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Sterling Shipyard Remediation and Infill

Fisheries Act Authorization Application

Prepared for:

Vancouver Fraser Port Authority (VFPA)

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Signature Page

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1 Introduction

The Vancouver Fraser Port Authority ('The Port Authority') is proposing a remedial excavation and infilling at the former Sterling Shipyard facility (the 'Site') located at 2089 – 2095 Commissioner Street, Vancouver, BC. The Site is currently contaminated with metals, polycyclic aromatic hydrocarbons (PAH) and polychlorinated biphenyls (PCBs) up to approximately 4 metres (m) depth. The purpose of the proposed excavation is to address the ecological risk associated with subsurface contamination, as well as to create new port industrial land. For the purposes of this report, 'the Project' refers to the Sterling Shipyard Remediation and infill and 'Project Area' refers to the Project footprint.

The Port Authority has retained SNC-Lavalin Inc. (SNC-Lavalin) to support environmental permitting and assessment works for the Project, including the preparation of a Category C Project Environmental Review (PER) submission to the Port Authority and a *Fisheries Act* Authorization (FAA) application. To support the permitting process, SNC-Lavalin was retained to prepare this FAA application.

1.1 Supporting Documents

Supporting documents submitted as part of this *Fisheries Act* Authorization Application are listed in Table 1 below.

Table 1: Supporting Documents

Title	Document No.
Habitat Assessment	677011-0000-4ERA-0001
Construction Environmental Management Plan (CEMP)	677011-0000-4ERA-0003

1.2 Regulatory Framework

The *Fisheries Act*[1] (FA) requires proponents to avoid, mitigate and offset death of fish and/or harmful alteration, disruption or destruction of fish habitat (HADD) resulting from projects. When HADD avoidance is not possible, efforts must be made to mitigate the extent of the HADD caused by the proposed work, undertaking, or activity associated with a project. When proponents are unable to completely avoid and mitigate HADD, they must seek an authorization under paragraph 35(2)(b) of the FA to carry out a work, undertaking or activity and offset impacts that are unavoidable or unmitigable. A FAA application must detail impact avoidance, mitigation and habitat offsetting measures that will be implemented throughout a project. Offsetting measures typically counterbalance HADD through positive contributions to the aquatic ecosystem.

1.2.1 Policy for Applying Measures to Offset Adverse Effects on Fish and Fish Habitat Under the *Fisheries Act*

Fisheries and Oceans Canada (DFO) provides guidance on offsetting to support FAAs via the *Policy for Applying Measures to Offset Adverse Effects on Fish and Fish Habitat Under the Fisheries Act* (DFO 2019). This guidance document was updated in December 2019 to reflect recent changes to the FA and is intended

[1] *Fisheries Act* (FA), RSC 1985, c.F-14, last amended on August 28, 2019.

to provide guidance on undertaking effective measures to offset the death of fish and HADD, consistent with the fish and fish habitat protection provisions of the FA.

1.3 Project Proponent: Contact Information

Name of Proponent:	Vancouver Fraser Port Authority
Primary Contact:	Theresa Rawle
Title:	Director, Planning and Development, Vancouver Fraser Port Authority
Address:	100 The Pointe, 999 Canada Place, Vancouver, BC, V6T 3T4
Telephone:	604-665-9000
Email:	theresa.rawle@portvancouver.com
Project Website:	N/A

2 Project Location

The Project is located at 2089 to 2095 Commissioner Street, Vancouver, BC, on the southern shoreline of the Central Vancouver Harbour, within the Burrard Inlet, at the former Sterling Shipyard. The Site is located within Port Authority jurisdiction in the northern portion of the City of Vancouver, BC. The Site comprises of an upland terrestrial area, an intertidal beach area and a subtidal water lot.

2.1 Geographic Coordinates

The geographic coordinates of the Site are presented in Table 2 below.

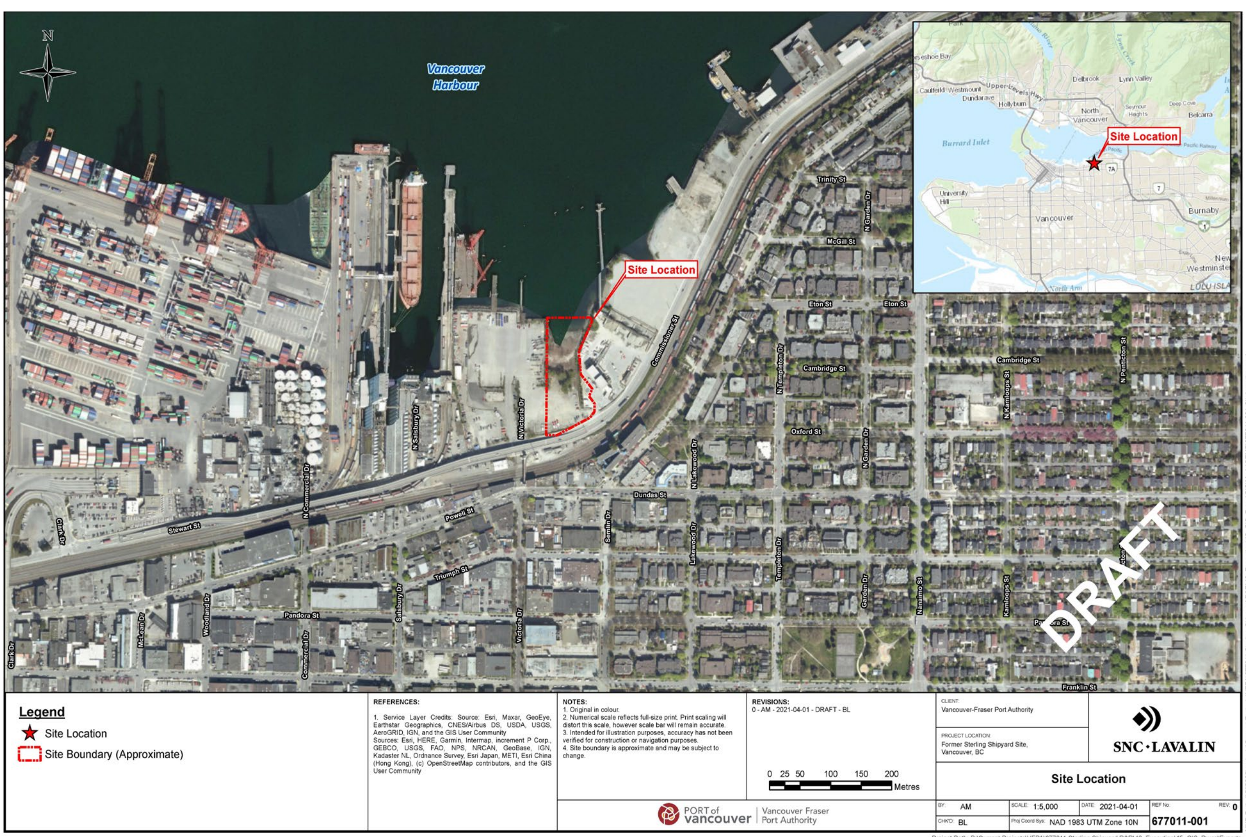
Table 2: Project Coordinates

Latitude	Longitude
49° 17' 12.5" N	123° 03' 52.7" W

2.2 Small-Scale Site Plan

Please refer to Figure 1 for a small-scale plan identifying the overall location and boundaries.

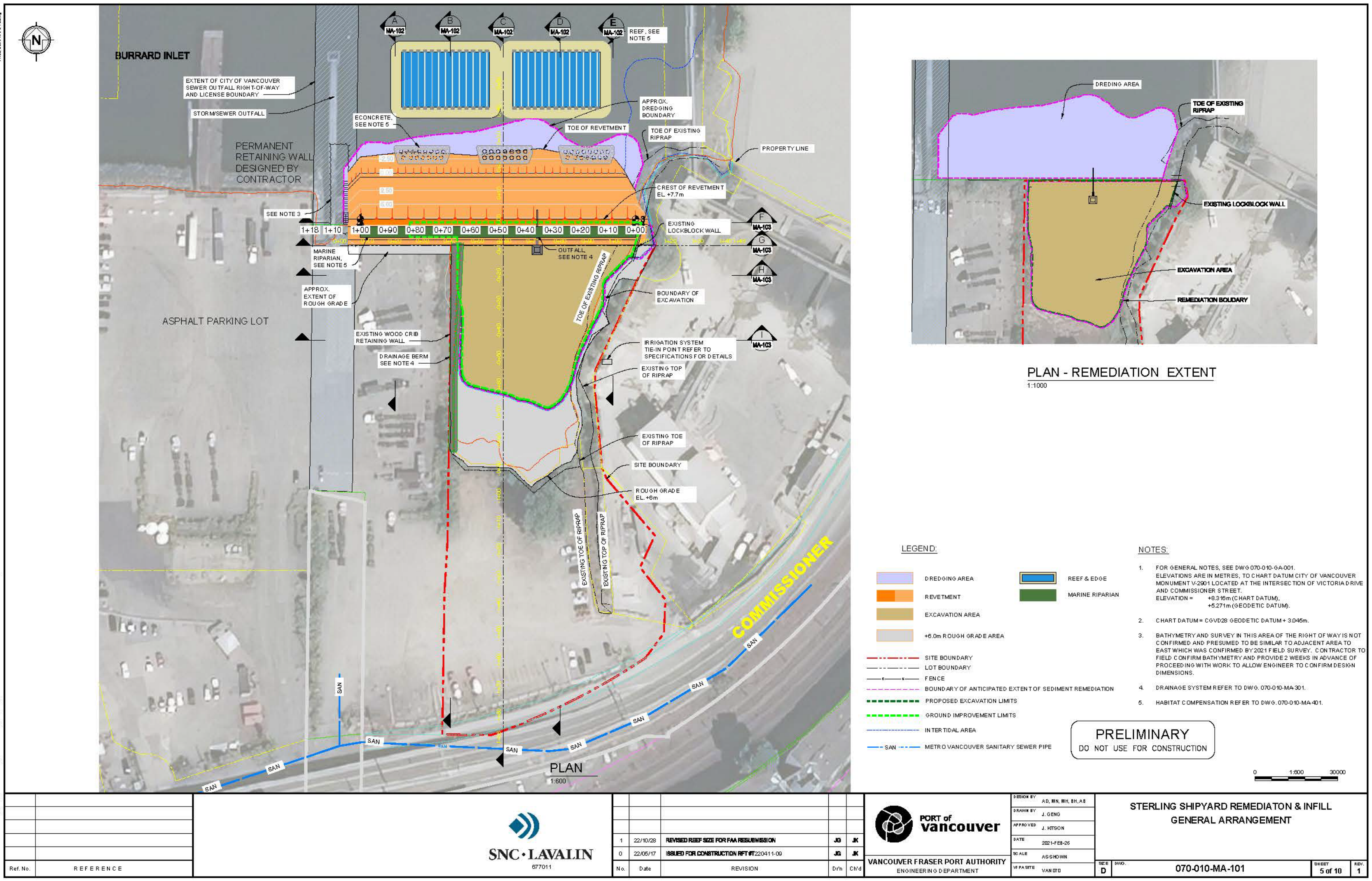
Figure 1: Small-Scale Site Plan



2.3 Large-Scale Site Plan

Please refer to Figure 2 for a large-scale site plan indicating the size and spatial relationship of the planned Project components and of existing structures, landmarks, water bodies and other geographic features.

Figure 2: Large-Scale Site Plan



2.4 Waterbodies Potentially Affected

The only waterbody likely to be affected by the proposed works is the Pacific Ocean, specifically the southern shoreline of the Central Vancouver Harbour, within the Burrard Inlet.

2.5 Community Nearest to the Project Location

The Site is located within Port Authority jurisdiction in the northern portion of the City of Vancouver, BC, Canada.

3 Description of Proposed Works, Undertakings and Activities

3.1 Purpose and Overview

The Project aims to undertake a brownfield redevelopment to create approximately 0.5 ha of new port industrial land on the Site. The majority of Project works will take place within the Site's intertidal zone, of which approximately 80% is considered to be contaminated. The Site substrate is contaminated with industrial woodwaste, metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) up to approximately 4 m depth (Golder, 2009). The redevelopment of the Site will include remedial excavation of contaminated sediment to address current unacceptable ecological risks, followed by infilling with clean engineered fill material.

A rock berm will be installed in the low intertidal area of the Site to provide revetment for the development. The rock berm will be 100 m in length (east to west) with a maximum elevation of 7.7 m. The remedial excavation will occur at an average depth of 3.5 m in the intertidal area consisting of approximately 11,300 m^3 by shored excavation and at an average depth of 1.7 m in the subtidal area consisting of approximately 5,475 m^3 by dredging.

The excavation will be backfilled with engineered fill, which will be compacted after placement. Engineered fill will also be placed on the upland area of the Site. The finished surface of the Site will be graded gravel.

3.2 Description of Existing Structure

At the present time, no structures exist on the Site. Remnants of the former Sterling Shipyard's infrastructure, such as cut-off wooden pilings, remain embedded in the Site and will be removed as a part of the remediation work.

Project Overview – Works, Undertakings and Activities

The Project will involve the excavation of contaminated fill, following which the Site will be infilled. The Port Authority has reviewed several engineering options for the excavation and infill and have selected an option involving a rock berm being installed on the northern face of the Site up to the proposed finish grade. Excavation and infilling will occur on the landward side of the rock berm. This option requires removal of a liquefiable sand layer beneath the berm by remedial dredging in order to provide stability for the berm. Expected Project works, undertakings and activities are shown in the drawing package which is included as **Appendix I**.

The Project's works, undertakings and activities are as follows:

1) Site Preparation.
2) Rock Berm Construction.
3) Remedial Excavation.
4) Infilling and Rough Grading.
5) Habitat Offsetting.
6) ECOncrete Pilot Study.

3.3 Detailed Works, Undertakings and Activities

3.3.1 Site Preparation

The following tasks are anticipated for Site preparation:

- Establishment of Site access points and routes;
- Removal of trees and other vegetation on the southern portion of the Site;
- Establishment of laydown, stockpiling, equipment storage and any other areas required for Project works;
- Installation of erosion and sediment control measures where applicable;
- Installation of a silt curtain around the in-water work area;
- Establishment of water quality monitoring sites upstream and downstream of the work area;
- Demolition of existing infrastructure;
- Mobilization of machinery, materials and equipment onto the Site; and
- Initial dredging up to a depth of 3 m within the in-water work area to provide clearance for barges, if determined to be necessary.

3.3.2 Rock Berm Construction

The following tasks are anticipated for dredging of the rock berm footprint:

- Dredging of the rock berm footprint to remove a liquefiable sand layer to provide rock berm stability:
  - Dredging to an average depth of 1.7 m below existing seabed surface in the subtidal area, removing approximately 5,475 m^3 of subtidal material.
  - Dredging to be conducted using a barge-mounted clamshell dredge. Dredge material to be loaded onto a barge into waterproof containment and then transported off-site.
- Dredge material to be offloaded on-site or transported to a permitted disposal facility:
  - Dredge material destined for the Site will be decanted via settling tanks and/or basins.
  - Dredge material destined for off-site disposal will be disposed as contaminated material.
- Placement of rock and riprap materials onto seabed:
  - Rocks to be lowered into berm footprint from barge via clamshell bucket or grapple from a barge-mounted crane.

3.3.3 Remedial Excavation

The following tasks are anticipated for remedial excavation:

- Excavation of substrate from the intertidal and subtidal area of the Site, up to an average depth of 3.5 m below Site grade;
- Excavation is to take place in wetted conditions from both barge and land;

- Sampling and testing of excavated substrate;
- Management of dredge decant water; and
- Disposal of contaminated substrate.

3.3.4 Infilling and Rough Grading

The following tasks are anticipated for backfilling and grading:

- Placement of engineered fill on the Site:
  - Backfilling the excavation site with 41,000 m^3 of engineered fill; and
  - Placement of additional engineered fill to elevate Site grade to approximately 6 m elevation.
- Grading and compaction of the newly placed engineered fill.

3.3.5 Habitat Offsetting

A Habitat Offsetting Plan will be implemented as part of Project construction. Please refer to **Section 10** for the offsetting plan.

3.3.6 ECOncrete Pilot Study

A pilot study will be conducted as part of this Project to evaluate the effectiveness of ECOncrete in creating viable fish habitat. Please refer to **Section 10.7** for the offsetting plan.

3.4 Project Engineering Specifications, Scale Drawings and Dimensional Drawings (for physical works)

Project engineering specifications are included as **Appendix I**.

3.5 Operations, Maintenance and Closure

At this time there are no plans for future development at the Site, therefore there are no plans for operations, maintenance or closure. The Project aims solely to remediate existing contamination to mitigate environmental risk. While new Port Authority land will be created, any future developments with the potential to cause HADD will be permitted through a future *Fisheries Act* Authorization (if necessary).

4 Phases and Schedule

The Project construction timeline is expected to start in Q2 2023 and conclude by Q1, 2024.

The detailed Project schedule, in sequence, is outlined in Table 3 below (to be provided to DFO as soon as available). The detailed schedule will be developed by the selected contractor. It is expected that contractor selection will occur in Q2, 2023.

Table 3: Project Construction Schedule

Construction Stage	Task	Start Date	End Date
1. Site Preparation	Silt curtain installation	TBD	TBD
	Vegetation clearing	TBD	TBD
2. Rock Berm Construction	Dredging	TBD	TBD
	Rock Berm Construction	TBD	TBD
3. Remedial Excavation	Remedial Excavation/Dredging	TBD	TBD
4. Infilling	Infilling	TBD	TBD
	Rough Grading	TBD	TBD
5. Habitat Offsetting	Reef Construction	TBD	TBD
	Marine Riparian Planting	TBD	TBD
	Kelp Rope Installation	TBD	TBD
	Offsite Log Dump Restoration	TBD	TBD
	ECOncrete Pilot Study	TBD	TBD
6. Effectiveness Monitoring	Year 1	Jan 2025	Dec 2025
	Year 2	Jan 2026	Dec 2026
	Year 3	Jan 2027	Dec 2027
	Year 4	Jan 2028	Dec 2028
	Year 5	Jan 2029	Dec 2029

The end result of the Project will be an infilled and graded Site without any facilities. Therefore, operational and decommissioning start and end dates are not included in the Project schedule.

5 Consultations

5.1 Indigenous Groups

5.1.1 Overview of Pre-Engagement

A pre-engagement period was incorporated into the Project to support VFPA's commitment to meaningful consultation and to the advancement of reconciliation with Indigenous groups. During pre-engagement, Indigenous groups were invited to provide input and feedback during the early stages of project design. This input was then incorporated into the materials included for submission as part of the PER Application.

5.1.1.1 Scope of Indigenous Engagement

The proposed project falls within the traditional territory of the following Indigenous groups:

- Leq'a:mel First Nation
- Musqueam Indian Band
- Seabird Island First Nation
- Shxw'ow'hamel First Nation
- S'ólhTéméxw Stewardship Alliance
    - Aitchelitz First Nation
    - Chawathil First Nation
    - Cheam First Nation
    - Kwaw'Kwaw'Apilt First Nation
    - Scowlitz First Nation
    - Shxwha:y Village
    - Skawahlook First Nation
    - Skwah First Nation
    - Skowkale First Nation
    - Soowahlie First Nation
    - Squiala First Nation
    - Sumas First Nation
    - Tzeachten First Nation
    - Yakweakwioose First Nation
    - Yale First Nation
- Squamish Nation
- Tsleil-Waututh First Nation
- Vancouver Island Groups

- Cowichan Tribes
- Halalt First Nation
- Lyackson First Nation
- Penelakut Tribe
- Stz'uminus First Nation
- Ts'uubaa-asatx Nation (Lake Cowichan)

Given the location of the project in the Burrard Inlet, focus of pre-engagement was with the following Indigenous groups:

- Musqueam Indian Band
- Tsleil-Waututh Nation
- S’ólhTéméxw Stewardship Alliance
- Squamish Nation

5.1.2 Summary of Pre-Engagement Activities

Engagement with Indigenous groups regarding the proposed project began in December 2020 when Indigenous groups were sent a letter introducing the Project. The Port Authority’s archaeological consultant provided Indigenous groups with a copy of the Archaeological Overview Assessment (AOA) report for review in January 2021. Early meetings with Indigenous groups regarding the Project occurred in February and March of 2021.

Due to the confidential nature of the Project, including the nature and location of the contamination on site, the Port Authority required Indigenous groups to sign a Non-Disclosure Agreement (NDA) to receive information during the pre-engagement period. Once an NDA was executed with an Indigenous group, Project-related materials were distributed for review and comment.

Project-related materials were sent to those Indigenous groups who had executed an NDA in May 2021. A 45 calendar day comment window was provided. Early draft versions of documents were provided wherever possible to provide Indigenous groups with the opportunity to provide input prior to documents being finalized for submission to PER.

Members of the Project team met with Indigenous groups to discuss feedback on the Project in July 2021 and formal responses were issued to Indigenous groups, where possible, in August 2021 prior to submission of the application to the PER process. Issues raised by Indigenous groups were in relation to the rationale for the Project, composition of imported fill, proposed approach to habitat offsetting, impacts to fish and fish habitat, economic benefits, and archaeology and cultural heritage.

During this early engagement process, Indigenous groups provided the Project team with feedback in regard to Project design. One of these comments was specifically related to the size of the vegetation band at the top of the rock berm, and the request was made for the Project team to increase the size of the vegetation band in the next phase of design. In response to this request, the Project team increased the size of the vegetation band in the updated habitat offsetting proposal.

5.1.2.1 Overview of Consultation during the Project and Environmental Review (PER)

Upon commencement of the PER process, the Port Authority PER team formally delegated the procedural aspects of consultation to the applicant to support continuity of ongoing discussions between Indigenous groups. The following is a summary of consultation during the PER process, and has been included here, as the Project team continued to discuss the Habitat Offsetting Plan and other details with respect to the FAA application during the PER Indigenous consultation process.

The Project team sent Indigenous groups a referral package on September 28, 2021 and requested to receive comments by November 12, 2021. This referral package included the following documents, which were submitted as part of the application to PER:

- Project and Environmental Review Overview Memo
- Application Form
- Site Plans (60% Drawings)
- Geotechnical Report (60% Geotechnical)
- Habitat Assessment
- Construction Environmental Management Plan (CEMP)
- Habitat Offsetting Plan – Included within the Fisheries Act Authorization application
- Noise Assessment Screening Worksheet
- Traffic Management Plan
- Archaeology Overview Assessment (AOA)
- Marine Design Criteria
- Geotechnical Instrumentation and Monitoring Plan

The Project team also shared updated versions of the Project documents partway through the PER process, as the Project design advanced. The following documents were provided to Indigenous groups at the end of November 2021, at the 90% design stage:

- 90% engineered drawings
- 90% geotechnical report (redlined version)
- 90% marine design criteria (redlined version)
- 90% Environmental Remediation Design Report
- Stormwater Management Design Criteria for the rough grade design

In early December 2021, the Project team also provided Indigenous groups with updated, redlined versions of the FAA application to help support early engagement with Indigenous groups, in advance of consultation by DFO. The FAA application was updated to incorporate changes based on early feedback from Indigenous groups, including an increase in the size of the riparian vegetation planting zone, and the addition of an ECOncrete pilot project.

The Project team provided Indigenous groups with the following documentation for review in advance of DFO consultation on the file to support Indigenous groups with their review of the file, once the referral was sent by DFO:

- *Fisheries Act* Authorization application report – including Habitat Offsetting Plan (redlined version)
- Planting plan for the proposed vegetation band

Through the PER consultation phase, the Project team responded to several rounds of comments from Indigenous groups and held meetings with Indigenous groups to discuss key issues, as requested. Key issues raised during PER consultation included comments pertaining to the design of habitat offsetting for the Project, proposed approaches to environmental monitoring, potential impacts on water quality due to sedimentation and runoff, potential impacts to air quality, potential impacts of noise, and management of invasive species.

On March 7, 2022, the Project team submitted a final report to PER outlining the consultation activities performed during the PER review period. On March 8, 2022, the Project team received confirmation from PER that the report was accepted and the procedural aspects of consultation during the PER process had been completed.

5.1.2.2 Overview of Supplementary Engagement on the Habitat Offsetting Proposal

In April 2022, DFO notified the Project team that the habitat offsetting proposed in the FAA application was insufficient. The Project team was directed to find options to add to the habitat offsetting proposal, and to conduct additional Indigenous engagement for proposed revisions to the FAA application.

The Project team re-initiated engagement with Indigenous groups in May 2022. Engagement activities included:

- A site visit to the Project site for interested Indigenous groups
- A series of workshops and meetings
- Document review
- Response and comment tables

The objective of this supplementary engagement was to involve Indigenous groups in shortlisting potential habitat projects for further feasibility study, and to identify additions to the habitat offsetting proposal that would be deemed satisfactory by Indigenous groups.

In October 2022, the Project team presented Indigenous groups with proposed revisions to the FAA application, including a preliminary draft of revised habitat balance calculations. These proposed changes were accepted by Indigenous groups, and the Project team was directed to move forward in resubmitting the FAA application to DFO with these changes incorporated.

5.1.2.3 Engagement Activities, by Indigenous Group

Engagement activities undertaken with each Indigenous group, including a summary of comments received from each Indigenous group, is outlined in further detail in the *Sterling Shipyards Remediation and Infill Project: Report on the record of Indigenous consultation performed by VFPA Development* included in Appendix II.

6 Description of Fish and Fish Habitat

6.1 General Description

A detailed marine habitat assessment is presented in the Project Habitat Assessment Report. A terrestrial field survey was conducted on October 26, 2020. An intertidal survey was conducted on May 13, 2021 and a subtidal dive survey was conducted by Foreshore Marine & Environmental Services on May 17, 2021.

The Site is located at the former Sterling Shipyard on the southern shore of Central Vancouver Harbour, within Burrard Inlet. The Site surface is sloped downward to the north, towards Burrard Inlet. A steep and densely vegetated slope (sloping down towards Burrard Inlet) runs along the southern boundary of the beach. The beach is an intertidal zone with a moderate gradient towards Burrard Inlet. A wooden log retaining wall runs north to south along the western boundary of the beach, the upper (western) side of which is vegetated with Himalayan blackberry (*Rubus armeniacus*). A riprap slope (sloping down towards the Site) with blackberry bushes runs north to south along the eastern portion of the intertidal beach. The Site is topographically depressed from the west, south and east sides. The Site's beach substrate is dominated by cobble, along with sand and gravel. In general, the entire surface of the Site is covered by historic and recently deposited debris and refuse (SNC-Lavalin, 2021b). Rusted metal components of the former shipyard are abundant on the surface of the entire Site, as well as old line (rope), and wooden residuals of former shipyard infrastructure. Numerous cut-off decaying wooden posts (i.e., remains of pilings) are present on the northwest portion of the Site, along with other embedded wooden remnants of the Site's former infrastructure. Logs and large items of waste timber are abundant on the upper limits of the intertidal zone, forming a linear tidal wrack running east to west across the beach.

During recent field visits, (October 26, 2020, May 13, 2021 and May 17, 2021), the following aquatic wildlife was observed on the Site:

- Earwig species (likely *Anisolabis maritima*) and sandhoppers (unidentified marine amphipods) on the upper limits of the intertidal zone;
- Acorn barnacles (*Balanus glandula*), Pacific Oyster (*Crassostrea gigas*), Blue mussels (*Mytilus edulis*) periwinkles (*Littorina* spp.), Shore crabs (*Hemigrapsus nudus* and *H. oregonensis*) and limpets (*Lottia spp.* and *Tectura spp*.) within the middle and lower intertidal zone; and
- Green urchins (*Strongylocentrotus droebachiensis*), hermit crabs (*Pagarus spp*.) and ochre seastars (*Pisaster ochraceous*) within the lower intertidal zone.

Aquatic vegetation observed during the intertidal survey on May 13, 2021, included rockweed, Turkish washcloth, leafy and crustose phases (*Mastocarpus papillatus*) and sea lettuce. During the subtidal dive survey conducted on May 17, 2021, seaweeds observed in the subtidal area included sugar kelp (*Laminaria* spp.), *Sargassum*, sea lettuce (*Ulva* sp.), seersucker kelp (*Costaria costata*), broad acid weed (*Desmarestia herbacea*), rockweed (*Fucus* sp.), and unidentified red filamentous algae.

A review of DFO's Aquatic Species at Risk (SAR) map (DFO, 2019a) indicated 14 SAR with potential to occur in the marine habitat of the Burrard Inlet, including eight fish species and six marine mammal species. Identified fish SAR are considered unlikely to occur within the Site due to the silt-covered nature of the intertidal and shallow subtidal seabed and a lack of complex habitat structures. Marine mammal SAR are considered to have the potential to occur within the waterlot of the Site.

Please refer to the Project Habitat Assessment Report for a detailed overview of marine and terrestrial habitat on the Site, including species presence, SAR assessment and habitat classification.

6.2 Site Contamination

Previous studies have identified contamination in sediment and pore water/seepage water across the upland, intertidal and subtidal areas of the Site, particularly in areas containing debris, wood waste and/or former shipyard-associated facilities (SNC-Lavalin, 2018). The contaminated fill layer ranges in thickness from 4 m to over 8 m and overlies native marine sands and glacial till. Within the Site footprint, approximately 80% of surface sediments are contaminated with metals, PAHs, and/or PCBs that occur at concentrations above applicable provincial and federal criteria/guidelines. Additionally, metals, petroleum hydrocarbons (PHCs) and PAHs have been identified in porewater/seepage water collected from the Site intertidal zone at concentrations greater than applicable provincial and federal guidelines for protection of marine aquatic life (CCME, 2021).

Within the upland area, a human health risk assessment (HHRA) confirmed that a future development scenario of infilling of the intertidal area posed no unacceptable risks (Golder, 2009). However, shallow soil contamination (metals, hydrocarbons, PAH) and wood waste fill material remain present across the upland area which may impose constraints for future development (i.e., additional disposal costs, limitations on building design or placement of utilities, generation of methane gas requiring subslab ventilation under buildings) (Golder, 2009).

6.2.1.1 Toxicology

Contamination has been identified in both sediment and porewater at the Site. Within the Site footprint, approximately 80% of surface sediments are contaminated with metals (Cu, As, Zn, Pb, Hg, Zn), PAHs, and/or PCBs, at concentrations above applicable provincial and federal criteria/guidelines. Contaminants in sediment at concentrations greater than guidelines protective of aquatic life, particularly those in excess of the CCME Probable Effects Levels (PELs), have been identified on the Site (Golder, 2009). PAHs and heavy metals (Cu, Pb, Hg, As, Zn, Cd, and Cr [total]) have measured concentrations in excess of PELs, with exceedances of an order of magnitude being observed in some cases (Golder, 2009). The presence of contaminants in excess of PELs indicates the potential for adverse effects to marine biota directly or indirectly exposed to these contaminants in sediment.

In addition to the contaminants present in Site sediment, a previous study conducted by SNC-Lavalin studied the concentrations of contaminants within seepage and porewater on the Site (SNC-Lavalin, 2018). The study indicated that several parameters identified in seepage and porewater collected from the Site's intertidal area exceeded the provincial and federal WQGs for Aquatic Life, including:

- Dissolved and total boron;
- Dissolved and total zinc;
- Dissolved and total cadmium;
- Dissolved and total copper;
- Dissolved selenium;
- Total arsenic;
- Total chromium;
- Total mercury; and
- Total manganese.

Following the identification of contaminants in porewater at the Site during the 2018 study, toxicity testing was performed on porewater samples collected from three locations; selected toxicity tests evaluated survival, reproduction and/or growth endpoints for three relevant species (kelp, bivalves and amphipods). Results of this testing indicated significant effects to reproduction and growth resulting from exposure to porewater samples collected from two of three sampling locations (SNC-Lavalin, 2018). Observed effects included reduced success of kelp germination and growth, as well as abnormal bivalve larvae development. No significant effects were identified in the amphipod toxicity test. A summary of the significant effect results from the 2018 study is presented in Table 4 below.

Table 4: Effects of Site Seepage Water on Kelp and Bivalves (SNC-Lavalin, 2018)

Endpoint	Lab Control	100% Seep Water	% Reduction
Kelp Germination (% Success)	70.8 - 72.8%	12.4 - 64.6%	8.2 - 58.4%
Kelp Development (Tube length)	10.5 - 10.9 µm	4.8 - 10.3 µm	2 - 56%
Bivalve Development (% Normal)	81.3 - 84%	29 - 84.6%	0 - 52.3%

The identification of contaminants in sediment and porewater at concentrations greater than applicable guidelines protective of marine aquatic life, in addition to the results of direct toxicity testing, provide strong lines of evidence to indicate the Site offers habitat with reduced ecosystem productivity, especially for sedentary or organisms with limited mobility that would spend the majority of their life cycle exposed to sediment and porewater at the Site. As a result, it is likely that chronic negative impacts on growth and reproduction are occurring to marine biota exposed to sediments and porewater at the Site.

6.2.1.2 Supplementary Information

In addition to the interpretation of toxicity testing results conducted on porewater, and to provide further context for observed sediment exceedances, a literature review was performed to obtain supplementary information relating to the potential effects of the identified sediment contamination with metals, PAHs and PCBs to marine biota at and beyond the Site. This additional information provides further context regarding potential long-term effects of existing contamination on sensitive primary and secondary producers and the risk for biomagnification of contaminants as they move through food chains to higher trophic levels. Effects to aquatic life, including fish, mollusks and marine vegetation associated with elevated concentrations of PAHs and heavy metals were identified, presented in Table 5 and expanded upon in the subsequent sections. While this list provides examples of potential effects to marine life, it is not exhaustive. There are other effects that have not been incorporated due to the intensive study required to fully define them. Each contaminant has the potential to cause multiple effects depending on the route of exposure and exposure concentration. Additionally, the potential for trophic transfer, which was identified for two of the contaminants (heavy metals and PCBs) in **Section 6.2.1.2.3**, has not been incorporated despite having the potential to impart long-term effects on the greater regional ecosystem.

Table 5: Summary of Literature Review on Potential Effects of PCB, PAH and Metal Contamination

Affected Resource	Adverse Effect	Citation
Marine Wildlife	Toxicity from exposure to PAHs, PCBs and metals.	Diego Carlos Ernesto, 2007; Mayer-Pinto et al., 2020; SNC-Lavalin, 2018.
Marine Vegetation	Reduced growth rate and nitrogen fixation in eelgrass as a result of Cu, Hg, Pb and Zn accumulation. Reduced photosynthetic activity in kelp as a result of heavy metals accumulation.	Gaeckle, 2012; Lewis, 2009; Lyngby & Brix, 1984; Mayer-Pinto et al., 2020.

Table 5 (Cont'd): Summary of Literature Review on Potential Effects of PCB, PAH and Metal Contamination

Affected Resource	Adverse Effect	Citation
Seabirds, Marine Wildlife and Vegetation	Trophic transfer of metals, PAHs and PCBs accumulated within vegetation and aquatic wildlife into the marine environment, creating toxicological effects across the food web within and beyond the Site.	Diego Carlos Ernesto, 2007; Gaeckle, 2012; Honda & Suzuki, 2020; Hu et al., 2020.
Fish and Infauna	Avoidance of the Site due to hydrocarbons (fish) and metals (infauna) in the water column.	CCME, 1999; Tierney *et al*., 2010.

6.2.1.2.1 Avoidance

Avoidance behaviour has been observed in both fish and infauna when exposed to environments containing elevated concentrations of PHCs and metals (CCME, 1999; Tierney et al., 2010). Coho salmon smolts and rainbow trout, both of which appear within Burrard Inlet, have been observed to exhibit avoidance behavior under exposure to water containing elevated concentrations of monocyclic hydrocarbons and metals (Tierney et al, 2010). Coho salmon smolts exhibited avoidance at concentrations of 1.4 mg/L monocyclic aromatic hydrocarbons and rainbow trout at concentrations of at 1.6 µg/L copper(II) chloride ($CuCl_2$), 0.1 µg/L copper sulfate ($CuSO_4$) and 5.6 µg/L zinc sulfate ($ZnSO_4$). The copepod *Schizopera knabeni* and the amphipod *Diporeia* spp. have similarly been observed to exhibit avoidance of sediment with elevated concentrations of PAHs (CCME, 2010). Due to the observed avoidance behavior exhibited by infauna in response to contaminated sediment, the value and productivity of existing habitat on the Site may be reduced by existing contamination potentially inducing avoidance behaviour in local marine wildlife.

6.2.1.2.2 Impact to Aquatic Vegetation

Metal contamination in Site sediment and porewater may adversely impact marine vegetation growth from the uptake and accumulation of heavy metals within vegetation tissue. Kelp has been observed to undergo decreased photosynthetic activity when exposed to heavy metal contaminants (Mayer-Pinto *et al.,* 2020). Elevated concentrations of Cd, Cu, Pb and Zn are present within the Site's intertidal zone and these metals have been shown to have the potential to be taken up and accumulate in eelgrass tissues (Lewis, 2009; Lyngby & Brix, 1984). Accumulation of metals within vegetation tissue can result in toxic effects, including reduced growth rate when exposed to water with 5 µm Cu and Cd concentrations and 50 µm Pb and Zn concentrations for up to 19 days (Gaeckle, 2012). Additionally, nitrogen fixation rate within eelgrass have been observed to be reduced by 24-hour exposure to water with 100 mg/L concentrations of Pb and 10 mg/L concentrations of Hg (Gaeckle, 2012). Effects of long-term exposure (e.g., several months) to lower concentrations of metal contaminants have not been well-studied. However, though concentrations of these metals in porewater at the Site are lower than the thresholds associated with effects, toxicity testing using porewater collected from the Site resulted in reduced growth and reproduction of kelp. Therefore, it is possible that marine vegetation within the Site's waterlot is in a state of reduced growth and nitrogen fixation function due to long-term exposure to metal contaminants and these potential effects have reduced the long-term productivity of the existing habitat at the Site.

6.2.1.2.3 Trophic Transfer

Contaminants taken up by marine vegetation or low trophic level organisms (e.g., invertebrates associated with sediments) can accumulate in these organisms (bioaccumulation) and, in some cases, can be transferred and magnify through increasing trophic levels (biomagnification) (Hu *et al.,* 2020; Gaeckle, 2012). Aquatic vegetation containing sequestered heavy metals may be grazed on by marine wildlife, contributing to bioaccumulation of heavy metals in local fish and marine wildlife, including seabirds (Hu *et al.,* 2020; Gaeckle, 2012). Plant matter with elevated levels of heavy metals that has become detached from the seabed can release heavy metals through decomposition (Gaeckle, 2012). Experimental designs in marine environments contaminated by heavy metals have shown Cu concentrations within the bodies of marine wildlife of 37.43 µg/g in mollusks and 7.41 µg/g in fish (Hu *et al.,* 2020). Additionally, PAHs can accumulate in marine wildlife, including invertebrates and carnivorous fish (Honda & Suzuki, 2020).

PCBs likewise bioaccumulate in aquatic life. Bioaccumulation of sediment-borne PCBs within Burrard Inlet has been modeled and predicted to significantly transfer across trophic levels within local wildlife, including benthic organisms, fish, seabirds and marine mammals (Diego Carlos Ernesto, 2007). The potential for bioaccumulation and biomagnification of Site-sourced contaminants through increasing trophic levels, further indicates that contaminants currently present in Site porewater and sediment are likely negatively impacting marine wildlife both within and beyond the Site.

7 Description of Effects on Fish and Fish Habitat

Project effects include the permanent alteration of intertidal and subtidal fish habitat, destruction of marine riparian vegetation, destruction of aquatic vegetation, and death of infauna, microfauna and macrofauna as a result of dredging, rock berm construction, remedial excavation, and infilling.

- Approximately 1,555 m^3 of marine riparian habitat will either be removed or otherwise lose its riparian function.
- Approximately 2,835 m^2 of subtidal and 4,870 m^2 of intertidal fish habitat will be affected by dredging and excavation, with 2,020 m^2 of the subtidal area and 660 m^2 of intertidal area being permanently covered by rock berm revetment and 815 m^2 of subtidal zone being temporarily disturbed by dredging during construction. This location contains some kelp habitat and a limited community of seaweeds, all of which will be destroyed.
- Microfauna, Infauna and Macrofauna (e.g., shore crabs, bivalves) will be harmed/killed by crushing/burial within the intertidal and subtidal zone during dredging, rock berm construction and remedial excavation and infilling. Large crustaceans and fish will be salvaged during pre-construction fish salvaging and are not expected to be harmed.

7.1 Pathways of Effects

DFO's Pathways of Effects (PoE) were used to analyze the Project scope and identify activities that are likely to or have the potential to result in HADD. PoE identifies a list of in-water and land-based activities (PoE activities) that have the potential to cause HADD, with each such activity being associated with a series of effects by which HADD may be caused (PoE effects).

Potential HADD resulting from Project activities has been analyzed in its potential likelihood, magnitude, geographical extent and duration. Table 6 below outlines the HADD analysis criteria applied to each PoE activity as it pertains to a Project construction stage.

Table 6: Evaluation Rating Criteria for Project HADD

Category							
Likelihood		Magnitude		Extent		Duration	
Rating	Definition	Rating	Definition	Rating	Definition	Rating	Definition
Low	The likelihood of HADD occurring is considered unlikely or non-existent	Low	No measurable HADD	Low	The HADD is limited to Project footprint	Low	The HADD is not expected to persist significantly beyond the construction period
Moderate	The likelihood of HADD occurring is considered somewhat likely	Moderate	HADD including: › Temporary disruption of habitat › Harmful alteration of habitat	Moderate	The HADD extends into areas immediately beyond footprint boundary	Moderate	The HADD is expected to temporarily persist for beyond the construction period

Table 6 (Cont'd): Evaluation Rating Criteria for Project HADD

Category							
Likelihood		Magnitude		Extent		Duration	
High	The likelihood of HADD occurring is considered high or certain	High	HADD including: › Death of fish › Permanent alteration or destruction of fish habitat	High	The HADD is widespread and trans-boundary in nature	Permanent	Residual permanent HADD will remain after construction

Mitigation measures proposed for the Project were categorized for each potential PoE effect and evaluated for their proposed effectiveness. Please refer to Table 7 for criteria used to evaluate the effectiveness of mitigation measures.

Table 7: Evaluation Rating Criteria for Proposed Mitigation Effectiveness

Rating	Evaluation Definition
Low	Proposed mitigations are not expected to effectively minimize HADD, or potential HADD is considered inevitable
Moderate	Proposed mitigations are expected to effectively mitigate potential HADD to a significant extent, but temporary HADD may still persist
High	Proposed mitigations are expected to fully mitigate potential HADD

Proposed mitigation measures were categorized for each PoE effect stemming from a specific PoE activity. Due to significant overlap between PoE activities in their effects, the majority of proposed mitigation measures have been categorized into general mitigations that are applicable for a given effect across project stages. Table 8 below outlines general mitigation measures associated with PoE effects.

Following the evaluation criteria outlined in Table 6 and Table 7, as well as the general mitigations outlined in Table 8, the PoE analysis was implemented for the Project. Each Project construction stage was categorized by PoE activities and their associated PoE effects, with corresponding mitigation measures proposed. Please refer to Table 9 below for the PoE analysis.

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Table 8: General Mitigations for Pathways of Effects

Row No.	DFO Effect	Proposed Mitigation Measures
1	Change in Sediment Concentrations	› Work within DFO Least-Risk timing window (August 16 - February 28) as much as feasible. › Ensure a qualified Environmental Monitor (EM) is on-site for the duration of works. › A silt curtain must be in place prior to the start of works. › Avoid work in precipitation wherever possible. › Conduct works in low tide levels whenever possible. › Implement and follow an Erosion and Sediment Control (ESC) plan throughout works. › Restrict equipment works and access in water wherever possible. › Stop work during heavy precipitation, if there is any risk of sediment or sediment-laden water entering the marine environment or any risk of excessive erosion of disturbed soil/substrate. "Heavy precipitation" will be defined at the on-site EM's discretion and may include precipitation that causes overland flow of run-off/precipitation and/or greatly increases the risk of sedimentation to marine waters. › Control runoff from construction areas to ensure that silt or deleterious substances are not carried into the marine environment. › Install ESC measures in advance of the work. The EM will assist with recommendations for appropriate ESC measures based on-site conditions (e.g., tide level, weather) at the time of Project execution, and will monitor ESC controls through the duration of the Project. ESC measures may include: Silt fencing, sand bag berms, silt curtains. › The contractor is responsible for having all ESC measures on-hand before the start of works. › All sediment-laden water will be removed from the site for off-site disposal or let to decant in waterproof containment and discharged ONLY if tested to meet CCME Water Quality Guidelines for Protection of Aquatic Life. › Inspect/maintain ESC measures around exposed or disturbed soil/substrate in any areas or locations where a risk of migration of sediments, sediment-laden water or debris from the work area exists, as well as during periods of prolonged rainfall, and immediately before and after a rainfall event. If ESC measures are observed to be clogged or damaged, cleanout or repairs will be made immediately. › Monitor water quality throughout the entire duration of works. Monitoring standards should adhere to the Canadian Council of Ministers of Environment (CCME) Guidelines for Turbidity. – Clear water: Maximum increase of 8 NTUs from background levels for a short-term exposure (E.g., 24-hour period). – Turbid Waters: Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 and 80 NTUs. – Please refer to the Project Construction Environmental Management Plan (CEMP) for water quality monitoring requirements. › Stop work and adjust ESC controls if any silt, sediment, debris or Project-related water is observed leaving the work area and entering the surrounding environment. › Complete works as soon as possible once they are started. Always protect and stabilize exposed soil areas at the end of the workday. Measures include, but are not limited to, covering the area with polyethylene sheeting or tarps or boards. › Dispose of all Project-related waste at an appropriate facility. › Conduct ALL works in adherence to the Project CEMP and relevant Environmental Protection Plans (EPPs) prepared by the Contractor.

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Table 8 (Cont'd): General Mitigations for Pathways of Effects

Row No.	DFO Effect	Proposed Mitigation Measures
2	Change in Contaminant Concentrations	› Work within DFO Least-Risk timing window (August 16 - February 28) as much as feasible. › Ensure a qualified EM is on-site for the duration of works. › A silt curtain must be in place prior to the start of works. › Conduct works in low tide levels whenever possible. › All handling of contaminated or suspect contaminated materials must be carried out in accordance with the Project CEMP, the BC *Contaminated Sites Regulation* (CSR) and the *Environmental Management Act* (EMA). › Avoid work in precipitation wherever possible. › Implement and follow a Spill Prevention and Emergency Response Notification Plan (SPERNP) for the Project. › Restrict equipment works and access in water wherever possible. › Inspect all machinery and ensure all machinery is in full working order, being free of leaks and drips. › All hose connections of machinery must be wrapped in sorbent material. › Report any and all spills to the Project EM, regardless of volume or duration. › All fuel-filled equipment and tanks will be placed in secondary containment when not in use. Secondary containment must be capable of containing 110% of all fluid within the equipment or tank. › Spill kits will be available and present on all machinery, capable of absorbing the largest possible spill associated with that machinery's work. › A large central spill kit, containing absorbing booms and other materials for spills to water, must be available on-site and accessible to all on-site personnel, who must be trained in its use. › Hydraulic oil used in machinery must be biodegradable where possible. › Hydraulic hoses and couplings will be inspected and free of leaks and/or excess hydrocarbons prior to use near the marine environment. › Impervious materials, such as tarps, drip pans or spill trays, will be placed underneath equipment and machinery during servicing when there is a potential for accidental drips or spills. › Machinery will not be left on-site overnight. If this cannot be avoided, machinery must be placed in a staging area located at least 30 m from the marine high-water mark or any drainage features, (such as catch basins) and be placed atop of drop pans and/or sorbent material. › Refuelling and/or lubricating of vehicles must be conducted in a designated area located at least 30 m from the marine high-water mark and from any drainage features (such as catch basins). All refuelling and/or lubricating of vehicles must take place atop of absorbent sheets/pads or within an impermeable lined basin. › Stop work during heavy precipitation. Ensure all on-site personnel are trained and knowledgeable in the Project SPERNP and are able to adequately respond to spills and emergencies on-site. › Conduct ALL works in adherence to the Project CEMP and relevant EPPs prepared by the Contractor.
3	Potential mortality of fish/eggs/ova from equipment	› Work within the DFO Least-Risk timing window whenever feasible (August 16 - February 28) as much as feasible. › Engage a qualified EM to be assigned to the Project for the duration of works. › Develop and implement an ESC plan and SPERNP for the Project. › In-water excavation or dredging works may not take place until a fish salvage has been conducted, salvaging as many fish and large motile crustaceans as possible before machinery begins work. Please refer to the Project CEMP for fish salvage requirements. › Clearly delineate the area of intertidal/seabed disturbance and do not impact the areas beyond those limits unless absolutely necessary. › Avoid impacts to seabed beyond what is necessary to complete the Project. › Limit machinery access to within the Project footprint, avoid unnecessary machinery access Any machinery will have all connections wrapped with sorbent material, and hydraulic hoses and couplings will be inspected and free of leaks and excess hydrocarbons prior to use near the marine environment. › Immediately report all spills to the EM regardless of volume. › All fuel-filled equipment to be placed in secondary containment when not in use; Secondary containment will be able to contain 110% of fluid within the equipment being stored in containment.

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Table 8 (Cont'd): General Mitigations for Pathways of Effects

Row No.	DFO Effect	Proposed Mitigation Measures
3 (Cont'd)	Potential mortality of fish/eggs/ova from equipment (Cont'd)	› Hydraulic oil used in machinery will be vegetable-based and biodegradable such as EcoSafe, Environ or similar. › Conduct ALL works in adherence to the Project CEMP and relevant EPPs prepared by the Contractor.
4	Change in Food Supply	› Work within DFO Least-Risk timing window (August 16 - February 28) as much as feasible. › Ensure a qualified EM is on-site for the duration of works. › Limit vegetation removal only to that which is necessary. › Carry out habitat offsetting as part of Project works. › Clearly delineate the area of intertidal/seabed disturbance and do not impact the areas beyond those limits unless absolutely necessary. › Avoid impacts to seabed beyond what is necessary to complete the Project. › Limit machinery access to within the Project footprint, avoid unnecessary machinery access. › Conduct ALL works in adherence to the Project CEMP and relevant EPPs prepared by the Contractor.
5	Change in Habitat Structure and Cover	› Work within DFO Least-Risk timing window (August 16 - February 28) as much as feasible. › All work will be conducted after a silt curtain is installed and approved by the EM. › Ensure a qualified EM is on-site for the duration of works. › Clearly delineate the area of intertidal/seabed disturbance and do not impact the areas beyond those limits unless absolutely necessary. › Avoid impacts to seabed beyond what is necessary to complete the Project. › Limit machinery access to within the Project footprint, avoid unnecessary machinery access on the seabed. › Carry out habitat offsetting as part of Project works. › Conduct ALL works in adherence to the Project CEMP and relevant EPPs prepared by the Contractor.
6	Change in Dissolved Oxygen	› Work within DFO Least-Risk timing window (August 16 - February 28) as much as feasible. › Ensure a qualified EM is on-site for the duration of works. › All work will be conducted after a silt curtain is installed and approved by the EM. › Carry out habitat offsetting as part of Project works. › Clearly delineate the area of seabed disturbance and do not disturb the seabed beyond those limits. › Avoid impacts to seabed beyond what is necessary to complete the Project. › Limit machinery access to within the Project footprint, avoid unnecessary machinery access on the seabed. › Conduct ALL works in adherence to the Project CEMP and relevant EPPs prepared by the Contractor.

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Table 8 (Cont'd): General Mitigations for Pathways of Effects

Row No.	DFO Effect	Proposed Mitigation Measures
7	Lethal or sublethal effects on fish or marine mammals.[2]	› Work within DFO Least-Risk timing window (August 16 - February 28) as much as feasible. as much as feasible. › Ensure a qualified EM is on-site for the duration of works. › Conduct acoustic monitoring during works to ensure nose thresholds do not exceed levels that are harmful to fish and marine mammals. › Retain a Marine Mammal Observer (MMO) to conduct marine mammal observation during dredging. › Establish and monitor a 1,000 m buffer zone around the work area. If this zone is entered by a marine mammal, stop all underwater dredging activity. › Ramp-up and pre-watches must be conducted before the start of any underwater noise-generating activity. Please refer to the Project CEMP for a detailed overview of pre-watch and ramp-up procedures. – The MMO will pre-watch the 1,000 m buffer zone for 30 minutes. If a marine mammal enters the buffer zone, the MMO will confirm that they left before restarting the 30-minute pre-watch. – If buffer zone is clear for 30 minutes during pre-watch, dredging must ramp-up for a minimum of 20 minutes before reaching maximum noise output (please refer to the Project CEMP). – The pre-watch and ramp-up procedures will be established by the Project EM/MMO. › If a marine mammal species at risk is observed within the 1,000 m buffer zone, stop work immediately. › Conduct ALL works in adherence to the Project CEMP and relevant EPPs prepared by the Contractor.

[2] This is not a formal DFO Pathway of Effects but is a necessary consideration for this activity. Therefore, this has been added as a potential PoE for this Project.

Table 9: Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation?
Site preparation › Vegetation Clearing › Silt fence installation › Initial grading	Vegetation clearing	Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna	› Implement all applicable general mitigations in row 1 of Table 8 › Use by-hand methods to remove vegetation where possible	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Change in contaminant concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8 › Use by-hand methods to remove vegetation where possible.	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Change in food supply	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 4 of Table 8 › Riparian planting will be implemented as part of habitat offsetting	Low	Likelihood: High Magnitude: High Extent: Low Duration: Low	Yes Permanent Alteration
	Use of industrial equipment	Change in contaminant concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8	High	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No
		Potential mortality of fish/eggs/ova from equipment	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 3 of Table 8	High	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No
	Excavation	Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8	High	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No

Table 9 (Cont'd): Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation?
Site preparation › Vegetation Clearing › Silt fence installation › Initial grading (Cont'd)	Grading	Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8	High	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No
Rock Berm Construction › Dredging of liquifiable sand layer › Installation of rock berm › Dewatering/Decanting of Dredge Material	Use of industrial equipment	Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8 › All rock material used for the berm must be free of silts and fines › Barge spudding will be kept to a minimum	High	Likelihood: Low Magnitude: Moderate Extent: Moderate Duration: Low	No
		Change in contaminant concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8 › All barges used for loading of dredge material will be lined with waterproof containment	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Potential mortality of fish/eggs/ova from equipment	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 3 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Low	Yes Crushing/burial

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Table 9 (Cont'd): Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation??
Rock Berm Construction › Dredging of liquifiable sand layer › Installation of rock berm › Dewatering/Decanting of Dredge Material (Cont'd)	Dredging	Change in sediment concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8 › All rock material used for the berm must be free of silts and fines › Barge spudding will be kept to a minimum › Clamshell buckets will be raised/lowered slowly › Use single grabs with clamshell › Load dredge material onto barges cautiously; avoid loss of sediment over barge rails › Ensure clamshell bucket is empty after unloading prior to moving it back over water	High	Likelihood: Low Magnitude: Moderate Extent: Moderate Duration: Low	No
		Change in contaminant concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8 › All barges used for loading of dredge material will be lined with waterproof containment › Load dredge material onto barges cautiously; avoid loss of sediment over barge rails › Ensure clamshell bucket is empty after unloading prior to moving it back over water	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Change in food supply	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 4 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent alteration
		Change in habitat structure and cover	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 5 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration

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Table 9 (Cont'd): Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation?
Rock Berm Construction › Dredging of liquifiable sand layer › Installation of rock berm › Dewatering/Decanting of Dredge Material (Cont'd)	Underwater pressure and noise	Lethal or sublethal effects on fish or marine mammals[3]	Fish Marine Mammal Species at Risk	› Implement all applicable general mitigations in row 7 of Table 8	High	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No
	Addition and removal of aquatic vegetation	Change in food supply	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 4 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent alteration
		Change in habitat structure and cover	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 5 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
		Change in dissolved oxygen	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 6 of Table 8	Low	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No

[3] This is not a formal DFO Pathway of Effects but is a necessary consideration for this activity. Therefore, this has been added as a potential PoE for this Project.

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Table 9 (Cont'd): Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation?
Rock Berm Construction › Dredging of liquifiable sand layer › Installation of rock berm › Dewatering/Decanting of Dredge Material (Cont'd)	Placement of material or structures in water	Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8 › All rock material used for the berm must be free of silts and fines › Lower rock material slowly onto seabed	High	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No
		Change in food supply	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 4 of Table 8	Low	Likelihood: Moderate Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
		Change in habitat structure and cover	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 5 of Table 8	Low	Likelihood: Moderate Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
	Wastewater management	Change in contaminant concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8 › The Contractor will develop and Implement and follow a Dredge and Excavated Water Management plan (DEWMP) for the Project › All barges used for loading of dredge material will be lined with waterproof containment › Load dredge material onto barges cautiously; avoid loss of sediment over barge rails › Ensure clamshell bucket is empty after unloading prior to moving it back over water	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
Remedial Excavation › Dredging of wet sediment behind rock berm › Excavation of sediment within intertidal zone and upland area	Dredging/ Excavation	Change in sediment concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8 › Barge spudding will be kept to a minimum › Clamshell buckets will be raised/lowered slowly › Use single grabs with clamshell › Load dredge material onto barges cautiously; avoid loss of sediment over barge rails	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Change in contaminant concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No

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Table 9 (Cont'd): Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation?
Remedial Excavation › Dredging of wet sediment behind rock berm › Excavation of sediment within intertidal zone and upland area (Cont'd)		Change in food supply	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 4 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
		Change in habitat structure and cover	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 5 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
	Wastewater Management	Change in contaminant concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8 › The Contractor will develop and Implement and follow a Dredge and Excavated Water Management plan (DEWMP) for the Project › All barges used for loading of dredge material will be lined with waterproof containment › Load dredge material onto barges cautiously; avoid loss of sediment over barge rails › Ensure clamshell bucket is empty after unloading prior to moving it back over water	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
	Underwater pressure and noise	Lethal or sublethal effects on fish or marine mammals[4]	Fish Marine Mammal Species at Risk	› Implement all applicable general mitigations in row 7 of Table 8	High	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No

[4] This is not a formal DFO Pathway of Effects but is a necessary consideration for this activity. Therefore, this has been added as a potential PoE for this Project.

Table 9 (Cont'd): Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation?
Remedial Excavation › Dredging of wet sediment behind rock berm › Excavation of sediment within intertidal zone and upland area (Cont'd)	Addition and removal of aquatic vegetation	Change in food supply	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 4 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
		Change in habitat structure and cover	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 5 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
		Change in dissolved oxygen	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 6 of Table 8	Low	Likelihood: Low Magnitude: Low Extent: Low Duration: Low	No
	Use of industrial equipment	Change in sediment concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8	High	Likelihood: Low Magnitude: Moderate Extent: Moderate Duration: Low	No
		Change in contaminant concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Potential mortality of fish/eggs/ova from equipment	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 3 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Low	Yes Crushing/burial

Table 9 (Cont'd): Project Activities PoE Analysis and Proposed Mitigations

Project Activity	Pathway of Effects Activity	Effects	Affected fish and fish habitat	Proposed Mitigation Measures	Predicted Effectiveness of mitigation measures	Characteristics of Potential Residual HADD after Mitigation	Permanent residual HADD or death to fish after mitigation?
Backfilling and Grading › Infilling of Excavation › Grading of surface › Vibro-compaction	Placement of material or structures in water	Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8 › All imported infilling material must be confirmed free of silts and fines	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Change in food supply	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 4 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
		Change in habitat structure and cover	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 5 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Permanent	Yes Permanent Alteration
	Grading	Change in sediment concentrations	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
	Use of industrial equipment	Change in sediment concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 1 of Table 8	High	Likelihood: Low Magnitude: Moderate Extent: Moderate Duration: Low	No
		Change in contaminant concentrations	Seaweed/Algae Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 2 of Table 8	High	Likelihood: Low Magnitude: Moderate Extent: Low Duration: Low	No
		Potential mortality of fish/eggs/ova from equipment	Microfauna Infauna Macrofauna Fish	› Implement all applicable general mitigations in row 3 of Table 8	Low	Likelihood: High Magnitude: High Extent: Low Duration: Low	Yes Crushing/burial

8 Measures and Standards to Avoid and Mitigate HADD

Several different remediation methods and end uses for the Site have been considered over the years and these investigations have resulted in several different alternative designs (SNC-Lavalin, 2017). Each remedial design alternative presented a different set of potential effects to fish habitat and previous conceptual offsetting plans were developed for review during the options evaluation (SNC-Lavalin, 2014a). The Project design has been optimized to limit HADD and provide a reduction in contaminant loading in the local marine ecosystem.

DFO's hierarchy of measures emphasizes that efforts should be made to first prevent adverse effects. When avoidance is not feasible, efforts should be made to minimize adverse effects. As a last resort, any residual adverse effects that are inevitable should be offset to compensate for loss of fish and fish habitat through positive contributions to the aquatic ecosystems. Detailed mitigations to protect fish and fish habitat are outlined in the Project CEMP, as well as discussed in the Pathway of Effects (Section 7.1 of this report) and have been designed in accordance with DFO's hierarchy of measures (See SNC-Lavalin, 2021).

8.1 Least-Risk Timing Windows

The least-risk fisheries work dates applicable to the Project are presented in Table 10 below.

Table 10: Project Least-Risk Timing Windows

Least-Risk Period	Start Date	End Date
Fisheries and Oceans Canada (DFO) Least-Risk work window for Burrard Inlet[1]	August 16	February 28

1 DFO. 2014. British Columbia Marine/Estuarine Timing Windows for the Protection of Fish and Fish Habitat – South Coast and Lower Fraser Areas.

Initial Site preparation and construction activities are planned to start outside of the least-risk period. Ground disturbance activities (e.g., vegetation removal, wood debris removal) will not commence until a silt curtain has been installed around the work area.

In-water works will be kept within the DFO least-risk work window for Burrard Inlet as much as possible. Due to the long-term nature of the Project, in-water works outside the least-risk window will occur. In-water works will not occur until a fish salvage has been completed by a Qualified Environmental Professional (QEP). If in-water works are planned outside of the DFO least-risk period, additional monitoring and mitigation measures will be implemented to prevent impacts to species during sensitive life stages, at the discretion of the Project Environmental Monitor (EM). Please refer to the Project Construction Environmental Management Plan (CEMP; document No. 677011-0000-4ERA-0003) for sensitivity-period related mitigations.

8.2 Environmental Compliance Monitoring During Construction

A detailed monitoring plan, including responsibilities on behalf of multiple monitors, is outlined in the Project CEMP. Environmental monitors (EMs) will be responsible for monitoring all in-water works, sensitive construction works on the upland area of the Site and water quality monitoring throughout the Project. Additionally, marine mammal observation (MMO) monitoring will be conducted by a QEP. Please refer to the Project CEMP for EM and MMO requirements, including frequency and intensity of construction and water quality monitoring.

8.3 Contingency Measures

Avoidance and mitigation measures described in the CEMP (SNC-Lavalin, 2021) and Pathway of Effects are well established and expected to be effective. However, should any of these measures fail for any reason, work will be stopped by the EM (or other Project representative) and the incident reporting procedures outlined in the Project CEMP will be followed. Works will not resume until effective strategies to address observed or imminent impacts, HADD and/or non-compliances are developed and implemented in consultation with DFO and potentially affected Indigenous groups.

9 Residual HADD and Death of Fish

9.1 Residual Temporary and Permanent Effects to Fish Habitat

Residual HADD is HADD that occurs after implementing DFO Measures to Protect Fish and Fish Habitat and other impact mitigation and avoidance measures, as described in the Project CEMP (SNC-Lavalin, 2021a). For the Project, residual HADD occurs through the following DFO Pathways of Effects[5]:

- Excavation;
- Use of industrial equipment;
- Vegetation clearing;
- Removal of aquatic vegetation;
- Dredging; and
- Placement of material or structures in water.

This assessment aligns with the DFO's initial Project Review (DFO file #20-HPAC-01293), which indicated that HADD would be caused by excavation and/or infilling of marine riparian habitat, intertidal aquatic habitat and subtidal aquatic fish habitat. HADD caused by the Project will be in the form of destruction of fish habitat, death to fish, permanent alteration of fish habitat and temporary disruption of fish habitat. Specifically, the Project results in HADD to habitat types and spatial areas described in Table 11 and shown on Drawing 070-010-MA-101 (Appendix I).

5 https://www.dfo-mpo.gc.ca/pnw-ppe/pathways-sequences/index-eng.html

Table 11: Expected Residual HADD by Habitat Type (m^2)

Habitat Type	Project Component	Tidal Elevation (M)	HADD Surface Area	Description of Pre-Construction Condition	Effect Type	Description of Post-Construction Condition
Marine Riparian	Vegetation Clearing, Remedial Excavation and Infilling	HHW (+5 m to +7.6 m)	1,555	Contaminated Land (Riparian)	Destruction	Land (Non-Riparian)
Intertidal	Remedial Excavation and Infilling	(0 m) to HHW (+5.0 m)	4,210	Contaminated Intertidal Zone	Destruction	Land
Intertidal	Berm Construction (incl. dredge pre-berm construction)	Chart Datum (0 m) to + 5.0 m	660	Contaminated Intertidal Zone	Destruction	Riprap Revetment
Subtidal	Berm Construction (incl. dredge pre-berm construction)	(0 m) to - 8.5 m	2,020	Contaminated Subtidal Zone	Permanent Alteration	Riprap Revetment
Subtidal	Dredging	> -7.0 m	815	Contaminated Subtidal Zone	Temporary Disruption	Subtidal Zone
	Total Area (m^2)		**9,260**			

Depths and elevations are relative to Chart Datum.

Approximately 9,260 m^2 of marine intertidal and subtidal habitat will be disturbed during the Project, with 6,890 m^2 of that area being destruction and permanent alteration and 815 m^2 being temporary disruption during construction (Refer to Drawing 070-010-MA-101, Appendix I). These alterations constitute a loss of foraging habitat for fish and crustaceans, colonizable habitat for bivalves and barnacles, aquatic vegetation, and prey production for juvenile fish species.

9.2 Death of Fish

Efforts to salvage motile invertebrates will be undertaken prior to the start of construction. However, given the nature of the Project, death of fish of all species observed in within the intertidal and subtidal portions of the Site is likely to occur. Please refer to the Project Habitat Assessment for species observed. Death of fish is expected to occur during dredging, rock berm construction, remedial excavation and infilling in the form of crushing and burial of resident invertebrate organisms.

Please refer to the Project CEMP for fish salvage details, as well as measures to protect fish habitat and minimize death of fish during construction.

10 Offsetting Plan

10.1 Offsetting Precedence

To establish context, a review of select habitat offsetting projects was conducted by SNC-Lavalin. Projects were selected for their proximity to the Site and/or similarity of works to the Sterling Shipyard Remediation and Infill Project.

The different types and magnitudes of HADD, the ways in which specific effects to fish habitat occur, and the types of habitat features created to offset HADD were reviewed for each project. Each project was assessed individually and habitat balances were calculated based on the relative quality and quantity of habitat affected and created. It is considered beneficial to offset habitat and create aquatic productivity in the local area impacted by a project. However, recent changes to the FA have increased opportunities for proponents to consolidate offsetting credits within registered DFO Habitat Banks for projects with large footprints (E.g., New Brighton Park Shoreline Habitat Restoration Project). Therefore, plans that included both off-site and on-site offsetting were reviewed. The reviewed projects and their offsetting characteristics include:

- A/B Jetty Recapitalization Project (SLR, 2015);
- Big Trout River Sawmill Expansion (Pearson et al., 2005);
- Canadian Forces Ammunition Depot - Rocky Point (SNC-Lavalin, 2019);
- Canadian Manuscript Report of Fisheries and Aquatic Science 2729 (Pearson et al., 2005);
- Centerm Expansion Project (AECOM, 2017);
- Columbia Containers Infill Project (PGL, 2017);
- Former Sterling Shipyard Intertidal Remediation and Conceptual Intertidal Habitat Offset Plans for Remediation (SNC-Lavalin, 2014a);
- George Massey Tunnel Replacement (Hemmera, 2016);
- Gillis Cove Marina (Pearson et al., 2005);
- Jenson Brook Wetland Restoration (Pearson et al., 2005);
- Johnson Street Bridge Replacement (Stantec, 2012);
- Lafarge Vancouver Harbour Plant (Aqualibrium, 2001);
- LNG Canada (Kitimat) (LNG Canada, 2015);
- Lost Creek Pipeline Crossing (Pearson et al., 2005);
- New Brighton Park Shoreline Habitat Restoration Project (VFPA, 2016);
- Pacific Northwest LNG (Pacific Northwest LNG, 2014);
- Point Hope Graving Dock (Hemmera, 2019);
- Trans Mountain Pipeline Expansion Project (Stantec, 2014);
- Viterra-Cascadia Terminal Capacity Expansion (Hemmera, 2019); and
- Westridge Marine Terminal Upgrade and Expansion (Stantec, 2017).

Table 12 summarizes the general observations of the literature review. It should be noted that most publicly available offsetting plans are conceptual in nature and not necessarily representative of the offsetting measures that were permitted. Therefore, many of the documents reviewed did not provide complete information. It should also be noted that some projects addressed multiple types of HADD and utilized multiple types of offsets, each with different offsetting ratios. Furthermore, many of these projects were carried out under previous versions of the FA.

Table 12: Result Summary for Literature Review of Habitat Offsetting Projects in Coastal BC

Project Type	Habitat Affected	Number of Projects	Offset Types	HADD: Offset Ratio (Mean)
Addition/Removal of Infrastructure	Riparian	1	› Riparian Planting (1)	› N/A
	Intertidal	5	› Salt Marsh (1) › Riprap Reef (4) › Eelgrass (1) › Habitat Bench (1)	› N/A › 1:1 › N/A › N/A
	Subtidal	4	› Riprap Reefs (3) › Eelgrass (1)	› 1:2 › 1:4
Infilling / Excavation	Riparian	5	› Riparian Planting (3) › Stream Enhancement (2)	› 1.5:2.5 › 1:2
	Intertidal	3	› Riprap Reefs (2) › Pocket Beach (1)	› N/A › N/A
	Subtidal	4	› Riprap Reef (4) › Salt marsh (1) › Eelgrass (1)	› 1.88: 2.5 › N/A › N/A
	Intertidal	1	› Salt Marsh (1) › Eelgrass (1) › Mudflat (1)	› 1:2 › 1:2 › 1:2
	Subtidal	1	› Riprap Reef (1)	› 1:1
Habitat Banks	N/A	1	› Riparian Planting (1) › Salt Marsh (1) › Riprap Reef (1)	› N/A › N/A › N/A

10.2 Classifying Existing Habitat by Productive Capacity and Ecosystem Function

The productive capacity of habitat varies, with some habitats contributing more to fisheries productivity per unit area than others (Williams, 2005). Consideration for these differences is important when determining the amount of HADD that should be offset (Williams, 2005). In a study commissioned by DFO to develop a compensation policy for aquaculture applications, Williams (2005) employed the methods proposed by Short et al. (2000) to create relative productivity ratings for various marine habitat types in the Pacific Northwest. These ratings, expressed in mass of carbon per unit area per year (g C m −2 yr −1) provide useful indications of the types of ecological functions each habitat provides relative to another. Moreover, these values were in general agreement to those compiled from other studies investigating the productivity of marine habitats. For example, Lalli & Parsons (1997) reviewed average annual primary production reported in scientific literature, which amounted to:

› <250 $gCm^{-2}y^{-1}$ for unvegetated sediment;
› 150 $gCm^{-2}y^{-1}$ for mudflat habitat;

- 200-400 $gCm^{-2}y^{-1}$ for salt marsh habitat;
- 120-650 $gCm^{-2}y^{-1}$ for eelgrass habitat;
- 100 to 1000 $gCm^{-2}y^{-1}$ for rocky intertidal shore habitat; and
- 600 to 3000 $gCm^{-2}y^{-1}$ for kelp forest habitat.

Importantly, these studies are not meant to illustrate absolute productivity values, but rather to show relative values of benthic marine habitats and highlight the high primary productivity of vegetated benthic habitats (e.g., eelgrass, rocky intertidal shores, etc.) compared to unvegetated, detritus-enriched habitats (Lalli & Parsons 1997; Williams, 2005).The habitat types where HADD is expected to occur during the Project have been scored according to the rating system developed by Williams (2005) and Short et al. (2000) to create a relative habitat value (RHV) for each affected habitat type. Within these literature sources, each type of habitat was ranked in consideration of productivity and contribution to ecological functions relative to other types of habitats listed.

For the purposes of this report, the total score (summed rank values for each of 13 ecological services) were used to evaluate RHV for each type of habitat affected and created by the Project. Table 13 below outlines the criteria used by Williams (2005) to rank each habitat type in its contribution to one of 13 ecological services.

Table 13: Habitat Rankings Based on Relative Contributions to Ecological Functions (Williams, 2005)

Rank	Rank Value	Description
N/A	0	This habitat type is not considered or inferred to contribute to the ecological functions in question.
Low	1	This habitat type is considered or inferred to contribute to the ecological functions in question in a minor capacity relative to the other types of habitats listed.
Moderate	2	This habitat type is considered or inferred to contribute to the ecological functions in question in a significant capacity, but less so relative to the other types of habitats listed.
High	3	This habitat type is considered or inferred to contribute to the ecological functions in question most significantly relative to the other types of habitats listed.

The following RHVs were presented in the literature (Short et al., 2000; Williams, 2005):

Table 14: Relative Habitat Value by Affected Habitat Type at the Sterling Shipyard Site

Ecosystem Function	Values	Marine Riparian[1*]	Intertidal[2*]	Subtidal[3*]
Canopy structure	Habitat, refuge, nursery, settlement, and support of fisheries	Moderate	NA	High
Primary production	Food for herbivores and support for fisheries and wildlife	Moderate	Low	High
Epibenthic and benthic production	Support of food web and fisheries	N/A	Moderate	High
Nutrient and contaminant filtration	Improved water quality and support of fisheries	High	N/A	N/A

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Table 14 (Cont'd): Relative Habitat Value by Affected Habitat Type at the Sterling Shipyard Site

Ecosystem Function	Values	Marine Riparian[1*]	Intertidal[2*]	Subtidal[3*]
Sediment filtration and trapping	Improved water quality, counter sea level rise, and support for fisheries	High	N/A	N/A
Epiphyte and epifaunal substratum	Support of secondary production and fisheries	N/A	Low	Moderate
Oxygen production	Improved water quality and support of fisheries	High	Low	Moderate
Organic production and export	Support of estuarine, offshore food webs, and fisheries	Low	Low	Moderate
Nutrient regeneration and recycling	Support of primary production and fisheries	N/A	Low	Moderate
Organic matter accumulation	Support of food webs and counter sea level rise	N/A	NA	N/A
Wave and current energy dampening	Prevents erosion/resuspension and increases sedimentation	High	Low	Moderate
Seed production and vegetative expansion	Self-maintenance of habitat and support of fisheries	N/A	Low	High
Self-sustaining ecosystem	Recreation, education, and landscape level biodiversity	High	Low	High
Total score (High+Moderate+Low)		15+4+1= 20/39	0+2+8 = 10/39	15+10+0 = 25/39
Relative Value (%)		51%	26%	64%

Note: Scoring: high = 3; moderate = 2; low = 1; N/A = 0; maximum total score = 39.
Table modified from Short et al. (2000) and Williams (2005) to fit site conditions.
1 Equivalent to Backshore Vegetation in Williams (2005).
2 Habitat type not available in Williams (2005), determinations made by report authors based Short et al. (2000) and Williams (2005) to fit site conditions.
3 Equivalent to Macroalgae beds/reefs in Williams (2005).
* Habitat classification and value to be updated pending results of May 2021 field studies.

10.2.1 Effects of Historical Contamination on Habitat Value

10.2.1.1 Relative Habitat Value

The lines of evidence presented in Section 6.2 indicate the potential for reduced primary and secondary productivity, contaminant bioaccumulation in marine biota and resulting effects, as well as the likely alteration of behaviour of marine and riparian species at the Site. Additionally, due to the potential for bioaccumulation and biomagnification of Site contaminants in the food chain, there is the potential for these contaminants to be transferred beyond the Site boundaries, affecting fish and wildlife in Vancouver Harbour at large. As a result, SNC Lavalin initially suggested a reduction in the existing relative habitat values at the Site. However, this reduction was removed from the HADD calculations following feedback from Indigenous groups.

Site toxicology testing has shown endpoint reductions of over 50% in the development of bivalves and kelp, which constitute reductions to ecological functions used to determine habitat value as per Williams (2005) (please refer to **Section 10.2**). Performing toxicity testing on all relevant marine biota that have the potential to be present at the Site was not considered feasible. However, the existing results can be used as indicators to identify effects may be impacting key groups of organisms.

The potential effects to marine biota resulting from exposure to Site sediments were not directly measured, and, thus, these potential effects, though likely occurring (see **Section 6.2.1.1** and **Section 6.2.1.2**) are not accounted for in the quantitative assessment of habitat value provided. Furthermore, the potential for Site contaminants to bioaccumulate in biota and/or biomagnify in local food webs, which is likely to be occurring (see **Section 6.2.1.2**), was not accounted for in Site habitat values.

10.2.1.2 Relative Duration of Effect

Effects were classified as either destruction, permanent alteration or temporary disturbance of habitat (See Table 11); each of these constitutes a HADD that must be offset. Literature and offsetting precedence suggest that temporary disturbances can be offset with relatively less habitat that permanent alteration or destruction of habitat. For instance, for their Jetty Recapitalization Project at CFB Esquimalt, SLR (2015) did not offset for temporary habitat disturbances caused by their project. However, rather than offer no offsets for temporary disruptions of fish habitat caused by the Project, SNC-Lavalin has taken a conservative approach and suggested a reduction in offsets by of 75% for of the impacted area. temporary disruptions of fish habitat caused by the Project.

10.2.2 Summary and Estimate of Total Residual HADD

The information in Table 15 summarizes the total HADD expected to be caused by the Project and estimates the recommended amount of habitat offsetting required for the Project. The amount of HADD has been determined by considering the HADD footprint area, Relative Habitat Value (RHV) of each affected habitat type, the duration of effect (temporary or permanent), and existing contamination in the site footprint.

Table 15: Estimate of Total Offsetting Required

Work, Undertaking or Activity	Habitat Type	HADD Footprint Area (m^2)[1]	Proportion of Total HADD	Relative Habitat Value (RHV)[2]	Offsetting Required Based on RHV (m^2)[3]	Reduction in Offsets due to Temporary Impact (%)	Estimate of Total Offsetting Required (m^2)[4]
Dredging (w/o berm)	Marine Riparian	0	0	51%	0	N/A	0
	Intertidal	0	0	26%	0	N/A	0
	Subtidal	815	8%	64%	522	75%	130
Berm Construction (incl. dredging beneath)	Marine Riparian	0	0	51%	0	N/A	0
	Intertidal	660	6%	26%	172	N/A	172
	Subtidal	2,020	19%	64%	1,293	N/A	1,293
Remedial Excavation and Infilling	Marine Riparian	1,555	14%	51%	793	N/A	793
	Intertidal	4,210	39%	26%	1,095	N/A	1,095
	Subtidal	0	0	64%	0	N/A	0

Table 15 (Cont'd): Estimate of Total Offsetting Required

Work, Undertaking or Activity	Habitat Type	HADD Footprint Area (m^2)[1]	Proportion of Total HADD	Relative Habitat Value (RHV)[2]	Offsetting Required Based on RHV (m^2)[3]	Reduction in Offsets due to Temporary Impact (%)	Estimate of Total Offsetting Required (m^2)[4]
Reef Construction (Offset)	*Subtidal*	1,280	14%	64%	819	N/A	819
Total		**10,540**	**100%**		**4,694**		**4,302**

[1] - Summary Provided in Table 11.
[2] - Summary Provided in Table 14.
[3] - Calculated as: HADD Footprint x RHV.
[4] - Calculated as: HADD Footprint x RHV x (100% - Reduction in Offsets due to Temporary Impact).

10.3 Habitat Offsetting

The HADD identified and described in **Section 9.1** must be offset to complete the Project in compliance with the FA. The subsections below identify and describe the habitat offsetting options and approaches considered and recommended for the Project.

10.3.1 Approach

SNC-Lavalin has designed this offsetting approach based on the *Policy for Applying Measures to Offset Adverse Effects on Fish and Fish Habitat Under the Fisheries Act* (DFO, 2019). The focus of the Project's offsetting plan is on the creation of marine fish habitat to counterbalance the residual death of fish and/or HADD of fish habitat resulting from carrying on works, undertakings or activities.

DFO recommends implementing a hierarchy of measures where efforts are first made to prevent HADD (measures to avoid; DFO, 2019). When avoidance is not possible, efforts should be made to minimize (measures to mitigate) HADD resulting from the proposed work, undertaking, or activity. As a last resort, any residual HADD should then be addressed by efforts to counterbalance HADD through positive contributions to the aquatic ecosystems (measures to offset; DFO, 2019).

10.3.2 Considerations

10.3.2.1 DFO Guiding Principles

Offsetting measures have been developed in accordance with DFO's guiding principles (DFO, 2019):

- **Principle 1:** Measures to offset should support fisheries management objectives and give priority to the restoration of degraded fish habitat.
- **Principle 2:** Benefits from measures to offset should balance the adverse effects resulting from the works, undertakings or activities.
- **Principle 3:** Measures to offset should provide additional benefits to the ecosystem.
- **Principle 4:** Measures to offset should generate self-sustaining benefits over the long term.

To guide proponents in meeting these principles, DFO provides four categories of offsetting measures (DFO, 2019):

- **Habitat Restoration and Enhancement:** Habitat restoration (i.e., actions taken to return fish habitat to an improved or unimpaired condition) and enhancement (i.e., actions taken to improve fish habitat quality) include physical manipulation of existing fish habitat to improve its capacity to produce and sustain fish.
- **Habitat Creation:** Habitat creation is the development or expansion of aquatic habitat into a terrestrial area. These measures to offset can be used when the fish habitat that was degraded and cannot be restored by manipulation of the original or surrounding fish habitat.
- **Chemical or Biological Manipulations:** This group of measures to offset includes chemical manipulation of waterbodies to address water quality issues, stocking of fish or shellfish, and management or control of aquatic invasive species. These measures should be used only when the other types of measures to offset are not available, and only under specific circumstances, such as where the site-specific issues are well understood, the limitations to fish production are known, and fisheries management objectives are clear for the fishery.
- **Complementary Measures:** Complementary measures are actions like data collection and scientific research related to maintaining or enhancing the conservation and protection of fish and fish habitat. Complementary measures may be considered in areas where there are limited opportunities for on-the-ground measures to offset fish and fish habitat residual effects and where there is limited understanding or data on fish populations. Complementary measures may comprise up to 10% of the required amount of the measures to offset; the remaining 90% of the amount of measures to offset should consist of habitat enhancement, restoration or creation.

10.3.2.2 DFO Fisheries Management Objectives

The following fisheries management objectives apply or potentially apply to the Project Area:

- Vancouver Fraser Port Authority Habitat Enhancement Program: focused on creating, restoring and enhancing fish and wildlife habitat (DFO, 2019).
- Southern Pacific Salmon Integrated Fisheries Management Plan (DFO, 2020): outlines fishery management objectives for salmon stocks of concern along the BC south coast including protection of marine habitats.
- Burrard Inlet Action Plan: A Tsleil-Waututh Perspective aims to improve the environmental health and integrity of Burrard Inlet (Tsleil-Waututh, 2017).

Measures to offset have designed to contribute to the objectives identified in the above fisheries management objectives.

10.3.2.3 Productivity Potential

To develop effective habitat offsets, it is important to understand the components of the local ecosystem, identify target species life history phases and identify the potential ecological functions the offsetting habitat will provide.

10.3.2.3.1 Potential Target Species

SNC-Lavalin (2014) identified the major historical fishery species groupings and their potential uses of the Project Site, which are summarized in Table 16.

Table 16: Summary of Historical Fish Habitat and Potential Uses at the Sterling Shipyard Site (modified from SNC-Lavalin, 2014a)

Fish Type	Migration Area	Foraging Area	Spawning Grounds	Rearing Area
Pacific salmon	X	X		
Pacific herring		X		
Rockfish				X
Lingcod/greenlings		X		X
Forage fish (surf smelt and sand lances)	X	X		
Seaperches		X		X
Decapod crustaceans		X		X
Flatfishes				X
Bivalves		X		

10.3.2.3.2 Ecological Functions

Intertidal and shallow subtidal habitats serve a variety of ecological functions in Vancouver Harbour.

Vancouver Harbour is a migration corridor for juvenile salmon from Lynn Creek and Seymour River (among other watercourses) to the ocean (Hancock & Marshall, 1986). The high proportion of purpose-built low value habitat along the southern shore of this basin provides few places for migrating juvenile salmon to take cover (Stantec, 2009). Much of the shoreline in this area consists of sheet-piles and bulkheads. Shallow water areas like the Site might be preferred migration areas for young salmon, therefore maintaining shallow water corridors is considered a priority.

Shallow foreshore habitats provide foraging and rearing habitats for juvenile fish as the higher water temperatures, increased light penetration and prey production increases their growth and survival (Lamont et al., 2014; Lewis & Ganshorn, 2007). Given that existing surface sediments at the Site are contaminated with metals, PAHs and PCBs over about 80% of the intertidal area and to depths of 4 m, the sediment within approximately 50% of the intertidal zone is likely acutely toxic to benthic invertebrates and may induce behavioural effects (please refer to Section 10.2.1). Thus, it is likely that the existing intertidal areas of the Site are currently providing little, if any, foraging opportunity or benefit for fish.

Shallow foreshore habitats provide spawning habitat for some fish species (Lamont et al., 2014; Lewis & Ganshorn, 2007); however, historical contamination reduces the Site's capacity to support significant fish spawning (please refer to Section 10.2.1). However, remediation of the Site may provide opportunities for enhancing spawning of certain fish or invertebrates.

DFO notes that areas where habitat conditions are considered poor or degraded will provide for the greatest opportunities for enhanced benefit from offsetting (DFO, 2019). The infilling and shoreline modifications should allow for increased foraging opportunities through development of riparian, emergent and submerged vegetated habitats.

Ecological functions that could be targeted by habitat offsetting at site are summarized in Table 17.

Table 17: Ecological Functions that Could Be Targeted by Habitat Offsetting at the Sterling Shipyard Site (modified from SNC-Lavalin 2014)

Ecological Functions	Existing Site Conditions	Remediation Plan Including Infill and Riprap Shoreline
Migration	Approximately 60 m of shallow water along the edge of the cobble beach.	The addition of shallow water habitat at the base of the ~80 m long riprap shoreline will maintain a migration corridor for young fish, including juvenile salmonids.
Foraging/rearing habitat	The contaminated site does not presently offer significant foraging or rearing habitat.	The addition of a marine riparian vegetation, aquatic vegetation and/or clean substrate will increase the areal amount of viable fish habitat on-site and lead to increased diversity of prey produced at the Site, increased growth and survival of young fish, and ultimately increased productivity on-site.
Spawning habitat	The cobble beach's contaminated substrate does not allow for viable spawning habitat.	A habitat bench with the addition of an upper medium coarse sand beach may provide enhanced opportunities for spawning of forage fish (e.g., Pacific herring or Pacific sand lance), which would support increased production of juvenile fish in Burrard Inlet.

10.3.3 Selection of Offsetting Measures

The offsetting measures described in this report are intended to counterbalance residual HADD caused by the Project through Habitat Restoration and Enhancement; one of DFO's four categories of offsetting measures. A series of 17 offsetting measures were evaluated in the preliminary stages of habitat offsetting planning. These options were intended to offset Project-related HADD to the existing but contaminated marine riparian zone, intertidal zone, and shallow subtidal zone that are currently utilized by marine invertebrates (decapods, bivalves, gastropods etc.), seaweeds, and potentially salmonids and forage fish throughout their various life stages.

A series of offsetting measures have been evaluated against the considerations described in **Section 10.3.2** of this report including:

› DFO Guiding Principles;
› DFO Fisheries Management Objectives; and
› Productivity Potential.

Potential offsetting options have also been evaluated for other important factors including:

› Proximity to the worksite;
› HADD caused by offsetting itself;
› Adherence to DFO offsetting policy requirements (i.e., likelihood of receiving DFO approval);
› Environmental benefits of proposed offsetting;
› Likelihood of long-term success;
› Engineering and construction feasibility;
› Engineering and construction costs;
› Regulatory requirements; and
› Other potential impacts (e.g., navigation hazards etc.).

A series of 17 conceptual offsetting project options were generated based on a review of previous offsetting reports for marine projects in the area, scientific literature, and from the SNC-Lavalin team's professional experience with DFO offsetting projects. Two general types of habitat offsetting have been proposed herein:

- **Revetment (Berm) Enhancements:** A berm will be constructed as part of the Project design and is required to isolate the Site from the marine environment during remediation, as well as to maintain the grade of the newly infilled site. DFO guiding principle 3 states that 'measures to offset should provide additional benefits to the ecosystem'. DFO interprets this as the coincidental positive benefits of the works, undertakings and activities being authorized should not be considered as measures to offset. Therefore, any positive habitat gains that occur by colonization of the rock berm cannot be considered as habitat offsetting for the Project. However, the berm itself can be enhanced to increase the habitat value of the berm which can be considered habitat offsetting. The berm-enhancement measures must be specifically designed as habitat offsetting. Potential berm-enhancement approaches are discussed below.
- **Standalone Offsetting**: These are habitat offsetting project types that can be implemented either off-site or on-site but are not intended to enhance the Project's berm.

A breakdown of 17 potential types of conceptual offsetting options for the Project was analyzed for their observed effectiveness and benefits through literature review, as well as their relative habitat values as per Williams (2005). These options were provided to the Port Authority in the preliminary stages of habitat offsetting planning.

Following this preliminary stage, two offsetting options (Subtidal reefs and Marine riparian planting) were chosen for the Project. However, during the Project's completeness review by DFO, and during consultations with Indigenous groups, a desire for a more robust habitat offsetting plan was unanimously expressed.

The Project team then held workshops with local Indigenous groups to help guide the revisions of the offsetting plan in a mutually and ecologically beneficial direction. These workshops resulted in the design of two additional components to the offsetting plan for the Project and a reduction in the size of the original subtidal reef footprint.

Therefore, a total of four offsetting components were chosen to be implemented for the Project:

- Subtidal reefs;
- Seeded kelp ropes;
- Marine riparian planting; and
- Restoration of a historic log dump site (offsite).

Table 18 includes the considerations for these options.

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Table 18: Summary of Conceptual Offsetting Options for the Sterling Shipyard Site

Offsetting Option	Description	DFO Category	Environmental Benefits	Relative Probability of Success	DFO Guiding Principles: Support fisheries management objectives	DFO Guiding Principles: Balance adverse effects resulting from works	DFO Guiding Principles: Provide additional benefits to ecosystem	DFO Guiding Principles: Self-sustaining benefits over long term	Advantages	Disadvantages
Subtidal Reefs or Reef Complexes	A riprap mound or complex of mounds is installed in the subtidal zone, acting as an artificial reef.	Habitat Restoration /Enhancement	› Structural habitat and interstitial spaces for fish refuge and spawning (LNG Canada 2015). › Substrate for attachment for algae and invertebrates (LNG Canada 2015).	High	Yes	Yes	Yes	Yes	› Commonly used for DFO permitting. › Promotes diverse fish, invertebrate and seaweed community. › Stable and permanent.	› HADD associated with footprint must be accounted for. › Land tenure, lease (or similar) required for footprint. › Potential navigation hazard.
Marine Riparian Planting	Installing grasses, sedges, shrubs, and trees in the supralittoral zone fronting the site or off-site.	Habitat Restoration /Enhancement	› Ecosystem functions for fish including food production, temperature regulation, wave energy absorption, and provision of structure (Levings and Jamieson 2001). › Bank stabilization, filtering of sediments and nutrients, storing and delaying the release of terrestrial runoff (Lievesley et al, 2017).	High	Yes (dependant upon adequate vegetation survival)	Yes (dependant upon adequate vegetation survival)	Yes (dependant upon adequate vegetation survival)	Yes (dependant upon adequate vegetation survival)	› Commonly used for DFO permitting. › Provides ecosystem functions for fish. › Visually appealing. › Relatively easy installation.	› Limited footprint available on-site. › A potential that plants will die before becoming established.

Table 18 (Cont'd): Summary of Conceptual Offsetting Options for the Sterling Shipyard Site

					DFO Guiding Principles					
Offsetting Option	**Description**	**DFO Category**	**Environmental Benefits**	**Relative Probability of Success**	**Support fisheries management objectives**	**Balance adverse effects resulting from works**	**Provide additional benefits to ecosystem**	**Self-sustaining benefits over long term**	**Advantages**	**Disadvantages**
Kelp Seeding	Fifteen 29 m long lines of sugar kelp (*Saccharina latissimi*) seeded ropes, with several ropes also seeded with bull kelp (*Nereocystis luetkeana*) anchored to the subtidal reefs.	Habitat Restoration /Enhancement	› Kelp performs a diversity of roles within marine ecosystems (i.e., food, three dimensional habitat, refuge, spawning substrate, etc.) › Forming a natural wave break for the shoreline › Increase biodiversity on rock reefs	Moderate	Yes (depending on survival)	Yes (depending on survival)	Yes (depending on survival)	Yes (depending on survival)	› Small footprint can return considerable environmental benefits if successful › The Site has supported kelp in the recent past	› Survivability uncertain › Estimated mature footprint (m^2) does not adequately quantify ecological benefits
Offsite Log Dump Restoration (Area A) in Indian Arm	Remediate accessible intertidal and subtidal area historically contaminated with industrial wood waste and debris and restore to natural state.	Habitat Restoration /Enhancement	› Increase aerobic conditions leading to increases in biodiversity	Moderate	Yes	Yes, in an offsite location	Yes, in an offsite location	Yes, if area is adequately restored to former state	› Increasing biodiversity in the area › Increasing long term water quality › Important to local indigenous groups	› Depth of wood waste is unknown and may not be fully accessible for complete removal. › Challenging and sensitive area to conduct a remedial excavation

10.3.4 Quantifying Required Offsetting

10.3.5 Classifying Habitat by Productive Capacity and Ecosystem Function

As discussed in **Section 10.3.2**, the productive capacity of habitat varies, with some habitats contributing more to fisheries productivity per unit area than others (Lalli & Parsons, 1993; Williams, 2005).

The conceptual offsetting options initially presented to the Port Authority have been scored according to the rating system developed by Williams (2005) and Short et al. (2000) to create a relative RHV for each potential offsetting option and aid in offsetting option selection.

Based on the criteria outlined by Williams (2005), the evaluation of preliminary offsetting options for the Project was provided to the Port Authority in the preliminary stages of habitat offset planning. Table 19 provides an analysis of the final four chosen options. Please refer to **Section 10.2** and Table 13 for background context related to the habitat evaluation rating system.

Table 19: Relative Habitat Value of Selected Offsetting Options

Ecosystem Function	Values	Subtidal Reefs[1]	Marine Riparian Planting[2]	Kelp Seeding[1]	Offsite Log Dump Clean Up[3]
Canopy Structure	Habitat, refuge, nursery, settlement, and support of fisheries.	High	Moderate	High	N/A
Primary Production	Food for herbivores and support for fisheries and wildlife.	High	Moderate	High	Low
Epibenthic and benthic production	Support of food web and fisheries.	High	N/A	High	High
Nutrient and contaminant filtration	Improved water quality and support of fisheries.	N/A	High	N/A	N/A
Sediment filtration and trapping	Improved water quality, counter sea level rise, and support for fisheries.	N/A	High	N/A	Moderate
Epiphyte and epifaunal substratum	Support of secondary production and fisheries.	Moderate	N/A	Moderate	N/A
Oxygen Production	Improved water quality and support of fisheries.	Moderate	High	Moderate	N/A
Organic Production and export	Support of estuarine, offshore food webs, and fisheries.	Moderate	Low	Moderate	High
Nutrient regeneration and recycling	Support of primary production and fisheries.	Moderate	N/A	Moderate	Moderate

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Table 19 (Cont'd): Relative Habitat Value of Selected Offsetting Options

Ecosystem Function	Values	Subtidal Reefs[1]	Marine Riparian Planting[2]	Kelp Seeding[1]	Offsite Log Dump Clean Up[3]
Organic matter accumulation	Support of food webs and counter sea level rise.	N/A	Moderate	N/A	N/A
Wave and current energy dampening	Prevents erosion/resuspension and increases sedimentation.	Moderate	High	Moderate	N/A
Seed production and vegetative expansion	Self-maintenance of habitat and support of fisheries.	High	N/A	High	N/A
Self-sustaining ecosystem	Recreation, education, and landscape level biodiversity.	High	High	High	Moderate
Total score (High+Moderate+Low)		15+10+0 = 25/39	15+4+1 = 20/39	15+10+0 = 25/39	6+6+1 – 13/39
Relative Habitat Value (%)		**64%**	**51%**	**64%**	**33%**

Note: Scoring: high = 3; moderate = 2; low = 1; N/A = 0; maximum total score = 39.
Table modified from Short et al. (2000) and Williams (2005) to fit site conditions.
1 Equivalent to Macroalgae beds/reefs in Williams (2005)
2 Equivalent to Backshore Vegetation in Williams (2005)
3 Based on Mudflat in Williams (2005) with site specific modifications

The options are shown on Drawing 070-010-MA-401 (Appendix I) and discussed in detail in the following sections.

10.3.5.1.1 Revetment – Marine Riparian Vegetation Zone

A marine riparian vegetation zone is proposed to be installed behind the top edge of the revetment. Incorporating a marine riparian vegetation zone will require adding appropriate substrate/soil in this area to allow planting; soil thickness atop the riprap will be at least 0.75 m. Marine riparian vegetation will be endemic to the lower mainland and species that are drought- and salt-spray-resistant will be prioritized. Additionally, the installation of an automated watering system will be considered in the design. Measures to maximize water retention in soil will also be explored and implemented wherever feasible. Marine riparian planting will be developed with consideration to the intended end-use of the property. The type of vegetation will be determined during engineering design which is currently underway. Care is being taken to choose vegetation with roots that will not penetrate deep enough to destabilize the revetment.

Marine riparian vegetation includes numerous species of grasses, sedges, shrubs, and trees found near the HHWLT (Levings & Jamieson, 2001). These areas provide important ecosystem functions for fish including food production, temperature regulation, wave energy absorption, and provision of structure (Levings & Jamieson, 2001) as well as bank stabilization, filtering of sediments and nutrients, storing and delaying the release of terrestrial runoff (Lievesley et al., 2017).

The detailed riparian planting plan will be provided to DFO as soon as it is available.

The footprint of the proposed marine riparian vegetation zone is 470 m^2 and the RHV of backshore vegetation (per Williams, 2005) is 51%. The feature provides 240 m^2 of habitat offsets for the Project.

Riparian planting is not considered to require a protective setback during Site operation and maintenance. However, all future Site developments and maintenance operations must not disturb the marine riparian area or interfere with its function. Protective measures, such as temporary setbacks during future construction or maintenance operations, may be implemented as future Site development and maintenance operations are planned.

A detailed marine riparian planting plan is being prepared and will be provided to DFO for review. This will include soil types, plant species, plant spacing, plant density, planting timing and methods, and monitoring and maintenance requirements.

10.3.5.1.2 Subtidal Reef

Boulder mounds are proposed for the subtidal zone to act as an artificial reef. The reef will provide:

- Structural habitat and interstitial spaces for fish refuge and spawning.
- Substrate for algae and invertebrate attachment (LNG Canada 2015);
- Hard, complex, substrate for attachment of seaweed/kelp;
- Habitat for fish and motile and encrusting invertebrates (Gascon and Miller, 1980); and
- Important edge habitat by providing edge effect and will enhance the surrounding substrates (Hemmera, 2019a; Hemmera, 2019b; Stantec, 2013; Stantec, 2014).

Relevant literature indicates that the installation of multiple smaller reefs facilitates greater species density than the installation of fewer larger reefs (Bohnsack et al., 1994), SNC-Lavalin proposes the installation of two (2) riprap reefs, each with a length (north to south) of 20 m and a width (west to east) of 32 m, for a footprint of 640 m^2 for each reef, or 1,280 m^2 total footprint for both reefs. To account for the sloped sides associated with the perimeter of each reef, SNC-Lavalin calculated the total surface area using a digital 3D model of the proposed reef. This total value was calculated to be 2,270 m^2.

An additional benefit of the boulders comprising the subtidal reef is that they provide a naturally complex colonizable surface area, which is known to correlate with fish abundance (Gratwicke & Speight, 2004). The rugosity and interstitial spaces of the reef boulders can be considered fish habitat for offsetting purposes. There are two recent examples demonstrating the calculation of colonizable surface area in habitat offsetting programs which received FAAs (however, it should be noted that the FAA was updated after these projects were permitted):

- Hemmera (2019b) who estimated the colonizable surface area of a standardized piece of riprap and corrected boulder to boulder contact points and riprap depression into the seabed. This resulted in a ~3.5:1 3D to 2D surface area relationship (i.e., 100 m^2 of reef surface area was credited as 350 m^2 of offset habitat).
- SNC-Lavalin (2016) who applied a 'void factor' of 2.5 to account (i.e., 100 m^2 of reef surface area was credited as 250 m^2 of offset habitat).

To provide a conservative approach, SNC-Lavalin is proposing using 2.5:1 (3D to 2D surface area relationship) for the reef proposed herein.

For this offsetting plan, 1,280 m^2 of riprap reef is envisioned, which provides 5,675 m^2 of colonizable surface area (2,270 m^2 3D surface area x 2.5 void factor = 5,675 m^2 colonizable surface area) as fish habitat after factoring in rugosity and interstitial space. Moreover, the reefs are expected to enhance a total of 1,010 m^2

of edge habitat along the lower intertidal and shallow subtidal face of the revetment. This edge habitat is not included in the offsetting calculations.

The combined colonizable surface area of the proposed subtidal reefs is 5,675 m^2 and the RHV of reefs (per Williams, 2005) is 64%. Therefore, this feature provides 3,632 m^2 of habitat offsets for the Project.

The detailed engineering design of the reefs is attached in Appendix I.

10.3.5.1.2.1 Reef Construction

Proposed subtidal reefs shall be constructed from barges. Rock material will be transported to the reef footprints by barge and a crane barge will lower rocks into reef footprints. An underlay of crushed gravel substrate will be placed on the reef footprints to provide geotechnical stability for the boulders. The Project CEMP provides mitigations to be observed by the contractor to protect water quality and fish habitat during subtidal works.

10.3.5.1.3 Kelp Rope Seeding

Consultations between the Project team and Indigenous groups illuminated the desire for the addition of more "soft" components to the Project's original offsetting plan. To incorporate this desire, while acknowledging that space is limited on the Project site, the anchoring of seeded kelp ropes to the proposed subtidal reef was explored.

In early 2022, the VFPA commissioned Canadian Kelp Resources (CKR) to conduct a feasibility assessment (Appendix III) for potential kelp restoration at the Project Site.

The report indicated that their firsthand experience and the relevant literature indicates that four variables are key to the success of kelp restoration (CKR, 2022):

1. If kelp is declining to larger environmental issues (i.e., warming water, pollution, etc.) restoration efforts will typically be ineffective.
2. If a wild kelp bed is nearby, restoration efforts are more likely to succeed, as nearby kelp beds provide a natural source of spores for recruitment.
3. An abundance of herbivores of concern (i.e., urchins) decrease the chance of restoration success.
4. If restoration efforts can be maintained for several years, there is a higher chance of success.

As the Project Site favours three of these variables and the third can be achieved through the proposed offset monitoring program, the assessment report concluded that overall, the Project Site is a good candidate for kelp restoration.

The results of the feasibility assessment were shared with Indigenous groups, who generally viewed the addition of this offset component favorably, provided that long term monitoring was carried out as proposed by CKR (2022) and in the overall Project compliance monitoring plan (Section 10.4).

Following receipt of the feasibility assessment results and feedback from Indigenous groups, the Port Authority decided to incorporate kelp restoration into the Project offsetting plans. In keeping with recommendations by CKR, the Project plans to include fifteen, 20 m long, seeded kelp ropes with each end securely anchored to the proposed subtidal reef. These ropes will be primarily seeded with sugar kelp (*Saccharina latissima*) but will also include a smaller percentage of bull kelp (*Nereocystis leutkeana*). Kelp species were chosen based on ecological relevance, local presence, site environmental conditions, site elevation and industry familiarity. The kelp ropes will be installed immediately following the construction of the rock reefs. Installation will be guided and overseen by Canadian Kelp Resources Ltd.

10.3.5.1.4 Restoration of Historic Log Dump in Indian Arm (Offsite)

The Port Authority consulted with local Indigenous groups to explore offsite options for restoration that are of high importance to their members, as onsite offsetting options are limited at the Project Site. Representatives of the local indigenous groups expressed a desire for the restoration of a former log dump facility, at the northern extent of Indian Arm and adjacent to the Indian River Estuary in BC (Appendix IV). The log dump is located within a water lot that is considered to be an orphaned site within the Port Authority's jurisdiction.

The Port Authority retained Keystone Environmental Ltd. (Keystone) to conduct a feasibility study on the proposed log dump restoration area in early summer of 2022 (Appendix IV). Desktop and field assessments of the site were conducted between August and October 2022 and included a historical and biophysical review of the site, dive surveys, sediment sampling and analysis, and side scan sonar surveys. Results of the multi-faceted assessment process indicated that an area of approximately 3,769 m^2, comprising both intertidal and subtidal habitats, was high in anthropogenic waste materials, low in biological diversity and technically feasible for remediation.

The intended outcome for the remediation of the former log dump is to remove all accessible anthropogenic materials (i.e. logs, ropes, cables, wood waste etc.) and allow the area to naturally return to a healthy, functioning ecosystem. To achieve this, the anthropogenic materials would likely be dredged using a barge mounted crane and clamshell bucket. Dredged material would be deposited onto a scow for offsite disposal. Disposal options are currently pending further site investigations and regulatory approvals (Keystone, 2022). This work has sensitive environmental considerations which are further described in the Log Dump Biophysical Assessment (Keystone, 2022; Appendix IV) along with recommended mitigation measures to reduce harm to fish and fish habitat. The timing of the work is expected to be concurrent with the Project works and all in-water work will occur within the regional least risk window.

10.3.5.2 Accounting for HADD Associated with the Offsets Themselves

Constructing habitat offsets in the marine environment can cause HADD which must be accounted for in habitat offsetting plans.

The footprint beneath the proposed reef consists of subtidal habitat with a relative habitat value of 64%, according to Williams (2005) (as described in Section 6.2 of this report). The reefs have a combined footprint of 1,280 m^2 resulting in a HADD of 819 m^2 (Calculated as: Reef Footprints x RHV of Existing Footprint). This HADD is considered in the Project's habitat balance (**Section 10.3.5.5**).

The footprint of the riparian planting is upon the newly created berm which is already considered as HADD and additional HADD is not expected from the riparian planting.

There is also habitat alteration associated with the restoration of the former log dump site. However, this restoration is being carried out solely for the purpose of improving severely degraded habitat and fits within DFO's guiding principles, which encourages the physical manipulation of existing fish habitat to improve its capacity to produce and sustain fish (DFO, 2019). Therefore, although some existing degraded habitat will require alteration to proceed with this restoration work, the long-term benefits of removing these deleterious wastes outweigh the unavoidable impacts associated with this type of undertaking. The potential effects of the proposed dredging work on fish and fish habitat, along with recommended mitigation measures to reduce harm are described in in Keystone's biophysical assessment report (Appendix IV).

10.3.5.3 Habitat Offsetting Timeline

The habitat offsetting measures will be constructed concurrently with the Project construction.

10.3.5.4 Accounting for Time Lag and Uncertainty

There will be a time lag between the occurrence of HADD associated with the Project and the benefits to the ecosystem provided by the full establishment of the proposed offsets. There is also uncertainty due to the potential that newly planted riparian vegetation and kelp seeded ropes fail to establish. To account for this time lag and uncertainty, SNC-Lavalin has proposed installing 10% more offsetting than HADD (i.e., replacing habitat at a 11:10 ratio), which is consistent with other recent marine habitat offsetting plans (e.g., Hemmera, 2019).

In addition, a comprehensive monitoring program will be developed and implemented to manage the inherent uncertainties associated with habitat restoration and establishment. This will involve using simple and easily quantifiable criteria to evaluate the success of offsets over time.

10.3.5.5 Habitat Balance Sheet for Offsetting Plan

A summary of the HADD associated with Project activities and proposed offsetting measures is provided in Table 20. A summary of the proposed offsetting is provided in the habitat balance in Table 21. As designed, the Project requires 4,732 m^2 of offsetting and the offsetting plan creates 5,565 m^2 of offsets (a net gain of 833 m^2 of habitat).

Table 20: Habitat Balance: Total HADD and Offsetting Required for the Project

Work, Undertaking or Activity	Habitat Type	HADD Footprint Area (m^2)[1]	Offsetting Required (m^2)[2]	Proposed Offset Ratio (Offset: HADD)[3]	Total Offsets Required (m^2)
Dredging	*Subtidal*	815	130	11:10	143
Berm Construction	*Intertidal*	660	172	11:10	190
	Subtidal	2,020	1293	11:10	1,423
Remedial Excavation and Infilling	*Marine Riparian*	1,555	793	11:10	873
	Intertidal	4,210	1095	11:10	1,204
Reef Installation	*Subtidal*	1,280	819 [4]	11:10	901
Total		**10,540**	**4,302**		**4,732**

[1] – Summary Provided in Table 11 and Table 18.
[2] – After considering RHV and duration of impacts (calculations shown in Tables 13 and 18 of FAA memo).
[3] – 11:10 ratio proposed to correct for uncertainty and time lag.
[4] – Calculated as: Reef Footprint x RHV of Existing Footprint (1280 * 0.64).
[5] – While Table 10 indicated that 9,260 m^2 of HADD occurs, adding the 1,280 m^2 of HADD associated with the reef offsets themselves increases the total HADD to 10,540 m^2.

The total habitat offsets required by the Project, after considering RHV and duration of impacts is 4,302 m^2 (Table 20). After correcting for uncertainty and time lag, a minimum of 4,732 m^2 of habitat offsets are required. A total of 5,656 m^2 of habitat offsets are proposed to be constructed after considering RHV (Table 21).

Table 21: Habitat Balance: Offsetting Measures

Proposed Offset Type	Habitat Type	Proposed Habitat Offsets (m^2)[1]	RHV of Offset Type[2]	Habitat Value of Proposed Offsets (m^2)[3]
Revetment Marine Riparian	*Marine Riparian*	470	51%	240
Rock Reefs	*Subtidal*	5,675 [4]	64%	3,632
Kelp Seeding	*Intertidal and Subtidal*	702[5]	64%	450
Log Dump Clean Up	*Intertidal and Subtidal (offsite)*	3,769[6]	33%	1,243
Total		**10,616**		**5,565**

[1] – Summary Provided in Section 10.3.
[2] – Per Williams (2005), as described in Table 19.
[3] – Calculated as offset Footprint x RHV of Offset.
[4] – Two 20x32m reefs providing 5,675 m^2 of colonizable surface area (Based on void factor of 2.5 X 3D surface area of reef (2270 m^2)).
[5] – Based on proposed plan (CKR, 2022) of 15 kelp seeded ropes, 20 m in length, with an average mature frond length of 1.8 m and an average density of 1 frond per 10 cm of rope (CKR, 2022 and E-flora BC, 2022).
[6] – Based on 'Area A' approximate measurements, described in Keystone Environmental presentation, September 15, 2022 and updated October 27, 2022.

10.4 Monitoring and Reporting

As part of the FAA application, the Port Authority is required to provide monitoring measures as part of the offsetting plan. Monitoring measures are required to assess the effectiveness of the measures to offset relative to their objectives. The monitoring measures are also required to include contingency measures that will be implemented if deficiencies are detected.

There are two types of monitoring that will become conditions of the FAA (if approved). These include:

- **Compliance monitoring**: to confirm that Project construction, including habitat offsetting measures, were constructed as described in the FAA application, in compliance with the Project CEMP and/or FAA conditions, and may require construction to be stopped, or additional mitigation/contingency measures to be implemented so that works can continue in compliance with environmental requirements.
- **Effectiveness monitoring:** to confirm that the measures to offset were constructed as designed, meet the proponents offsetting obligations, and have been effective in counterbalancing the death of fish or HADD, as described in the FAA application, and may identify the need for contingency measures, maintenance or repairs to the installed offsets should deficiencies be found.

10.4.1 Compliance Monitoring Plan

The proposed compliance monitoring plan for the Project includes the following:

- Presence of on-site EM(s) during project construction, including installation of the proposed offsetting measures, to conduct sampling as described in the CEMP, to monitor the implementation of avoidance and mitigation measures referred to the CEMP and/or permit conditions, and to stop work where non-compliance or unpermitted HADD may occur or be imminent until appropriate resolutions have been implemented by the Project team.
- Submission of a Construction Monitoring Report to DFO indicating whether the measures and standards to avoid and mitigate impacts to fish and fish habitat were conducted according to the conditions of the FAA. This report will include:
  - A summary of works, undertakings or activities carried out;
  - A summary of fish and marine mammal species observed;
  - A summary of the fish salvaged, including dates, number of individuals salvaged (by species and life stage), and location(s) of salvage and relocation activities;
  - A summary of all monitoring results (e.g., water quality monitoring programs etc.);
  - Dated photographs and EM inspection reports that demonstrate effective implementation and functioning of avoidance and mitigation measures described in the CEMP or FAA; and
  - Dated photographs and a summary of non-compliances / issues that arose or occurred in relation to fish and fish habitat and details of any contingency measures that were implemented.

10.4.2 Effectiveness Monitoring Plan

The proposed effectiveness monitoring plan for the Project includes:

- Post-construction as-built surveys and report; and
- Habitat effectiveness surveys and reports.

10.4.2.1 Post-Construction As-Built Surveys and Report

Post-construction as-built surveys and reporting will include:

- Submission of a Post-Construction As-Bult Report to DFO within 150 days of construction completion which includes the following:
  - A description of works, undertakings or activities that occurred and materials that were used which includes area, elevation, bathymetry, and slope of construction works;
  - Geo-referenced as-built drawing(s) of the completed works, undertakings or activities, which includes bathymetry and elevation data both pre- and post-construction (e.g., sidescan or multibeam sonar, or similar);
  - An assessment of the stability (signs of potential erosion, failure, movement, sinking or other physical alteration that may affect stability) of the offsetting measures;

  - A comparison of the completed authorized works, undertakings or activities with the proposed design dimensions, including habitat offsetting measures; and
  - As assessment of whether installed offsetting measures are sufficient to offset death of fish and/or HADD caused by actual project construction.

10.4.2.2 Habitat Effectiveness Surveys and Reports

- Annual surveys of the offsetting measures to be conducted in the prime growing season (May through September) once per year for five years post-construction (i.e., 2024, 2025, 2026, 2027 and 2028). These surveys will:
  - Be designed and directed by a suitably experienced QEP (e.g., Registered Professional Biologist with marine biological and/or marine riparian expertise, or equivalent);
  - Provide geo-referenced and dated photographs or video of the offsetting measures showing colonization progress;
  - Provide a qualitative and quantitative assessment of colonization of offsetting measures by marine flora and fauna (i.e., species composition and density of seaweed/algae, vegetation, invertebrate, and fish communities);
  - Provide an assessment of the physical stability of the offsetting measures;
  - Identify any functional concerns with the offsetting measures;
  - Be summarized in annual reports which are to be provided to DFO by December 15th of each monitoring year; and
  - Provide an assessment of the success of the offsetting measures in meeting their objectives (Year 5 report only).

Site specific effectiveness monitoring for the offsite log dump restoration project is detailed in Section 8 of the *Log Dump Biophysical Assessment to Inform Habitat Restoration* (Keystone, 2022; Appendix IV).

10.4.2.2.1 Success Criteria

Success criteria differ between offset types:

- **Riparian planting**: The riparian planting plan shall be considered successful if, by Year 5 of the monitoring program, the substrate is physically stable (i.e., no loss of material or erosion have occurred), plant survival is 80 % or greater, and invasive vegetation has not established in the planting area.
- **Riprap reef complexes**: The subtidal rock reefs shall be considered successful if, by Year 5 of the monitoring program, the habitat structures are physically stable (i.e., no loss of material or material failure have occurred) and the reef complexes remain available to be utilized by target species as subtidal reef habitat. In addition, the riprap reef complexes will be monitored for species diversity through dive surveys and transect studies, with total species counts and diversity reported. This will occur yearly until Year 5.
- **Kelp restoration**: The kelp restoration shall be considered successful if, by Year 5 of the monitoring program, the kelp ropes have successfully inoculated healthy, mature kelp fronds onto the artificial reefs with an average area coverage of 2 mature individuals per 10 m^2 of reef area (Reed et al, 2014).

The health and density of the kelp will be assessed by a professional biologist that specializes in assessing marine vegetation.

- **Log Dump Restoration**: The log dump clean up efforts shall be considered successful if the restored area remains free of wood waste and the restoration area meets a target of at least 80% abundance and biodiversity of benthic and epibenthic biota, compared to a suitable reference site after five years (Keystone, 2022).

10.4.3 Offsetting Monitoring Contingency Planning

If the proposed habitat offsetting measures are not functioning as intended by Year 5, contingency measures will be developed in consultation with DFO. Contingency measures are expected to include, but are not limited to:

- Augmenting or altering offsetting measures to improve performance;
- Stabilizing or modifying offsetting measures that are eroding, sinking into the substrate or any other factor causing destabilization or poor functionality; and/or
- Installing additional offsetting measures on-site or off-site.

10.5 Cost of Implementing the Habitat Offsetting Plan

A Class A cost estimate was prepared for the Project by Hanscomb. The cost for installation of the habitat offsetting is estimated as follows:

- Reefs (installation and materials): $345,500[6]
- Seeded kelp rope installation: $33,000
- Marine Riparian Planting (installation, materials, plant stock, soils): $56,500
- Irrigation system for marine riparian planting area, plus tie into water main: $70,000
- Restoration of offsite log dump: $2,249,000

In addition to the installation and materials cost, 5 years of effectiveness monitoring is required. The cost for this is anticipated at $40,000 per year, for a total cost of $200,000.

Therefore, the anticipated cost of implementing the Habitat Offsetting Plan is $2,954,000 CAD.

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[6] We recognized that the volume of rock has decreased slightly of the offshore reefs following the last FAA application submission, but we believe it is prudent to maintain the cost estimate value given the following reasons:

- the cost of the contractor's plant and the like remains the same or has likely increased.
- the cost of the material has likely increased (i.e. the cost per tonne has increase and purchasing fewer tonnes will result in a similar cost).

10.6 Land Ownership or Tenure for Habitat Offsetting

All offsetting is intended to occur on land or waterlots managed by the Port Authority. Tenure for this land will be obtained during the Port Authority permitting process.

10.7 ECOncrete Pilot Study

The Port will be completing a pilot study to evaluate the feasibility, cost, performance, and habitat functionality of ECOncrete. This pilot study is a value-added component to the environmental measures and commitments under the CEMP and is not to be included as part of offsetting associated with the FAA. The ECOncrete performance will be monitored over a five-year period and the results will be shared with DFO via a supplement to the FAA monitoring reports.

ECOnrete is a relatively novel technology that uses a proprietary concrete mix that promotes marine growth. Moreover, ECOncrete adds texturing agents to the concrete mix to create complex concrete surface textures to promote marine attachment and growth. Lastly, ECOncrete is poured into moulds to create complex ecological niches to promote marine growth and attachment.

There are several moulds available from the manufacturer. For this pilot study, the Port Authority intends to evaluate two of these moulds (See Figure 5) and compare their performance to that of standard riprap reef which are used widely as marine habitat offsetting in BC:

- Standard Armour Block: a textured 1.2 x 1.2 m ECOncrete block intended to "*create marine habitats, encourage growth of marine flora and fauna, increase species richness, reduce the influence of invasive species and enhance biodiversity*[7]*".*
- Fish Hub Armour Block: a Standard Armour Block with added screening to provide refugia for fishes.

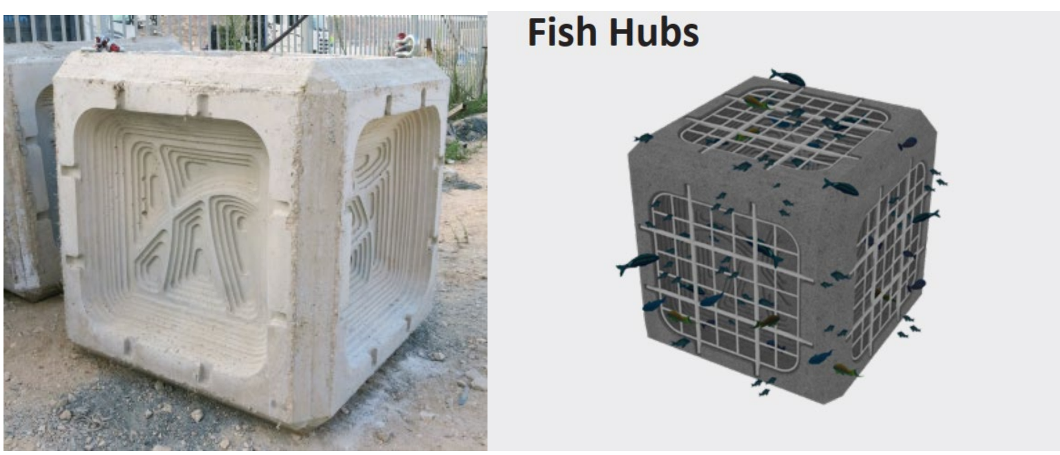

Figure 3: ECOncrete Standard Armour Block (Left) and Fish Hub Armour Block (Right).

[7] https://econcretetech.com/

With this pilot project, the Port Authority intends to evaluate the effectiveness and applicability of the two types of ECOncrete relative to that of riprap, therefore 3 treatment groups will be established in the Project footprint:

1. Standard Armour Block
2. Fish Hub Armour Block
3. Standard Riprap Reef

These treatments will be established in similar biophysical conditions along the proposed berm toe, as depicted in Drawing 070-010-MA-401 in Appendix I.

As part of ongoing habitat effectiveness monitoring, surveys to compare colonization of each treatment type will be conducted by divers or remotely operated vehicle (ROV). Colonization and ecological performance of each of the 3 treatment groups will be compared statistically each year to determine how they are performing relative to each other. Metrics will include but not be limited to species abundance, species richness, biodiversity, and percent cover of algae, seaweeds, invertebrates, and fishes.

The footprint of the ECOncrete blocks on the seabed have not been considered as an additional HADD for the Project as the area in which they will occupy has already been considered in the habitat balance by other Project activities (i.e., dredging).

11 Financial Guarantee

A financial guarantee is required when submitting an application for authorization under the *Fisheries Act*. The financial guarantee is intended to cover the cost of implementing the offsetting plan and must be sufficient to cover the cost for implementing all elements of the offsetting plan, including compliance and effectiveness monitoring measures.

DFO uses financial guarantees to provide a financial assurance mechanism in the event that an offsetting plan is not completed. This allows DFO to access funds to ensure the implementation of the offsetting plan or elements of the plan which have not been implemented by the applicant in the timeframe allotted in their authorization.

The Regulations exempt an applicant who is Her Majesty in right of Canada, Her Majesty in right of a province or the government of a territory from the requirement of providing financial guarantee. As the Port Authority is a federal government entity, it is exempt from providing a financial guarantee.

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This report has been prepared and the work referred to in this report has been undertaken by SNC-Lavalin, for the exclusive use of Vancouver Fraser Port Authority, who has been party to the development of the scope of work and understands its limitations. The methodology, findings, conclusions and recommendations in this report are based solely upon the scope of work and subject to the time and budgetary considerations described in the proposal and/or contract pursuant to which this report was issued. Any use, reliance on, or decision made by a third party based on this report is the sole responsibility of such third party. SNC-Lavalin accepts no liability or responsibility for any damages that may be suffered or incurred by any third party as a result of the use of, reliance on, or any decision made based on this report.

The findings, conclusions and recommendations in this report (i) have been developed in a manner consistent with the level of skill normally exercised by professionals currently practicing under similar conditions in the area, and (ii) reflect SNC-Lavalin's best judgment based on information available at the time of preparation of this report. No other warranties, either expressed or implied, are made with respect to the professional services provided Vancouver Fraser Port Authority or the findings, conclusions and recommendations contained in this report.

The findings and conclusions contained in this report are valid only as of the date of this report and may be based, in part, upon information provided by others. If any of the information is inaccurate, new information is discovered or project parameters change, modifications to this report may be necessary.

This report must be read as a whole, as sections taken out of context may be misleading. If discrepancies occur between the preliminary (draft) and final version of this report, it is the final version that takes precedence. Nothing in this report is intended to constitute or provide a legal opinion.

SNC-Lavalin disclaims any liability to the Vancouver Fraser Port Authority and to third parties in respect of the use of (publication, reference, quoting, or distribution), any decision made based on, or reliance on this report or any of its contents.

Appendix I

Project Design

STERLING SHIPYARD
REMEDIATION & INFILL

SITE LOCATION
NTS

DRAWING LIST

070-010-GA-000	COVER SHEET - DRAWING LIST AND SITE LOCATION
070-010-GA-001	DESIGN CRITERIA AND GENERAL NOTES
070-010-GA-002	EXISTING SITE AND DEMOLITION PLAN
070-010-GA-003	CONCEPTUAL CONTRACTOR PLAN LAYOUT
070-010-MA-101	GENERAL ARRANGEMENT
070-010-MA-102	SECTIONS
070-010-MA-103	SECTIONS
070-010-MA-201	REVETMENT PLAN AND SECTIONS
070-010-MA-301	DRAINAGE SYSTEM PLAN AND SECTIONS
070-010-MA-401	HABITAT OFFSETTING

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

Ref. No.	REFERENCE

SNC·LAVALIN
677011

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	A. DIJKERMAN
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-MAR-01
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
COVER SHEET
DRAWING LIST AND SITE LOCATION

SIZE	DWG.	SHEET	REV.
D	070-010-GA-000	1 of 10	1

DATE: 2022/10/27 - 5:44pm
PATH: Q:\677011 Sterling Shipyard R&R\40_Execution\45_GIS_Dwgs\MA-Marine\070-010-GA-000.dwg

TITLE BLOCK: DL-TB.dwg

DESIGN CRITERIA

1.0 CODE AND STANDARDS

THE STRUCTURE 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.
- NATIONAL BUILDING CODE OF CANADA (NBCC)
- BRITISH COLUMBIA BUILDING CODE (BCBC)

2.0 REFERENCES

- SNC-LAVALIN GEOTECHNICAL REPORT, DOC 677011-0000-4GER-0001
- SNC-LAVALIN ENVIRONMENTAL REMEDIATION DESIGN REPORT, DOC 677011-0000-4ER-0001
- UNDERHILL GEOMATICS LTD. TOPOGRAPHIC SURVEY, L-263
- CONSTRUCTION AND MATERIAL SPECIFICATIONS 677011-1000-4PEG-0001
- SNC-LAVALIN GEOTECHNICAL INSTRUMENTATION AND MONITORING PLAN, DOC 677011-0000-4GER-0001
- SNC-LAVALIN MARINE DESIGN CRITERIA 677011-0000-4PEC-0002
- SNC-LAVALIN STORMWATER MANAGEMENT DESIGN CRITERIA 677011-0000-41EC-0001

3.0 UNITS AND MEASUREMENTS

3.1 CONSTRUCTION DRAWINGS AND SPECIFICATIONS WILL BE IN ACCORDANCE WITH THE INTERNATIONAL SYSTEM OF UNITS (SI). ALL ELEVATIONS SHALL BE IN METERS AND ALL DIMENSIONS SHALL BE IN MILLIMETERS UNLESS NOTED OTHERWISE.

3.2 VERTICAL DATUM IS CHART DATUM (CD). THE CANADIAN GEODETIC DATUM (CGVD28) IS APPROXIMATELY 3.045 m ABOVE CD (CD=CGVD28+3.045m).

3.3 UTM HORIZONTAL DATUM IS DATUM NAD 83. ZONE 10.

4.0 DESIGN LIFE

4.1 THE COMPONENTS OF THE PROPOSED REVETMENT ARE DESIGNED FOR THE FOLLOWING SERVICE LIFE:

- EARTHWORK AND ROCK ARMOUR: 50 YEARS

5.0 ENVIRONMENTAL LOADS AND EFFECTS DESIGN PARAMETERS ADOPTED FOR THE ROCK-FILL PROTECTION BERM DESIGN:

- TIDAL CURRENT < 1.0 m/s
- SIGNIFICANT WAVE HEIGHT = 0.9 m
- PEAK WAVE PERIOD = 3.2 s

6.0 LIVE LOADS

SURCHARGES:

- 18 kPa UDL LIVE LOAD AT A SETBACK DISTANCE OF 4 m OF THE BERM CREST.

7.0 SEISMIC LOADS

EVENT	Sa (0.2)	Sa (0.5)	Sa (1.0)	Sa (2.0)	PGA
100 YEARS	0.183	0.151	0.077	0.042	0.078
2475 YEARS	0.809	0.716	0.406	0.247	0.351

- SEISMIC DESIGN CRITERIA BASED ON NBCC 2015
- SITE CLASS C

FOR THIS PROJECT, A PERFORMANCE-BASED APPROACH WAS ADOPTED BY CONSIDERING TWO LEVELS OF SEISMIC PERFORMANCE FOR THE SEISMIC DESIGN; "OPERATING LEVEL EVENT" (OLE) AND "CONTINGENCY LEVEL EVENT" (CLE). OLE REFERS TO SEISMIC PERFORMANCE FOR AN EARTHQUAKE WITH A 40% PROBABILITY OF EXCEEDANCE IN 50 YEARS (I.E., 1/100 EARTHQUAKE RETURN PERIOD), AND CLE REFERS TO SEISMIC PERFORMANCE FOR AN EARTHQUAKE WITH 2% PROBABILITY OF EXCEEDANCE IN 50 YEARS (I.E., 1/2,475-YEAR EARTHQUAKE RETURN PERIOD). THE PERFORMANCE OBJECTIVE FOR THESE TWO EARTHQUAKE SCENARIOS ARE AS FOLLOWS:

- PERFORMANCE OBJECTIVE FOR OLE: MINOR, EASILY REPAIRABLE DAMAGE WITH NO INTERRUPTION TO OPERATIONS; AND
- PERFORMANCE OBJECTIVE FOR CLE: REPAIRABLE DAMAGE WITH SOME INTERRUPTION TO OPERATIONS, HOWEVER, ANY STRUCTURE SHOULD NOT COLLAPSE AFTER A 2,475-YEAR EARTHQUAKE EVENT. THERE MAY BE TEMPORARY LOSS OF OPERATIONS WHICH SHOULD BE RESTORABLE, HOWEVER, LOSS OF LIFE IS TO BE PREVENTED

8.0 MARINE DESIGN CRITERIA

DESIGN WATER LEVELS:

TIDE LEVEL	2021 ELEVATION [m, CD]	2071 ELEVATION [m, CD]
HISTORICAL EXTREME HIGH WATER (HEHW)	5.6	6.4
HIGHER HIGH WATER LARGE TIDE (HHWLT)	5.0	5.8
HIGHER HIGH WATER MEAN TIDE (HHWMT)	4.5	5.3
MEAN WATER LEVEL (MWL)	3.1	3.9
LOWER LOW WATER MEAN TIDE (LLWMT)	1.2	2.0
LOWER LOW WATER LARGE TIDE (LLWLT)	0.1	0.9
HISTORICAL EXTREME LOW WATER (ELLW)	-0.3	0.5

INCLUDES SEA LEVEL RISE OF 0.8m FOR DESIGN YEAR 2071 FOR INFRASTRUCTURE DESIGN LIFE.

GENERAL NOTES

1.0 MATERIAL

1.1 REFER TO REVETMENT MATERIALS TECHNICAL SPECIFICATIONS IN 677011-1000-4PEG-0001.

1.2 REFER TO STRUCTURAL FILL IN GEOTECHNICAL REPORT 677011-0000-4GER-0001.

2.0 CONSTRUCTION

2.1 REFER TO REVETMENT CONSTRUCTION SPECIFICATIONS IN 677011-1000-4PEG-0001.

3.0 REMEDIATION

3.1 ALL EXCAVATED (INTERTIDAL AREA) AND DREDGED (SUBTIDAL AREA) MATERIALS, INCLUDING CONTAMINATED SEDIMENTS AND UNDERLYING GEOTECHNICALLY UNSUITABLE SANDS ARE CLASSIFIED AS GREATER THAN BC CONTAMINATED SITES REGULATION (CSR) INDUSTRIAL LAND USE (IL) SOIL STANDARDS BUT LESS THAN BC HAZARDOUS WASTE REGULATION (HWR) STANDARDS FOR OFFSITE DISPOSAL.

3.2 THE CONTRACTOR WILL BE RESPONSIBLE FOR MANAGING ALL PROJECT WATER DURING CONSTRUCTION EXECUTION, INCLUDING MANAGEMENT OF GROUNDWATER AND SEEPAGE INTO THE INTERTIDAL EXCAVATION AREA, AND REDUCING DREDGE WATER GENERATION DURING CONSTRUCTION IN THE SUBTIDAL AREA. THE CONTRACTOR SHALL IMPLEMENT CONSTRUCTION METHODS AND SCHEDULE THAT MINIMIZE THE WATER MANAGEMENT REQUIREMENTS. THIS INCLUDES PERFORMING THE INTERTIDAL AREA REMEDIATION DURING SUMMER MONTHS AND/OR AT A TIME OF YEAR WHEN HIGH TIDE CONDITIONS ARE LESS FREQUENT; AND, DEVELOPING AN EFFECTIVE WATER MANAGEMENT PLAN BY INCORPORATING APPROPRIATE REMEDIATION AND BACKFILLING SEQUENCE TO MINIMIZE THE GENERATION OF WATER AND MAINTAIN SAFE AND UNINTERRUPTED PROGRESS OF OPERATIONS. PROJECT WATER THAT CANNOT BE KEPT AWAY FROM ENTERING THE REMEDIATION FOOTPRINT MUST BE COLLECTED BY THE CONTRACTOR FOR ANALYTICAL TESTING. WATER NOT MEETING THE CCME GUIDELINES FOR PROTECTION OF AQUATIC LIFE (WQG/AL) GUIDELINES MUST NOT BE DISCHARGED INTO BURRARD INLET AND MUST UNDERGO ON SITE TREATMENT AND/OR BE DISPOSED OF APPROPRIATELY OFF-SITE TO ENSURE REGULATORY AND PER COMPLIANCE. DISCHARGING OF TREATED WATER MUST BE IMPLEMENTED FOLLOWING THE CEMP REQUIREMENTS. THE WATER MANAGEMENT SCHEME MUST INCLUDE A WATER TREATMENT AND DISCHARGE TRAIN CAPABLE OF HANDLING THE WATER VOLUME AND QUALITY COMMENSURATE WITH CONTRACTOR'S EXECUTION PLAN. THE WATER MANAGEMENT PLAN IS CONSIDERED AS PART OF THE CONTRACTOR'S EXECUTION PLANS TO BE REVIEWED AND APPROVED BY THE PORT AUTHORITY.

3.3 POREWATER/GROUNDWATER INFLOW IS EXPECTED WITHIN THE INTERTIDAL AREA FROM EXCAVATIONS, AND FROM THE EAST AND WEST SIDES BORDERING THE LAFARGE PROPERTY AND FORMER MARCO FACILITY, RESPECTIVELY. ESTIMATED THEORETICAL SEEPAGE RATE RANGES AT EACH OF THESE INTERFACES FOR A 1 M THICK CROSS SECTION ARE AS FOLLOWS:

ESTIMATED SEEPAGE RANGE - NORTH PORTION OF INTERTIDAL AREA	
INFLOW SOURCE	SEEPAGE RATE (L/MINUTE)
EAST SIDE	4 TO 24
WEST SIDE	8 TO 44
BOTTOM	0 TO 2
TOTAL	12 TO 70

ESTIMATED SEEPAGE RANGE - SOUTH PORTION OF INTERTIDAL AREA	
INFLOW SOURCE	SEEPAGE RATE (L/MINUTE)
EAST SIDE	1 TO 12
WEST SIDE	6 TO 32
BOTTOM	0 TO 2
TOTAL	7 TO 46

THE FLUX OF WATER FROM ABOVE SOURCES WILL BE HIGHLY DEPENDENT ON EXCAVATION AND BACKFILLING METHOD AND SEQUENCE, AREA AND DEPTH BEING EXCAVATED, TIDAL CONDITION AND SEASONAL VARIATIONS. SEDIMENT REMOVAL IN THE INTERTIDAL AREA SHALL BE IMPLEMENTED DURING LOW TIDE PERIODS TO REDUCE WATER INFLOW TO THE WORK AREA. IF THE REMEDIATED MATERIAL MUST BE IN A DEWATERED CONDITION PRIOR TO TRANSPORT FOR OFF-SITE DISPOSAL, EFFECTIVE ACTIVE OR PASSIVE DEWATERING WILL BE NEEDED, AND THE EXCESS WATER IS CONSIDERED CONTAMINATED WITH HYDROCARBONS, METALS AND PCB, AND WILL REQUIRE TREATMENT PRIOR TO DISCHARGE OR DISPOSAL.
WATER WILL BE GENERATED DURING MECHANICAL DREDGING IN THE SUBTIDAL AREA, REQUIRING DEWATERING AND MANAGEMENT OF THE RESULTANT WATER. DREDGE OPERATORS SHALL HOLD FILLED CLAMSHELL OR ENVIRONMENTAL BUCKETS OVER WATER FOR ONE TO TWO MINUTES TO MINIMIZE THE AMOUNT OF WATER BEING LOADED FOR SUBSEQUENT MANAGEMENT AND/OR DIRECT TRANSPORT/DISPOSAL. THE CONTRACTOR SHALL OUTLINE ITS WATER MANAGEMENT AND ANALYTICAL TESTING PLAN FOR ACCEPTANCE BY THE PORT AUTHORITY PRIOR TO ANY DISCHARGE ACTIVITIES.

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

0 1:1 50

Ref. No.	REFERENCE

SNC·LAVALIN
677011

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

PORT of vancouver
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	AD, GMJ, MN, BH
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-MAR-01
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
DESIGN CRITERIA AND
GENERAL NOTES

SIZE D | DWG. 070-010-GA-001 | SHEET 2 of 10 | REV. 1

TITLE BLOCK: DL-TB.dwg

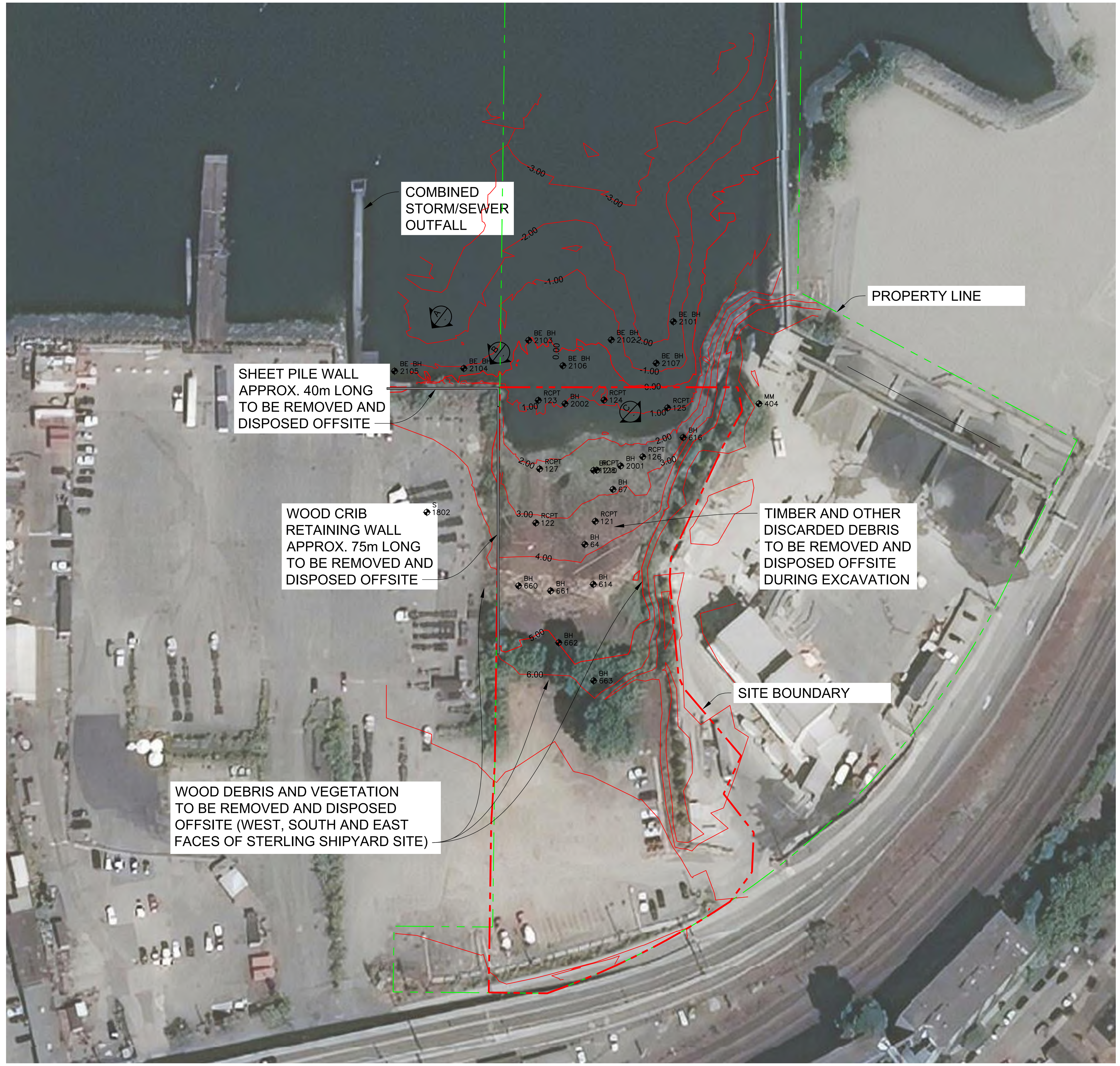
DATE: 2022/10/27 - 5:45pm
PATH: Q:\677011 Sterling Shipyard R&R\40_Execution\45_GIS_Dwgs\MA-Marine\\070-010-GA-001.dwg

TITLE BLOCK: DL-TB.dwg

VIEW A

VIEW B

VIEW C



PLAN
1:750

LEGEND:

SITE BOUNDARY
PROPERTY LINE
FENCE
BOREHOLE

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001.

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

0 1:750 50000

Ref. No.	REFERENCE

SNC·LAVALIN
677011

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

PORT of vancouver
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	AD, BL
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-FEB-26
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
EXISTING SITE AND DEMOLITION PLAN

SIZE	DWG.	SHEET	REV.
D	070-1-010-GA-002	3 of 10	1

DATE: 2022/10/27 - 5:46pm
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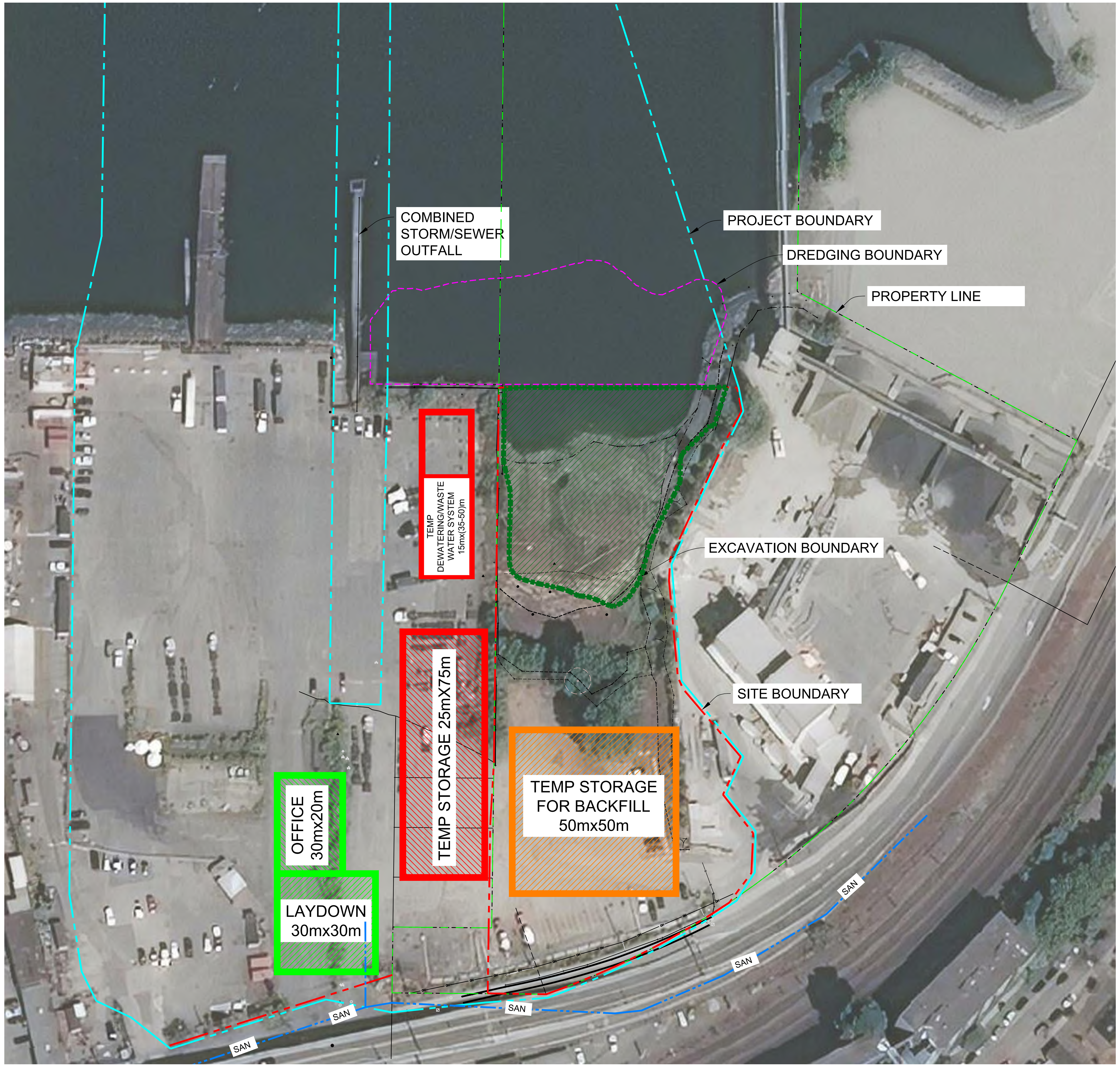


PLAN
1:750

LEGEND:

- PROJECT BOUNDARY
- SITE BOUNDARY
- PROPERTY LINE
- PROPOSED EXCAVATION LIMITS
- SAN — METRO VANCOUVER SANITARY SEWER LINE
- PRIORITY 1 AREAS
- PRIORITY 2 AREAS
- PRIORITY 3 AREAS

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001.

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

0 1:750 50000

DATE: 2022/10/27 - 5:47pm
PATH: Q:\677011 Sterling Shipyard R&R\40_Execution\45_GIS_Dwgs\MA-Marine\070-010-GA-003.dwg

Ref. No.	REFERENCE

SNC·LAVALIN
677011

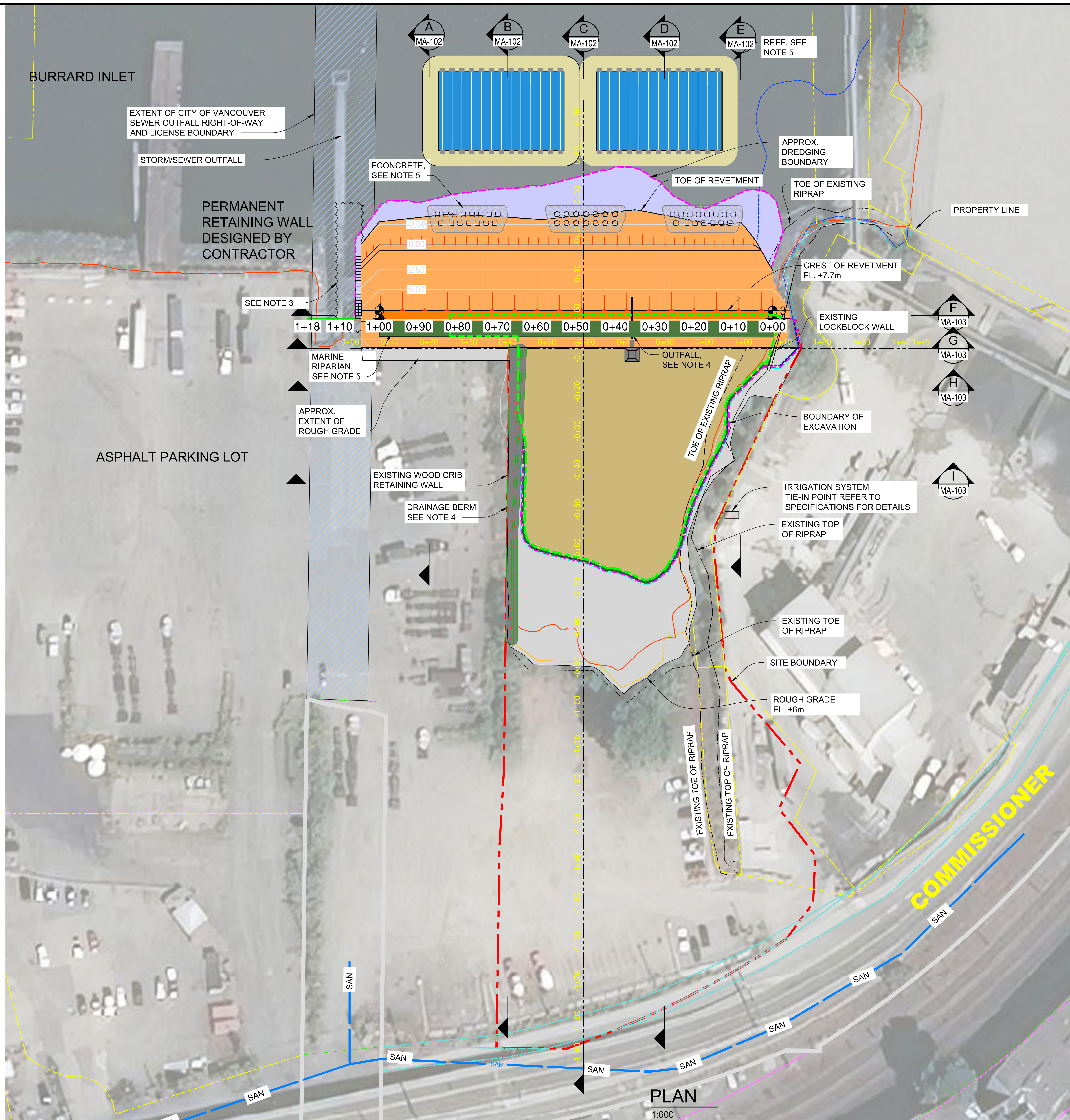
No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

PORT of vancouver
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

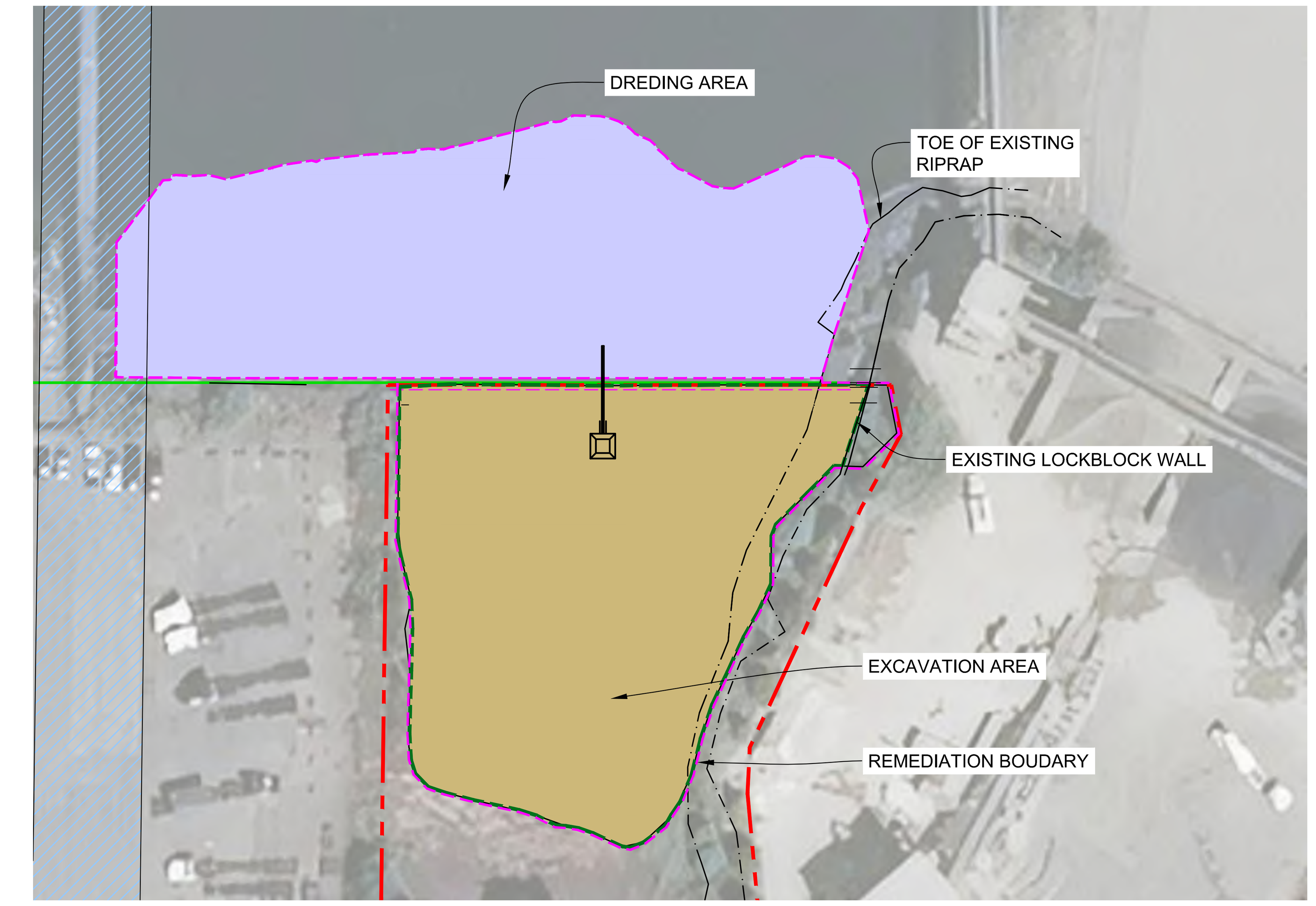
DESIGN BY	AD, BH
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-MAY-12
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATION & INFILL
CONCEPTUAL CONTRACTOR PLANT LAYOUT

SIZE	DWG.	SHEET	REV.
D	070-010-GA-003	4 of 10	1



PLAN
1:600



PLAN - REMEDIATION EXTENT
1:1000

LEGEND:

- DREDGING AREA
- REVETMENT
- EXCAVATION AREA
- +6.0m ROUGH GRADE AREA
- REEF & EDGE
- MARINE RIPARIAN
- SITE BOUNDARY
- LOT BOUNDARY
- FENCE
- BOUNDARY OF ANTICIPATED EXTENT OF SEDIMENT REMEDIATION
- PROPOSED EXCAVATION LIMITS
- GROUND IMPROVEMENT LIMITS
- INTERTIDAL AREA
- SAN — METRO VANCOUVER SANITARY SEWER PIPE

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001. ELEVATIONS ARE IN METRES, TO CHART DATUM CITY OF VANCOUVER MONUMENT V-2901 LOCATED AT THE INTERSECTION OF VICTORIA DRIVE AND COMMISSIONER STREET.
   ELEVATION = +8.316m (CHART DATUM), +5.271m (GEODETIC DATUM).
2. CHART DATUM = CGVD28 GEODETIC DATUM + 3.045m.
3. BATHYMETRY AND SURVEY IN THIS AREA OF THE RIGHT OF WAY IS NOT CONFIRMED AND PRESUMED TO BE SIMILAR TO ADJACENT AREA TO EAST WHICH WAS CONFIRMED BY 2021 FIELD SURVEY. CONTRACTOR TO FIELD CONFIRM BATHYMETRY AND PROVIDE 2 WEEKS IN ADVANCE OF PROCEEDING WITH WORK TO ALLOW ENGINEER TO CONFIRM DESIGN DIMENSIONS.
4. DRAINAGE SYSTEM REFER TO DWG. 070-010-MA-301.
5. HABITAT COMPENSATION REFER TO DWG. 070-010-MA-401.

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

0 1:600 30000

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

Ref. No. | REFERENCE

SNC·LAVALIN
677011

PORT of vancouver
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	AD, MN, MH, BH, AB
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-FEB-26
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
GENERAL ARRANGEMENT

SIZE D | DWG. 070-010-MA-101 | SHEET 5 of 10 | REV. 1

TITLE BLOCK: DL-TB.dwg

DATE: 2022/10/27 - 5:29pm
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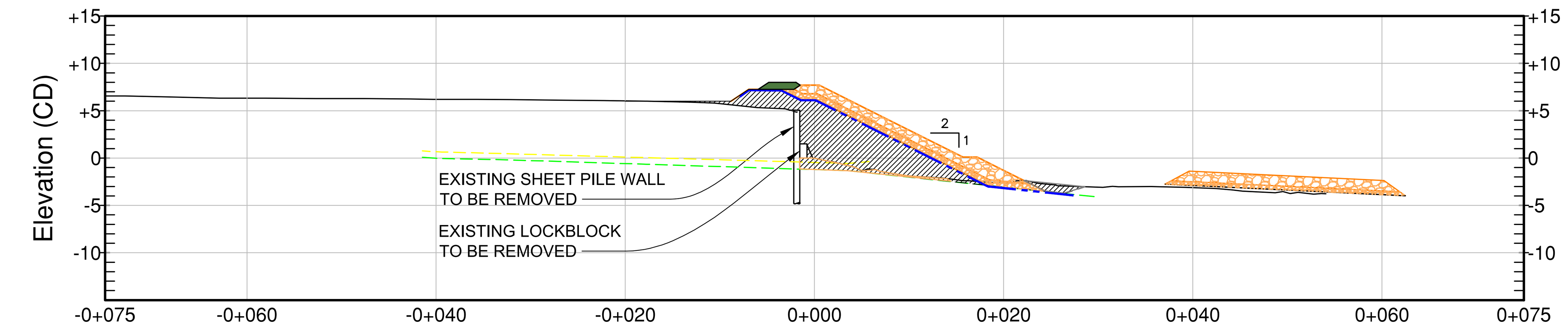
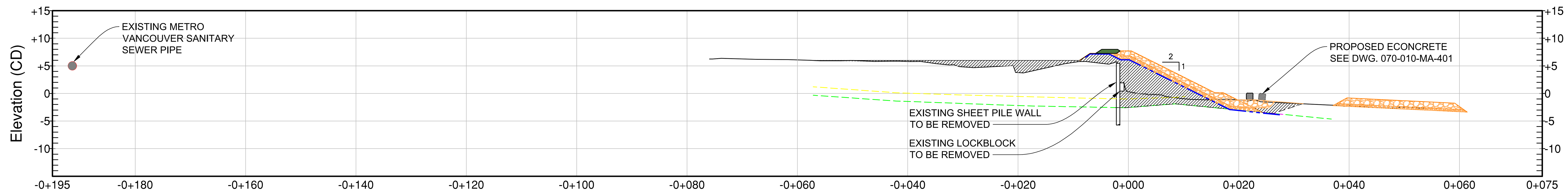


A SECTION
MA-101 1:500
NOTE: FOR DETAILS NOT SHOWN, SEE SECTION C



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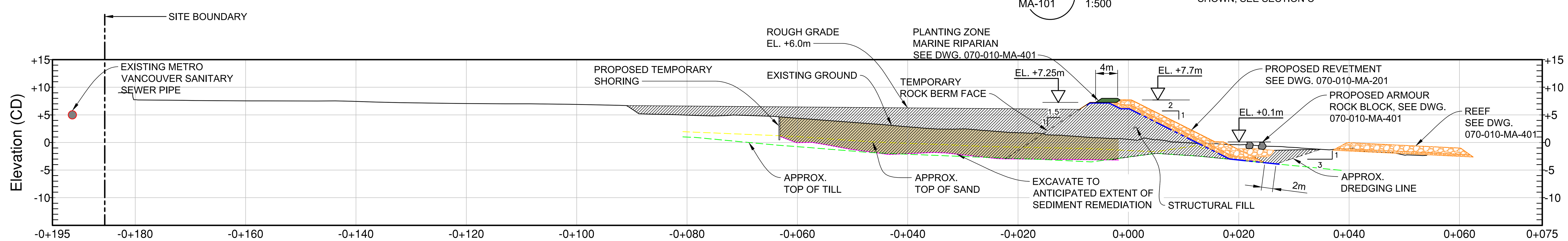
MA-101 1:500
NOTE: FOR DETAILS NOT SHOWN, SEE SECTION C



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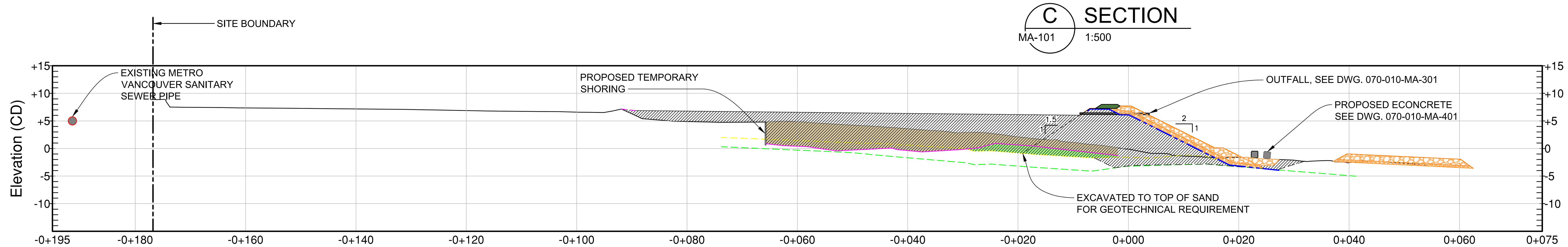

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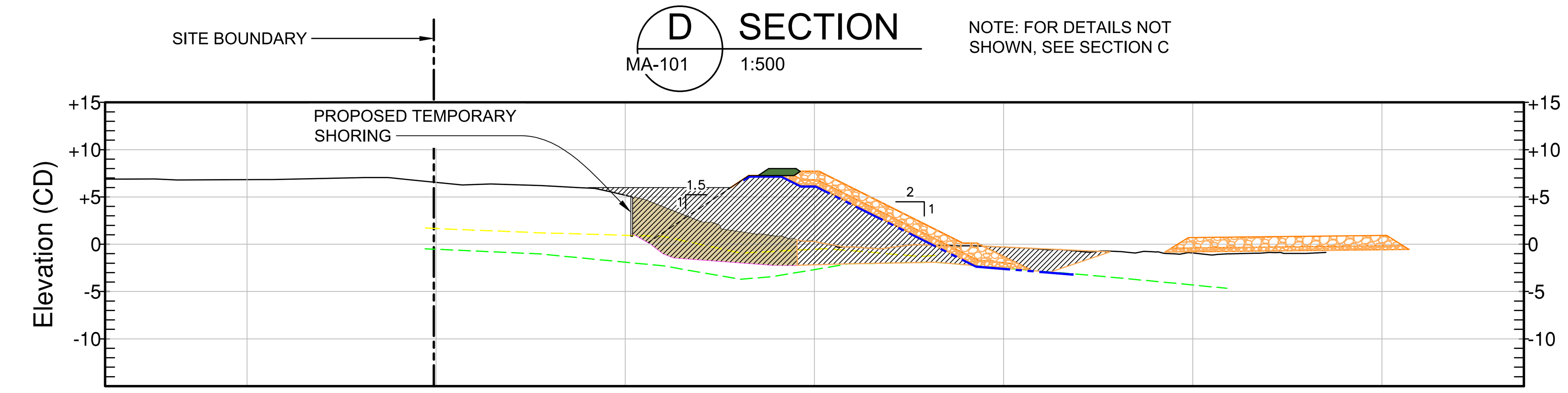
MA-101 1:500
NOTE: FOR DETAILS NOT SHOWN, SEE SECTION C



E SECTION
MA-101 1:500
NOTE: FOR DETAILS NOT SHOWN, SEE SECTION C

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001.

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

0 1:500 25000

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

Ref. No.	REFERENCE

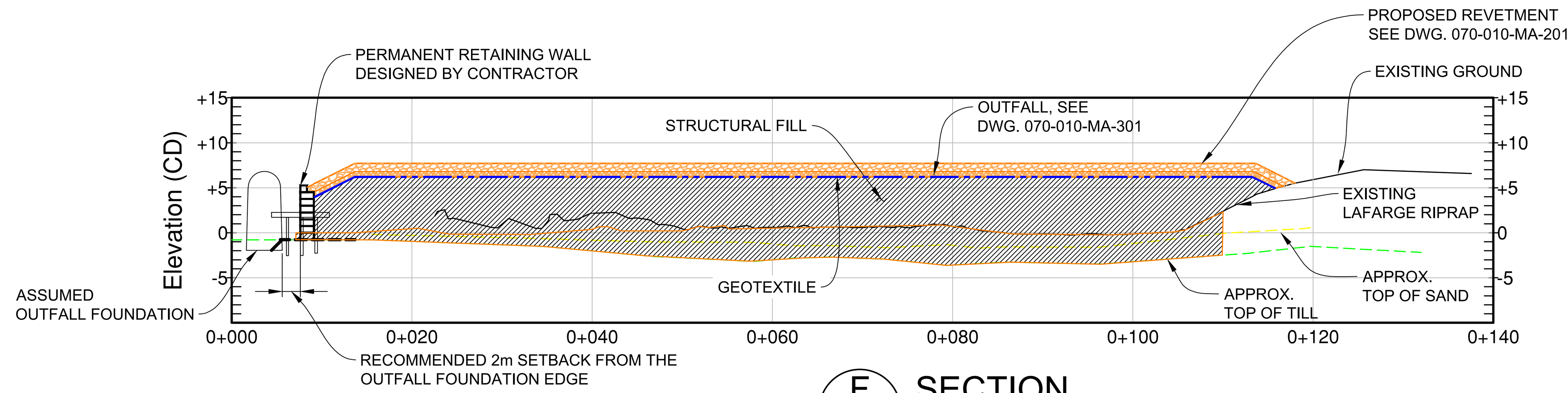
SNC·LAVALIN

PORT of vancouver
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

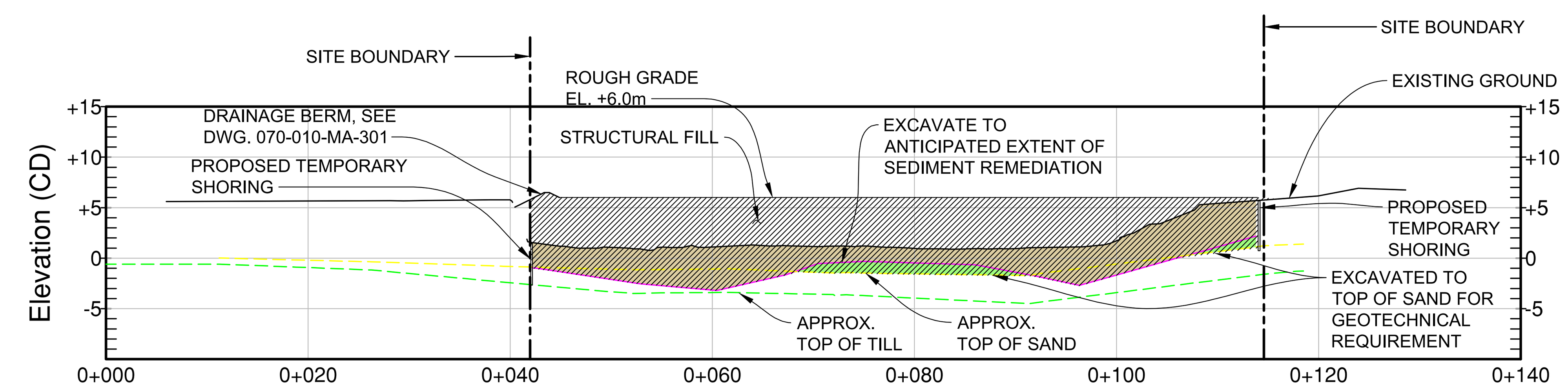
DESIGN BY	AD, NA, GMJ, MN, MH, BH, AB, BL
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-MAR-01
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL SECTIONS

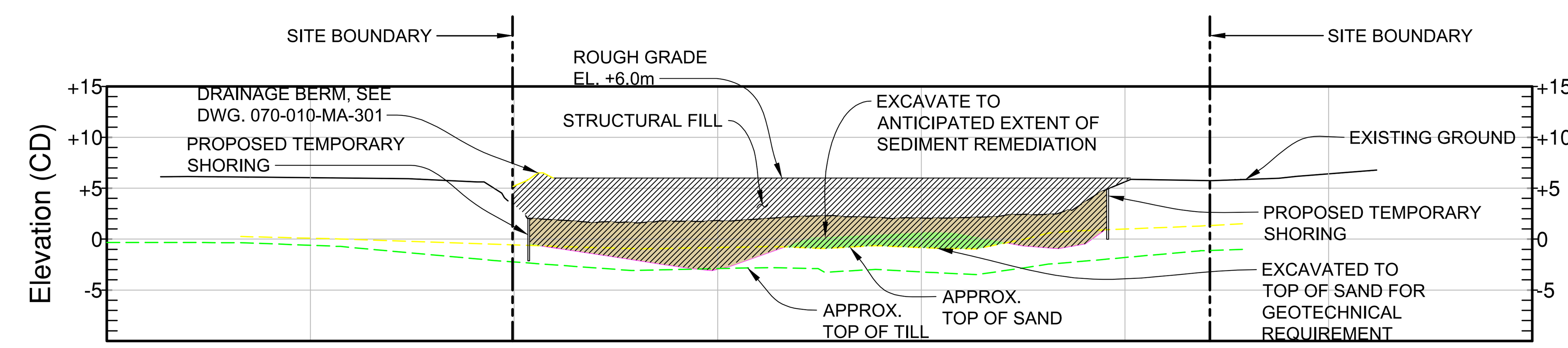
SIZE	DWG.	SHEET	REV.
D	070-010-MA-102	6 of 10	1



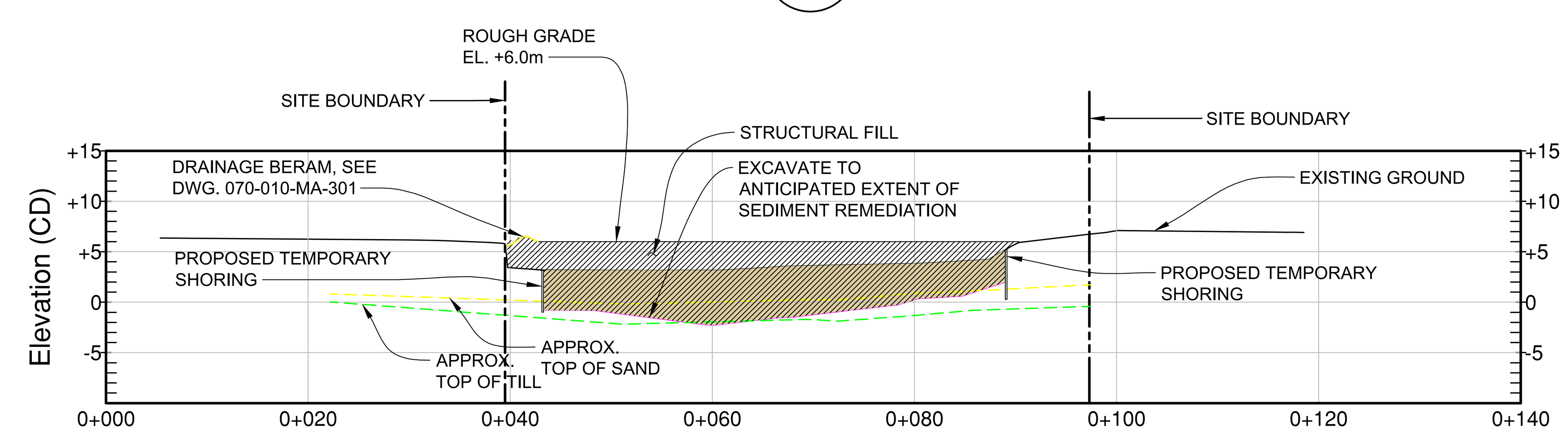
F SECTION
MA-101 1:500



G SECTION
MA-101 1:500



H SECTION
MA-101 1:500



I SECTION
MA-101 1:500

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001.

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

0 1:500 25000

Ref. No.	REFERENCE

SNC·LAVALIN

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

PORT of vancouver

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	AD, NA, GMJ, MN, MH, BH, AB, JR
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-MAR-03
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
SECTIONS

SIZE	DWG.	SHEET	REV.
D	070-010-MA-103	7 of 10	1

TITLE BLOCK: DL-TB.dwg

DATE: 2022/10/27 - 5:31pm
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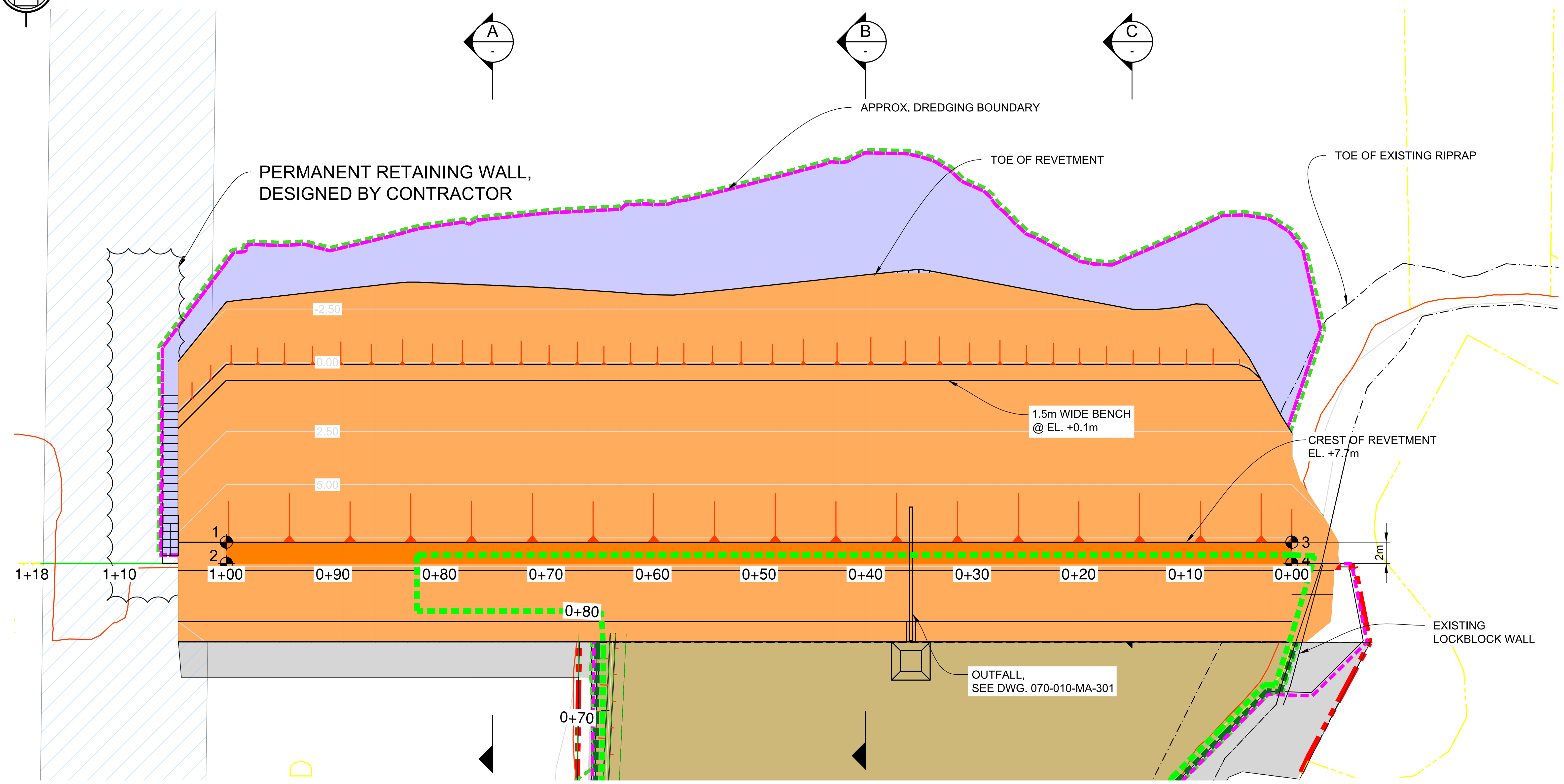
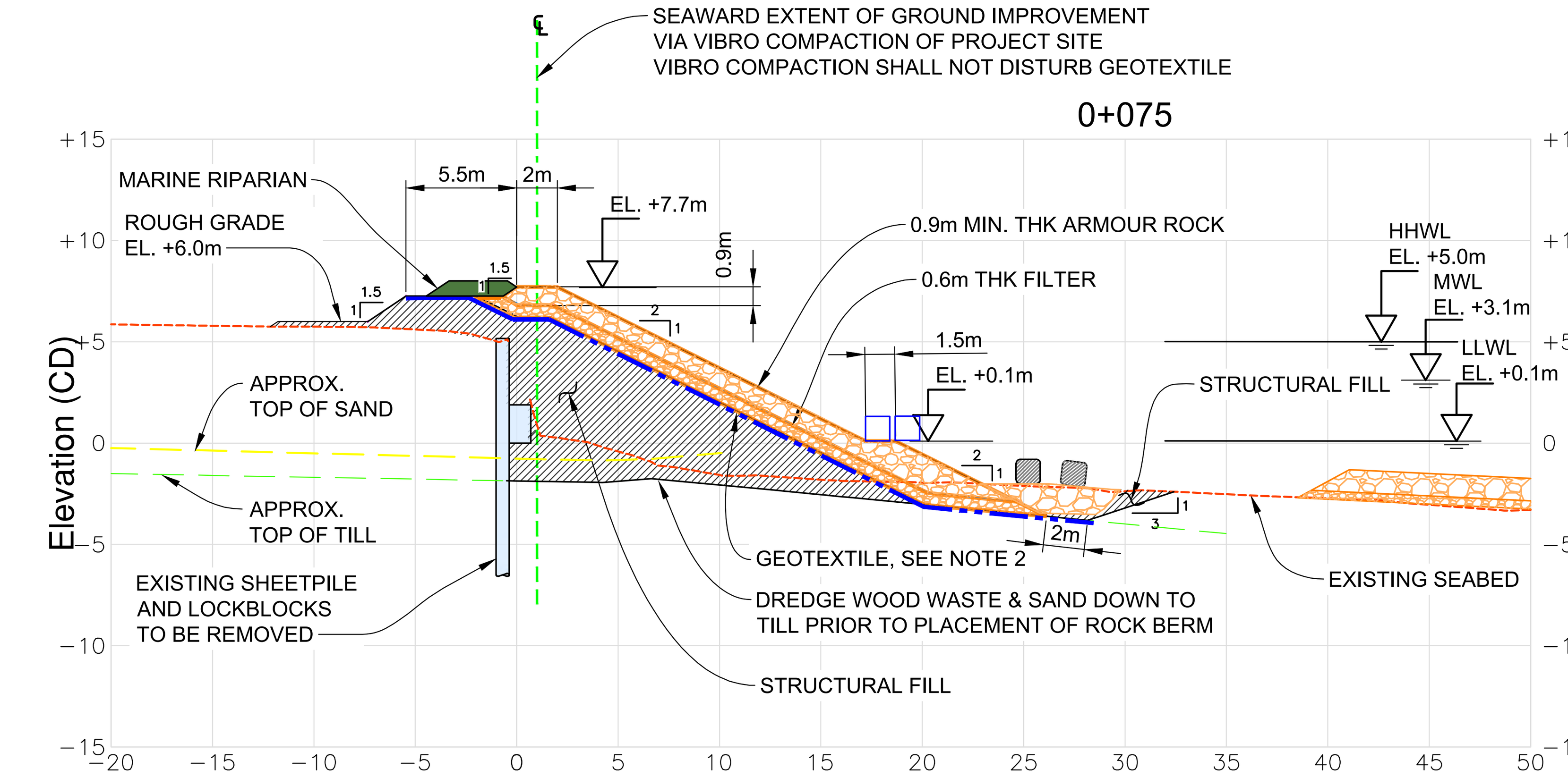


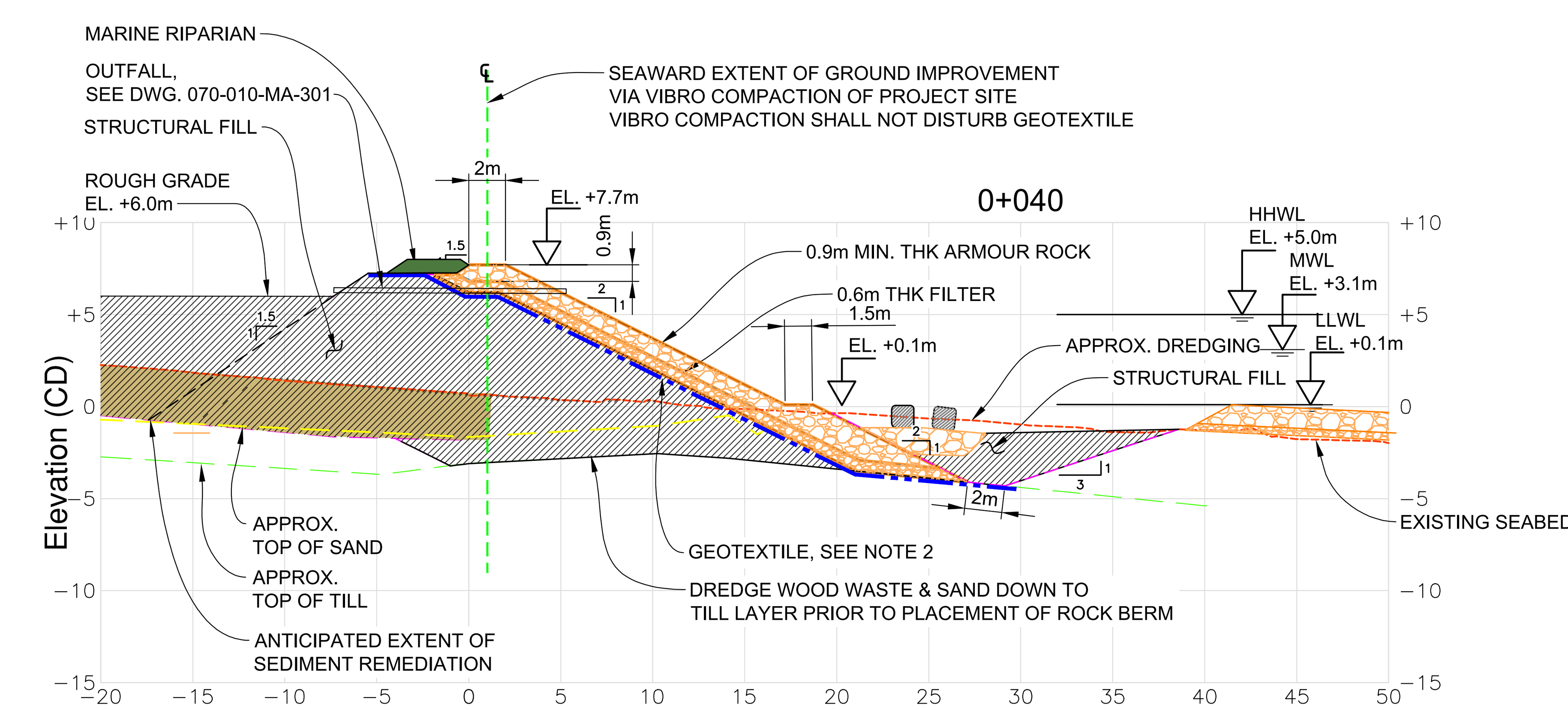
REVETMENT PLAN

1:300



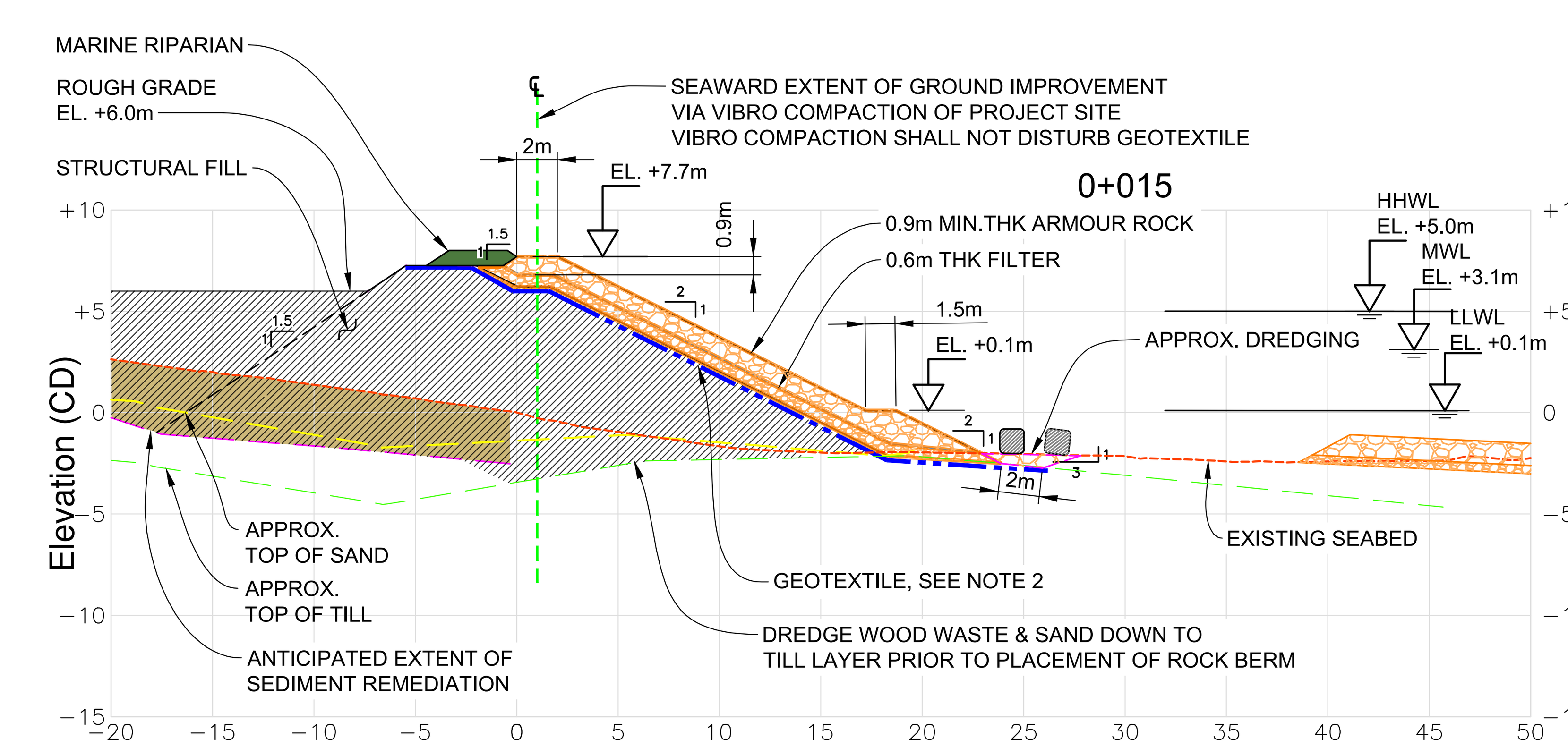
A SECTION

1:300



B SECTION

1:300



C SECTION

1:300

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

Point Table

Point #	Northing	Easting	Elevation
1	5459400.38	495246.88	+7.70
2	5459398.38	495246.88	+7.70
3	5459400.38	495346.88	+7.70
4	5459398.38	495346.88	+7.70

VOLUME TABLE (m^3)

DREDGING	6100
SEDIMENT CONTAMINATION - INTERTIDAL AREA	11300
ARMOUR ROCK	2650
FILTER	1700

AREA TABLE (m^2)

DREDGING	3360
SEDIMENT CONTAMINATION - INTERTIDAL AREA	3270

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001.
2. FOR GEOTEXTILE REFER TO DOCUMENT 677011-1000-4PEG-0001.

LEGEND:

- DREDGING AREA
- REVETMENT
- EXCAVATION AREA
- SITE BOUNDARY
- LOT BOUNDARY
- FENCE
- BOUNDARY OF ANTICIPATED EXTENT OF SEDIMENT REMEDIATION
- INTERTIDAL AREA
- PROPOSED EXCAVATION LIMITS
- GROUND IMPROVEMENT LIMITS

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

Ref. No. REFERENCE

SNC·LAVALIN

PORT of vancouver
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	AD, NA, GMJ, MN, MH, BH, AB, JR, BL
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-MAR-02
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
REVETMENT PLAN AND SECTIONS

SIZE D | DWG. 070-010-MA-201 | SHEET 8 of 10 | REV. 1

TITLE BLOCK: DL-TB.dwg
DATE: 2022/10/27 - 5:32pm
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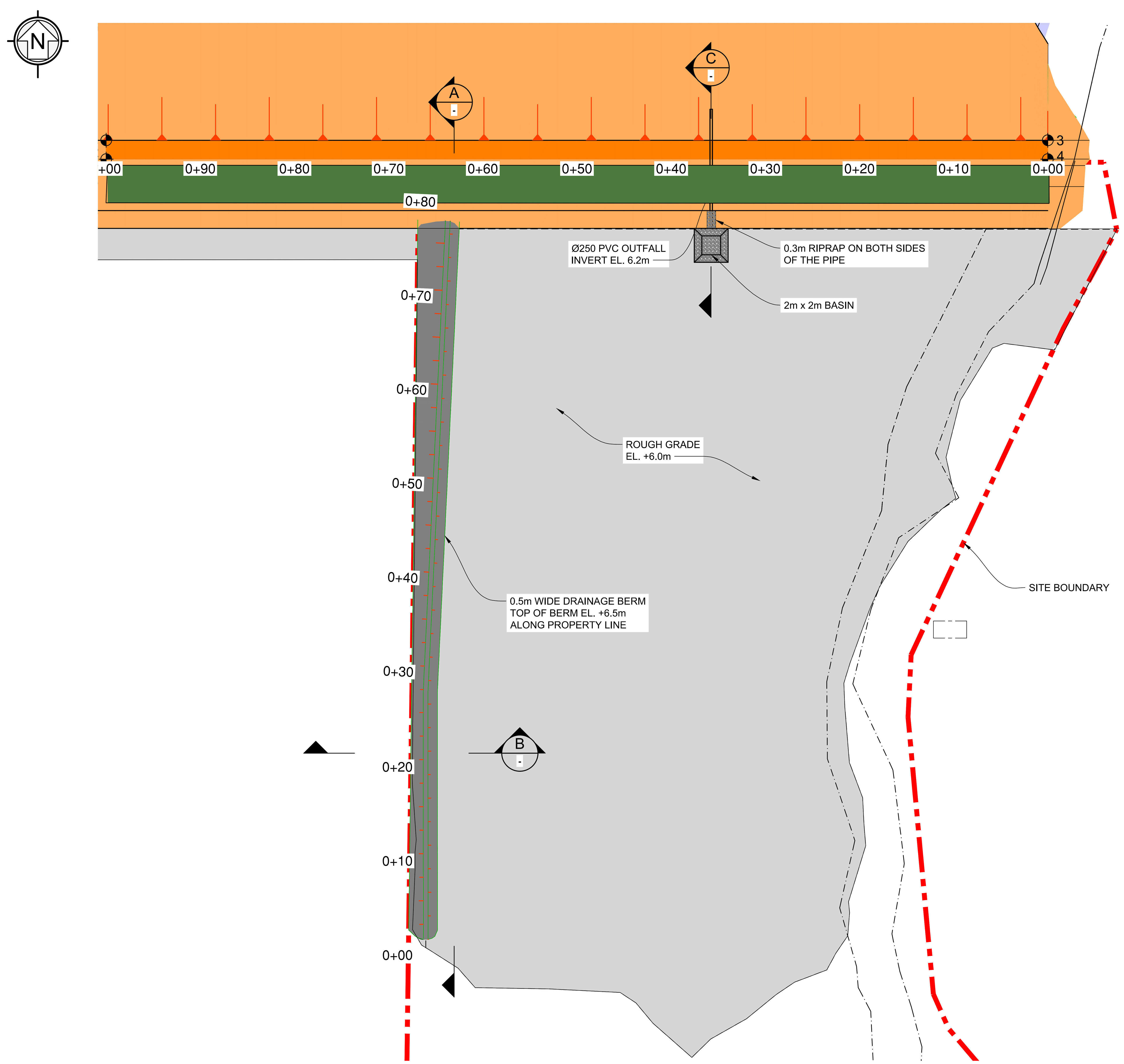
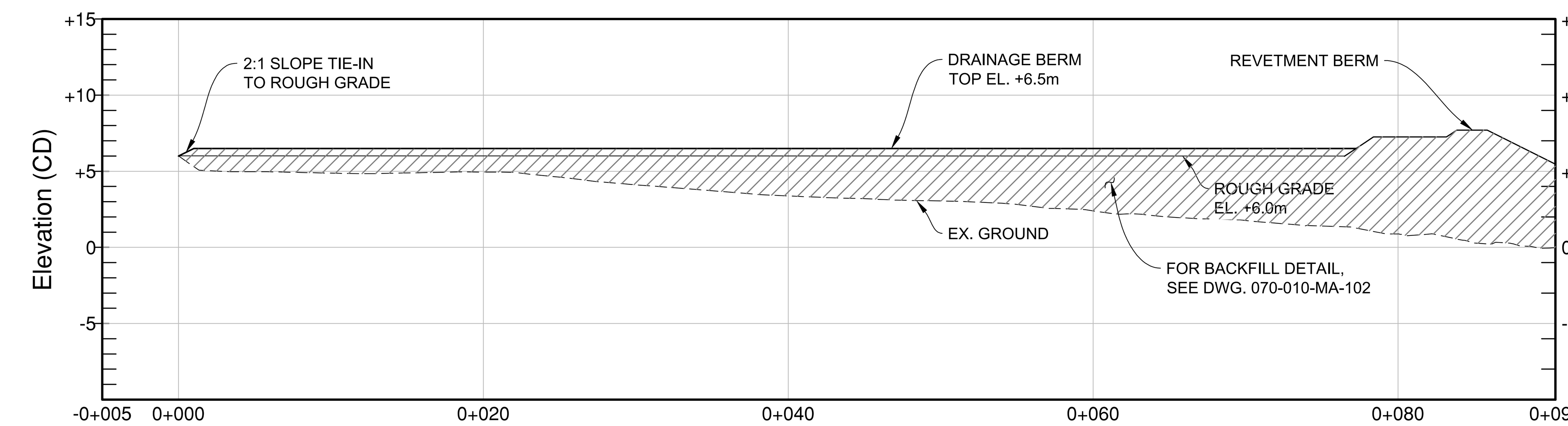
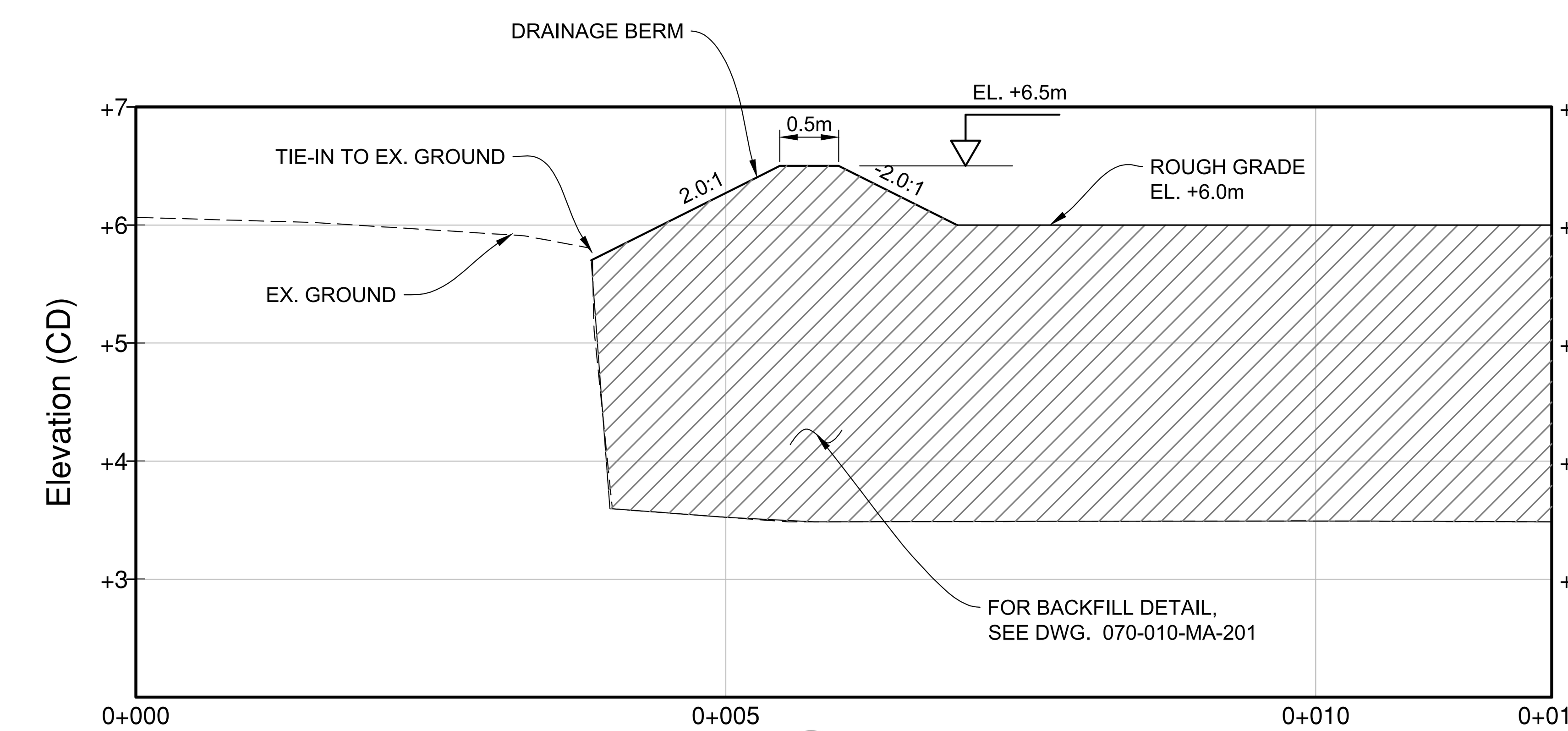


DRAINAGE BERM PLAN
1:300

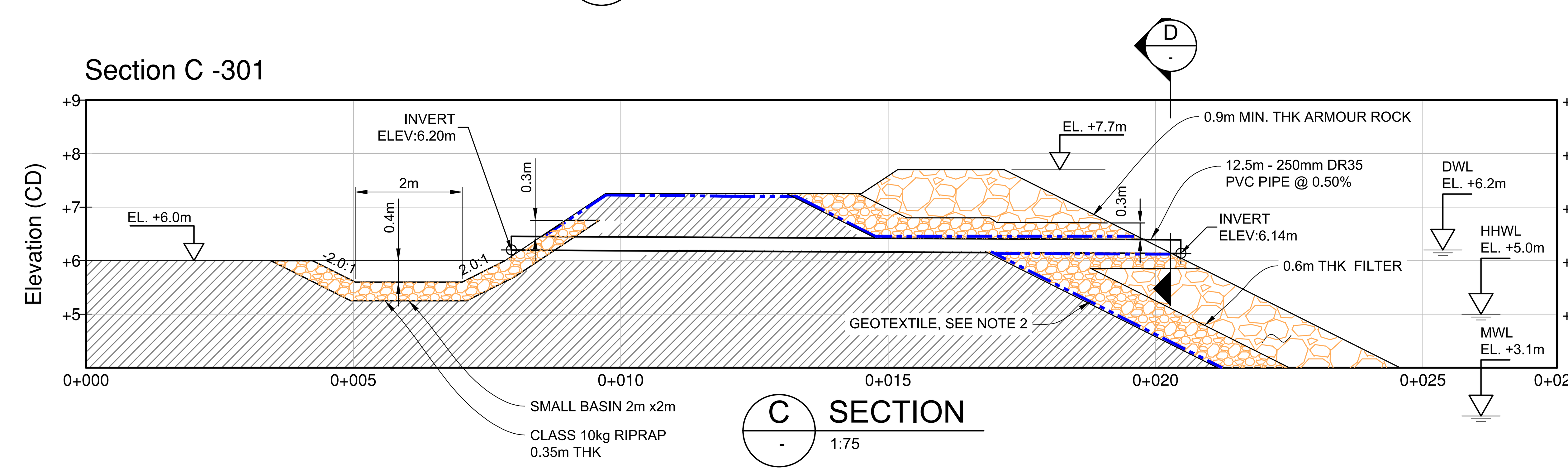


A SECTION
1:300

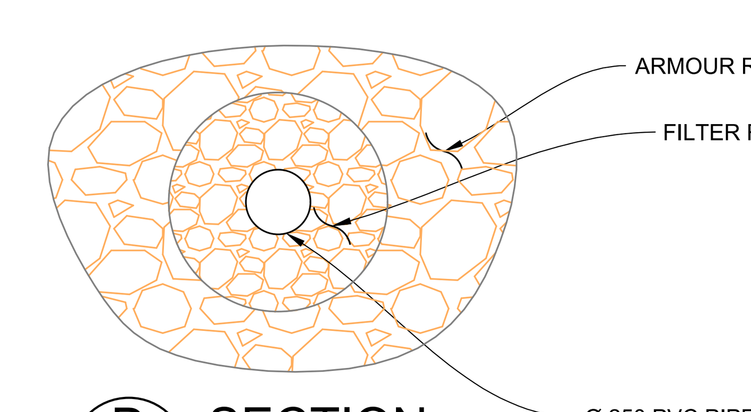


B SECTION
1:50

Section C -301



C SECTION
1:75



D SECTION
1:25

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001.
2. FOR GEOTEXTILE REFER TO DOCUMENT 677011-1000-4PEG-0001.

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

0 1:300 15000

Ref. No.	REFERENCE

SNC·LAVALIN

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

PORT of vancouver

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	AD, CL
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-MAR-02
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
DRAINAGE SYSTEM
PLAN AND SECTIONS

SIZE	DWG.	SHEET	REV.
D	070-010-MA-301	9 of 10	1

DATE: 2022/10/27 - 5:39pm
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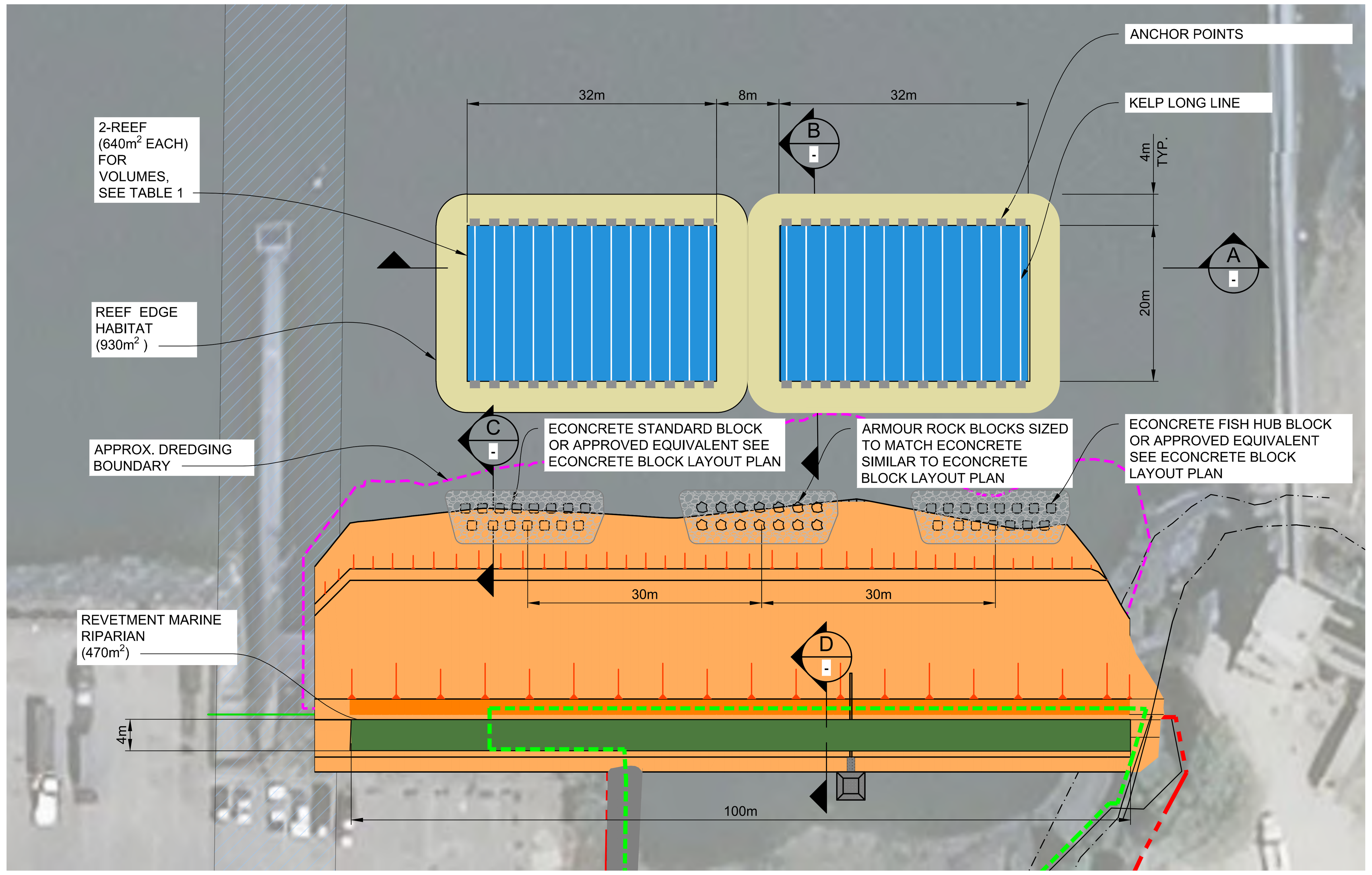


LEGEND:

REEF & EDGE

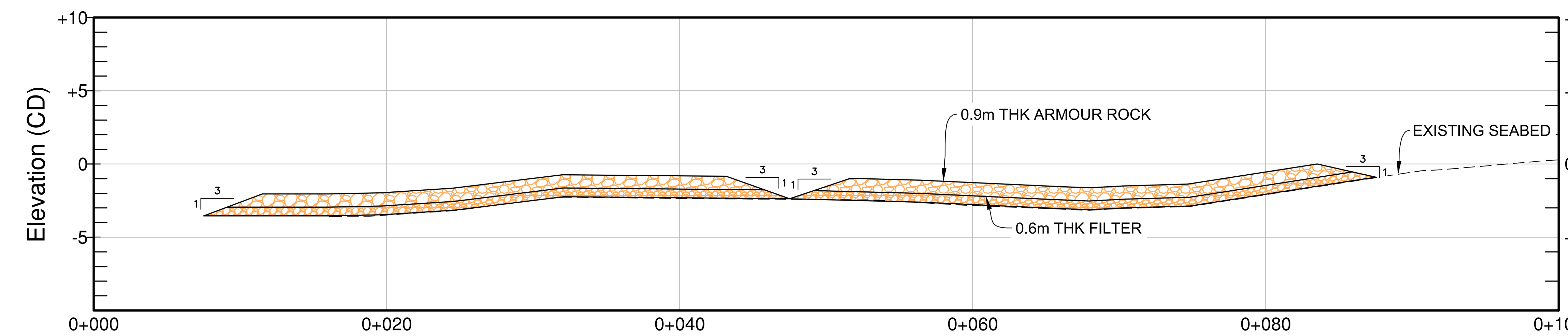
MARINE RIPARIAN

PLAN - HABITAT COMPENSATION

1:1000

PROPOSED NATIVE TREE AND SHRUB SPECIES TO BE PLANTED IN THE MARINE RIPARIAN											
SPECIES		MARINE	DRY	SOME MOISTURE	HEIGHT (M)	SIZE	NOTES	NUMBER OF POTS	% OF TOTAL	POT SIZE
SCIENTIFIC NAME	COMMON NAME									
TREES										
ACER CIRCINATUM	VINE MAPLE	✓		✓	9	TALL	DROUGHT TOLERANT	8	1	#2
PINUS CONTORTATA	SHORE PINE	✓	✓	✓	5-15	TALL	FAST GROWING	8	1	#2
RHAMNUS PURSHIANA*	CASCARA	✓	✓	✓	8-10	TALL	FRUITING	11	2	#2
SHRUBS										
AMELANCHIER ALNIFOLIA	SASKATOON	✓	✓	✓	1-5	TALL		41	5	#2
CORNUS STOLONIFERA*	RED OSIER DOGWOOD	✓		✓	1-6	TALL	FAST GROWING; FRUITING	40	5	#2
CORYLUS CORNUTA*	BEAKED HAZELNUT	✓	✓	✓	4	TALL	FRUITING	25	4	#2
HOLODISCUS DISCOLOR	OCEAN SPRAY	✓		✓	4	TALL		41	5	#2
LONICERA INVOLUCRATE*	BLACK TWINBERRY	✓			1-3	LOW	LIKES SHADE; FRUITING	15	1.5	#2
OEMLERIA CERASIFORMI*S	INDIAN PLUM	✓	✓		1.5-5	TALL	EARLY FLOWERING; FRUITING	73	10	#2
PHYSOCARPUS CAPITATUS	PACIFIC NINEBARK	✓	✓		2-4	LOW		15	1.5	#2
RIBES SANQUINEUM*	RED -FLOWERING CURRANT	✓	✓	✓	1-3	TALL	FRUITING	40	4	#2
ROSA GYMNOCARPA*	BALDHIP ROSE		✓	✓	1.5	LOW	DRIER SITES; FRUITING	63	10	#1
ROSA NUTKEANA*	NOOTKA ROSE	✓	✓	✓	3	LOW	FRUITING	100	10	#1
RUBUS PARVIFLORUS*	THIMBLEBERRY	✓	✓	✓	0.5-3	LOW	THICKET; FRUITING	83	10	#1
RUBUS SPECTABILIS*	SALMONBERRY	✓		✓	2-3	LOW	THICKET; FRUITING	80	10	#1
SALIX SCOULERIANA	SCOULER'S WILLOW	✓	✓	✓	2-12	TALL	DRY UPLAND SITES	30	1.5	#2
SALIX SITCHENSIS	SITKA WILLOW	✓		✓	1-8	TALL		11	3.5	#2
SAMBUCUS RACEMOSA*	RED ELDERBERRY	✓		✓	3-6	TALL	FRUITING	40	5	#2
SYMPHORICARPOS ALBUS*	SNOWBERRY	✓	✓	✓	1-2	LOW	THICKET; FRUITING	90	10	#1
TOTAL								814	100	

NOTE: * DENOTES FRUITING SPECIES.



A - REEF SECTION

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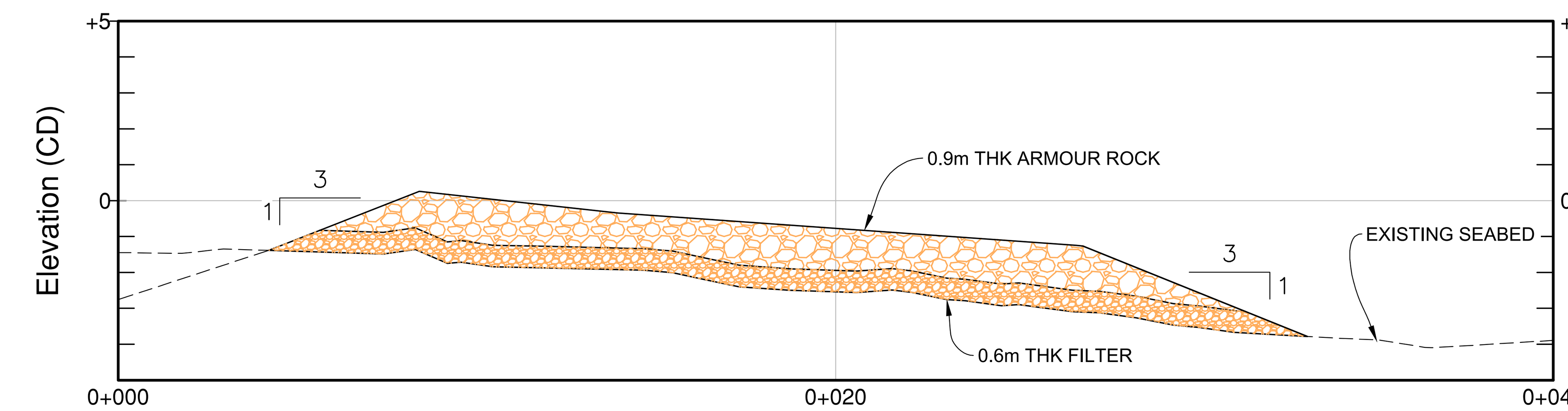

B - REEF SECTION

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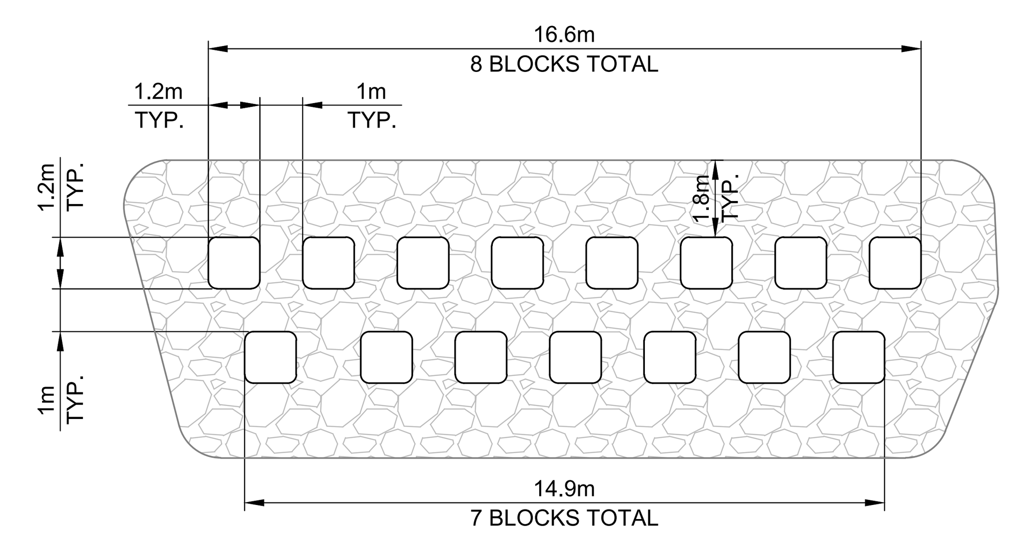
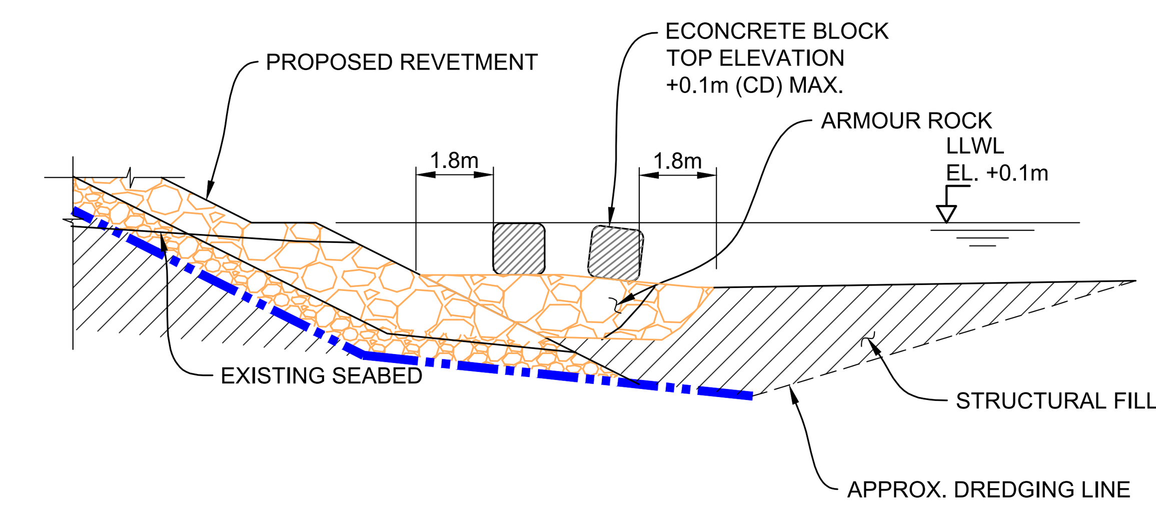


PLAN - ECONCRETE BLOCK LAYOUT

1:150



C - SECTION

1:150

2 REEF VOLUME (m^3) - TABLE 1	
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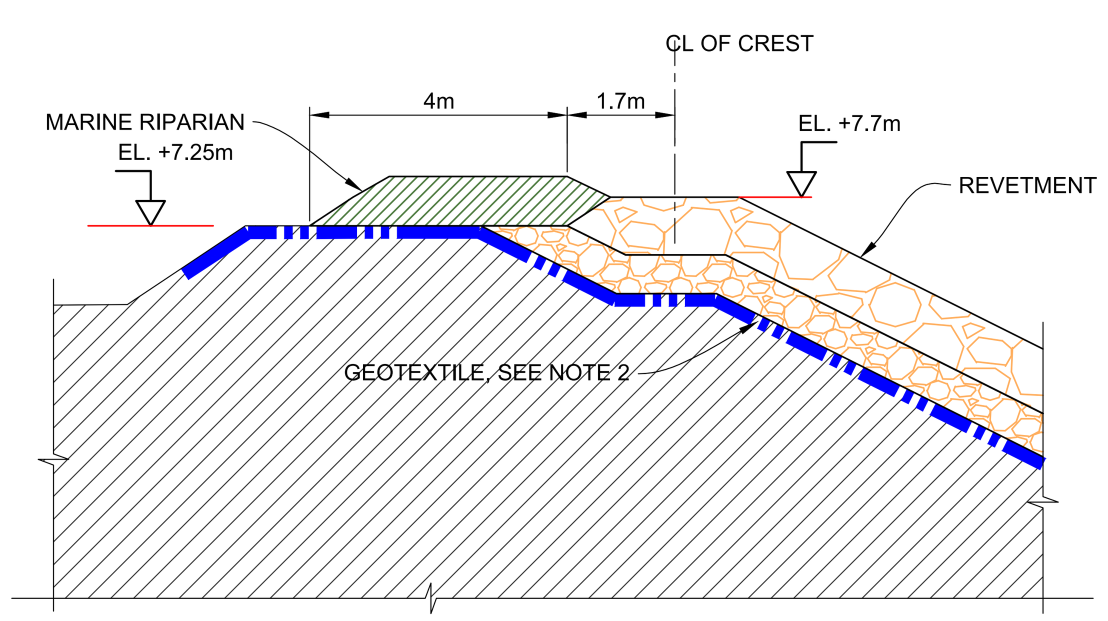
FILTER	1320



D - SECTION

1:100

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

NOTES:

1. FOR GENERAL NOTES, SEE DWG 070-010-GA-001.
2. FOR GEOTEXTILE REFER TO DOCUMENT 677011-1000-4PEG-0001.
3. CONTRACTOR TO DESIGN, SUPPLY, INSTALL AND MAINTAIN AN AUTOMATIC IRRIGATION SYSTEM TO IRRIGATE THE PLANTING ZONE. A SOLAR POWER CONTROL SYSTEM IS REQUIRED AS THERE IS NOT A SOURCE OF 120V POWER. THE TIE-IN POINT FOR THE IRRIGATION SYSTEM IS AS SHOWN ON THE DRAWINGS. A BACKFLOW PREVENTER AND WATER METER TO VFPA STANDARDS SHALL BE PROVIDED AT THE TIE-IN POINT.
4. KELP ROPES AND ANCHOR POINTS SHOWN ARE FOR ILLUSTRATIVE PURPOSES ONLY. FOR DETAILED INFORMATION ON KELP ROPE LOCATION AND CONNECTION METHODOLOGY REFER TO THE DOCUMENT "FEASIBILITY ASSESSMENT OF KELP RESTORATION AT STERLING SHIPYARD SITE FOR VANCOUVER FRASER PORT AUTHORITY" PREPARED BY CANADIAN KELP RESOURCES LTD. (2022).

0 1:500 25000

Ref. No.	REFERENCE

SNC·LAVALIN

No.	Date	REVISION	Dr'n	Ch'd
1	22/10/28	REVISED REEF SIZE FOR FAA RESUBMISSION	JG	JK
0	22/05/17	ISSUED FOR CONSTRUCTION RFT #T220411-09	JG	JK

PORT of vancouver

VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY	AD, NA, GMJ, AB, JR, BL, VO
DRAWN BY	J. GENG
APPROVED	J. KITSON
DATE	2021-FEB-26
SCALE	AS SHOWN
VFPA SITE	VAN 070

STERLING SHIPYARD REMEDIATON & INFILL
HABITAT OFFSETTING
PLAN AND SECTIONS

SIZE	DWG.	SHEET	REV.
D	070-010-MA-401	10 of 10	1

TITLE BLOCK: DL-TB.dwg

DATE: 2022/10/28 - 4:20pm
PATH: Q:\677011 Sterling Shipyard R&R\40_Execution\45_GIS_Dwgs\MA-Marine\\070-010-MA-101-102-103-201.dwg

Appendix II

Indigenous Consultation

Appendix III

Feasibility Assessment of Kelp Restoration at Sterling Shipyard Site for Vancouver Port Authority
Canadian Kelp Resources

Feasibility assessment of kelp restoration at Sterling Shipyard site for Vancouver Fraser Port Authority

Table of Contents

Executive summary

Project title: Sterling Shipyard Remediation and Infill

Project summary: The Vancouver Fraser Port Authority proposes to provide compensatory kelp habitat to replace habitat lost in the proposed fill and development at 2089 to 2095 Commissioner Street. The Vancouver Fraser Port Authority proposes the construction of 2 rip rap artificial reefs 40x32 m each on the base, rising to 32x24 m, for a total surface area of 768 m^2 each on the top, plus 1010m^2 of reef edge habitat. The tops and edges of these reefs are the proposed area for kelp restoration. CKR (Canadian Kelp Resources) has produced kelp seed for farms in BC since 1982 and is currently working to develop kelp restoration techniques. Kelp restoration is an ongoing subject of trials and refinement of methodologies.

Kelp restoration is recommended at the Sterling Shipyard site, using primarily sugar kelp (*Saccharina latissima*) on 15 long-lines, with an option to plant several of the long-lines with bull kelp (*Nereocystis leutkeana*) in addition to sugar kelp. Optimal planting time is November through February; spores would settle on the artificial reef the following fall, hopefully developing into a mature kelp forest on the artificial reefs the following spring, for a project timeline of 16 – 18 months minimum.

Kelp restoration

Kelp are prominent member of intertidal, and shallow subtidal marine communities in temperate regions, forming productive and diverse forests along rocky coastlines (Druehl and Clarkeston 2016). Kelp perform a multitude of roles in marine ecosystems. As primary producers, they form the base of many shallow water food chains, providing food to herbivores such as sea urchins and snails (e.g., Duggins et. al. 1989, Schiel and Foster 2015, Dunn et al. 2017). Kelp also create complex three-dimensional habitat, providing refuge, food, spawing and nursery areas essential to many commercially and ecologically important invertebrate and fish species, including salmon (eg. Holbrook et al. 1990, Tegner and Dayton 2000). More complex habitats are widely accepted to increase biodiversity (Jones 1997); kelp, for instance, serves as habitat for colonization by other plant and animal species (Steneck et al. 2002, Springer et al. 2010, Smale et al. 2013, Druehl and Clarkeston 2016). Finally, kelp forests also affect the adjacent shore by forming a wave break (Mork 1996). The successful establishment of kelp onto rip rap habitat would result in a more complex habitat and increased biodiversity in the Sterling Shipyard site.

Kelp restoration has been attempted in various forms since the 1950's. Due to the size, complexity, and timescale of kelp population dynamics, results from kelp restoration efforts are often mixed or unclear (reviewed in: Schiel and Foster 1992, Eger et al. 2022). Generally, studies have found four variables (detailed below) that may determine the success of a project. It is important to consider these four variables before deciding that kelp restoration is appropriate. The artificial reef under discussion will be replacing soft bottom habitat, and the kelp community will be replacing the soft-bottom community. The loss soft bottomed habitat must be weighed against the potential gains from the kelp forest habitat, and the risk of restoration failure (reviewed in Schiel and Foster 1992). If the four variables below are unfavorable to success, it may be wise to reconsider the restoration project.

(1) If kelp is declining due to larger environmental issues (e.g, warming water,sewage pollution), restoration efforts are typically ineffective. Sugar kelp (*Saccharina latissima*), and Seersucker kelp (*Costaria costata*) were found in the low- and inter-tidal of the Sterling Shipyard site, and bull kelp (*Nereocystis leutkeana*) has been noted adjacent to the site (SNC-Lavalin Habitat Assessment). This suggests larger environmental issues do not preclude the growth of kelp at the site. Sugar kelp was found in greater abundance in 2014 (SNC-Lavalin Habitat Assessment), which may indicate either population declines due to environmental stressors, or may be a result of natural population fluctuation (reviewed in Schiel and Foster 1992).

(2) If a wild bed of kelp is nearby, restoration efforts are more likely to succeed, as nearby kelp beds provide a natural source of spores for recruitment (reviewed in: Schiel and Foster 1992,

Eger et al. 2022a and b). The existence of kelp in the Sterling Shipyard site (as noted in 1) suggests there may be nearby kelp beds that will help colonize the artificial reefs. This is not guaranteed, as it is assumed the kelp found in the intertidal and subtidal surveys will be eliminated by the dredging and artificial reef construction. However, this project has a small footprint relative to Vancouver harbour, and we may assume the species would also be found on the inter- and subtidal habitat surrounding the site.

(3) An abundance of herbivores of concern, primarily sea urchins, decrease the chance of success. Herbivores can graze down new recruits and prevent kelp from establishing. Urchin dominated systems and kelp dominated systems represent two different environmental equilibriums (Eger et al. 2022a and b). Urchins may need to be removed year-round, for several years before restoration efforts in urchin dominated areas may be successful at tipping the ecosystem back to a kelp dominated equilibrium (Schiel and Foster 1992, Campbell et al. 2014, Eger et al 2022). Less than 10 urchins/m^2 is essential, and 1 urchins/m^2 or less is preferable (Tamaki et al. 2009, Eger et al. 2022a). Green urchins (*Strongylocentrotus droebachiensis*) were only found to be present (rather than common or abundant) in one of five intertidal transects, and not at all in the sub-tidal transects. This suggests an acceptably low urchin density. Monitoring urchin densities after spore settlement will indicate whether urchin removal is warranted.

(4) If restoration efforts can be maintained for several years, there is a higher chance of success. Kelp recruitment varies naturally from year to year based on environmental conditions, and restoration efforts may need to extend over several years before conditions are right for success (reviewed in: Schiel and Foster 1992, Eger et al 2022b). If the project funds permit, multi-year attempts will increase the chance of success. Monitoring of kelp recruitment on the Sterling Shipyard artificial reefs can inform if further restoration attempts are required.

Overall, Sterling Shipyard is a good location to attempt kelp restoration. The first three variables are generally favourable, while the final variable (maintaining restoration efforts for several years) will be dictated by the project's budget. Further, the inter- and sub-tidal area at the Sterling Shipyard site is reportedly contaminated with metals, PAH's and/or PCB's above provincial and federal guidelines. Dredging and excavation is incorporated into the development plan for Sterling Shipyard, regardless of the kelp restoration aspect of the project (SNC-Lavalin Habitat assessment). Accordingly, as the variables suggest the site is a good option for kelp restoration, and the soft-bottom ecosystem will be lost due to the remediation, we recommend kelp restoration at the Sterling Shipyard site.

Restorations strategies and criteria

There are five general strategies that have been employed for kelp restoration: Long-lines, green gravel, sori bags, adult transplants, and spore gel. Long-lines and green gravel require the collection of reproductive tissue from wild kelp (sori), and the release of spores and culture of juvenile kelp in the lab, followed by the outplanting of the lines or gravel with attached young kelp to the restoration location. Transplanting adult or juvenile kelp from an existing kelp bed has been one of the most used methods and requires a donor bed to source the transplanted kelp from. A variation of this method is sori bags, in which only the reproductive tissue is "transplanted" in mesh bags anchored on the substrate to be restored. Finally, spore gel involves "planting" spores released from the sori immediately onto the substrate to be restored, and holding them in place with a sticky, biodegradable gel.

A more detailed description of each of these methods is given in Appendix I. The five methods were evaluated (Table 1) according to the following criteria: Does the method maintain genetic diversity? Is the method appropriate for the rip rap substrate? Does the method have a negative environmental impact? How large is the existing knowledge and technology base surrounding the method? And what are the relative costs for each method? These criteria are discussed below.

Table 1. Evaluation of various restoration strategies for the Sterling Shipyard site. Green indicates more favourable, yellow indicates mixed, and red indicates less favourable aspects of each method with regard to the criteria.

Method	Maintains genetic diversity	Appropriate for rip rap	Environmental impact	Knowledge and technology base	Relative Cost
Long-lines	Yes	Yes	Outcome dependent	Yes	$$
Green gravel	Yes	No	Outcome dependent	In development	$
Transplants	No	Yes	Negative	Yes	$$
Sori bags	Yes	Yes	Outcome dependent	Yes	$$
Spore gel	Yes	Yes	Outcome dependent	No	$$$

Maintenance of genetic diversity: Reduced genetic variation is associated with reduced resiliency and adaptability, and increased susceptibility to environmental stress at a population level. (Reusch et al. 2005, Reusch and Hughes 2006, Jump et al. 2009, Laikre et al. 2010, Valero et al. 2017). In one study, reduced genetic diversity was found to increase the impact of a marine heat wave for populations of the spiney kelp (*Ecklonia radiata,* Wenberg et al. 2018). Thus, for restoration efforts to be long-lasting, it is important to ensure a high genetic diversity in the outplanted kelp. Any method which makes use of many donors, ideally from several different kelp beds, will have a higher genetic diversity. Typically, it is easier, causes less environmental disturbance to other kelp beds, and more cost effective to use methods involving the collection of reproductive tissue to produce spores (long-lines, green gravel, sori bags, and spores in gel) rather than entire individuals (adult transplants) to ensure high genetic diversity.

Appropriate for rip rap: Artificial reefs constructed of large boulders are typically inappropriate for green gravel, which can be easily washed into cracks between the boulders, where they will not receive enough light to grow. Long-lines, sori bags, and adult transplants, by contrast are secured by anchors or bolts into the rip rap, and the spores in gel adhere directly to the rip rap surface.

Environmental impact: As discussed above, an increase in biodiversity is dependent on the successful establishment of kelp in the habitat being replaced with the artificial reef. Long-lines, green gravel, sori bags, and spore gel have no intrinsic negative environmental impact, provided the apparatus used for long-lines and sori bags is removed. Adult transplants have a scale-dependent negative impact on the existing kelp bed from which the transplants are drawn.

Knowledge and technology base: Existing knowledge and examples of success for a given method increase the chances of success at Sterling Shipyard and are summarized below.

> **Long-lines** are industry standard in kelp farming (Kim et al. 2019) but are rarely employed in restoration efforts. The method has been employed in Washington in the 1980s; long-line cultures of bull kelp (*Nereocystis leutkeana*) were deployed to inoculate a new marine bulkhead in Elliott Bay, near Seattle. A bull kelp bed did become established and has persisted (Allan, Pers. Comm.). More recently, similar attempts by the Puget Sound Restoration Fund have resulted in limited bull kelp recruitment but have been somewhat more successful for sugar kelp (Heath, Pers. Comm.). In these studies, it was not clear as to the origin of the new recruits: from the long-lined kelp or a natural spore source. Success may be partially a function of the density of the spore-delivering kelp. In a similar experimental design, drifting *Sargassum* (a macroalgae) was successfully capture by nets and help above the substrate to be restored, resulting in the growth of *Sargassum* on the substrate below (Yatsuya 2010).

Green gravel and variations on green gravel (eg. outplanting young kelp on ceramic tiles) has not demonstrated uniformly successful results. Although a preliminary trial by Canadian kelp Resources demonstrated successful introduction of sugar kelp (*Saccharina latissima*) on a limited scale, a larger scale attempt was largely unsuccessful, indicating there are still questions to be answered regarding methodology. Puget Sound Restoration Fund's work with green gravel have likewise not resulted in successful establishment of bull kelp in the seeded areas, and an earlier attempt in Washington showed no success when outplanting small (<1mm) lab grown kelp on petri dishes (Carney et al 2005). A study in Norway, by contrast, showed success after nine months with sugar kelp outplanted on green gravel (Fredriksen et al. 2020), and interest in the method remains high.

Adult or juvenile transplants is one of the most employed restoration techniques, and delivers a range of results, with failures often attributed to urchin herbivory (eg: North 1976, Hernandes-Carmona et al. 2000, Tamaki 2009, Eger 2022). Juvenile bull kelp transplanted in Puget sound did not survive to maturity (Pers. Comm. Brian Allen). Transplanted Paddle weed kelp (*Ecklonia cava*) saw high survival rates for the first two years, after which almost all transplants died (Serisawa et al. 2003). Layton et al. (2021) successfully transplanted adult spiney kelp, but notes transplant attempts frequently yield poor results, and different locations and conditions will require specifically tailored transplant techniques. Transplants of giant kelp (*Macrocystis pyrifera*) in Mexico were successful between 7% and 41% of the time, while transplants of bull kelp in Puget sound had a success rate of 28% after 10 months (Carney et al. 2005).

Sori bags, like adult transplants, has historically been one of the most employed methods, and has similarly mixed results. An experiment with giant kelp in Mexico showed successful inoculation of the substrate through sori bags, particularly when the substrate was clean of other algae prior to installing the bags (Hernandes-Carmona et al. 2000). However, an attempt in Puget sound to relocate the sori of bull kelp reported disappointing numbers: less than 5 kelp recruits were found on the substrate surrounding the transplants (Pers. Comm. Brian Allen). A 20 – 60% success rate for recruits was found inside the porus sacks with giant kelp sori, (Westermeier et al. 2014). There have also been successful attempts using sori bags with paddle weed kelp and the macro algae *Sargassum* in Japan (Choi et al. 2000), and with the macro algea *Lessonia nigressens* in Chile (Vasquez and Tala 1995).

Spore gel has been employed by one research group in Japan, demonstrating success up to 8 months after seeding (Yotsukura et al. 2021), although the success is lower over the long term (Yotsukura pers. comm.). Other researchers used polysaccharide-like alginates to encapsulate the spores of *Sargassum fulvellum*, and reported the technique was successful in the very short term (40 days) but did not report long term results (Jung et al. 2020).

Relative Costs are estimated based on the lab time, boat time, dive time, and research and development efforts required. Costs are lowest for green gravel which requires no diving or apparatus, only the purchase of lab grown kelp on gravel and the boat time to deploy it over the reef. Long-lines require purchasing the lab-grown young kelp, the construction of kelp farm apparatus, and divers to deploy the farm structure and the kelp seed. Costs for adult transplants will be comprised of diver and boat time, and construction of the individual anchor and float system for each transplant. Adult transplants require significant effort from divers, including repeated dives to replace transplanted kelp that did not survive (Carney et al. 2005, Eger et al. 2022). The sori bag methods requires repeated dives every 2 weeks by a trained individual to replenish the sori and is dependent on being able to repeatedly source sori from near-by beds. The spores gel method would likely incur the most costs, as it requires research and development of techniques and apparatus.

Recommendation: Based on the above, we recommend long-lines as the most appropriate for the Sterling Shipyard site (Image 1). Sori bags are a close second but are dependent on repeated dives by a diver trained to identify sori, and we anticipate difficulty with logistics and sourcing sori. Green gravel is not an option due to the nature of the substrate. Adult transplants do not maintain genetic diversity without significant impact to the source bed, and the spore gel method is too new to be cost-effective.

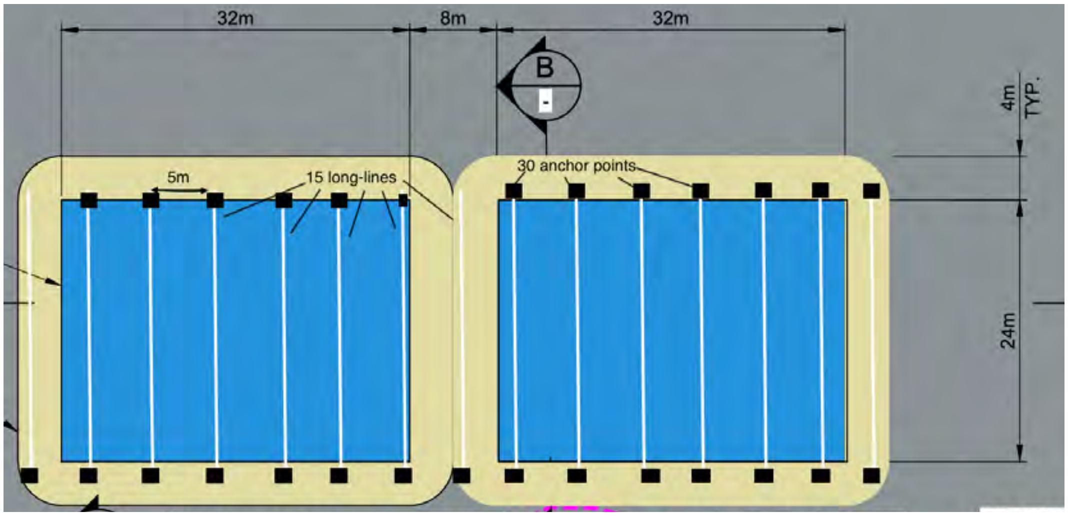


Image 1. Long-lines with anchor points superimposed on the diagram of the proposed artificial reefs at the Sterling Shipyard site (original image from the Vancouver Port Authority Engineering Department).

<u>Restoration species</u>

The B.C. coast is host to 30 kelp species (Druehl and Clarkeston 2016). Within the Georgia Strait area, the following 6 species have been reported: sugar kelp (*Saccharina latissima*), bull kelp (*Nereocystis leutkeana*), seersucker kelp (*Costaria costata*), winged kelp (*Alaria marginata*), colander kelp (*Neoagarum fimbriatum*), and Setchell's kelp (*laminaria setchellii,* UBC herbarium, Druehl 1967, Druehl and Hsiao 1977). These kelp were evaluated as to their viability for introduction to the Sterling Shipyard site according to the following criteria: Ecological relevance, local presence, appropriate environmental conditions, appropriate elevation, and industry familiarity (Table 2).

Table 2. Evaluation of the six species of kelp present in the Georgia Strait for their viability as restoration species at the Sterling Shipyard site.

Species	Ecological relevance	Present nearby	Appropriate elevation	Appropriate environmental conditions	Industry familiarity
Sugar kelp (*Saccharina latissima*)	High	Yes	Yes	Yes	High
Bull kelp (*Nereocystis leutkeana*)	High	Yes	Possibly	Possibly	Low
Seersucker kelp (*Costaria costata*)	Low	Yes	Possibly	Yes	Some
Winged kelp (*Alaria marginata*)	Low	No	Possibly	Yes	High
Colander kelp (*Neoagarum fimbriatum*)	High	No	Possibly	Yes	Low
Setchell's kelp (*Laminaria setchellii*)	High	No	Yes	No	Some

Ecological relevance: Some kelp species (sugar kelp, bull kelp, colander kelp and Setchell's kelp) grow large and/or form dense canopies, providing biomass and complex habitat that fuel marine food chains, and increase biodiversity. Other species of kelp (seersucker kelp, winged kelp) are relatively small and/or grow sparsely. The former are necessarily better candidates for creating more biodiverse ecosystems.

Local presence: The best indicator we have for which species will thrive is the species that are already at the location. Sugar kelp, bull kelp, seersucker kelp have all been reported on or adjacent to the Sterling Shipyard site. Sugar kelp was found in 3 of the 5 intertidal transects, in the low intertidal (common in 2, present in 1), and in all three quadrats of the first subtidal transect. The second subtidal transect was primarily on a sandy/silty substrate, where we would not expect kelp to grow. Bull kelp was not found within the site but was noted to be adjacent to it (SNC-Lavalin Habitat Assessment).

Appropriate environmental conditions: Kelp require specific ocean temperatures, salinity, nutrients, water motion (currents and waves), light, and substrate (Dayton 1985). We can assume that regional variables such as temperature, salinity, and nutrients will be appropriate for these six species as they already exist in the Georgia Strait. For water motion, the current speed at the Sterling Shipyard site is reported to be not more than 2 knots, while most waves are expected to be small than 0.6 m (SNC-Lavalin Marine Design Criteria). This within the tolerances of sugar kelp, seersucker kelp, winged kelp, and colander kelp. Bull kelp thrives in higher current habitats, so this is likely marginal for bull kelp, and Setchell's kelp requires exposed habitats with wave action, and would not thrive at the Sterling Shipyard site.

Appropriate elevation: Intertidal and shallow subtidal species are arranged in horizontal bands (zones) along the shore, according to the elevation. Desiccation tolerance drives the upper elevation limits for species (Doty 1946, Druehl and Hsiao 1977), and competition and herbivory often drive the lower limit (Lubchenco 1980). The precise elevation of each species' band will vary from location to location with shoreline topography, wave action (Harley and Helmuth 2003) and the freshwater input to an area (Jorde and Klavestad 1963, Druehl 1981) and not all species will be present at each location. When mature, seersucker kelp and winged kelp are found in the low to mid-intertidal, Setchell's kelp is found in the low intertidal, sugar kelp is found lower in the low intertidal and subtidal, colander kelp is found below sugar kelp in the subtidal, and bull kelp thrives from the shallow subtidal to below colander kelp (Druehl and Hsaio 1977, Vadas 1968, Druehl and Clarkston 2016). At the Sterling Shipyard site, sugar kelp has been reported from depths of 0 CD to -3.5 m CD in 2014, or, more recently, from -0.8 CD to -3.0 m CD (SNC Lavalin habitat assessment). The available elevation of the artificial reef ranges between approximately -3.5 m and 0 m CD. We can therefore expect that as regards appropriate elevation, winged kelp and seersucker kelp may thrive in the shallowest parts of the reef, Setchell's kelp and sugar kelp is likely to thrive over most of the artificial reef, and colander kelp and bull kelp may thrive in the deepest parts of the reef.

Industry familiarity: Species with which kelp seed producers are familiar are more likely to be successful, as specific details such as spore release methods and timing are known. Sugar kelp is the most farmed species on the B.C. coast; laboratory and outplanting methodologies are well established for it. Canadian kelp Resources has also repeatedly produced winged kelp successfully for kelp farmers. Seersucker kelp and Setchell's kelp have only been produced in small batches for trials and experiments, and Seersucker kelp has the added difficulty of a slightly earlier spore season. While Canadian kelp resources has been working with bull kelp and colander kelp for several years, bull kelp does not reliably grow when outplanted, while the optimal timing for colander kelp remains to be determined.

Recommendation: Based on the above, we recommend sugar kelp as the most appropriate species to outplant at Sterling Shipyard. Sugar kelp is a common and abundant cold-water species that is found as a major understory component in the low intertidal in the Salish Sea. In the spirit of optimism, we also recommend that a few long-lines of bull kelp be outplanted with sugar kelp. Bull kelp and sugar kelp can be grown on the same long-line together (Image 2), making the cost to also implement bull kelp relatively low, while, in the case of successful restoration, the benefit is high. Bull kelp is a charismatic, and common subtidal Salish Sea species. This species is the only canopy-forming species in the Straits of Georgia. While bull kelp stands throughout the Salish sea and beyond are diminishing, presumably from environmental stresses, there is widespread interest in bull kelp restoration due to its ecological importance.

Image 2. Bull kelp (Nereocystis leutkeana) and sugar kelp (Saccharina latissima) have been grown together on the same line. Bull kelp is buoyant, and grows upwards in the water column, while sugar kelp is neutrally or slightly negatively buoyant, and hangs downwards.

<u>Timeline</u>

This project may consist of one outplanting (Table 3), or multiple outplantings (Table 4) over several years, depending on success of the first outplanting, and funding. Sugar kelp and bull kelp produce sori in the fall, and pending lab timelines, outplantings are possible between November and February. Kelp growth is typically rapid in the spring, with outplanted kelp becoming visible on the lines in April or May. The outplanted kelp will produce sori and release spores in the fall. These spores will, ideally, settle on the artificial reef below. The success of these spores will not be known until this second generation of kelp becomes visible the following April. As sori for a second long-line outplanting must be collected in the fall, it is not possible to assess the success of the first year's outplanting before initiating a second outplanting (Table 4). It is, however, possible to skip a year in order to assess the success of the first year's outplanting was successful before attempting another outplanting in the third year (this timeline is not presented). The long-lines need to be removed from the water between outplantings to prevent overgrowth of other organisms. It beneficial to seed the artificial reef with kelp seed as soon as possible after it is installed, as settlement by competing algae may make it harder for kelp to establish (Yotsokura, pers. comm, Hernandes-Carmona et al. 2000). Urchin monitoring is suggested in the timelines. If unacceptably high urchin populations are discovered in these surveys, urchin removal on a monthly or bi-monthly basis is recommended.

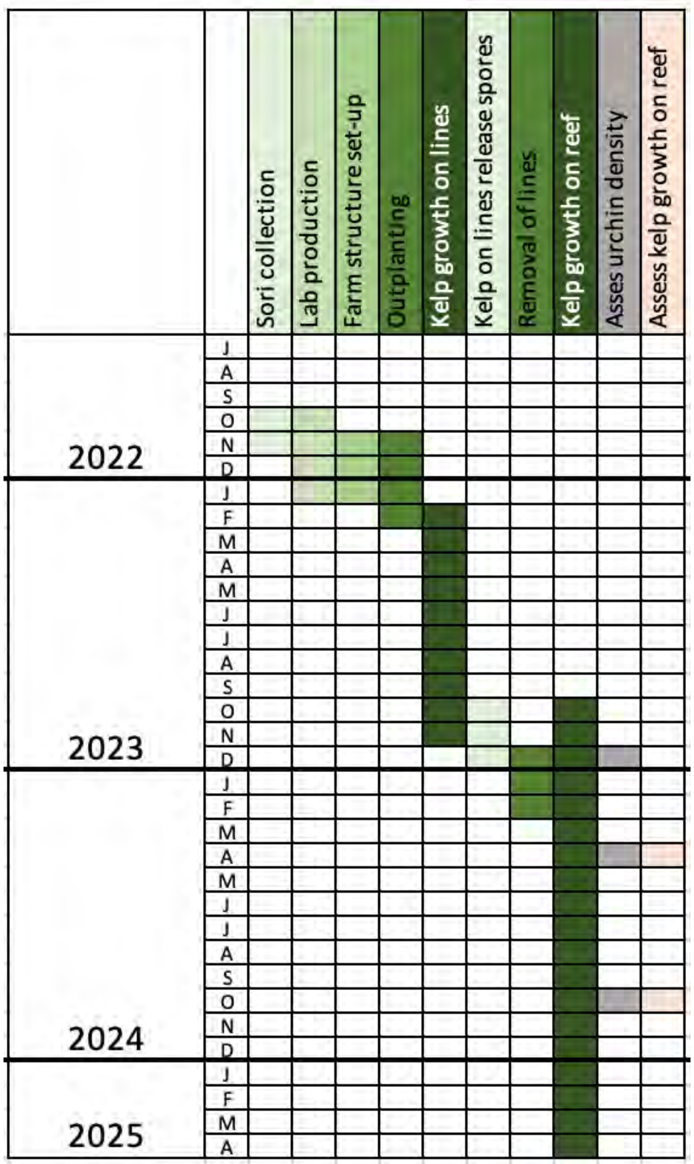
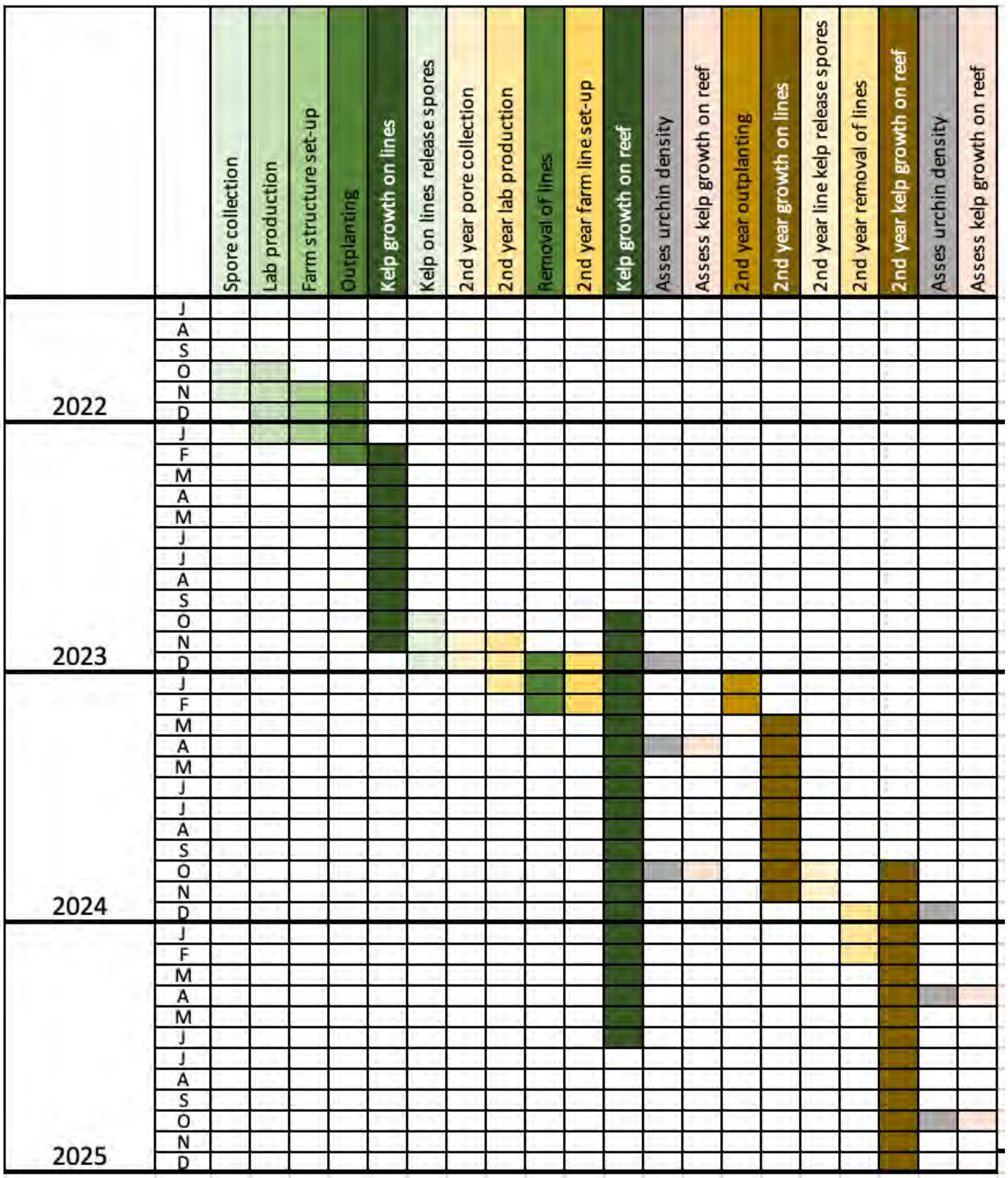


Table 3. Potential timeline for a one-time outplanting of kelp on long-lines for restoration of the artificial reef beneath the long-lines.

Table 4. Potential timeline for two years of kelp outplantings on long-lines for restoration of the artificial reef beneath the long-lines.



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Appendix I: Kelp restoration methodologies

1. Long-lines

Laboratory-produced kelp sporophytes on string (Image 3) are deployed onto line (rope) horizontally above the artificial reef. After about 12 months, the kelp on the lines will be mature (Image 4) and will release spores to inoculate the artificial reef below. These spores, if successful at inoculating the new rock structure and completing their sexual cycle, will establish a new population of kelp about 6 months after being released, giving a total time from initiation to completion of about 18 months.

The basic cultivation structures consist of two 1 m vertical ½" lines 20 m apart, anchored directly into the rip rap, and topped by a pressure float, joined by a 20 m ½" cultivation line just below the float (Image 5).

The cultivation lines should be suspended about 1 m above the substrate. The whole structure is intended to remain submerged. The cultivation lines are pre-treated by submersion in seawater for at least 48 h to remove any industry chemicals before they are seeded. The cultivation lines are attached to the vertical lines by long-line snaps, making them easily detachable. In some applications, the lines may be seeded from a small boat, for restoration purposes, the lines are deeper, and must be seeded underwater by SCUBA: The cultivation line is disconnected from the vertical line, passed through the center of the spools of kelp string (Image 6), and advanced to the far end of the cultivation line, unspooling the string as it is moved forwards. The seeded string must be kept taut against the line. The empty spool is slipped off at the far end by unsnapping the cultivation line from the vertical line, before re-securing the snap to the vertical line.

Image 3. Young kelp is grown on a spool (string wound around a PVS plastic pipe) in the lab.

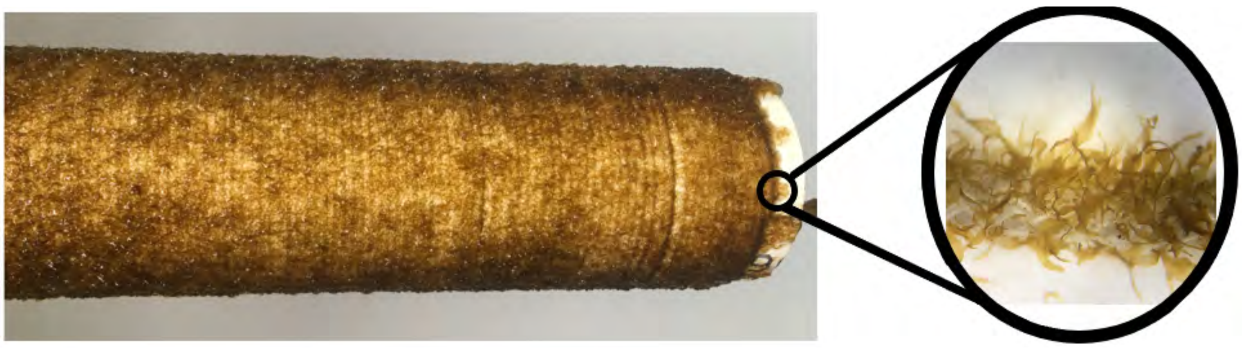


Image 4. Mature sugar kelp on a cultivation line. After outplanting in the fall or winter, kelp will grow rapidly in the spring, and produce spores the following fall.

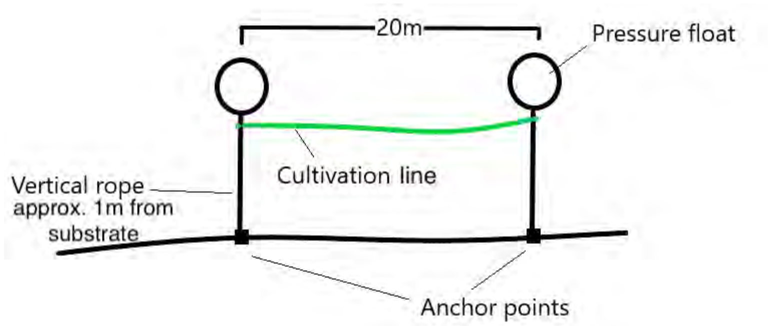


Image 5. Basic cultivation structure for long-line cultivation. Not to scale. Anchor points may be drilled into the rip rap, or may be removable anchors.

Image 6. Seeding the long line structure. The seed spool has been pulled over the long line snap and is about to be unspooled along the cultivation line.

2. Green Gravel

Small, laboratory-produced kelp sporophytes on gravel (Image 7) are deployed directly on/near the rip rap. If the young kelp successfully extend their holdfasts to the new rock structure, the gravel will establish a new population within about 6 months (Fredriksen et. Al. 2020).

Image 7. Small kelp (<1 cm) on gravel in the lab. As kelp mature, stronger individuals will outcompete the others, and one kelp individual will remain per gravel.

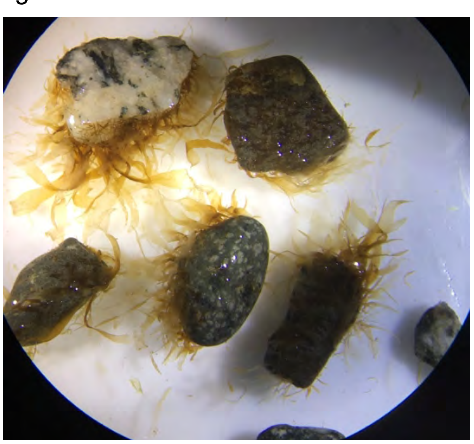
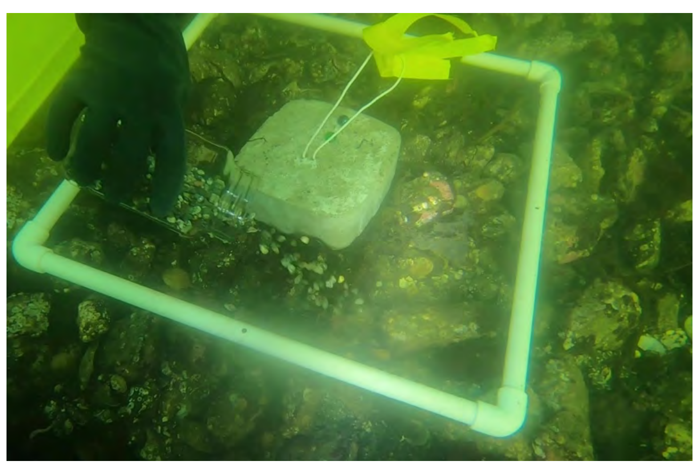


Image 8. A diver deploys green gravel onto small cobble at a test study site.



If the location for deployment can be easily located from the water surface, green gravel may be deployed by sprinkling them from the water surface in a small boat. More precise seeding is done by divers (Image 8). Current recommended density is 400 pieces of gravel/square meter. Gravel is most likely to thrive where it falls among algal turf of bottom irregularities, in areas with low currents. Gravel is unlikely to thrive if it falls into deep, shaded cracks.

3. Adult transplants

Adult, or juvenile kelp are relocated from an established bed to the new location. When they produce spores, these will populate the seafloor around the transplant and give rise to a new bed of kelp near the transplant. (Eger et al. 2022, Layton et al. 2021, North 1976). A source bed is required, preferably near the restoration location to minimise the stress to the kelp during transportation. The ecological impacts on the source bed should be considered. The kelp are detached from the bottom, then either attached to a weight by rubber bands (Layton et al. 2021); or tied by their hold-fast to a float and 0.25 m tether, which is fastened to the bottom in the new location (North 1978). One transplant may seed an area up to 5 m away from the parent Sundene 1962, Dayton 1973, Anderson and North 1966, North 1978, Layton et al. 2021). Approximately 96 kelp individuals would be required to cover the Sterling Shipyard reef, with additional required to replace the kelp that die (one study reported 30% transplant survival rate, Carney et al. 2005). A diver may transplant 50 – 200 small kelp individuals in a day, depending on the method of re-attachment, less than 10 per day for larger, more cumbersome individuals (North 1978). According to one study, the cost of transplants is estimated to be between \$120 - \$200 USD/m^2, requiring multiple plantings to replace transplants that died (Carney et al. 2005).

4. Sori bags

Sori bags are similar to the transplant method, however only the reproductive tissue (sori) are removed from the donor plant and moved to the new location. When the sori release their spores, given appropriate environmental conditions, these will populate the seafloor around the transplant and give rise to a new bed of kelp. (Vasquez and Tala 1995, Choi et al. 2000, Westermeier et al. 2014). As conditions suitable for spore development can vary from week to week, this method requires that every few weeks fresh sori are put into the bag, with the hope that the correct environmental conditions will align with a spore release. As with the transplant method, a porous sack with sori would be required every 5 m in to allow the following generation to evenly seed the substrate (Sundene 1962, Dayton 1973, Anderson and North 1966, North 1978, Layton et al. 2021).

5. Spore gel

Kelp spores are released into tanks on-location and suspended in a water-soluble cellulose gel. The gel is pumped down a hose and applied to substrate. Either divers or an underwater camera are required during deployment (Yotsukura et al. 2021). Kelp spores are applied directly to the substrate in high concentrations. The kelp plants then mature and reproduce as they would be expected to in the wild.

Appendix IV

Log Dump Biophysical Assessment to Inform Habitat Restoration
Keystone Environmental Ltd.

Keystone Environmental
Knowledge-Driven Results

October 31, 2022

Ms. Kate Schendel, M.Sc., P.Ag.
Environmental Specialist, Site Assessment
Vancouver Fraser Port Authority
100 The Point, 999 Canada Place
Vancouver, BC V6C 3T4

Dear Ms. Schendel:

Re: Log Dump Biophysical Assessment to Inform Habitat Restoration
Indian Arm, British Columbia
Keystone Environmental Project No.:17657

We have enclosed the report titled *Log Dump Biophysical Assessment to Inform Habitat Restoration*. We are pleased to submit this report to the Vancouver Fraser Port Authority and appreciate the opportunity in supporting this important project.

If you have any questions, please do not hesitate to contact us.

Sincerely,

Keystone Environmental Ltd.

2022-10-31

Duncan Clark, B.Sc., R.P.Bio.
Senior Marine Biologist / Project Manager

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Keystone Environmental

Knowledge-Driven Results

Log Dump Biophysical Assessment to Inform Habitat Restoration

Indian Arm
British Columbia, Canada

Prepared for: Vancouver Fraser Port Authority

Project No.17657
October 2022

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EXECUTIVE SUMMARY

Keystone Environmental Ltd. was retained by the Vancouver Fraser Port Authority to conduct a feasibility study of the proposed restoration of a former log dump facility in the northern extent of Indian Arm, adjacent to the Indian River Estuary in British Columbia. The site was utilized as a log dump for forestry purposes until 2019 and was identified as a potential area of habitat offsetting that could be utilized to supplement the habitat offsetting plan for another VFPA project, located within Vancouver Harbour.

To inform the study, field assessments were conducted between August 2, 2022 and October 19, 2022 that included SCUBA dive surveys, sediment sampling and laboratory analysis and side scan sonar surveys to map benthic debris and obtain bathymetric information. Based on the results of the assessments, an approximately 3,769 m^2 area within the water lot boundary was identified as feasible for restoration. The size and location of the area was determined based on the presence of anthropogenic debris (e.g., logs, cables, rope, coarse wood waste) and low abundance and diversity of marine organisms.

Restoration of the identified area would involve removal (dredging) of anthropogenic materials to restore the seabed to a more natural state, resulting in an increase in habitat value and biodiversity. Dredging would be conducted by a clamshell dredge, operated from a barge mounted crane, secured using spuds and/or anchors. The dredged material would be deposited onto a scow and towed off-Site for disposal. Disposal options are currently being explored and will be refined in the upcoming months after additional sampling and discussions with regulators.

Mitigation measures are proposed to avoid or mitigate potential effects to fish and fish habitat during the restoration works. The restoration works will be monitored to confirm the effectiveness of mitigation measures and implement adaptive management measures if required. A five-year post-restoration effectiveness monitoring program will be conducted to confirm that biological communities become re-established in the restoration area.

Restoration works would be permitted separately under the VFPA PER process and would be subject to Indigenous consultation.

This Executive Summary is subject to the same general limitations as contained in the report and must be read in conjunction with the entire report.

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1. INTRODUCTION

Keystone Environmental Ltd. (Keystone Environmental) was retained by the Vancouver Fraser Port Authority (VFPA) to conduct a feasibility study of the proposed clean-up of a former log dump facility located in the northern extent of Indian Arm, adjacent to the Indian River Estuary, British Columbia (the Site; **Figures 1 and 2** in **Appendix A**). The Site was identified as a potential area for off-site habitat offsetting, which could be utilized to supplement the habitat offsetting plan for another VFPA project, located in Vancouver Harbour. This report will support a *Fisheries Act* Authorization (FAA) application, including the habitat offsetting plan that is being developed by SNC-Lavalin Inc. (SNC-Lavalin). The potential for the Site as a location for off-site habitat offsetting was identified following feedback from Indigenous Groups during the FAA application consultation phase.

The scope of the Keystone Environmental feasibility study included:

- A desktop review and field visits to provide a description of existing biophysical conditions;
- Collection of sediment samples to inform substrate composition, quality, and the presence and distribution of man-made and debris; and
- Completion of sonar and dive surveys to update the distribution of aquatic debris.

1.1 Site Background

Logging practices occurring at the Indian Arm log dump facility and boom storage date back to approximately 1968 (Cascade Environmental 2013), where significantly large amounts of harvesting took place (M.C. Wright and Associates 2007; EBA Engineering Consultants Ltd. 2007). When BC Timber Sales took over the facility's lease in 1996, the Site was in full operation, watering approximately 121 591 cu/m of wood (M.C. Wright and Associates 2007). On February 6, 2007, a site inspection was conducted, and it was determined that the site was no longer active (EBA Engineering Consultants Ltd. 2007). The site has since been held by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development, who notified the port authority that they no longer needed the lands in 2019, and the site has not been used for forestry purposes since that time. The site is in over-holding, and is considered an orphaned site.

2. METHODS

Keystone Environmental performed a desktop review and a field assessment of the Project footprint to document existing physical and biological conditions.

2.1 Desktop Review

The following available databases and resources were used to support the desktop review:

- BC Biogeoclimatic Ecosystem Classification Program BECweb
- BC Ministry of Environment's (MOE) Fisheries Information Summary System (FISS)
- BC iMap GIS application
- BC Habitat Wizard
- BC Conservation Data Centre (CDC) Species List and Ecosystem Explorer, and Element Occurrence Reports
- Burrard Inlet – Indian Arm Eelgrass Mapping (SeaChange Marine Conservation Society and Tsleil-Waututh Nation 2015)
- Community Mapping Network of BC Atlas Gallery
- Environment Canada Species at Risk Act public species registry

The following historic inspection reports provided by VFPA were reviewed:

- Assessment of Impacts to Subtidal and Intertidal Habitat at the Indian Arm Environmental Exit Audit Sale: ROV Video Survey and Sonar Profiling (M.C. Wright and Associates 2007)
- Environmental Site Inspection, Indian Arm Log Dump Site, Burrard Inlet, BC (EBA Engineering Consultants Ltd. 2007)
- Indian Arm Log Sort, Follow-Up Environmental Site Inspection (Cascade Environmental Resource Group Ltd. 2013)
- Indian Arm Log Dump ROV Inspection (Can-Dive Construction Ltd. 2014)

2.2 Field Visits

The following site visits were conducted by Keystone Environmental to collect the information included in this biophysical survey report:

- August 2 and 3 2022 – dive biophysical assessment survey;
- August 17 and 18, 2022 – sediment sampling;
- August 21, 2022 – benthic debris survey; and
- October 19, 2022 – dive biophysical assessment survey

2.2.1 Dive Biophysical Assessment

A three-person team of WorkSafeBC certified divers who are also marine biologists conducted a marine and foreshore assessment of the Project footprint and the surrounding areas from on

August 2 and 3, and October 19, 2022. The divers conducted seven transects running perpendicular to the shoreline (see **Figure 3** in **Appendix A**) and multiple swims parallel to shore to document conditions. Six transects were located within the water lot and one reference transect was located west of the water lot across the Arm.

Transect lines consisted of sinking rope with markers at 5 m increments. The start and end points of each transect were secured using cinderblock anchors with lines attached to floating buoys with their locations mapped using a handheld GPS unit and referenced to existing shoreline infrastructure. Two biologist divers swam each transect together making two passes. During the first pass one diver filmed underwater video along the transect while the other noted the presence of any mobile organisms (e.g., fish or crabs), transitions in substrate or biota along the transect line and the locations of any notable anthropogenic debris (sunken boats, barges, cables etc.). During the second pass a 1 m^2 quadrat was placed at 5 m increments along the transect line. For each quadrat the following was recorded: depth using a dive computer (gauge depth), the percent coverage of substrate type and sessile organisms, density of infauna species and demersal fish, and any anthropogenic debris.

Transects ranged from 25 m to 100 m in length. Additionally, 11 shallow (i.e., 0.45 m or less) sediment core samples were collected by the divers to determine the presence of wood waste and substrate composition. **Table 1** describes substrate classification utilized for the surveys, while **Table 2** describes the relative abundance categories for observed biota.

Table 1 Substrate Classification (Wentworth, 1922)

Substrate	Diameter (mm)
Silt/Mud/Clay	<0.06
Sand	0.06–2
Gravel	2–64
Cobble	64–256
Boulder	>256 rounded
Bedrock	>256 angular

Table 2 Categorization of Site Relative Organism Abundance

Category	Flora/Sessile Species (Avg. % Coverage within Quadrats)	Motile Species (Total Count along all Transects)	Invertebrate Holes (Avg. Count/ m^2 within Quadrats)
Trace/ Rare	< 5	1	< 1
Sparse	5 – 25	2 – 4	1
Few	25 – 50	5 – 10	2 – 3
Common	51 – 75	11 – 30	4 – 9
Abundant	> 75	> 30	> 10

2.2.2 Sediment sampling

On August 17 and 18 a boat mounted Vibracore and VanVeen sediment grab (Ponar) were used to sample 16 different locations (SD22-1 through to SD22-16) located within the water-lot (**Figure 4, Appendix A**). A Vibracore was used to sample seven of the locations to determine the depth of bark accumulation and sediment chemistry at deeper depths. SD-9 was the only location where a core was successfully recovered due to difficulties with substrate type, slope, and depth. Surface samples (e.g., <0.5 m depth) were collected at each location, except for SD22-2, where no sample could be recovered after multiple attempts.

2.2.3 Benthic Debris Survey

A benthic debris survey was completed on August 21, 2022 using side scan sonar within subtidal portions of the water lot. The scans were conducted using a Ping DSP 3DSS-IDX-450 multi-beam side scan sonar. Data was collected using 450 kHz frequency. The sonar unit was deployed along the portside of the vessel at a fixed depth to gain the greatest image resolution. For each pass. The vessel's operator maintained a fixed speed between 2 and 4 knots and maintained a straight heading, while the sonar technician monitored for debris. Several passes were done within the water lot. Image capturing was completed in the Ping 3DSS software, while the imaging processing was completed on HyPack (**Figure 5**).

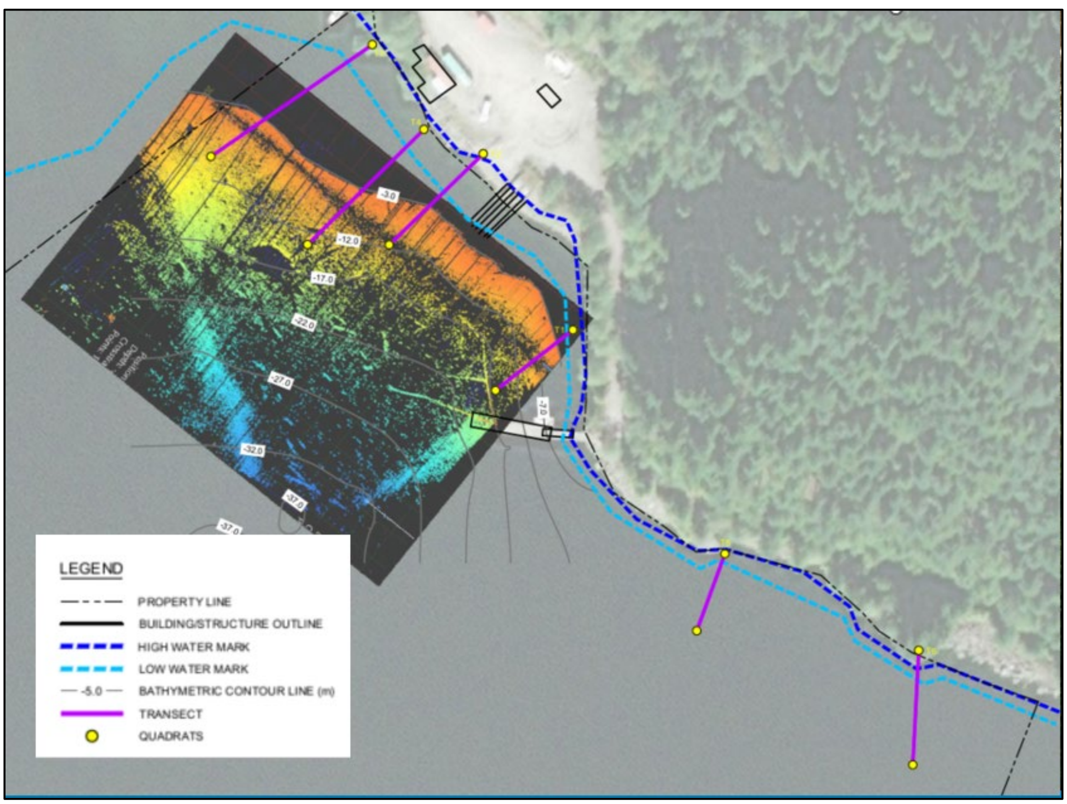

Figure 5. Indian Arm log dump site overview illustrating benthic sonar survey area.

3. DESCRIPTION OF FISH AND FISH HABITAT

3.1 Desktop Review

3.1.1 Climate

The Site is located within the Coastal Western Hemlock dry maritime (CWHdm) biogeoclimatic zone of British Columbia. This biogeoclimatic zone occurs in low to middle elevations (i.e., sea level to approximately 900 m) along British Columbia coasts and is characterized by high levels of annual precipitation and temperate weather conditions (BGCmap 2018). Vegetation typically includes a well-formed canopy layer dominated by western hemlock (*Tsuga heterophylla*) interspersed with western redcedar *(Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii*), as well as a sparse to moderately developed shrub and herb layer typified by *Vaccinium* species.

Climate normals from 1981 to 2010 for the Burnaby Simon Fraser U Station located within 20 km of the Site provided by Environment and Climate Change Canada (2022) show that the average temperature ranged from 3.6 to 17.2°C, with extreme values of -19.4°C (December 29, 1968) and 34.5°C (September 3, 1988). Total annual precipitation averaged 2,010 mm, with the bulk of the precipitation (1,052 mm) received between October and January.

3.1.2 Oceanography

The Site is in the upper portion of the Indian Arm fjord, approximately 18 km from Burrard Inlet and immediately south of the Indian River estuary. Indian Arm experiences mixed, mainly semidiurnal tides, with strong declinational variation over 2 weeks (Thomson 1981). The mean tidal range is approximately 3.3 m and the spring tidal range is approximately 4.9 m (Thomson 1981).

Indian Arm receives large amounts of freshwater inputs from various sources such as the Indian River, numerous small peripheral streams, Buntzen Powerhouse #1 and #2 (via controlled amounts of freshwater discharge from Buntzen Lake) and direct precipitation (Davidson 1979; Thomson 1981). Although salinity and temperature vary seasonally within inlets along the coast, Indian Arm experiences primarily a two-layer structure with low-salinity water in approximately the top 5 m overlying more saline water at depths (Davidson 1979; Thomson 1981). In addition, the bathymetry at the south end of the Indian Arm is composed of broad sill-like shallows, which further restricts large exchange of salt water with Burrard Inlet (Thomson 1981). Therefore, the primary form of circulation consists of a surface outflow of brackish water driven by freshwater accumulation in the basin and the inflow of salty water at depths. The surface currents in Indian Arm are primarily southwards, but of variable strengths depending on quantity of freshwater inputs, strength of winds, and tides (ebb or flood).

3.1.3 Marine Vegetation

Marine vegetation is a critical ecosystem component, contributing to the oceanic carbon cycle, and providing food and cover (including protection for juvenile fish from predators). The BC Eelgrass Inventory Application (Community Mapping Network 2022) was used to identify known eelgrass habitat within proximity to the Site. The web application did not yield any known eelgrass beds within Indian Arm, however, traditional knowledge records indicate that eelgrass was present historically in the general vicinity of the Indian River esturay (SeaChange Marine Conservation Society and Tsleil-Waututh Nation 2015).

Similarly, the web application was used to identify known kelp bed occurences within the vicinity of the Site and the Site itself. Kelp beds are also known as highly diverse and productive environments for juvenile fish species with significant importance to the Pacific herring who deposit their eggs on the plants. Kelp grows on hard substrates in the lower intertidal and shallow subtidal zones. There are no known kelp beds situated within the vicinity of Site or the Site itself.

3.1.4 Marine Fish

The following fish species in **Table 3** have been recorded at and within 1 km of the Site. Databases reviewed included the Fisheries Inventory Data Queries (British Columbia Ministry of Environment 2022a) and Habitat Wizard (British Columbia Ministry of Environment 2022b). A more detailed analysis of fish species at risk is discussed in Section 3.1.6.

Table 3 Fish Species with Potential to Occur within 1 km of the Site

Type	Common Name	Scientific Name
Anadromous	Coho salmon	*Oncorhynchus kisutch*
	Chinook salmon	*Oncorhynchus tshawytscha*
	Pink salmon	*Oncorhynchus gorbuscha*
	Sockeye salmon	*Oncorhynchus nerka*
	Chum salmon	*Oncorhynchus keta*
	Rainbow trout/steelhead	*Oncorhynchus mykiss*
	Cutthroat trout	*Oncorhynchus clarkia*
	Bull trout	*Salvelinus confluentus*
	Dolly varden	*Salvelinus malma*
	Shiner Perch	*Cymatogaster aggregate*
	Surf smelt	*Hypomesus pretiosus*
Demersal	English sole	*Parophrys vetulus*
	Rockfish	*Genus Sebastes*
	Pacific Sanddab	*Citharichthys sordidus*
	Starry flounder	*Platichthys stellatus*
	Longspine thornyhead	*Sebastolobus altivelis*
	Surf smelt	*Hypomesus pretiosus*
	Sculpin spp.	Cottidae

3.1.5 Marine Mammals

The most abundant marine mammal in Burrard Inlet and Indian Arm is the Harbour seal (*Phoca vitulina*) (Butler et al 2015). However, few observations have been made in the northernmost reach of the Indian Arm in proximity to the Site. Transient and resident populations of Killer whales (*Orcinus orca*), Grey whales (*Eschrichtius robustus*), and Harbour porpoises (*Phocoena vomerina*) periodically enter Burrard Inlet and Indian Arm.

3.1.6 Listed Species at Risk

The BC Conservation Data Centre (British Columbia Ministry of Environment 2022c) database was queried for known occurrences of rare and endangered species within two kilometres of the Site; the search did not yield any known occurrences of provincially or federally listed aquatic species.

Based on Biological Resources – Marine Mammals on BC iMap, DFO aquatic species at risk map, habitat profiles, and known catches of fish and invertebrate species, the identified species at risk with potential to occur within the vicinity of the Site are summarized below in **Table 4.**

The Site has not been identified as critical habitat for marine species at risk (Fisheries and Oceans Canada 2022; Fisheries and Oceans Canada 2018).

3.2 Biophysical Assessment Results

3.2.1 Substrate Conditions

Substrate conditions within the area of Transects 1, 2, 3 and 4 (**Figure 3**) consisted of a riprap armoured intertidal shoreline, transitioning to a mixture of cobble and gravel in the lower intertidal zone (**Photographs 1, 2,** and **3)**. Silt to silty sand substrate was observed within the lower intertidal and shallow subtidal zones, extending to deeper depths (**Photographs 4, 5** and **6**). Sand substrate extended higher in the intertidal zone along Transect 3 (e.g., to an elevation of +2 m chart datum). In general, the substrate within the subtidal zone along Transect 3 had a higher sand content (silty sand) compared to the silt substrate observed within the subtidal zone in the areas of Transects 1, 2, and 4. A gravel/ cobble barge ramp was present near Transect 2 (**Photograph 1**).

The shoreline near the site access dock was relatively steep and gradually became flatter moving northwest towards the estuary. Slopes observed at Transect 1, Transect 2, Transect 4 and Transect 3 were 53%, 35%, 29% and 23% respectively. South of Transect 1, the substrate transitioned to a steeper bedrock and boulder shoreline throughout the intertidal and subtidal zones, which continued south of the existing site access dock, past Transects 5 and 6 (**Photograph 7**). Sediment cores were collected from 4 of the 6 transects that were located within the water lot (transects 1 through 4). No hand cores could be collected from either Transect 5 or Transect 6 due to the presence of bedrock or boulder substrate. The north-western section of the water lot (Transect 3) was the only transect where hand cores contained no visible wood debris (**Photograph 8**). Hand cores collected from Transects 1, 2 and 4 contained wood debris with a thin layer of silt at the surface (**Photographs 9** and **10**).

Table 4 Species at Risk with Potential to Occur at the Site (Fisheries and Oceans Canada 2022)

Species at Risk	Scientific Name	BC List Status[1]	SARA List Status[2]	COSEWIC Status	Habitat	Likelihood of Occurence at Site
Marine Fish and Invertebrate Species						
Longspine Thornyhead	*Sebastolobus altivelis*	No Status	Special Concern	Special Concern	Prefer soft sand or mud substrate in deep waters (e.g., below 370 m) characterized by low productivity, high pressure and reduced oxygen.	Low probability of being present within the shallow waters, unsuitable substrate and build-up of wood waste present on Site.
Yelloweye Rockfish	*Sebastes ruberrimus*	No Status	Special Concern	Threatened	Known to occupy near shore rocky reef waters within the Strait of Georgia	Low probability of being present within the shallow waters, unsuitable substrate and build-up of wood waste present on Site.
Rougheye Rockfish type I / type II	*Sebastes sp. Type I / Type II*	Blue	Special Concern	Special Concern	Commonly occur on the sea floor (water depths of 170 – 660 m) with soft substates in areas with frequent boulders and on slopes greater than 20 degrees.	Low probability of being present within the shallow waters, unsuitable substrate and build-up of wood waste present on Site.
Northern Abalone	*Haliotis kamtschatkana*	Red	Endangered	Endangered	Occur on rocks along exposed and semi-exposed coastlines, typically within 10 m of surface.	Low probability of being present at Site. Suitable substrate and biota habitat are not present on Site.
Marine Mammal Species						
Grey Whale	*Eschrichtius robustus*	Blue	Special Concern	Special Concern	Typically occur in shallow coastal waters in the North Pacific Ocean. However, during migration, they do tend to cross deep waters far from shore	Low probability of being present within vicinity the Site. Unlikely to be found at the Site.

Species at Risk	Scientific Name	BC List Status[1]	SARA List Status[2]	COSEWIC Status	Habitat	Likelihood of Occurence at Site
Northeast Pacific transient population Killer Whale	*Orcinus orca*	Red	Threatened	Threatened	Habitat within 5.4km of the coastline is considered necessary for feeding.	Low probability of being present within vicinity the Site. Unlikely to be found at the Site.
Northeast Pacific southern resident Killer Whale	*Orcinus orca*	Red	Endangered	Endangered	Habitat within 5.4km of the coastline is considered necessary for feeding.	Low probability of being present within vicinity the Site. Unlikely to be found at the Site.
Harbour Porpoise	*Phocoena*	Blue	Special Concern	Special Concern	Known to occupy deep BC waters exceeding 200 m. Identified deep water habitat includes the Strait of Georgia	Low probability of being present within vicinity the Site. Unlikely to be found at the Site.
Humpback Whale	*Megaptera novaeangliae*	Blue	Special Concern	Special Concern	Northern feeding grounds in the summer – typically follow coastline.	Low probability of being present within vicinity the Site. Unlikely to be found at the Site.
Leatherback Sea Turtle	*Dermochelys coriacea*	No Status	Endangered	Endangered	Prefer deep waters in the daytime and shallow waters during the night. Rarely occur in Canadian pacific waters, with only 126 sightings in BC waters from 1931 to 2009.	Low probability of being present within vicinity the Site and on Site.

[1]BC Conservation Data Centre listing: Red is the provincial equivalent of the federal Endangered and Threatened categories; Blue is equivalent to Special Concern; Yellow indicates not at risk
[2]SARA Listed Schedule 1

The sonar survey and underwater transect surveys showed that most of the benthic debris was in Area A (**Figure 3**), between transect 1 and just north of transect 4 and was composed of silt and wood waste (logs and bark) in relatively high concentrations throughout the area with some anthropogenic debris (**Photographs 6, 11,** and **12**). The area from the north edge of the water lot to just south of transect 3 was found to have relatively low concentrations of wood waste. In general, minimal bark, wood waste debris and anthropogenic materials (e.g., metal, cables, rope) were observed within the intertidal zone. Steel log skids were observed south of the barge ramp, along with a short section of a steel and timber retaining wall to the north of the barge ramp (**Photograph 1**).

3.2.2 Sediment Chemistry

Fifteen sediment samples were collected within the water lot (**Figure 4**); a surface sample could not be collected at location SD22-2 as planned. On average, the samples consisted of 7% gravel, 35% sand, 35% silt, and 25% clay. All samples exceeded Environment and Climate Change Canada's Disposal at Sea criteria for copper. Additional exceedances of Disposal at Sea criteria for cadmium and arsenic were also found. In general, the exceedances within the northern half of the site (SD22-1, and SD22-3 through SD22-8) had lower concentrations than the southern half of the site (SD22-9 through SD22-16) as shown on **Figure 4**. Copper concentrations were between 23.7 mg/L and 39.3 mg/L in the north compared to between 25.1 mg/L and 197 mg/L in the south. The northern half of the site had only two cadmium exceedances at SD22-7 and SD22-8, while the southern half of the site had cadmium exceedances at all locations, in addition to two arsenic exceedances.

A composite sediment sample consisting of SD22-1, and SD22-3 through SD22-8 was submitted for Tier II testing consisting of the following:

- 10-day amphipod: Environment Canada (1998), EPS 1/RM/35;
- Echinoderm larval development: Environment Canada (2014), EPS 1/RM/58; and
- Solid-phase Microtox: Environment Canada (2002), EPS 1/RM/42.

Additional sediment sampling within Area A is planned to delineate areas where disposal at sea criteria were exceeded and determine disposal options for dredged material. This includes drilling to determine the depth of existing wood waste accumulation over top of native substrate. Discussions with Environment and Climate Change Canada are ongoing to determine which areas will be suitable for disposal at sea.

3.2.3 Biological Conditions

In general, the abundance and diversity of biota within Area A (**Figure 3**) was low. Vegetation was limited to few diatoms and no sensitive vegetation (e.g., eelgrass or kelp) was observed. Barnacles (*Balanus glandula)* and mussels (*Mytilus trossulus*) were few and sparse respectively and were observed primarily within the riprap, cobble and gravel intertidal areas. Invertebrate holes or clam siphons were rare. Shore crabs (*Hemigraspus spp.*) were the most abundant invertebrate species observed primarily within the intertidal and shallow subtidal areas. Dungeness crab (*Metacarcinus magister*) and California sea cucumbers (*Parastichopus* *californicus*) were sparse and few in abundance respectively. A patchy distribution of Beggiatoa bacteria was observed on the surface of the seabed within Area A, which is an indicator of areas where there are significant levels of wood debris buried in sediments (Elliott et. al. 2006).

Observed finfish included copper rockfish (*Sebastes caurinus*), pile perch (*Rhacochilus vacca*), shiner perch (*Cymatogaster aggregata*), striped perch (*Embiotoca lateralis*), sculpin, sole (*Pleuronichthys coenosus*), and black-eye goby (*Rhinogobiops nicholsii*).

A greater diversity of clam siphons and benthic invertebrate holes and mounds were found to the north of Area A, along Transect 3.

Table 5 List of Marine Species Observed within Area A (Figure 3)

Common Name	Scientific Name	Abundance	Elevation metres Chart Datum	
			Upper	Lower
Vegetation				
Diatoms	*Bacillariophyta*	few	-0.4	-3.2
Sessile Invertebrates				
Hydroids	Unidentified hydrozoan *spp.*	Trace	-9.4	-9.4
Barnacles	*Balanus glandula*	Few	3.6	-0.4
Pacific blue mussel	*Mytilus trossulus*	Sparse	3.1	1.7
Clam holes, mounds	Unidentified bivalves	Rare	-2.5	-7.3
Horse clam	*Tresus sp.*	Rare	-1.2	-2.4
Mobile Invertebrates				
California sea cucumber	*Parastichopus californicus*	few	-4.7	-12.3
Shore crab	*Hemigraspus spp.*	Abundant	1.2	-2.4
Dungeness crab	*Metacarcinus magister*	sparse	-1.2	-6.7
Chiton	*Tonicella spp.*	sparse	0.2	-3.2
Fish (pelagic)				
Copper rockfish	*Sebastes caurinus*	Common	-3.2	-12.3
Pile perch	*Rhacochilus vacca*	few	3.1	-1.6
Sculpin	*Unidentified spp.*	few	1.0	0.4
Shiner perch	*Cymatogaster aggregata*	Rare	-11.3	-11.3
Striped perch	*Embiotoca lateralis*	Common	1.0	-12.3
Juvenile sole	*Pleuronichthys coenosus*	Sparse	-1.2	-6.7
Black eye goby	*Rhinogobiops nicholsii*	Few	-12.3	-12.3

4. DETERMINATION OF POTENTIAL RESTORATION AREA

Wood waste in marine environments is different from naturally occurring large woody debris and elevated quantities of wood waste have been shown to negatively affect benthic and epi-benthic biota, resulting in a reduction in the diversity of benthic invertebrate communities (Breems and Goodman 2009). These negative effects are caused by physical alteration of sediment characteristics, acute toxicity through the production of leachate and long-term toxicity associated with the anaerobic decomposition of wood waste (Breems and Goodman 2009).

As outlined in Section 3.2, the majority of wood waste and anthropogenic debris were observed between Transect 1 and Transect 3. Minimal wood waste was observed along Transect 3 and a higher abundance of clam siphons and invertebrates holes were also observed within the sediment, indicative of a more abundant benthic invertebrate population. The substrate south of Transect 1 consisted of a mixture of bedrock and large boulders with minimal woody debris observed.

Based on the findings of the biophysical assessment and the limitations associated with dredging at deeper depths, approximately 3,769 m^2 (Area A; **Figure 3**) has been identified as feasible for restoration, which would involve the removal of wood waste and anthropogenic debris associated with the former log dump operation to restore the seabed to a more natural state and increase biodiversity of the benthic environment.

5. RESTORATION METHODOLOGY

The restoration would involve removal of materials using a clamshell dredge (i.e., a crane fitted with a clamshell bucket) situated on a barge, secured in position using spuds and/ or anchors. The dredge material would be placed onto a scow and towed to an off-Site disposal location using a tugboat. Disposal options are currently being investigated and may include either Disposal at Sea and/ or upland disposal.

All restoration works would be conducted from the water and no equipment access to upland areas is anticipated to be required.

6. POTENTIAL EFFECTS ON FISH AND FISH HABITAT

Based on the project description provided in Sections 4 and 5 and the environmental conditions identified in Section 3, Keystone Environmental completed an analysis to identify potential effects to fish and fish habitat, marine mammals, and aquatic species at risk. The following DFO Pathways of Effects diagrams[1] for common in-water activities were considered when identifying the potential effects of the project: Dredging and Use of Industrial Equipment. Note that the potential effects listed here are without the implementation of mitigation measures, which are described in Section 7. Potential effects to fish and fish habitat from the restoration works may include:

- Potential mortality of fish/ eggs from equipment due to direct physical disruption from operation of equipment and dredging. The risk is greater for low mobility organisms such as sea stars as opposed to finfish or crabs that are more likely to move outside of the work area. In general, the biodiversity and abundance of organisms within the proposed restoration area is low.
- Injury to marine mammals because of physical harm from direct contact with equipment (e.g., clamshell bucket, barges, scows, tug boats).
- Temporary change in sediment concentrations within the marine environment due to dredging causing suspension or resuspension of sediments resulting in:
  - Decreased water quality.
  - Reduction in visibility and damage to fish gills.
- Temporary change in contaminant concentrations from heavy machinery during works that could impact marine aquatic species. Examples include but are not limited to refuelling of equipment and failure or leaks from hydraulic lines. Effects can include:
  - Direct mortality of organisms; and
  - Bioaccumulation of contaminates in fish, resulting in deformities, alterations in growth, reproductive success and competitive abilities and a loss/ reduction of food supply.
- Change in habitat structure due to dredging. This would be considered a permanent positive change.

Mitigation measures to reduce potentially harmful effects are described in Section 7.

[1] http://www.dfo-mpo.gc.ca/pnw-ppe/pathways-sequences/index-eng.html

7. MEASURES AND STANDARDS TO AVOID OR MITIGATE HARMFUL IMPACTS TO FISH AND FISH HABITAT

The following measures will be implemented during the restoration works to reduce the potential negative effects to fish and fish habitat described in Section 6.

7.1 Avoidance Measures

- The restoration works will be conducted within the timing window for the protection of fish and fish habitat, Area 28 – Vancouver, Burrard Inlet (inland from Point Grey to Point Atkinson): August 16 – February 28[2].
- An efficient and experienced contractor will be selected to complete the dredging to minimize the duration of the project and associated temporary effects.
- Implement ramp up procedures during clamshell dredging to allow for fish to vacate the area prior to the start of normal operations. Ramp up will involve initially placing the bucket down to discourage fish presence, then wait 30 seconds and repeat the process prior to dredging. The ramp up will be conducted each time there is a break of 30 minutes in dredging. Fish are expected to avoid the dredge area after equipment ramp-up is initiated.
- Position barges and other vessels in a manner that reduces disturbances to the foreshore. With the exception of barge spuds or anchors, equipment will not be permitted to rest on the seabed.

7.2 Industrial Equipment Usage

- Operation of marine equipment will be from a floating platform (i.e., barge). There will not be any operation of machinery on land or within the intertidal zone.
- The limits of the restoration area will be clearly identified in the field and disturbance of the marine environment outside of this area will be avoided.
- Equipment (e.g., cranes, excavators, power tools) used in and around water will be kept clean and in good working condition (e.g., free of leaks, excess oil, and grease).
- Biodegradable hydraulic fluid will be used in hydraulic components of equipment where that option is feasible according to equipment manufacturer specifications.
- Vessels associated with the project works will not intentionally approach within 100 m of solitary whales, porpoises or dolphins, or within 200 m of these organisms when with a calf or calves, or within 200 m of a Killer whale. If one of these organisms comes within the setback distance, vessel operators will immediately reduce speed, and cautiously change course to avoid them.
- If there is a risk of harm to a marine mammal from direct contact with vessels or equipment, works will be temporarily suspended until there is no longer a risk of harm from direct contact.
- In the event of a marine mammal in distress, a marine mammal vessel strike, or a fish kill VFPA will report the information upon receipt to the DFO Observe, Record and Report 24-hour

[2] https://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/bc-s-eng.html#area-28

hotline at 1.800.465.4336. The information will also be reported to Tsleil-Waututh Nation. Collisions with marine mammals will also be reported to the Canadian Coast Guard within two hours of collision occurrence.

7.3 Changes in Water Quality

- Anthropogenic debris, waste or other miscellaneous materials removed from the marine environment will be contained for disposal at a designated facility.
- An appropriately qualified environmental monitor will be retained to conduct water quality monitoring during dredging. During water quality monitoring, water quality measurements will be collected by the environmental monitor prior to the start of works each day and a minimum of approximately every 2 hours during in-water works. The monitoring frequency can be adjusted at the discretion of a qualified professional as part of adaptive management.
- During Project works the contractor will be required to maintain water quality criteria from the Canadian Water Quality Guidelines for the Protection of Aquatic Life outlined in **Table 6**.

Table 6 Water Quality Criteria for Evaluating Project Works

Water Body	Turbidity[1]	pH[2]
Marine	Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period) during clear flows or in clear waters Maximum average increase of 2 NTUs from background levels for a longer term exposure (e.g., 30-d period) during clear flows or in clear waters Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 and 80 NTUs Should not increase more than 10% of background levels when background is > 80 NTUs	7.0 to 8.7

Table Notes
[1] Criteria obtained from the Canadian Water Quality Guidelines for the Protection of Aquatic Life: Total Particulate Matter. Canadian Council of Ministers of the Environment 2002.
[2] Criteria obtained from the Canadian Water Quality Guidelines for the Protection of Aquatic Life: pH (marine). Canadian Council of Ministers of the Environment 1999.

- Water quality samples will be collected at multiple stations within the work area and a background reference that is at a suitable distance from the work area such it is not influenced by Project works, as determined by the environmental monitor. The sample stations will include:
  - Warning station(s) located within 25 m of the dredging;
  - Compliance station(s) located within 50 m of the dredging; and
  - Compliance station(s) located within 20 m of a silt curtain if one is deployed.
- Water quality measurements will be collected at two to three evenly spaced depths (tide dependent) through the water column at each station:
  - One metre (1 m) below the water surface;

  - Mid-water column; and
  - One to two metres (1–2 m) above the seabed.
- If water quality data exceed criteria (Table 6) at the warning station(s), the environmental monitor will advise the contractor, so they may consider adaptive measures as required to prevent exceedances at the compliance station(s).
- If water quality data exceed regulatory criteria at one or more compliance stations at any point, the environmental monitor will advise the Contractor that work must stop, and adaptive measures be implemented by the contractor to address the issue(s). Work may resume when water quality returns to below the criteria in Table 6.

- Adaptive management measures may include reducing dredge cycle times, allowing water to drain from the clamshell bucket before moving to deposit material on a scow, or the installation of a silt curtain to contain turbidity within the dredge area.

7.4 Changes in Contamination Concentrations

Spill Prevention

The following measures shall be applied by the contractor throughout project in order to help prevent an environmental incident related to a spill from occurring:

- Equipment will be kept clean and in good working condition (e.g., free of leaks, excess oil, and grease). At a minimum, daily inspections of heavy equipment must be conducted by the contractor and documented.
- Equipment refuelling and servicing will not be conducted onsite, unless a plan is in place that includes containment to collect any potentially spilled fuel or oil.
- A minimum of one of the contractors' staff, trained in spill response and the specifics of the contractors' Spill Response Plan will be onsite at all times.
- Drip trays will be used under stationary equipment.
- If fuel and other hazardous material is stored on vessels, secondary containment must be in place.
- A spill containment kit will be accessible onsite and in each piece of equipment.

Spill Response

The contractor will develop a Site-specific Spill Response Plan for the project to be approved by VFPA prior to commencement of the work. The plan will be based on the type and quantities of potentially deleterious substances being used, will identify potential risks (particularly with respect to spills to the marine environment) and will outline procedures to facilitate rapid deployment of resources in the event of a spill to minimize the impact and risk to the environment, the public and personnel on-site. The plan will also address machinery and equipment fuelling and servicing and spill response supplies to be kept on-site as well as roles and responsibilities and notification and reporting procedures for spills. Used spill response materials and/or contaminated soils will be disposed of at a registered, licensed waste disposal facility.

Spill Reporting

All spills and environmental incidents on water or land will be immediately reported to VFPA. All reportable spills will be reported by VFPA to Emergency Management BC (EMBC) by calling 1-800-663-3456. All spills into a water body are reportable and will require notification to DFO, Violations and Reporting at 604-666-3500 in addition to EMBC. Tsleil-Waututh Nation will also be notified of the spills as soon as possible. A spill is reportable under legislation if an actual or potential contravention of a permit/approval condition occurs and/or if the volume of a substance spilled, or likely to be spilled is equal to or greater than the minimum quantity outlined in the BC Spill Reporting Regulation or if the spill of a listed substance enters, or is likely to enter a body of water. Following the spill event, the contractor shall complete an Environmental Incident Report as soon as possible within a time period agreed to by VFPA. The report shall include the following information:

- Name and contact details of the individual reporting the spill, witnesses to the spill event, the individual who caused the spill and who the spill was reported to.
- The location of the spill and the area impacted.
- The type/composition of substance released.
- The volume of substance released.
- What happened to cause the spill and why.
- The immediate action taken to manage the spill including the type of spill response material used and the PPE used.
- The quantity of used spill material, how it will be stored and disposed of offsite.
- The follow up actions taken to prevent recurrence and key lessons identified from the incident.
- Photos of the spill, prior to clean up and after clean-up.

7.5 Environmental Monitoring

An environmental monitor will monitor the restoration works to confirm the conditions of environmental approvals are being met. Full-time monitoring will be required during all dredging works. Monitoring measures will include, but will not be limited to:

- Attending a kick-off meeting with the construction crew prior to commencement of the works to review environmental requirements and expectations on the project.
- Visual inspections of equipment and site cleanliness.
- Assessing the adequacy of on-site fuel storage and transfer procedures, as well as on-site spill response equipment and procedures.
- Documenting visual observations for the presence of fish and marine mammals.

- If injured or dead fish and/or marine mammals are observed in the project area, stop works to assess the need for adaptive strategies to prevent further harmful impacts.
- Collecting water quality samples at multiple stations around the work area and at a reference location that is located at a suitable distance from the work area as determined by the Environmental Monitor to document the size and duration of the sediment plume associated with dredging and confirm water quality meets the conditions of Section 7.3.
- A summary environmental monitoring report will be prepared within 60 days of the completion of restoration works. The report will detail the in-water works conducted, timing of these works, total in-water area directly affected, frequency of the monitoring, confirm if there was non-compliance observed or reported with approval terms and a description of these incidents, methods used to determine risk of project works to fish and fish habitat, and recommendations to the contractor for further Site-specific mitigation factors.

7.6 Contingency Measures

If the avoidance and mitigation measures outlined above are found to be insufficient to prevent harmful effects to fish or fish habitat, the following contingency measures will be implemented:

- The environmental monitor will require works to stop until a suitable strategy to address the issues is implemented by the contractor. This may include the installation of a silt curtain to address water quality issues.
- Works may be completed during different tide conditions or with different transfer techniques if issues with turbidity are identified by the environmental monitor.

8. POST-RESTORATION EFFECTIVENESS MONITORING

Monitoring is required to assess the effectiveness of the removal of wood waste and the recovery of the benthic invertebrate population within the restoration area. An as-built survey will be conducted following the completion of restoration works to confirm that wood waste and other anthropogenic debris were successfully removed from the restoration area and to document any adjustments made during dredging.

Effectiveness monitoring will be conducted following the completion of restoration works and over a period of five years thereafter in years 1, 2, 3, and 5 post-restoration. Reports will be produced for each post-restoration monitoring event. The restoration area will be evaluated based on performance criteria established at a reference area or areas in close proximity to the site. The location(s) of the reference site(s) will be determined after the completion of the restoration works, during the first effectiveness monitoring assessment.

During each monitoring visit, the restoration area and nearby reference site(s) will be surveyed by a professional biologist (R.P.Bio.) using a dive team and/or with a drop camera to document substrate conditions, coverage of marine vegetation, species diversity and relative abundance of infaunal and fish species. This will include collecting information through transect and quadrat surveys to document existing conditions. Sediment samples will be collected by divers or ponar and processed through a 2 mm screen to remove large debris and a 0.5 mm screen to collect samples, which will be analyzed in a biological laboratory for benthic invertebrate taxonomic composition (down to the lowest practical taxonomic level) and abundance. Evaluation will be conducted using the following criteria to determine if the restoration works have been successful:

- The restoration area remains free from wood waste; and
- The restoration area will be compared to a suitable reference site(s) with the target of at least 80% abundance and biodiversity of benthic and epibenthic biota after five years relative to the reference site(s). Each year of effectiveness monitoring should demonstrate an increase in abundance and diversity or marine organisms within the restoration area from the previous year.

Finfish surveys are not proposed as the success of the restoration area will be linked to the recovery of the benthic and epibenthic populations. However, fin fish observations will be recorded during the monitoring events as additional information.

8.1 Contingency Measures

If the restoration is not on track to meet performance targets within by year 3, this will be reported to DFO and VFPA. An assessment by a qualified professional will be conducted to determine why the habitat is not functioning as intended. If there is a feasible option that can be accommodated to alter the habitat to meet performance targets this would be implemented. Examples may include placement of an enhancement sand layer or seeding sediments with invertebrate communities if natural colonization is not observed. The success of the option would be evaluated in year 5.

9. CONCLUSION

Based on the results of the biophysical assessment and the limitations associated with dredging at deeper depths, an area of 3,789 m^2 has been identified as suitable for restoration. Restoration will involve the removal of wood waste and anthropogenic debris to restore the seabed to a more natural state and allow the recovery of the benthic and epibenthic biological community over time. Removal of wood waste would be completed using a clamshell dredge operated from a marine barge. Removed wood waste and anthropogenic materials would be placed onto a scow or barge and towed off-site for disposal. Disposal options may include either disposal at sea under a permit from Environment and Climate Change Canada, upland disposal, or a combination of the two. Disposal options are currently being explored and will be refined in the coming months after additional sediment sampling and drilling to determine the depth of wood waste accumulation.

The effectiveness of the restoration works will be evaluated during a five year post-restoration monitoring program with assessments completed in year 1, year three and year five. If after year five, performance criteria are not being met, contingency measured may be considered. The restoration works will be utilized as habitat offsetting to supplement the habitat offsetting plan for another VFPA project, located within Vancouver Harbour, but will be permitted separately under the VFPA PER process, and will be subject to Indigenous consultation.

10. LIMITATIONS

This report has been prepared and reviewed by Keystone Environmental approved personnel who have the credentials and knowledge of the applicable public laws, regulations, and/or policies which apply to this report. The finding of this report only pertain to the scope of work provided by Vancouver Fraser Port Authority. Any use, reliance or decisions made based on this report by other parties without prior written approval by Keystone Environmental Ltd. are the responsibility of such parties and Keystone Environmental Ltd. accepts no responsibility for damages, if any, suffered by other parties because of decisions made or actions based on this report. The report was written by Stefania Custeau, B.Sc. R.B.Tech., Mitchell Hewitt, B.Sc. B.I.T., and reviewed by Duncan Clark R.P.Bio. Duncan Clark is the Professional of Record.

Sincerely,

Keystone Environmental Ltd.

2022-10-31

Duncan Clark, B.Sc., R.P.Bio.
Senior Marine Biologist / Project Manager

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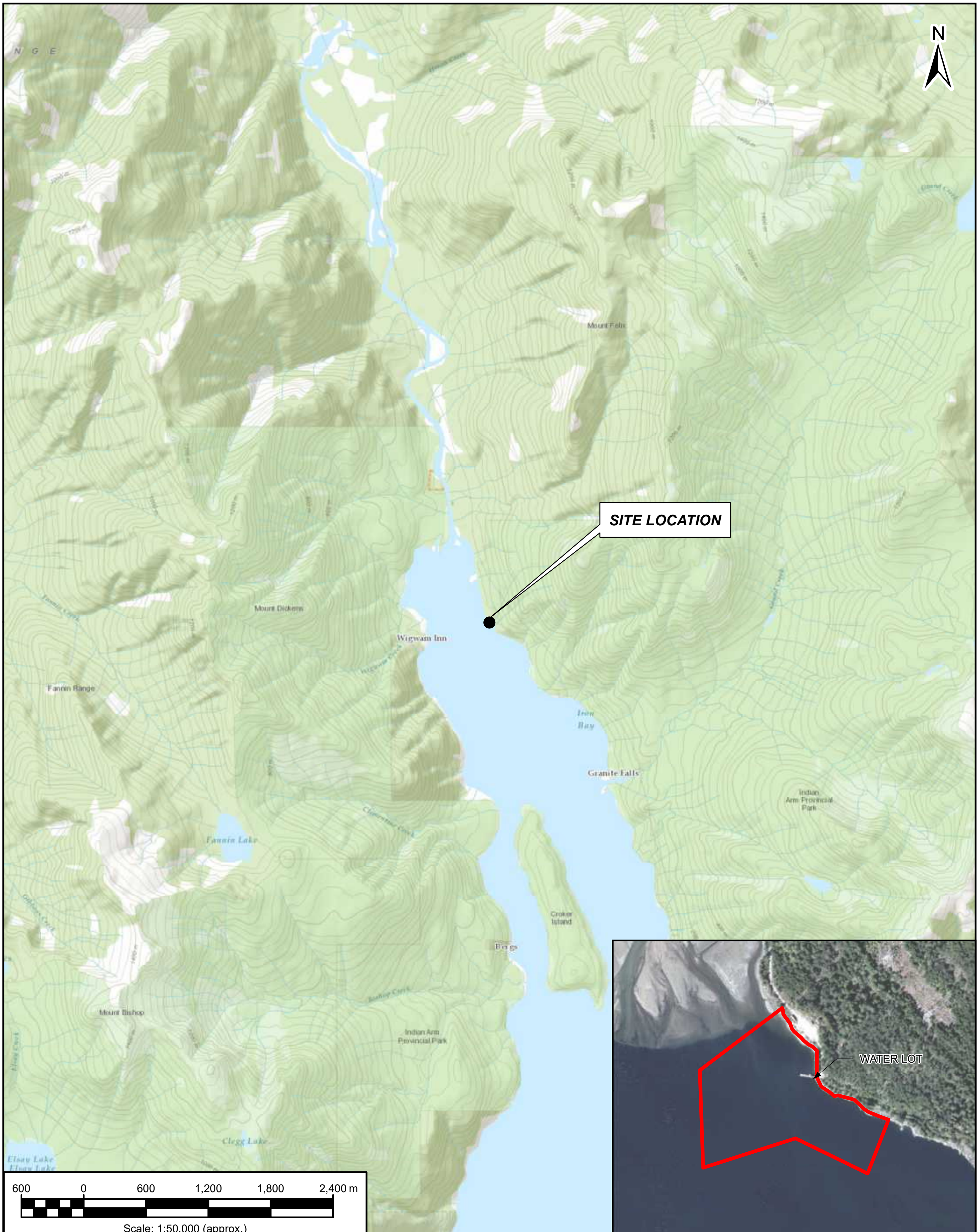
APPENDIX A

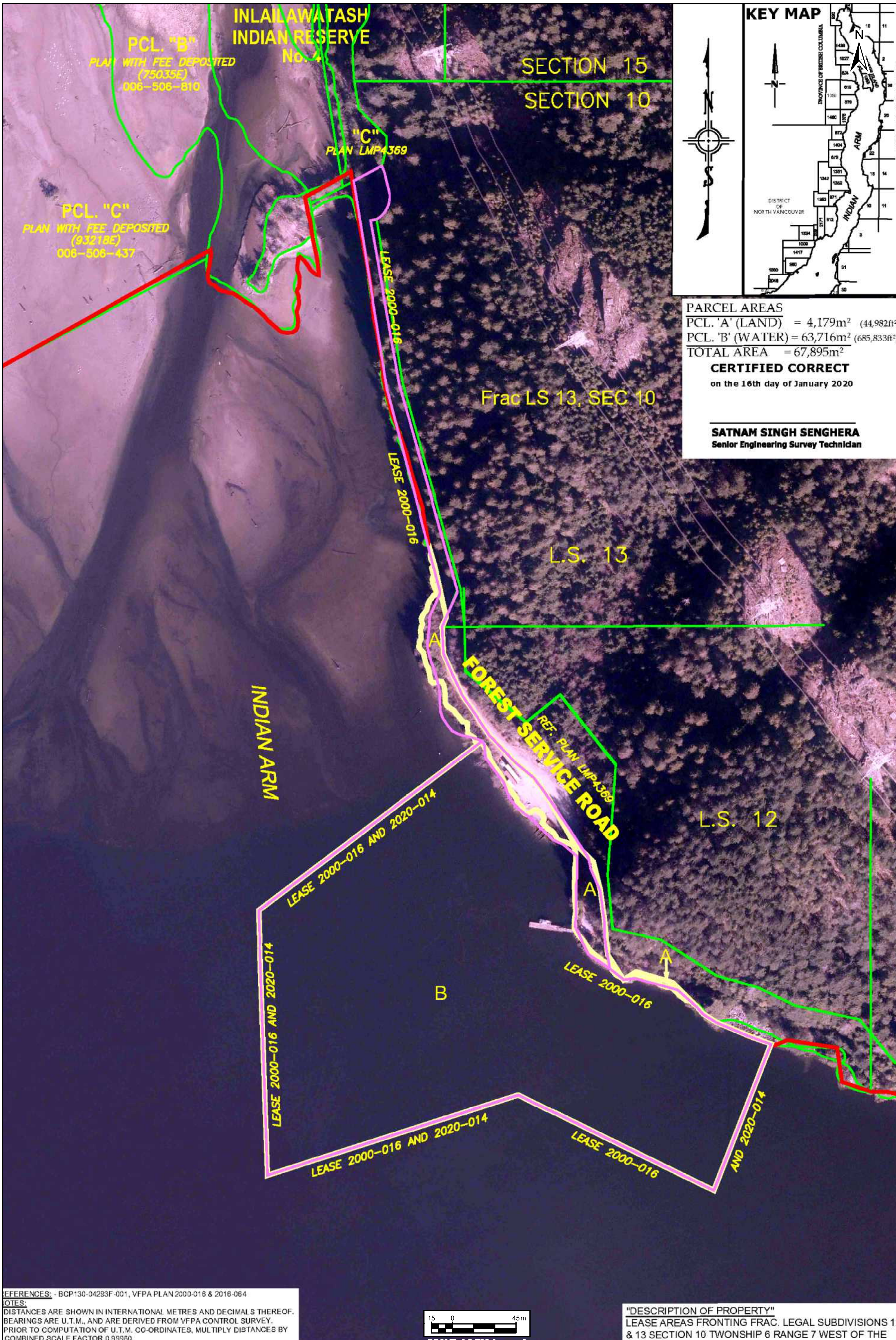
FIGURES

Keystone Environmental
Knowledge-Driven Results



Keystone Environmental	Indian Arm Log Dump North Vancouver, B C Vancouver Fraser Port Authority			**Figure 1** Location Plan
	REVISION No. A	DATE Oct. 2022	PROJECT No. 17657-05	

DRAWN BY: CY DOCUMENT PATH: \\key-fs2012\Common\17600-17699\17657 - VFPA\6 Figures\1 Working\GIS_CADD\VFPA_IndianArmLogDumpOffsettingPlan\Fig1-LocationPlan-RA.mxd



Keystone Environmental

NOTES:
1) THIS DRAWING IS FOR GENERAL INFORMATION ONLY. LOT BOUNDARIES AND FEATURES ARE APPROXIMATE.

Indian Arm Log Dump
North Vancouver, B C
Vancouver Fraser Port Authority

REVISION No.	DATE	PROJECT No.
A	Oct. 2022	17657-05

Figure 2

Lease Plan No. 2020-014

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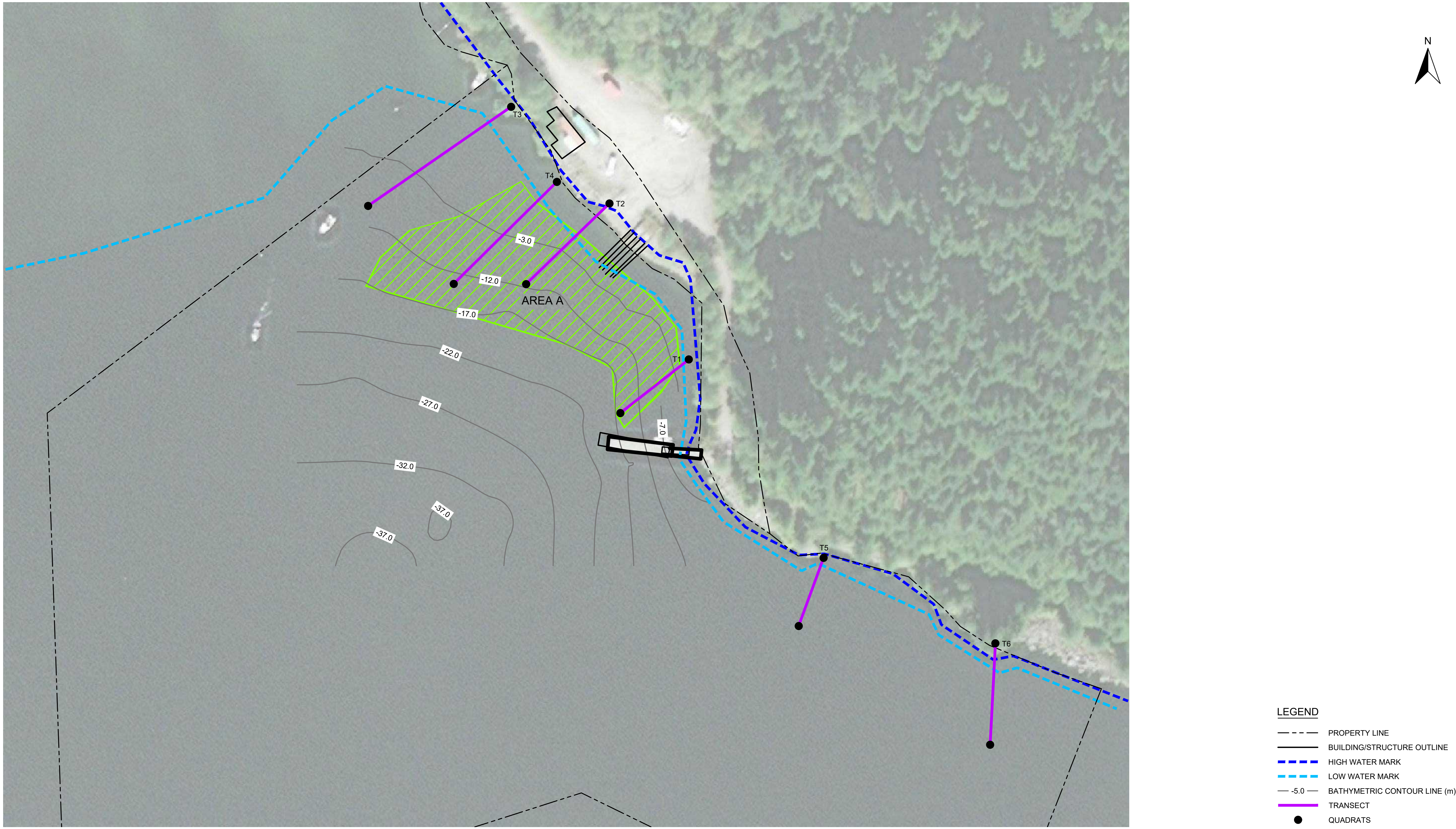


Keystone Environmental

NOTES:
1. THIS DRAWING IS FOR GENERAL INFORMATION ONLY. LOT BOUNDARIES AND FEATURES ARE APPROXIMATE.
2. DATE OF AERIAL PHOTO IS UNKNOWN.

10m 0 50m

SCALE: 1:1250(approx.)

Indian Arm Log Dump
Fjord, B C
Vancouver Fraser Port Authority

REVISION No.	DATE	PROJECT No.
A	Oct. 2022	17657-05

Figure 3
Site Plan

PLOT SCALE: 1:1 DRAWN BY: TL CADD FILE No. \\key-fs2012\Common\17600-17699\17657 - VFPA\6 Figures\1 Working\GIS_CADD\VFPA_IndianArmLogDumpOffsettingPlan\Fig3-Site Plan-RA2_Large Area A.dwg

SD22-1	Date	copper	Other Metals	PAHs	PCBs
0.2	18-Aug-22	30.5	<ECCC	<ECCC	<RDL

SD22-3	Date	copper	Other Metals	PAHs	PCBs
0.1	18-Aug-22	23.7	<ECCC	<ECCC	<RDL

SD22-4	Date	copper	Other Metals	PAHs	PCBs
0.2	18-Aug-22	36.9	<ECCC	<ECCC	<RDL

SD22-5	Date	copper	Other Metals	PAHs	PCBs
0.2	18-Aug-22	35.2	<ECCC	<ECCC	<RDL

SD22-6	Date	copper	Other Metals	PAHs	PCBs
0.2	18-Aug-22	39.3	<ECCC	<ECCC	<RDL
Duplicate		36.1	<ECCC	<ECCC	<RDL

SD22-7	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.2	18-Aug-22	0.793	36.6	<ECCC	<ECCC	<RDL

SD22-8	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.2	18-Aug-22	0.625	33.4	<ECCC	<ECCC	<RDL

SD22-9	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.2	17-Aug-22	1.05	62.9	<ECCC	<ECCC	<RDL
0.9		1.02	42.8	<ECCC	<ECCC	<RDL

SD22-10	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.2	17-Aug-22	0.751	197	<ECCC	<ECCC	<RDL

SD22-11	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.2	17-Aug-22	0.847	47	<ECCC	<ECCC	<RDL
Duplicate		1.01	56.1	<ECCC	<ECCC	<RDL

SD22-12	Date	arsenic	cadmium	copper	Other Metals	PAHs	PCBs
0.2	17-Aug-22	7.87	0.989	25.1	<ECCC	<ECCC	<RDL

SD22-13	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.1	18-Aug-22	0.877	42.1	<ECCC	<ECCC	<RDL

SD22-14	Date	arsenic	cadmium	copper	Other Metals	PAHs	PCBs
0.1	17-Aug-22	7.79	1.22	51.9	<ECCC	<ECCC	<RDL

SD22-15	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.2	17-Aug-22	0.972	50.5	<ECCC	<ECCC	<RDL

SD22-16	Date	cadmium	copper	Other Metals	PAHs	PCBs
0.1	18-Aug-22	0.808	47.4	<ECCC	<ECCC	<RDL

LEGEND

INDIAN ARM WW

KEYSTONE SEDIMENT SAMPLE (2022)

PCOC CONCENTRATION(S) IN SEDIMENT CONCENTRATION(S) LESS THAN ENVIRONMENT AND CLIMATE CHANGE CANADA SCREENING LEVELS

PCOC CONCENTRATION(S) IN SEDIMENT CONCENTRATION(S) GREATER THAN ENVIRONMENT AND CLIMATE CHANGE CANADA SCREENING LEVELS

PAHs	POLYCYCLIC AROMATIC HYDROCARBONS
PCBs	POLYCHLORINATED BIPHENYLS
<	LESS THAN
RDL	REPORTED DETECTION LIMIT
--	NOT ANALYZED
ECCC	ENVIRONMENT AND CLIMATE CHANGE CANADA SCREENING LEVELS
mbg	METRES BELOW GRADE

SAMPLE I.D. — ANALYTE

SED	Date	PAHs
0.5	DD-MMM-YY	<100

DEPTH (m) — RESULTS

NOTES:
1. Sediment Sample Values Are Presented As Micrograms Per Gram (μg/g) [parts per million (ppm)].
2. Sample Exceeding ECCC in RED.

Keystone Environmental

NOTES:
1. THIS DRAWING IS FOR GENERAL INFORMATION ONLY. LOT BOUNDARIES AND FEATURES ARE APPROXIMATE.
2. DATE OF AERIAL PHOTO IS 2021.

5 0 25 m

SCALE: 1:750 (approx.)

Indian Arm Log Dump
North Vancouver, B C
Vancouver Fraser Port Authority

REVISION No.	DATE	PROJECT No.
A	Sep. 2022	17657-05

Figure 4

Sediment Analytical Results

DRAWN BY: CY Document Path: \\key-fs2012\Common\17600-17699\17657 - VFPA\6 Figures\1 Working\GIS_CADD\Fig2-Sediment-Analytical-RA.mxd

APPENDIX B

PHOTOGRAPHS

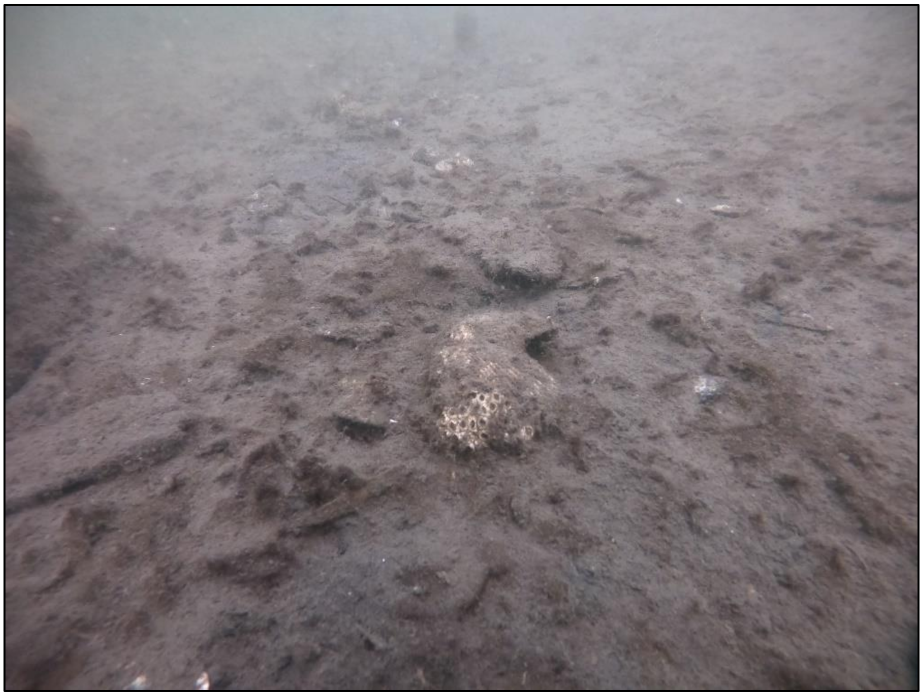
Keystone Environmental
Knowledge-Driven Results

Photograph 1: Former log dump showing existing log skids, barge ramp, timber and wood retaining wall and riprap armoured shoreline.

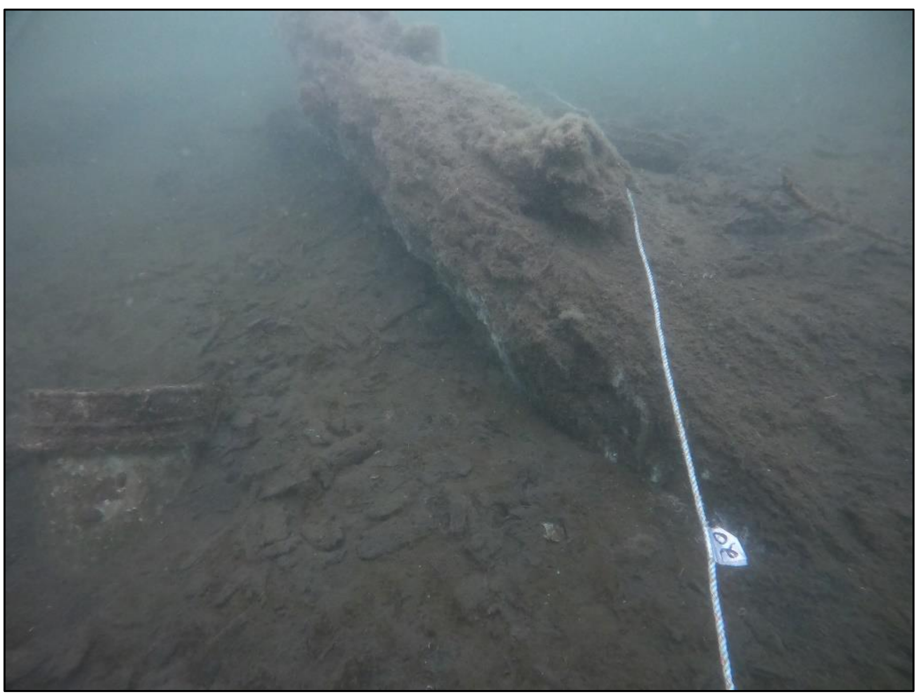
Photograph 2: Riprap armoured intertidal zone devoid of bark with minimal anthropogenic debris present.

Photograph 3: Riprap armoured intertidal zone with minimal woody debris or anthropogenic materials present within intertidal.

Photograph 4: Silty substrate with diatoms, shore crabs and invertebrate holes observed on Transect 3.



Photographs 5: View of silty substrate on Transect 4. Large amount of wood waste (bark) and shells



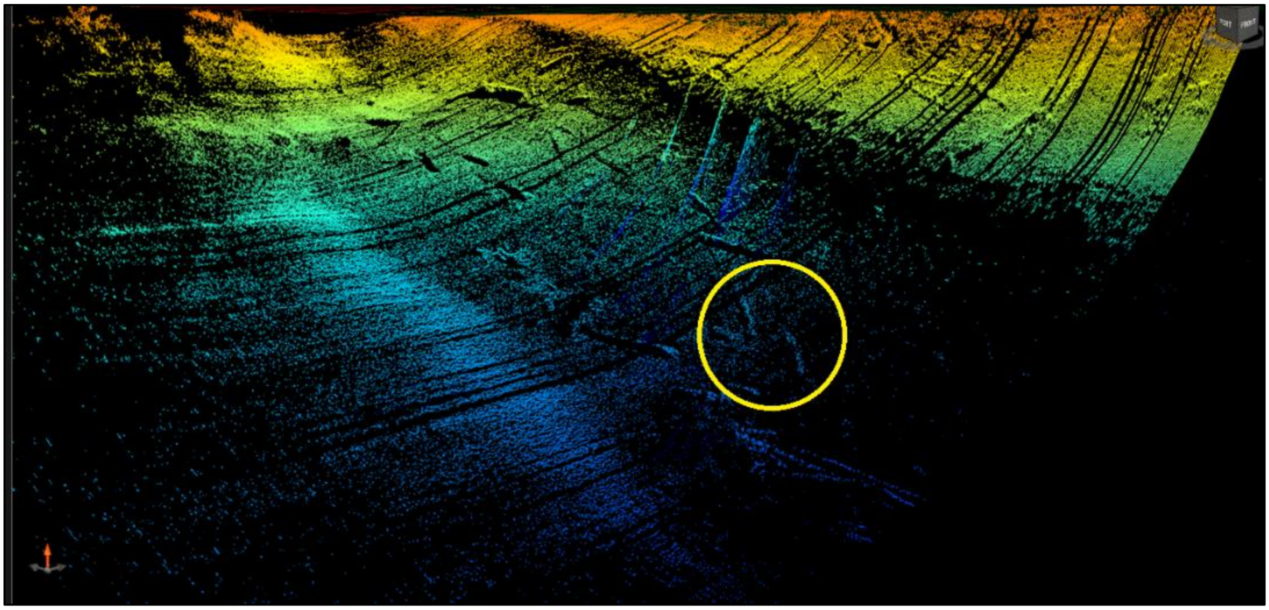
Photograph 6: View of silt and bark substrate with large log on Transect 2.

Photograph 7: View of bedrock/ boulder substrate observed south of the site access dock.

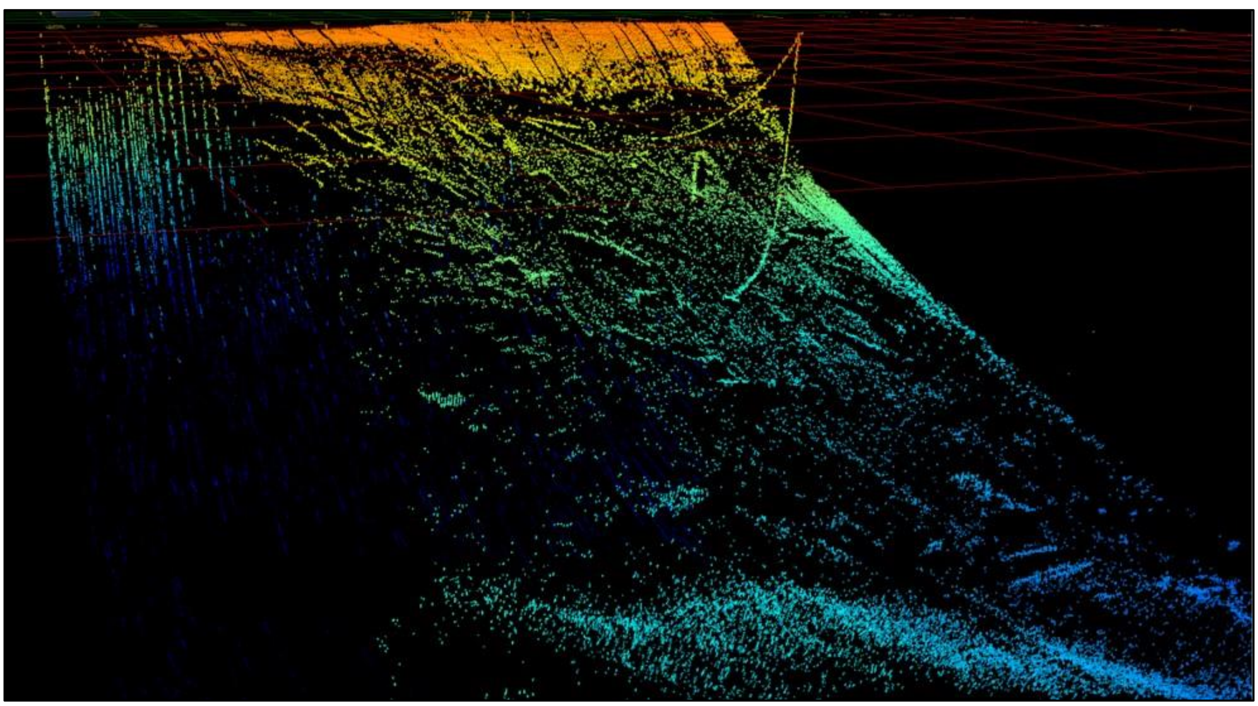
Photograph 8: Transect 3 hand core with no woody debris observed.

Photograph 9: Transect 2 hand core with woody debris present.

Photograph 10: Transect 1 hand core with woody debris present.



Photograph 11: Sonar results from Area A of the water lot showing steep slope. Yellow polygon highlighting an example of the wood debris (logs).



Photograph 12: Sonar results from Area A of the water lot showing steep slope. Several large logs and debris, along with site access dock mooring lines and anchors are visible.

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