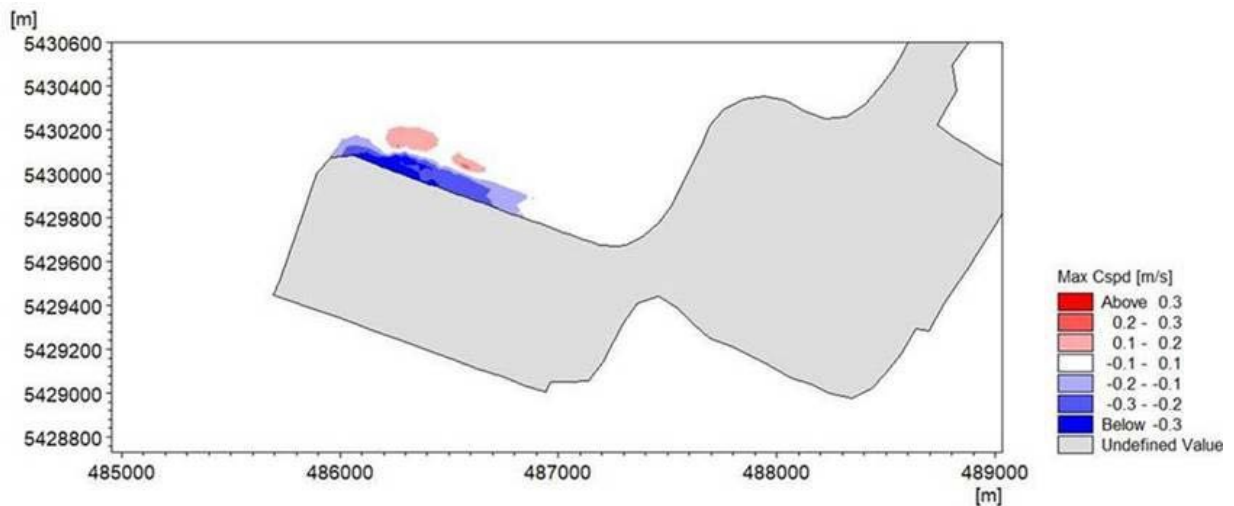


FIGURE 5-3: DIFFERENCE OF PEAK CURRENTS BETWEEN PRE- AND POST-PROJECT CONDITIONS

5.2. Permissible Bed Shear Stress

Stantec (2016a, b) conducted an exploratory investigation of soil properties and performed laboratory tests on samples collected from borings.

Per the Unified Soil Classification System (USCS), Table 5-2, surficial sediments at the project site classify as poorly graded sand (SP), poorly graded sand with silt (SP-SM), and silty sand (SM), generally described as poorly graded sand with fines (silt), interbedded by layers of silt (Stantec, 2016a). From west to east, the content of fines in the sand ranges from 5 to 15% (silt

content), increasing to 15-30%. About 5 metres below the surface, transitioning to grey, sandy silt (ML) with an overall fines content of 65% (Stantec 2016b).

TABLE 5-2: UNIFIED SOIL CLASSIFICATION SYSTEM (ABBREVIATED)

Classification		ID	Description
Gravels	Clean	GW	Well graded gravels
		GP	Poorly graded gravels
	With Fines	GM	Silty gravels
		GC	Clayey gravels
Sands	Clean	SW	Well graded sands
		SP	Poorly graded sands
	With Fines	SM	Silty sands
		SC	Clayey sands
Silts and Clays LL 50% or less		ML	Inorganic silts
		CL	inorganic clays
		OL	Organic silts or clays
Silts and Clays LL greater than 50%		MH	Inorganic silts
		CH	inorganic clays
		OH	Organic silts or clays
Highly Organic Soils		Pt	Peat

In the following, information is provided on the permissible shear stress for material types such as those existing and planned for the site.

Table 5-3 summarizes typical permissible shear stresses for materials in the range from non-cohesive to cohesive material. Shear stress is defined as the force per unit area (expressed in N/m²) applied parallel to the surface of a material.

Permissible shear stress for non-cohesive material depends on the submerged weight of the material relative to the tractive force. The submerged weight is commonly described by a characteristic material grain size. The angularity of the material also affects its stability, but to a lesser degree when the material is placed horizontally or near-horizontally.

The grain sizes of cohesive materials are typically so small that the diameter does not affect the stability of the materials. The permissible shear stress for cohesive materials is therefore more complex and depends primarily on the plasticity index (PI) of the material, the void ratio, and to a lesser extent the angularity of the grains.

The plasticity index (PI) of materials obtained from surficial soil samples ranged from about 7 to 9, Stantec (2016a). Based on this the permissible shear stress is estimated to be around 2.5 to 3.0 N/m².

TABLE 5-3: TYPICAL PERMISSIBLE SHEAR STRESS, REPRODUCED FROM FHWA (2005)

Material Category	Material Type	Permissible Shear Stress (N/m ²)
Bare Soil (PI = 10)	Clayey sands	1.8 to 4.5
	Inorganic silts	1.1 to 4.0
	Silty sands	1.1 to 3.4
Bare Soil Cohesive (PI ≥ 20)	Clayey sands	4.5
	Inorganic silts	4.0
	Silty sands	3.5
	Inorganic sands	6.6
Bare Soil Non-cohesive (PI < 10)	Finer than coarse sand d ₇₅ < 1.3 mm	1.0
	Fine gravel d ₇₅ = 7.5 mm	5.6
	Gravel d ₇₅ = 15 mm	11.0
Gravel	Coarse gravel d ₅₀ = 25 mm	19.0
	Very coarse gravel d ₅₀ = 50 mm	38.0
Rock riprap	d ₅₀ = 0.15 m	113.0
	d ₅₀ = 0.30 m	227.0

By coupling the calibrated HD and SW model, tidal-induced and storm wave-induced bed shear stress at each model grid were combined to represent a normalized annual condition. Figure 5-4 illustrates the maximum pre-project bed shear stress, as well as the approximate outline of existing dense eelgrass or marsh beds (dark green line). Result indicates that although the majority of the existing dense eelgrass or marsh beds fall in the bed shear stress less than 1 N/m² (light blue color), the upper-end threshold can be near 2.5-3 N/m² as some local spots can see eelgrass growth up to this zone, e.g. areas near Canoe Pass and the Delta Port entrance. Figure 5-5 investigates the maximum bed shear stress after the onsite marshes are created. Result indicates that the entire onsite marshes area falls in the zone with bed shear stress less than 1 N/m². In addition, there are very minor (nearly non-noticeable) changes from the pre-project condition.

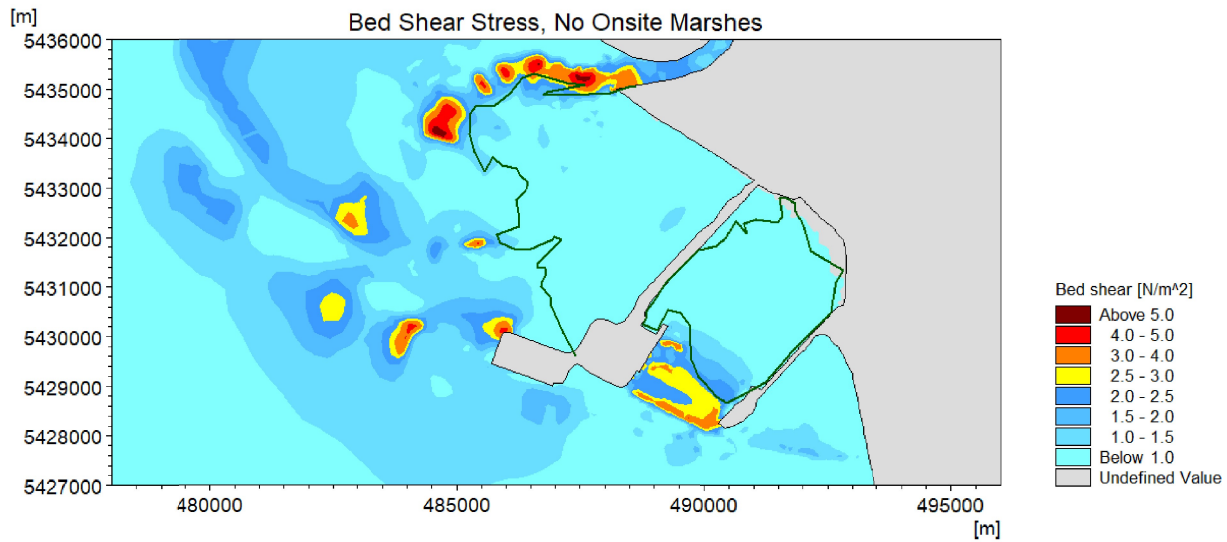


FIGURE 5-4: PRE-PROJECT BED SHEAR STRESS

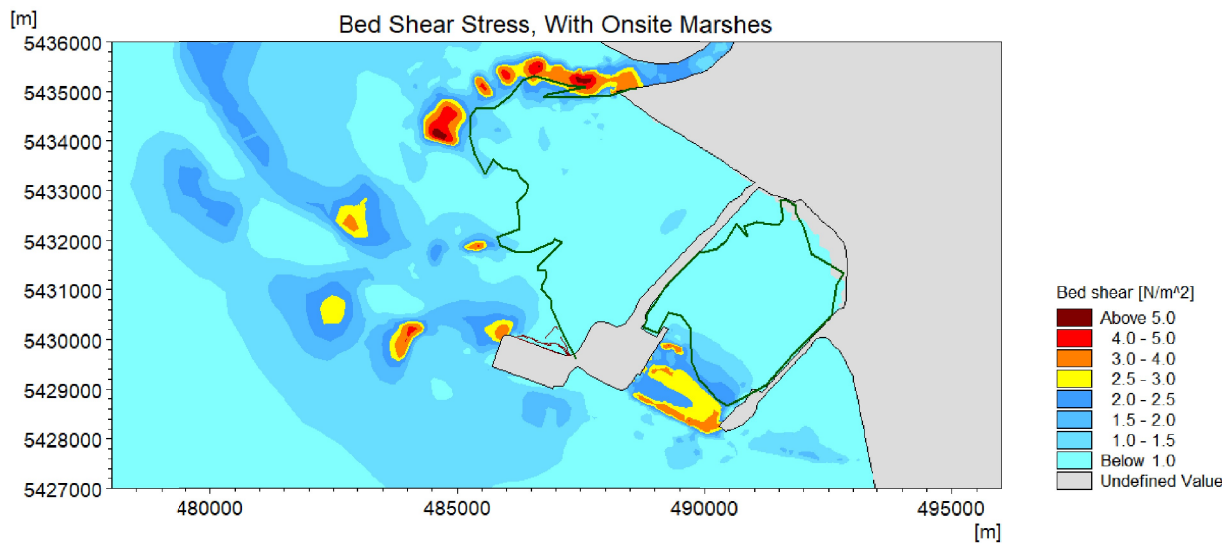


FIGURE 5-5: POST-PROJECT BED SHEAR STRESS

5.3. Biological Design Criteria

5.3.1. Eelgrass Salinity Range

The optimal salinity range for eelgrass is 10-30 ppt. Although it can tolerate short periods of 0 ppt. without any reduction in growth. Figure 5-6 and Figure 5-7 indicates salinity values for the project location based on high slack and ebb tides respectively (RBT2 EIS Appendix 9.5-A). Table 5-4 shows the estimated salinity ranges for existing and proposed conditions extracted from the figures and based on both high slack and ebb tides.

TABLE 5-4: SALINITY RANGES FOR EXISTING AND PROPOSED EELGRASS ZONES

Description	Eelgrass Zone	
	Existing	Proposed
Salinity Range (ppt)	22.5 - 30	10.5 - 30

Based on the ranges obtained from the below figures and per Table 5-4 it is concluded that the salinity levels remain within the optimal range for the proposed eelgrass area.

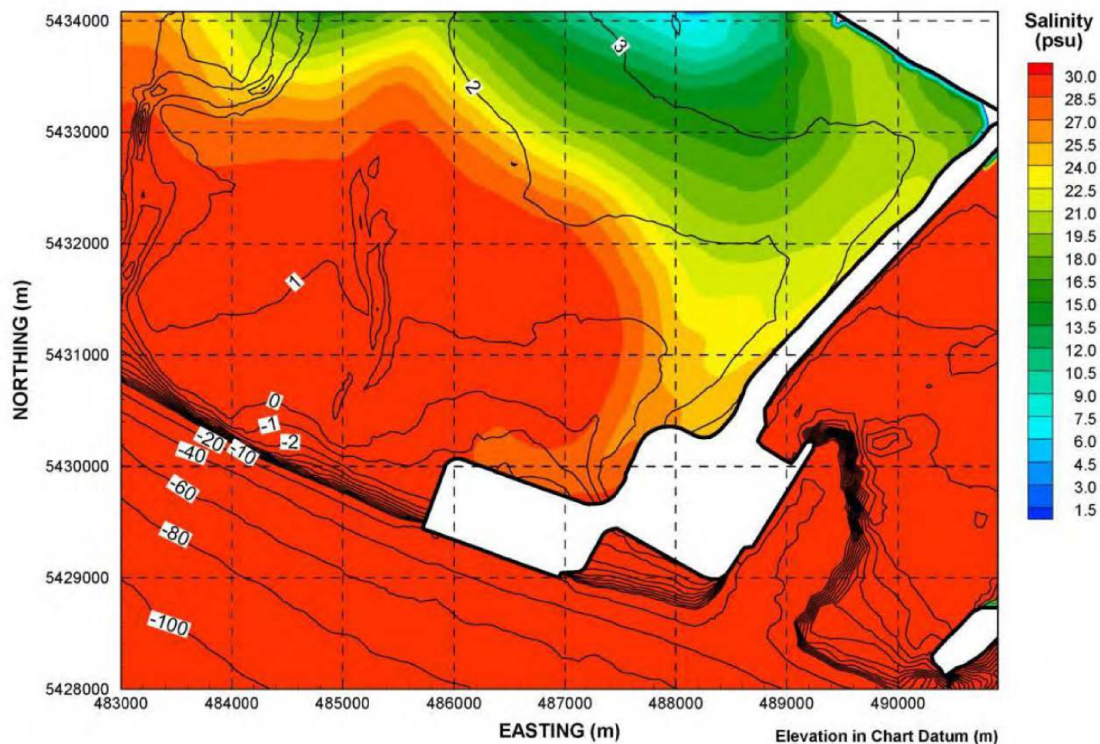


FIGURE 5-6: SALINITIES ASSOCIATED WITH A HIGH SLACK TIDE

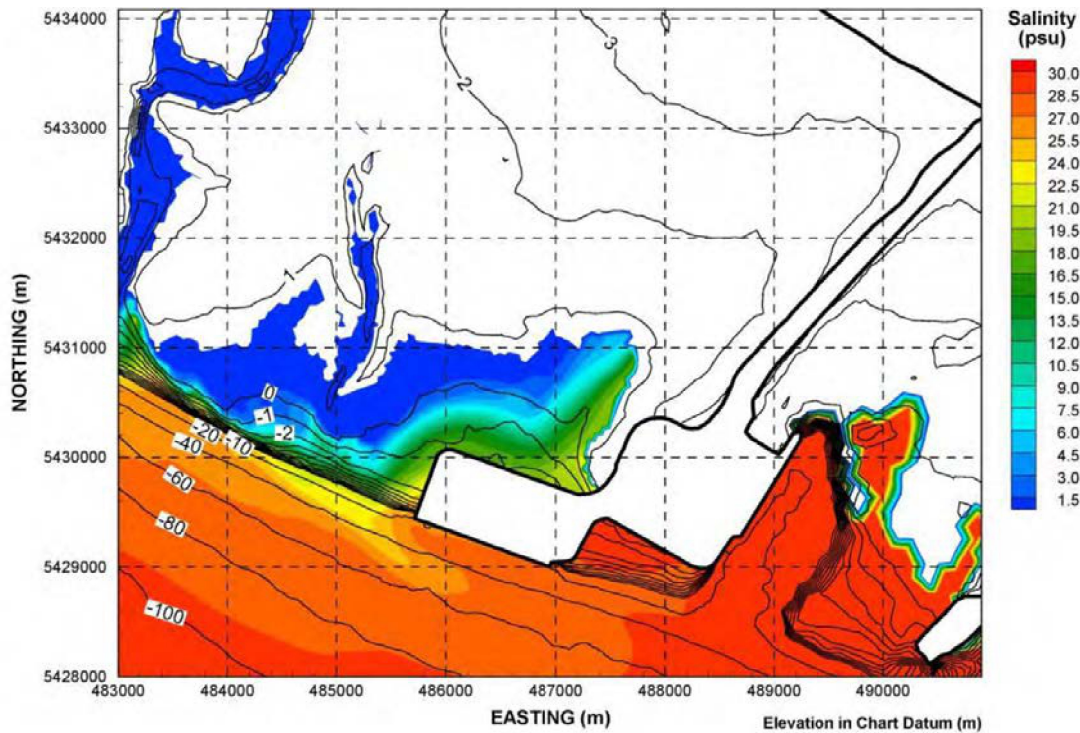


FIGURE 5-7: SALINITIES ASSOCIATED WITH AN EBB TIDE

5.3.2. Intertidal Marsh Salinity Range

Intertidal marsh habitat is characterized by emergent vascular plants that exist in the elevation range of +3.2 to +4.8 m CD that is regularly covered during high tides. At Roberts Bank, typical species of intertidal marsh habitats include sedges such as *Carex lyngbyei* and *Schoenoplectus pungens*, saltgrass species, e.g. *Distichlis spicata*, and succulents including *Sarcocornia pacifica* (Hemmera 2014). The salinity tolerance of marsh vegetation ranges between 18 to 30 ppt (GLW, 2017).

Table 5-5 shows that salinity levels at the existing tidal marsh area (northwest of delta port) are about 25 ppt. The salinity range estimated for the proposed intertidal marsh zone along the northern side of RBT2 is within the optimal range.

TABLE 5-5: SALINTY RANGES FOR EXISTING AND PROPOSED TIDAL MARSH ZONES

Description	Marsh Zone	
	Existing	Proposed
Salinity Range (ppt)	24 - 25.5	18 – 25.5

The intertidal marsh can be created on raised areas adjacent to the terminal and causeway at elevations between +3.0 m chart datum (CD) and +5.0 m CD (EIS Appendix 17-B, Drawing 17-B1), where wave energy is dissipated in the high intertidal (supralittoral) zone.

Table 5-6 summarizes elevation and salinity tolerance ranges of dominant low and high intertidal marsh species measured on Roberts Bank.

TABLE 5-6: PROJECT AND REGIONAL MARSH HABITAT SALINITY TOLERANCE

Plant Species	Salinity Range (PPT)
Seacoast Bulrush	2 – 20
Lyngbye’s Sedge	0 – 15
Saltgrass	4 – 35
Baltic Rush	2 – 15
Pacific Silverweed	0 – 15
Pickleweed	18 – 35
Three-Square Bulrush	0 – 20
Softstem Bulrush	0 – 11
Arrowgrass	0 – 30

References:

- 1) GLW (2009)
- 2) GLW (2017a)

5.3.3. Intertidal Marsh Elevation Range

Table 5-7 summarizes elevation ranges of dominant low and high intertidal marsh species on Roberts Bank identified in field surveys.

Blank cells indicate that the respective species was not observed at the indicated location, or elevation data was not collected.

TABLE 5-7: PROJECT AND REGIONAL MARSH HABITAT ELEVATION RANGES

Plant Species	Elevation Range (m CD)		
	Roberts Bank ¹	DeltaPort Causeway ¹	Steveston Jetty South Arm ²
Seacoast Bulrush	3.0 – 3.8	3.4 – 4.0	3.0 – 3.2
Lyngbye’s Sedge	3.1 – 4.2		3.1 – 3.9
Saltgrass	3.8 – 5.0	3.8 – 5.0	
Baltic Rush	3.0 – 3.4		3.2 – 4.0
Pacific Silverweed	3.0 – 4.2		
Pickleweed	3.6 – 4.5	3.6 – 4.7	
Three-Square Bulrush	2.6 – 3.8	3.2 – 3.9	2.8 – 3.3
Softstem Bulrush	3.1 – 4.3		
Arrowgrass	3.6 – 4.0	3.6 – 4.0	

References:

- 1) GLW (2009)
- 2) GLW (2017a)

5.3.4. Intertidal Marsh Wave Tolerance

Douglass et al. (2004) have studied the tolerance of marsh vegetation with respect to wave exposure.

Figure 5-8 summarizes the applicable guidance. The green lines in the figure indicate significant wave height limits permitting marsh vegetation to propagate. The blue lines indicate wave heights at which wetland vegetation will be subject to erosion. The red lines indicate the wave threshold above which wetland species are unable to grow.

The studies by Douglass et al. (2004) found that the upper limit of wave energy for existence of salt marsh could be quantified as:

- Median (H_{50}) $H = 0.13$ m
- Corresponding $H_{80} = 0.25$ m

Sites with less wave energy were observed to have vegetation along the shoreline, while sites exposed to larger wave heights were unable to support marsh habitat.

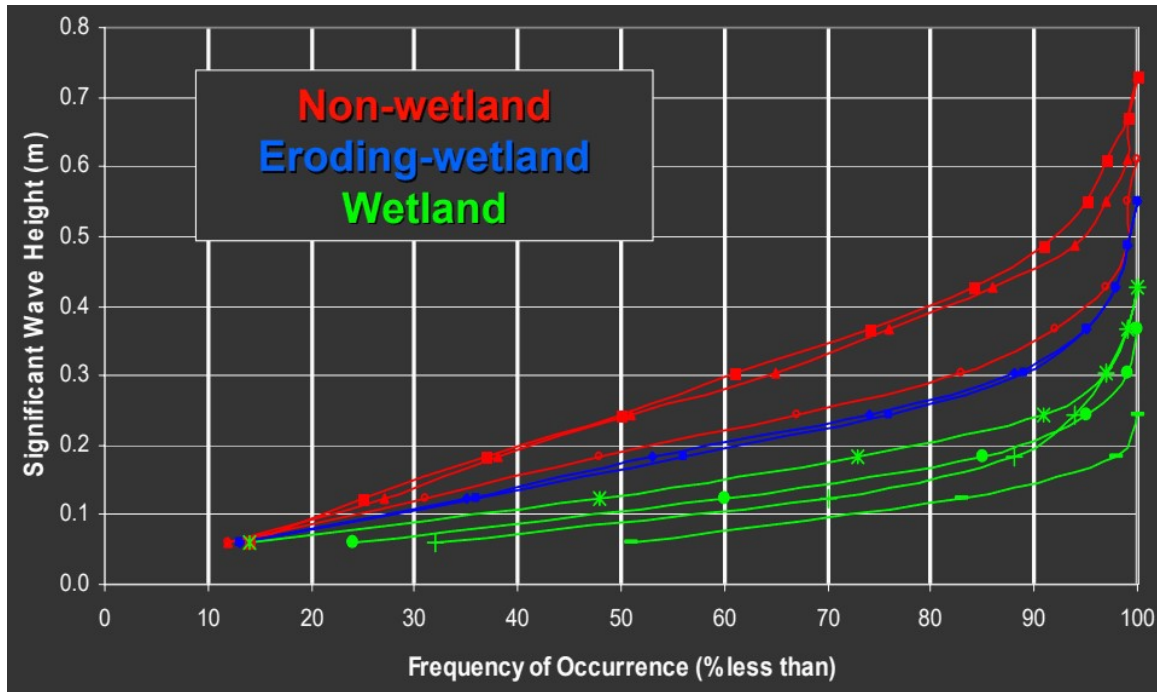


FIGURE 5-8: WAVE HEIGHT TOLERANCE FOR MARSH SPECIES, DOUGLASS (2004).

5.3.5. Rock Berm Stone Size

The median stone mass for a stable riprap distribution can be determined using the Hudson equation (CEM, 2011):

$$M_{50} = \frac{\rho_s \times H^3}{K_D \times \left(\frac{\rho_s}{\rho_w} - 1\right)^3 \times \cot \alpha} \quad 5-1$$

Where:

- H Characteristic wave height (H_s)
- M_{50} Median mass of stone armor unit
- ρ_s Mass density of stone
- ρ_w Mass density of water
- K_D Stability coefficient
- α Slope angle

Based on the equation 5-1, median stone mass would be equal to 740 kg.

Table 5-8 demonstrates the gradation of rock sizes in each class of riprap. To meet the minimum requirements, class of 1000 kg is selected for design purposes.

TABLE 5-8: GRADATION OF ROCK SIZES IN EACH CLASS OF RIPRAP

CLASS OF RIPRAP (kg)	*NOMINAL THICKNESS OF RIPRAP (mm)	ROCK GRADATION PERCENTAGE SMALLER THAN GIVEN ROCK MASS (kg)		
		15%	50%	85%
10	350	1	10	30
25	450	2.5	25	75
50	550	5	50	150
100	700	10	100	300
250	1000	25	250	750
500	1200	50	500	1500
1000	1500	100	1000	3000
2000	2000	200	2000	6000
4000	2500	400	4000	12000

* The thickness of riprap, measured at right angles to the slope, for the class specified, shall be the nominal thickness stated, unless otherwise shown on the Drawings or required by the Ministry Representative.

5.3.6. Rock Berm Crest Elevation

Wave action behind a rock structure can be caused by wave overtopping and wave penetration if the structure is permeable. The wave transmission can be characterized by a transmission coefficient, C_t , defined as the ratio of transmitted to incident characteristic wave heights. The transmission coefficient is defined by equation 5-2 as follows:

$$C_t = \frac{H_{st}}{H_s} \quad 5-2$$

Where:

H_{st} Transmitted characteristic wave height

H_s Incident characteristic wave height

Based on Table 3-3 and Table 3-4, the maximum 1-year return period wind speed from northwest-west (NW-W) direction and maximum wave height is equal to 36 knots and 1 m respectively. For design purposes, the maximum transmitted wave for intertidal marsh zone is selected to be 0.1 m. Therefore, the transmission coefficient (C_t) equals 0.1.

Equation 5-3 indicates the wave transmission formula by van der Meer et al. (1991) for rock armored low-crested, and submerged structures, which accounts for the crest width of structure.

$$C_t = \left(0.031 \times \frac{H_s}{D_{n50}} - 0.24 \right) \times \frac{R_c}{D_{n50}} + b \quad 5-3$$

Where:

- H_s Significant wave height of incident waves
- D_{n50} Median of nominal diameter of rocks for design condition
- R_c Freeboard, negative for submerged structure
- b Constant based on crest width

Based on equation 5-3 and a crest width of 5 m, the required freeboard above HHW-MT taken as an average of mean high tides is $R_c = 1.1$ m, which corresponds to a crest elevation of the rock berm of about +5.2 m CD (Figure 5-9).

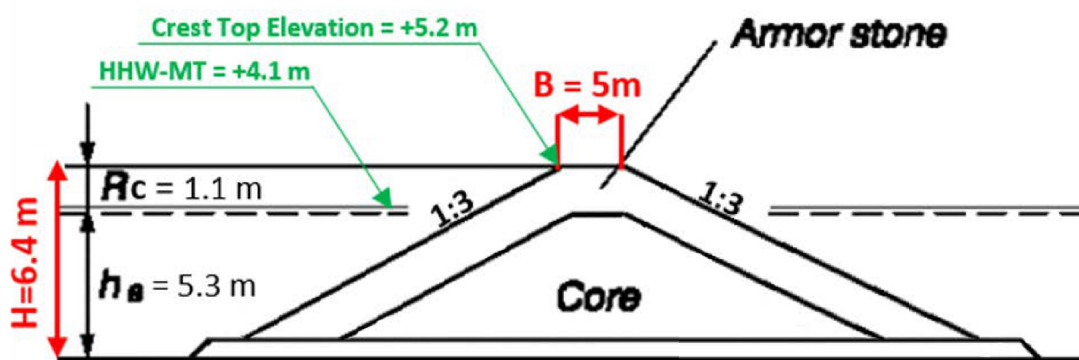


FIGURE 5-9: ROCK BERM CREST ELEVATION AND DETAILS (VAN DER MEER-1991)

5.3.7. Marsh Channel Dimensions

To provide channel characteristics and dimensions within a tidally dominated coastal landscape, Hughes (2002) and other studies suggest the existence of a relationship between cross-sectional area and tidal prism for tidal channels. Their approach reasonably fits a wide range of channels and inlets. The findings from Hughes (2002) was augmented with data for local mudflat and marsh channels on Sturgeon Bank and Roberts Bank. Data for tidal prism, channel width, channel depth, and cross-sectional area was collected for existing marsh channels and channels on the mudflat. Figure 5-10 presents the observed relationship where green circles are representative of marsh channels and orange circles representative of channels on the mudflats.

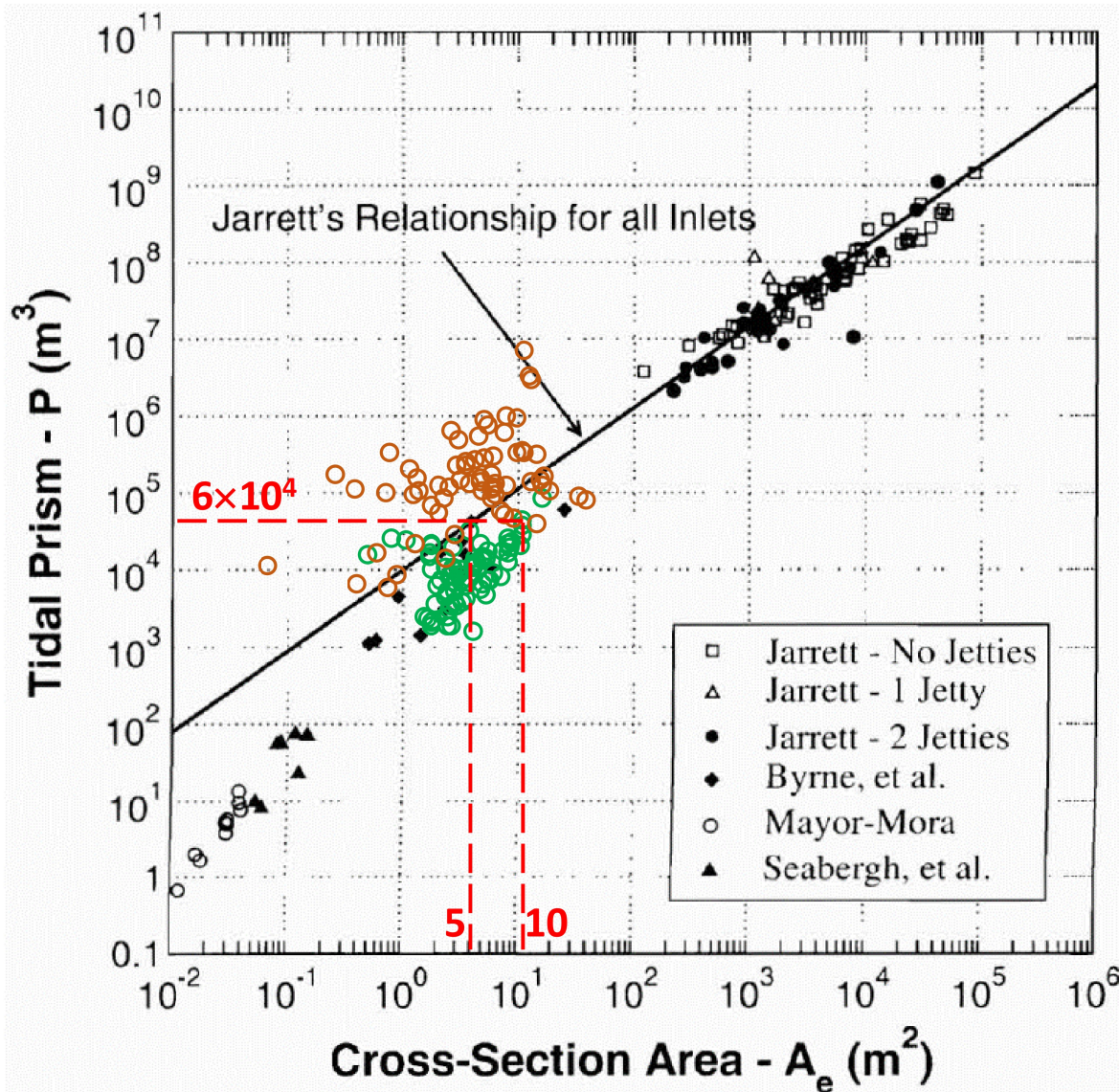


FIGURE 5-10: EQUILIBRIUM CROSS-SECTION AREA VERSUS TIDAL PRISM DATA

The plan areas of the intertidal marsh zone and rock berm are about 76,000 m² and 44,000 m² respectively (120,000 m² in total). Based on Table 3-1, HHW-MT equals to 4.1 m (CD) and LLW-MT is about 1.2 m (CD). Since the suggested marsh vegetation is located at around elevation 3.6 m (CD), the maximum water volume needed to route through the channel is approximately 6×10⁴ m³. Using the relationship, an equilibrium cross-sectional area during peak discharge is estimated around 5 m² if using Jarrett's relationship and about 10 m² based on the local marsh channel data. In addition, based on the simulation modeling results, the maximum discharge for the channel out of intertidal marsh zone is approximately 12 m³/s. Based on Friedrichs (1995), the relationship between cross-sectional area and peak discharge for tidal channels is shown in Figure 5-11. It confirms the finding from previous method about the optimal cross-sectional area for the channel is about 10 m² based on Friedrichs relationship.

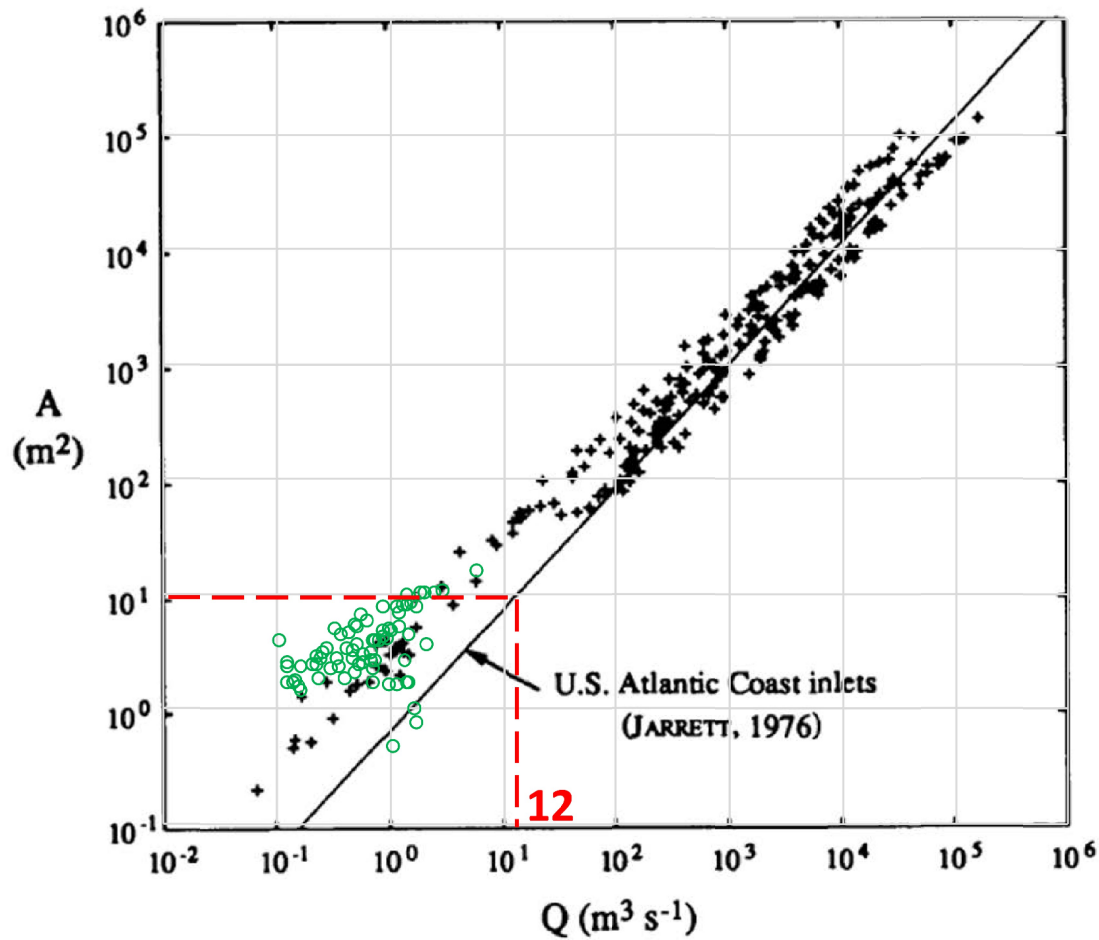


FIGURE 5-11: CROSS-SECTIONAL AREA VS. PEAK DISCHARGE FOR SHELTERED TIDAL CHANNELS (FRIEDRICHS,1995)

While there is great variability within tide-dominated systems, the channel width-to-depth ratio can be split into two discrete groups of tidal channels, namely marsh channels and channels on mudflats (Hughes, 2011). Adopting this concept, aerial photographs and LiDAR survey were used to estimate the width-to-depth ratios for marsh channels and mudflat channels on Sturgeon Bank and Roberts Bank. The data is shown in Figure 5-12, where the green circles represent marsh channel dimensions and the orange circles are representative of channels on the mudflats. The marsh channel data correlates well with Hughes (2011) data in the figure. The suggested range of the proposed marsh channel geometry is indicated by the dashed red lines in the figure. The suggested range is from a 5 m wide and 0.7 m deep channel to a 10 m wide and 1.4 m deep channel.

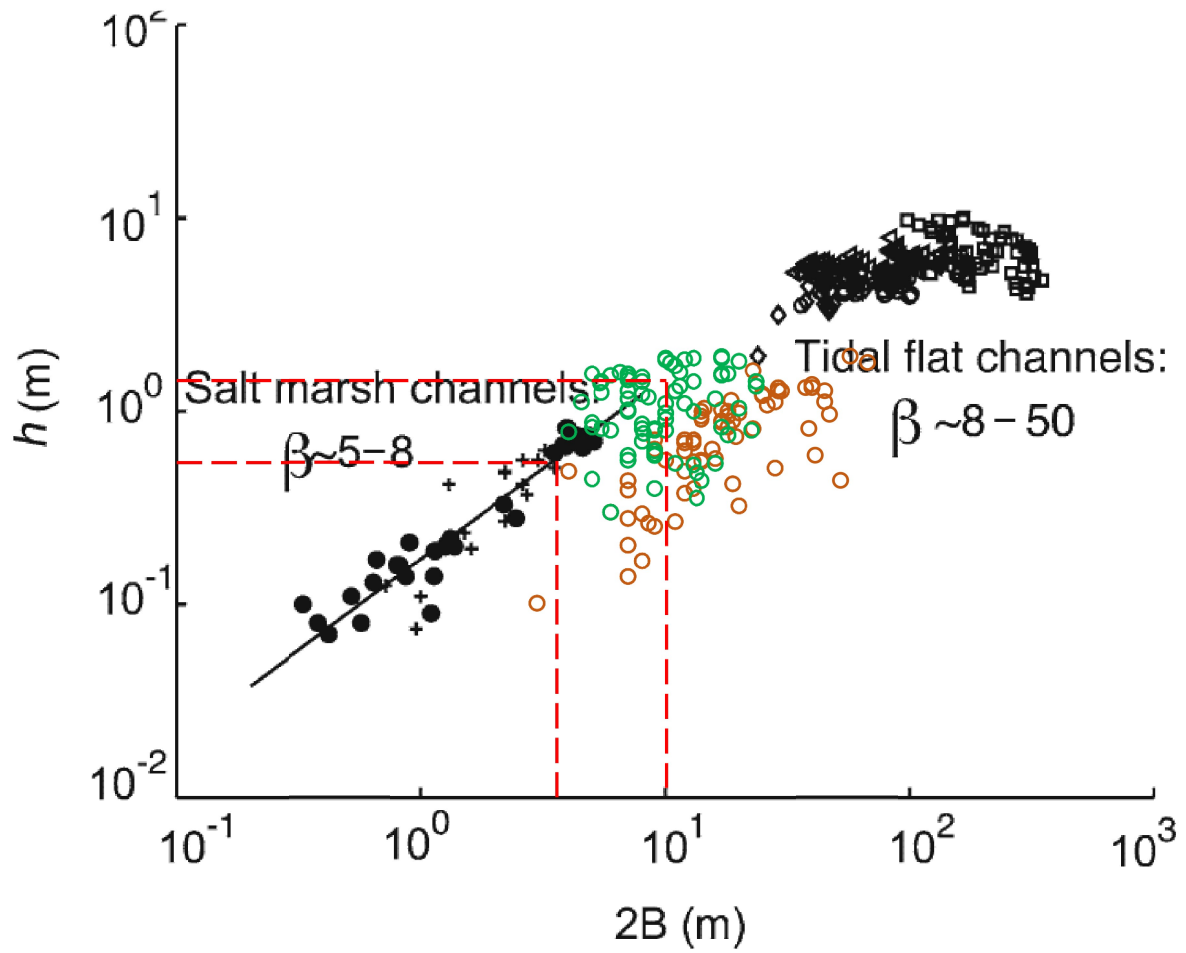


FIGURE 5-12: WIDTH-TO-DEPTH RATIO FOR TIDAL CHANNELS (ADOPTED FROM HUGHES 2011)

6. Conclusions

Overall evaluation from the analyses conducted for this report indicates that:

- Post-project current speeds around the peripheral boundaries and RBT2 project areas are equal to or less than pre-project values.
- The proposed marsh and eelgrass habitat meets the outline design criteria.
- The salinity range in the area proposed for new eelgrass plantings is within the optimal range for eelgrass.
- The salinity range estimated for the proposed intertidal marsh zone along the northern side of RBT2 is within the optimal range for select salt-tolerant species.
- Based on the salinity tolerance parameters; Saltgrass, pickleweed, and Arrowgrass species may be candidate marsh vegetation for the onsite marsh habitat. The preferred elevation range for these species is 3.6 to 5.0 m CD.
- The freeboard of the rock berm is estimated to be 1.1 m above Higher High Water-Mean Tide (HHW-MT). This corresponds to a crest elevation of about +5.2 m CD.
- The suggested marsh channel dimensions range from a 5 m wide and 0.7 m deep channel to a 10 m wide and 1.4 m deep channel.

7. References

BIEAP-FREMP (2006). Environmental Management Strategy for Dredging in the Fraser River Estuary. Burrard Inlet Environmental Action Program (BIEAP) and Fraser River Estuary Management Program (FREMP).

BC Ministry of Environment (BC MOE, 2007), Lower Mainland Region Dyke Mapping. 2007.

Canadian Hydrographic Services (2005). Charts #3492.

CBA (2010). Roberts Bank and Sturgeon Bank Reach Overview – Phase 2. A report for BIEAP-FREMP.

CEM (2011). U.S. Army Corps of Engineers, Engineering and Design “Coastal Engineering Manual”.

DHI (2008). MIKE C-Map. User Guide.

Durance, C. (2014). Eelgrass Habitat Creation in British Columbia. A Presentation to Port Metro Vancouver. October 1, 2014.

Egbert, G. F. and Erofeeva, L. (2010). OSU Tidal Inversion. <http://volkov.oce.orst.edu/tides/global>.

Friedrichs, C.T., 1995. Stability Shear Stress and Equilibrium Cross-Sectional Geometry of Sheltered Tidal Channels. *Journal of Coastal Research* (11), p1062-1074.

FHWA (2005). *Design of Roadside Channels with Flexible Linings*. Hydraulic Engineering Circular No. 15, Third Edition. Publication No. FHWA-NHI-05-114. U.S. Department of Transportation, Federal Highway Administration. National Highway Institute. September 2005.

GLW (2009). *Roberts Bank and Sturgeon Bank Reach Overview. Backgrounder*. Prepared for Fraser River Estuary Management Program. Prepared by Gary Williams, GL Williams & Associates Ltd., 2907 Silver Lake Place, Coquitlam BC V3C 6A2; and Andre Zimmermann, Derek Ray, Charlene Menezes, Northwest Hydraulic Consultants, 30 Gostick Place, North Vancouver, BC V7M 3G3. October 27, 2009.

GLW (2017). Preliminary determination of planting quantities for South Arm Jetty. Prepared for Moffatt & Nichol. Prepared by Gary Williams, Professional Wetland Scientist. GL Williams & Associates Ltd., Coastal and Estuarine Habitat, 2907 Silver Lake Place, Coquitlam BC V3C 6A2.

Hemmera Environchem Inc. (2014). Roberts Banks Terminal 2, Technical Data Report, Marine Vegetation.

Hemmera Environchem Inc. (2015a). Existing Ecological Conditions Proposed Tsawwassen Eelgrass Enhancement Project.

Hemmera Environchem Inc. (2015b). Tsawwassen Eelgrass Enhancement Project Source Sediment Characterization.

Hughes, Z.J., 2011. Chapter 11: Tidal Channels on Tidal Flats and Marshes, Principles of Tidal Sedimentology. Editors: Davis Jr., R.A. and Dalrymple, R.W. Publisher: Springer Netherlands.

Jacques Whitford-Axys (2007). Vancouver Island Transmission Reinforcement Project; Application for Navigable Waters Act Authorization for Habitat Compensation Works on Roberts Bank, Tsawwassen, BC.

Jacques Whitford-Axys (2007). Vancouver Island Transmission Reinforcement Project; Fish Habitat Compensation Plan, Tsawwassen, BC.

Moffatt & Nichol (2012). Memorandum on Updated Hydrodynamic Model of Roberts Bank, prepared for Hemmera Environchem Inc. Reference Job No. 7627-22. Dated March 16, 2012.

Moffatt & Nichol (2020). Proposed Eelgrass at Elev -1 W/ Temp. Access Road & Intertidal Ranges. Dated February 26, 2020.

North Hydraulic Consultants (2006). Lower Fraser River Hydraulic Model: Recorded Flow Splits. Drawing Prepared for Fraser Basin Council. North Vancouver, BC.

Precision Identification (2013). Assessment of Potential Eelgrass Transplant Sites, prepared for Port Metro Vancouver. Tsawwassen, Delta. April 2013.

Stantec (2013). Sturgeon and Roberts Bank LiDAR July 2013. Data file Prepared for Port of Vancouver.

Stantec (2016a). *Borehole Record*. Project: Roberts Bank Terminal 2. Prepared for: Port of Vancouver. Prepared by: Stantec. Dates of Borings: 2016/08/25 to 2016/08/30.

Stantec (2016b). *Profile B-B' – Fines Content*. Container Capacity Improvement Program, Roberts Bank Terminal 2. Proposed Terminal Expansion. Dwg. 34-347-GT-0304, sheet 1 of 1, Rev. A. Scale 1:2500H, 1:500V. Date: 12/02/16.

Appendix IR2020-1.1-A2
Roberts Bank Terminal 2 Onsite Habitat
Offsetting Design Report



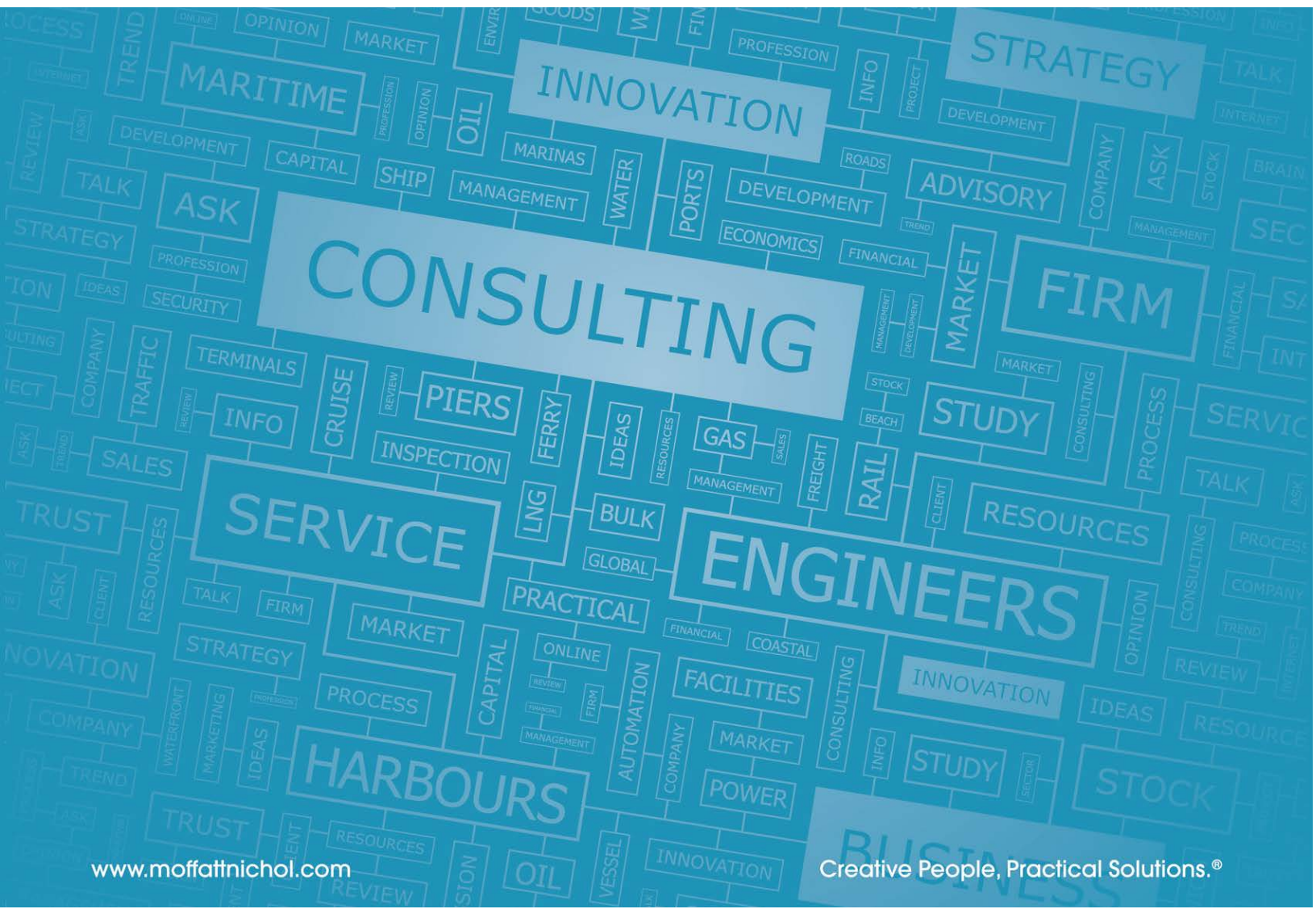
moffatt & nichol

Roberts Bank Terminal 2 Onsite Habitat Offsetting Design Report

PRODUCED FOR



AUGUST 14, 2020



Document Verification

Client	Vancouver Fraser Port Authority
Project name	RBT2 Onsite Habitat Offsetting
Document title	Design Report
Date	August 14, 2020
Project number	9117

Revision	Description	Issued by	Date	Checked
A	Draft	AA/LW	June 24, 2020	MC
B	Issued for Review	AA/LW	August 14, 2020	YN/MC

Produced by:
Moffatt & Nichol, Vancouver
Suite 301 - 777 West Broadway
Vancouver BC V5Z 4J7 Canada
T +1-604-707-9004
www.moffattnichol.com

Table of Contents

Document Verification.....	i
Disclaimer.....	v
1. Introduction.....	1
1.1. Project Site.....	2
2. Coastal Setting.....	3
2.1. Background.....	3
2.2. Fraser River Salinity Data.....	6
2.3. Environmental Conditions.....	9
2.3.1. Water Levels.....	9
2.3.2. Extreme Water Levels.....	10
2.3.3. Winds.....	10
2.3.4. Wind Wave Characteristics - Onsite Marsh.....	12
2.3.5. Currents at the Rock Reef.....	14
2.3.6. Geotechnical Conditions.....	14
3. Design Criteria.....	15
3.1. General Design Criteria.....	15
3.1.1. Project Datum and Units.....	15
3.1.2. Service Life and Return Period.....	15
3.1.3. Codes, Standards and Design Guidelines.....	15
3.1.4. Functional Requirements – Marsh and Eelgrass.....	15
3.1.5. Functional Requirements – Rocky Reef.....	17
3.2. Proposed Marsh and Eelgrass.....	18
3.3. Proposed Rock Reef.....	20
3.4. Design Criteria.....	22
3.4.1. Coastal Design Parameters.....	22
3.4.2. Planting Elevations.....	22
3.4.3. Rocky Reef Elevations.....	22
3.4.4. Spatial Constraints.....	22
3.5. Wave and Hydrodynamic Modeling.....	22
3.5.1. Model Description.....	22
3.5.2. Peak Tidal Currents.....	25
3.5.3. Permissible Bed Shear Stress.....	28
3.5.4. Salinity Modeling, Eelgrass.....	29
3.5.5. Salinity Modeling, Marsh.....	31
3.6. Rock Berm Stone Size.....	32
3.7. Rock Berm Crest Elevation.....	32
3.8. Marsh Channel Dimensions.....	33
4. Construction Details.....	34

4.1. Site Descriptions.....	34
4.2. Construction Features	34
4.2.1. Marsh and Eelgrass.....	34
4.2.2. Rock Reef.....	34
4.3. Site Access.....	34
4.4. Construction Methodology	35
4.5. Construction Schedule.....	36
5. Construction Direct Cost	38
5.1. Cost Considerations	38
5.2. Limitations.....	38
References.....	39
Appendix A: Project Drawings.....	A
Appendix B: Coastal Analysis Report.....	B
Appendix C: Borehole Records	C
Appendix D: Construction Schedule.....	D

List of Figures

Figure 1-1: Roberts Bank Terminal 2 (eelgrass, intertidal marsh, rocky Reef) location	2
Figure 2-1: Fraser River Delta fringe physiography (after Williams et al, 2009).....	3
Figure 2-2: Bathymetry in The Vicinity of the Project (CHS, 2005)	4
Figure 2-3: Fraser River Daily discharge, (EC 2017)	5
Figure 2-4: Effects of freshets on water level in the Fraser River Estuary, British Columbia	6
Figure 2-5: Location of Fraser River Water Quality Buoy.....	7
Figure 2-6: Water temperature and salinity data from Fraser River WQ Buoy (ENVIRODAT, 2017).....	8
Figure 2-7: Variation of salinity with flood and ebb tide (ENVIRODAT, 2017).....	9
Figure 2-8: Annual Wind Rose	11
Figure 2-9: Location of observation points for Wave characteristics approaching Onsite Marsh and eelgrass	12
Figure 3-1: Schematic of Interrelationships and Habitat characteristics (after Roni et al, 2002)	16
Figure 3-2: Proposed Eelgrass and Marsh Concept layout	19
Figure 3-3: Typical onsite Marsh and Eelgrass cross sections.	20
Figure 3-4: Rock Reef Layout	21
Figure 3-5: Rock Reef typical section.	21
Figure 3-6: Model domain for the spectral wave and hydrodynamic models	24
Figure 3-7: Unstructured grid elements near RBT2	24
Figure 3-8: Overall model bathymetry	25
Figure 3-9: Pre-project peak currents	27
Figure 3-10: Post-project peak currents.....	27
Figure 3-11: Difference of peak currents between pre- and post-project conditions	28

Figure 3-12: Pre-project bed shear stress.....	29
Figure 3-13: Post-project bed shear stress	29
Figure 3-14: Salinities associated with a high slack tide (RBT2 EIS Appendix 9.5-A)	30
Figure 3-15: Salinities associated with an ebb tide (RBT2 EIS Appendix 9.5-A)	31
Figure 3-16: Rock berm crest elevation and details (van der Meer-1991)	32
Figure 4-1: Temporary Access Road	35

List of Tables

Table 2-1: Tidal datums for Tsawwassen (CHS, 2005).....	10
Table 2-2: Extreme high water levels (m, CD) estimated at RBT2 (Worley Parsons, 2014)	10
Table 2-3: Extreme wind speeds at Sandheads (Worley Parsons, 2014).....	10
Table 2-4: wave characteristics for data-point locations (NW winds).....	13
Table 2-5: Peak wave period for Selected locations (NW Winds).....	13
Table 3-1: BIEAP-FREMP Habitat Management Guideline (CBA 2010).....	17
Table 3-2: Depth-Averaged Current speed for existing and proposed conditions.....	26
Table 3-3: Salinity ranges for existing and proposed eelgrass zones.....	30
Table 3-4: Salinity ranges for existing and proposed tidal marsh zones	31
Table 4-1: Total Habitat Area	34
Table 5-1: Marsh & Eelgrass Construction direct cost	38
Table 5-2: Rock Reef Construction direct cost.....	38

Disclaimer

Moffatt & Nichol devoted effort consistent with (i) the level of diligence ordinarily exercised by competent professionals practicing in the area under the same or similar circumstances, and (ii) the time and budget available for its work, to ensure that the data contained in this report is accurate as of the date of its preparation. This study is based on estimates, assumptions and other information developed by Moffatt & Nichol from its independent research effort, general knowledge of the industry, and information provided by and consultations with the client and the client's representatives. No responsibility is assumed for inaccuracies in reporting by the Client, the Client's agents and representatives, or any third-party data source used in preparing or presenting this study. Moffatt & Nichol assumes no duty to update the information contained herein unless it is separately retained to do so pursuant to a written agreement signed by Moffatt & Nichol and the Client.

Moffatt & Nichol's findings represent its professional judgment. Neither Moffatt & Nichol nor its respective affiliates, makes any warranty, expressed or implied, with respect to any information or methods disclosed in this document. Any recipient of this document other than the Client, by their acceptance or use of this document, releases Moffatt & Nichol and its affiliates from any liability for direct, indirect, consequential or special loss or damage whether arising in contract, warranty (express or implied), tort or otherwise, and irrespective of fault, negligence and strict liability.

This report may not be used in conjunction with any public or private offering of securities, debt, equity, or other similar purpose where it may be relied upon to any degree by any person other than the Client. This study may not be used for purposes other than those for which it was prepared or for which prior written consent has been obtained from Moffatt & Nichol.

Possession of this study does not carry with it the right of publication or the right to use the name of "Moffatt & Nichol" in any manner without the prior written consent of Moffatt & Nichol. No party may abstract, excerpt or summarise this report without the prior written consent of Moffatt & Nichol. Moffatt & Nichol has served solely in the capacity of consultant and has not rendered any expert opinions in connection with the subject matter hereof. Any changes made to the study, or any use of the study not specifically identified in the agreement between the Client and Moffatt & Nichol or otherwise expressly approved in writing by Moffatt & Nichol, shall be at the sole risk of the party making such changes or adopting such use.

This document was prepared solely for the use by the Client. No party may rely on this report except the Client or a party so authorised by Moffatt & Nichol in writing (including, without limitation, in the form of a reliance letter). Any party who is entitled to rely on this document may do so only on the document in its entirety and not on any excerpt or summary. Entitlement to rely upon this document is conditioned upon the entitled party accepting full responsibility and not holding Moffatt & Nichol liable in any way for any impacts on the forecasts or the earnings from the project resulting from changes in "external" factors such as changes in government policy, in the pricing of commodities and materials, price levels generally, competitive alternatives to the project, the behaviour of consumers or competitors and changes in the owners' policies affecting the operation of their projects.

This document may include "forward-looking statements". These statements relate to Moffatt & Nichol's expectations, beliefs, intentions or strategies regarding the future. These statements may be identified by the use of words like "anticipate," "believe," "estimate," "expect," "intend," "may," "plan," "project," "will," "should," "seek," and similar expressions. The forward-looking statements reflect Moffatt & Nichol's views and assumptions with respect to future events as of the date of this study and are subject to future economic conditions, and other risks and uncertainties. Actual and future results and trends could differ materially from those set forth in such statements due to various factors, including, without limitation, those discussed in this study. These factors are beyond Moffatt & Nichol's ability to control or predict. Accordingly, Moffatt & Nichol makes no warranty or representation that any of the projected values or results contained in this study will actually be achieved.

This study is qualified in its entirety by, and should be considered in light of, these limitations, conditions and considerations.

1. Introduction

The Vancouver Fraser Port Authority (VFPA) is proposing to create habitat to offset impacts from construction of the Roberts Bank Terminal 2 (RBT2). RBT2 is a proposed marine container terminal in Delta, British Columbia (BC), approximately 35 km south of downtown Vancouver, BC. The terminal would be constructed west of the existing Westshore and Deltaport terminals, as shown on Figure 1-1.

Two onsite habitat offsetting projects (hereafter referred to as the Project) under investigation include:

- an onsite marsh and eelgrass bed located on the northern perimeter of the RBT2 terminal; and
- a rocky reef located immediately east of the RBT2 terminal

This report provides the criteria that have been considered in developing the design for the Project. A discussion of the existing site conditions is provided in Section 2. By characterizing the existing site conditions the design concept was developed. The criteria used to develop the design of the site are discussed in Section 3. Project design criteria also include a combination of the functional, physical and biological criteria as well as the applied engineering standards.

The construction details for the Project are discussed in Section 4. Following a general site description, the features of the Project are presented, including: the eelgrass habitat, containment structure, marsh, site access, rocky reef layout, construction methodology and construction schedule. Section 5 provides details on the construction direct cost (CDC) estimate.



FIGURE 1-1: ROBERTS BANK TERMINAL 2 (EELGRASS, INTERTIDAL MARSH, ROCKY REEF) LOCATION

1.1. Project Site

The marsh/eelgrass beds are proposed to be located on the northern perimeter of the proposed RBT2 terminal. The rocky reef would supplement existing rocky reef located east of RBT2, offshore of the Westport terminal. The site lies on the Fraser River Delta, adjacent to Delta, British Columbia.

The proposed subtidal eelgrass beds are located adjacent to existing eelgrass on the Fraser River Delta in elevations ranging from 0.0 m to -2.0 m Chart Datum (CD). The marsh area is proposed to be placed directly against the proposed terminal boundary ranging from +3.6 m to +5.0 m and contained with rock berms.

The proposed rocky reef site was selected because of the current relatively low sub bottom habitat values and adjacency to previously constructed successful habitat. The site was originally started with prototype reefs in 1983 and have undergone several expansions between 1985 to 2007. The proposed rocky reef extension consists of constructing a series of boulder mounds located adjacent to the existing Westshore coal terminal in Delta (Figure 1-1). Existing rocky reef habitat in the area will be supplemented by the proposed additions. The configuration comprising the Project currently consists of a series of linear boulder features as well as separate smaller mounds interspersed amongst the linear features. The proposed rocky reef exists in waters from roughly -2.0 m to -5.0 m CD (subtidal range).

2. Coastal Setting

2.1. Background

The proposed project site is in Roberts Bank, which is a shallow offshore estuarine area on the outer edge of the Fraser River Delta. Roberts Bank supports a productive and diverse ecosystem that supports critical fish and wildlife functions. Figure 2-1 gives a general impression of the physiography of the delta, where the dashed line marks the reach boundary of Sturgeon Bank and Roberts Bank. Figure 2-2 shows the water depth in the vicinity of the project. The site is located close to the edge of the Fraser River Delta, and is also affected by waves from the Salish Sea. A brief review of the general physical setting of the Fraser River system and Delta is presented in this section.



FIGURE 2-1: FRASER RIVER DELTA FRINGE PHYSIOGRAPHY (AFTER WILLIAMS ET AL, 2009)

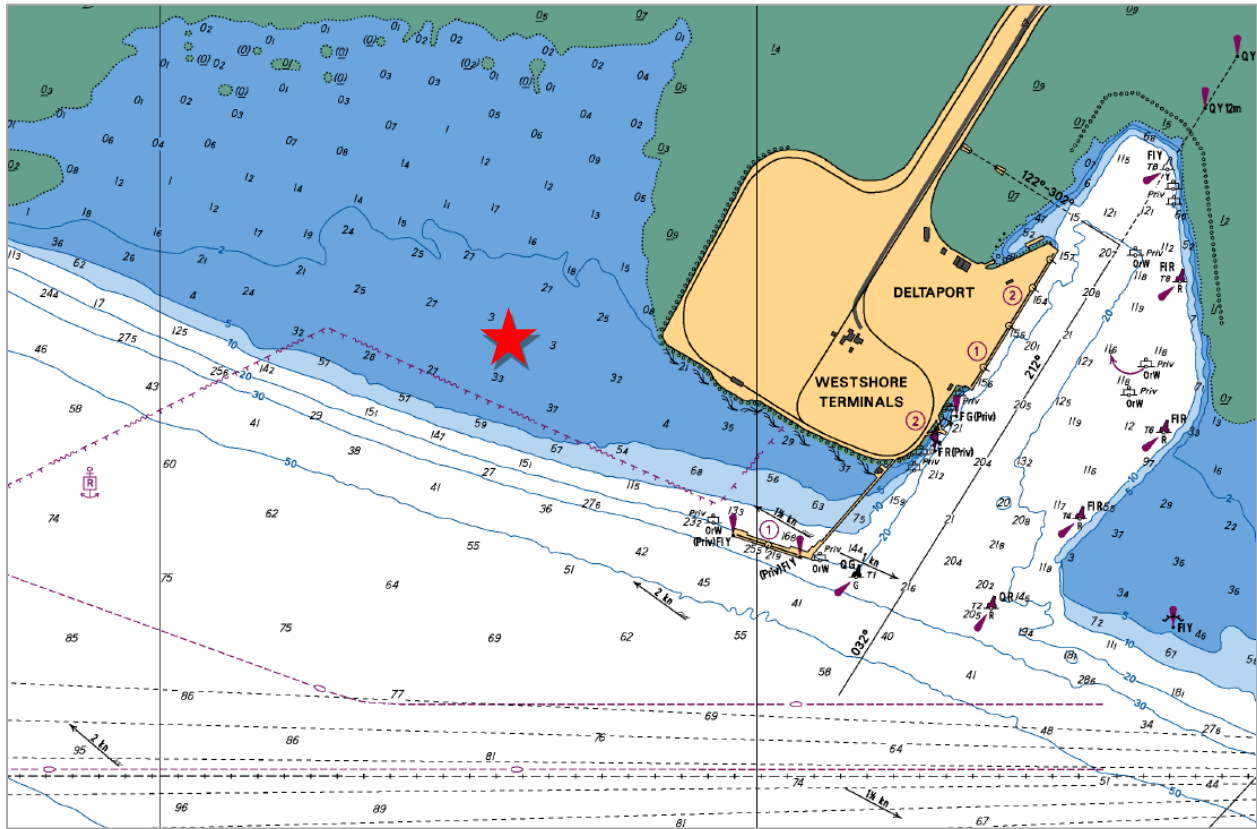


FIGURE 2-2: BATHYMETRY IN THE VICINITY OF THE PROJECT (CHS, 2005)

The gross drainage area of the Fraser River is approximately 217,000 km². Hydrometric data, including water level and discharge data has been measured at Hope since 1912, capturing a period of record of 106 years.

Figure 2-3 summarizes the maximum, minimum, and mean discharge data recorded at Hope. Additionally, the year 1991 is shown, taken as representative of average conditions.

Outflow from the river remains fairly constant over the months from January to mid-April, and subsequently increases rapidly through mid-June to early July. Over the months of July to October, the outflow decreases pronouncedly, followed by a more gradual decrease of the outflow in October and November, until a somewhat constant discharge is reached around December.

The pronounced increase in outflow over the late spring and summer months (freshet) is due to melting of snow accumulated in the mountains over the winter months.

The peak annual discharge around mid-June can range from approximately 4,000 m³/s (blue curve) to 14,000 m³/s (green curve). The average peak annual discharge is around 7,000 m³/s (brown curve). In dry years, the base outflow can be as low as 600-1,000 m³/s, increasing to 2,000-4,000 m³/s in wet years.

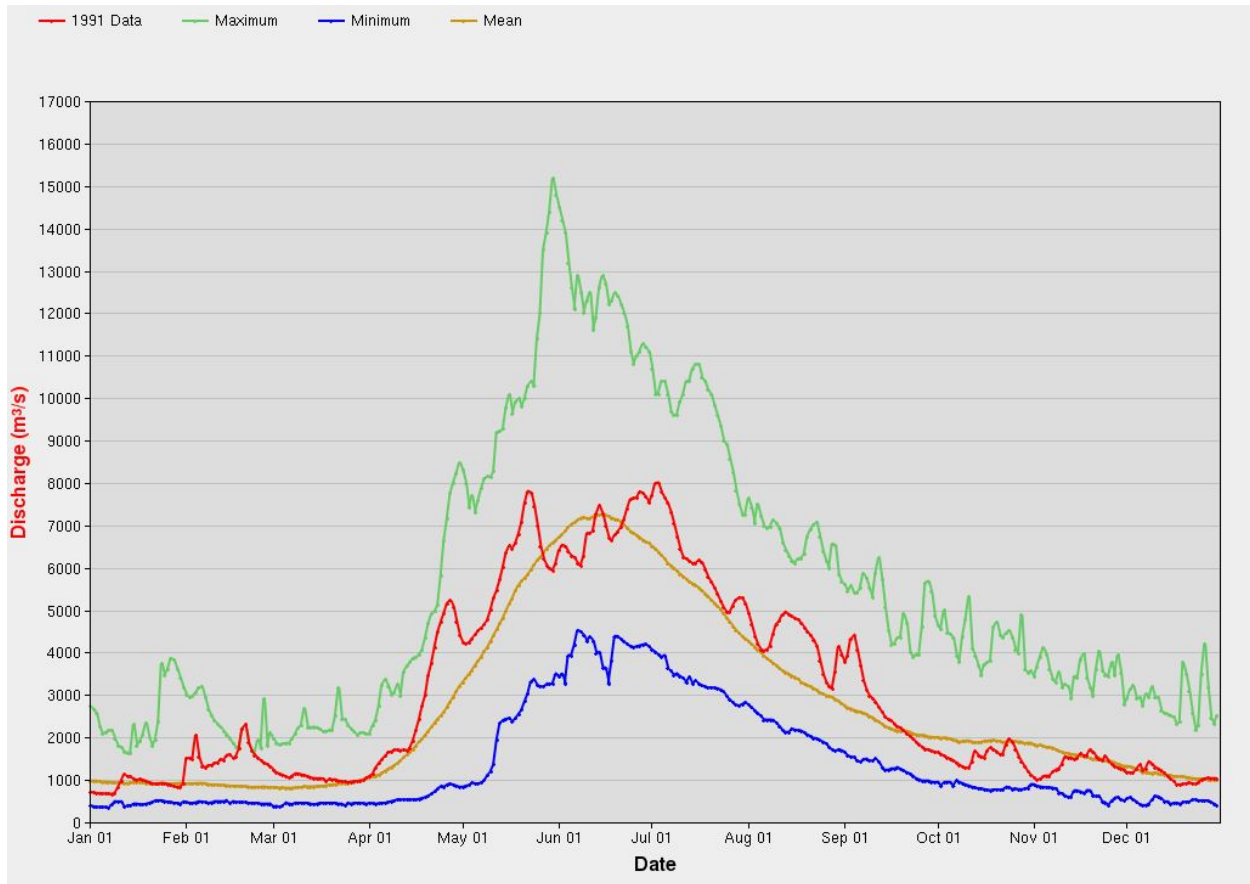


FIGURE 2-3: FRASER RIVER DAILY DISCHARGE, (EC 2017)

Due to the distributary flow share, the water levels along the south arm are affected by the freshets. Figure 2-4 shows the effects of freshets on water level in the reach starting from Sand Heads, in open water, to New Westminster (Ferguson 1991). The figure shows that mean water level rises by more than 1 m from Sand Heads to New Westminster during freshets.

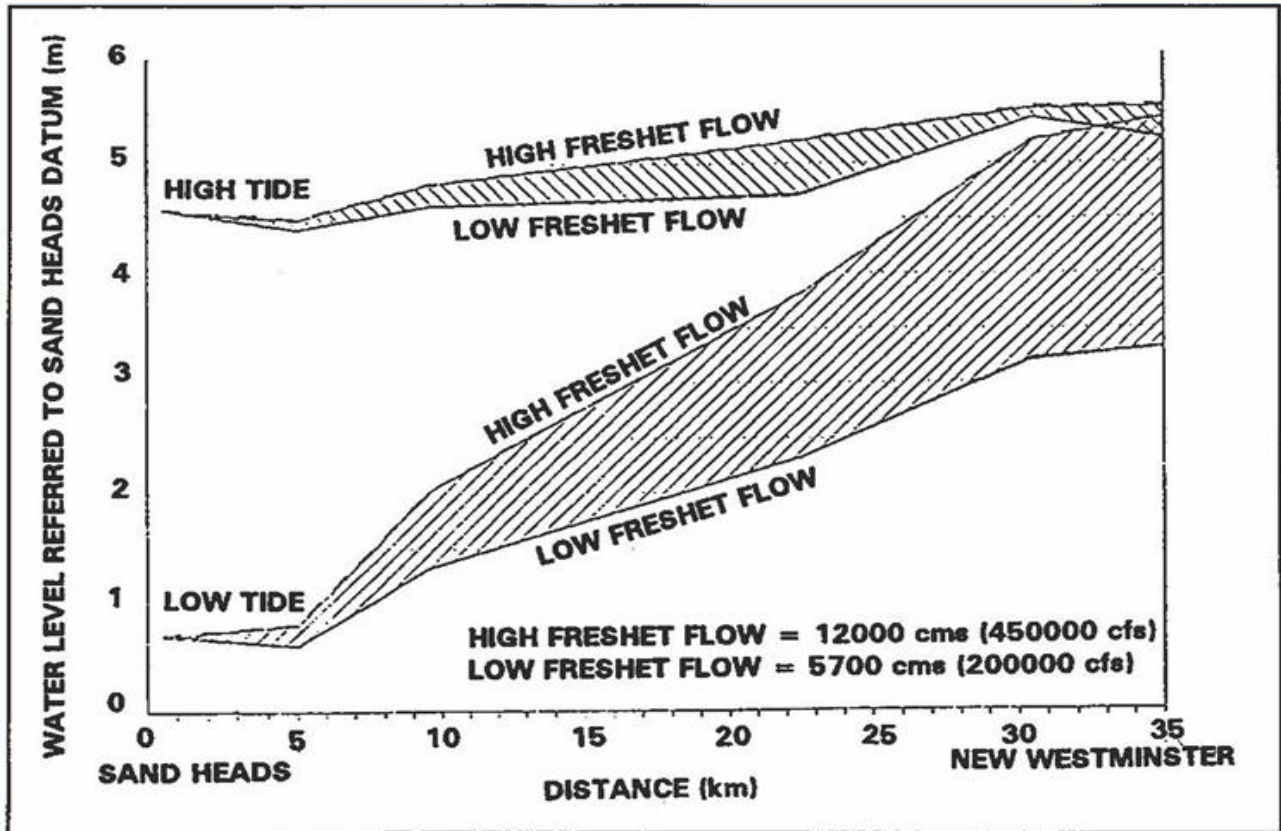


FIGURE 2-4: EFFECTS OF FRESHETS ON WATER LEVEL IN THE FRASER RIVER ESTUARY, BRITISH COLUMBIA

2.2. Fraser River Salinity Data

Water is drawn from the Fraser River for consumption, industrial, and agricultural uses. The salinity of the water depends on how far upstream the water is sourced. The extent of salinity intrusion up the Fraser River is strongly dependent on the river outflow (discharge), which varies annually. The salinity intrusion is greater in years with low river discharge.

Salinity data was acquired from ENVIRODAT (2016) for the Fraser River Water Quality Buoy. The buoy provides continuous real-time sampling of surface water quality parameters utilized to assess the quality of Fraser River fresh water. The location of the buoy is shown in Figure 2-5, which is near Tilbury at Gravesend Reach, at Latitude/Longitude 49.1484°N, 123.0392°W.

The buoy provides continuous real-time tracking of dissolved oxygen (DO) content, water pH value, conductivity, turbidity, water velocity, and water temperature. Levels of trace metals, nutrients, major ions, and coliforms are logged bi-weekly. The buoy also has the ability to track levels of a range of organic contaminants, including: pesticides, nonylphenols, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and polybrominated diphenyl ether (PBDEs).

Additional instrumentation on the buoy captures wind speed, wind direction, air pressure, relative humidity, water depth, and latitude/longitude position and heading.

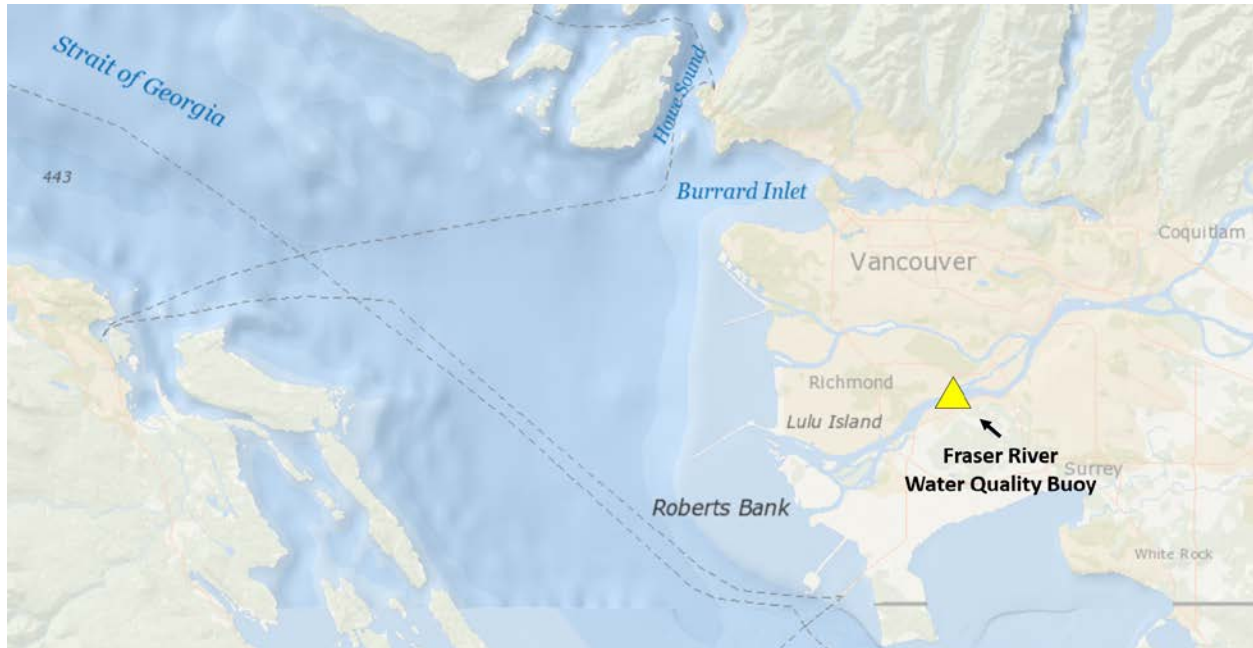


FIGURE 2-5: LOCATION OF FRASER RIVER WATER QUALITY BUOY

Figure 2-6 provides a summary of water temperature and salinity over the range of years from 2008 through 2017. Water temperature is indicated by the blue and grey curves according to the scale on the left side of the figure. Salinity levels are indicated by the yellow to red curves per the scale on the right side of the figure.

The temperature variation falls within a fairly narrow range, progressively increasing from 2-4°C in January to 18-22°C peaking in August, followed by a steady decrease in water temperature through December.

Salinity levels throughout the year are inversely related to outflow from the Fraser River. Salinities of up to 15-18 parts per thousand (ppt) are recorded in the months from September to April (low discharge months). Over the summer months from May through August, i.e. the peak discharge months, the water is fresh.

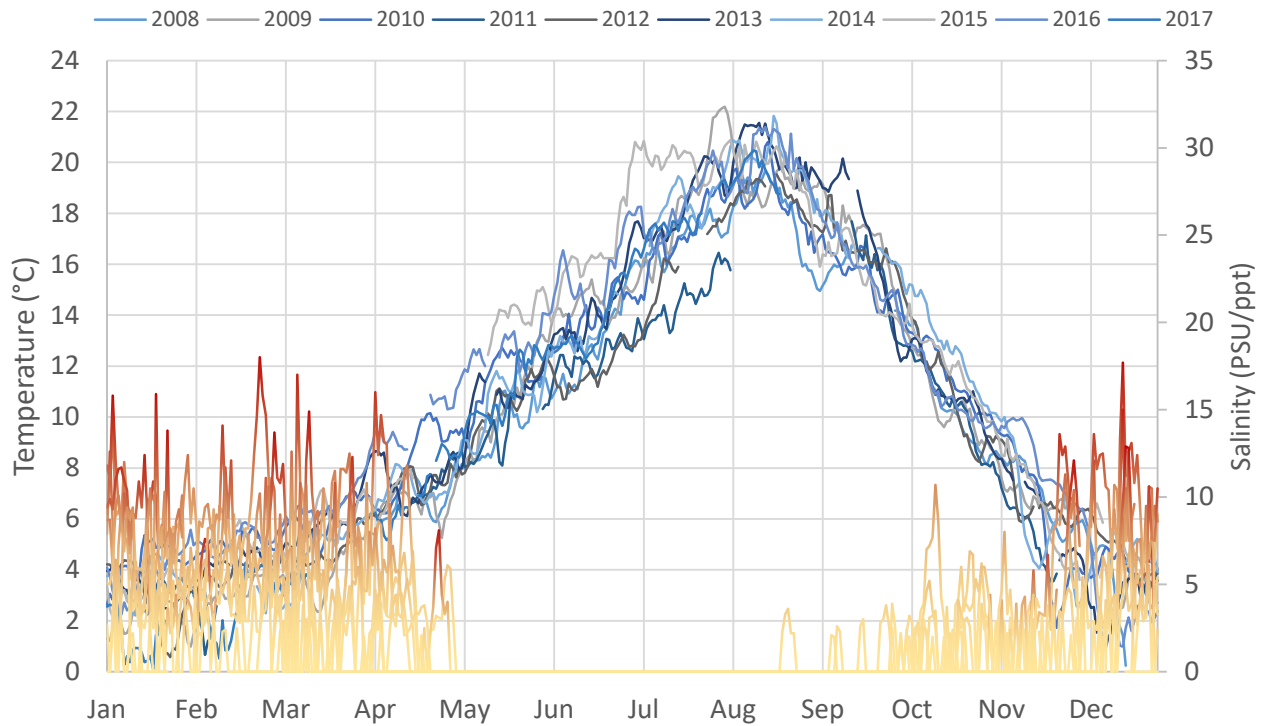


FIGURE 2-6: WATER TEMPERATURE AND SALINITY DATA FROM FRASER RIVER WQ BUOY (ENVIRODAT, 2017)

Figure 2-7 shows an example of the intertidal variation of salinity levels. The dark blue curve indicates the tide stage recorded at the buoy in meters relative to the scale on the left-hand side. The green curve shows the corresponding flow velocities in meters per second, measured on the same scale. Flood tides are denoted by positive values and ebb tides by negative values. Tidal currents oscillate around a mean of around -0.4 m/s, which represents the steady outflow from the river.

The variation of the salinity level is indicated by the orange/red curve, with units in PSU/ppt per the scale on the right-hand side of the figure. The variation of the salinity follows each tidal cycle, increasing on flood tides as saltwater propagates inland, and decreasing on ebb tides where more freshwater flows out.

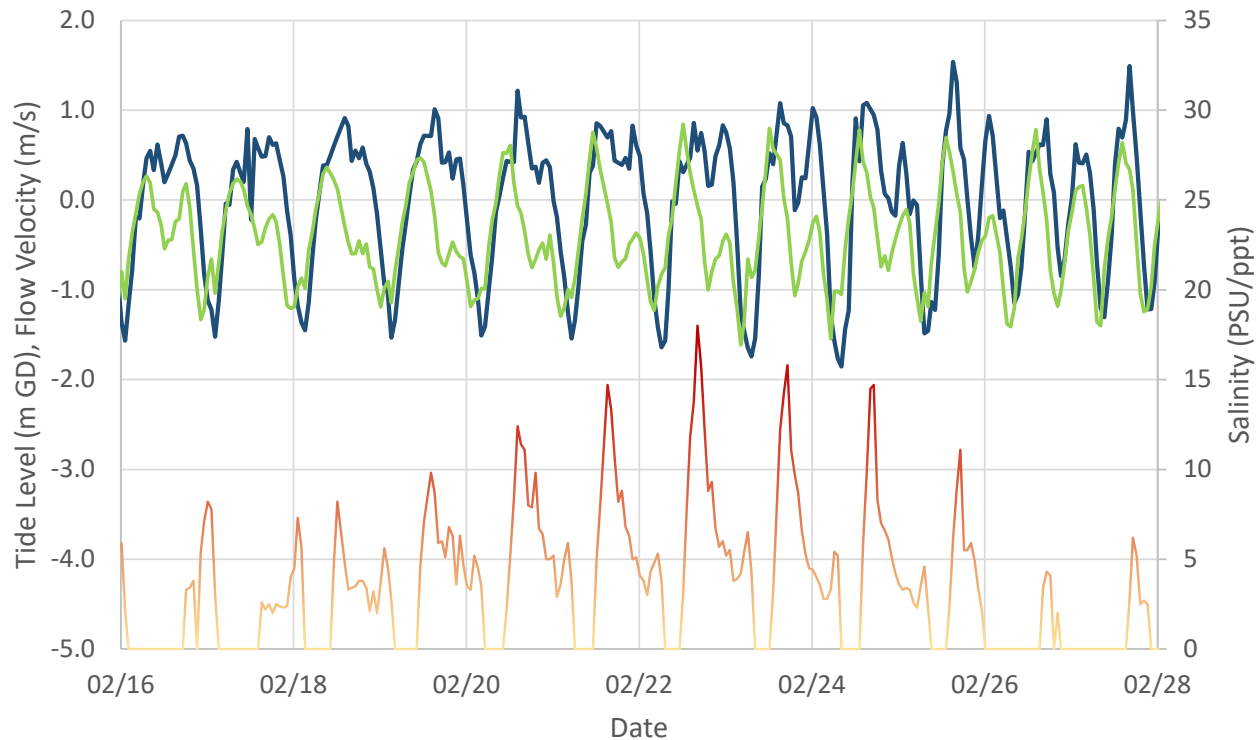


FIGURE 2-7: VARIATION OF SALINITY WITH FLOOD AND EBB TIDE (ENVIRODAT, 2017)

2.3. Environmental Conditions

2.3.1. Water Levels

Total water level consists of astronomical and meteorological tide components, as well as river flow in an estuarine environment. Astronomical tides refer to the tidal levels which result from gravitational effects, e.g. of the Earth, Sun and Moon, without any atmospheric influences.

Table 2-11 summarizes tidal datums at Tsawwassen based on the Canadian Hydrographic Service (CHS) *Nautical Chart 3492* (CHS, 2005).

- Higher High Water Large Tide (HHWLT): The average of the highest high waters, one from each of 19 years of predictions.
- Higher High Water Mean Tide (HHWMT): The average from all the higher high waters from 19 years of predictions.
- Mean Water Level (MWL): The average of all hourly water levels over the available period of record.
- Lower Low Water Mean Tide (LLWMT): The average of all the lower low waters from 19 years of predictions.
- Lower Low Water Large Tide (LLWLT): The average of the lowest low waters, one from each of 19 years of predictions.

TABLE 2-1: TIDAL DATUMS FOR TSAWWASSEN (CHS, 2005)

Tidal water surface	Chart Datum (m)
Higher High Water Large Tide (HHWLT)	+4.8
Higher High Water Mean Tide (HHWMT)	+4.1
Mean Water Level (MWL)	+3.0
Lower Low Water Mean Tide (LLWMT)	+1.2
Lower Low Water Large Tide (LLWLT)	+0.1
Chart Datum (CD)	0.0

2.3.2. Extreme Water Levels

The second component of total water level, meteorological tides (or residual), refer to changes in expected astronomical tides caused by local meteorological conditions. The positive value of residual is commonly called storm surge as the water surface is elevated due to the passage of a low-pressure storm system. Extreme value estimates are summarized in Table 2-2.

TABLE 2-2: EXTREME HIGH WATER LEVELS (M, CD) ESTIMATED AT RBT2 (WORLEY PARSONS, 2014)

Description	Return Period (Years)				
	2	5	10	50	100
Extreme High Water Level (m, CD)	5.02	5.15	5.22	5.35	5.39

2.3.3. Winds

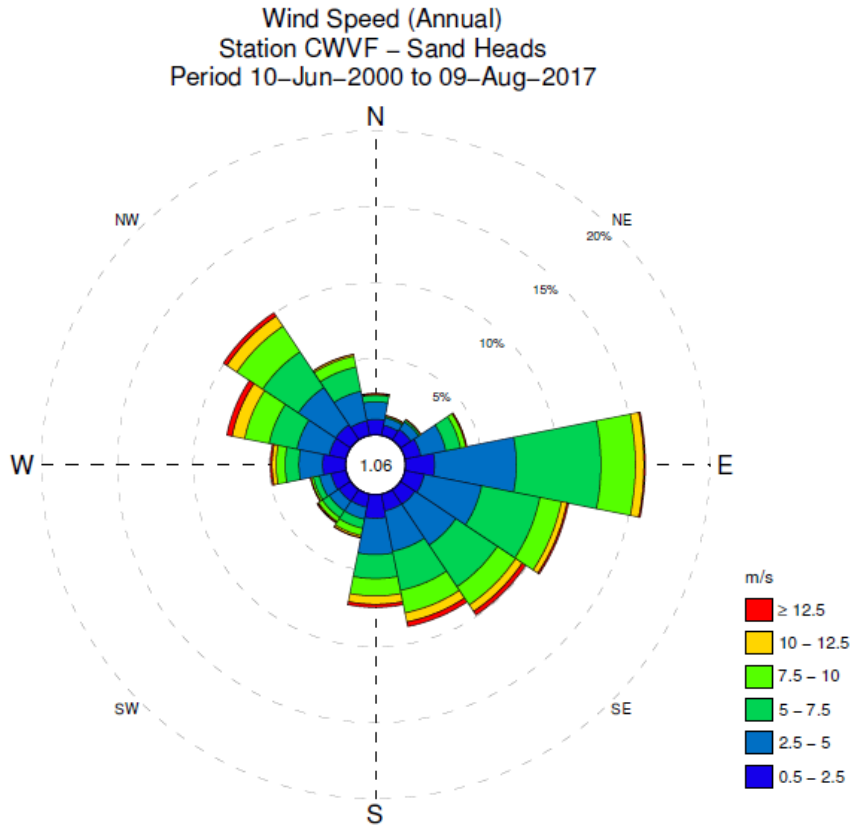
Wind data for Sandheads is archived in the Environment Canada National Climate Data and Information network. A total of 24 years of data between 1995 and 2018 was analyzed. Figure 2-8 presents the annual wind rose and shows the prevailing wind direction is from the east. Stronger winds are aligned northwesterly or east/southeasterly, which reflects the open water orientation of the Strait of Georgia. The largest recorded wind speed was approximately 50 knots.

Table 2-3 summarizes wind speed extremes. The 50-year and 100-year return period omni-directional winds are 50 and 51 knots.

TABLE 2-3. EXTREME WIND SPEEDS AT SANDHEADS (WORLEY PARSONS, 2014)

Wind Direction	Return Period (Year)							
	1	2	5	10	25	30	50	100
Omni-Directional (knots)	40	42	44	46	48	49	50	51
SE-S (knots)	38	40	43	45	47	48	49	51

Wind Direction	Return Period (Year)							
	1	2	5	10	25	30	50	100
NW-W (knots)	36	39	42	44	47	48	49	51



Percentage of Occurrence

Total	2.71	1.30	1.58	4.12	15.77	10.97	9.91	8.87	7.40	2.92	2.63	2.36	4.93	7.99	10.05	5.42	98.94
					0.11	0.27	0.31	0.20					0.11	0.35	0.26		1.81
12.5				0.57	0.37	0.52	0.61	0.55	0.14				0.27	0.84	0.80	0.12	5.01
10			0.35	2.27	1.44	1.45	1.52	1.15	0.49	0.32	0.15	0.59	1.65	2.03	0.73		14.27
7.5	0.43	0.10	0.14	0.99	5.57	3.91	3.29	2.62	1.58	0.62	0.54	0.41	0.90	1.87	2.82	1.63	27.43
5	1.16	0.50	0.62	1.68	5.38	3.85	3.24	2.71	2.40	0.79	0.77	0.78	1.56	2.16	2.96	1.98	32.55
2.5	0.99	0.65	0.80	1.04	1.89	1.27	1.13	1.10	1.53	0.87	0.90	0.98	1.49	1.12	1.16	0.95	17.88
0.5																	
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total

FIGURE 2-8: ANNUAL WIND ROSE

2.3.4. Wind Wave Characteristics - Onsite Marsh

M&N (2020) conducted a wind-wave analysis using MIKE-21 Spectral Wave (SW) model to estimate the exposure of the proposed marsh and eelgrass zones to wave action. Figure 2-9 shows the location of observation points within the proposed habitat area.

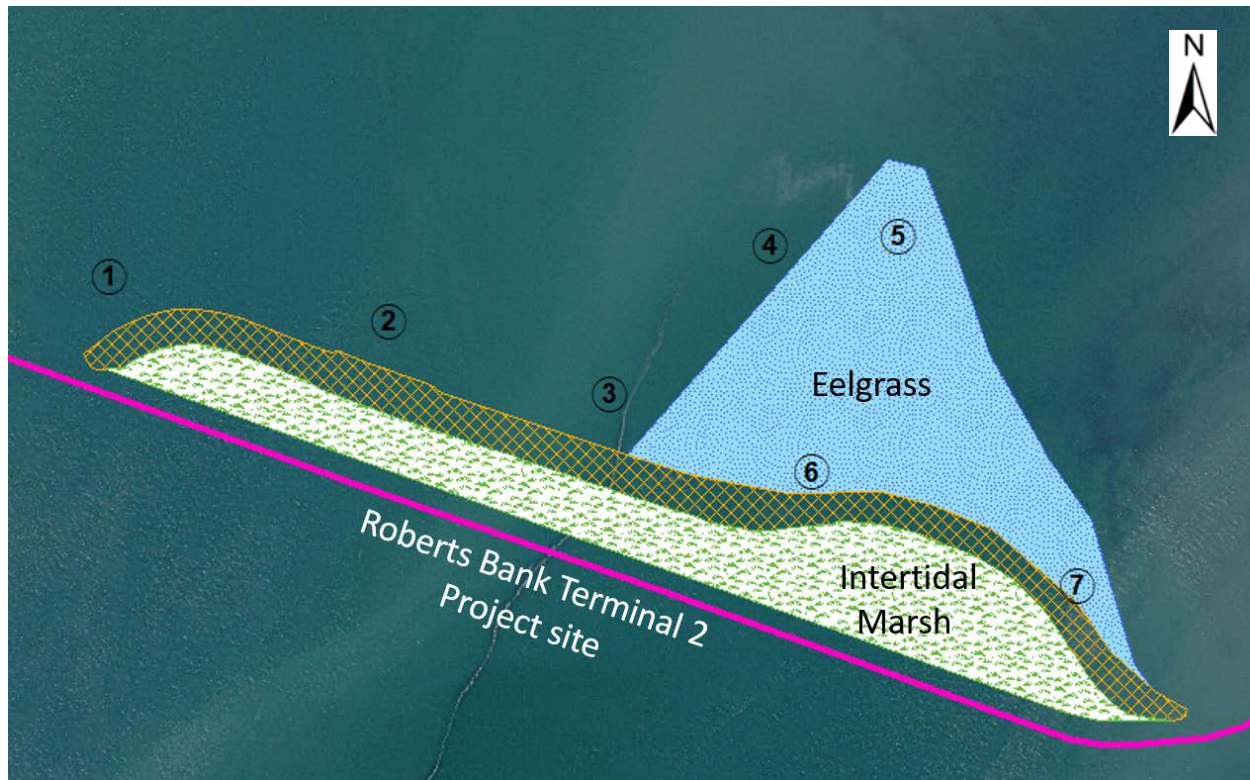


FIGURE 2-9: LOCATION OF OBSERVATION POINTS FOR WAVE CHARACTERISTICS APPROACHING ONSITE MARSH AND EELGRASS

A detailed discussion of wind wave analysis is presented in Appendix B. At the proposed onsite habitat area, wave breaking processes (i.e. depth limited breaking waves) associated with water levels were found to govern the potential wave heights at the project site.

Table 2-4 and Table 2-5 shows the detailed wave characteristics for 7 observation-points presented in Figure 2-9. Point #1 is the most exposed resulting in higher waves compared to other observation points, therefore considered most critical location for design purposes. These values are obtained during a normal high tide without Sea-Level Rise (SLR).

TABLE 2-4: WAVE CHARACTERISTICS FOR DATA-POINT LOCATIONS (NW WINDS)

Wind Speed (knots)	Significant Wave Height (m)						
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
5	0.21	0.19	0.19	0.20	0.19	0.19	0.19
10	0.29	0.27	0.27	0.28	0.27	0.27	0.27
15	0.42	0.40	0.39	0.39	0.39	0.38	0.37
20	0.54	0.51	0.50	0.51	0.50	0.50	0.47
25	0.68	0.63	0.62	0.65	0.63	0.61	0.59
30	0.84	0.78	0.76	0.79	0.78	0.75	0.72
35	1.00	0.94	0.92	0.95	0.93	0.91	0.86
40	1.17	1.11	1.08	1.10	1.08	1.07	1.01
45	1.35	1.28	1.25	1.26	1.24	1.23	1.16
50	1.53	1.45	1.42	1.42	1.40	1.40	1.31
55	1.70	1.63	1.59	1.57	1.55	1.57	1.46

TABLE 2-5: PEAK WAVE PERIOD FOR SELECTED LOCATIONS (NW WINDS)

WSPD (knots)	Peak Wave Period (s)						
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
10	2.7	2.7	2.7	2.7	2.7	2.7	2.7
15	2.9	2.8	2.8	2.8	2.7	2.8	2.7
20	3.0	2.9	2.9	2.9	2.9	2.9	2.9
25	3.2	3.2	3.1	3.1	3.1	3.1	3.1
30	3.4	3.3	3.3	3.3	3.3	3.3	3.3
35	3.6	3.5	3.5	3.6	3.5	3.5	3.5
40	3.8	3.7	3.7	3.7	3.7	3.7	3.6
45	4.0	3.9	3.9	3.9	3.9	3.9	3.9
50	4.1	4.1	4.0	4.1	4.1	4.0	4.0
55	4.3	4.2	4.2	4.2	4.2	4.2	4.1

Highest waves are observed at Point #1, with a Hs of up to 1.70 m. Based on the wind data presented in Section 2.3.3, the 100-year extreme wind is in the order of 51 knots, therefore a the corresponding 100-year wave is expected to be in the order of 1.53 m with peak wave period of 4.1 seconds. Other observation points behind the proposed landmass are more sheltered compared to Point 1, and therefore the resulting wave heights are smaller. The peak periods from measured storms for model calibration are between 6 and 7 seconds at the height of the storm. The shallower depths, especially in stations 5, 6, and 7 result in a depth limited wave condition.

2.3.5. Currents at the Rock Reef

The maximum velocity on the bottom under the 50-year design event is calculated to be about 2.1 m/s. The required stable rock size based on commonly used bridge scour protection and a factor of safety of 1.5 is 225 mm. Thus, the proposed boulder clusters are not likely to be displaced by wave-induced horizontal particle velocities during the 50-year design storm event. However, in order to ensure that any potential movement of the boulders occurs within the rock bedding and not onto the adjacent seabed or rock reef, it is recommended that they not be placed within 2 m of the edge of the rock bedding. (NHC, 2015)

2.3.6. Geotechnical Conditions

The proposed project is located at Roberts Bank which forms the western boundary of the modern day Fraser River delta. The Fraser River delta is a geologically young feature, being about 10,000 years old. Roberts Bank is an even younger feature than the Fraser River delta, representing the geologically most recent depositions associated with deltaic formation, likely over no more than the last 2000 years.

The delta consists of layered sands and fined sediments washed down from the Coast Mountains. The RBT2 site is underlain by a granular soil unit consisting of loose to compact recently deposited sands, silts, and interbedded sand and silts that vary in thickness from 75m to in excess of 100m. Geotechnical reports prepared for the proposed Roberts Bank Terminal 2 include soil borings in the vicinity of the marsh/eelgrass areas. The substrate is suitable to accommodate stable placement of the rock berm and fill materials.

Stantec conducted geotechnical site investigation program in 2016 which includes collection of soil samples at the proposed RBT2 area. For the onsite marsh area, borehole record at the northwest corner of the proposed terminal shows that the surface soil consists of mostly sand with traces of silt material (Appendix C).

3. Design Criteria

This section describes the criteria that guided the design of the proposed Project. This section includes a description of the functional, physical and biological design criteria as well as the applied engineering standards.

3.1. General Design Criteria

3.1.1. Project Datum and Units

Horizontal datum is based on NAD83 UTM Zone 10. The vertical datum is Chart Datum (CD). All drawings are presented in SI (metric) units.

3.1.2. Service Life and Return Period

Standard industry practice is to design shore protection without any factors of safety implicit in the design methods applied. Durable design is achieved by selecting a design condition that is unlikely to be exceeded over the service life of the structure. For permanent structures that are designed to withstand no damage, such as a marine terminal, a 50-year or more return period event is often used. However, for this project the containment structures for the habitat features are less critical since the sites do not constitute existing flood protection infrastructure (BC MOE 2007). As such, a return period of 25 years for the extreme event will be used in the design. The shore protection measure under consideration is a rubble mound construction which typically does not fail catastrophically, but rather, tends to fail incrementally, which can be repaired to extend the lifespan. The existing rock reef elements have been in place for decades in a stable configuration and are not considered critical structures.

3.1.3. Codes, Standards and Design Guidelines

The following guidelines, codes, and standards shall be used for this project:

- British Columbia Building Code 2018 (BCBC'18);
- Coastal Engineering Manual (CEM, US Army Corps of Engineers, 2002).

3.1.4. Functional Requirements – Marsh and Eelgrass

Figure 3-1 shows a schematic of processes and controls that define a habitat. Engineering and other interventions must take note of the delicate balance among relevant factors to avoid destruction or significant modification of a habitat.

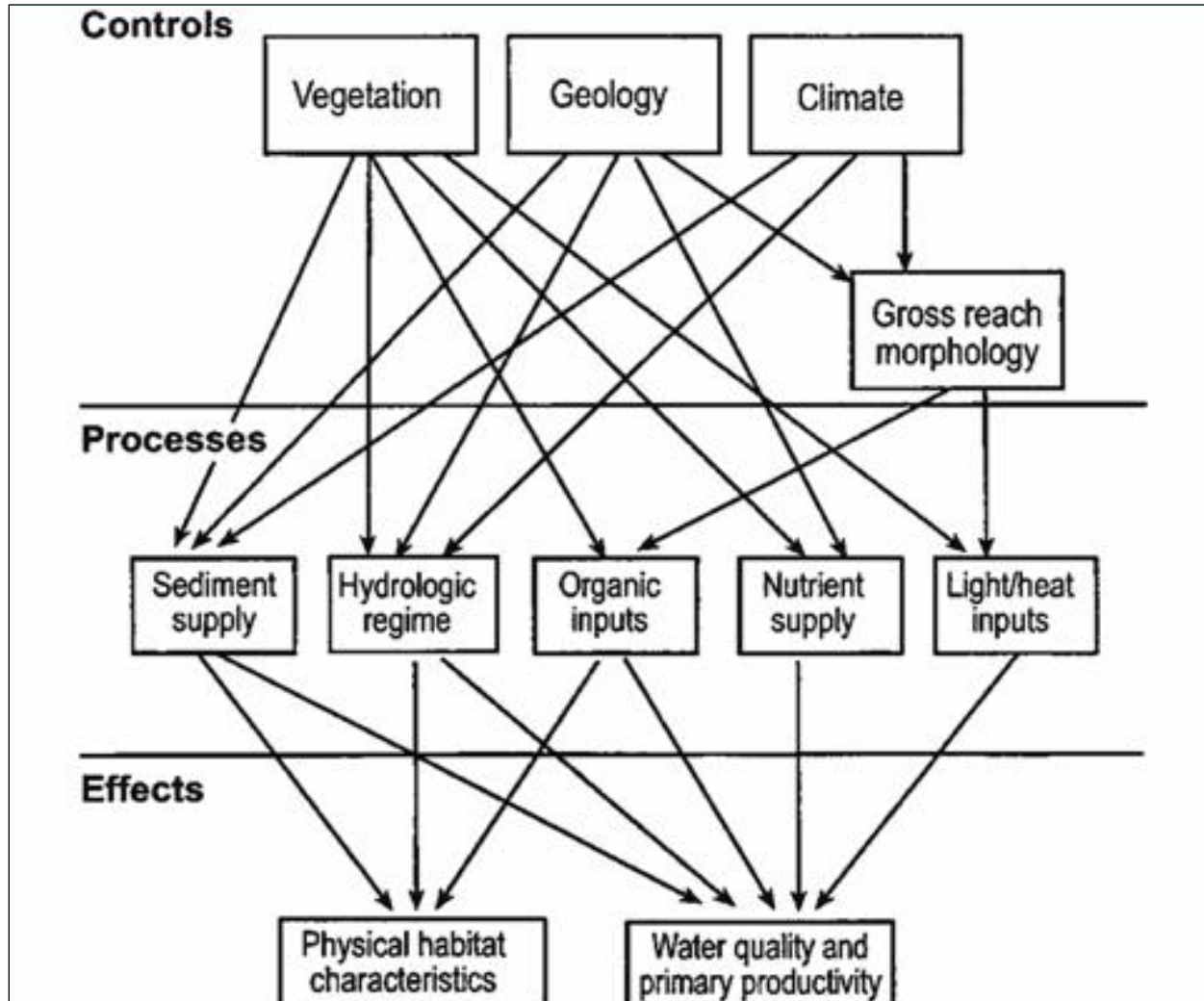


FIGURE 3-1: SCHEMATIC OF INTERRELATIONSHIPS AND HABITAT CHARACTERISTICS (AFTER RONI ET AL, 2002)

It is important that identified habitats are preserved and maintained. In their habitat management strategy policy statement, BIEAP-FREMP (CBA, 2010) has identified four basic guidelines for marine works. Relevant highlights of these guidelines are summarized in Table 3-1.

TABLE 3-1: BIEAP-FREMP HABITAT MANAGEMENT GUIDELINE (CBA 2010)

Guideline	Description
1	<p>Preserve habitat features to maintain fish and wildlife functions:</p> <ul style="list-style-type: none"> • fish feeding (marshes), • waterfowl and shorebird nesting, • roosting and feeding (trees and shrubs), • leaf and insect input, and • wildlife feeding and refuge cover.
2	Design facilities to minimize structure or surface footprints, even for elevated structures such as docks.
3	Preserve intertidal areas, including sand flats, mudflats and marsh to the degree possible.
4	For mitigation consider complexing marsh habitat, e.g. tidal channels, planting, large woody debris to improve fish access and utilization.

3.1.5. Functional Requirements – Rocky Reef

The proposed rocky reef site was selected because of the current relatively low sub bottom habitat values and adjacency to previously constructed successful habitat. The site was originally started with prototype reefs in 1983 and have undergone several expansions from 1985 to 2007. The reef designs provided hard, stable substrates in the productive shallow sub-tidal zone to benefit fish, invertebrate, and algal communities.

Strong tidal currents flush the seaward margin of the Deltaport facility to support a diverse and productive marine community on the hard, stable surfaces of the reef and within the voids of the artificial structure itself. The Port reports that the existing rock reef features remain physically stable and continue to perform well, sustaining a diverse and productive marine community. In addition to supporting an abundant fish and invertebrate community, subtidal vegetation algae (e.g. *Nereocystis*) is well established (Williams et al., 2006).

The existing reefs were constructed using large angular riprap that was randomly stacked to create large crevices and provide a large surface area for sessile organisms to attach. Crevices of varying size in the interstitial spaces of subtidal reefs are well documented to provide excellent habitat for a wide variety of resident fish. The open matrix of a well-constructed rock rubble reef also promotes good exposure to strong tidal flushing that increases food and oxygen availability within the reef structure itself. Lingcod, for example, typically select habitats with these characteristics for their nest sites as they promote successful spawning and offer good egg attachment substrates. Exposure to strong and efficient tidal flushing has been shown to ensure efficient oxygen delivery to the center of lingcod nests (Cass *et al.* 1990).

Rock Reef provides:

- important habitat for fish and wildlife including juvenile salmon, Pacific herring, Dungeness crab, Lingcod, and sea stars

- refuge and nurseries for juvenile fish and invertebrates

3.2. Proposed Marsh and Eelgrass

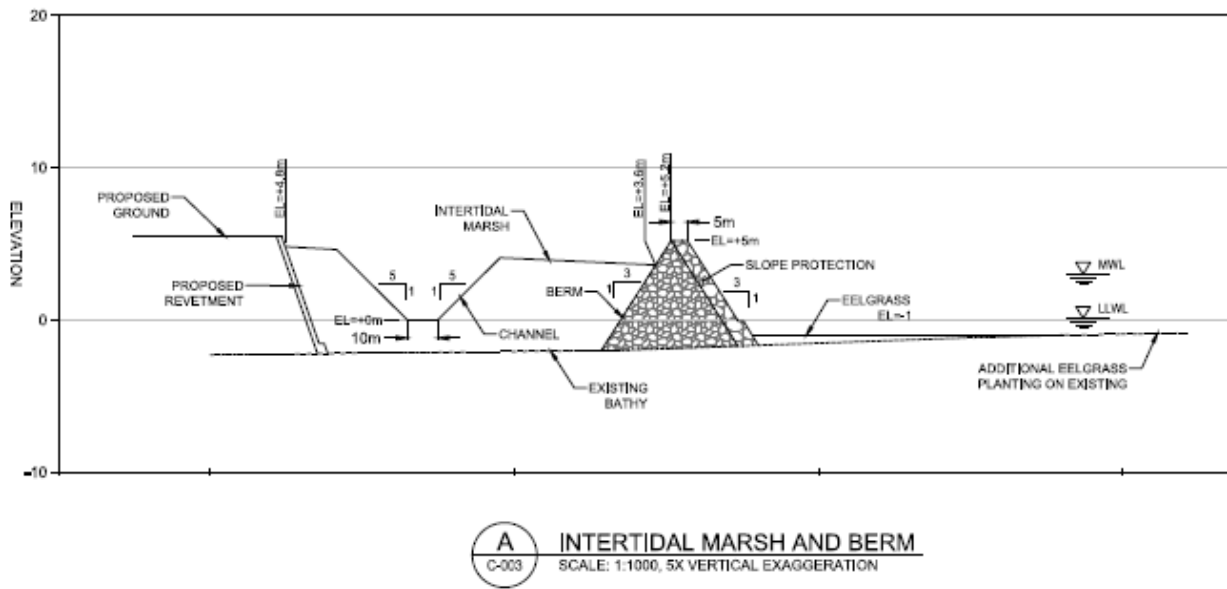
Intertidal marshes perform important ecological functions including shoreline stabilization, gas and nutrient regulation, contaminant filtering, nutrient supply, as well as increasing biological diversity. They also provide complex habitat use for shelter and food by organisms at a number of trophic levels. Intertidal marsh is generally defined as vegetated low-lying habitat for which flooding characteristics are determined by the tidal movement of the adjacent water body. Although the Fraser River supports three types of intertidal marsh habitat, the salt marsh is predominant along the existing causeway and is typically colonized by salt tolerant emergent plants. The structure and function of the marsh is heavily influenced by hydrology as well as salinity, substrate, and sediment supply. The overall goal for the project is to create marsh habitat with interconnected channels to enhance salmon passage and bird habitat. Elevations of the channels are designed to maximize circulation, while minimizing erosion that would require maintenance or detrimental impacts to adjacent habitat and navigation channels.

Eelgrass fills would consist of both filling in deeper areas where eelgrass currently is not growing, as well as transplanting in areas of proper elevation, but sparse or no eelgrass coverage.

Physical features of the marsh and eelgrass site include wave protection from northwest waves, erosion protection in channel areas subjected to higher current velocities, fills to support planted vegetation, and channels to connect the site to adjacent habitat and proposed marsh. The eelgrass area would include a protective fore-berm to protect it from scouring currents and fills to raise the existing sea floor. A plan and typical section of the proposed marsh and eelgrass is shown in Figure 3-2 and Figure 3-3.



FIGURE 3-2: PROPOSED EELGRASS AND MARSH CONCEPT LAYOUT



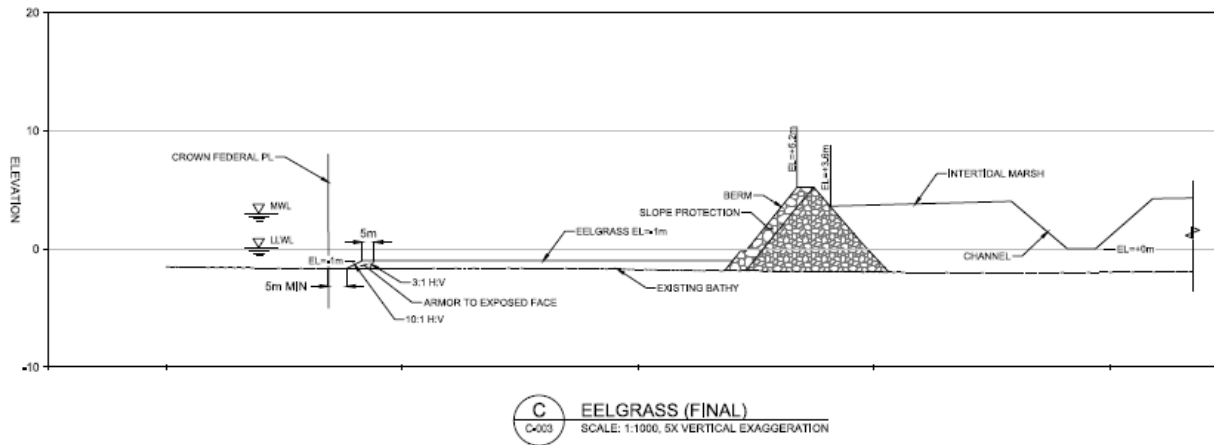
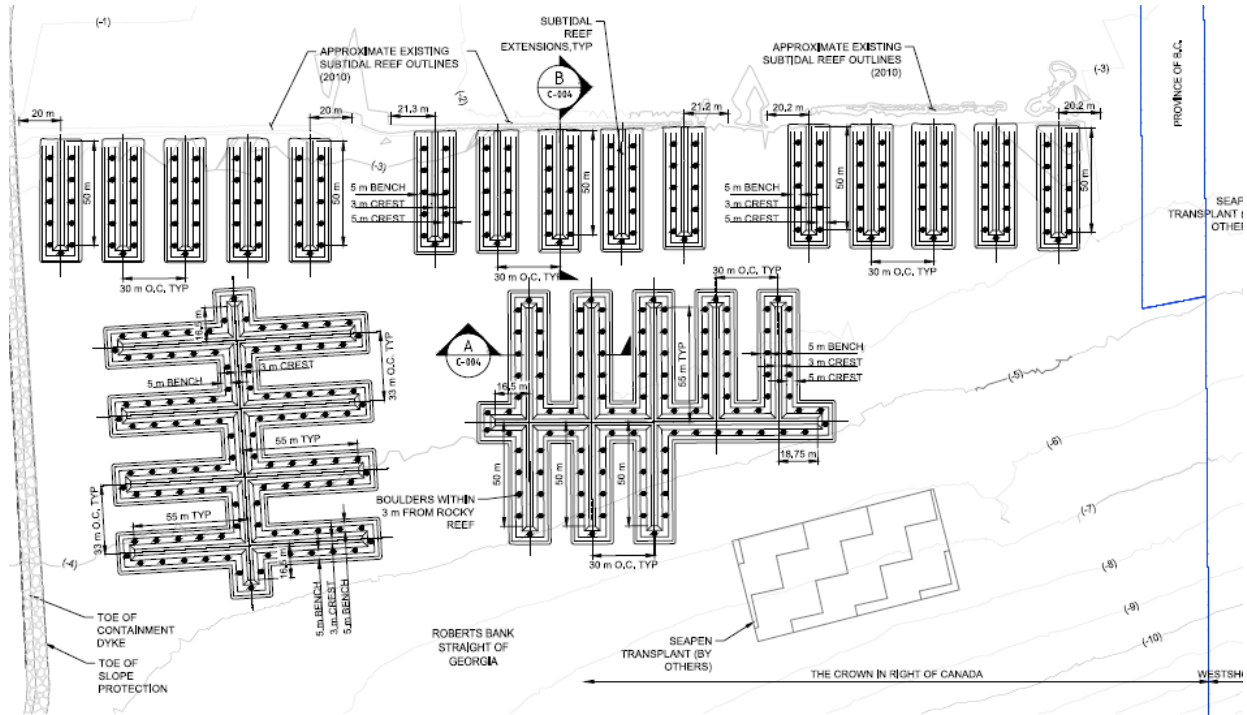


FIGURE 3-3: TYPICAL ONSITE MARSH AND EELGRASS CROSS SECTIONS.

3.3. Proposed Rock Reef

The proposed boulder clusters consist of 900 mm diameter boulders that would be placed on top of the 450 mm rock bedding adjacent to the rock reefs at elevations between -3.0 m and -4.0 m CD. The boulders would consist of both linear features and independent boulder clusters. The boulders would be placed in clusters of three boulders at a spacing of one cluster per 27 m². The bedding extends 5 m from the edge of the rock reef. Placement of the boulders on top of the bedding will cause them to project above the surrounding surface and is intended to provide improved habitat conditions. The proposed layout and typical sections are shown in Figure 3-4 and Figure 3-5.



QUANTITIES:

ARMOUR RIPRAP	15,100 m ³
BEDDING	17,500 m ³
BOULDER	422 m ³

EXISTING SUBTIDAL REEF	0,7 ha
PROPOSED AREA	4,0 ha
AREA 5m FROM EDGE OF REEF	5,84 ha
AREA 10m FROM EDGE OF REEF	7,14 ha

NOTES:

- BATHYMETRIC CONTOURS ARE SHOWN AT A 0,5m INTERVAL.
- BOULDERS SHALL BE PLACED THROUGHOUT THE BENCH OF EACH PROPOSED SUBTIDAL REEF IN CLUSTERS OF UP TO 3 BOULDERS. BOULDER DENSITY SHALL AVERAGE 1 PER 9m² (1 CLUSTER PER 27m²). THE BOULDERS SHALL NOT BE PLACED WITHIN 2m OF THE EDGE OF ROCK BEDDING. CLUSTERS PLACES AT 10,5m O.C.
- ALL ELEVATION OF CREST TO BE 1,5m ABOVE BEDDING.

FIGURE 3-4: ROCK REEF LAYOUT

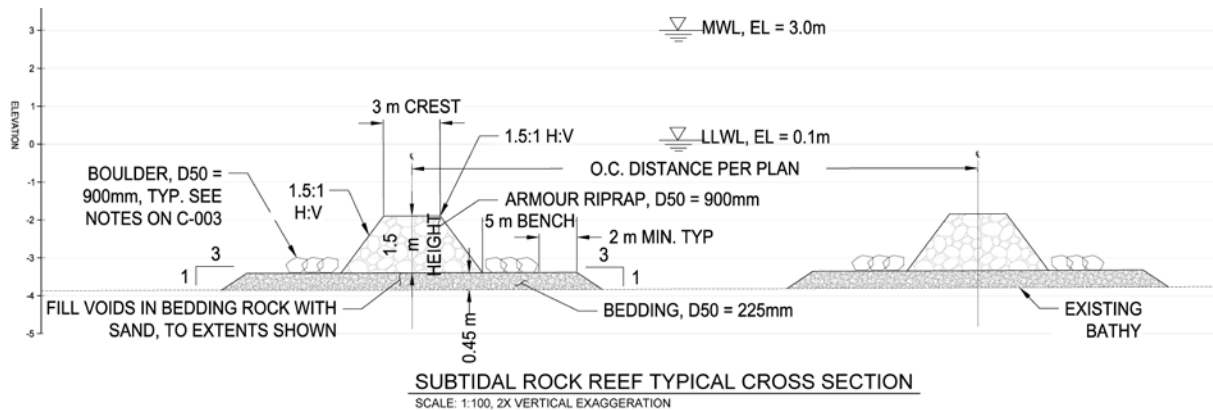


FIGURE 3-5: ROCK REEF TYPICAL SECTION.

3.4. Design Criteria

3.4.1. Coastal Design Parameters

The description of coastal design parameters, including tide, water levels, waves, and salinity were previously presented in Section 2.

3.4.2. Planting Elevations

Marsh construction at the marsh habitat enhancement site will consist of extending the marsh platform over the tidal flats, contained within a cobble gravel berm. The finished marsh design elevation will range between +3.6 and +5.0 m CD. The containment berm will consist of a rock berm. Suitable low marsh brackish plant species will be transplanted into the constructed marsh platform.

The eelgrass planting will range between -2.0 m CD and abut the existing eelgrass beds.

3.4.3. Rocky Reef Elevations

The bathymetry varies between -2.0 m and -5.0 m CD with the proposed reef crest elevations varying between -0.5 m and -3.5 m CD, which will support marine algal communities and provide habitat zonation in the well-flushed shallow subtidal region. The reefs are sited in subtidal waters so that they will not impede or obstruct the out-migration of juvenile salmon, particularly chum and pink that sweep around the end of the Deltaport facility during the Fraser River's springtime out-migration.

3.4.4. Spatial Constraints

The overall configuration for the marsh and eelgrass areas are confined by existing habitat to the north, proposed RBT2 terminal to the south, causeway to the east, and property boundaries on both north and east.

The rocky reef is limited to the north by the existing Westport terminal, to the east by the property boundary, to the west by the proposed RBT2 terminal, and to the south by a sharply dipping ocean floor. Existing rock reef will be expanded.

3.5. Wave and Hydrodynamic Modeling

This section describes wave and hydrodynamic modeling conducted in support of the marsh and eelgrass design.

3.5.1. Model Description

In 2020 Moffatt & Nichol prepared modeling of the onsite marsh project. The modeling were conducted to assess wave stress over the marsh substrate and to examine the salinity conditions to support the marsh habitat. The outcome was used to establish the amount of shore protection required to lessen wave action sufficiently to support vegetation, elevations for planting, as well as the salinity levels to

allow plant survival. Details of the study are provided in Appendix B in detail and are summarized in this report.

Coastal design parameters for wind, wave, tides, and river flows have been presented in section 2 and were used as input parameters for the model. Topography and bathymetry data in the shallow mudflats surrounding the project area was obtained from two LIDAR surveys conducted in 2013 and 2017 respectively. This was supplemented with additional data collected in 2019.

The Danish Hydraulic Institute MIKE-21 two-dimensional Spectral Wave (SW) and Hydrodynamic (HD) models were developed for the Lower Fraser River and Strait of Georgia to carry out the relevant analyses and to determine design requirements for the proposed marsh. Both models were calibrated to ensure that wave and hydrodynamic processes were adequately reproduced.

MIKE-21 is a modelling system developed by the Danish Hydraulic Institute (DHI) Water and Environment. It was selected for the project because of the flexibility and computational efficiency with its unstructured grid configuration. The unstructured grid makes it possible to resolve both large and small-scale flow and wave processes effectively. Finer resolution grid elements are used in the vicinity of the project area while coarser grid elements are used away from the areas of interest.

The SW model solves the wave action conservation equations and simulates the growth, decay, and transformation of wind-generated seas and long-period swells in offshore and coastal areas. The SW considers important physical processes, including wave growth by action of winds, shoaling and refraction due to depth variations, diffraction and reflection near structures, wave breaking in the surf zone, wave dissipation (including bottom friction, white capping, and wave-wave interaction), and some non-linear wave-current interactions.

The HD model solves the depth-averaged shallow water equations and simulates water level variations and flows in response to a variety of forcing functions. It has been applied extensively worldwide within oceanographic, coastal, and estuarine environments.

Different model grids were developed for the SW and HD model. The computational domain for the SW model covers the Strait of Georgia Basin, extended around Texada Island to the northwest and connected with Strait of Juan de Fuca to the south (orange polygon in Figure 3-6); while a smaller domain was used for the HD model (pink polygon in Figure 3-6) to resolve the complex circulation processes in the Fraser River Delta. The HD domain extends inland to Mission as the freshwater discharge source.

Figure 3-7 shows the unstructured grid elements near RBT2. The finest element resolution around the proposed marsh area is approximately 25 m. Figure 3-8 illustrates the overall model bathymetry.

The models were calibrated using measurement data available from DFO to compare model outputs versus actual measurements. The results were found to be in agreement with the measured data. Details are provided in Appendix B.

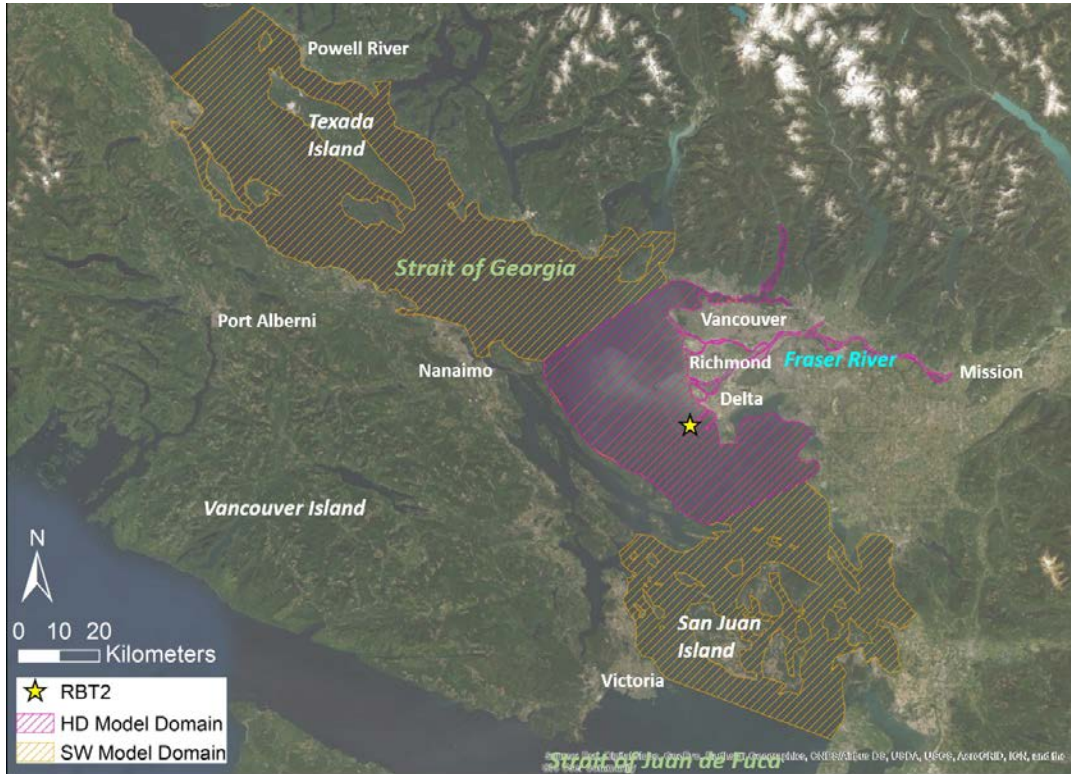


FIGURE 3-6: MODEL DOMAIN FOR THE SPECTRAL WAVE AND HYDRODYNAMIC MODELS

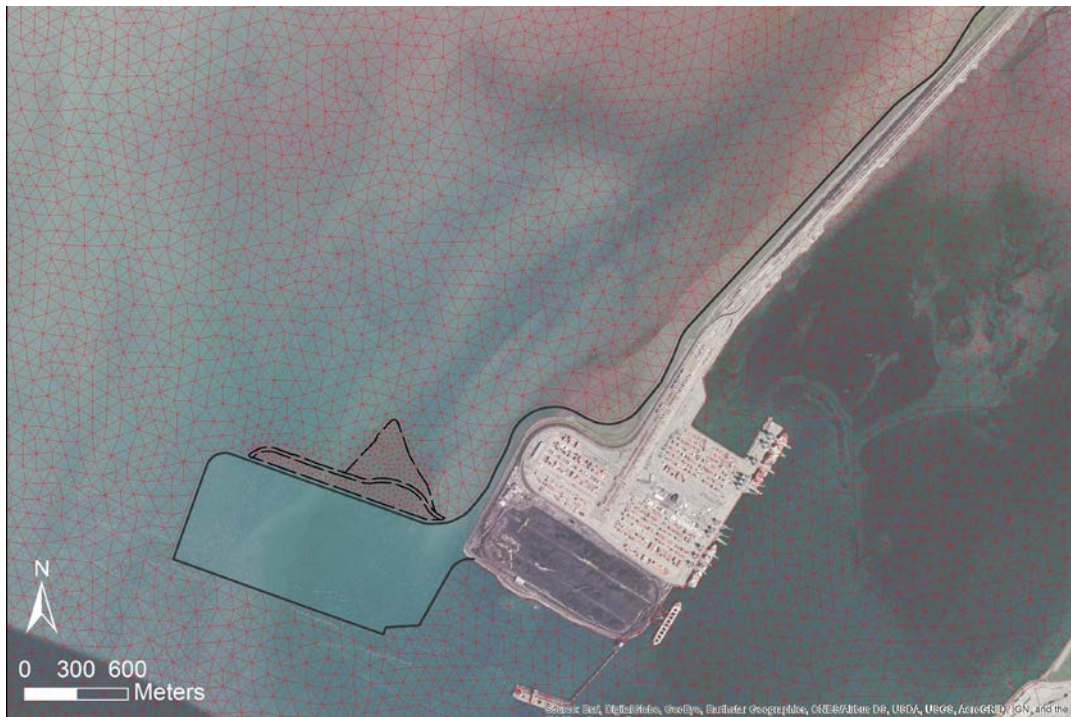


FIGURE 3-7: UNSTRUCTURED GRID ELEMENTS NEAR RBT2

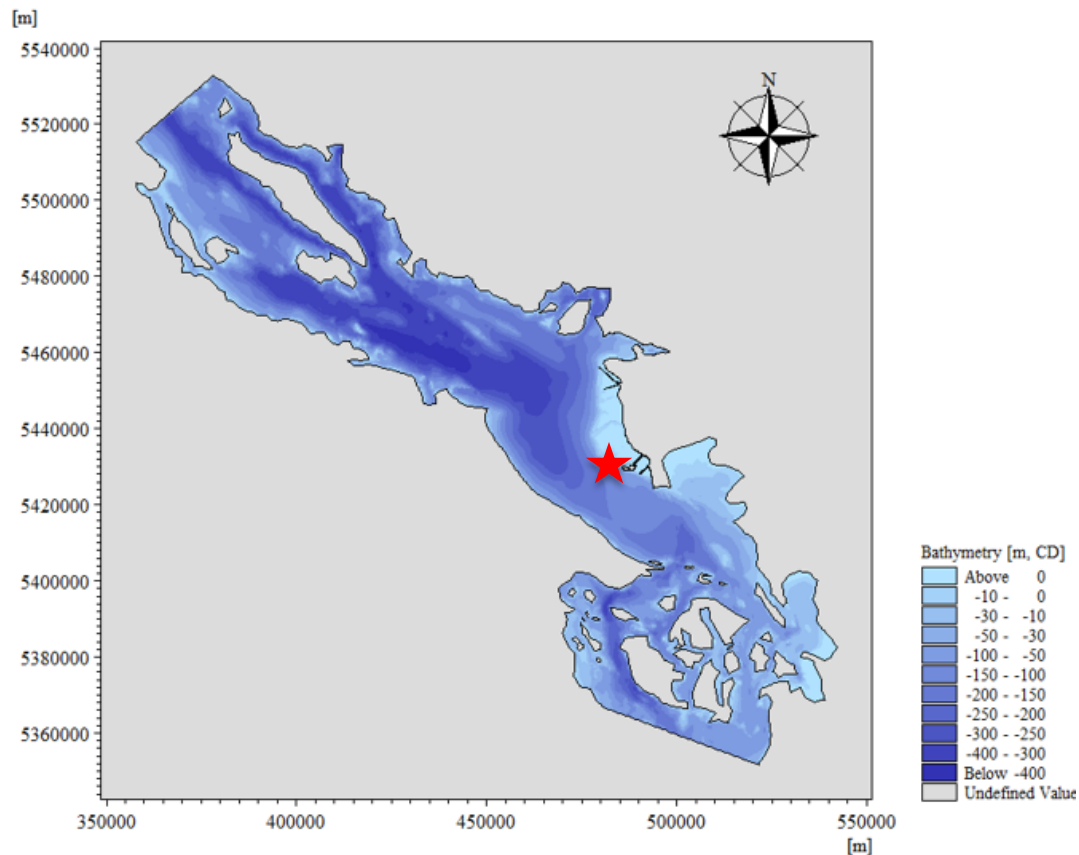


FIGURE 3-8: OVERALL MODEL BATHYMETRY

3.5.2. Peak Tidal Currents

Sediment mobilized by waves and tidal currents may either bury plants, expose roots and rhizomes or during heavy storms even uproot entire plants. Moderate current speeds tend to enhance eelgrass growth. The maximum current that eelgrass can withstand depends to some extent on the sediment type. The optimal range for eelgrass reported in the literature varies considerably, ranging between 0.02 to 1.20 m/s. The habitat is usually patchy (sub-optimal) at the higher velocities.

A recent study using a flume determined that the critical orbital velocity threshold for eelgrass growing in sand was 0.12 m/s and in mud 0.04 m/s, greater velocities resulted in increased sediment resuspension and therefore increased turbidity reducing the amount of photosynthetically active radiation (PAR) that reaches the plants. The roots and rhizomes of eelgrass growing in mud started to be uprooted around 0.15 m/s, while the eelgrass growing in sand could withstand that velocity. Eelgrass establishes best on a fairly level seabed, it would be best to minimize any slopes (Durance, 2014).

The MIKE-21 HD model was used to calculate peak current speeds in the RBT2 project area. The pre- and post-project peak current speeds within the existing and proposed intertidal marsh and subtidal

eelgrass zones are shown graphically in Figure 3-9 and Figure 3-10. Additionally, Figure 3-11 shows the difference of peak currents between the pre- and post-project conditions.

The detailed hydrodynamic analysis was undertaken to evaluate the potential change to the tidal hydrodynamics of the project’s boundary related to the construction of the proposed intertidal marsh and eelgrass beds. Table 3-2 provides the current speeds between the existing and proposed conditions for both intertidal marsh and subtidal eelgrass zones.

Hydrodynamic model results show that the post-project current speeds at the project boundaries are equal or less than the existing values and within the acceptable range to determine bedform impacts. Consequently, the construction of the intertidal marsh and eelgrass beds will have negligible impact to the tidal currents in the existing intertidal marsh and eelgrass zones with peak post-project current speeds of approximately 0.4 m/s. At the northwest corner of the RBT2, the area with the highest current speed (ranges 1 – 1.2 m/s), the current speed reduces at the post-project phase and still remains within the acceptable range defined for optimal eelgrass/marsh zone maximum current speed.

The overall evaluation indicates that post-project current speed are equal or less than pre-project values and construction of the new plan meet all the requirements and design criteria.

TABLE 3-2: DEPTH-AVERAGED CURRENT SPEED FOR EXISTING AND PROPOSED CONDITIONS

Description	Tidal Currents Condition			
	Existing		Proposed	
	Intertidal Marsh	Eelgrass	Intertidal Marsh	Eelgrass
Current Speed Range (m/s)	Below 0.4	0.4 – 0.6	Below 0.1	Below 0.4

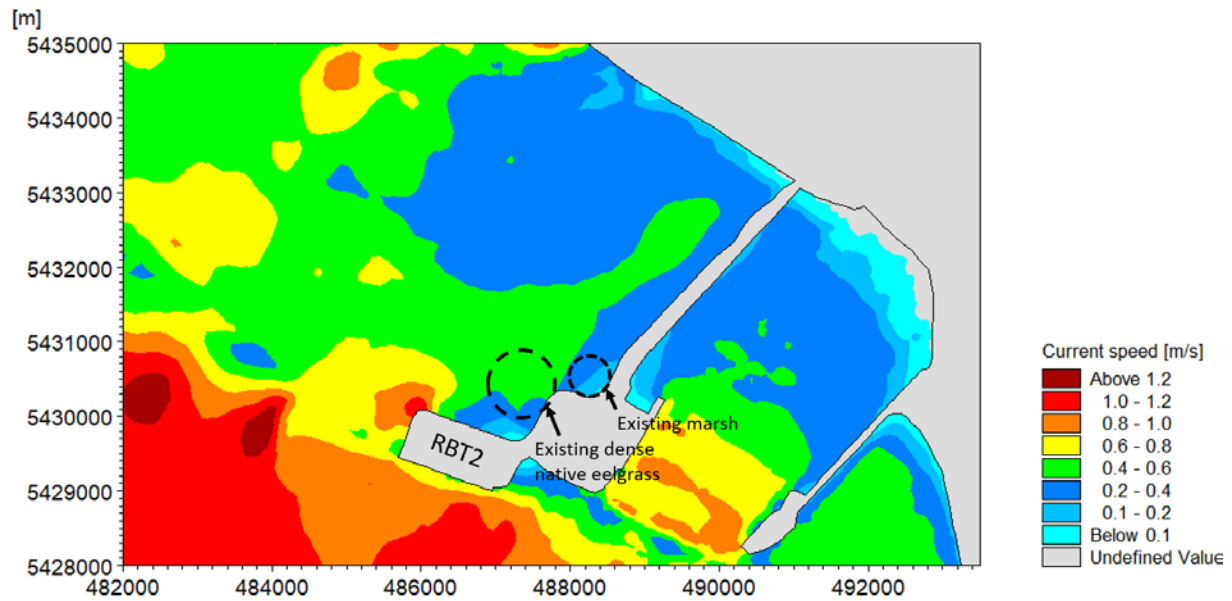


FIGURE 3-9: PRE-PROJECT PEAK CURRENTS

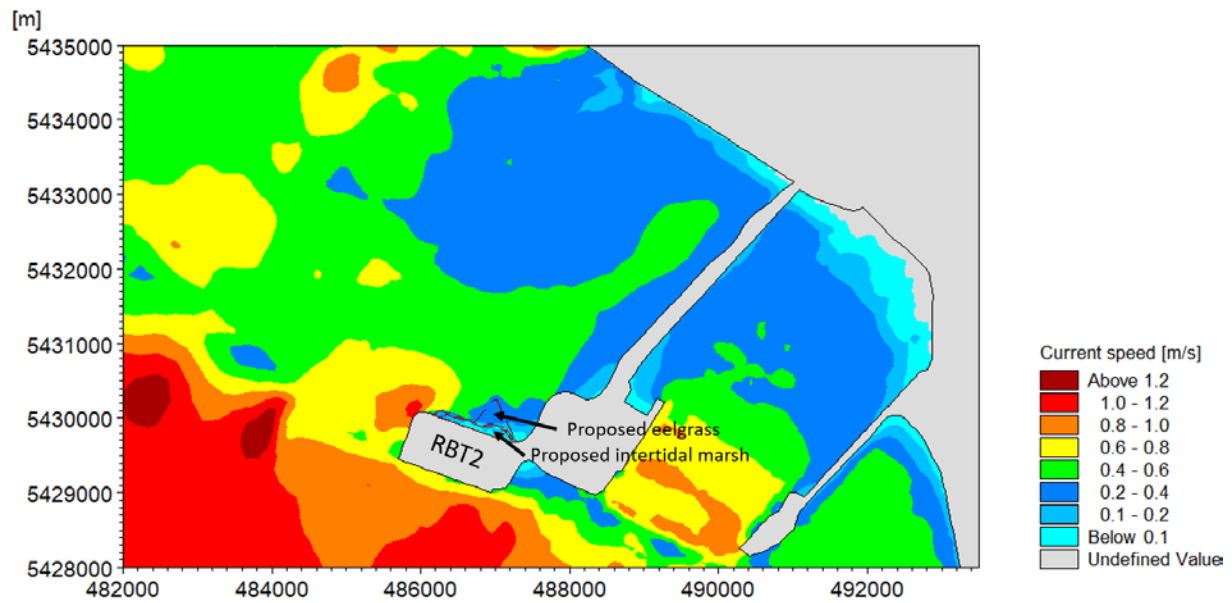


FIGURE 3-10: POST-PROJECT PEAK CURRENTS

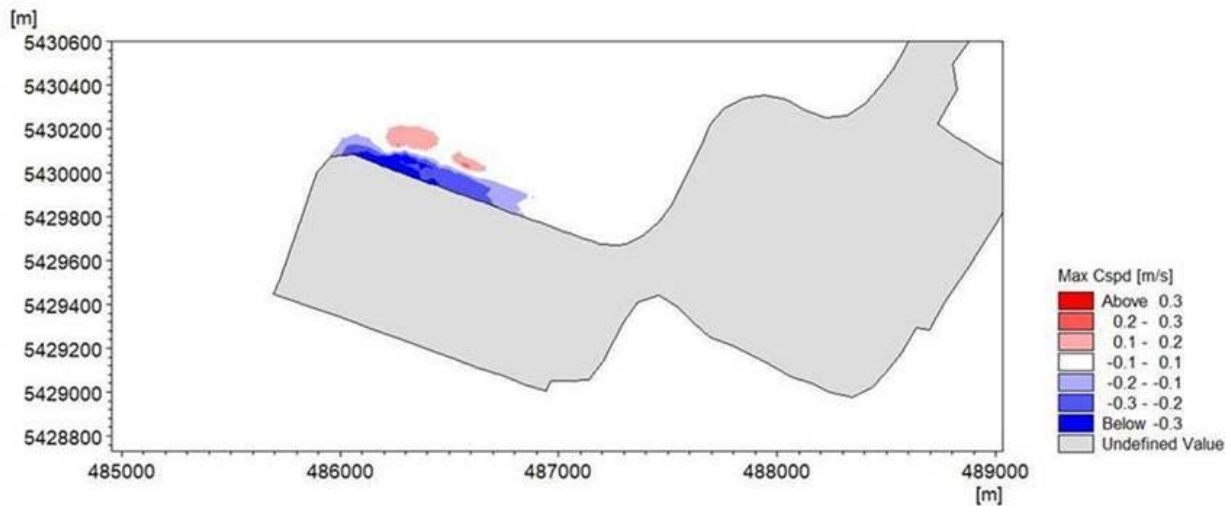


FIGURE 3-11: DIFFERENCE OF PEAK CURRENTS BETWEEN PRE- AND POST-PROJECT CONDITIONS

3.5.3. Permissible Bed Shear Stress

The plasticity index (PI) of materials obtained from surficial soil samples ranged from about 7 to 9, Stantec (2016a). Based on this the permissible shear stress is estimated to be around 2.5 to 3.0 N/m².

Modeling results indicates that although the majority of the existing dense eelgrass or marsh beds fall in the bed shear stress less than 1 N/m² (light blue color), the upper-end threshold can be near 2.5-3 N/m² as some local spots can see eelgrass growth up to this zone, e.g. areas near Canoe Passage and the Deltaport entrance. Figure 3-13 shows the post-construction maximum bed shear stress. Result indicates that the entire onsite marshes area falls in the zone with bed shear stress less than 1 N/m². In addition, there are very minor (nearly non-noticeable) changes from the pre-project condition.

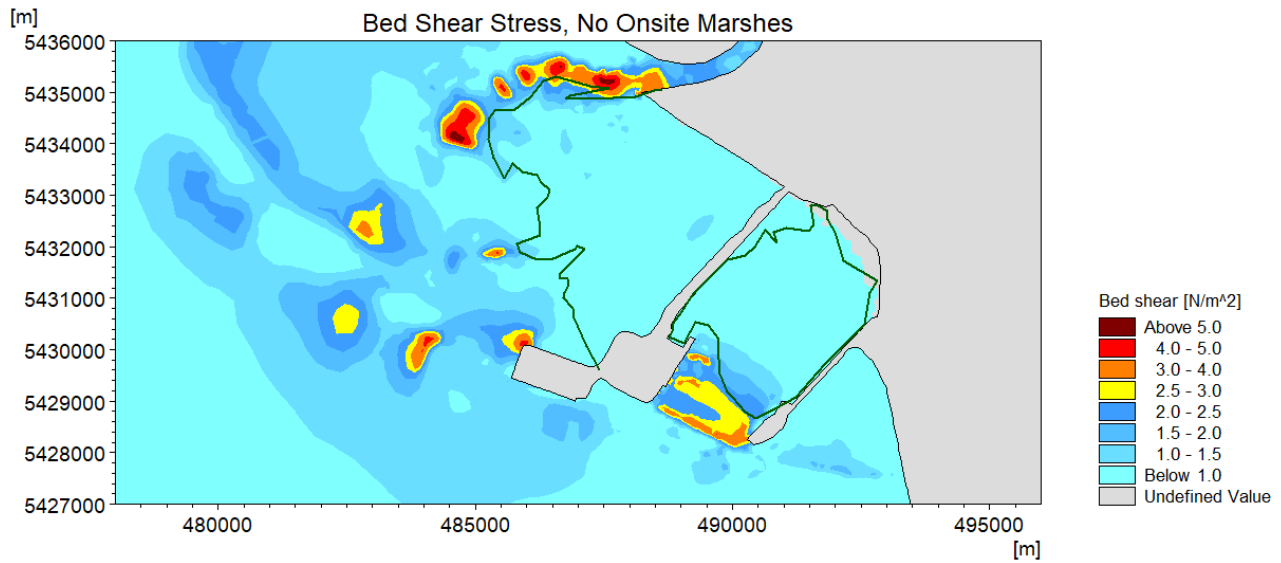


FIGURE 3-12: PRE-PROJECT BED SHEAR STRESS

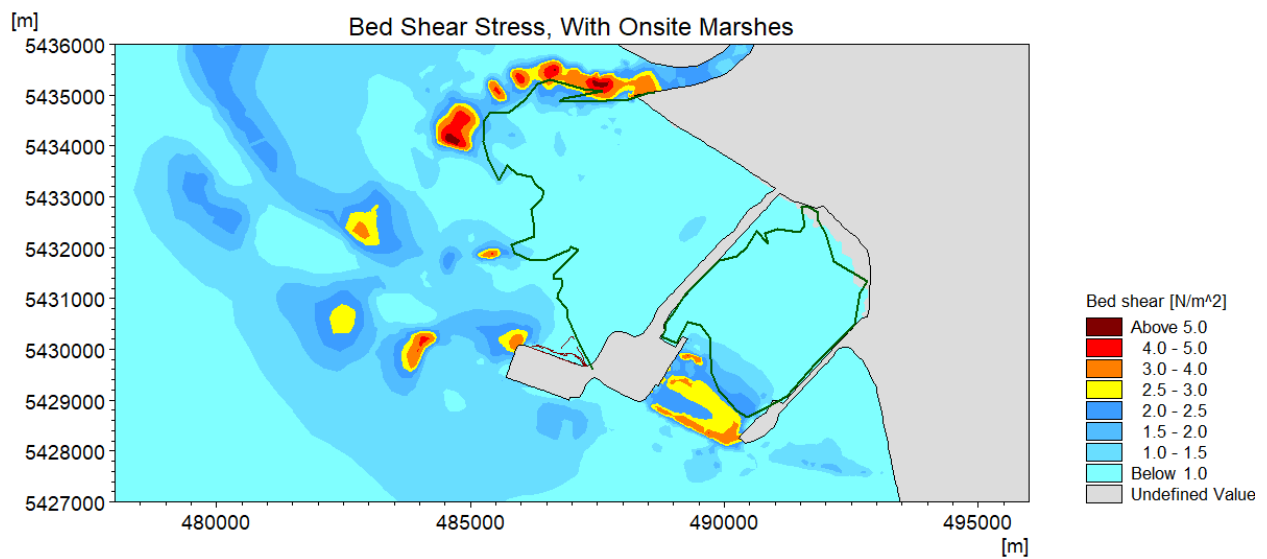


FIGURE 3-13: POST-PROJECT BED SHEAR STRESS

3.5.4. Salinity Modeling, Eelgrass

The optimal salinity range for eelgrass is 10-30 ppt. However, it can tolerate short periods of lower salinity without any reduction in growth. Figure 3-14 and Figure 3-15 illustrate salinity values for the project location based on high slack (The tide cycle between high and low tides) and ebb tides respectively (RBT2 EIS Appendix 9.5-A). Table 3-3 shows the estimated salinity ranges for existing and proposed conditions per the figures.

Therefore, it is concluded that the salinity levels remain within the optimal range for the proposed eelgrass area.

TABLE 3-3: SALINITY RANGES FOR EXISTING AND PROPOSED EELGRASS ZONES

Description	Eelgrass Zone	
	Existing	Proposed
Salinity Range (ppt)	22.5 - 30	10.5 - 30

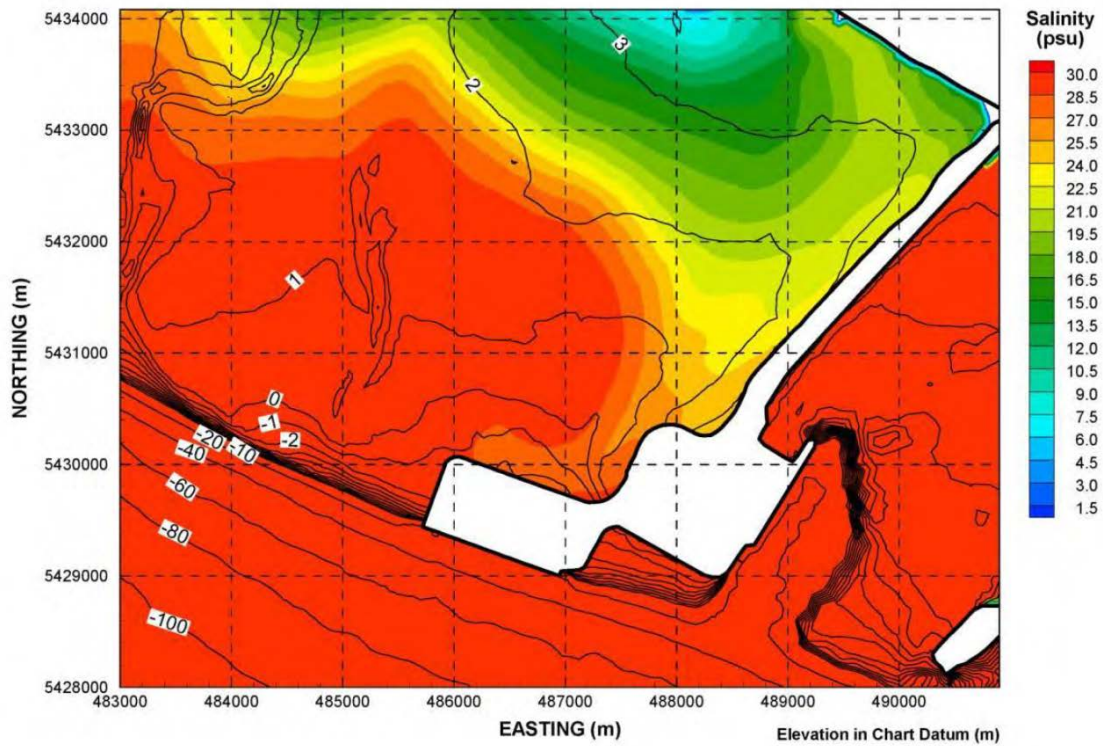


FIGURE 3-14: SALINITIES ASSOCIATED WITH A HIGH SLACK TIDE (RBT2 EIS APPENDIX 9.5-A)

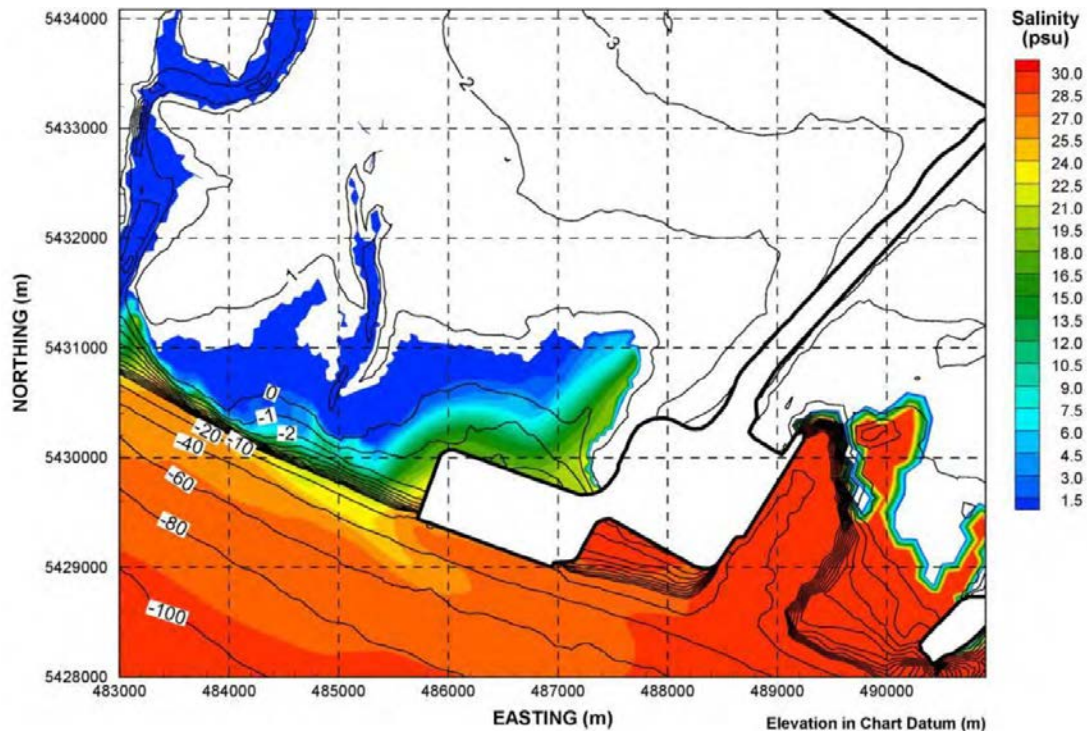


FIGURE 3-15: SALINITIES ASSOCIATED WITH AN EBB TIDE (RBT2 EIS APPENDIX 9.5-A)

3.5.5. Salinity Modeling, Marsh

Intertidal marsh habitat is characterized by emergent vascular plants that exist in the elevation range of +3.2 to +4.8 m CD that is regularly covered during high tides (Williams et al., 2009). At Roberts Bank, typical species of intertidal marsh habitats include sedges such as *Carex lyngbyei* and *Schoenoplectus pungens*, saltgrass species, e.g. *Distichlis spicata*, and succulents including *Sarcocornia pacifica* (Hemmera, 2014). The salinity tolerance of marsh vegetation ranges between 18 to 30 ppt (Williams, 2017).

Table 3-4 shows that salinity levels at the existing tidal marsh area (northwest of Deltaport) are about 25 ppt. The salinity range estimated for the proposed intertidal marsh zone along the northern side of RBT2 is within the optimal range.

TABLE 3-4: SALINTY RANGES FOR EXISTING AND PROPOSED TIDAL MARSH ZONES

Description	Marsh Zone	
	Existing	Proposed
Salinity Range (ppt)	24 - 25.5	18 – 25.5

A discussion of suitable plant ranges is included in the Modeling Report in Appendix B.

3.6. Rock Berm Stone Size

The median stone mass for a stable riprap distribution can be determined using the Hudson equation (CEM, 2011):

$$M_{50} = \frac{\rho_s \times H^3}{K_D \times \left(\frac{\rho_s}{\rho_w} - 1\right)^3 \times \cot \alpha} \quad 3-1$$

Where:

- H Characteristic wave height (H_s)
- M_{50} Median mass of stone armor unit
- ρ_s Mass density of stone
- ρ_w Mass density of water
- K_D Stability coefficient
- α Slope angle

Based on the equation 3-1, median stone mass would be equal to 740 kg.

To meet the minimum gradation requirements, class of 1000 kg is selected for design purposes.

3.7. Rock Berm Crest Elevation

Wave action behind a rock structure can be caused by wave overtopping and wave penetration if the structure is permeable. To achieve a wave environment behind the rock berm suitable for the marsh, the berm was found to require an elevation of +5.2 m CD as shown in Figure 3-16.

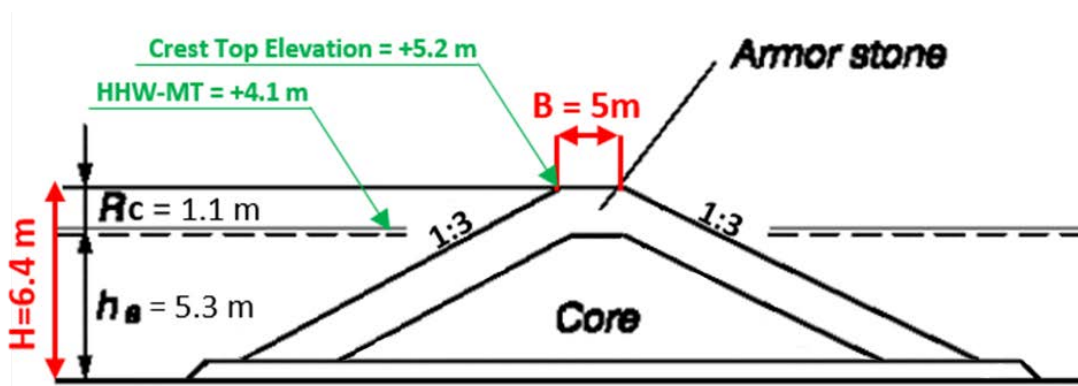


FIGURE 3-16: ROCK BERM CREST ELEVATION AND DETAILS (VAN DER MEER-1991)

3.8. Marsh Channel Dimensions

To provide channel characteristics and dimensions within a tidally dominated coastal landscape, Hughes (2002) and other studies suggest the existence of a relationship between cross-sectional area and tidal prism for tidal channels.

The suggested range of the proposed marsh channel geometry is from a 5 m wide and 0.7 m deep channel to a 10 m wide and 1.4 m deep channel. More details can be found in the Modeling Report in Appendix B.

4. Construction Details

4.1. Site Descriptions

The objective of the proposed marsh works is to raise the elevation of the existing mud flat to support intertidal habitat and allow for protective rock berms. The eelgrass works include fill to raise the seabed to optimum planting levels. The rock reef includes placement of bedding material and boulders to create the reef. Detailed drawings of the sites are included in Appendix A. Note that one side of the containment for the marsh fill would be the proposed RBT2 terminal, therefore, the phasing of the work would need to coincide with at least the outer berm construction. Detailed descriptions of the proposed work are covered in Sections 3.2 and 3.3. Constraints/elevations are covered in Sections 3.4.2 through 3.4.4.

4.2. Construction Features

4.2.1. Marsh and Eelgrass

The marsh area will be surrounded by a protective rock barrier. It is anticipated that the marsh and eelgrass construction would coincide with the RBT2 fills. This would include delivery of rock and fill using the temporary offloading ramps at RBT2.

The sand fill material could be either dredgeate sourced from the Fraser River where annual maintenance dredging occurs, or from offsite quarries depending on Fraser River sand availability. The total quantity of sand fill material required will include 10% for losses and sinkage.

4.2.2. Rock Reef

The rock reef consists of bedding and armor using local quarries placed from a barge. The bedding would be placed in advance to a distance of 15 m beyond the boulders, with boulders placed 1.5 m atop the bedding. The required bedding and rock for the rock reef including 10% tolerance for overbuild and sinkage.

TABLE 4-1: TOTAL HABITAT AREA

Marsh	Rock Berm for Marsh	Eelgrass	Rock Berm for Eelgrass	Rock Reef (no edge effect)	Total
9.4 ha	3.7 ha	9.1 ha	0.3 ha	4.2 ha	26.7 ha

4.3. Site Access

Access to the Marsh site will be via the proposed RBT2 marine terminal. A temporary access berm may be required for placement of the eelgrass material if it is not pumped into place. The reef access will be marine based equipment.

4.4. Construction Methodology

The proposed concept for the onsite Tidal Marsh site is to construct a rock berm encompassing the proposed fill area, place the fill material, and then the channels will be constructed. During construction the access will be from the RBT2 terminal area. The rock would then be placed and shaped using conventional land-based equipment such as excavators and loaders. This would allow rock to be placed over at all tide levels and allow for placement by land-based equipment throughout most of the tidal range. The eelgrass area will include an access road. It is expected that the rock material for the berm will come from a commercial quarry operation and be brought to the site by barge. The eelgrass area will also be filled with sandy material from either dredge offload across the RBT2 terminal, or from commercial quarries and trucked to the location. The fill on the eelgrass area would require a temporary access road, shown in Figure 4-1. The temporary access will be removed upon completion of construction.

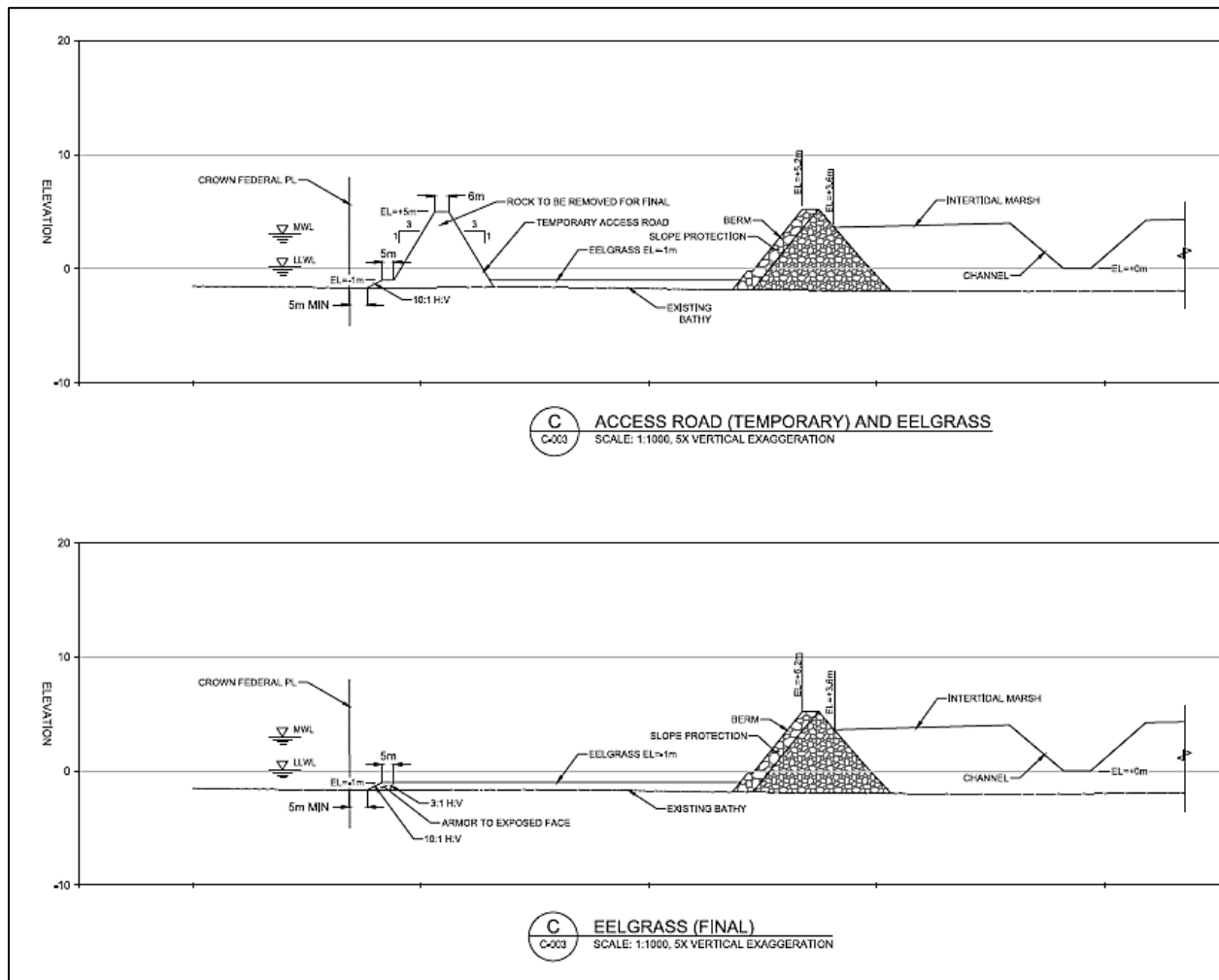


FIGURE 4-1: TEMPORARY ACCESS ROAD

The containment structure will be constructed from rock offloaded to the site from a floating derrick situated in the navigation channel, alongside the jetty. Due to the location of the navigation channel at

the Steveston Bend, the derrick barge would be required to move out of the channel to accommodate passing vessel traffic.

The proposed marsh area requires a significant volume of fill material to raise the elevation in the area between the containment berms. For the estimates the required fill volume for the marsh has been increased by a factor (10%) to allow for settlement, consolidation, and material losses during fill placement. Fill material in the marsh should not be placed until the perimeter has been enclosed.

Log booms will be added to the channel inlets/outlets to discourage infiltration.

The rock reef will be constructed with a derrick barge and rock barges using commercially sourced quarry material and pushed or placed in position. The placement may have limitations during salmon season.

4.5. Construction Schedule

The proposed Project would involve consideration of any constraints, typical production rates, and material delivery. Specifically, the schedule includes:

Fisheries Closures:

- Juvenile Salmon-applies to water column above elevation -5m (March 1 through August 15)
- Crab-applies to seabed below -5.0m (October 15 through March 30)

Marine Mammals:

- Temporary works stoppage if specific marine mammals are observed in the area.

Source/Equipment

- Fraser River Maintenance dredging operates from June 15 through February 28. Actual dates depend on freshet conditions and degree of shoaling in critical areas.
- The rates of offloading will consider the FRPD dredge 309 if the material is supplied through the Fraser River maintenance.
- Rock and some fill materials are assumed to be delivered by barge and spread onsite using land-based equipment mobilized via barge/crane.

Production Rates

- Working hours M-F, 6am-5pm
- Dredge pumpout 2500 m³/day. (Light loaded to allow closer approach to shore).
- Rock placement dyke 1000 m³/day
- Rock placement temp road 800 m³/day
- Rock Reef Bedding 500 m³/day
- Rock Reef Armor 250 m³/day

- Boulder Field placement 100 m³/day
- Onsite excavation/grading 1000 m³/day.
- Planting (Not covered in this document).

Based on these assumptions the schedule indicates a construction period over approximately three (3) months. See Appendix D for schedule layout.

5. Construction Direct Cost

5.1. Cost Considerations

The cost estimate includes supply and installation of the containment berm; marsh fill (sand); eelgrass fill (sand); bedding stone, boulder placement; environmental protection measures; mobilization/demobilization; and Site Modifications. An allowance is included for possible environmental protections measures that may be required by the approving agencies, such as, preparing an environmental protection plan, installing and maintaining turbidity booms. Direct costs are based on anticipated equipment, labor and materials using recently prepared estimates from an RBT2 CDC. The cost estimate excludes marsh planting; indirect costs for the owner's project management, construction administration and third-party consulting fees; and all applicable taxes.

- The costs are limited to the civil construction elements such as rock, fill, mobilization, etc.
- Planting costs are excluded from these estimates.
- The overall 2020 RBT2 CDC opinion of probable cost unit rates were used, where applicable.
- Contingency varies by status of design. The onsite eelgrass and marsh carry a 20% contingency.

For further background on CDC RBT2 cost drivers, estimate methods, limitations and uncertainties refer to Moffatt & Nichol Memorandum RBT2 CDC Summary and Cost Drivers Memo, Rev.A – DRAFT, dated February 28, 2020.

TABLE 5-1: MARSH & EELGRASS CONSTRUCTION DIRECT COST

Note: This section is removed.

TABLE 5-2: ROCK REEF CONSTRUCTION DIRECT COST

Note: This section is removed.

5.2. Limitations

In providing opinions of estimate, it is recognized that the OE has no control over the costs of labour, equipment or materials, over the Contractor's methods of determining prices, or of the bidding climate. Opinions of estimate prepared by the OE are based on reasonable professional judgement and experience and do not constitute a warranty, expressed or implied, that the Contractor's bids or the negotiated price of the Work, or the actual cost of the Work, will not vary from the Client's budget or from any opinion of estimate prepared by the OE.

References

- BC Ministry of Environment (BC MOE), Lower Mainland Region Dyke Mapping. 2007.
- BIEAP-FREMP, 2006. Environmental Management Strategy for Dredging in the Fraser River Estuary. Burrard Inlet Environmental Action Program (BIEAP) and Fraser River Estuary Management Program (FREMP).
- CBA, 2010. Roberts Bank and Sturgeon Bank Reach Overview – Phase 2. A report for BIEAP-FREMP.
- CEM, 2011. U.S. Army Corps of Engineers, Engineering and Design “Coastal Engineering Manual”.
- CHS (Canadian Hydrographic Services), 2005. Charts #3492
- CHS (Canadian Hydrographic Services), 2012. Canadian Tide and Current Tables, Volume 5.
- Durance, C. (2014). Eelgrass Habitat Creation in British Columbia. A Presentation to Port Metro Vancouver. October 1, 2014.
- ENVIRODAT, 2017. Water Quality Data from Fraser River [Data file]. Environment and Climate Change Canada (2017). Retrieved from Environment and Climate Change Canada ENVIRODAT database via data requested on June 23, 2017.
- Environment Canada (EC), 2017. *Historical Hydrometric Data. Daily Discharge*. Environmental and Natural Resources, Government of Canada. <https://wateroffice.ec.gc.ca> .
- Ferguson, A., 1991. Navigation, Dredging and Environment in the Fraser River Estuary. Navigation and Dredging Workshop Report, Fraser River Estuary Management Program, British Columbia, Canada.
- Fisheries Act, RSC 1985, c. F-14. Last amended on August 28, 2019.
- Moffatt & Nichol, 2020. Onsite Offsetting – Marsh and Eelgrass, Roberts Bank Terminal Project Modeling Report.
- Morrison, J., Quick, M.C. and Foreman, M.G.G., 2002. Climate change in the Fraser River watershed: flow and temperature projections. *Journal of Hydrology*, 263, 230-244.
- North Hydraulic Consultants, 2006. Lower Fraser River Hydraulic Model: Recorded Flow Splits. Drawing Prepared for Fraser Basin Council. North Vancouver, BC.
- VFPA, 2015. Roberts Bank Terminal 2 Project, Roberts Bank, Delta, BC – Environmental Impact Statement.
- Roni, P., Timothy, Beechie, T.J., Bilby, R.E., Leonetti, F.E., Pollock, M.M. and Pess, G.R., 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing in Pacific Northwest Watersheds. *North American Journal of Fisheries Management*, 22, 1-20.
- Stantec, 2016. *Borehole Record*. Project: Roberts Bank Terminal 2. Prepared for: Port of Vancouver. Prepared by: Stantec. Dates of Borings: 2016/08/25 to 2016/08/30

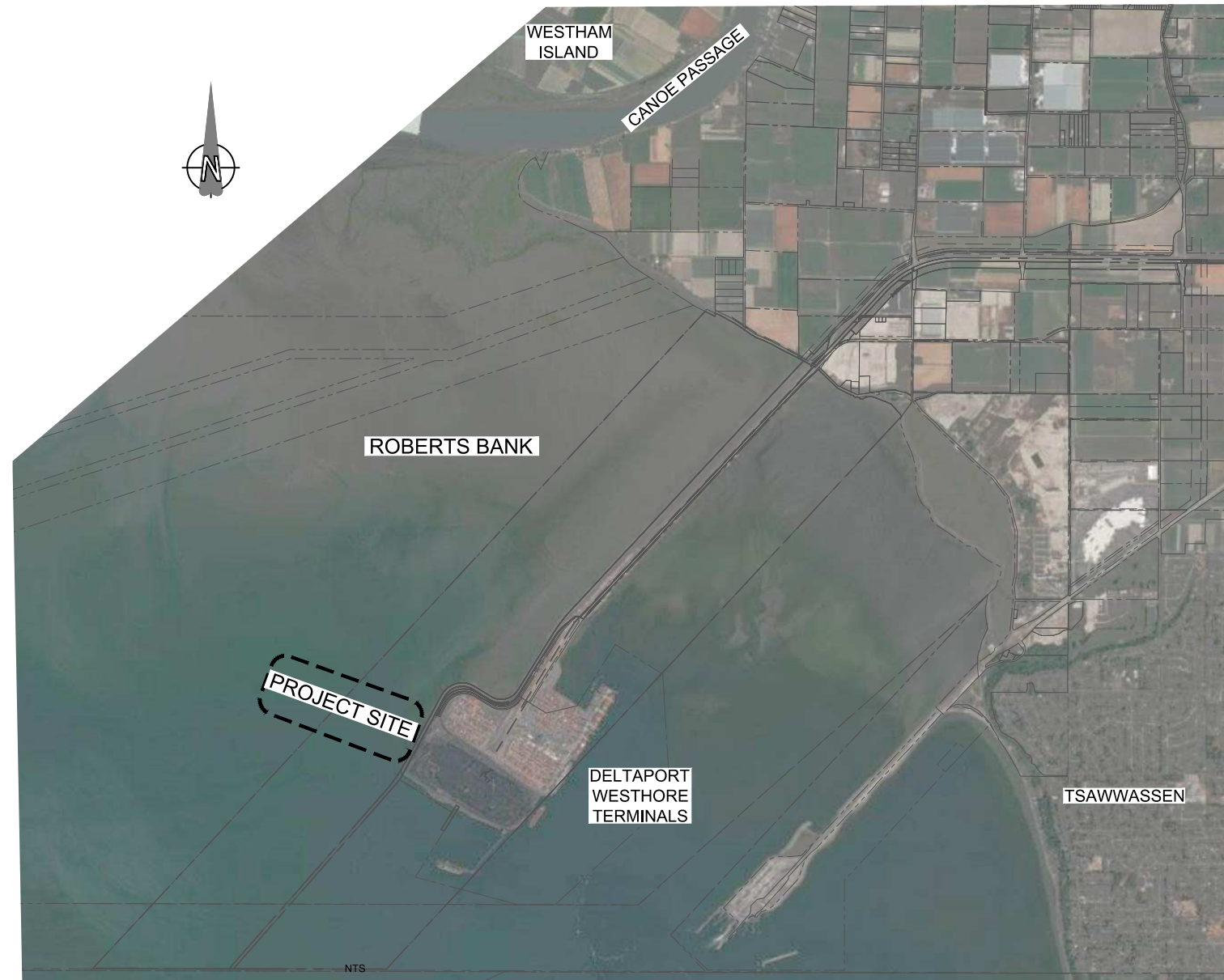
- Thomson, R.E., 1981. Oceanography of the British Columbia Coast. Canadian Special Publication of Fisheries and Aquatic Sciences, 56. Department of Fisheries and Oceans, 291p.
- Williams, G., Zimmermann, A., Ray, D. and Menezes C., 2009. Roberts Bank and Sturgeon Bank Reach Overview – Backgrounder. Prepared for Fraser River Estuary Management Program.
- Williams, G., 2017. Preliminary determination of planting quantities for South Arm Jetty. Prepared for Moffatt & Nichol.
- Williams, G., Millar, J., 2006. Vancouver Port Authority Deltaport Third Berth Proposed Habitat Compensation.
- Worley Parsons (2014). Container Capacity Improvement Program, Roberts Bank Terminal 2, Metocean Desktop Study.

Appendix A: Project Drawings

VANCOUVER FRASER PORT AUTHORITY

HABITAT ENHANCEMENT PROGRAM

ONSITE EELGRASS AND MARSH



VICINITY MAP
NTS

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

1	CHS CHART 3490
Ref.No.	REFERENCE



REVISION IN PROGRESS			
No.	Date	REVISION	Dr'n Ch'd



DESIGN BY	
DRAWN BY	
APPROVED	
DATE	
SCALE	
PMV SITE	

RBT2 OFFSETTING ONSITE EELGRASS AND MARSH TITLE SHEET & LOCATION			
SIZE	DWG.	G-001	SHEET
D			REV.

DRAWING LIST:

- G-001 TITLE SHEET & LOCATION
- G-002 DRAWING INDEX
- G-003 NOTES & SEQUENCE
- G-004 SITE AND ACCESS MAP
- C-001 SURVEY CONTROL
- C-002 PHOTOS - EXISTING CONDITIONS
- C-003 FILL/EXCAVATION PLANS
- C-004 FILL/EXCAVATION SECTIONS- SHEET 1 OF 2
- C-005 FILL/EXCAVATION SECTIONS- SHEET 2 OF 2
- PL-XXX PLANTING PLANS, AMENDMENTS ETC BY OTHERS (5-10 SHEETS)

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

Ref.No.	REFERENCE



IN ASSOCIATION WITH:



No.	Date	REVISION	Dr'n	Ch'd
		REVISION IN PROGRESS		



**PORT of
vancouver**

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	
DRAWN BY	
APPROVED	
DATE	
SCALE	
PMV SITE	

RBT2 OFFSETTING ONSITE EELGRASS AND MARSH DRAWING INDEX			
SIZE	DWG.	G-002	SHEET
D			REV.

TITLE BLOCK: DL-TB.dwg
 DATE: 2020/07/27 - 11:49am
 PATH: C:\VAN\9117 RBT2 Working Folder\CADD\Active_SheetSet (Mitigation)_EELGRASS AND MARSH HABITAT\9117-C-003.dwg



LEGEND:

	EXISTING DENSE NATIVE EELGRASS		VFPA BOUNDARY
	PROPOSED EELGRASS		CROWN FEDERAL PROPERTY LINES
	PROPOSED EELGRASS - ADDITIONAL PLANTING ON EXISTING		(XX) EXISTING BATHY
	PROPOSED INTERTIDAL MARSH		DAYLIGHT LINE
	ROCKY HABITAT IN FINAL FORM		

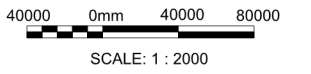
QUANTITIES:

FILL	472,900 m ³
CUT	71,300 m ³
ROCK	223,065 m ³

PROPOSED INTERTIDAL MARSH (INCLUDING CHANNEL)	9.4 ha
PROPOSED CHANNELS	3.5 ha
PROPOSED ROCKY BERM	3.9 ha
ROCK HABITAT IN FINAL FORM	0.3 ha
PROPOSED EELGRASS	9.1 ha

NOTES:

- ACCESS ROAD IS TEMPORARY FOR CONSTRUCTION OF THE EELGRASS PLANTING.
- ALL PROPOSED DESIGN SHALL REMAIN 5m MINIMUM FROM THE VFPA BOUNDARY LINE.
- BATHYMETRIC CONTOURS ARE SHOWN AT A 0.5m INTERVAL.



Ref.No.	REFERENCE

IN ASSOCIATION WITH:
moffatt & nichol

No.	Date	REVISION	Dr'n	Ch'd

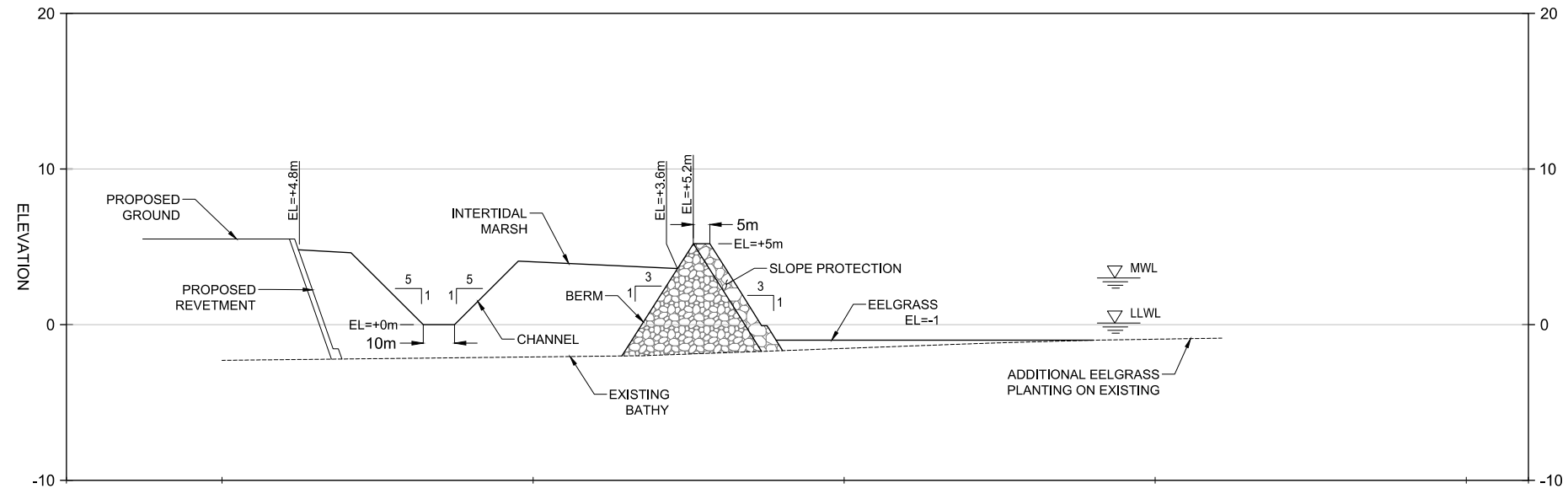
REVISION IN PROGRESS

VANCOUVER FRASER PORT AUTHORITY
 ENGINEERING DEPARTMENT

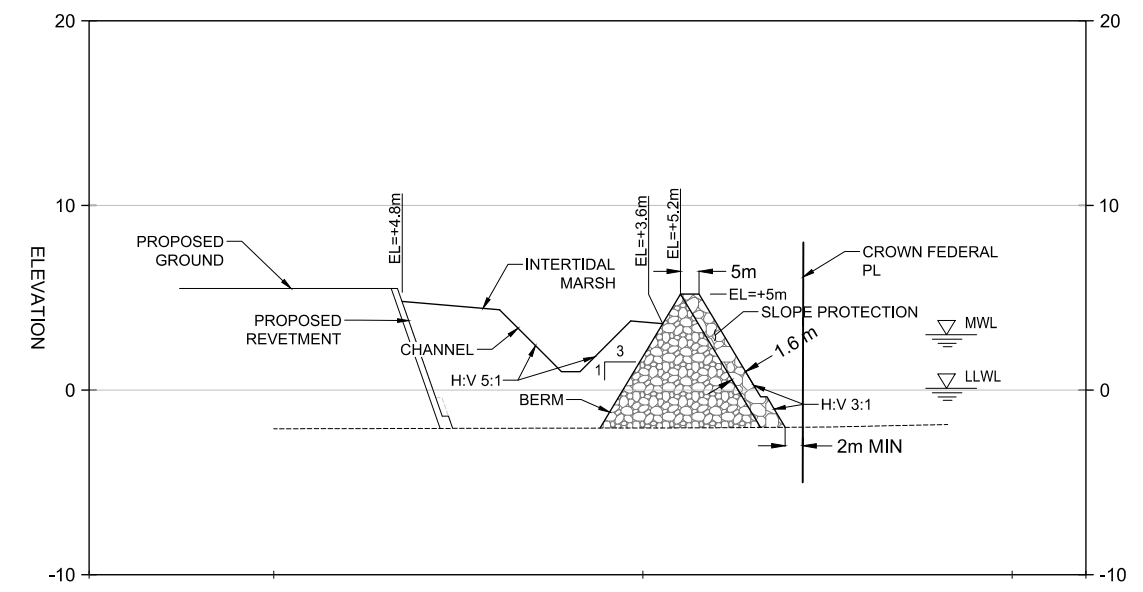
DESIGN BY	
DRAWN BY	
APPROVED	
DATE	
SCALE	
PMV SITE	

RBT2 OFFSETTING
 ONSITE EELGRASS AND MARSH
 PLAN VIEW LAYOUT

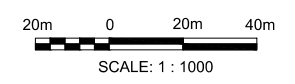
SIZE	Dwg.	C-003	SHEET	REV.
D				



A INTERTIDAL MARSH AND BERM
C-003 SCALE: 1:1000, 5X VERTICAL EXAGGERATION



B INTERTIDAL MARSH AND BERM
C-003 SCALE: 1:1000, 5X VERTICAL EXAGGERATION



IN ASSOCIATION WITH:



DESIGN BY
DRAWN BY
APPROVED
DATE
SCALE
PMW SITE

RBT2 OFFSETTING
ONSITE EELGRASS AND MARSH
SECTIONS, SHEET 1 OF 2

DATE: 2020/07/27 - 10:54am
PATH: Q:\VAN\9117 RBT2 Working Folder\CADD\Active\StreetSet (Mitigation)_EELGRASS AND MARSH HABITAT\9117-C-004.dwg
TITLE BLOCK: DL-TB.dwg

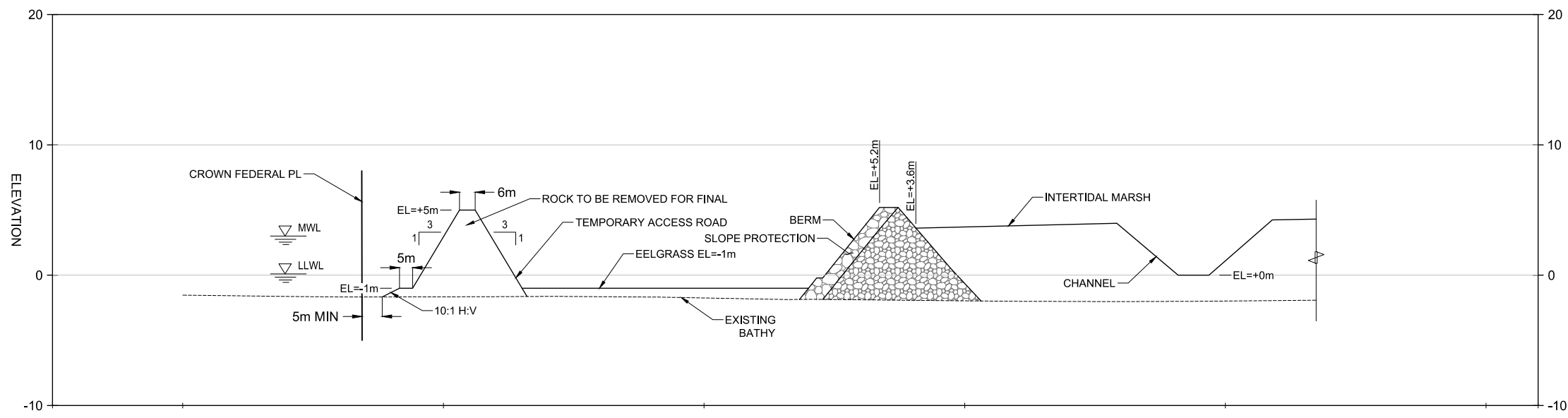
Ref.No.	REFERENCE

No.	Date	REVISION	Dr'n	Ch'd

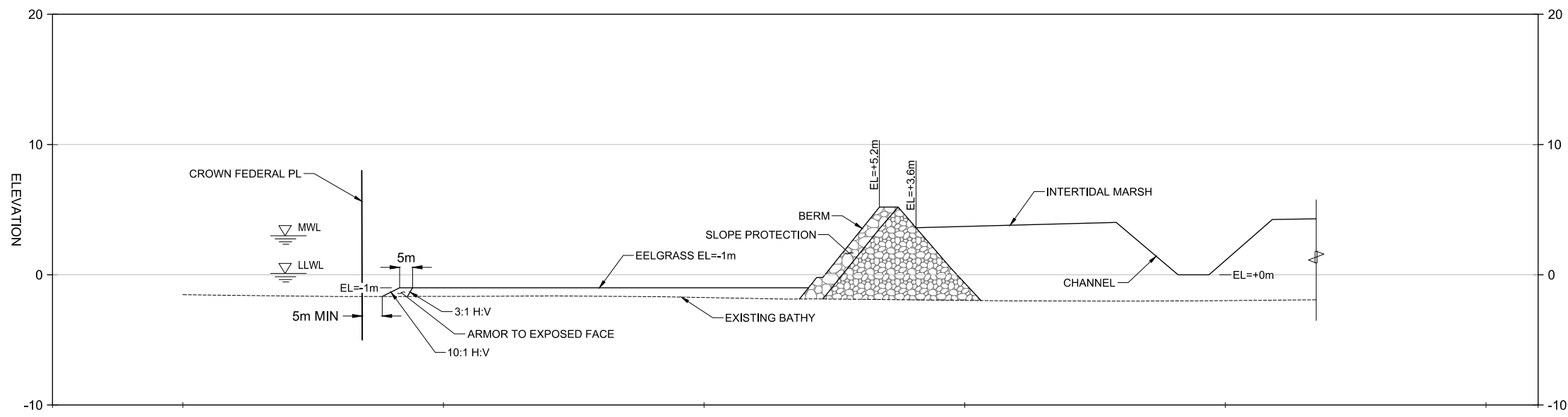
SIZE	DWG.	C-004	SHEET	REV.
D				

TITLE BLOCK: DL-TB.dwg

DATE: 2020/07/27 - 10:54am
PATH: Q:\VAN\9117 RBT2 Working Folder\CADD\Active\SheetSet (Mitigation)\EELGRASS AND MARSH HABITAT\9117-C-005.dwg



C ACCESS ROAD (TEMPORARY) AND EELGRASS
C-003 SCALE: 1:1000, 5X VERTICAL EXAGGERATION



C EELGRASS (FINAL)
C-003 SCALE: 1:1000, 5X VERTICAL EXAGGERATION



Ref.No.	REFERENCE

IN ASSOCIATION WITH:



moffatt & nichol

REVISION IN PROGRESS			
No.	Date	REVISION	Dr'n Ch'd



PORT of vancouver

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

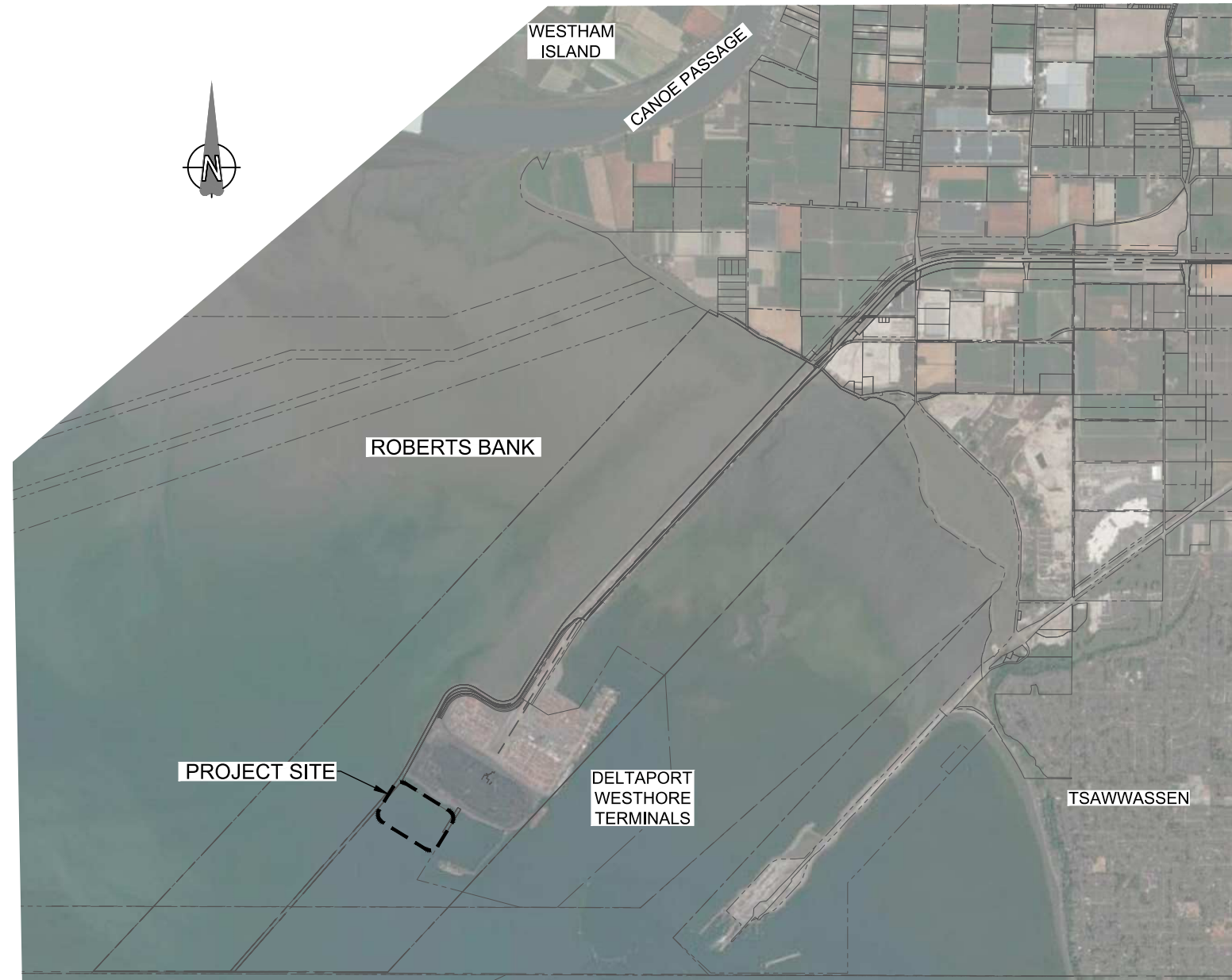
DESIGN BY	
DRAWN BY	
APPROVED	
DATE	
SCALE	
PMV SITE	

RBT2 OFFSETTING			
SIZE	DWG.	SHEET	REV.
D			

VANCOUVER FRASER PORT AUTHORITY

HABITAT ENHANCEMENT PROGRAM

ROCKY REEF



VICINITY MAP
NTS

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

DATE: 2020/07/24 - 11:25am
PATH: C:\VAN\9117_RB22_Working Folder\CADD\Active\SheetSet (Mitigation)_BOULDER_FIELD\9117-G-001.dwg
TITLE BLOCK: DL-TE.dwg

1	CHS CHART 3490
Ref.No.	REFERENCE

IN ASSOCIATION WITH:



moffatt & nichol

REVISION IN PROGRESS			
1	7/24/20	ISSUED FOR CLIENT REVIEW	AA
No.	Date	REVISION	Dr'n Ch'd



PORT of vancouver

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT



DESIGN BY	
DRAWN BY	
APPROVED	
DATE	
SCALE	
PMV SITE	

RBT2 OFFSETTING ROCKY REEF TITLE SHEET & LOCATION				
SIZE	DWG.	G-001	SHEET	REV.

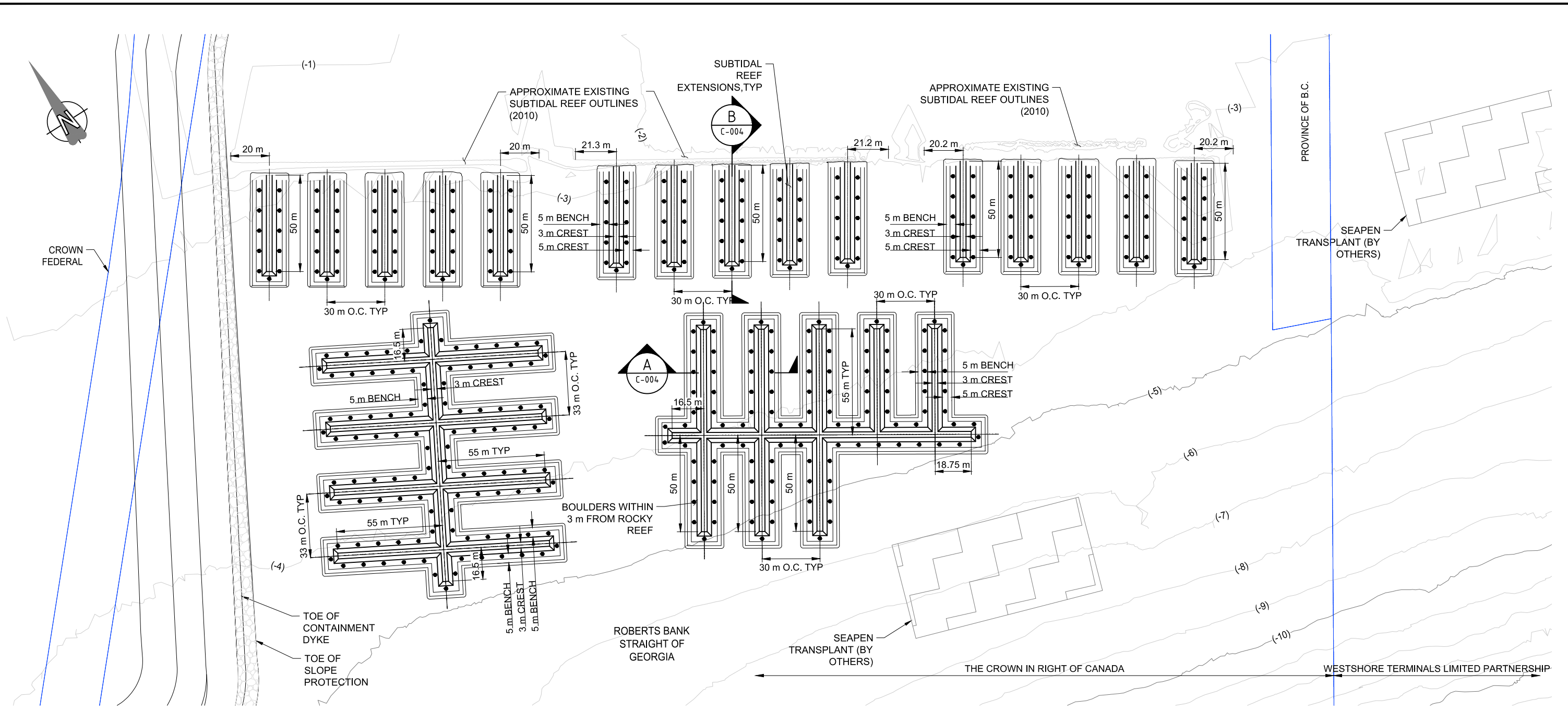
DRAWING LIST:

- G-001 TITLE SHEET & LOCATION
- G-002 DRAWING INDEX
- G-003 NOTES & SEQUENCE
- G-004 SITE AND ACCESS MAP
- C-001 SURVEY CONTROL
- C-002 PHOTOS - EXISTING CONDITIONS
- C-003 FILL/EXCAVATION PLAN
- C-004 FILL/EXCAVATION SECTIONS SHEET
- PL-XXX PLANTING PLANS, AMENDMENTS ETC BY OTHERS (5-10 SHEETS)

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

	 moffatt & nichol	IN ASSOCIATION WITH:	REVISION IN PROGRESS	 PORT of vancouver	DESIGN BY DRAWN BY APPROVED DATE SCALE PMV SITE	RBT2 OFFSETTING ROCKY REEF DRAWING INDEX	
Ref.No.	REFERENCE		1	7/24/20	ISSUED FOR CLIENT REVIEW	AA	
			No.	Date	REVISION	Dr'n Ch'd	VANCOUVER FRASER PORT AUTHORITY ENGINEERING DEPARTMENT
							SIZE D DWG. G-002 SHEET REV.

TITLE BLOCK: DL-TB.dwg
 DATE: 2020/07/24 - 11:28am
 PATH: Q:\VAN\9117 RBT2 Working Folder\CADD\Active\StreetSet (Mitigation)\BOULDER FIELD\9117-C-003.dwg



LEGEND:

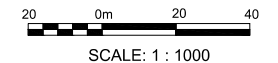
- SLOPE PROTECTION
- CROWN FEDERAL PROPERTY LINES
- (XX) EXISTING BATHY

QUANTITIES:

ARMOUR RIPRAP	15,100 m ³
BEDDING	17,500 m ³
BOULDER	422 m ³
EXISTING SUBTIDAL REEF	0.7 ha
PROPOSED AREA	4.0 ha
AREA 5m FROM EDGE OF REEF	5.64 ha
AREA 10m FROM EDGE OF REEF	7.14 ha

NOTES:

1. BATHYMETRIC CONTOURS ARE SHOWN AT A 0.5m INTERVAL.
2. BOULDERS SHALL BE PLACED THROUGHOUT THE BENCH OF EACH PROPOSED SUBTIDAL REEF IN CLUSTERS OF UP TO 3 BOULDERS. BOULDER DENSITY SHALL AVERAGE 1 PER 9m² (1 CLUSTER PER 27m²) THE BOULDERS SHALL NOT BE PLACED WITHIN 2m OF THE EDGE OF ROCK BEDDING. CLUSTERS PLACES AT 10.5m O.C.
3. ALL ELEVATION OF CREST TO BE 1.5m ABOVE BEDDING.



Ref.No.	REFERENCE
---------	-----------

IN ASSOCIATION WITH:

moffatt & nichol

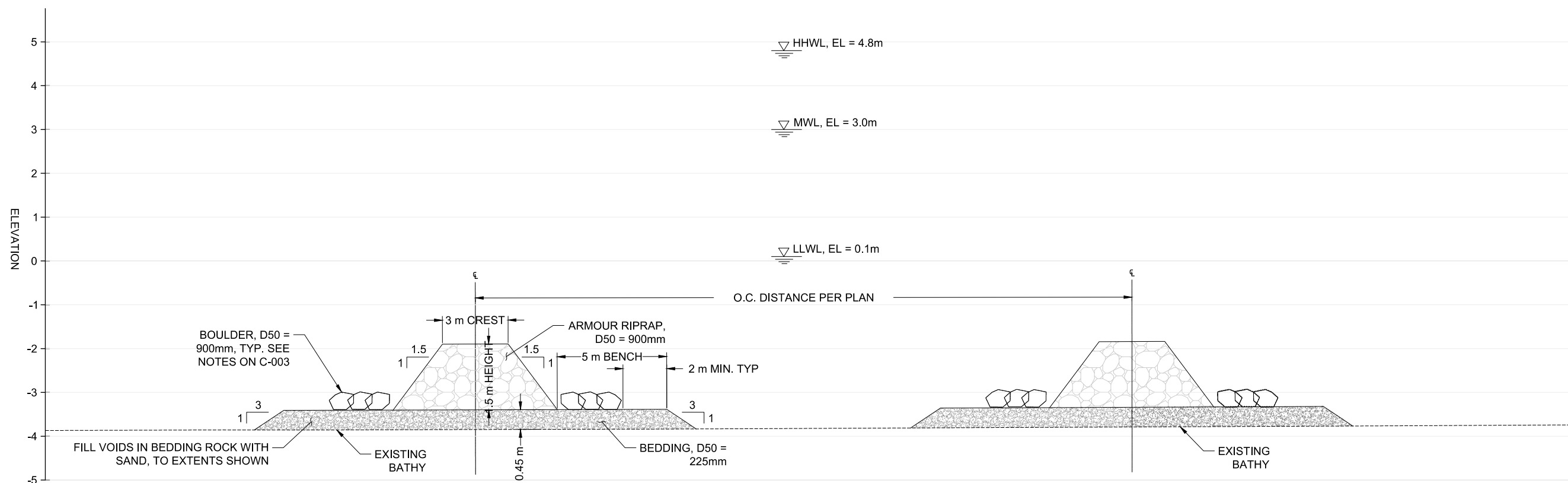
REVISION IN PROGRESS			
1	7/24/20	ISSUED FOR CLIENT REVIEW	
Rev. No.	Date	REVISION	Dr'n Ch'd

PORT of vancouver

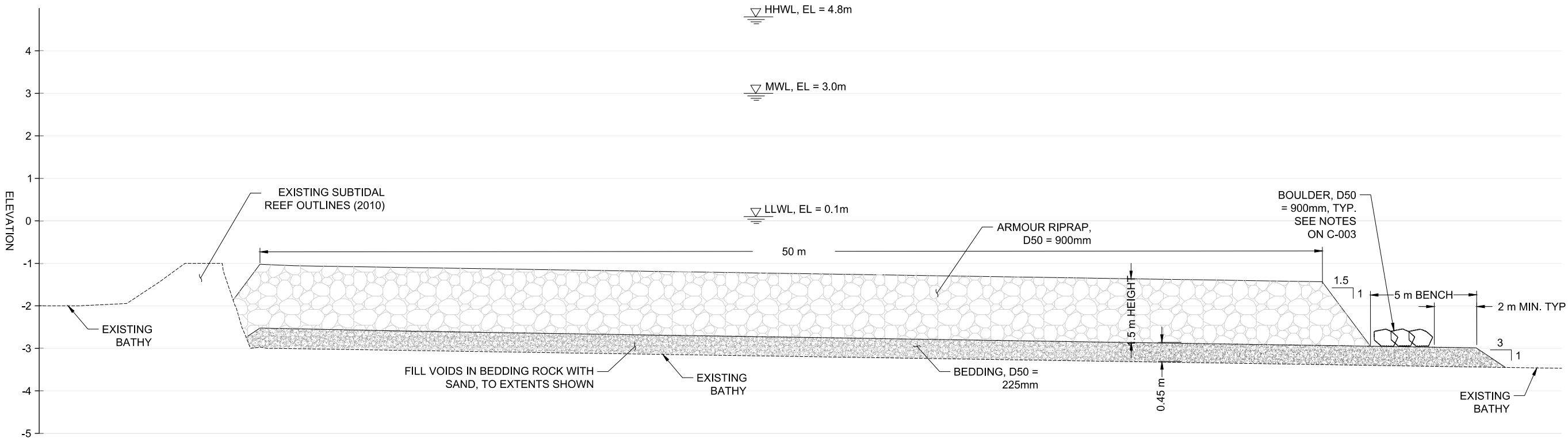
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

RBT2 OFFSETTING ROCKY REEF PLAN VIEW LAYOUT	
DESIGN BY	
DRAWN BY	
APPROVED	
DATE	
SCALE	
FMW SITE	
SIZE D	DWG. C-003
SHEET	REV.

TITLE BLOCK: DL-TB.dwg



SUBTIDAL ROCK REEF TYPICAL CROSS SECTION
SCALE: 1:100, 2X VERTICAL EXAGGERATION



SUBTIDAL ROCK REEF EXTENSIONS TYPICAL CROSS SECTION
SCALE: 1:100, 2X VERTICAL EXAGGERATION

DATE: 2020/07/24 - 11:29am
PATH: Q:\VAN\9117 RBT2 Working Folder\CADD\Active\SheetSet (Mitigation)_BOULDER FIELD\9117-C-004.dwg

Ref.No.	REFERENCE

IN ASSOCIATION WITH:

moffatt & nichol

No.	Date	REVISION	Dr'n	Ch'd
1	7/24/20	ISSUED FOR CLIENT REVIEW	AA	

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	
DRAWN BY	
APPROVED	
DATE	
SCALE	
PMW SITE	

RBT2 OFFSETTING
ROCKY REEF
ROCKY REEF SECTIONS

SIZE: D DWG: C-004 SHEET: REV:

Appendix B: Coastal Analysis Report

Document Verification

Client	Vancouver Fraser Port Authority
Project name	RBT2 On Site Offsetting – Marsh and Eelgrass
Document title	Modeling Report
Date	August 13, 2020
Project number	9117-0

Revision	Description	Issued by	Date	Checked
A	Draft	E. Omranian	May 29, 2020	M. Jorgensen
0	Final	M. Jorgensen	Aug 13, 2020	A. Alcorn

Produced by:
Moffatt & Nichol, Vancouver
Suite 301 - 777 West Broadway
Vancouver BC V5Z 4J7 Canada
T +1-604-707-9004
www.moffattnichol.com

Table of Contents

Document Verification.....	i
Executive Summary.....	v
Disclaimer.....	vi
Glossary.....	vii
1. Introduction.....	1
2. Site Description	2
3. Hydrographic Conditions.....	4
3.1. Water Levels.....	4
3.1.1. Astronomical Tides	4
3.1.2. Extreme Water Levels	4
3.2. Winds.....	5
4. Numerical Modelling Development	10
4.1. Model Description	10
4.2. Model Grid and Bathymetry	11
4.3. SW Model Calibration	14
4.4. HD Model Calibration.....	16
5. Design Criteria for Onsite Habitat Features	19
5.1. Peak Tidal Currents	19
5.2. Permissible Bed Shear Stress	21
5.3. Biological Design Criteria.....	24
5.3.1. Eelgrass Salinity Range.....	24
5.3.2. Intertidal Marsh Salinity Range	26
5.3.3. Intertidal Marsh Elevation Range.....	27
5.3.4. Intertidal Marsh Wave Tolerance.....	28
5.3.5. Rock Berm Stone Size.....	29
5.3.6. Rock Berm Crest Elevation.....	30
5.3.7. Marsh Channel Dimensions.....	31
6. Conclusions	35
7. References	36

List of Figures

Figure 2-1: Roberts Bank Terminal 2 (eelgrass, intertidal marsh, rocky reef) location.....	2
Figure 2-2: Example of existing marsh.....	3
Figure 3-1: Annual wind rose at sandheads.....	6
Figure 3-2: Wind-wave model data output locations.....	7
Figure 3-3: Significant wave height under 50 knots wind.....	8
Figure 3-4: Peak wave period under 50 knots wind.....	9
Figure 4-1: Meteocean data stations.....	10
Figure 4-2: Model domain for the spectral wave and hydrodynamic models.....	12
Figure 4-3: Unstructured grid elements near RBT2.....	12
Figure 4-4: Overall model bathymetry.....	13
Figure 4-5: Model bathymetry near RBT2 with onsite marshes.....	13
Figure 4-6: Selected winter storm event for wave calibration.....	14
Figure 4-7: Measured vs modelled H_s at Halibut Bank.....	15
Figure 4-8: Measured vs modelled T_p at Halibut Bank.....	15
Figure 4-9: Measured vs modelled water levels at DFO tide gauges.....	17
Figure 4-10: Measured vs modelled tidal constituents at DFO tide gauges.....	18
Figure 4-11: Measured vs modelled flow split.....	18
Figure 5-1: Pre-project peak currents.....	20
Figure 5-2: Post-project peak currents.....	21
Figure 5-3: Difference of peak currents between pre- and post-project conditions.....	21
Figure 5-4: Pre-project bed shear stress.....	24
Figure 5-5: Post-project bed shear stress.....	24
Figure 5-6: Salinities associated with a high slack tide.....	25
Figure 5-7: Salinities associated with an ebb tide.....	26
Figure 5-8: Wave height tolerance for marsh species, Douglass (2004).....	29
Figure 5-9: Rock berm crest elevation and details (van der Meer-1991).....	31
Figure 5-10: Equilibrium cross-section area versus tidal prism data.....	32
Figure 5-11: Cross-sectional area vs. peak discharge for sheltered tidal channels (friedrichs,1995).....	33
Figure 5-12: Width-to-depth ratio for tidal channels (adopted from hughes 2011).....	34

List of Tables

Table 3-1: Tidal datums for Tsawwassen (CHS, 2005).....	4
Table 3-2: Extreme high water levels estimated at RBT2 (Worley Parsons, 2014).....	4
Table 3-3: Extreme wind speeds at Sandheads (Worley Parsons, 2014).....	5
Table 3-4: Detailed wave characteristics for data-point locations	7
Table 3-5: Detailed normal tide Peak wave period for data-point locations	8
Table 5-1: Depth-average tidal Current velocities for existing and proposed conditions.....	20
Table 5-2: Unified soil classification system (abbreviated).....	22
Table 5-3: Typical permissible shear stress, reproduced from FHWA (2005).....	23
Table 5-4: Salinity ranges for existing and proposed eelgrass zones.....	25
Table 5-5: Salinity ranges for existing and proposed tidal marsh zones.....	26
Table 5-6: Project and regional marsh habitat salinity tolerance.....	27
Table 5-7: Project and regional marsh habitat elevation ranges	28
Table 5-8: Gradation of rock sizes in each class of riprap	30

Executive Summary

This report summarizes the design criteria for intertidal marsh and subtidal eelgrass zones as well as using hydraulic engineering manual to design a rock containment berm at northern side of Roberts Bank Terminal 2 (RBT2) site. Hydrodynamic modeling results (M&N 2020) are used to study and better understand the overall condition of the project's site.

A discussion of the existing site conditions is provided in Chapter 2. By characterizing the existing site conditions the design concept was developed.

A summary of metocean data utilized for the study including water levels, wind, and waves provided in Chapter 3.

Subsequently, the numerical modeling details are indicated in Chapter 4 and the criteria used to support the design of the site are discussed in Chapter 5. The Project design criteria also include a description of the functional, physical and biological criteria as well as the applied engineering standards using the Coastal Engineering Manual (CEM) developed by U.S. Army Corp of Engineers.

Overall conclusions are summarized in Chapter 6.

Findings and Conclusions

1. Post-project current speeds around the peripheral boundaries and RBT2 project areas are equal to or less than pre-project values.
2. The proposed marsh and eelgrass habitat meets the outline design criteria.
3. The salinity range in the area proposed for new eelgrass plantings is within the optimal range for eelgrass.
4. The salinity range estimated for the proposed intertidal marsh zone along the northern side of RBT2 is within the optimal range for select salt-tolerant species.
5. Based on the salinity tolerance parameters; Saltgrass, pickleweed, and Arrowgrass species may be candidate marsh vegetation for the onsite marsh habitat. The preferred elevation range for these species is 3.6 to 5.0 m Chart Datum (CD).
6. The freeboard of the rock berm is estimated to be 1.1 m above Higher High Water-Mean Tide (HHW-MT) with a crest width of 5 m. This corresponds to a crest elevation of about +5.2 m CD.
7. The suggested marsh channel dimensions range from a 5 m wide and 0.7 m deep channel to a 10 m wide and 1.4 m deep channel.

Disclaimer

Moffatt & Nichol devoted effort consistent with (i) the level of diligence ordinarily exercised by competent professionals practicing in the area under the same or similar circumstances, and (ii) the time and budget available for its work, to ensure that the data contained in this report is accurate as of the date of its preparation. This study is based on estimates, assumptions and other information developed by Moffatt & Nichol from its independent research effort, general knowledge of the industry, and information provided by and consultations with the client and the client's representatives. No responsibility is assumed for inaccuracies in reporting by the Client, the Client's agents and representatives, or any third-party data source used in preparing or presenting this study. Moffatt & Nichol assumes no duty to update the information contained herein unless it is separately retained to do so pursuant to a written agreement signed by Moffatt & Nichol and the Client.

Moffatt & Nichol's findings represent its professional judgment. Neither Moffatt & Nichol nor its respective affiliates, makes any warranty, expressed or implied, with respect to any information or methods disclosed in this document. Any recipient of this document other than the Client, by their acceptance or use of this document, releases Moffatt & Nichol and its affiliates from any liability for direct, indirect, consequential or special loss or damage whether arising in contract, warranty (express or implied), tort or otherwise, and irrespective of fault, negligence and strict liability.

This report may not be used in conjunction with any public or private offering of securities, debt, equity, or other similar purpose where it may be relied upon to any degree by any person other than the Client. This study may not be used for purposes other than those for which it was prepared or for which prior written consent has been obtained from Moffatt & Nichol.

Possession of this study does not carry with it the right of publication or the right to use the name of "Moffatt & Nichol" in any manner without the prior written consent of Moffatt & Nichol. No party may abstract, excerpt or summarise this report without the prior written consent of Moffatt & Nichol. Moffatt & Nichol has served solely in the capacity of consultant and has not rendered any expert opinions in connection with the subject matter hereof. Any changes made to the study, or any use of the study not specifically identified in the agreement between the Client and Moffatt & Nichol or otherwise expressly approved in writing by Moffatt & Nichol, shall be at the sole risk of the party making such changes or adopting such use.

This document was prepared solely for the use by the Client. No party may rely on this report except the Client or a party so authorised by Moffatt & Nichol in writing (including, without limitation, in the form of a reliance letter). Any party who is entitled to rely on this document may do so only on the document in its entirety and not on any excerpt or summary. Entitlement to rely upon this document is conditioned upon the entitled party accepting full responsibility and not holding Moffatt & Nichol liable in any way for any impacts on the forecasts or the earnings from the project resulting from changes in "external" factors such as changes in government policy, in the pricing of commodities and materials, price levels generally, competitive alternatives to the project, the behaviour of consumers or competitors and changes in the owners' policies affecting the operation of their projects.

This document may include "forward-looking statements". These statements relate to Moffatt & Nichol's expectations, beliefs, intentions or strategies regarding the future. These statements may be identified by the use of words like "anticipate," "believe," "estimate," "expect," "intend," "may," "plan," "project," "will," "should," "seek," and similar expressions. The forward-looking statements reflect Moffatt & Nichol's views and assumptions with respect to future events as of the date of this study and are subject to future economic conditions, and other risks and uncertainties. Actual and future results and trends could differ materially from those set forth in such statements due to various factors, including, without limitation, those discussed in this study. These factors are beyond Moffatt & Nichol's ability to control or predict. Accordingly, Moffatt & Nichol makes no warranty or representation that any of the projected values or results contained in this study will actually be achieved.

This study is qualified in its entirety by, and should be considered in light of, these limitations, conditions and considerations.

Glossary

CD	Chart Datum
CHS	Canadian Hydrographic Service
cm	Centimetres
DHI	Danish Hydraulic Institute
HD	Hydrodynamic
GD	Geodetic Datum
HA	Hectare
HHW-LT	Higher High Water - Large Tide
HHW-MT	Higher High Water - Mean Tide
H_s	Significant Wave Height
kg	Kilogram
m	metre
m	Metres
M&N	Moffatt & Nichol
m/s	Metres per second
mm	Millimetres
N	Newtons
N/m^2	Newton per square metre
NAD83	North American Vertical Datum of 1983
OOF	Onsite Offset Feature
PAR	Photosynthetically Active Radiation
PI	Plasticity Index
ppt	Parts per thousand
psu	Practical salinity unit
RBT2	Roberts Bank Terminal 2
SI	Système International
SW	Spectral Wave
T_p	Peak Wave Period
US	United States
USCS	Unified Soil Classification System
UTM	Universal Transverse Mercator
VFPA	Vancouver Fraser Port Authority

1. Introduction

The Roberts Bank Terminal 2 (RBT2) On Site Offsetting project (Project) consists of an intertidal marsh site and a subtidal eelgrass zone located north of the proposed RBT2 terminal and southwest of the existing Deltaport Terminal, British Columbia. In general, the Project involves converting lower-value subtidal areas into higher value eelgrass habitat through the construction of rock containment berms followed by placement of sand fill material and transplanting of eelgrass.

This report provides the criteria that have been considered in developing the design for the Project. A discussion of the existing site conditions is provided in Section 2. By characterizing the existing site conditions the design concept was developed.

Hydrographic conditions including water levels, wind, and waves discussed in Section 3.

Subsequently, the numerical modeling details are included in Chapter 4 and the criteria used to support the design of the site are discussed in Section 5. The Project design criteria also include a description of the functional, physical and biological criteria as well as the applied engineering standards. Conclusions are summarized in Chapter 6.

2. Site Description

On site offset features for the RBT2 Project consist of an eelgrass bed and an intertidal marsh zone located along the RBT2 causeway adjacent to the existing Westshore/Deltaport Terminals and to the north of RBT2 (Figure 2-1).



FIGURE 2-1: ROBERTS BANK TERMINAL 2 (EELGRASS, INTERTIDAL MARSH, ROCKY REEF) LOCATION

The Onsite Offset Features (OOF) involve creation of eelgrass beds by placement of sand fill between constructed containment berms. The eelgrass zone will be located at west-side of the existing Deltaport terminal adjacent to existing eelgrass colonies. The containment berms are comprised of quarry run rock and quarry screenings orientated along the north side of the proposed intertidal marsh zone, adjacent to the proposed RBT2. The site boundaries are constrained by property boundaries, existing habitat, and footprint of the proposed RBT2 terminal.

The proposed intertidal marsh zone will be placed along the north-side of RBT2 and protected and contained by a rock berm. The rock berm will serve to reduce vulnerability of intertidal marsh against wave action coming from west and contain the fill material. An example photo of existing marsh near the proposed site is shown in Figure 2-2.



FIGURE 2-2: EXAMPLE OF EXISTING MARSH

3. Hydrographic Conditions

3.1. Water Levels

3.1.1. Astronomical Tides

Total water level consists of astronomical and meteorological tide components. Astronomical tides refer to the tidal levels which result from gravitational effects, e.g. of the Earth, Sun and Moon, without any atmospheric influences.

Table 3-1 summarizes tidal datums at Tsawwassen based on the Canadian Hydrographic Service *Nautical Chart 3492* (CHS, 2005).

- Higher High Water Large Tide (HHW-LT): The average of the highest high waters, one from each of 19 years of predictions.
- Higher High Water Mean Tide (HHW-MT): The average from all the higher high waters from 19 years of predictions.
- Mean Water Level (MLW): The average of all hourly water levels over the available period of record.
- Lower Low Water Mean Tide (LLW-MT): The average of all the lower low waters from 19 years of predictions.
- Lower Low Water Large Tide (LLW-LT): The average of the lowest low waters, one from each of 19 years of predictions.

TABLE 3-1: TIDAL DATUMS FOR TSAWWASSEN (CHS, 2005)

Location	Elevation above Chart Datum (m, CD)				
	Large Tide		Mean Tide		Mean Water Level
	HHW	LLW	HHW	LLW	
Tsawwassen	4.8	0.1	4.1	1.2	3.0

3.1.2. Extreme Water Levels

The second component of total water level, meteorological tides (or residual), refer to changes in expected astronomical tides caused by local meteorological conditions. The positive value of residual is commonly called storm surge as the water surface is elevated due to the passage of a low-pressure storm system. Extreme value estimates are summarized in Table 3-2.

TABLE 3-2: EXTREME HIGH WATER LEVELS ESTIMATED AT RBT2 (WORLEY PARSONS, 2014)

Description	Return Period (Years)				
	2	5	10	50	100
Extreme High Water Level (m, CD)	5.02	5.15	5.22	5.35	5.39

3.2. Winds

Wind data for Sandheads is archived in the Environment Canada National Climate Data and Information network. A total of 24 years of data between 1995 and 2018 was analyzed. Figure 3-1 presents the annual wind rose and shows the prevailing wind direction is from the east. Stronger winds are aligned northwesterly or east/southeasterly, which reflects the open water orientation of the Strait of Georgia. The largest recorded wind speed was approximately 50 knots.

Table 3-3 summarizes wind speed extremes. The 50-year and 100-year return period omni-directional winds are 50 and 51 knots.

TABLE 3-3. EXTREME WIND SPEEDS AT SANDHEADS (WORLEY PARSONS, 2014)

Wind Direction	Return Period (Year)							
	1	2	5	10	25	30	50	100
Omni-Directional (knots)	40	42	44	46	48	49	50	51
SE-S (knots)	38	40	43	45	47	48	49	51
NW-W (knots)	36	39	42	44	47	48	49	51

M&N conducted a wind-wave analysis using MIKE-21 Spectral Wave (SW) model to estimate the exposure of the marsh and eelgrass zones to wave action. Figure 3-2 shows the location of output points.

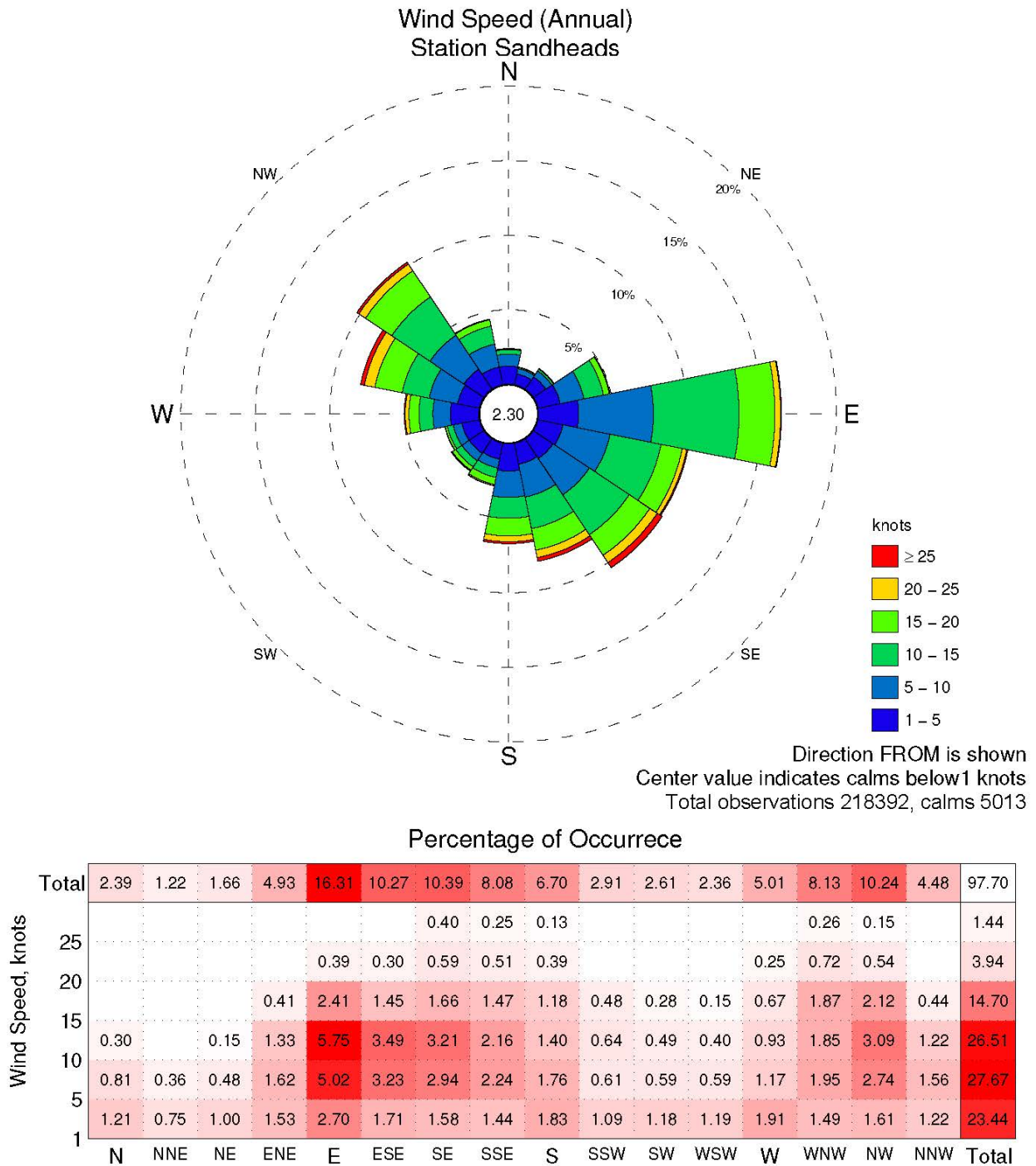


FIGURE 3-1: ANNUAL WIND ROSE AT SANDHEADS

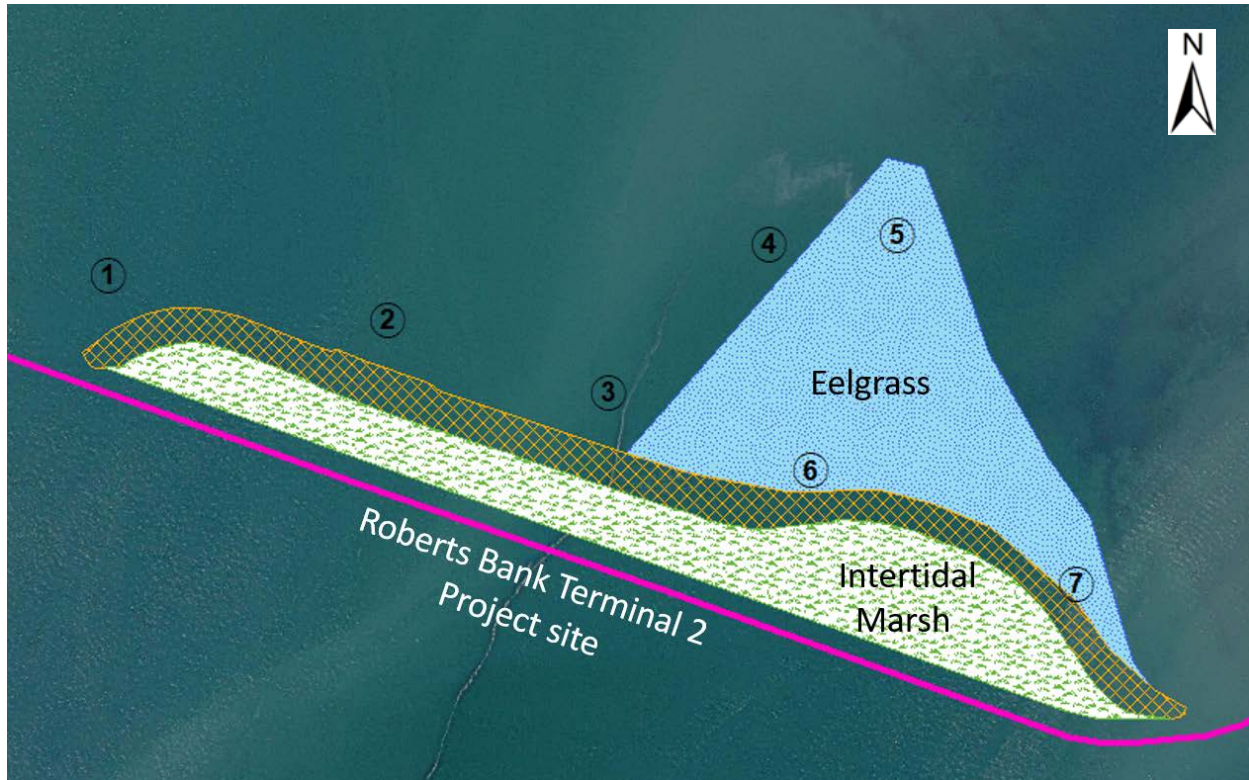


FIGURE 3-2: WIND-WAVE MODEL DATA OUTPUT LOCATIONS

Table 3-4 lists the significant wave height for the 7 selected locations (Figure 3-2). Comparing all locations, it is clear that Point 1 is the most exposed location. These values were obtained from a normal high tide without sea-level rise (SLR).

TABLE 3-4: SIGNIFICANT WAVE HEIGHT FOR SELECTED LOCATIONS

WSPD (knots)	Significant Wave Height (m)						
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
5	0.21	0.19	0.19	0.20	0.19	0.19	0.19
10	0.29	0.27	0.27	0.28	0.27	0.27	0.27
15	0.42	0.40	0.39	0.39	0.39	0.38	0.37
20	0.54	0.51	0.50	0.51	0.50	0.50	0.47
25	0.68	0.63	0.62	0.65	0.63	0.61	0.59
30	0.84	0.78	0.76	0.79	0.78	0.75	0.72
35	1.00	0.94	0.92	0.95	0.93	0.91	0.86
40	1.17	1.11	1.08	1.10	1.08	1.07	1.01
45	1.35	1.28	1.25	1.26	1.24	1.23	1.16
50	1.53	1.45	1.42	1.42	1.40	1.40	1.31
55	1.70	1.63	1.59	1.57	1.55	1.57	1.46

Similarly, Table 3-5 lists the corresponding peak wave period. For the design wind speed of 50 knots (e.g. 50-year return period), the peak wave period is around 4.1 seconds in the marsh area.

TABLE 3-5: PEAK WAVE PERIOD FOR SELECTED LOCATIONS

WSPD (knots)	Peak Wave Period (s)						
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
10	2.7	2.7	2.7	2.7	2.7	2.7	2.7
15	2.9	2.8	2.8	2.8	2.7	2.8	2.7
20	3.0	2.9	2.9	2.9	2.9	2.9	2.9
25	3.2	3.2	3.1	3.1	3.1	3.1	3.1
30	3.4	3.3	3.3	3.3	3.3	3.3	3.3
35	3.6	3.5	3.5	3.6	3.5	3.5	3.5
40	3.8	3.7	3.7	3.7	3.7	3.7	3.6
45	4.0	3.9	3.9	3.9	3.9	3.9	3.9
50	4.1	4.1	4.0	4.1	4.1	4.0	4.0
55	4.3	4.2	4.2	4.2	4.2	4.2	4.1

Figure 3-3 and Figure 3-4 present examples of significant wave height variations and peak wave period under 50 knots wind.

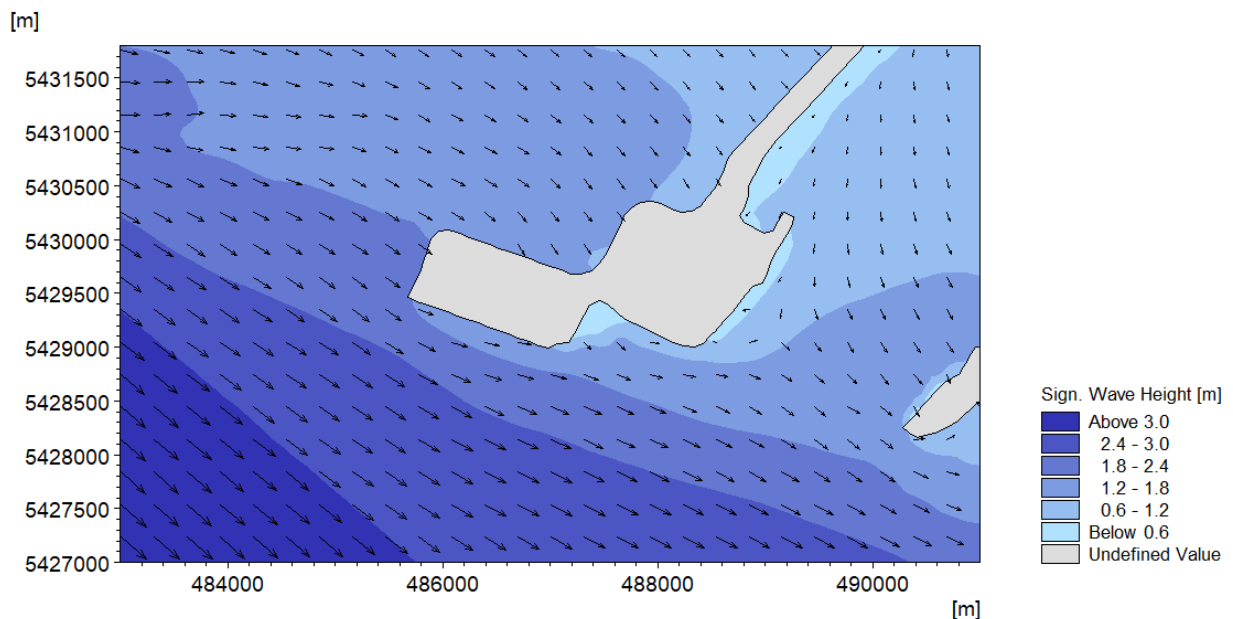


FIGURE 3-3: SIGNIFICANT WAVE HEIGHT UNDER 50 KNOTS WIND

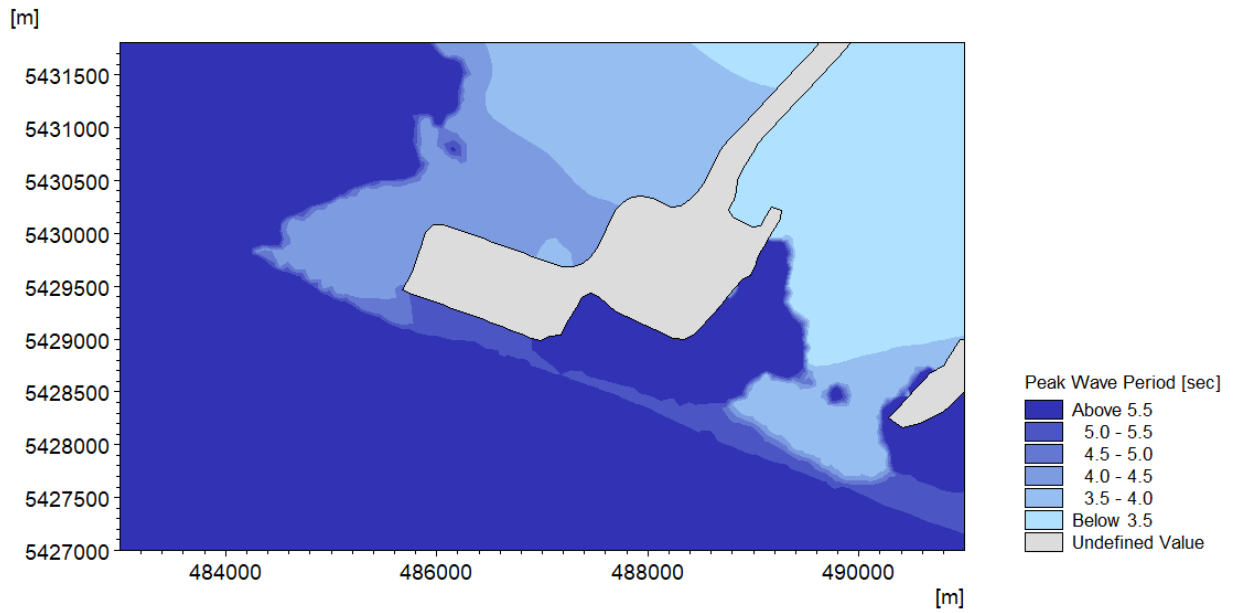


FIGURE 3-4: PEAK WAVE PERIOD UNDER 50 KNOTS WIND

4. Numerical Modelling Development

The Danish Hydraulic Institute MIKE-21 two-dimensional Spectral Wave (SW) and Hydrodynamic (HD) models were developed for the Lower Fraser River and Strait of Georgia to carry out the relevant analyses and to determine engineering requirements for the proposed marsh. Both models were calibrated to ensure that wave and hydrodynamic processes were adequately reproduced. Figure 4-1 depicts the locations of the meteocean data stations used in the model development.

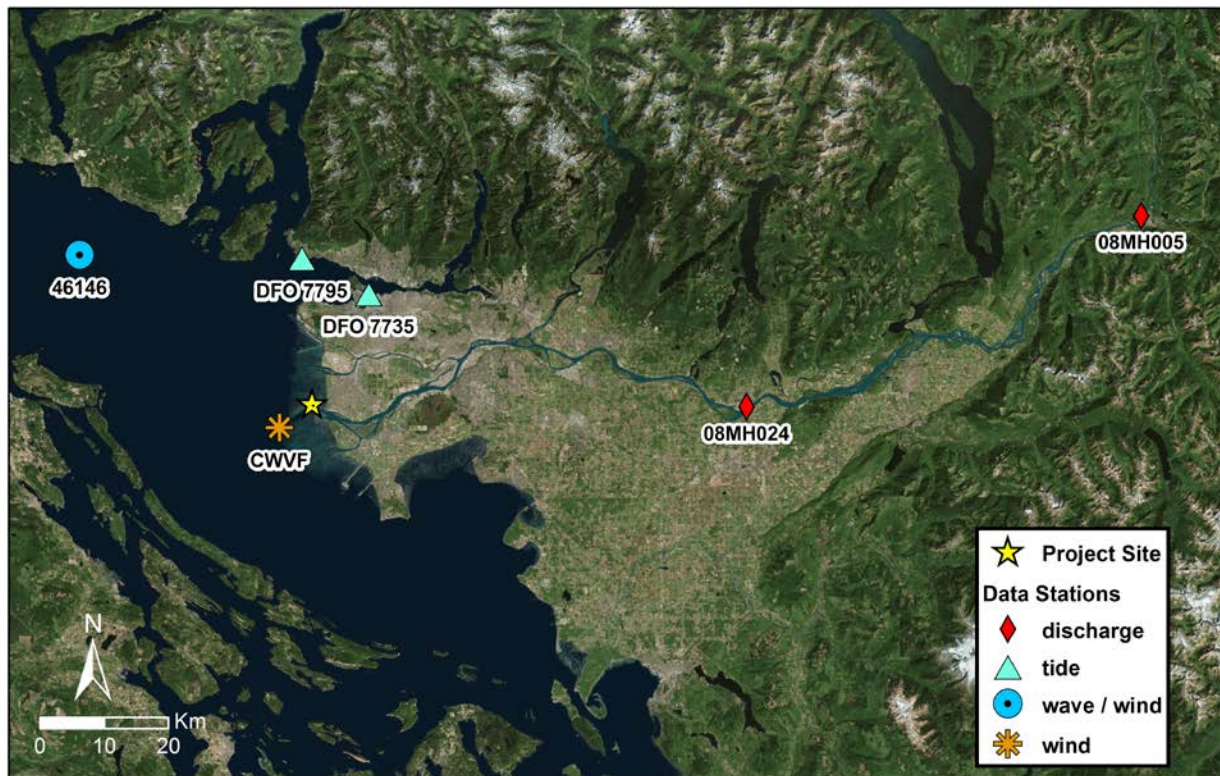


FIGURE 4-1: METEOCEAN DATA STATIONS

4.1. Model Description

MIKE-21 is a modelling system developed by the Danish Hydraulic Institute (DHI) Water and Environment. It was selected for the project because of the flexibility and computational efficiency with its unstructured grid configuration. The unstructured grid makes it possible to resolve both large and small-scale flow and wave processes effectively. Finer resolution grid elements are used in the vicinity of the project area while coarser grid elements are used away from the areas of interest.

The SW model solves the wave action conservation equations and simulates the growth, decay, and transformation of wind-generated seas and long-period swells in offshore and coastal areas. The SW considers important physical processes, including wave growth by action of winds, shoaling and refraction due to depth variations, diffraction and reflection near structures, wave breaking in the surf zone, wave dissipation (including bottom friction, white capping, and wave-wave interaction), and

some non-linear wave-current interactions. Although the model considers wave shoaling due to seabed changes and wave breaking where the water depth can't sustain the incident wave height, it should be noted that the focus of the study is on the design wave condition, which is occurred when the water level is high.

The HD model solves the depth-averaged shallow water equations and simulates water level variations and flows in response to a variety of forcing functions. It has been applied extensively worldwide within oceanographic, coastal, and estuarine environments.

4.2. Model Grid and Bathymetry

For computational efficiency and accuracy purposes, different model grids were developed for the SW and HD model. To accurately reproduce wave processes such as growth and propagation to RBT2, the computational domain for the SW model covers the Strait of Georgia Basin, extended around Texada Island to the northwest and connected with Strait of Juan de Fuca to the south (orange polygon in Figure 4-2); while a smaller domain for the HD model (pink polygon in Figure 4-2) to resolve the complex circulation processes in the Fraser River Delta. The HD domain extends inland to Mission as the freshwater discharge source.

Figure 4-3 shows the unstructured grid configuration (e.g. variable element resolutions) near RBT2. The finest element resolution around the proposed marsh area is approximately 25 m, while the coarsest grid element is about 650 to 700 m in the Strait of Georgia.

Bathymetry (or seabed elevations) for the majority of model domain was extracted from the C-Map Software of DHI, incorporating Jeppesen Norway's electronic database of global nautical charts (DHI, 2008). Figure 4-4 shows the average water depth in the Strait of Georgia is approximately 150 meters. The maximum depth can reach 400 meters, just south of Texada Island.

Bathymetry in the shallow mudflats surrounding the project area was based on Stantec's LiDAR survey conducted in July 2013 (Stantec, 2013). The LiDAR coverage included Roberts Bank and Sturgeon Bank. At the proposed onsite marshes, the design elevation was based on the preliminary concept drawing (M&N, 2020). Figure 4-5 presents the model bathymetry near RBT2, with onsite marshes. Vertical datum reference is Chart Datum (CD).

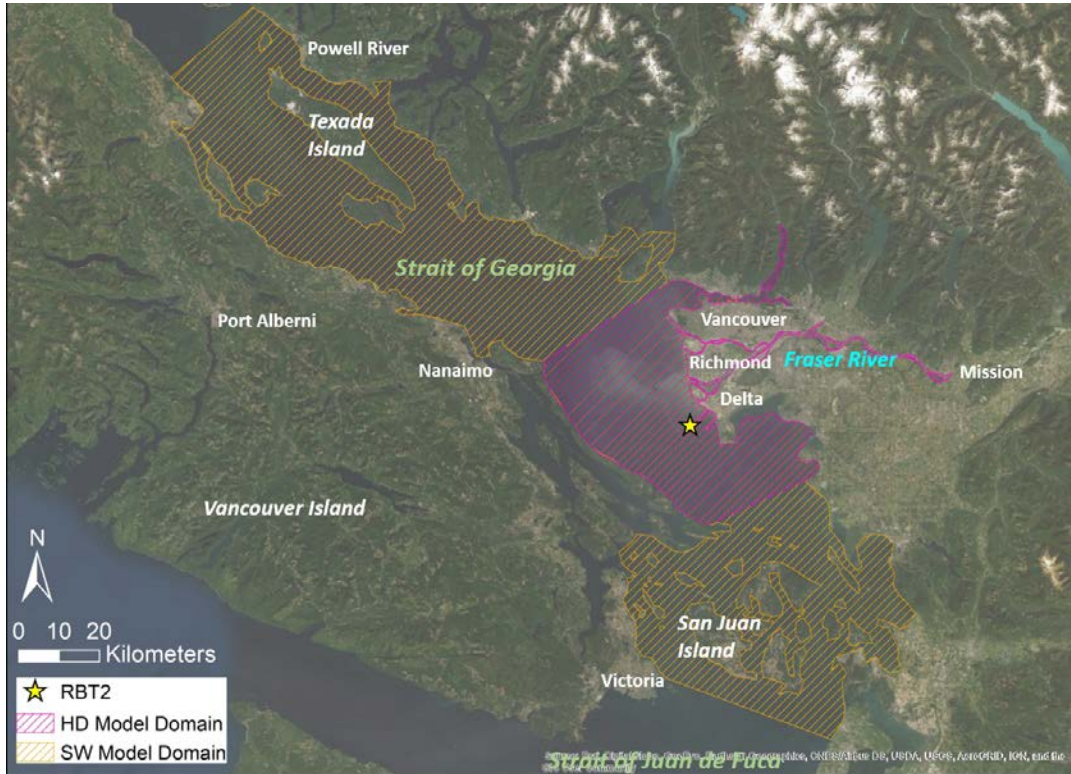


FIGURE 4-2: MODEL DOMAIN FOR THE SPECTRAL WAVE AND HYDRODYNAMIC MODELS

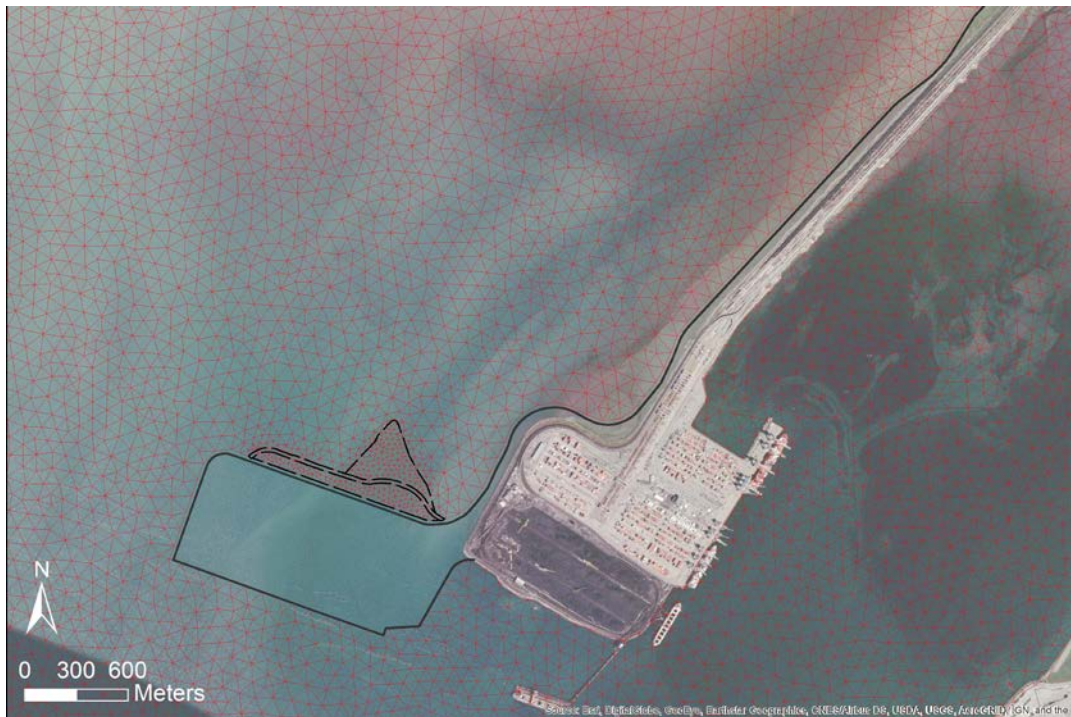


FIGURE 4-3: UNSTRUCTURED GRID ELEMENTS NEAR RBT2

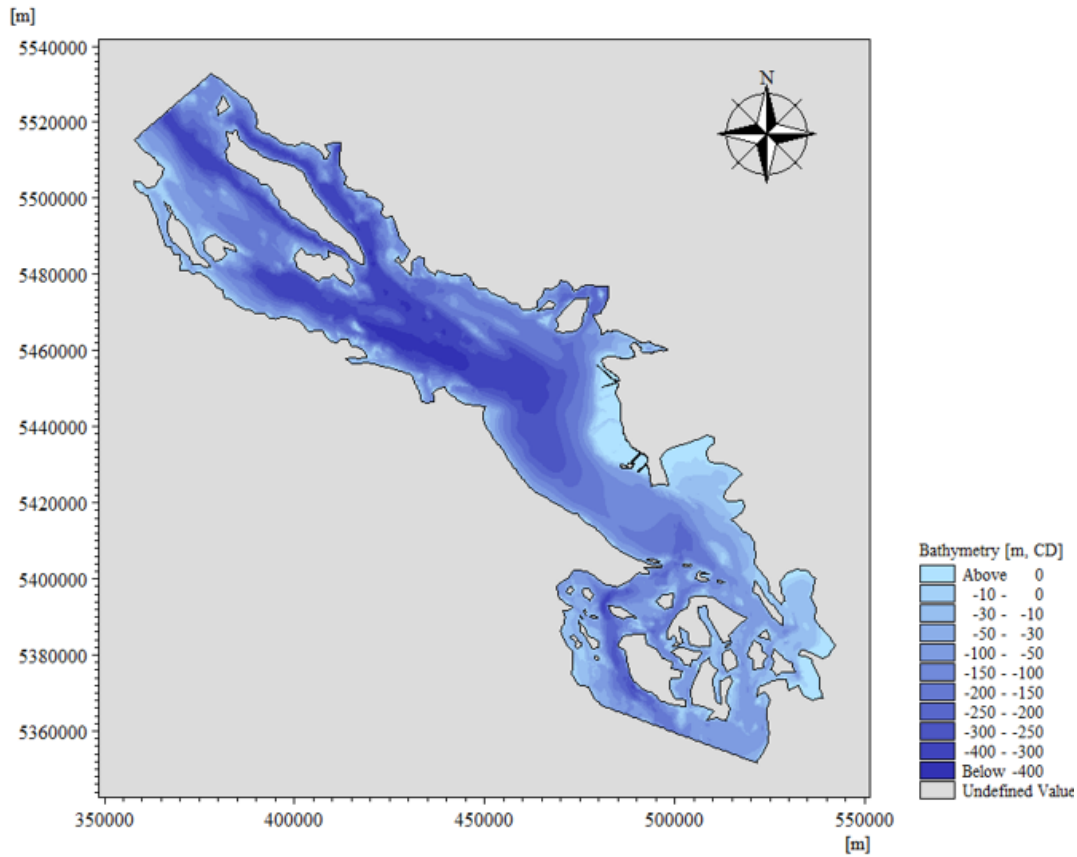


FIGURE 4-4: OVERALL MODEL BATHYMETRY

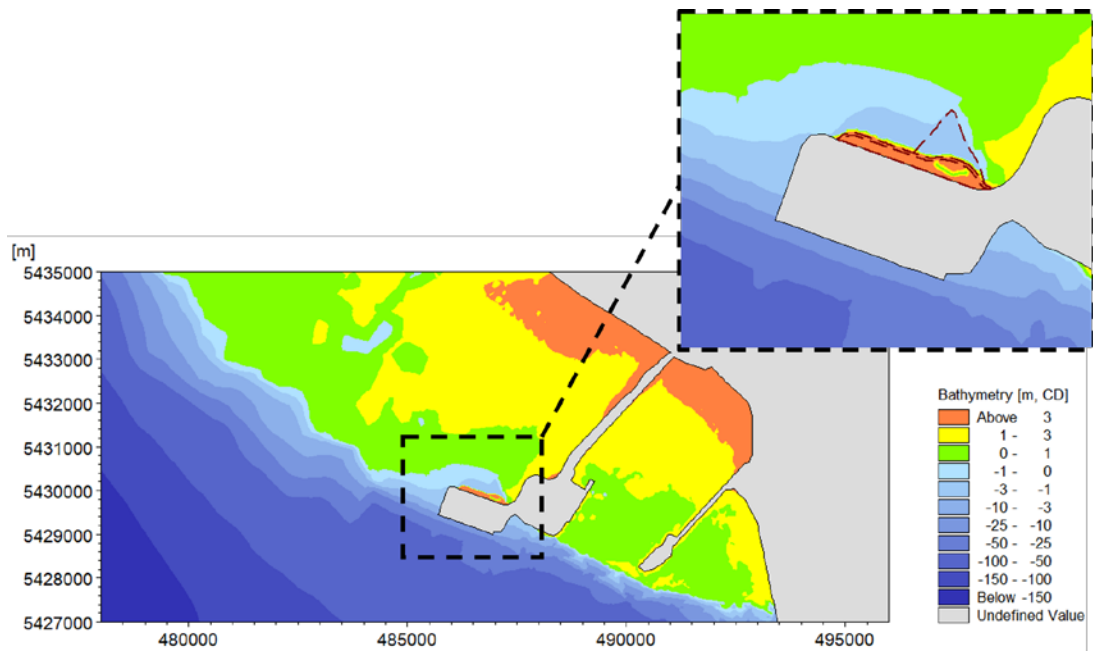


FIGURE 4-5: MODEL BATHYMETRY NEAR RBT2 WITH ONSITE MARSHES

4.3. SW Model Calibration

Typically, outputs from any numerical model need to be verified with field measurements, in order to show the model can reasonably reproduce the processes or environment of interest. This procedure is called model calibration.

The SW model was calibrated against hourly wave records at DFO Halibut Bank station (C46146, Figure 4-1), which include observations of significant wave height (H_s) and peak wave period (T_p) from 1996 to 2017.

A winter storm which occurred in Strait of Georgia in December 2001 was selected for SW model calibration because the storm had lasted more than 12 hours. Figure 4-6 shows the selected storm had retained wind speeds up to 40 knots (or 20 m/s) at Halibut Bank with predominant northwest-southeast directions.

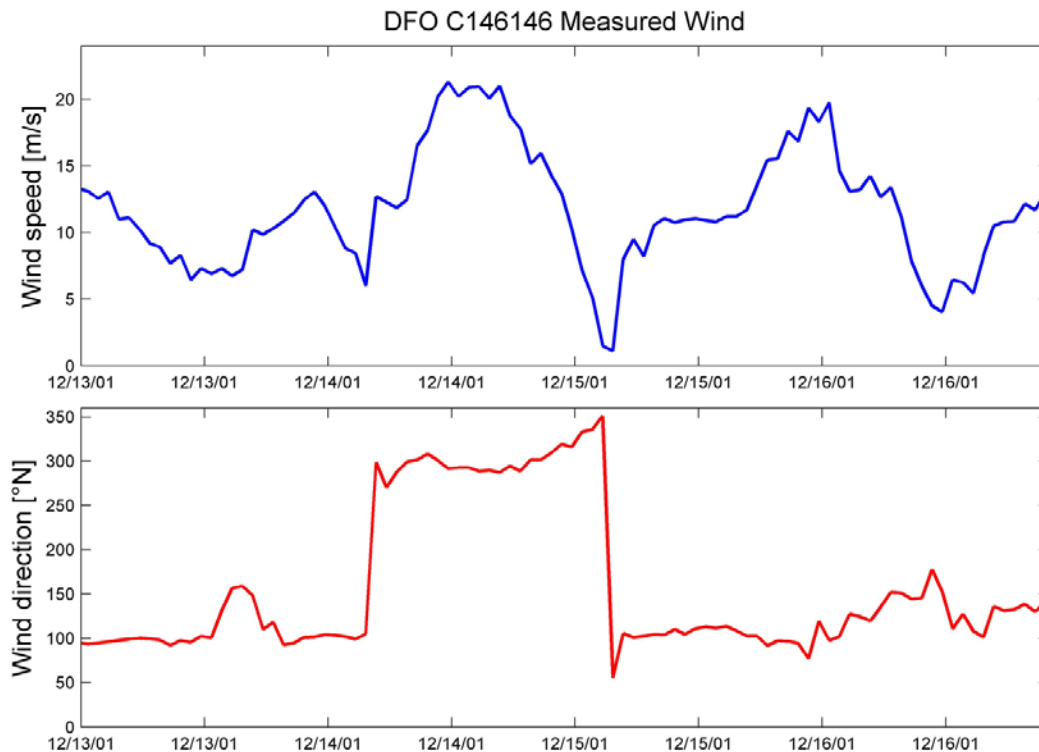


FIGURE 4-6: SELECTED WINTER STORM EVENT FOR WAVE CALIBRATION

Wave calibration was achieved by adjusting wave dissipation coefficients as well as spectral properties. In order to quantify the agreement between measured and model data, the following statistical parameters were determined.

- Root Mean Square Error (RMSE): $\varepsilon_{RMS} = \sqrt{(x - y)^2}$
- Mean Absolute Error (MAE, m): $MAE = |x - y|$

- Model Prediction Capability Index (d):
$$d = 1 - \frac{\overline{(x - y)^2}}{(\overline{|x - \bar{x}|} + \overline{|y - \bar{y}|})^2}$$

Where, x and y represent the measured and modelled data, respectively. A comparison between measured and modelled wave statistical parameters is presented in Figure 4-7 and Figure 4-8, and shows that the model is in reasonable agreement with the measurements.

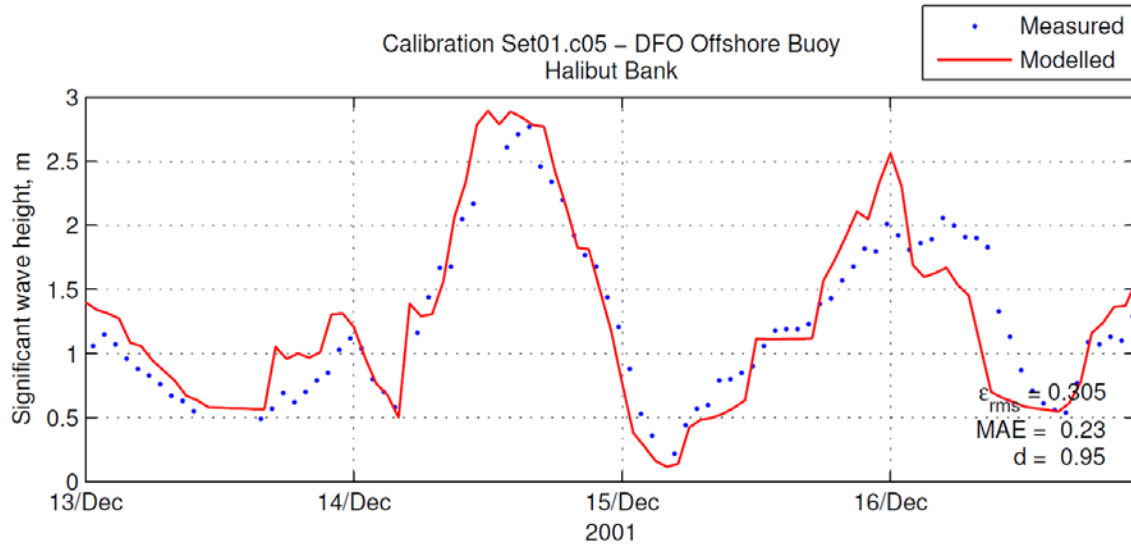


FIGURE 4-7: MEASURED VS MODELLED H_s AT HALIBUT BANK

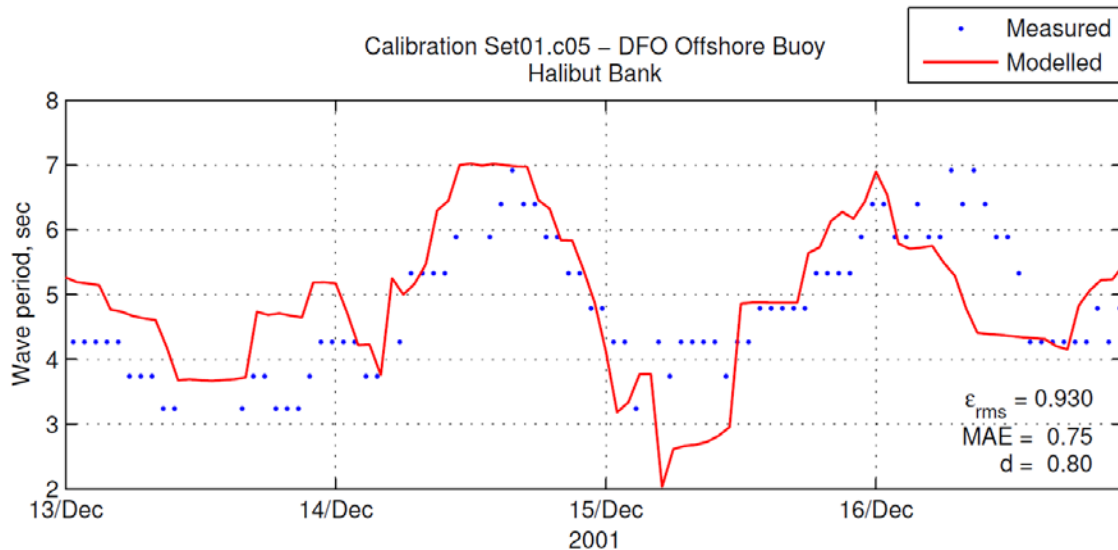


FIGURE 4-8: MEASURED VS MODELLED T_p AT HALIBUT BANK

4.4. HD Model Calibration

The HD model was calibrated against water levels and flow split. Modelled water levels were compared with tides measured at two DFO tide gauges, namely Point Atkinson and Vancouver, labelled as DFO7795 and DFO7735 in Figure 4-1. Modelled flow split was compared to measurements as reported by North Hydraulic Consultants (NHC, 2006).

The HD model was forced with astronomical tides and tidal currents, derived from the tidal constituent global database developed from TOPEX/Poseidon altimetry data (Egbert & Erofeeva, 2010), along its offshore tidal boundaries. In addition, Fraser River discharge measured at Mission (station 08MH024 in Figure 4-1) was used as the inland freshwater boundary.

A two-month simulation period was conducted between June 1 and July 31, 2012, in order to capture the higher-than-average discharges observed during the 2012 freshet season. A graphical comparison between measured and modelled water levels is provided in Figure 4-9 and shows that the HD model closely reproduces observed water level variations. Model prediction capability indices (d) of 0.99 (1.0 being perfect prediction) corroborate the accuracy of the modelled water levels at both tide gauges.

In addition, a comparison between the measured and modelled tidal constituents (i.e. the astronomical components of the tides) at both tide gauges was made. Figure 4-10 shows that the model adequately captures the amplitude of these constituents, with the M2 component amplitude being overpredicted by less than 7% and 3%, and the K1 component being overpredicted by 16% and 15%, respectively.

To confirm that the model correctly distributes flow into the North, Middle and South Arm of the Fraser river, modelled flow splits were also calculated. Flow split data collected by Public Works and Government Services Canada (PWGSC) from May 2005 to January 2006, was processed and reported by NHC in 2006. The blue and red boxes in Figure 4-11 indicate the measured and modelled flow splits, respectively. Overall, the model reproduces closely the flow distribution in the North, Middle and South Arm, with differences less than 1%. A slightly larger difference of 3% is found near Steveston.

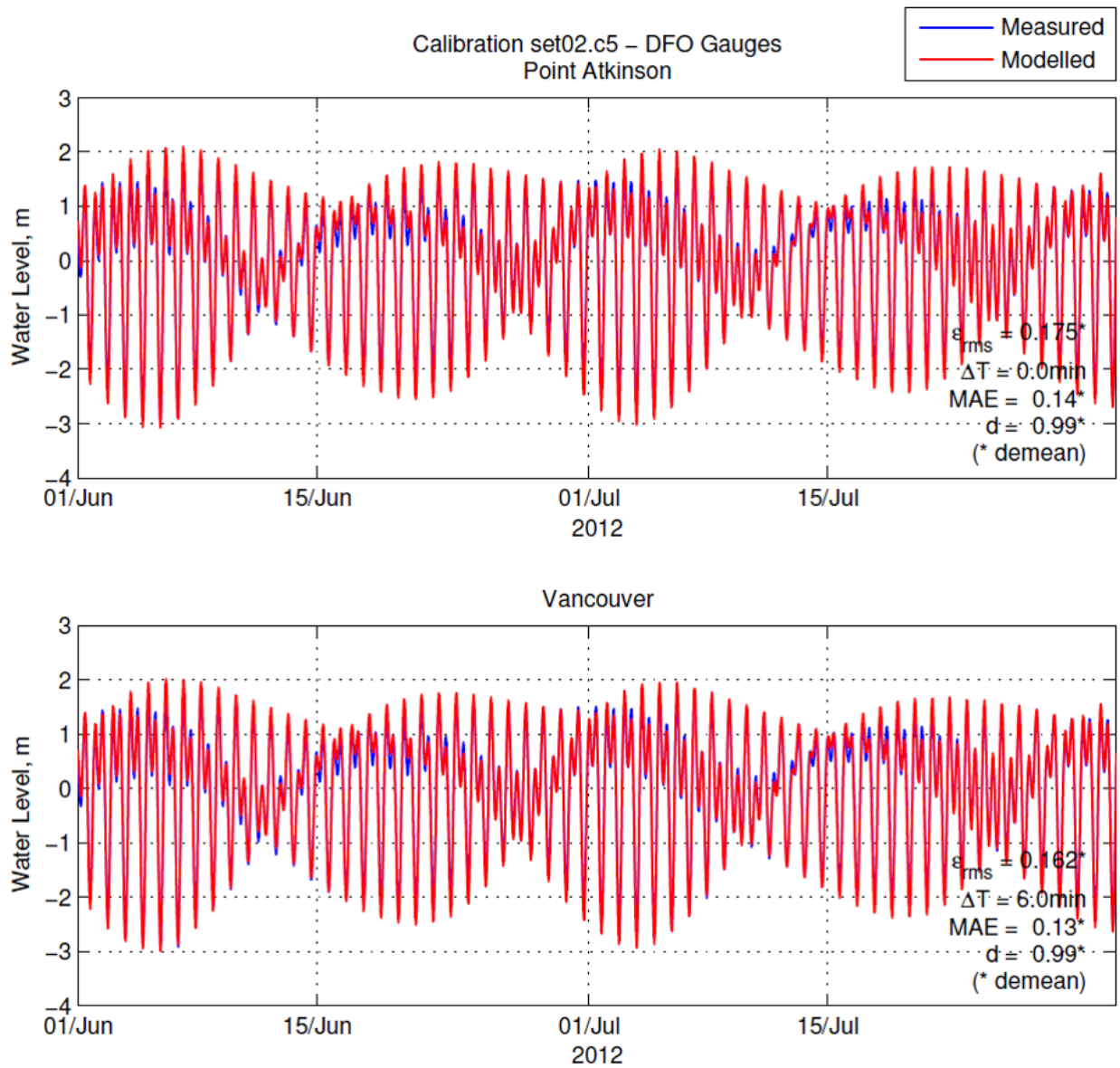


FIGURE 4-9: MEASURED VS MODELLED WATER LEVELS AT DFO TIDE GAUGES

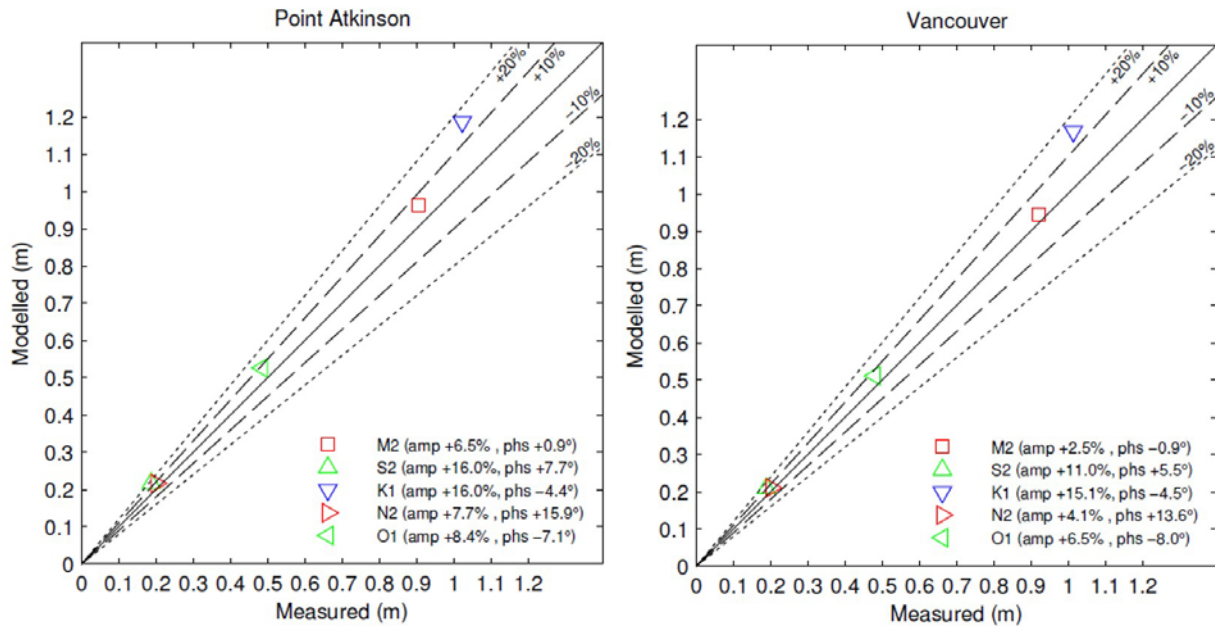


FIGURE 4-10: MEASURED VS MODELLED TIDAL CONSTITUENTS AT DFO TIDE GAUGES

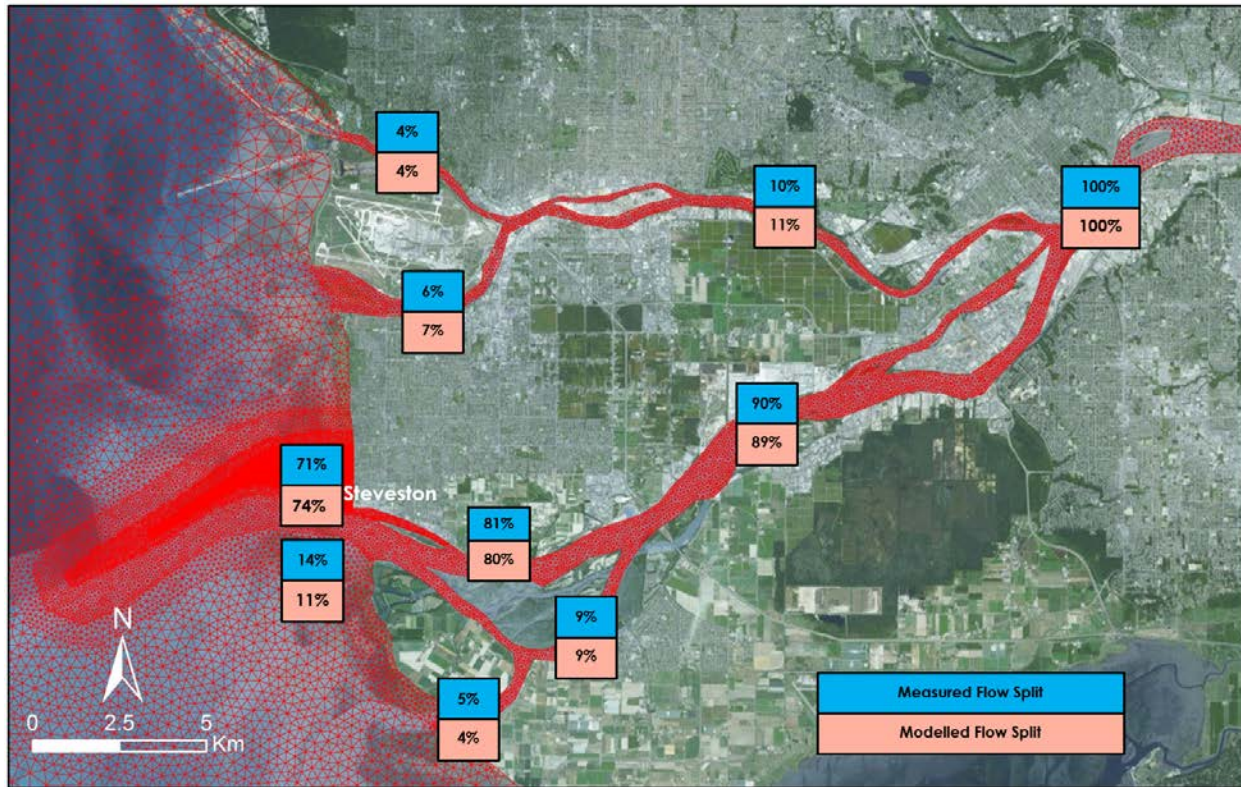


FIGURE 4-11: MEASURED VS MODELLED FLOW SPLIT

5. Design Criteria for Onsite Habitat Features

Onsite Offset Features for the RBT2 project include intertidal marsh, subtidal eelgrass, and rock berms. This section describes the design criteria that apply to these. This includes a description of the physical and biological design criteria as well as applicable engineering standards.

Horizontal datum is NAD83 UTM Zone 10N. The vertical datum is Canadian Hydrographic Service (CHS) Chart Datum (CD). All drawings are presented in SI (metric) units.

The following guidelines, codes, and standards are applicable:

- British Columbia Building Code 2018 (BCBC'18); and
- Coastal Engineering Manual (CEM, US Army Corps of Engineers, 2002).

5.1. Peak Tidal Currents

Sediment mobilized by waves and tidal currents may either bury plants, expose roots and rhizomes or during heavy storms even uproot entire plants. Moderate current speeds tend to enhance eelgrass growth. The maximum current that eelgrass can withstand depends to some extent on the sediment type. The optimal range for eelgrass reported in the literature varies considerably, a conservative range would be 2 to 120 cm s⁻¹. The habitat is usually patchy (sub-optimal) at the higher velocities.

A recent study using a flume determined that the critical orbital velocity threshold for eelgrass growing in sand was 12 cm s⁻¹ and in mud 4 cm s⁻¹, greater velocities resulted in increased sediment resuspension and therefore increased turbidity reducing the amount of photosynthetically active radiation (PAR) that reaches the plants. The roots and rhizomes of eelgrass growing in mud started to be uprooted around 15 cm s⁻¹, while the eelgrass growing in sand could withstand that velocity. Eelgrass establishes best on a fairly level seabed, it would be best to minimize any slopes (Durance C., 2014).

The MIKE-21 HD model was used to evaluate the changes to the tidal hydrodynamics due to the incorporation of the proposed intertidal marsh and eelgrass beds. The pre- and post-project peak current speeds within the existing and proposed intertidal marsh and subtidal eelgrass zones are shown graphically in Figure 5-1 and Figure 5-2. Additionally, Figure 5-3 shows the difference of peak currents between the pre- and post-project conditions. Table 5-1 provides depth-averaged current speeds for both the intertidal marsh and subtidal eelgrass zones.

Result shows that the post-project speeds at the project boundaries are equal or less than the existing values and within the acceptable range to predict bedform impacts. Consequently the construction of the intertidal marsh and eelgrass beds will have negligible impact to the tidal currents in the existing intertidal marsh and eelgrass zones with peak post-project current speeds of approximately 0.4 m/s. At the northwest corner of the RBT2, the area with the highest current speed (ranges 1 – 1.2 m/s) reduces at the post-project phase and still remains within the acceptable range defined for optimal eelgrass/marsh zone maximum current speed.

The overall evaluation indicates that post project current speeds are equal or less than pre-project values and construction of the new plan meet all the requirements and design criteria.

TABLE 5-1: DEPTH-AVERAGED CURRENT SPEED FOR EXISTING AND PROPOSED CONDITIONS

Description	Tidal Currents			
	Existing		Proposed	
	Intertidal Marsh	Eelgrass	Intertidal Marsh	Eelgrass
Current Speed Range (m/s)	Below 0.4	0.4 – 0.6	Below 0.1	Below 0.4

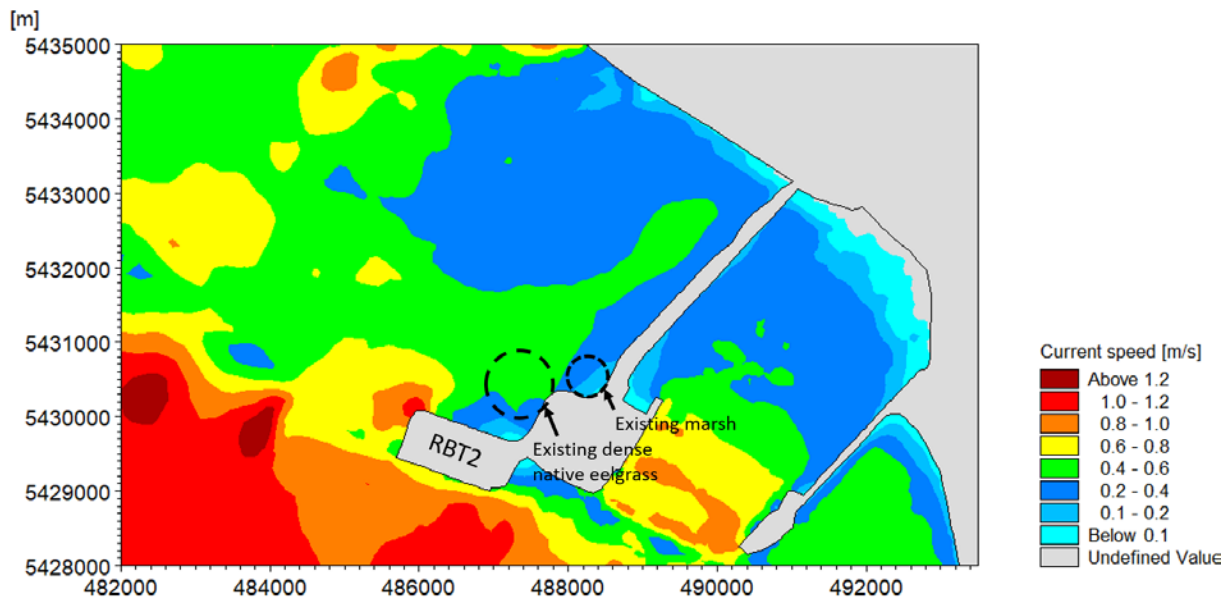


FIGURE 5-1: PRE-PROJECT PEAK CURRENTS

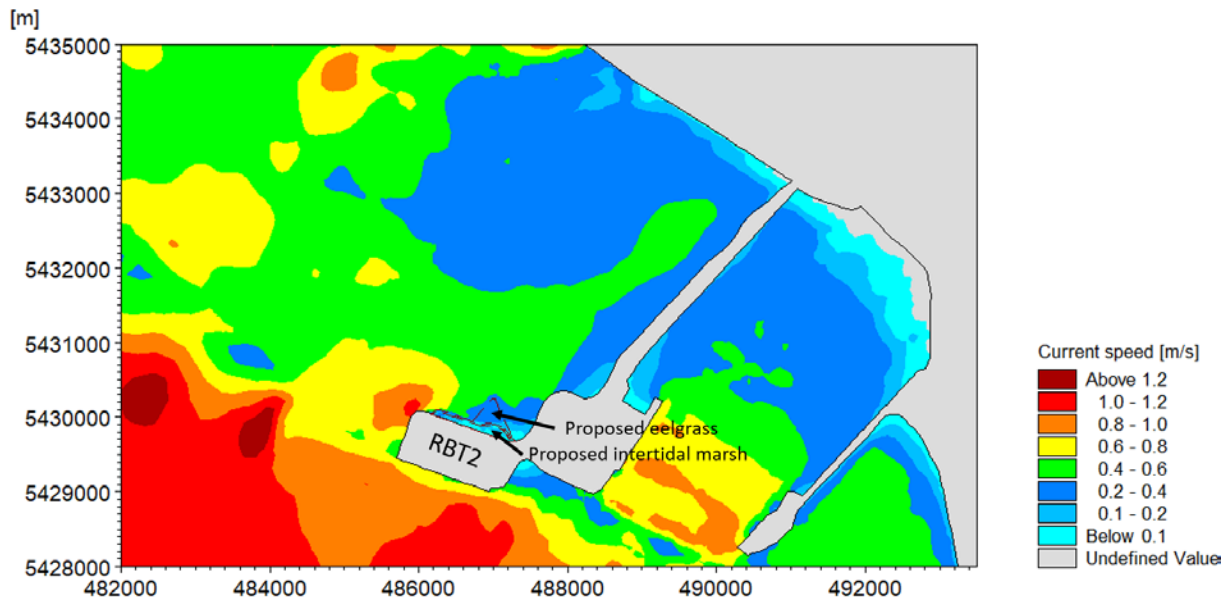


FIGURE 5-2: POST-PROJECT PEAK CURRENTS

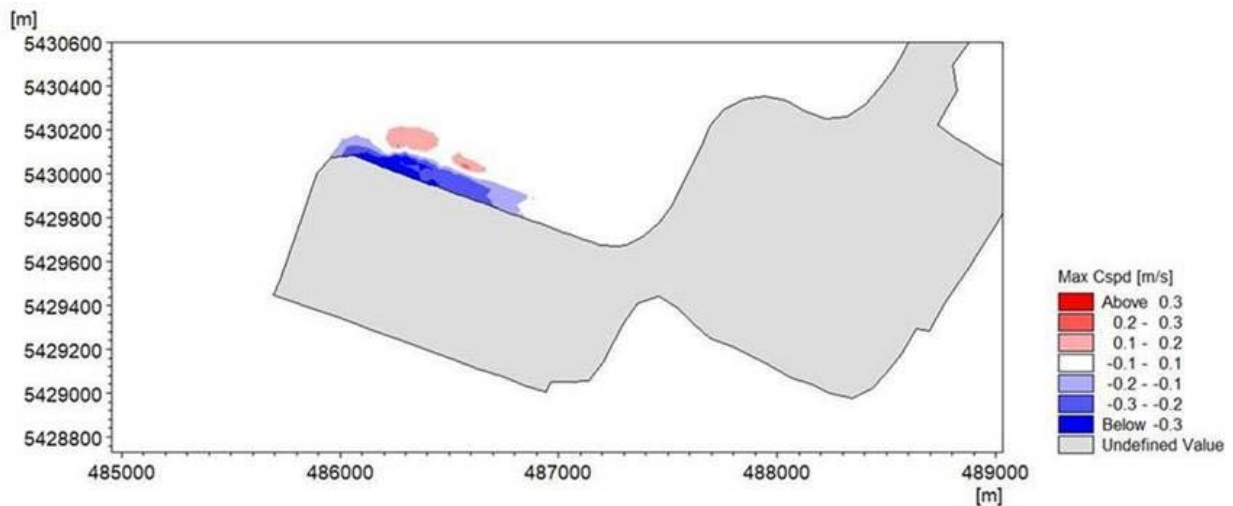


FIGURE 5-3: DIFFERENCE OF PEAK CURRENTS BETWEEN PRE- AND POST-PROJECT CONDITIONS

5.2. Permissible Bed Shear Stress

Stantec (2016a, b) conducted an exploratory investigation of soil properties and performed laboratory tests on samples collected from borings.

Per the Unified Soil Classification System (USCS), Table 5-2, surficial sediments at the project site classify as poorly graded sand (SP), poorly graded sand with silt (SP-SM), and silty sand (SM), generally described as poorly graded sand with fines (silt), interbedded by layers of silt (Stantec, 2016a). From west to east, the content of fines in the sand ranges from 5 to 15% (silt

content), increasing to 15-30%. About 5 metres below the surface, transitioning to grey, sandy silt (ML) with an overall fines content of 65% (Stantec 2016b).

TABLE 5-2: UNIFIED SOIL CLASSIFICATION SYSTEM (ABBREVIATED)

Classification		ID	Description
Gravels	Clean	GW	Well graded gravels
		GP	Poorly graded gravels
	With Fines	GM	Silty gravels
		GC	Clayey gravels
Sands	Clean	SW	Well graded sands
		SP	Poorly graded sands
	With Fines	SM	Silty sands
		SC	Clayey sands
Silts and Clays LL 50% or less		ML	Inorganic silts
		CL	inorganic clays
		OL	Organic silts or clays
Silts and Clays LL greater than 50%		MH	Inorganic silts
		CH	inorganic clays
		OH	Organic silts or clays
Highly Organic Soils		Pt	Peat

In the following, information is provided on the permissible shear stress for material types such as those existing and planned for the site.

Table 5-3 summarizes typical permissible shear stresses for materials in the range from non-cohesive to cohesive material. Shear stress is defined as the force per unit area (expressed in N/m²) applied parallel to the surface of a material.

Permissible shear stress for non-cohesive material depends on the submerged weight of the material relative to the tractive force. The submerged weight is commonly described by a characteristic material grain size. The angularity of the material also affects its stability, but to a lesser degree when the material is placed horizontally or near-horizontally.

The grain sizes of cohesive materials are typically so small that the diameter does not affect the stability of the materials. The permissible shear stress for cohesive materials is therefore more complex and depends primarily on the plasticity index (PI) of the material, the void ratio, and to a lesser extent the angularity of the grains.

The plasticity index (PI) of materials obtained from surficial soil samples ranged from about 7 to 9, Stantec (2016a). Based on this the permissible shear stress is estimated to be around 2.5 to 3.0 N/m².

TABLE 5-3: TYPICAL PERMISSIBLE SHEAR STRESS, REPRODUCED FROM FHWA (2005)

Material Category	Material Type	Permissible Shear Stress (N/m ²)
Bare Soil (PI = 10)	Clayey sands	1.8 to 4.5
	Inorganic silts	1.1 to 4.0
	Silty sands	1.1 to 3.4
Bare Soil Cohesive (PI ≥ 20)	Clayey sands	4.5
	Inorganic silts	4.0
	Silty sands	3.5
	Inorganic sands	6.6
Bare Soil Non-cohesive (PI < 10)	Finer than coarse sand d ₇₅ < 1.3 mm	1.0
	Fine gravel d ₇₅ = 7.5 mm	5.6
	Gravel d ₇₅ = 15 mm	11.0
Gravel	Coarse gravel d ₅₀ = 25 mm	19.0
	Very coarse gravel d ₅₀ = 50 mm	38.0
Rock riprap	d ₅₀ = 0.15 m	113.0
	d ₅₀ = 0.30 m	227.0

By coupling the calibrated HD and SW model, tidal-induced and storm wave-induced bed shear stress at each model grid were combined to represent a normalized annual condition. Figure 5-4 illustrates the maximum pre-project bed shear stress, as well as the approximate outline of existing dense eelgrass or marsh beds (dark green line). Result indicates that although the majority of the existing dense eelgrass or marsh beds fall in the bed shear stress less than 1 N/m² (light blue color), the upper-end threshold can be near 2.5-3 N/m² as some local spots can see eelgrass growth up to this zone, e.g. areas near Canoe Pass and the Delta Port entrance. Figure 5-5 investigates the maximum bed shear stress after the onsite marshes are created. Result indicates that the entire onsite marshes area falls in the zone with bed shear stress less than 1 N/m². In addition, there are very minor (nearly non-noticeable) changes from the pre-project condition.

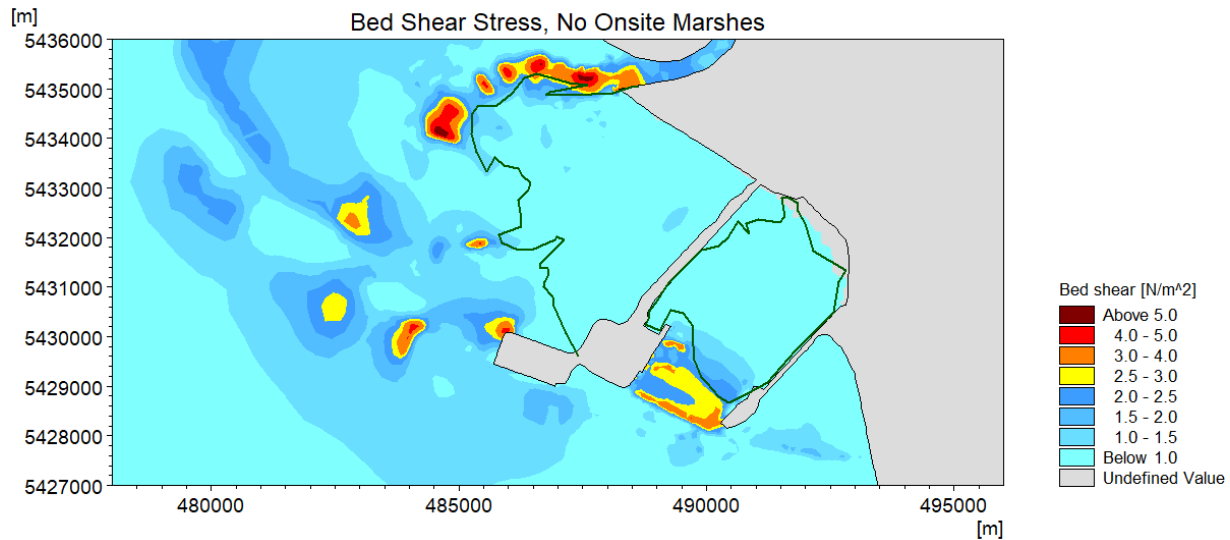


FIGURE 5-4: PRE-PROJECT BED SHEAR STRESS

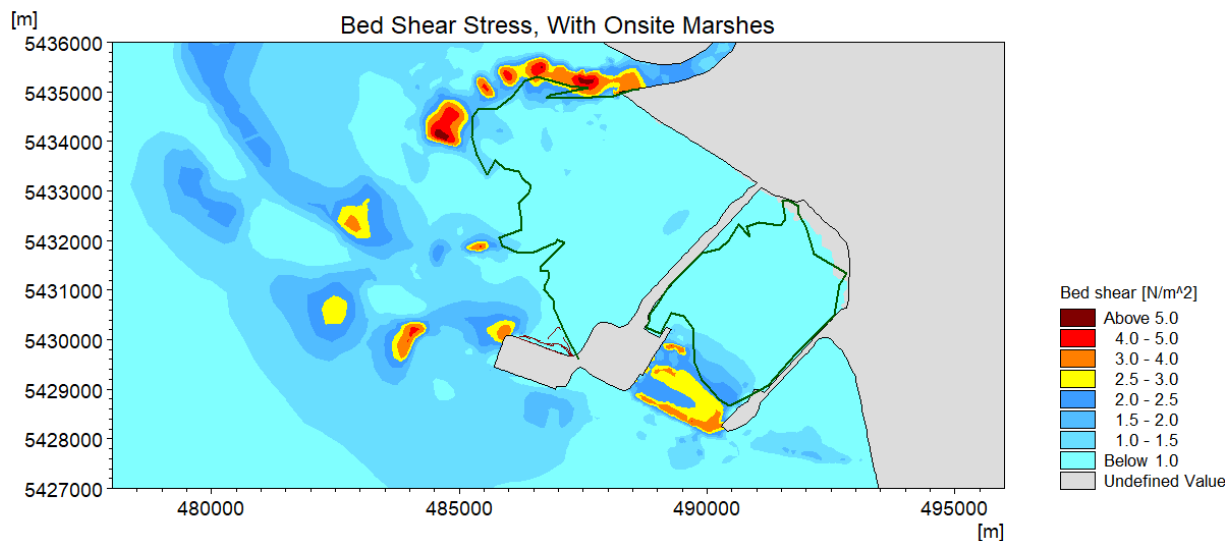


FIGURE 5-5: POST-PROJECT BED SHEAR STRESS

5.3. Biological Design Criteria

5.3.1. Eelgrass Salinity Range

The optimal salinity range for eelgrass is 10-30 ppt. Although it can tolerate short periods of 0 ppt. without any reduction in growth. Figure 5-6 and Figure 5-7 indicates salinity values for the project location based on high slack and ebb tides respectively (RBT2 EIS Appendix 9.5-A). Table 5-4 shows the estimated salinity ranges for existing and proposed conditions extracted from the figures and based on both high slack and ebb tides.

TABLE 5-4: SALINITY RANGES FOR EXISTING AND PROPOSED EELGRASS ZONES

Description	Eelgrass Zone	
	Existing	Proposed
Salinity Range (ppt)	22.5 - 30	10.5 - 30

Based on the ranges obtained from the below figures and per Table 5-4 it is concluded that the salinity levels remain within the optimal range for the proposed eelgrass area.

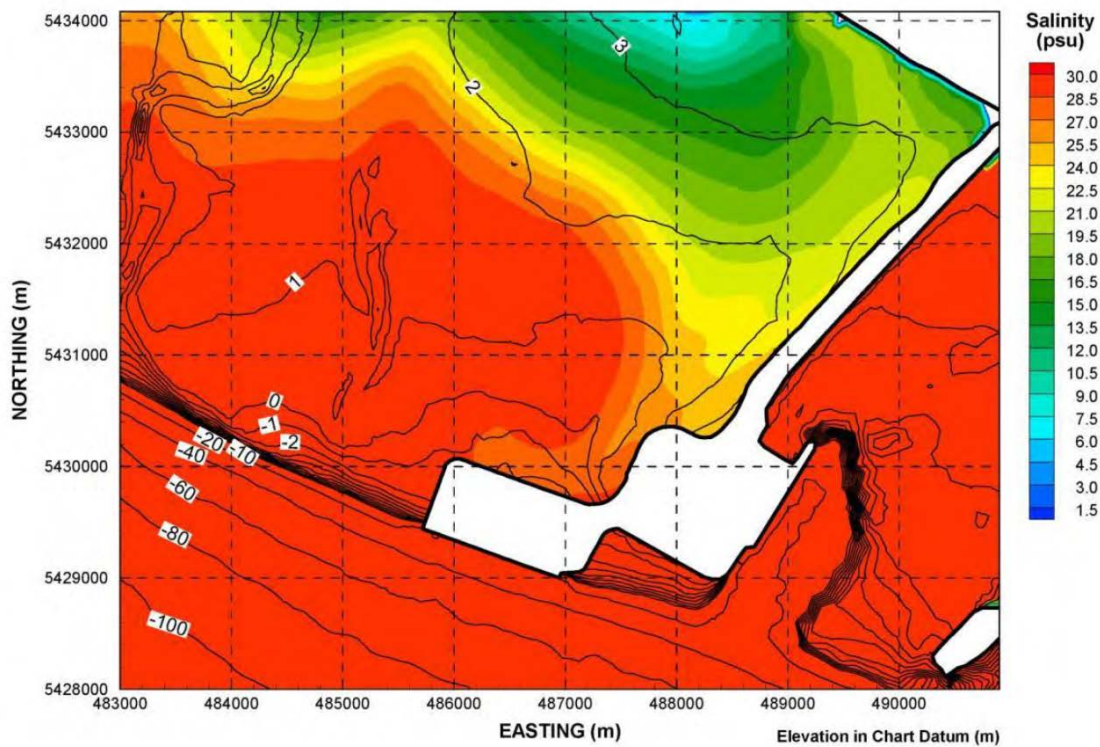


FIGURE 5-6: SALINITIES ASSOCIATED WITH A HIGH SLACK TIDE

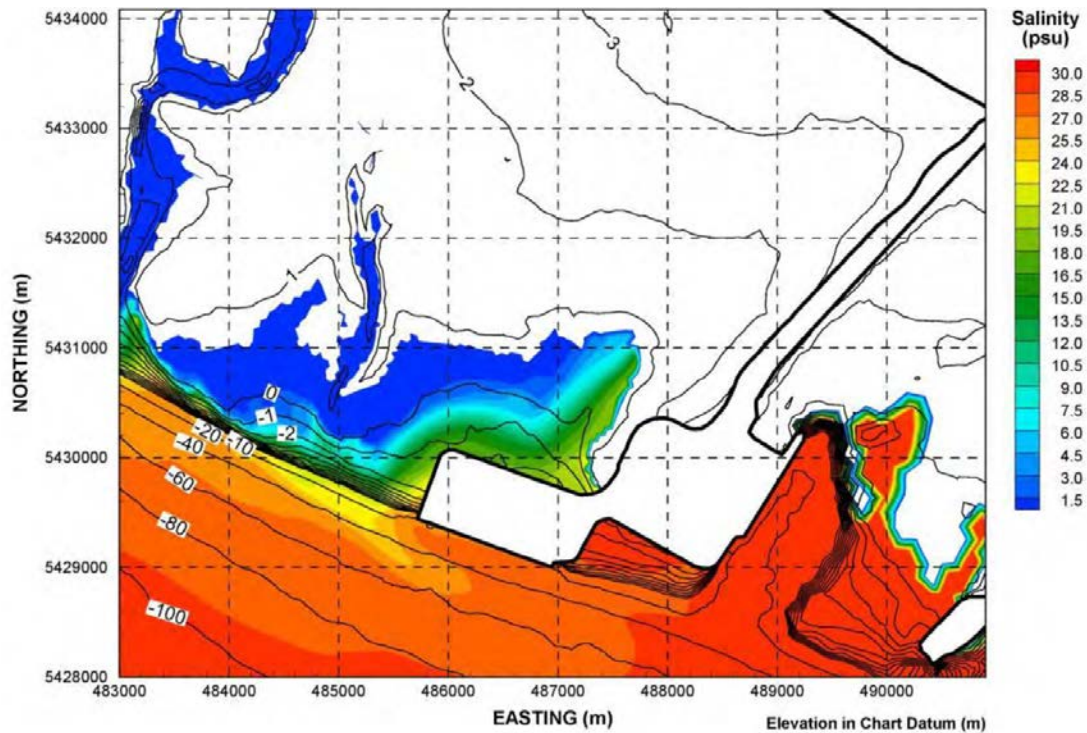


FIGURE 5-7: SALINITIES ASSOCIATED WITH AN EBB TIDE

5.3.2. Intertidal Marsh Salinity Range

Intertidal marsh habitat is characterized by emergent vascular plants that exist in the elevation range of +3.2 to +4.8 m CD that is regularly covered during high tides. At Roberts Bank, typical species of intertidal marsh habitats include sedges such as *Carex lyngbyei* and *Schoenoplectus pungens*, saltgrass species, e.g. *Distichlis spicata*, and succulents including *Sarcocornia pacifica* (Hemmera 2014). The salinity tolerance of marsh vegetation ranges between 18 to 30 ppt (GLW, 2017).

Table 5-5 shows that salinity levels at the existing tidal marsh area (northwest of delta port) are about 25 ppt. The salinity range estimated for the proposed intertidal marsh zone along the northern side of RBT2 is within the optimal range.

TABLE 5-5: SALINTY RANGES FOR EXISTING AND PROPOSED TIDAL MARSH ZONES

Description	Marsh Zone	
	Existing	Proposed
Salinity Range (ppt)	24 - 25.5	18 – 25.5

The intertidal marsh can be created on raised areas adjacent to the terminal and causeway at elevations between +3.0 m chart datum (CD) and +5.0 m CD (EIS Appendix 17-B, Drawing 17-B1), where wave energy is dissipated in the high intertidal (supralittoral) zone.

Table 5-6 summarizes elevation and salinity tolerance ranges of dominant low and high intertidal marsh species measured on Roberts Bank.

TABLE 5-6: PROJECT AND REGIONAL MARSH HABITAT SALINITY TOLERANCE

Plant Species	Salinity Range (PPT)
Seacoast Bulrush	2 – 20
Lyngbye’s Sedge	0 – 15
Saltgrass	4 – 35
Baltic Rush	2 – 15
Pacific Silverweed	0 – 15
Pickleweed	18 – 35
Three-Square Bulrush	0 – 20
Softstem Bulrush	0 – 11
Arrowgrass	0 – 30

- References:
- 1) GLW (2009)
 - 2) GLW (2017a)

5.3.3. Intertidal Marsh Elevation Range

Table 5-7 summarizes elevation ranges of dominant low and high intertidal marsh species on Roberts Bank identified in field surveys.

Blank cells indicate that the respective species was not observed at the indicated location, or elevation data was not collected.

TABLE 5-7: PROJECT AND REGIONAL MARSH HABITAT ELEVATION RANGES

Plant Species	Elevation Range (m CD)		
	Roberts Bank ¹	DeltaPort Causeway ¹	Steveston Jetty South Arm ²
Seacoast Bulrush	3.0 – 3.8	3.4 – 4.0	3.0 – 3.2
Lyngbye's Sedge	3.1 – 4.2		3.1 – 3.9
Saltgrass	3.8 – 5.0	3.8 – 5.0	
Baltic Rush	3.0 – 3.4		3.2 – 4.0
Pacific Silverweed	3.0 – 4.2		
Pickleweed	3.6 – 4.5	3.6 – 4.7	
Three-Square Bulrush	2.6 – 3.8	3.2 – 3.9	2.8 – 3.3
Softstem Bulrush	3.1 – 4.3		
Arrowgrass	3.6 – 4.0	3.6 – 4.0	

References:

- 1) GLW (2009)
- 2) GLW (2017a)

5.3.4. Intertidal Marsh Wave Tolerance

Douglass et al. (2004) have studied the tolerance of marsh vegetation with respect to wave exposure.

Figure 5-8 summarizes the applicable guidance. The green lines in the figure indicate significant wave height limits permitting marsh vegetation to propagate. The blue lines indicate wave heights at which wetland vegetation will be subject to erosion. The red lines indicate the wave threshold above which wetland species are unable to grow.

The studies by Douglass et al. (2004) found that the upper limit of wave energy for existence of salt marsh could be quantified as:

- Median (H_{50}) $H = 0.13$ m
- Corresponding $H_{80} = 0.25$ m

Sites with less wave energy were observed to have vegetation along the shoreline, while sites exposed to larger wave heights were unable to support marsh habitat.

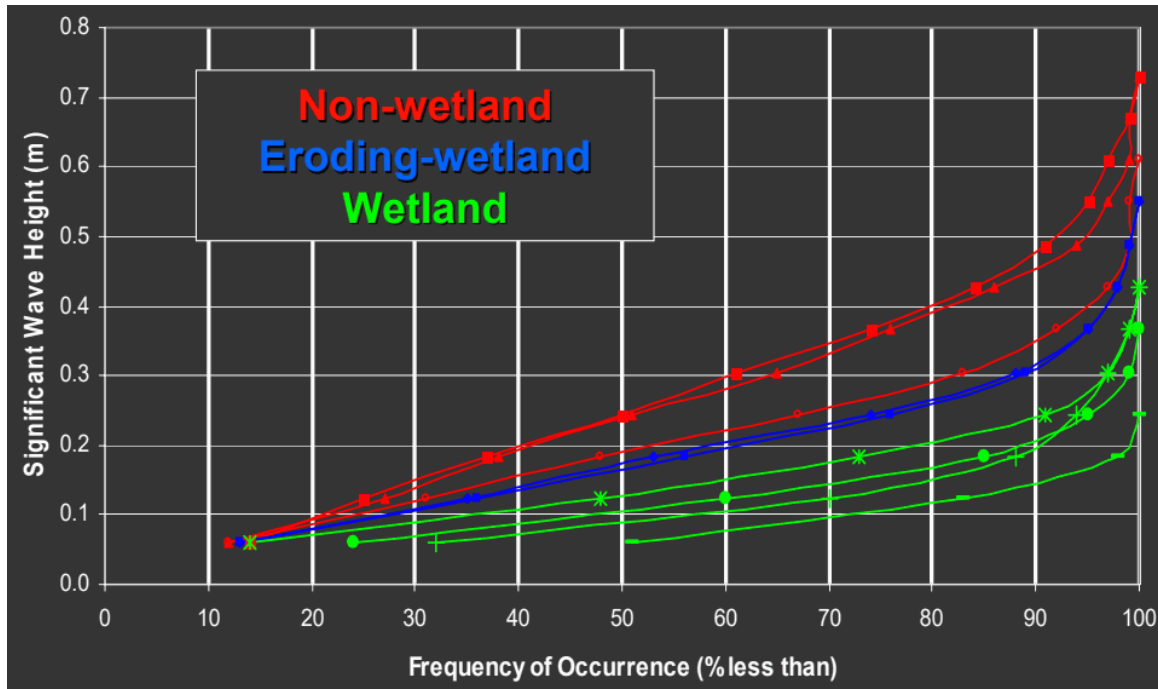


FIGURE 5-8: WAVE HEIGHT TOLERANCE FOR MARSH SPECIES, DOUGLASS (2004).

5.3.5. Rock Berm Stone Size

The median stone mass for a stable riprap distribution can be determined using the Hudson equation (CEM, 2011):

$$M_{50} = \frac{\rho_s \times H^3}{K_D \times \left(\frac{\rho_s}{\rho_w} - 1\right)^3 \times \cot \alpha} \quad 5-1$$

Where:

- H Characteristic wave height (H_s)
- M_{50} Median mass of stone armor unit
- ρ_s Mass density of stone
- ρ_w Mass density of water
- K_D Stability coefficient
- α Slope angle

Based on the equation 5-1, median stone mass would be equal to 740 kg.

Table 5-8 demonstrates the gradation of rock sizes in each class of riprap. To meet the minimum requirements, class of 1000 kg is selected for design purposes.

TABLE 5-8: GRADATION OF ROCK SIZES IN EACH CLASS OF RIPRAP

CLASS OF RIPRAP (kg)	*NOMINAL THICKNESS OF RIPRAP (mm)	ROCK GRADATION PERCENTAGE SMALLER THAN GIVEN ROCK MASS (kg)		
		15%	50%	85%
10	350	1	10	30
25	450	2.5	25	75
50	550	5	50	150
100	700	10	100	300
250	1000	25	250	750
500	1200	50	500	1500
1000	1500	100	1000	3000
2000	2000	200	2000	6000
4000	2500	400	4000	12000

* The thickness of riprap, measured at right angles to the slope, for the class specified, shall be the nominal thickness stated, unless otherwise shown on the Drawings or required by the Ministry Representative.

5.3.6. Rock Berm Crest Elevation

Wave action behind a rock structure can be caused by wave overtopping and wave penetration if the structure is permeable. The wave transmission can be characterized by a transmission coefficient, C_t , defined as the ratio of transmitted to incident characteristic wave heights. The transmission coefficient is defined by equation 5-2 as follows:

$$C_t = \frac{H_{st}}{H_s} \quad 5-2$$

Where:

H_{st} Transmitted characteristic wave height

H_s Incident characteristic wave height

Based on Table 3-3 and Table 3-4, the maximum 1-year return period wind speed from northwest-west (NW-W) direction and maximum wave height is equal to 36 knots and 1 m respectively. For design purposes, the maximum transmitted wave for intertidal marsh zone is selected to be 0.1 m. Therefore, the transmission coefficient (C_t) equals 0.1.

Equation 5-3 indicates the wave transmission formula by van der Meer et al. (1991) for rock armored low-crested, and submerged structures, which accounts for the crest width of structure.

$$C_t = \left(0.031 \times \frac{H_s}{D_{n50}} - 0.24\right) \times \frac{R_c}{D_{n50}} + b \quad 5-3$$

Where:

- H_s Significant wave height of incident waves
- D_{n50} Median of nominal diameter of rocks for design condition
- R_c Freeboard, negative for submerged structure
- b Constant based on crest width

Based on equation 5-3 and a crest width of 5 m, the required freeboard above HHW-MT taken as an average of mean high tides is $R_c = 1.1$ m, which corresponds to a crest elevation of the rock berm of about +5.2 m CD (Figure 5-9).

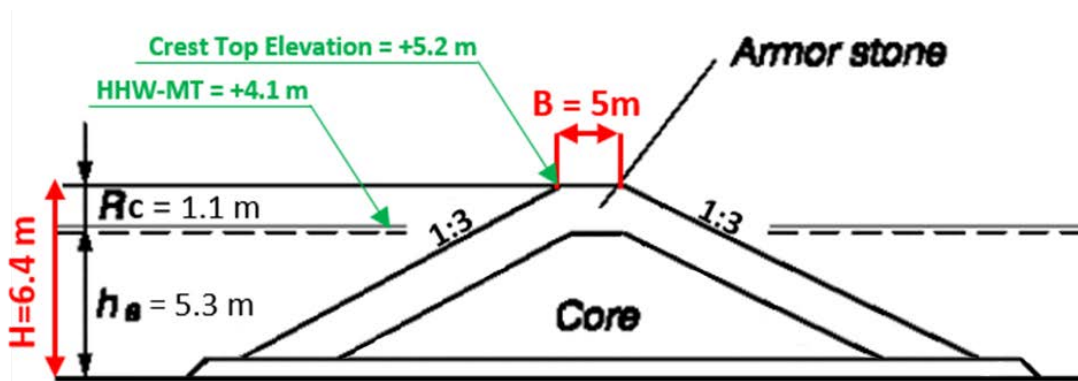


FIGURE 5-9: ROCK BERM CREST ELEVATION AND DETAILS (VAN DER MEER-1991)

5.3.7. Marsh Channel Dimensions

To provide channel characteristics and dimensions within a tidally dominated coastal landscape, Hughes (2002) and other studies suggest the existence of a relationship between cross-sectional area and tidal prism for tidal channels. Their approach reasonably fits a wide range of channels and inlets. The findings from Hughes (2002) was augmented with data for local mudflat and marsh channels on Sturgeon Bank and Roberts Bank. Data for tidal prism, channel width, channel depth, and cross-sectional area was collected for existing marsh channels and channels on the mudflat. Figure 5-10 presents the observed relationship where green circles are representative of marsh channels and orange circles representative of channels on the mudflats.

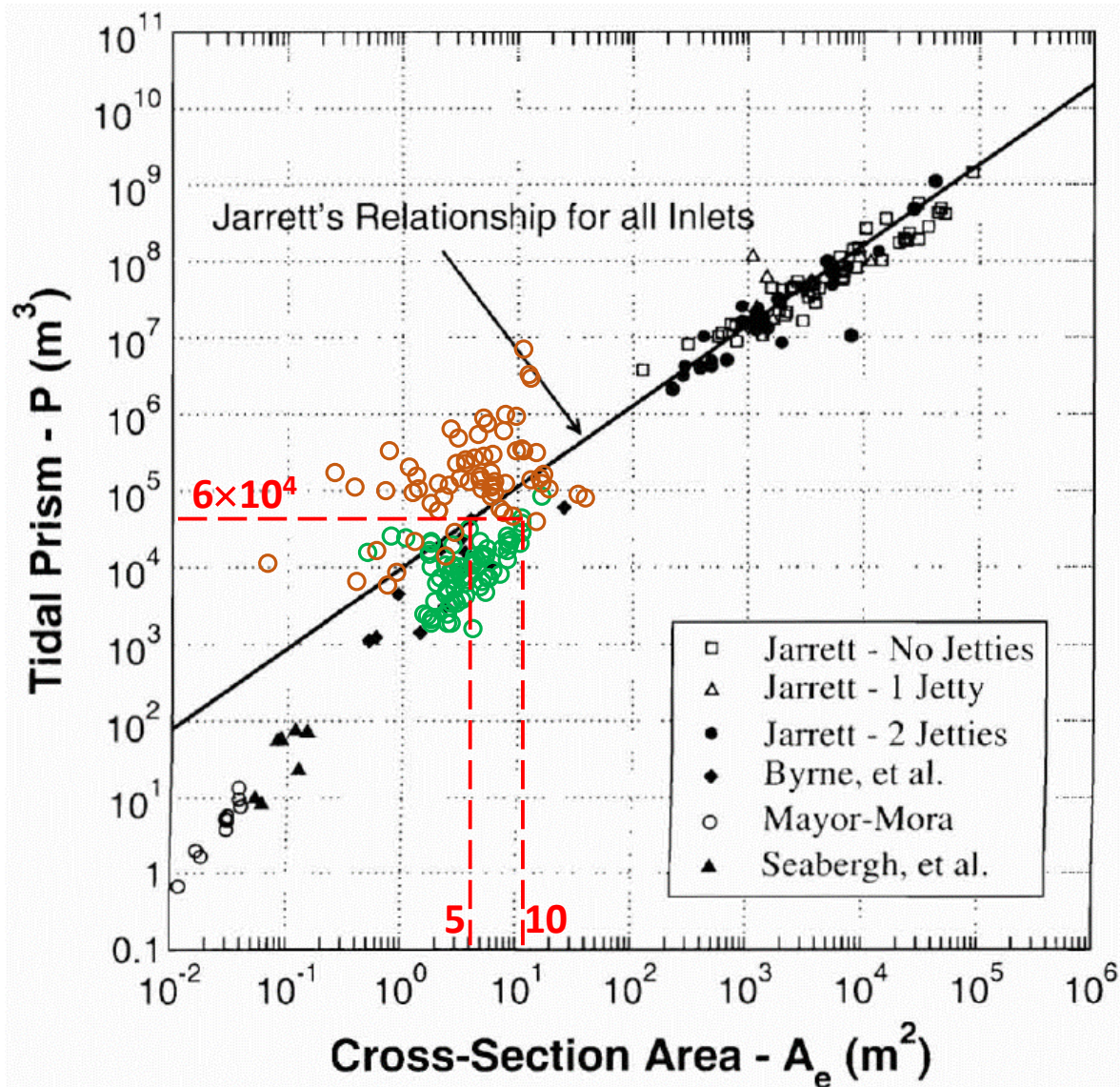


FIGURE 5-10: EQUILIBRIUM CROSS-SECTION AREA VERSUS TIDAL PRISM DATA

The plan areas of the intertidal marsh zone and rock berm are about 76,000 m² and 44,000 m² respectively (120,000 m² in total). Based on Table 3-1, HHW-MT equals to 4.1 m (CD) and LLW-MT is about 1.2 m (CD). Since the suggested marsh vegetation is located at around elevation 3.6 m (CD), the maximum water volume needed to route through the channel is approximately 6×10⁴ m³. Using the relationship, an equilibrium cross-sectional area during peak discharge is estimated around 5 m² if using Jarrett's relationship and about 10 m² based on the local marsh channel data. In addition, based on the simulation modeling results, the maximum discharge for the channel out of intertidal marsh zone is approximately 12 m³/s. Based on Friedrichs (1995), the relationship between cross-sectional area and peak discharge for tidal channels is shown in Figure 5-11. It confirms the finding from previous method about the optimal cross-sectional area for the channel is about 10 m² based on Friedrichs relationship.

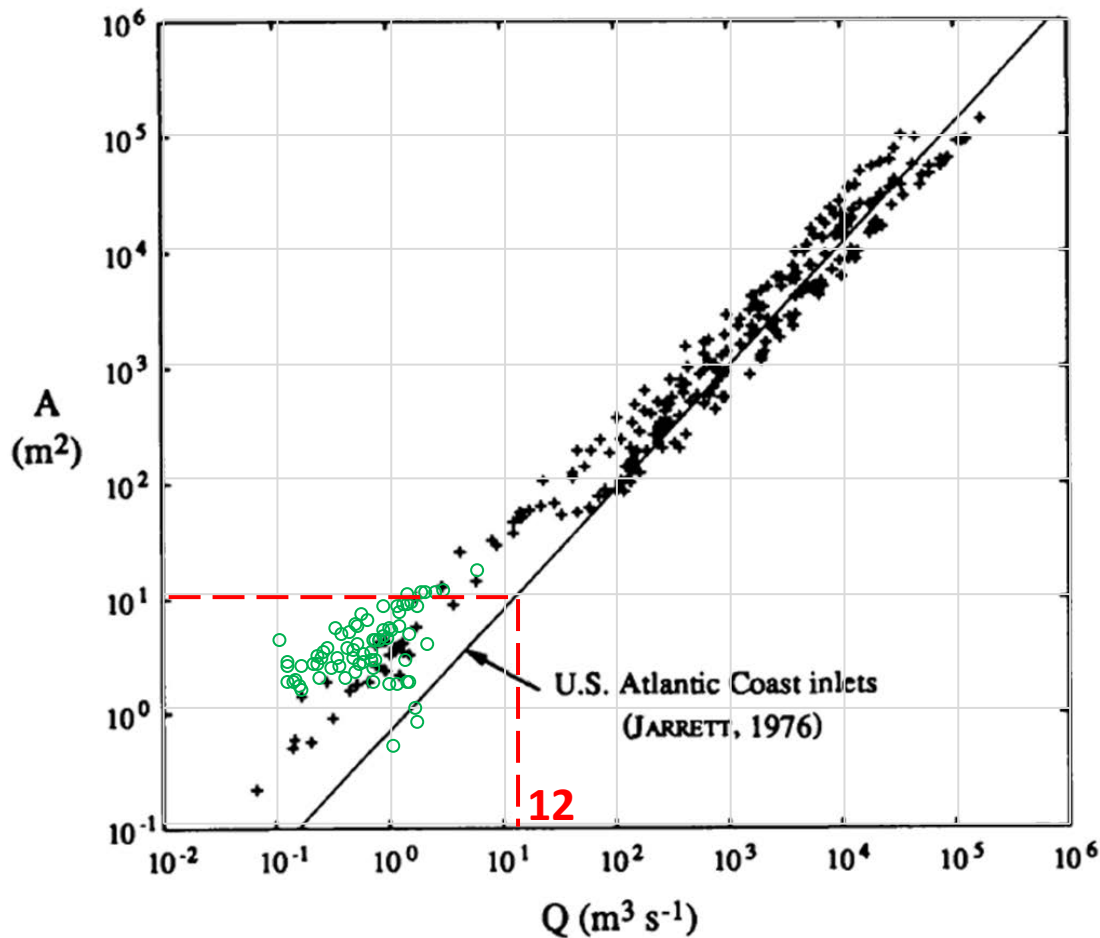


FIGURE 5-11: CROSS-SECTIONAL AREA VS. PEAK DISCHARGE FOR SHELTERED TIDAL CHANNELS (FRIEDRICHS,1995)

While there is great variability within tide-dominated systems, the channel width-to-depth ratio can be split into two discrete groups of tidal channels, namely marsh channels and channels on mudflats (Hughes, 2011). Adopting this concept, aerial photographs and LiDAR survey were used to estimate the width-to-depth ratios for marsh channels and mudflat channels on Sturgeon Bank and Roberts Bank. The data is shown in Figure 5-12, where the green circles represent marsh channel dimensions and the orange circles are representative of channels on the mudflats. The marsh channel data correlates well with Hughes (2011) data in the figure. The suggested range of the proposed marsh channel geometry is indicated by the dashed red lines in the figure. The suggested range is from a 5 m wide and 0.7 m deep channel to a 10 m wide and 1.4 m deep channel.

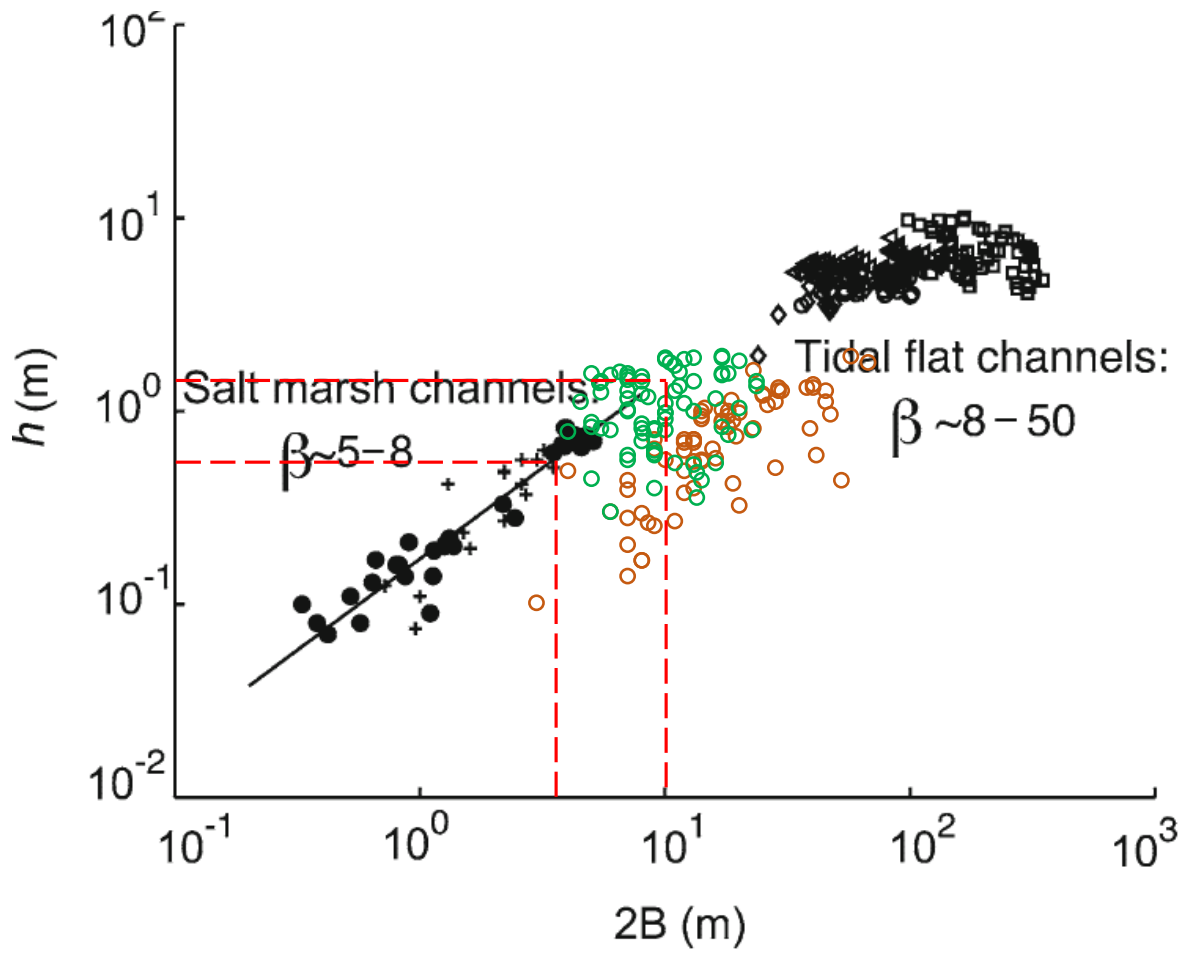


FIGURE 5-12: WIDTH-TO-DEPTH RATIO FOR TIDAL CHANNELS (ADOPTED FROM HUGHES 2011)

6. Conclusions

Overall evaluation from the analyses conducted for this report indicates that:

- Post-project current speeds around the peripheral boundaries and RBT2 project areas are equal to or less than pre-project values.
- The proposed marsh and eelgrass habitat meets the outline design criteria.
- The salinity range in the area proposed for new eelgrass plantings is within the optimal range for eelgrass.
- The salinity range estimated for the proposed intertidal marsh zone along the northern side of RBT2 is within the optimal range for select salt-tolerant species.
- Based on the salinity tolerance parameters; Saltgrass, pickleweed, and Arrowgrass species may be candidate marsh vegetation for the onsite marsh habitat. The preferred elevation range for these species is 3.6 to 5.0 m CD.
- The freeboard of the rock berm is estimated to be 1.1 m above Higher High Water-Mean Tide (HHW-MT). This corresponds to a crest elevation of about +5.2 m CD.
- The suggested marsh channel dimensions range from a 5 m wide and 0.7 m deep channel to a 10 m wide and 1.4 m deep channel.

7. References

BIEAP-FREMP (2006). Environmental Management Strategy for Dredging in the Fraser River Estuary. Burrard Inlet Environmental Action Program (BIEAP) and Fraser River Estuary Management Program (FREMP).

BC Ministry of Environment (BC MOE, 2007), Lower Mainland Region Dyke Mapping. 2007.

Canadian Hydrographic Services (2005). Charts #3492.

CBA (2010). Roberts Bank and Sturgeon Bank Reach Overview – Phase 2. A report for BIEAP-FREMP.

CEM (2011). U.S. Army Corps of Engineers, Engineering and Design “Coastal Engineering Manual”.

DHI (2008). MIKE C-Map. User Guide.

Durance, C. (2014). Eelgrass Habitat Creation in British Columbia. A Presentation to Port Metro Vancouver. October 1, 2014.

Egbert, G. F. and Erofeeva, L. (2010). OSU Tidal Inversion. <http://volkov.oce.orst.edu/tides/global>.

Friedrichs, C.T., 1995. Stability Shear Stress and Equilibrium Cross-Sectional Geometry of Sheltered Tidal Channels. *Journal of Coastal Research* (11), p1062-1074.

FHWA (2005). *Design of Roadside Channels with Flexible Linings*. Hydraulic Engineering Circular No. 15, Third Edition. Publication No. FHWA-NHI-05-114. U.S. Department of Transportation, Federal Highway Administration. National Highway Institute. September 2005.

GLW (2009). *Roberts Bank and Sturgeon Bank Reach Overview. Backgrounder*. Prepared for Fraser River Estuary Management Program. Prepared by Gary Williams, GL Williams & Associates Ltd., 2907 Silver Lake Place, Coquitlam BC V3C 6A2; and Andre Zimmermann, Derek Ray, Charlene Menezes, Northwest Hydraulic Consultants, 30 Gostick Place, North Vancouver, BC V7M 3G3. October 27, 2009.

GLW (2017). Preliminary determination of planting quantities for South Arm Jetty. Prepared for Moffatt & Nichol. Prepared by Gary Williams, Professional Wetland Scientist. GL Williams & Associates Ltd., Coastal and Estuarine Habitat, 2907 Silver Lake Place, Coquitlam BC V3C 6A2.

Hemmera Environchem Inc. (2014). Roberts Banks Terminal 2, Technical Data Report, Marine Vegetation.

Hemmera Environchem Inc. (2015a). Existing Ecological Conditions Proposed Tsawwassen Eelgrass Enhancement Project.

Hemmera Environchem Inc. (2015b). Tsawwassen Eelgrass Enhancement Project Source Sediment Characterization.

Hughes, Z.J., 2011. Chapter 11: Tidal Channels on Tidal Flats and Marshes, Principles of Tidal Sedimentology. Editors: Davis Jr., R.A. and Dalrymple, R.W. Publisher: Springer Netherlands.

Jacques Whitford-Axys (2007). Vancouver Island Transmission Reinforcement Project; Application for Navigable Waters Act Authorization for Habitat Compensation Works on Roberts Bank, Tsawwassen, BC.

Jacques Whitford-Axys (2007). Vancouver Island Transmission Reinforcement Project; Fish Habitat Compensation Plan, Tsawwassen, BC.

Moffatt & Nichol (2012). Memorandum on Updated Hydrodynamic Model of Roberts Bank, prepared for Hemmera Environchem Inc. Reference Job No. 7627-22. Dated March 16, 2012.

Moffatt & Nichol (2020). Proposed Eelgrass at Elev -1 W/ Temp. Access Road & Intertidal Ranges. Dated February 26, 2020.

North Hydraulic Consultants (2006). Lower Fraser River Hydraulic Model: Recorded Flow Splits. Drawing Prepared for Fraser Basin Council. North Vancouver, BC.

Precision Identification (2013). Assessment of Potential Eelgrass Transplant Sites, prepared for Port Metro Vancouver. Tsawwassen, Delta. April 2013.

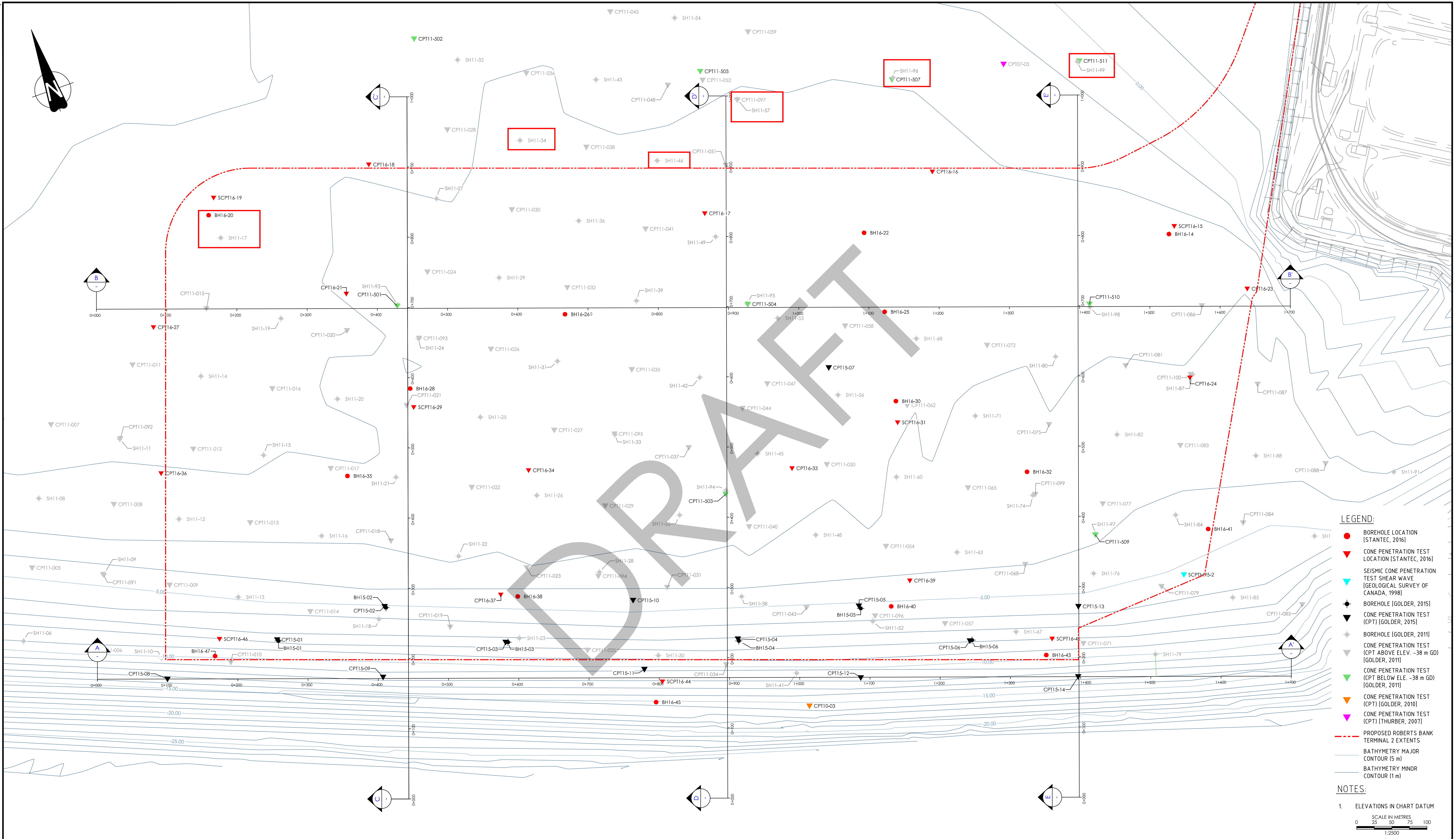
Stantec (2013). Sturgeon and Roberts Bank LiDAR July 2013. Data file Prepared for Port of Vancouver.

Stantec (2016a). *Borehole Record*. Project: Roberts Bank Terminal 2. Prepared for: Port of Vancouver. Prepared by: Stantec. Dates of Borings: 2016/08/25 to 2016/08/30.

Stantec (2016b). *Profile B-B' – Fines Content*. Container Capacity Improvement Program, Roberts Bank Terminal 2. Proposed Terminal Expansion. Dwg. 34-347-GT-0304, sheet 1 of 1, Rev. A. Scale 1:2500H, 1:500V. Date: 12/02/16.

Appendix C: Borehole Records

DATE: 2017/03/03 - 3:36pm
 PATH: \\CD1183-F05-workgroup\1158\active\115815019\7_drawings\6_geotech\6_figures\interpretive_drawings\34-347-GT-0300_test_hole_plan.dwg

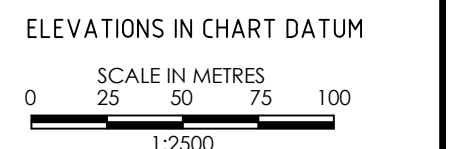


LEGEND:

- BOREHOLE LOCATION [STANTEC, 2016]
- ▼ CONE PENETRATION TEST LOCATION [STANTEC, 2016]
- ▲ SEISMIC CONE PENETRATION TEST SHEAR WAVE [GEOLOGICAL SURVEY OF CANADA, 1998]
- ◆ BOREHOLE [GOLDER, 2015]
- ▼ CONE PENETRATION TEST [GOLDER, 2015]
- ◆ BOREHOLE [GOLDER, 2011]
- ▼ CONE PENETRATION TEST [CPT ABOVE ELEV. -38 m GD] [GOLDER, 2011]
- ▼ CONE PENETRATION TEST [CPT BELOW ELEV. -38 m GD] [GOLDER, 2011]
- ▼ CONE PENETRATION TEST [CPT] [GOLDER, 2010]
- ▼ CONE PENETRATION TEST [CPT] [THURBER, 2007]
- - - PROPOSED ROBERTS BANK TERMINAL 2 EXTENTS
- BATHYMETRY MAJOR CONTOUR (5 m)
- BATHYMETRY MINOR CONTOUR (1 m)

NOTES:

- ELEVATIONS IN CHART DATUM



Ref.No.	REFERENCE
2	EXISTING ROBERTS BANK TERMINAL SURVEY, DWG NO. 34-347-GT-1150-1160 Rev. A, DATED 14/03/24
1	AECOM BATHYMETRY CONTOURS, DWG NO. 20000-ACL-RBT2, DATED 12/12/15



FOR DISCUSSION ONLY
 DO NOT USE FOR CONSTRUCTION
 Last Saved: Feb. 21/17 12:19pm

No.	Date	REVISION	Dr'n	Ch'd
C	11/14/16	2016 CPT LOCATIONS ADDITIONS	GH	HK
B	05/11/16	REVISED LOCATIONS FOR GEOLOGICAL SURVEY OF CANADA (1998)	GH	HK
A	04/29/16	INITIAL DRAFT	NP	HK



VANCOUVER FRASER PORT AUTHORITY
 ENGINEERING DEPARTMENT

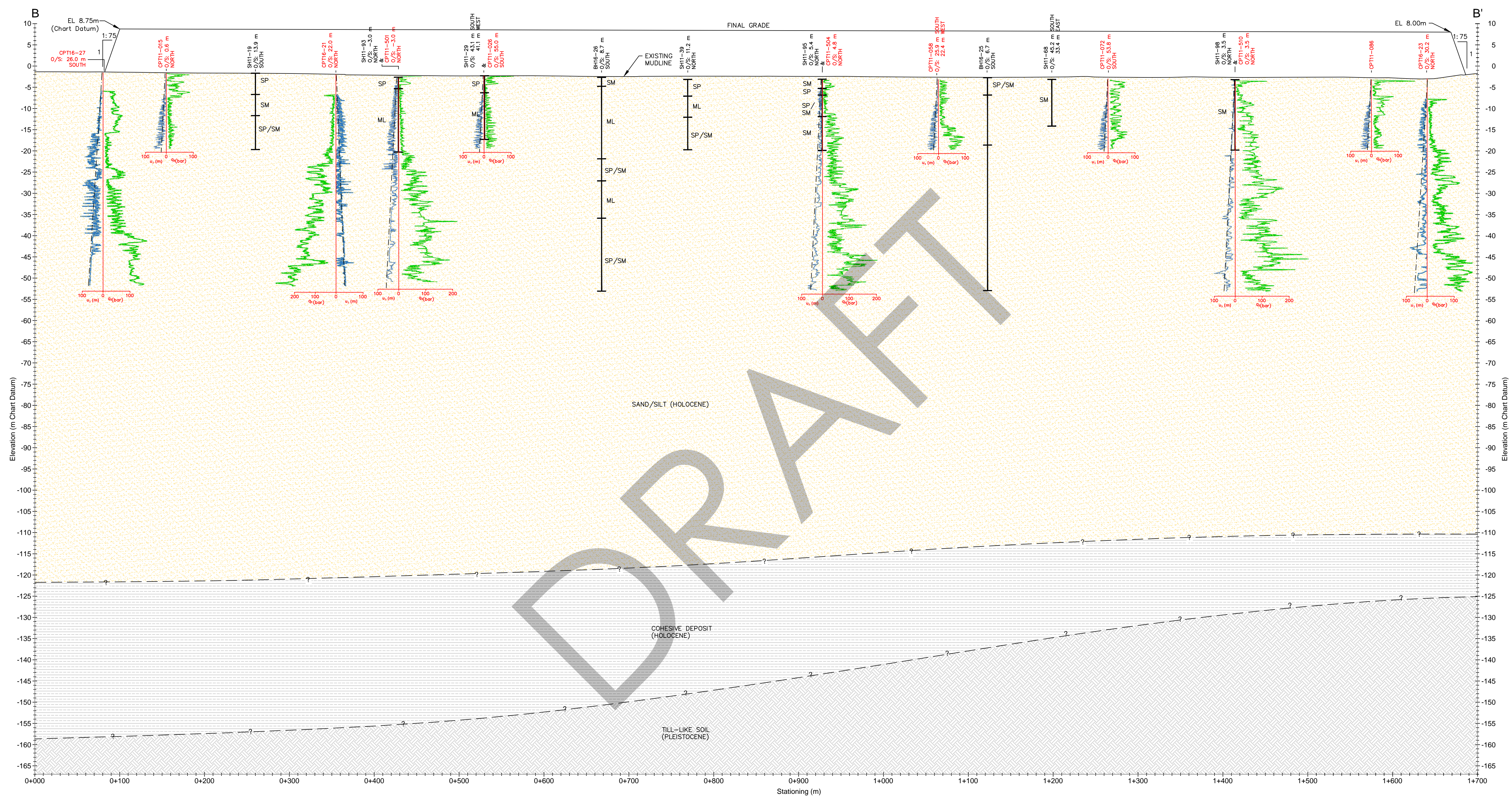
DESIGN BY	R. PLASTERER
DRAWN BY	G. HUYNH
APPROVED	H. KRISTIANSEN
DATE	04/29/16
SCALE	1:2500
PMV SITE	34

CONTAINER CAPACITY IMPROVEMENT PROGRAM
ROBERTS BANK TERMINAL 2
PROPOSED TERMINAL EXPANSION
AS-BUILT TEST HOLE LOCATION PLAN

SIZE Dwg. 34-347-GT-0300

SHEET 1 of 1 REV. A

DATE: 2017/03/03 - 3:43pm
 PATH: \\CD1183-F05\workgroup\1158\active\115815019\7_drawings\6_geotech\6_figures\interpretive_drawings\34-347-GT-0303_xsect_b_cpt_tip_resistance.dwg
 TITLE BLOCK: DL-TE.dwg



Profile View of B-B'
 Vertical Exaggeration: 5:1

LEGEND:

- CPT TIP RESISTANCE Q_t
- PORE WATER PRESSURE u_2
- SAND/SILT (HOLOCENE)
- CLAY (HOLOCENE)
- TILL-LIKE SOIL (PLEISTOCENE)

HORIZONTAL SCALE IN METRES
 0 25 50 75 100 125
 1:2500

VERTICAL SCALE IN METRES
 0 5 10 15 20 25
 1:500

- NOTES:**
- COHESIVE AND TILL DEPOSITS INFERRED BASED ON 2016 INVESTIGATION AND FROM FIGURE 5-1 OF GOLDER REPORT "ROBERTS BANK SEISMIC EVALUATION", (REPORT REF. NO. 10-1447-0150, DATED MAY 18, 2011)
 - 2016 PAIRED TEST HOLE DATA ILLUSTRATED AT ONE LOCATION.

Ref.No.	REFERENCE
1	AECOM BATHYMETRY CONTOURS, DWG NO. 20000-ACL-RBT2, DATED 12/12/15



FOR DISCUSSION ONLY
 DO NOT USE FOR CONSTRUCTION
 Last Saved: Feb. 21/17 11:46am

No.	Date	REVISION	Dr'n	Ch'd
B	12/02/16	2016 TEST HOLE DATA UPDATES	GH	HK
A	11/14/16	INITIAL DRAFT	GH	HK



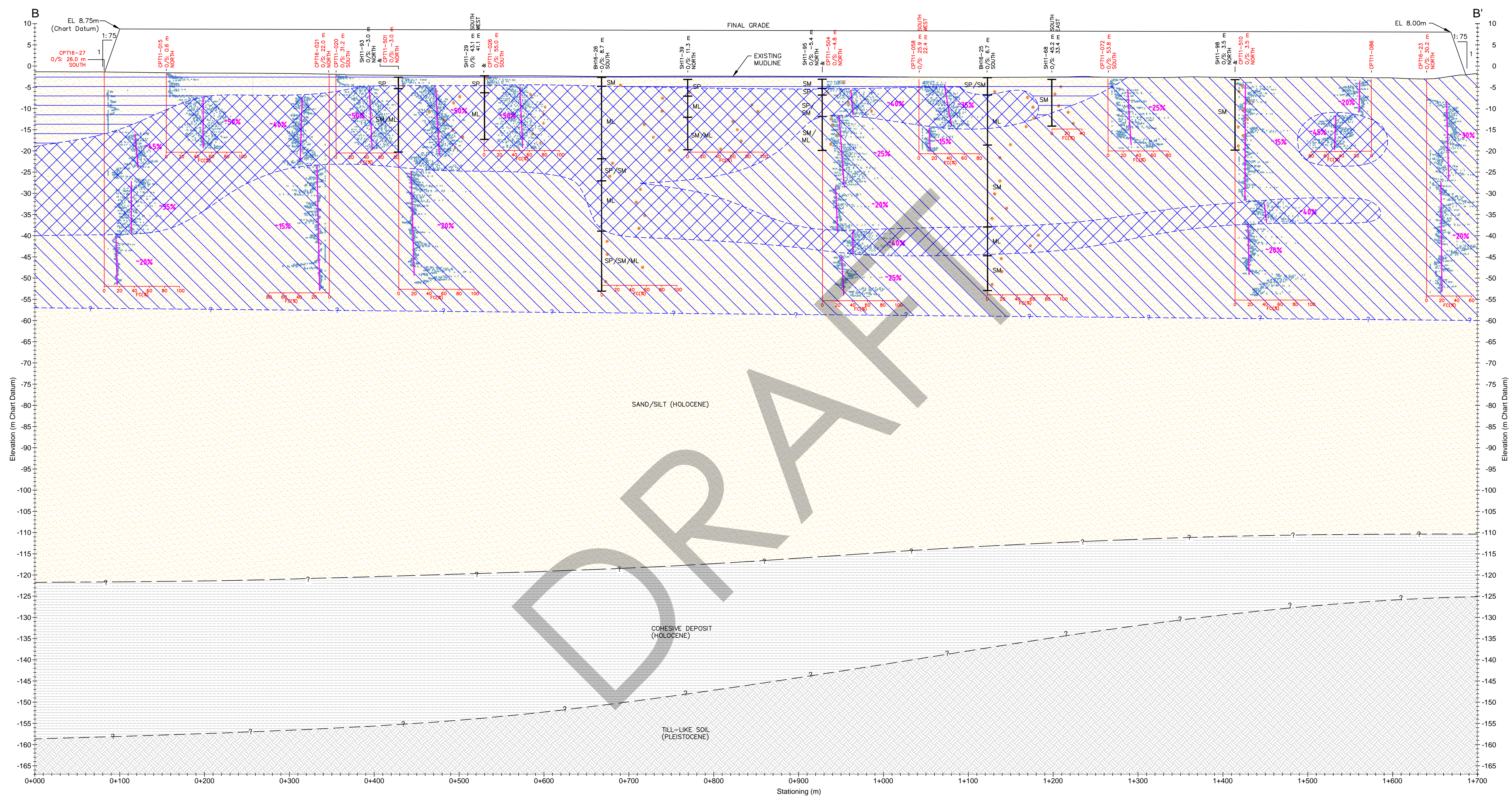
VANCOUVER FRASER PORT AUTHORITY
 ENGINEERING DEPARTMENT

DESIGN BY	M. YUAN
DRAWN BY	G. HUYNH
APPROVED	H. KRISTIANSEN
DATE	11/14/16
SCALE	1:2500H, 1:500V
PMV SITE	34

CONTAINER CAPACITY IMPROVEMENT PROGRAM
 ROBERTS BANK TERMINAL 2
 PROPOSED TERMINAL EXPANSION
 PROFILE B-B' - CPT TIP RESISTANCE Q_t

SIZE	DWG.	SHEET	REV.
D		1 of 1	B

DATE: 2017/03/03 - 3:45pm
 PATH: \\CD1183-F05\workgroup\1158\active\115815019\7_drawings\6_geotech\6_figures\interpretive_drawings\34-347-GT-0304_xsect_b_fines_content.dwg
 TITLE BLOCK: DL-TE.dwg



Profile View of B-B'
 Vertical Exaggeration: 5:1

LEGEND:

- APPARENT FINES CONTENT FROM CPT INTERPRETATION
- FINES CONTENT FROM LABORATORY TESTING
- REPRESENTATIVE FINES CONTENT
- 5-15% FINES CONTENT
- 15-30% FINES CONTENT
- >30% FINES CONTENT
- SAND/SILT (HOLOCENE)
- CLAY (HOLOCENE)
- TILL-LIKE SOIL (PLEISTOCENE)

HORIZONTAL SCALE IN METRES
 0 25 50 75 100 125
 1:2500

VERTICAL SCALE IN METRES
 0 5 10 15 20 25
 1:500

- NOTES:**
- COHESIVE AND TILL DEPOSITS INFERRED BASED ON 2016 INVESTIGATION AND FROM FIGURE 5-1 OF GOLDR REPORT 'ROBERTS BANK SEISMIC EVALUATION', (REPORT REF. NO. 10-1447-0150, DATED MAY 18, 2011)
 - 2016 PAIRED TEST HOLE DATA ILLUSTRATED AT ONE LOCATION.

Ref.No.	REFERENCE
1	AECOM BATHYMETRY CONTOURS, DWG NO. 20000-ACL-RBT2, DATED 12/12/15



FOR DISCUSSION ONLY
 DO NOT USE FOR CONSTRUCTION
 Last Saved: Feb. 21/17 11:37am

No.	Date	REVISION	Dr'n	Ch'd
A	12/02/16	INITIAL DRAFT	GH	HK

PORT of vancouver

VANCOUVER FRASER PORT AUTHORITY
 ENGINEERING DEPARTMENT

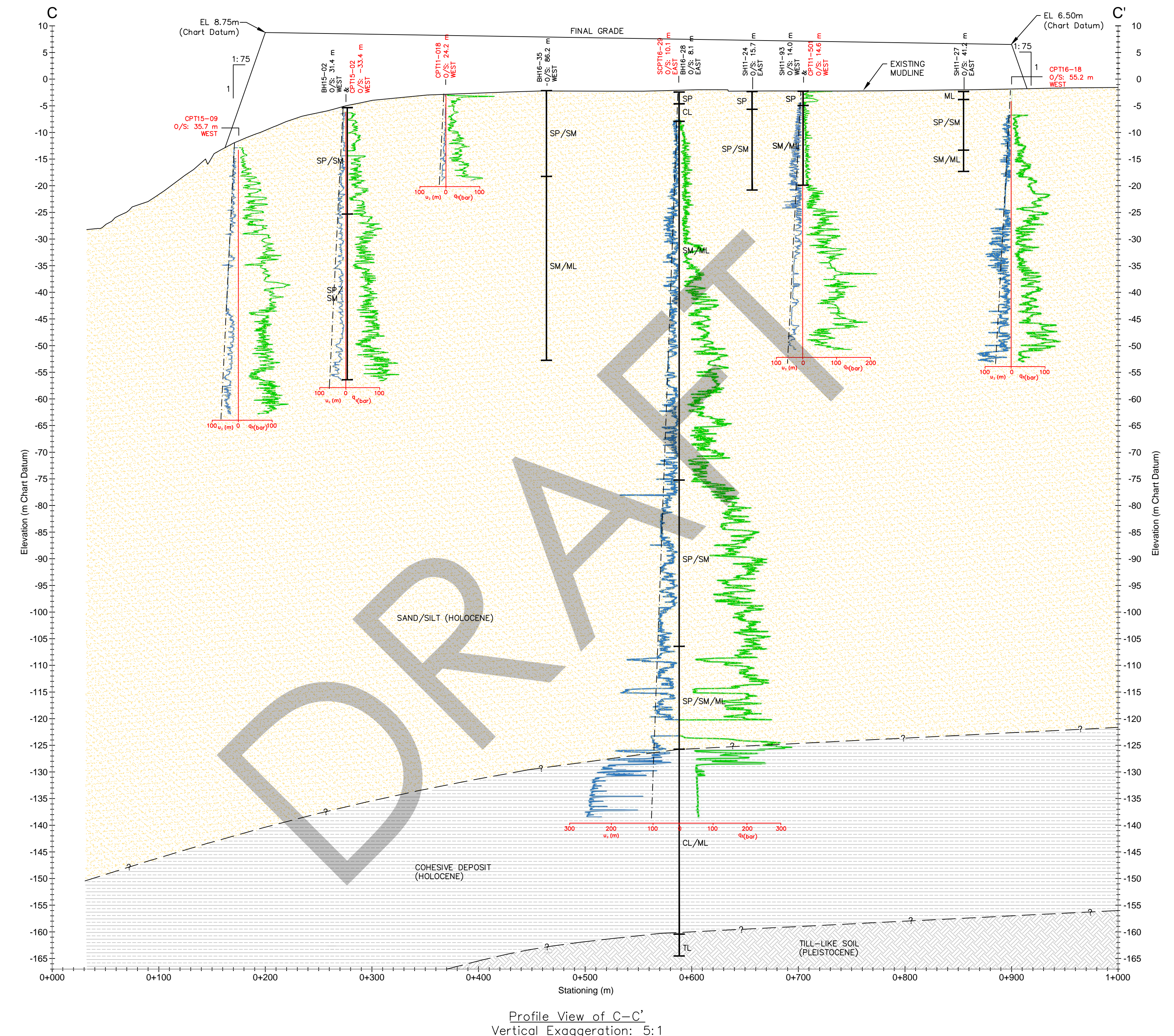
DESIGN BY	M. YUAN
DRAWN BY	G. HUYNH
APPROVED	H. KRISTIANSEN
DATE	12/02/16
SCALE	1:2500H, 1:500V
PMV SITE	34

CONTAINER CAPACITY IMPROVEMENT PROGRAM
 ROBERTS BANK TERMINAL 2
 PROPOSED TERMINAL EXPANSION
 PROFILE B-B' - FINES CONTENT

34-347-GT-0304

SHEET 1 of 1
 REV. A

DATE: 2017/03/03 - 3:46pm
 PATH: \\CD1183-F05\workgroup\1158\active\115815019\7_drawings\6_geotech\6_figures\interpretive_drawings\34-347-GT-0305_xsect_c_cpt_tip_resistance.dwg
 TITLE BLOCK: DL-TE.dwg



LEGEND:

- CPT TIP RESISTANCE Q_t
- PORE WATER PRESSURE u_2
- SAND/SILT (HOLOCENE)
- CLAY (HOLOCENE)
- TILL-LIKE SOIL (PLEISTOCENE)

HORIZONTAL SCALE IN METRES
 0 25 50 75 100 125
 1:2500

VERTICAL SCALE IN METRES
 0 5 10 15 20 25
 1:500

- NOTES:**
- COHESIVE AND TILL DEPOSITS INFERREED BASED ON 2016 INVESTIGATION AND FROM FIGURE 5-1 OF GOLDER REPORT 'ROBERTS BANK SEISMIC EVALUATION', (REPORT REF. NO. 10-1447-0150, DATED MAY 18, 2011)
 - 2016 PAIRED TEST HOLE DATA ILLUSTRATED AT ONE LOCATION.

Ref.No.	REFERENCE
1	AECOM BATHYMETRY CONTOURS, DWG NO. 20000-ACL-RBT2, DATED 12/12/15



FOR DISCUSSION ONLY
 DO NOT USE FOR CONSTRUCTION
 Last Saved: Feb. 21/17 11:46am

No.	Date	REVISION	Dr'n	Ch'd
B	12/02/16	2016 TEST HOLE DATA UPDATES	GH	HK
A	04/29/16	INITIAL DRAFT	NP	HK



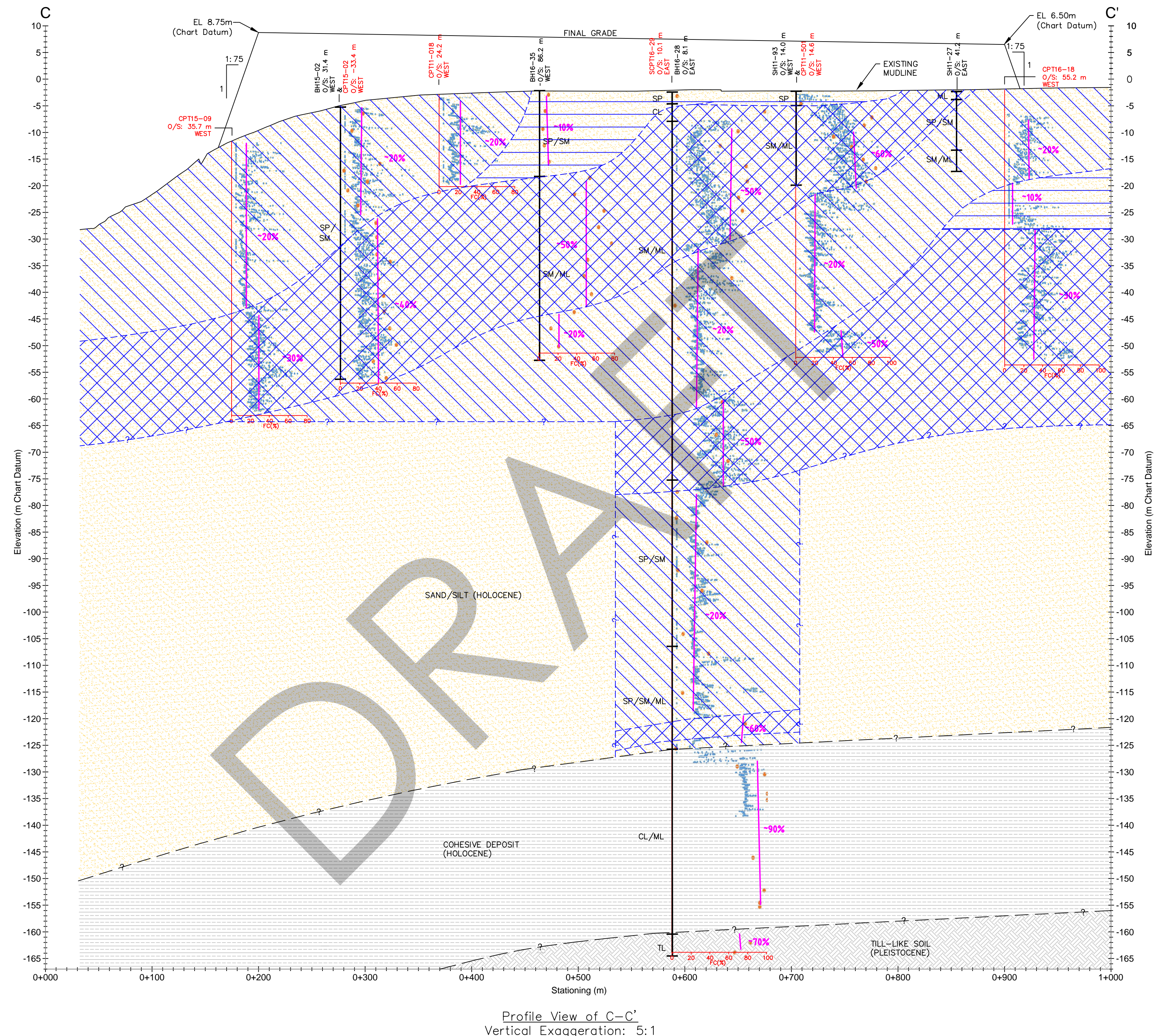
VANCOUVER FRASER PORT AUTHORITY
 ENGINEERING DEPARTMENT

DESIGN BY	R. PLASTERER
DRAWN BY	G. HUYNH
APPROVED	H. KRISTIANSEN
DATE	04/29/16
SCALE	1:2500H, 1:500V
PMV SITE	34

CONTAINER CAPACITY IMPROVEMENT PROGRAM
 ROBERTS BANK TERMINAL 2
 PROPOSED TERMINAL EXPANSION
 PROFILE C-C' - CPT TIP RESISTANCE Q_t

SIZE DWG. 34-347-GT-0305 SHEET 1 of 1 REV. B

DATE: 2017/03/03 - 3:47pm
 PATH: \\CD1183-F05\workgroup\1158\active\115815019\7_drawings\6_geotech\6_figures\interpretive_drawings\34-347-GT-0306_xsect_c_fines_content.dwg
 TITLE BLOCK: DL-TE.dwg



Profile View of C-C'
 Vertical Exaggeration: 5:1

LEGEND:

- APPARENT FINES CONTENT FROM CPT INTERPRETATION
- FINES CONTENT FROM LABORATORY TESTING
- #%#--- REPRESENTATIVE FINES CONTENT
- [Blue diagonal hatching] 5-15% FINES CONTENT
- [Blue cross-hatching] 15-30% FINES CONTENT
- [Blue grid hatching] >30% FINES CONTENT
- [Yellow stippled] SAND/SILT (HOLOCENE)
- [Grey stippled] CLAY (HOLOCENE)
- [Grey cross-hatching] TILL-LIKE SOIL (PLEISTOCENE)

HORIZONTAL SCALE IN METRES
 0 25 50 75 100 125
 1:2500

VERTICAL SCALE IN METRES
 0 5 10 15 20 25
 1:500

- NOTES:**
- COHESIVE AND TILL DEPOSITS INFERRED BASED ON 2016 INVESTIGATION AND FROM FIGURE 5-1 OF GOLDER REPORT 'ROBERTS BANK SEISMIC EVALUATION', (REPORT REF. NO. 10-1447-0150, DATED MAY 18, 2011)
 - 2016 PAIRED TEST HOLE DATA ILLUSTRATED AT ONE LOCATION.

Ref.No.	REFERENCE
1	AECOM BATHYMETRY CONTOURS, DWG NO. 20000-ACL-RBT2, DATED 12/12/15



FOR DISCUSSION ONLY
 DO NOT USE FOR CONSTRUCTION
 Last Saved: Feb. 21/17 11:24 am

No.	Date	REVISION	Dr'n	Ch'd
A	12/02/16	INITIAL DRAFT	GH	HK



VANCOUVER FRASER PORT AUTHORITY
 ENGINEERING DEPARTMENT

DESIGN BY	R. PLASTERER
DRAWN BY	G. HUYNH
APPROVED	H. KRISTIANSEN
DATE	12/02/16
SCALE	1:2500H, 1:500V
PMV SITE	34

CONTAINER CAPACITY IMPROVEMENT PROGRAM
 ROBERTS BANK TERMINAL 2
 PROPOSED TERMINAL EXPANSION
 PROFILE C-C' - FINES CONTENT

SIZE DWG. 34-347-GT-0306

SHEET 1 of 1 REV. A



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)															
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		WATER CONTENT / ATTERBERG LIMITS (%) NON-PLASTIC															
0	-1.45	Grey, poorly-graded SAND (SP-SM) with silt - with a few shell fragments and organics - passing #200 at 1.2 m: 10.2% fines - traces of silt below 3.1 m - passing #200 at 3.1 m: 2.3% fines																							
1																									
2																									
3																									
4																									
5	-6.35	Grey, sandy SILT (ML) - with silty sand seams and partings - with a few shell fragments and organics - passing #200 at 5.8 m: 65.2% fines - traces of sand below 7.5 m - hydrometer test at 9.0 m: gravel= 0%, sand= 6%, silt=78%, clay= 16% - with sand below 10.2 m - passing #200 at 10.5 m: 76.9% fines - passing #200 at 13.1 m: 76.1% fines - sandy below 14. 6 m - passing #200 at 15.9 m: 50.9% fines - hydrometer test at 18.9 m: gravel= 0%, sand= 49%, silt=42%, clay= 8%																							
6																									
7																									
8																									
9																									
10																									
11																									
12																									
13																									
14																									
15																									
16																									
17																									
18																									
19																									
20																									

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)													
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		WATER CONTENT / ATTERBERG LIMITS (%) NON-PLASTIC													
20		Grey sandy SILT (ML) - with silty sand seams and partings - with a few shell fragments - traces of organics below 20.8 m - with sand below 22.3 m - passing #200 at 22.3 m: 76.0% fines																					
21																							
22																							
23																							
24	-25.75																						
25		Grey, poorly-graded SAND (SP-SM) with silt - with a few shell fragments - hydrometer test at 24.4 m: gravel= 0%, sand= 94%, silt=3%, clay= 3%																					
26																							
27	-28.35																						
28		Mud Rotary drilling below 26.9 m																					
29																							
30		- traces of organics at 30.0 m																					
31																							
32																							
33																							
34																							
35																							
36		- traces of silt below 36.0 m - hydrometer test at 36.0 m: gravel= 0%, sand= 97%, silt=3%, clay= 0%																					
37																							
38																							
39																							
40																							

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)													
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		WATER CONTENT / ATTERBERG LIMITS (%) NON-PLASTIC													
40		Grey, poorly-graded SAND (SP) - traces of silt and shell fragments																					
43	-44.45	Grey, silty SAND (SM) - hydrometer test at 43.25 m: gravel= 0%, sand= 61%, silt=35%, clay= 4%			PT	13	0.60	33.1															
45					PT	14	0.48																
48	-49.45	Grey, poorly-graded SAND (SP-SM) with silt - hydrometer test at 48.0 m: gravel= 0%, sand= 92%, silt=7%, clay= 1%			PT	15	0.50	28.2															
50	-50.05	Sonic drilling below 48.6 m			BS	16	0.30	23.2															
51		Grey, silty SAND (SM) - hydrometer test at 49.7 m: gravel= 0%, sand= 78%, silt=17%, clay= 5%																					
52		- sand seam with woody organics at 52.0 m																					
53		- poorly-graded sand with silt from 52.1 m to 52.8 m																					
54	-55.05	Grey, sandy SILT (ML) - with silty sand partings - with a few shell fragments - passing #200 at 54.0 m: 69.5% fines			BS	17	0.30	31.8															
57		- passing #200 at 57.0 m: 60.2% fines			BS	18	0.30	34.8															
60		- traces of mica/pyrite below 59.4 m																					

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)											
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		40	80	120	160								
60		Grey, sandy SILT (ML) - with silty sand partings - with a few shell fragments and mica/pyrite - with silty sand seams below 61.0 m - passing #200 at 60.1 m: 68.9% fines - hydrometer test at 63.7 m: gravel= 0%, sand= 37%, silt=55%, clay= 8%			BS	19	0.30	33.3													
61																					
62																					
63																					
64																					
65																					
66	-67.15	Grey, poorly-graded SAND (SP-SM) with silt - with sandy silt partings - with a few shell fragments - passing #200 at 67.1 m: 8.6% fines - passing #200 at 73.2 m: 6.1% fines			BS	21	0.30	29.1													
67																					
68																					
69																					
70																					
71																					
72																					
73																					
74																					
75																					
76																					
77																					
78	-79.65	Grey, sandy SILT (ML)																			
79																					
80	-81.05	Grey, silty SAND (SM)																			

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)														
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		WATER CONTENT / ATTERBERG LIMITS (%) NON-PLASTIC														
80		Grey, silty SAND (SM) - with sandy silt partings - with a few shell fragments - hydrometer test at 80.5 m: gravel= 0%, sand= 73%, silt=21%, clay= 6% - traces of organics below 81.7 m																						
81						BS	23	0.30	20.0															
82																								
83																								
84																								
85																								
86	-87.45	Grey, poorly-graded SAND with silt (SP-SM) - with sandy silt partings - with a few shell fragments - passing #200 at 86.0 m: 8.9% fines - passing #200 at 91.1 m: 6.9% fines - no visible shell fragments or organics below 93.3 m - 600 mm thick layer of poorly-graded sand with silt at 95.4 m - passing #200 at 95.7 m: 9.7% fines																						
87						BS	24	0.30	27.6															
88																								
89																								
90																								
91																								
92																								
93																								
94																								
95																								
96																								
97																								
98	-98.95	Grey, silty SAND (SM) - 600 mm thick layer of silt with sand at 98.1 m - traces of organics below 99.7 m																						
99																								
100																								

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)										
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		40	80	120	160							
-100.00		Grey, silty SAND (SM) - occasional poorly-graded sand with silt seams and partings below 100.6 m																		
-101.00		- passing #200 at 101.8 m: 19.6% fines			BS	27	0.30	25.9												
-102.00	-104.05	Grey, poorly-graded SAND with silt (SP-SM)																		
-103.00																				
-104.00																				
-105.00	-107.25	Grey, sandy SILT (ML) - occasional silty sand seams																		
-106.00		- passing #200 at 106.7 m: 53.3% fines			BS	28	0.30	28.6												
-107.00	-108.75	Grey, silty SAND (SM) - frequent sandy silt seams and partings																		
-108.00		- traces of organics																		
-109.00																				
-110.00	-111.75	Grey, poorly-graded SAND with silt (SP)																		
-111.00	-112.85	Grey, sandy SILT (ML)																		
-112.00	-113.65	Grey SILT (ML) - traces of sand and shell fragments																		
-113.00					BS	29	0.30	27.7												
-114.00	-115.75	Grey, silty SAND (SM) - traces of organics																		
-115.00																				
-116.00																				
-117.00																				
-118.00		- seam of poorly-graded sand with silt at 117.7 m																		
-119.00		- hydrometer test at 118.9 m: gravel= 0%, sand= 51%, silt=40%, clay= 9%																		
-120.00					BS	30	0.30	29.0												

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)	
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		40	80
-120	-121.65	Grey, silty SAND (SM) Mud Rotary drilling below 120.2 m									
-121		Grey, SILT (ML) with sand - with a few shell fragments									
-122											
-123		- hydrometer test at 123.1 m: gravel= 0%, sand= 16%, silt=56%, clay= 28%			PT	31	0.43				
-124		- traces of sand below 124.2 m									
-125		- hydrometer test at 124.2 m: gravel= 0%, sand= 9%, silt=55%, clay= 36%			PT	32	0.60				
-126		- vane shear test at 125.9 m: peak shear strength undetermined remolded shear strength = 150kPa			VANE						
-127		- vane shear test at 126.2 m: peak shear strength = 345kPa remolded shear strength = 128kPa			VANE						
-128											
-129	-130.65	Grey, elastic SILT (MH) - traces of sand			PT	33	0.39				
-130		- hydrometer test at 129.2 m: gravel= 0%, sand= 1%, silt=54%, clay= 45%									
-131	-132.25	- hydrometer test at 130.1 m: gravel= 0%, sand= 1%, silt=54%, clay= 45%			PT	34	0.43				
-132		Sonic drilling below 130.8 m									
-133		- vane shear test at 131.4 m: peak shear strength undetermined remolded shear strength = 233kPa			VANE						
-134		- vane shear test at 131.7 m: peak shear strength = 426kPa remolded shear strength = 197kPa			VANE						
-135											
-136											
-137	-138.61	Grey, elastic SILT (MH) - traces of sand and shell fragments			BS	35	0.30	44.6			
-138											
-139											
-140											

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)	
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		40	80
-140		Grey, elastic SILT (MH) - traces of sand and shell fragments									
-143	-144.45	Grey, lean CLAY (CL) - traces of sand and shell fragments - hydrometer test at 143.3 m: gravel= 0%, sand= 9%, silt=69%, clay= 22%			BS	36	0.30	37.5			
-149	-150.85	Grey, SILT (ML) - traces of sand and shell fragments			BS	37	0.30	36.3			
-155	-156.45	Grey, fat CLAY (CH) - traces of sand and shell fragments			BS	38	0.30	37.6			
-158	-158.55	TILL: grey, lean clay with sand - traces of gravel - passing #200 at 157.6 m: 82.2% fines			BS	39	0.30	32.3			

UNDRAINED SHEAR STRENGTH (kPa)	WATER CONTENT / ATTERBERG LIMITS (%)	NON-PLASTIC	STANDARD PENETRATION TEST, blows/0.30 m
40 80 120 160	W _P W W _L	◆	●
10 20 30 40 50 60 70 80 90			

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)



BOREHOLE RECORD

BH16-20

CLIENT Port of Vancouver NORTHING 5430016 PROJECT NO. 115815019
 PROJECT Roberts Bank Terminal 2 EASTING 485992 BH SIZE HQ (96 mm)
 DATES BORING 2016/08/25 to 2016/08/30 METHOD Sonic / Mud Rotary DATUM Chart

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				OTHER TESTS	UNDRAINED SHEAR STRENGTH (kPa)													
					TYPE	NUMBER	RECOVERY (m)	MOISTURE CONTENT (%)		WATER CONTENT / ATTERBERG LIMITS (%) NON-PLASTIC													
-160		TILL: grey silty sand with gravel - passing #200 at 160.2 m: 30.9% fines			BS	40	0.30																
-161																							
-162	-164.05	- lean clay with sand below 161.7 m - traces of gravel below 161.7 m - mottled with white below 161.7 m End of BH16-20 at 162.6 m																					
-163																							
-164																							
-165																							
-166																							
-167																							
-168																							
-169																							
-170																							
-171																							
-172																							
-173																							
-174																							
-175																							
-176																							
-177																							
-178																							
-179																							
-180																							

Sample Types: BS - Bulk Sample; SS - Split Spoon; PT - Piston Tube; HQ - Continuous Core

■ Pocket Penetrometer (kPa)

PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429979.5 E: 485997.2 UTM

RECORD OF SONIC HOLE: SH11-17

SHEET 1 OF 2
 DATUM: Chart Datum

DRILLING DATE: May 21, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES		RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT %		ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL		SAND	FINES		
0		SEA FLOOR		-1.94											
		Wet, dark grey, fine to medium SAND, trace to some silt, contains shell fragments and organics.		0.00											
1		- Contains silt layer at 0.9m. - Contains silt layer at 1.2m.			1	GS			0	97	3				
2		- Contains silt layer at 1.7m. - Contains silt layer at 2.6m.													
3					2	GS			0	99	1				
4															
5		- Contains wood fragments at 4.6m.			3	GS			0	99	1				
6				-8.04											
		Wet, dark grey, silty SAND interlayered with sandy SILT and SILTY CLAY.		6.10	4	GS			0	7	93	11			
7															
8															
9					5	GS			0	21	79	4			
10															

CONTINUED NEXT PAGE

File: N:\BUR-Graphics\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY BC REGION LIBRARY.GLB bdrzdzk 08/22/11

DEPTH SCALE
 1 : 50



LOGGED: C.H.C.
 CHECKED: R.O.

PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429979.5 E: 485997.2 UTM

RECORD OF SONIC HOLE: SH11-17

SHEET 2 OF 2
 DATUM: Chart Datum

DRILLING DATE: May 21, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN				GRADATION %			PLASTICITY INDEX	FINES CONTENT %				ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS					
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND	FINES	WATER CONTENT %		PLASTICITY INDEX	DESIGN - Measured	CPT Interpreted	field est. - lab			ice est. -				
10	Frasste XL Sonic	Sonic	Wet, dark grey, silty SAND interlayered with sandy SILT and SILTY CLAY. (continued) - Sand layer from 10.0m to 10.5m.	[Strata Plot]	-13.94	6	GS						0	86	14											
11																										
12			Wet, dark grey, sandy SILT interlayered with CLAYEY SILT.	[Strata Plot]	12.00																					
13																										
14																										
15																										
16																										
17																										
18																										
19																										
20																										

File: N:\BUR-Graphics\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY GLB bdrzdzk 08/22/11

DEPTH SCALE
 1 : 50



LOGGED: C.H.C.
 CHECKED: R.O.

RECORD OF SONIC HOLE: SH11-34

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN				GRADATION %			PLASTICITY INDEX	FINES CONTENT %				ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND	FINES	WATER CONTENT %		PLASTICITY INDEX	Design - Measured	CPT Interpreted	field est. lab		
0			SEA FLOOR Wet, dark grey SAND, some silt to silty interlayered with CLAYEY SILT, contains organics		-3.01 0.00	1	GS					0	81	19		●					
1						2	GS					0	90	10		●					
2																					
3			Wet, dark grey, fine to medium SAND, trace to some silt. - Contains silt layer at 3.1m.		-6.01 3.00	3	GS					0	96	4		●					
4			- Contains silt layer at 4.0m. - Contains wood fragments at 4.4m.																		
5	Fraste XL Sonic		- Contains silt layer at 4.9m. - Contains wood fragments at 5.0m.																		
6			- Contains silt layer at 5.8m.																		
7			- Contains silt layer at 7.1m.																		
8			- Contains silt layer at 7.8m.																		
9			- Contains silt layer from 9.0m to 9.3m. - Contains silt layer at 9.6m.			5	GS					0	94	6		●					
10																					

CONTINUED NEXT PAGE

PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-34

SHEET 2 OF 2
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429967 E: 486445 UTM

DRILLING DATE: May 15, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN				GRADATION %			PLASTICITY INDEX	FINES CONTENT %				ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %				GRAVEL		SAND	FINES	WATER CONTENT %			
80	60	40								20	Wp	Wi	field est.		lab			ice est.	Design - Measured	CPT Interpreted	
10	Frasite XL Sonic		Wet, dark grey, fine to medium SAND, trace to some silt. (continued) - Contains silt layer at 10.1m.				6					0	92	8	●						
11								6	GS												
12								7	GS												
13								8	GS												
14								- Contains silt layer at 14.0m.		8											
15								- Contains silt layer at 14.6m.													
16								- Contains silt layer at 15.3m.		9											
17								- Contains silt layer at 15.3m.													
17								End of Sonic Hole.													
18																					
19																					
20																					

File: N:\BUR-GRAPHICS\PROJECTS\2011\44711-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY.GLB bdrzdzak 08/22/11



PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429873.5 E: 486619.3 UTM

RECORD OF SONIC HOLE: SH11-46

SHEET 1 OF 2
 DATUM: Chart Datum

DRILLING DATE: May 13, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN			GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - <input type="checkbox"/> Measured - <input type="checkbox"/> CPT Interpreted - <input type="checkbox"/> 20 40 60 80	WATER CONTENT % field est. - <input type="checkbox"/> lab ice est. - <input type="checkbox"/> Wp W WI	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
		DESCRIPTION	STRATA PLOT ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY % 80 60 40 20	GRAVEL	SAND	FINES						
0		SEA FLOOR Wet, dark grey, fine SAND, trace to some silt, contains shell fragments.	-2.40 0.00														
1				1	GS		1		0	97	3						
2				2	GS				0	86	14						
3		Wet, dark grey SILT and SAND interlayered with CLAYEY SILT. - Organics (wood pieces) layer at 2.85m. - Organics (wood pieces) layer at 2.9m. - Organics (wood pieces) layer at 3.0m.	-5.00 2.60				2										
4		Wet, dark grey fine to medium SAND, trace to some silt, contains shell fragments.	-6.10 3.70						0	97	3						
5	Fraste XL Sonic			3	GS		3										
6				4	GS				0	92	8						
7		Wet, dark grey, sandy SILT interbedded with CLAYEY SILT, contains organics (wood fibres)	-8.85 6.45				4										
8																	
9				5	GS		5		0	31	69						
10																	

CONTINUED NEXT PAGE

DEPTH SCALE
 1 : 50



LOGGED: M.J.K.
 CHECKED: R.O.

File: N:\BUR-Graphics\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FNES DESIGN) Template BC REGION BOREHOLE LIBRARY.GLB bracedak 08/22/11

PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429873.5 E: 486619.3 UTM

RECORD OF SONIC HOLE: SH11-46

SHEET 2 OF 2
 DATUM: Chart Datum

DRILLING DATE: May 13, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN				GRADATION %			PLASTICITY INDEX	FINES CONTENT %				ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS				
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND	FINES	WATER CONTENT %		PLASTICITY INDEX	Design -	Measured -	CPT Interpreted -			field est. -	lab ice est. -		
10			Wet, dark grey, sandy SILT interbedded with CLAYEY SILT, contains organics (wood fibres) (continued)																						
11																									
12					- Becomes more sandy at 12.0m.		6	GS				0	27	73											
13	Fraste XL	Sonic			7	GS				0	43	57													
14			Wet, dark grey, silty SAND, contains organics (wood fibres).																						
15							8	GS				0	78	22											
16			End of Sonic Hole.																						

File: N:\BUR-GRAPHICS\PROJECTS\2011\44711-1447-0150\2000-2001\GPJ Output Form\BC_SONIC BOREHOLE (FINES DESIGN) Template\BC REGION BOREHOLE (FINES DESIGN) Template\BC REGION LIBRARY\GLB_bdrzdsk_08/22/11

DEPTH SCALE
 1 : 50



LOGGED: M.J.K.
 CHECKED: R.O.

PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-57

SHEET 1 OF 2
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429917.6 E: 486756 UTM

DRILLING DATE: April 30, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - Measured - CPT Interpreted - WATER CONTENT % field est. - lab - ice est. -	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND					FINES	
0	Frasite XL Sonic	SEA FLOOR		-2.25													
		Wet, dark grey, fine SAND and SILT.		0.00													
1							1										
2			Wet, dark grey, fine to medium SAND, trace to some silt, trace to some sandy SILT layers contains shell fragments and organic seams.		-3.50 1.25			2									
3						1	GS			0	96	4					
4			Wet, dark grey, silty SAND interlayered with CLAYEY SILT.		-5.70 3.45			2									
5					2	GS			0	86	14						
6							3										
7		- Fine SAND layer at 7.0m to 7.2m.					3			0	25	75					
8							4			0	64	36					
9		- Wood pieces at 8.9m. Wet, dark grey, fine SAND, trace to some silt interlayered with CLAYEY SILT.		-11.29 9.04			4			0	85	15					
10							5			0	85	15					

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50



LOGGED: M.J.K.

CHECKED: R.O.

File: N:\BUR-GRAPHICS\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY GLB lbrzcdk 08/22/11

PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-57

SHEET 2 OF 2
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429917.6 E: 486756 UTM

DRILLING DATE: April 30, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN				GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - <input type="checkbox"/> Measured - <input type="checkbox"/> CPT Interpreted - <input type="checkbox"/> 20 40 60 80	WATER CONTENT % field est. - <input type="checkbox"/> lab - <input type="checkbox"/> ice est. - <input type="checkbox"/> 10 20 30 40	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS			
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND	FINES									
10	Frasite XL Sonic		Wet, dark grey, fine SAND, trace to some silt interlayered with CLAYEY SILT. (continued) - Contains silty SAND layer at 8.9m.		-15.15																	
11					6	GS		6			0	97	3									
12					7	GS		7			0	75	25									
13							Wet, dark grey, fine SAND, trace silt, contains shell fragments and organics.		12.90													
14					8	GS		8			0	96	4									
15					9	GS		9			0	98	2									
16					10	GS		10			0	92	8									
17							End of Sonic Hole.		17.04													
18																						
19																						
20																						

File: N:\BUR-Graphics\PROJECTS\2011\44711-1447-0150\2000-2001\GPJ Output Form\BC_SONIC BOREHOLE (FINES DESIGN) Template\BC REGION TEMPLATE BETA 1.GDT Library\BC REGION LIBRARY.GLB bdrzdzsk 08/22/11

DEPTH SCALE
1 : 50



LOGGED: M.J.K.
CHECKED: R.O.

PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429872.2 E: 486975.2 UTM

RECORD OF SONIC HOLE: SH11-96

SHEET 1 OF 6
 DATUM: Chart Datum

DRILLING DATE: May 1, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT %		ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
		DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND	FINES		WATER CONTENT %	PLASTICITY INDEX		
0		SEA FLOOR Wet, dark grey, fine SAND and SILT to silty SAND, contains wood fragments	-2.24 0.00	1	GS		1		0	75	25		20	40		
2		Wet, dark grey, fine SAND, some silt to silty. - Sandy SILT layer at 3.25m to 3.55m.	-4.24 2.00	2	GS		2		0	77	23		20	40		
4		Wet, dark brown, fine to medium SAND, trace to some silt, contains wood fibres. - Clayey SILT seams with organics from 4.6m to 4.7m. - Contains shells - Clayey SILT seams with organics from 4.9m to 4.95m	-6.14 3.90	3	GS		3		0	89	11		20	40		
6		- Clayey SILT seams with organics from 6.1m to 6.15m.		4	GS		4		0	91	9		20	40		
8		- Clayey SILT seams with organics from 8.0m to 8.1m.		5	GS		5		0	84	16		20	40		
9		Wet, dark grey SILT and fine SAND interlayered with CLAYEY SILT.	-10.64 8.40										20	40		

CONTINUED NEXT PAGE

File: N:\BUR-GRAPHICS\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY.GLB lbrzcdsk 08/22/11

DEPTH SCALE
 1 : 50



LOGGED: M.J.K.
 CHECKED: R.O.

PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429872.2 E: 486975.2 UTM

RECORD OF SONIC HOLE: SH11-96

SHEET 2 OF 6
 DATUM: Chart Datum

DRILLING DATE: May 1, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN			GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - Measured - CPT Interpreted - WATER CONTENT % field est. - lab - ice est. -	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND	FINES				
10			Wet, dark grey SILT and fine SAND interlayered with CLAYEY SILT. (continued)														
11			Wet, dark grey, fine to medium SAND, trace to some silt.		-13.14 10.90	6	GS		6		0	85	15				
12																	
13			- Clayey SILT seam at 12.8m.			7	GS		7		0	90	10				
14																	
15						8	GS		8		0	80	20				
16			End of Sonic Hole.		-18.24 16.00												
17																	
18																	
19																	
20																	

CONTINUED NEXT PAGE

File: N:\BUR-GRAPHICS\PROJECTS\2011\44711-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY GLB bdrzdzak 08/22/11

DEPTH SCALE
 1 : 50



LOGGED: M.J.K.
 CHECKED: R.O.

PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429872.2 E: 486975.2 UTM

RECORD OF SONIC HOLE: SH11-96

SHEET 3 OF 6
 DATUM: Chart Datum

DRILLING DATE: May 1, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - Measured - CPT Interpreted - 20 40 60 80 WATER CONTENT % field est. - lab - ice est. - Wp W WI	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND				
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																

CONTINUED NEXT PAGE

File: N:\BUR-Graphics\PROJECTS\2011\44711-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FNES DESIGN) Template BC REGION LIBRARY GLB ldrzdzdk 08/22/11



PROJECT No.: 11-1447-0150
 LOCATION: Refer to Site Plan.
 N: 5429872.2 E: 486975.2 UTM

RECORD OF SONIC HOLE: SH11-96

SHEET 4 OF 6
 DATUM: Chart Datum

DRILLING DATE: May 1, 2011
 DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - <input type="checkbox"/> Measured - <input type="checkbox"/> CPT Interpreted - <input type="checkbox"/> field est. - <input type="checkbox"/> lab - <input type="checkbox"/> ice est. - <input type="checkbox"/>	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND				
30																
31																
32																
33																
34																
35																
36																
37																
38																
39																
40																

CONTINUED NEXT PAGE

File: N:\BUR-Graphics\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION TEMPLATE BETA 1.GDT Library BC REGION LIBRARY.GLB bdrzdzsk 08/22/11



PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-96

SHEET 5 OF 6
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429872.2 E: 486975.2 UTM

DRILLING DATE: May 1, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - <input type="checkbox"/> Measured - <input type="checkbox"/> CPT Interpreted - <input type="checkbox"/> field est. - <input type="checkbox"/> lab - <input type="checkbox"/> ice est. - <input type="checkbox"/>	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND					FINES
40																
41																
42																
43																
44																
45																
46																
47																
48																
49																
50																

CONTINUED NEXT PAGE

File: N:\BUR-GRAPHICS\PROJECTS\2011\44711-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION TEMPLATE BETA 1.GDT Library BC REGION LIBRARY.GLB bdrzdzsk 08/22/11



PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-99

SHEET 1 OF 4
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429805 E: 487230.4 UTM

DRILLING DATE: May 1, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - Measured - CPT Interpreted - WATER CONTENT % field est. - lab ice est. -	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS
			DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND				
0			SEA FLOOR Wet, dark grey, fine SAND, some silt to silty.		-0.78 0.00											
1			Wet, dark grey, silty fine SAND. - Contains silt layer at 1.6m.		-1.78 1.00	1	GS	2	150	0	63	37				
2			Wet, dark grey, sandy SILT interlayered with CLAYEY SILT. - Contains sand layer at 2.4m.		-2.88 2.10											
3			- Contains sand layer at 3.1m. - Contains sand layer at 3.3m.			2	GS	3		0	69	31				
4			Wet, dark grey, fine to medium SAND, trace to some silt, contains shell fragments and wood fragments. - Contains silty layer at 4.8m.		-4.78 4.00	3	GS			0	93	7				
5			- Contains silty layer at 5.6m. - Contains silty layer at 5.8m.					4								
6						4	GS			0	92	8				
7								5								
8																
9						5	GS			0	94	6				
10					-10.78			6								

CONTINUED NEXT PAGE

File: N:\BUR-Graphics\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY.GLB lbracediak_08/22/11

DEPTH SCALE
1 : 50



LOGGED: C.H.C.
CHECKED: R.O.

PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-99

SHEET 2 OF 4
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429805 E: 487230.4 UTM

DRILLING DATE: May 1, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - <input type="checkbox"/> Measured - <input type="checkbox"/> CPT Interpreted - <input type="checkbox"/> field est. - <input type="checkbox"/> lab ice est. - <input type="checkbox"/>	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS	
		DESCRIPTION	STRATA PLOT ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No. RECOVERY %	GRAVEL	SAND	FINES						
10	Fraste XL Sonic	Wet, dark grey, silty SAND interlayered with sandy SILT.	10.00													
11						7										
12		Wet, dark grey, fine to medium SAND, trace to some silt. - Contains silty sand layer at 11.7m.	-12.18 11.40	6	GS			0	85	15						
13						8										
14						7	GS		0	87	13					
15						8	GS		0	86	14					
16		Wet, grey, CLAYEY SILT, some sand, contains silty sand pockets.	-16.98 16.20			10										
17																
18		End of Sonic Hole.	-18.78 18.00													
19																
20																

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50



LOGGED: C.H.C.

CHECKED: R.O.

File: N:\BUR-GRAPHICS\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION BOREHOLE LIBRARY.GLB bdrzdsk 08/22/11

PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-99

SHEET 3 OF 4
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429805 E: 487230.4 UTM

DRILLING DATE: May 1, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT % Design - <input type="checkbox"/> Measured - <input type="checkbox"/> CPT Interpreted - <input type="checkbox"/> field est. - <input type="checkbox"/> lab ice est. - <input type="checkbox"/> Wp W WI	ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND					FINES
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																

CONTINUED NEXT PAGE

File: N:\BUR-Graphics\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION TEMPLATE BETA 1.GDT Library BC REGION LIBRARY.GLB bdrzdzsk 08/22/11

DEPTH SCALE

1 : 50



LOGGED: C.H.C.

CHECKED: R.O.

PROJECT No.: 11-1447-0150

RECORD OF SONIC HOLE: SH11-99

SHEET 4 OF 4
DATUM: Chart Datum

LOCATION: Refer to Site Plan.
N: 5429805 E: 487230.4 UTM

DRILLING DATE: May 1, 2011
DRILLING CONTRACTOR: Foundex Explorations Ltd.

DEPTH SCALE METRES	DRILLING RIG DRILLING METHOD	SOIL PROFILE		SAMPLES			RUN		GRADATION %			PLASTICITY INDEX	FINES CONTENT %		ADDITIONAL LAB. TESTING	TEST RESULTS, NOTES AND COMMENTS	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RUN No.	RECOVERY %	GRAVEL	SAND		FINES	WATER CONTENT %			PLASTICITY INDEX
30																	
31																	
32																	
33																	
34																	
35																	
36																	
37																	
38																	
39																	
40																	

CONTINUED NEXT PAGE

File: N:\BUR-Graphics\PROJECTS\2011\1447\11-1447-0150\2000-2001\GPJ Output Form BC SONIC BOREHOLE (FINES DESIGN) Template BC REGION TEMPLATE BETA 1.GDT Library BC REGION LIBRARY.GLB lbracediak 08/22/11

DEPTH SCALE

1 : 50

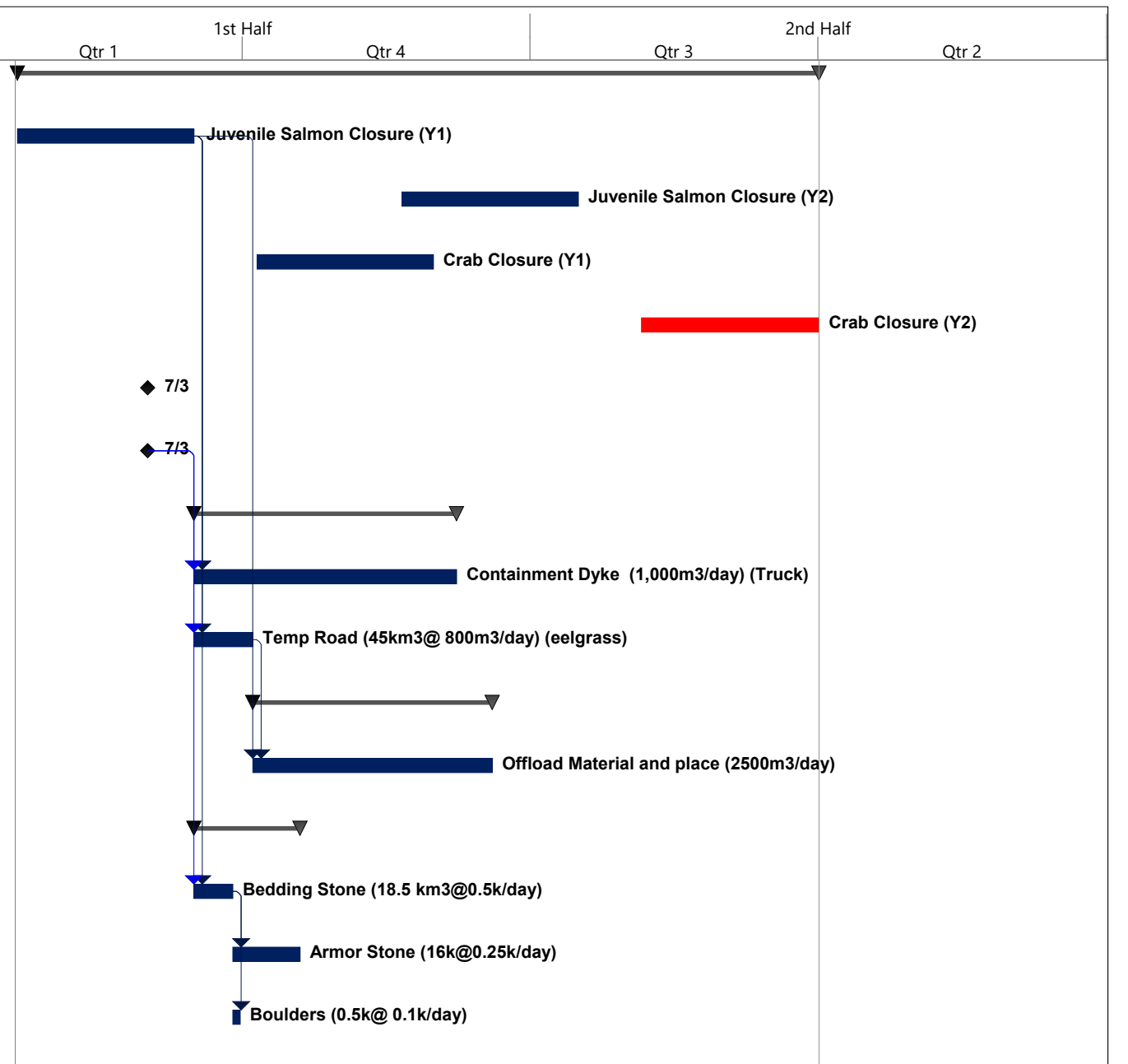


LOGGED: C.H.C.

CHECKED: R.O.

Appendix D: Construction Schedule

ID	Task Name	Duration	Predecessors	Start	Finish	
1	Environmental Closures	763 days		Wed 3/1/23	Tue 4/1/25	
2	Juvenile Salmon Closure (Y1)	168 days		Wed 3/1/23	Tue 8/15/23	
3	Juvenile Salmon Closure (Y2)	168 days		Fri 3/1/24	Thu 8/15/24	
4	Crab Closure (Y1)	168 days		Sun 10/15/23	Sat 3/30/24	
5	Crab Closure (Y2)	169 days		Tue 10/15/24	Tue 4/1/25	
6	Milestones and Target Dates	0 days		Mon 7/3/23	Mon 7/3/23	
7	Start of Construction	0 days		Mon 7/3/23	Mon 7/3/23	
8	Marsh Dyking (Incl Rip-Rap) (0.25MM3)	250 days		Wed 8/16/23	Sun 4/21/24	
9	Containment Dyke (1,000m3/day) (Truck)	250 days 7,2		Wed 8/16/23	Sun 4/21/24	
10	Temp Road (45km3@ 800m3/day) (eelgrass)	56 days 7,2		Wed 8/16/23	Tue 10/10/23	
11	Fill Marsh and Eelgrass Areas (0.57 MM3)	228 days		Wed 10/11/23	Sat 5/25/24	
12	Offload Material and place (2500m3/day)	228 days 10,2		Wed 10/11/23	Sat 5/25/24	
13	Place Rock Reef (Incl Boulders) (0.25MM3)	101 days		Wed 8/16/23	Fri 11/24/23	
14	Bedding Stone (18.5 km3@0.5k/day)	37 days 7,2		Wed 8/16/23	Thu 9/21/23	
15	Armor Stone (16k@0.25k/day)	64 days 14		Fri 9/22/23	Fri 11/24/23	
16	Boulders (0.5k@ 0.1k/day)	7 days 14		Fri 9/22/23	Thu 9/28/23	



Project: 2018.07.09 RBT2BaseSched
Date: Wed 6/17/20

Task		Inactive Task		Manual Summary Rollup		External Milestone		Manual Progress	
Split		Inactive Milestone		Manual Summary		Deadline			
Milestone		Inactive Summary		Start-only		Critical			
Summary		Manual Task		Finish-only		Critical Split			
Project Summary		Duration-only		External Tasks		Progress			



moffatt & nichol

Moffatt & Nichol, Vancouver
Suite 301 - 777 W. Broadway
Vancouver BC V5Z 4J7
Canada
T +1-604-707-9004

www.moffattnichol.com