Marine Design Criteria

Sterling Shipyard Remediation and Infill

Prepared for:

Vancouver Fraser Port Authority

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1 General

1.1 Introduction

The Vancouver Fraser Port authority (port authority) is remediating the former Sterling Shipyard Site (the Site) at 2089 to 2095 Commissioner Street, as part of the Sterling Shipyard Remediation and Infill Project. The Site is located between the Lafarge Ready Mix concrete plant at the East (“Lafarge”), and the Former Marco Marine Container Inc. (“Marco”) facility to the West, which is currently used for surface parking by various nearby companies. The City of Vancouver Victoria Drive combined sewer outfall is located west of the Site and discharges into Burrard Inlet. The site includes an upland area, and an undeveloped intertidal and subtidal areas including a beach formerly occupied by the shipyard boat way extending to beyond the low tide line.

Numerous environmental investigations since the early 1990s identified hydrocarbon and metal contamination across the Site, associated with fill containing debris and/or woodwaste, and the former boat way and ancillary facilities. The port authority considered multiple remedial options for the Site and has opted to conduct remedial excavation of all known contaminated sediments in the intertidal area. The remediation will be followed by Site redevelopment to infill the intertidal area and raise the Site grade to create additional usable industrial land.

1.2 Scope of Work

The port authority is conducting remedial excavation of the contaminated site in the intertidal area. The remediation will be followed by site redevelopment to create additional industrial land.

As part of the site redevelopment, a rock berm is proposed at the Northern face of the site. The project requires removal of liquefiable sand layer for geotechnical stability.

Excavation is proposed for the contaminated wet material in the intertidal zone shoreward of the proposed berm.

Anticipated Sequence: Initial work of dredging material under proposed rock berm would take place behind a silt curtain and the remainder will be performed behind the berm. Liquefiable material shall be removed under the berm footprint prior to its construction. Initial dredge is from marine equipment or other means and can be reached during reasonable tidal work windows.

Seismic Stability: Vibro-compaction shall be undertaken over the whole site (up to the crest of the rock berm), which will address the liquefaction issue in the sand layer shoreward of the proposed berm, and also compact the fill placed for the reclamation. Vibro-compaction shall be done after reclamation, through the fill and embankment. Sandy material further seaward under the proposed berm shall be dredged prior to placement of the proposed rock berm.

1.3 Functional Requirement

1.3.1 Rock Revetment

The design of the revetment needs to account for site-specific conditions. The following considerations are used for design of the structure.

- Rock armour should be sized to be statically stable. There should be little to no damage to the armour layer under design conditions.
- A suitable layer of filter rock should always be used to prevent loss of fines from the slope material under combined wave and current loads.
- Geotextile is recommended below the filter layer to protect against migration of fine grains.
- The stability of the rock armour protection on the seaward side is designed for minimal damage under the design wave and water level conditions described in this document.

1.3.2 Remediation

The excavated or dredged material shall be tested and treated for the contaminants. Contaminated material shall be identified and accommodate with special handling and disposal considerations. Refer to Sterling Shipyard Remediation and Infill Project Environmental Remediation Design Report 677011-0000-4ER-0001, SNC-Lavalin 2021.

1.3.3 Infill and Final Industrial Land

The following considerations are recommended for the infill of the intertidal area:

- Once remediated the intertidal area shall be infilled with engineered fill and vibro-compacted to allow for future industrial development. Refer to Sterling Shipyard Remediation and Infill Project Geotechnical Report 677011-0000-4GER-0001.
- To accommodate the future usage of the site, the design shall limit the number of buried elements from any new or existing infrastructure at the site and at interfaces with the neighbouring properties.
- The site elevation was defined by the VFPA, the entire site will be raised to a rough grade EL +6.0 m CD which will be lower than the revetment crest elevation. The site will be raised by others to a final grade of no greater than + 7.7 m CD.

1.3.4 Storm Water Management

The storm water management proposed is temporary for the design rough grade, until such time as final grading by others is completed. The final stormwater designer should either remove the proposed outfall or validate the proposed outfall size, elevation, and location.

The proposed grading design shows that the intertidal area will be infilled to the elevation of 6.0 m CD, which will be lower than most of the surrounding area (except the northwest corner). The total surface area of the infill is 5,000 m^2. With a smaller berm built along the west boundary of the intertidal area, the 1:100

year stormwater flow volume will be stored and infiltrated in the intertidal area. The maximum water depth will be less than 0.1 m and will not flood the surrounding area.

In case of emergency such as the failure of infiltration due to high ground water season, a 250 mm diameter overflow pipe is designed, and its outlet invert is set at 6.2 m CD to drain the intertidal area and avoid the stormwater flooding the surround area. Since the Design Water Level (DWL) is 6.2 m CD for year 2021, the check valve will not be needed at the pipe outlet.

Refer to storm water management design criteria, document # 677011-0000-41EC-0001.

1.3.5 Neighbouring Property & Interfaces

The following considerations are recommended for the design of adjacent properties:

- Marco Site:
  - The revetment shall extend West in front of the existing Marco Sheet Pile Wall.
  - All existing obsolete infrastructure at Marco Site shall be removed and disposed of prior to placement of the revetment. This include any lock blocks, sheet piles, timber cribs, anchors and any anchor walls that may be buried.
  - All geotechnical works performed for revetment stability at the Sterling Site shall be extended to the Marco Site, which includes any removal of liquefiable material and disposal of contaminated material. This also includes vibro-compaction of a 10-20 m strip behind the crest of the revetment on both the Sterling and Marco Sites and within the Sterling Infill Area. Refer to Sterling Shipyard Remediation and Infill Project Geotechnical Report 677011-0000-4GER-0001.
  - The revetment crest will be set at the same elevation as the Sterling Site.
  - The rough grade of the infill area of the adjacent infill area will be set at the same elevation as the Sterling Site.
  - A transition grade suitable for Highway Trucks maximum 6% shall be designed at the interface at the revetment crest (Northern Face of Marco) and at the Sterling Infill Area (Eastern Face of Marco).
- Lafarge Site:
  - Contaminants excavation extent shall overlap with the existing Lafarge Revetment. The upper portion of the Lafarge Revetment which will not be impacted by the excavation and shall be temporarily retained during construction phase. The majority of the Lafarge Revetment at the interface with the Sterling Site will be infilled (i.e. buried) at the final stage.
  - The Sterling revetment crest and the final infill area at the Sterling Site shall be designed to a higher elevation than existing grade at Lafarge.
  - A transition grade suitable for Highway Trucks maximum 6% shall be designed at the interface.
- City of Vancouver Victoria Drive Outfall
  - The toe of the Rock Berm shall minimize encroachment into the Right of Way of the Outfall.
  - A permanent retaining wall shall be designed and constructed by the Contractor at the western interface of Marco site. This wall shall retain the berm locally as to limit encroachment onto the CoV Right of Way. For extent, refer to design drawings 677011-0000-4PDD-70-010.

2 Code & Standards

2.1 General

- The design of all work shall be in accordance with the most current version of the relevant codes and standards at the time of design listed in the following subsection.
- Where conflicts exist between two or more relevant standards, the more stringent requirements shall prevail. In case of any conflict between the Design Criteria and any industry codes and standards, the Design Criteria shall take precedence.

2.2 Design Codes and Standards

The project will be designed to conform to the most current version of the following codes and standards at the time of design:

- CAN/CSA S6-14 Canadian Highway Bridge Design Code.
- CIRIA, CUR, CETMEF (2007). The Rock Manual. The use of rock in hydraulic engineering, 2nd edition, C683, CIRIA, London.
- EurOtop. Manual on wave overtopping of sea defenses and related structures, 2nd edition, 2018.
- Canadian Tide and Current Tables, Volume 5, 2021.

2.3 References and Design Guidelines

The following references were used in this document:

[1] BC Ministry of Environment. "Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use: Draft Policy Discussion Paper". 27 January 2011.

[2] Guidelines – Shoreline Protection, (Vancouver Harbour) Inspection, Maintenance, Design and Repair, Version 1.0, Vancouver Fraser Port Authority Engineering & Maintenance Department April 2018.

[3] Clague et al., (2005). Tsunami Hazard to North and West Vancouver, British Columbia. Clague, J, Orwin, J, Simon Fraser University - Centre for Natural Hazard Research.

[4] Vancouver Fraser Port Authority Centerm Expansion Project and South Shore Access Project, Schedule 6 Design and Construction requirements.

[5] Sterling Shipyard Remediation and Infill Project Environmental Remediation Design Report 677011-0000-4EER-0001, SNC-Lavalin, 2021.

[6] Sterling Shipyard Remediation and Infill Project Geotechnical Report 677011-0000-4GER-0001, SNC-Lavalin, 2021.

[7] Topographic Survey of a Portion of Parcel P, Block 17, District Lot 184 and the Public Harbour Of Burrard Inlet, Group 1, New Westminster District, Plan LMP47343, L-263 Rev 0, Underhill Geomatics Ltd., Nov 03, 202089.

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2.4 Health and Safety

- WCB Occupational Health and Safety Regulations
- NBCC, National Building Code of Canada.

2.5 Units and Measurements

The metric system of units shall be used throughout the project.

2.5.1 Vertical Datum

The vertical datum is Chart Datum (CD) unless otherwise specified. The Canadian Geodetic Datum (CGVD28) at Sterling Shipyard is approximately 3.045 m above CD.

2.5.2 Horizontal Datum

UTM horizontal datum is datum NAD 83. Zone 10.

3 Basis of Design

3.1 Design Life

3.1.1 Service Life

Design service life for the various components shall be as follows:

- Revetment service life: 50 years.
- Achieving the design service life requires regular inspection to identify any deterioration or damage and undertaking repairs of identified items.

3.1.2 Design Event

Current year design in 2021: An annual exceedance probability (AEP) of 1/100 or a 1% chance of exceedance in any given year was used for this assignment as a result of the urban location of the site and the value of upland developments. The berm will be designed for maximum high tide (HHWLT) and total storm surge during designated storm. This translates as current water levels along with the 1 in 100-year wave and 1 in 100-year storm surge.

In 2071: The berm will be designed to withstand, without threat to life, and with repairable damage being acceptable, for maximum high tide (HHWLT) and the expected sea level rise (at a project defined level of exposure probability (1% risk of occurrence) and the annual exceedance probability (AEP) of 1/10 expected storm.

3.2 Loads and Forces

3.2.1 Live Load (LL)

- Container Truck: WB20
- Highway Truck Load : S6-00 CL-625 or Internal Transfer Vehicle whichever has greater impact.
- 18 kPa UDL Live Load (9 kPa for each container) for seismic analysis at a setback of 4 m from the seaward end of the revetment crest.

Live loads shall not exceed a maximum surcharge of 18 kPa placed with a four meter set back from the crest of the revetement for slope stability. However, if in the future use of the development indicates that the site will be under a higher magnitude of live load and traffic load, a geotechnical engineer should be consulted, and the slope stability should be reassessed.

3.2.2 Seismic Loads (EQ)

- Refer to Sterling Shipyard Remediation and Infill Project Geotechnical Report 677011-0000-4GER-0001. The Site has been designated as Seismic Class “C”.

3.3 Site Conditions

3.3.1 Survey Data

Existing site and bathymetry elevations were obtained from the following sources:

Topographic Survey of a Portion of Parcel P, Block 17, District Lot 184 and the Public Harbour Of Burrard Inlet, Group 1, New Westminster District, Plan LMP47343, L-263 Rev 0, Underhill Geomatics Ltd., Nov 03, 2020.

3.3.2 Geotechnical

The site is generally composed of a wood-waste top layer, followed by a sand layer, resting on top of a hard till layer. The geotechnical analyses as per Sterling Shipyard Remediation and Infill Project Geotechnical Report 677011-0000-4GER-0001 indicate that, without soil densification, a large earthquake would likely induce soil liquefaction in the uniform sand fills, and due to the sloped topography, cause lateral migration (sliding) of up to 300 mm in these fill materials. Post-liquefaction settlement is also predicted to occur, with extents between 15 mm and 80 mm predicted in the modelling. The Site has been designated as Seismic Class “C”.

To mitigate the liquefaction and slope stability risks, the proposed berm is recommended to be placed on the dense glacial till, thereby requiring removal (by dredging) of the woodwaste and loose sandy fills from the berm footprint. Behind the berm (landside) only the woodwaste need be removed, though the fill sand would remain (unless removal is recommended for environmental purposes) and be densified. Operations to remove the woodwaste (especially from the intertidal area) should be conducted in staged segments and be monitored by a geotechnical engineer to reduce risk of impacting the adjacent properties.

3.3.3 Design Water Level

The designated water level for the current design year of +6.2 m CD was considered. It accounts for astronomical tide levels (HHWLT), storm surge. The designated water level excludes wave effects.

› Astronomical tide levels in the site are defined based on long term measurements at CHS station 7735, located at the northern end of Canada Place and reported relative to Chart Datum. Tide ranges are officially reported in Volume 5 of the Canadian Tide and Current Tables and updated annually. The latest version of Volume 5 should always be consulted.

Table 1: Tidal Levels (Vancouver Harbour)

Tidal Condition	Water Level (m, CD))
Historical Extreme High Water (HEHW)	5.6
Higher High Water, Large Tide (HHWLT)	5.0
Higher High Water, Mean Tide (HHWMT)	4.5
Mean Water Level (MWL)	3.1
Lower Low Water, Mean Tide (LLWMT)	1.2
Lower Low Water, Large Tide (LLWLT)	0.1
Historical Extreme Low Water (ELLW)	-0.3

The HHWLT of 5.0 m CD was adopted to calculate the Design Water Level.

- Storm surge: Definition of expected storm surges in Vancouver are summarized in Provincial Guidelines for sea dikes, Ref[1], based on detailed analysis of residual water level measurements throughout southern British Columbia waters and from CHS Station 7735 within the harbour (corresponding to an AEP of 1/100).

Table 2: Summary of Storm Surge Expected in Vancouver Harbour (Ref [1])

AEP (percent chance of being equaled or exceeded in any year)	AEP (1/average recurrence interval in years)	Vancouver Harbour
50%	Annual Expected	0.73
20%	1/5	0.83
10%	1/10	0.9
4%	1/25	1.0
2%	1/50	1.1
1%	1/100	1.2
0.2%	1/500	1.3
0.1%	1/1000	1.4

- Sea Level rise: SLR and the elevation of future mean sea level and elevations of tidal levels are very important considerations with respect to potential overtopping and upland flooding at any terminal site. Current BC Provincial Guidelines, Ref [1], recommends that shoreline planning should consider 0.8 m of global average SLR by the year 2071.

The Design Water Level (DWL), which accounts for astronomical tide, storm surge and sea level rise (SLR) over the 50-year project life, is summarized in Table 4. The DWL does not include wave effects due to wave-structure or wave-shoreline interaction, such as wave run-up or overtopping.

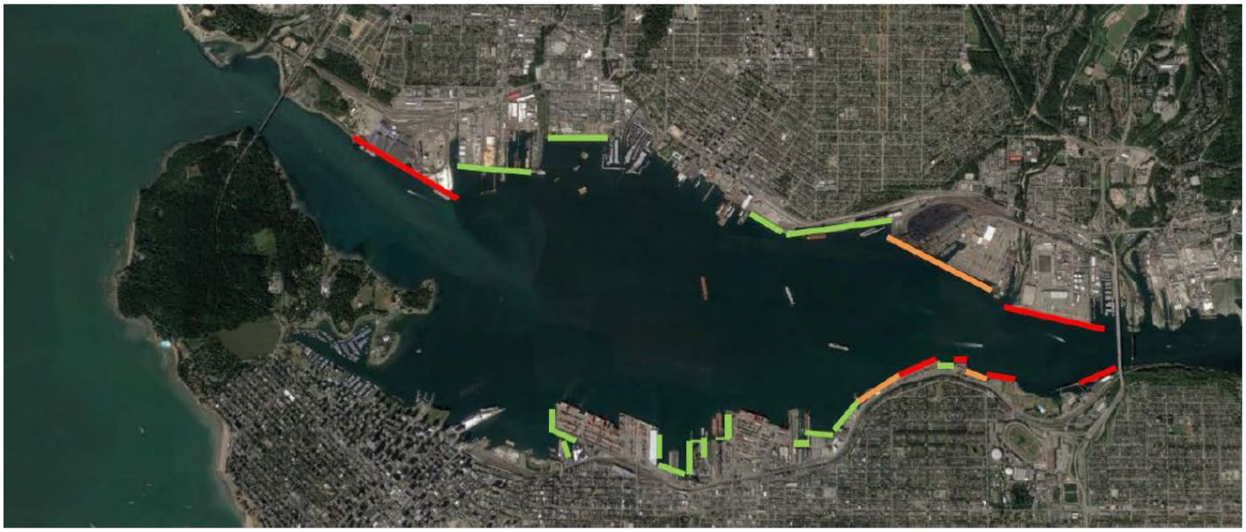
Table 3: Summary of the DWL for Sterling Shipyard Site

Design Year	AEP	Storm Surge (m)	SLR (m)	HHWLT	DWL m CD
Current year design (2021)	1:100	1.2	0	5	6.2
Design for year 2071 (50 years lifespan)	1:10	0.9	0.8	5	6.7

3.3.4 Current

According to Ref [2], strong tidal currents are not believed to be present at the project sites. In most cases currents are weak (less than 2 knots). Figure 1 indicates that the project site is exposed to slow currents.

Figure 1: Tidal Current Zones for planning (Red = fast, Orange = moderate, Green = slow) – Ref [2]



3.3.5 Tsunami

According to Clague et al., Ref. [3]), tsunami with expected AEP between 1/400 and 1/600 would occur at Cascadia Subduction Zone (CSZ). The potential effects of a tsunami are unlikely to occur in conjunction with a storm surge and thereby is not considered further in this assessment.

3.3.6 Vessel Induced Waves

The resulting estimated maximum wave height from a harbour vessel wake is considerably less than expected during the design storm but are expected on a more regular occurrence Ref. [2]; therefore, vessel induced waves are not considered further in this assessment.

3.3.7 Wind

The wind climate in the area of study reflects the combination of synoptic scale wind forcing over southern British Columbia and the orographic features of the area. No long-term and over-water wind measurement is available at the area of the study. The wind climate for this assessment was considered based on recommendations on Ref [2].

Vancouver International Airport (YVR) Stations (1108447 and 1108395), and Vancouver Harbour (VH) (1108446) are assumed as a representative of the wind climate at the project site.

A comparison of the wind measurements at VH and two YVR stations indicated that the average, wind speeds at the VH station are approximately 0.93 * YVR wind speeds.

An extreme value analysis was conducted, considering factored (0.93) YVR winds on a directional basis resulted in 1/100 (1%) AEP overwater wind speeds of 23.0m/s for Westerly winds and 1/10 AEP overwater windspeed of 19.9 m/s. Average AEP overwater wind speeds were 16.2 m/s for Westerly winds. The easterly winds are slightly smaller than westerly winds and was not included for the purpose of this assessment.

3.3.8 Wind-Generated Design Wave

Design wind waves within site project was considered generated from westerly winds blowing along the harbour axis. The longest fetch in the harbour is approximately 4.4 km, from the project site to Stanley Park, for westerly winds.

The deep-water wind waves described were transformed (desktop method) to near shore accounting for refraction, diffraction, and shoaling.

Table 4: Wind-Generated Waves, Westerly Direction

Wind m/s (Westerly)	Hs (m)	AEP (1/average recurrence interval in years)	T_p (sec)	Fetch(km)
23 m/s	0.9	1/100	3.2	4.4
16.2 m/s	0.6	1/1	2.8	4.4
19.9 m/s	0.7	1/10	2.8	4.4

3.3.9 Wave Overtopping

CIRIA 2007 and Eurotop 2018 provide guidance on the limits of overtopping discharges to provide safety to structures, vehicles, and pedestrians.

The crest elevation was set such that only marginal overtopping (<1 L/m/s) occurs under the total water level scenario described in Section 3.3.3 and wave effects.

3.4 Revetment Design Criteria

The revetment design parameters, slope, rock size, geometry, width and elevation are defined in this section.

3.4.1 Crest Width and Elevation

The revetment crest elevation was defined based on the design water level and checked for acceptable overtopping levels (Section 3.3.9). Freeboard allowance was not considered, considering that the overtopping volume was acceptable for the land use.

The Design Water Level (DWL) was discussed in section 3.3.3. The design crest elevation was defined to keep the overtopping below the acceptable rate (1 L/m/s). Elevations were defined for 2021 (current) and 2071 (end of design life).

Table 5: Crest Elevation

Year	HHWLT (m CD)	SLR (m)	Storm Surge (m)	Wave Effects(m)	Design Crest Elevation (m) CD
2021	5.0	0.0	1.2	1.3	7.5
2071	5.0	0.8	0.9	1.0	7.7

The revetment crest elevation was set to EL 7.7 m CD. The overtopping rate was restricted to maximum acceptable level.

A crest width of 2.0 m was defined to reduce the overtopping rates and to meet the recommended minimum crest width of 3xD_{50} (nominal size of the armour rock) - Eurotop 2018.

3.4.2 Slopes

The slope 2:1 (H:V) was adopted for armour layer and filter layer to consider ground improvement and geotechnical stability in the revetment design.

These slopes were selected to meet overtopping and stability design criteria.

3.4.3 Scour and Toe Protection

The revetment slope was extended to the limit of the dredge area to provide scour protection at the toe. The artificial reef is being designed as habitat compensation will also provide additional scour protection.

3.4.4 Rock Sizes

The rock size calculations were conducted using deep water Van der Meer and Van Gent's methodology (CIRIA 2007). A minimum of two layers of armour rock and three layers of filter rock was considered for this design.

Table 6: Recommended Rock Armour and Filter sized for the Site

Armour Rock Median Mass (kg)	Amour Layer Thickness (m)	Filter Rock Median Mass (kg)	Filter Layer Thickness (m)
200	0.9	22	0.6

Rock materials should be angular quarried stone of a dense, hard, and durable character. This requirement allows for better interlocking and friction between rocks, and ultimately a more stable slope. Median sizes for sub-angular or rounded rock will need to be increased. The aspect ratio, l/d (ratio between the maximum dimension, l, and the minimum dimension, d) of each individual rock piece should be less than 3.0. This prevents rocks from being flat and slab-like, which in turn limits breakage and sliding of individual rocks. (Ref[2]).

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