CONTROLLING RECONTAMINATION DURING PHASE 2 REMEDIATION AT THE ESQUIMALT GRAVING DOCK

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ABSTRACT

The Esquimalt Graving Dock (EGD) is located in Esquimalt Harbour on Vancouver Island, British Columbia, and is managed by Public Works and Government Services Canada (PWGSC). PWGSC developed a multi-phase remedial action plan and engineering design for cleaning up contaminated sediments in and adjacent to the EGD Waterlot. Phase 1A was completed in 2013 and included installation of a sheetpile perimeter wall around the existing timber jetty structures to prevent re-contamination of remediated sediments during subsequent phases of the project. Phase 1B was completed in March 2014 and included 144,000 cubic metres (m^3) of remedial dredging and off-site upland disposal of contaminated sediments. Phase 2 activities were conducted from October 2015 through December 2016 and comprised demolition of the timber-piled South Jetty structures, re-driving of the perimeter sheetpile wall and construction of a temporary re-suspension barrier (TRB), remedial dredging and off-site upland disposal of 37,800 m^3 of contaminated sediments, placement of capping materials, and modifications to the remaining jetty structure. This paper describes the design and construction of the TRB and performance monitoring conducted during Phase 2 remediation to prevent and assess recontamination of the surrounding areas that were previously remediated.

The TRB design required the re-drive of the sheetpile perimeter wall and installation of several floating silt curtains to fully contain re-suspended sediment, with a unique system to seal the curtain to the wall to avoid recontamination of capping material placed following dredging in each construction zone. The design included gates that could be opened for vessels moving into and out of the construction zone.

Project-specific water quality performance criteria were developed to protect aquatic life and to monitor the effectiveness of the TRB in preventing recontamination of the previously remediated areas. More than 20,000 field measurements of water quality and approximately 400 samples of total suspended solids (TSS), metals, and PAHs

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were used to monitor effectiveness of the system. Water quality data suggested that the TRB was generally effective in preventing the escape of contaminated sediments outside the containment area.

Surface sediments outside the perimeter of the Phase 2 work boundaries were sampled to establish baseline conditions prior to remedial activities and following substantial completion of the Phase 2 project. In localized areas with higher sediment contaminant concentrations, clean sand was placed outside the Phase 2 work area to provide a clean sediment surface at the end of construction. Armour rock was also placed along the alignment of the extracted sheetpile to isolate localized areas where some contaminated sediment was present following sheetpile extraction.

Keywords: suspended sediments, recontamination, containment, water quality, sediment monitoring, contingency actions

INTRODUCTION

Background

The EGD Waterlot is located in Esquimalt Harbour, British Columbia, and has a long history of naval and industrial activity within the harbour and on the uplands along the shoreline, dating back to the mid-1800s (Figure 1). The EGD, which has been owned and operated by the federal government since 1927, is managed by the federal custodian, PWGSC. The EGD has the largest solid-bottom commercial drydock on the West Coast of the Americas (Figure 2) and has been used by numerous commercial operators for civilian and military ship repair and construction operations. Contamination of sediments in the project area is primarily due to legacy contaminants from historical sources such as metals, TBT, PCBs, and PAHs. Prior to open-water remediation conducted as part of Phase 1B, the highest levels of sediment contamination were located near the mouth of the EGD and beneath the South Jetty. This paper discusses the challenges of controlling recontamination of the Phase 1B remediation area during Phase 2 construction.

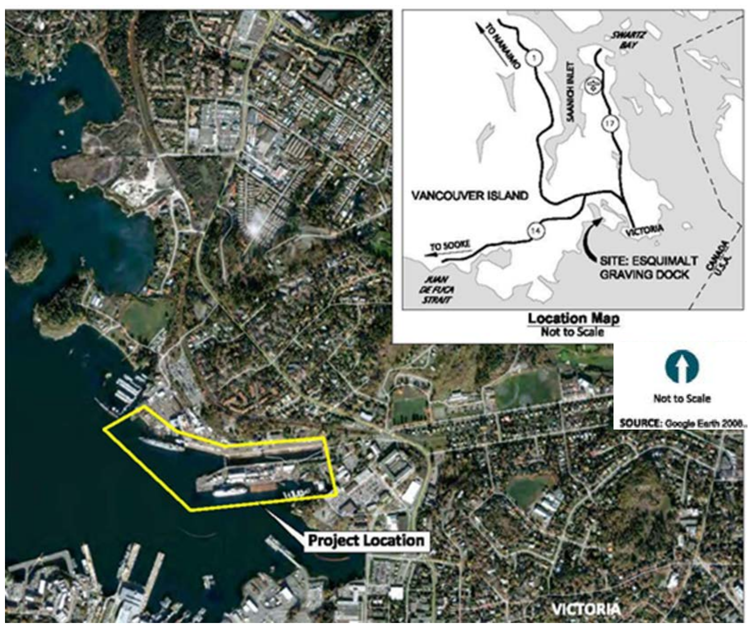

Figure 1. Vicinity map.

Figure 2. Project area and boundaries.

The EGD Waterlot Remediation Project (EGD Project) was conducted as part of the Government of Canada’s FCSAP, which is a cost-shared program that supports federal departments, agencies, and consolidated Crown corporations in addressing contaminated sites for which they are responsible. The primary objective of this program is to address the risks these sites pose to human health and the environment and to reduce the associated financial liability. Completion of the EGD Project has also established baseline conditions for future site operations, which may support a potential change in facility governance that is under consideration.

General management goals for the EGD Project focus on removing the maximum amount of contamination practicable, while allowing graving dock facility operations to resume expeditiously. Removing contamination serves to reduce the Government of Canada’s financial liability, establish baseline conditions for future operations, reduce risks to human health and the environment, and achieve FCSAP objectives.

The EGD Project sought to remove the maximum amount of contaminated sediments that exceeded the most stringent numeric criteria for a given contaminant based on the Canadian Council of Ministers of the Environment (CCME) Probable Effects Level (PEL) or British Columbia Contaminated Sites Regulation (CSR) Sediment Quality Criteria for typical contaminated sites ($SedQC_{tcs}$). These numeric criteria are referred to as numeric remedial action objectives (NRAOs) and were also used as the basis for cap modeling within the Phase 2 project area and recontamination assessment outside the Phase 2 project area. Figure 3 shows concentrations above NRAOs within the Phase 2 project area prior to remediation.

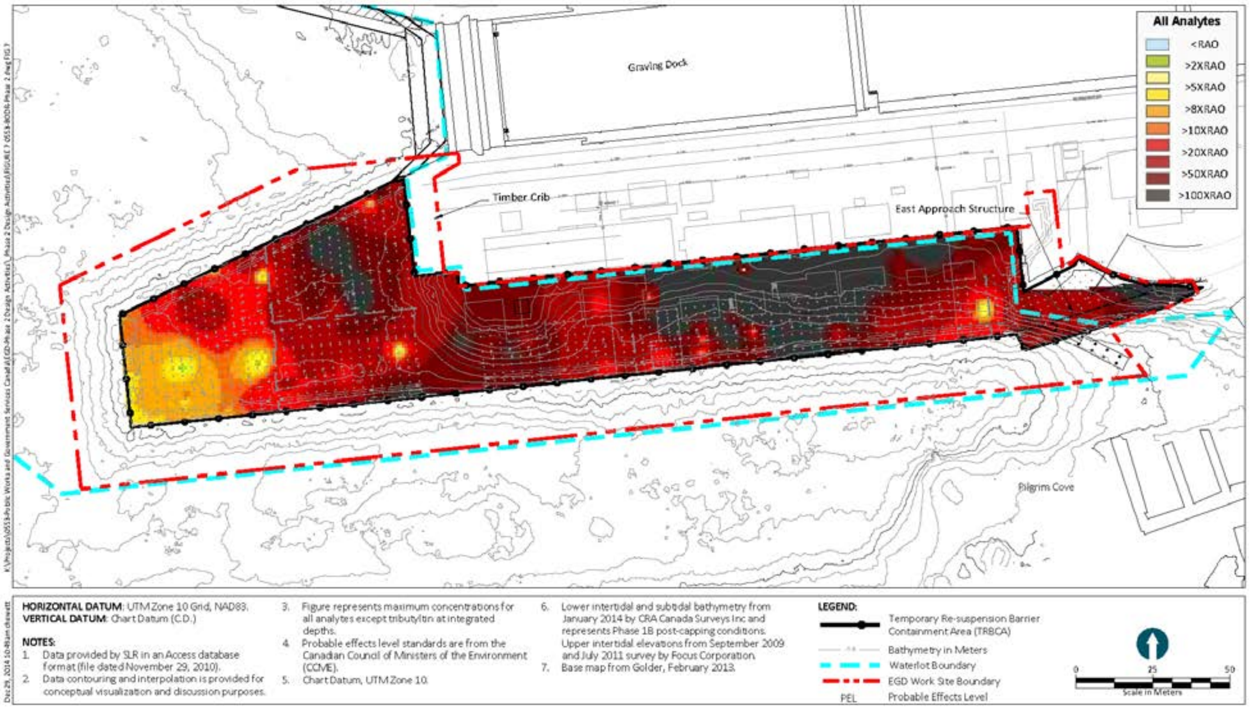

Figure 3. Maximum contaminant concentration at integrated depths.

Phased Approach

A remedial options assessment (ROA) was conducted as part of the development of the initial Remedial Action Plan/Risk Management Plan (RAP/RMP). Various alternatives and technologies were evaluated, and the preferred alternative selected by PWGSC consisted of maximum practicable removal of contaminated sediments through dredging and off-site disposal, to be conducted in two phases to address sediment contamination as soon as possible. Phase 1 consisted of open-water sediment remediation and was completed in March 2014, while Phase 2 addressed remediation of the sediments beneath the South Jetty (Figure 2).

Phase 1A – Installation of Underpier Erosion Protection System

Phase 1A consisted of the installation of an underpier erosion protection system (sheetpile wall) around the South Jetty structure to prevent re-suspension and transport of contaminated under-jetty sediment into the open-water area that was to be remediated as part of Phase 1B. The sheetpile wall provided a barrier against waves and propeller wash (propwash) from vessels operating adjacent to the South Jetty. The sheetpile wall was designed to be protective for selected design vessel operational conditions, with appropriate seabed embedment depths and attachment to the deck of the South Jetty to provide structural integrity. The construction was implemented in three segments along the jetty perimeter to minimize the disruption to EGD operations and accommodate fishery windows, as specified by Fisheries and Oceans Canada (DFO). Construction of Phase 1A occurred from October 2012 to April 2013.

Phase 1B – Open-water Dredging

Phase 1B consisted of remediation of the open-water area of the Waterlot, with maximum practicable removal of approximately 144,000 m^3 of contaminated sediments (Figure 2). The dredge prism design and overall construction sequencing for remedial dredging were established to maximize contaminant removal, minimize potential for dredge residuals and recontamination, and minimize impact to ongoing EGD operations during construction. A post-construction sand layer was placed at the end of Phase 1B to address dredge residuals and provide a clean post-constructions surface. Construction of Phase 1B occurred from June 2013 to March 2014.

Phase 1C – Construction of Compensatory Fish Habitat

New intertidal marsh fish habitat was constructed at a separate location in Esquimalt Harbour to compensate for impacts associated with the project, particularly the temporary disruption of habitat underneath the South Jetty due to the installation of the underpier erosion protection sheetpile wall in Phase 1A. Construction of Phase 1C occurred from September 2013 to April 2014.

Phase 2 – Underpier Remediation

Phase 2 of the project consisted of the demolition of the timber pile-supported portion of the South Jetty and removal of approximately 37,800 m^3 of contaminated sediments beneath the jetty. The perimeter sheetpile wall installed in Phase 1A was re-driven to serve as part of the TRB around the work area. The entire Phase 2 area was capped to isolate remaining contamination prior to the removal of the sheetpile wall and final modification of the remaining steel pile-supported jetty to support ongoing use. Dredged material from the Phase 2 area consisted of fine-grained sediments and fill materials, with contamination extending as deep as 5 metres (m) below the existing mudline. As a result, the Phase 2 design involved several measures to prevent recontamination, maximize the amount of contamination removed, cap any contamination that could not be removed, minimize disturbance to EGD operations, and provide a usable structure at the end of the construction. Phase 2 remediation was conducted by Malahat Nation-Quantum Murray (MNQM) and occurred from October 2015 to December 2016.

RECONTAMINATION CHALLENGES

This paper describes the challenges of controlling recontamination of the Phase 1B area during Phase 2 remediation, including design and construction of the TRB, and water quality and sediment performance monitoring conducted during Phase 2 construction. Project components were incorporated into the design and construction to control suspended sediments and potential recontamination of Phase 1B areas. Also described are the water quality and sediment monitoring programs used to assess TRB performance and conduct any required contingency actions.

Recontamination Considerations

Preventing recontamination of the Phase 1B area was one of the primary challenges for Phase 2. The original design of the perimeter sheetpile wall was intended to continue to isolate underpier contamination as part of the TRB system during Phase 2 construction, but a number of risks remained that could have resulted in recontamination of the Phase 1B area. These risks included the failure of the TRB, a spill of contaminated sediment from the derrick or dredge material barge, or deposition of suspended sediments with elevated contaminant concentrations associated with opening the TRB for vessel movement into and out of the work area. Design elements intended to address these risks and prevent and mitigate potential recontamination are described below.

The project design anticipated substantial suspended sediments within the temporary re-suspension barrier containment area (TRBCA) as a result of dredging activities, from the dropping, dragging, and lifting actions of the dredging bucket. The degree of turbidity is dependent on the conditions of the site (e.g., slope, current, and structure), type of bucket, and operator performance (e.g., speed, overfilling, or over-penetration of the bucket). Generally, open buckets generate more turbidity than closed buckets (e.g., environmental buckets) through spillage and washout from the bucket during lifting. The incomplete closure of the bucket from debris and rocks will result in sediment leaking from the bucket (Figure 4). Phase 2 dredging was conducted in open-water areas using conventional derrick dredging, but also in areas beneath the remaining steel pile-supported pier. The underpier dredging was conducted using a Gradall, which is an articulated excavator that dragged sediments down the slope into areas accessible by conventional derrick dredging. This approach was envisioned during design and was expected to contribute to substantial suspended sediments within the TRBCA. As such, an effective barrier was required to keep suspended sediments from spreading to previously remediated Phase 1B areas.

Underpier Erosion Protection System (Sheetpile Wall)

As previously discussed, an underpier erosion protection system (sheetpile wall) was installed in Phase 1A of the project to provide a barrier against waves and propwash from vessels operating adjacent to the South Jetty that could potentially cause erosion, and to prevent transport of re-suspended contaminated sediments from the underpier area (during the Phase 2 dredging work) into the cleaned-up Phase 1B open-water area. When initially installed, the sheetpile wall was pinned to the seaward edge of the timber jetty structure deck. Prior to initiating Phase 2 remedial activities, the timber jetty structure was removed and the wall was driven deeper—to an approximate top elevation of 0 m Chart Datum (CD)—to maintain its stability while still isolating the Phase 2 contaminated sediments from the newly-remediated Phase 1 sediments.

When unpinned and driven deeper, the sheetpile wall design changed from a propped cantilever system to a free cantilever system. To understand the stability of the wall after the re-drive, an analysis based on the propwash forces on the sheetpile wall during Phase 2 remediation was completed using a Computational Fluid Dynamics (CFD) model. Additionally, the dynamic pressure acting on the sheetpile wall due to waves and suction forces was estimated. Both analyses considered a maximum 2.5 m of sediment removal from within the Phase 2 dredge area to support the structural and geotechnical design of the wall.

Temporary Re-suspension Barrier Containment Area

To address the potential for recontamination of the Phase 1B area due to migration of suspended sediments, the design required use of a TRB system, which was to be designed by the contractor. The TRB included a floating silt curtain that overlapped with the top of the re-driven sheetpile wall. The re-driven sheetpile wall served as the lower portion of the TRB system. The area inside the TRB was designated as the TRBCA.

The objective of the TRB was to create a physical barrier around the jetty perimeter (and dredge equipment) to prevent the spread of suspended sediment generated during dredging operations. The TRB extended around the entire Phase 2 work area (Figure 4) and included an area along the eastern side where a full-length silt curtain was necessary because sheetpile could not be installed during Phase 1A due to presence of shallow bedrock (Figure 5). The contractor partitioned the work area using additional "intermediate" TRBs to physically isolate contractor-defined subareas to prevent recontamination during construction. A portion of the project area with hazardous waste-level contamination was isolated completely with a full-length intermediate TRB system, and was dredged first to limit the spread of hazardous waste-level sediments to other parts of the Phase 2 area. All TRBs were intended to facilitate compliance with water quality requirements outside the TRBCA during dredging and capping activities, as described in the Environmental Management Plan (EMP; G3 Consulting Limited, 2014).

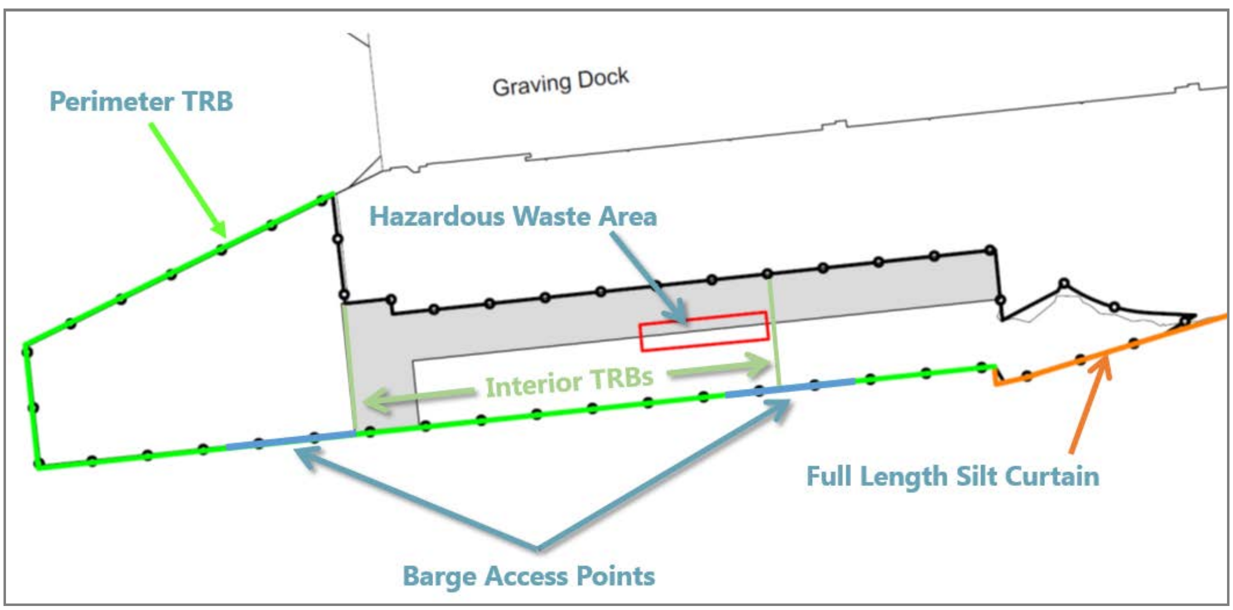

Figure 4. Perimeter and interior temporary re-suspension barriers.

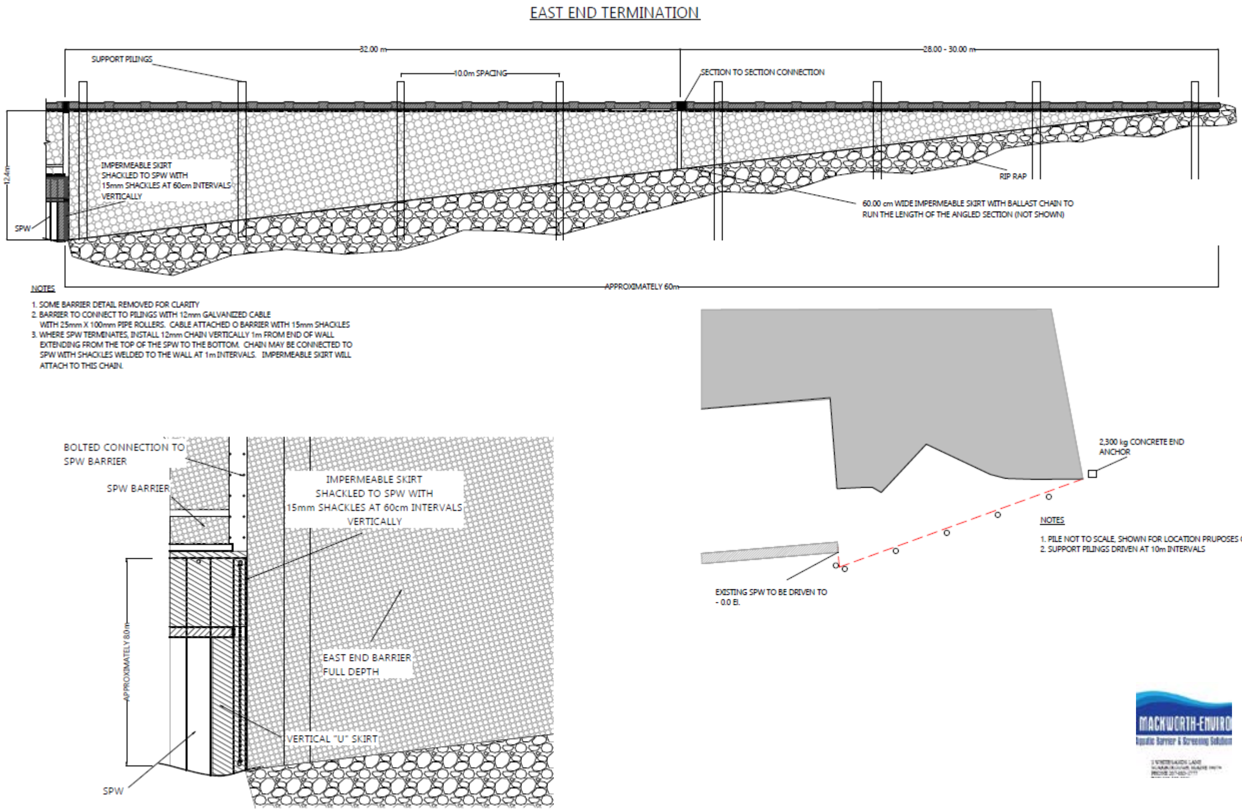

Figure 5. East End profile – Full length curtain.

The TRB system was designed and stamped by the contractor's third party engineer, Macworth-Enviro. Prior to construction, the contractor was required to submit the method statement describing the design, procurement, installation, operation, maintenance, monitoring, repairs, cleaning, removal, and disposal of the TRB system. The contractor was required to develop a system that was capable of withstanding forces from wind waves and currents, as well as forces from its vessel movements.

The silt curtains used for the TRBs were constructed of flexible, reinforced, thermoplastic material, including a tri-layer filter media (FW402 – 10 ounce [oz]), suspended from a 2.5-centimetre flotation hood constructed of 36-oz coolthane-coated nylon (Figure 6). The bottom of the curtain was constructed with an impermeable layer U-skirt, which overlapped on both sides of the top of the sheetpile wall that was anchored with a 12-millimetre chain ballast (Figure 7). TRBs are most effective on projects where they are not opened and closed to allow equipment access to the dredging or disposal area; however, for the Phase 2 project, it was necessary to allow several openings of the TRB to facilitate ingress/egress of the contractor's equipment into/out of the TRBCA. Silt curtains block or reduce the flow of water (including suspended contaminated sediments), and therefore are easily affected by tides and currents, and their effectiveness can be adversely impacted by high current velocities, moderate to large wave conditions, or large tidal variation. Some flow of water could not be prevented given the wide tidal range in Esquimalt Harbour, but the TRB system provided the maximum possible isolation of suspended sediments and dissolved concentrations, while still allowing water exchange.

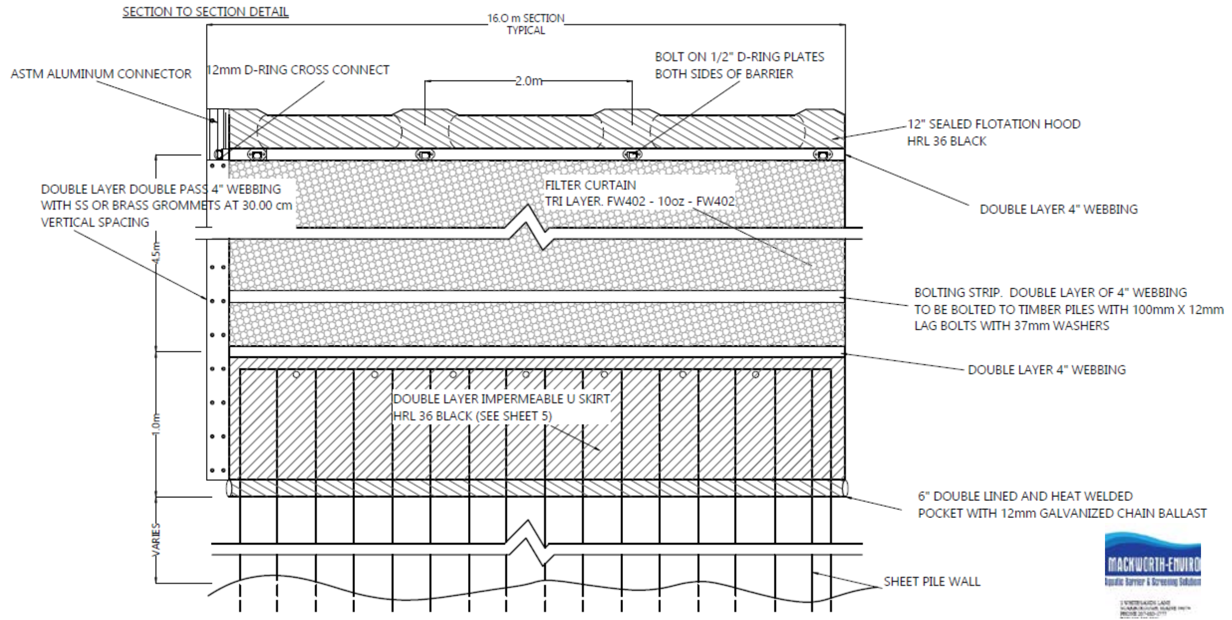

Figure 6. Typical perimeter temporary re-suspension barrier curtain.

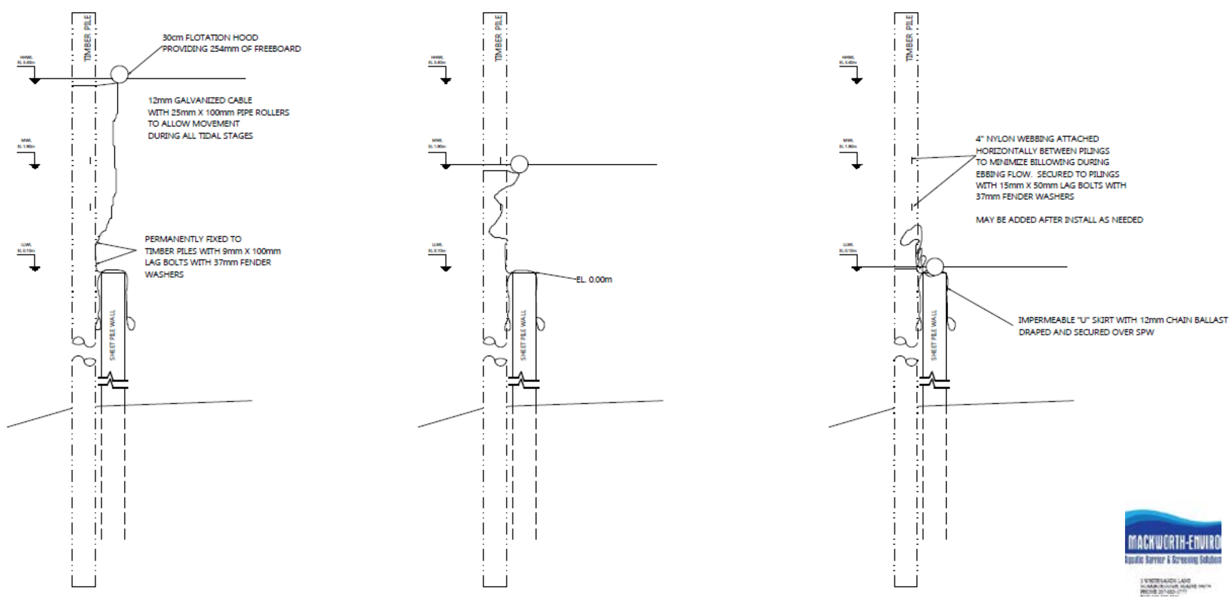

Figure 7. High/low water perimeter temporary re-suspension barrier profile.

TRB maintenance was required due to damage and wear, primarily through patching silt curtain holes. Scheduled openings were conducted at the barge access points, which were planned in advance and intended to be as short in duration as possible.

Intensive Water Quality Monitoring

Water Quality Monitoring Plan

An EMP (G3 Consulting Limited, 2014), including a WQMP and Water Quality Performance Criteria, was developed prior to tendering the Phase 2 construction contract. The objectives of the Phase 2 Water Quality Performance Criteria were to: 1) protect aquatic life; and 2) protect against recontamination of the previously remediated areas of the EGD Waterlot. The Phase 2 Water Quality Performance Criteria that were applied when the contractor was working within the TRBCA are presented in Table 1.

Table 1. Phase 2 water quality performance criteria for contractor activities within the TRBCA.

Parameter	Unit	Criteria	
		Early Warning (25 m)	**Compliance (100 m)**
Total Suspended Solids	mg/L	5	
Turbidity	Nephelometric Turbidity Units	2.5	
Dissolved Oxygen	mg/L	5 maximum; 8 mean	
pH	-	7.0 to 8.7	
Total Arsenic	µg/L	125	12.5
Total Copper	µg/L	30	3
Total Zinc	µg/L	100	10
Polycyclic Aromatic Hydrocarbons[1]	µg/L	1 to 510	0.1 to 51

Note: 1. The range of Phase 2 Water Quality Performance Criteria for individual PAH congeners is presented.

PWGSC's Environmental Monitor (Azimuth Consulting Group Partnership [Azimuth]) assessed the contractor's compliance with the Water Quality Performance Criteria at an array of Early Warning monitoring stations located 25 m outside the TRBCA, and an array of Compliance Point monitoring stations located 100 m outside the TRBCA. Ambient water quality in Esquimalt Harbour was also regularly assessed at eight reference locations. The locations of the Phase 2 water quality monitoring stations are illustrated in Figure 8.

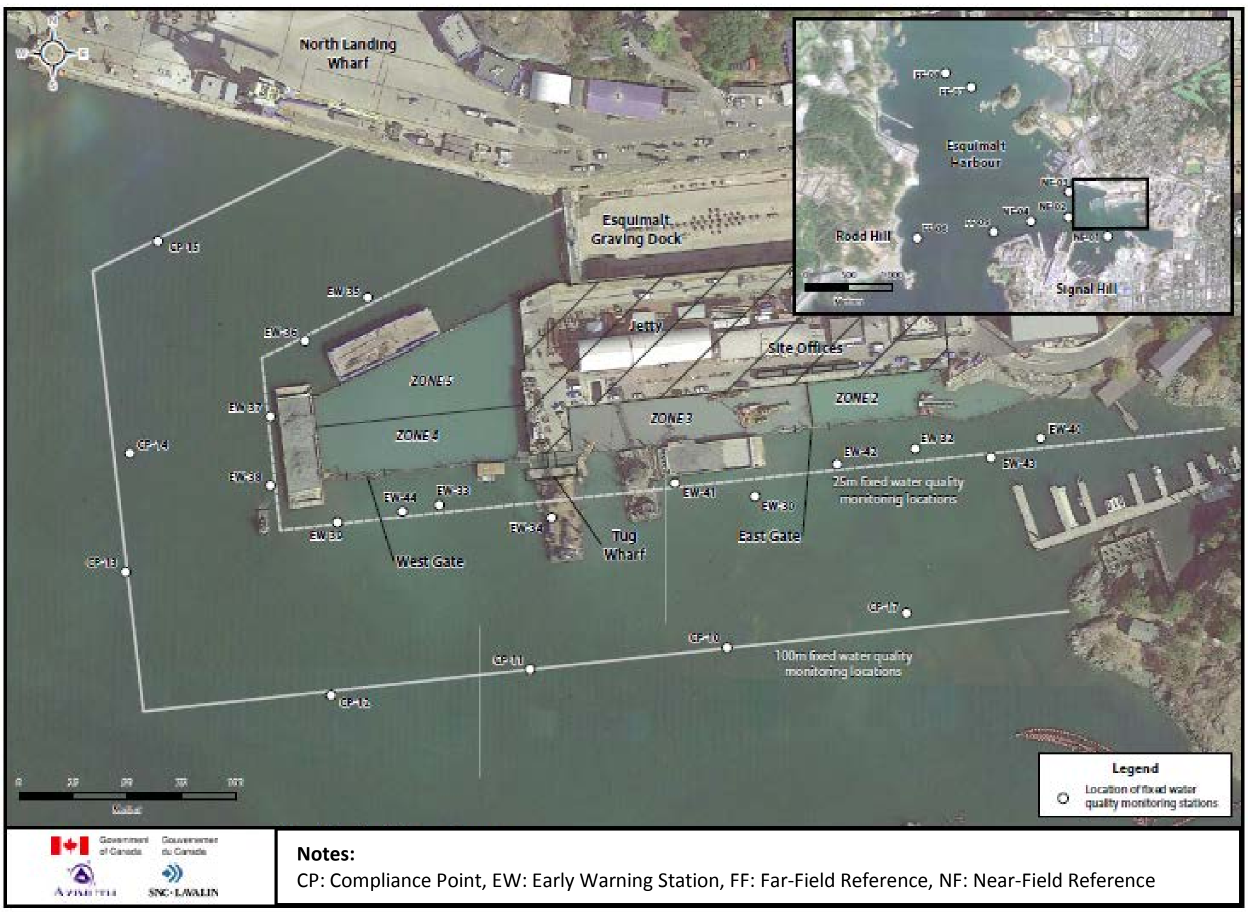

Figure 8. Locations of Phase 2 water quality monitoring stations.

The WQMP required frequent assessment of water quality in the receiving environment. Receiving environment water quality was monitored at least once a day for the first several weeks of any new contractor activity that had the potential to change water quality (e.g., dredging in a new zone, or using different dredge equipment or methods).

The Phase 2 Water Quality Performance Criteria included water quality parameters that were measured in the field in situ and in-water samples submitted to analytical chemistry laboratories. The use of in situ criteria allowed for faster assessment and response than possible with laboratory parameters, which required a lag time of at least 24 hours between the time when a water sample was collected and when the results were reported. Laboratory analyses, however, provided more sensitive and specific measures of water quality. Water quality monitoring for Phase 2 used a complimentary approach, where in situ measures of water quality were treated as indicators and verified with laboratory measures of water quality where warranted.

The Phase Water Quality Performance Criteria applied at 25-m Early Warning stations for TRB openings for TSS and turbidity were higher than those that were applied when the TRB was closed. The receiving environment criteria for TSS and turbidity were relaxed during TRB openings in recognition that TRB openings were short-term, relatively infrequent events. The contractor was required to assess water quality inside the TRBCA to determine when conditions were acceptable for opening the TRBCA, while still complying with the Water Quality Performance Criteria in the receiving environment outside of the TRBCA. During TRB openings, water quality monitoring was conducted in the vicinity of the opening to verify that Water Quality Performance Criteria were met, and to assess the adequacy of the water quality criteria applied within the TRBCA prior to opening.

The Phase 2 Water Quality Performance Criteria were generally consistent with those that had been developed for Phase 1B, with the important exception that the criteria for TSS, and for turbidity as an in situ surrogate measure of TSS, were considerably lower for Phase 2 than those used for Phase 1B. This change was necessary to provide an added level of assurance that particulate matter was not escaping from the TRBCA and potentially re-contaminating the previously remediated areas of the EGD Waterlot. The Phase 2 Water Quality Performance Criteria for TSS and turbidity were lower than their respective British Columbia Ambient Water Quality Guidelines for the protection of aquatic life by about a factor of five, and were also within the range of measured background conditions in Esquimalt Harbour.

There was concern that the contractor would have difficulty meeting the stringent Water Quality Performance Criteria for turbidity and TSS. The concern was, however, mitigated by building flexibility into the Phase 2 WQMP. The Phase 2 WQMP was based on an adaptive management approach whereby the intensity of water quality monitoring could be adjusted in response to the contractor's ability to demonstrate compliance with the environmental protection requirements of the contract. The Phase 2 WQMP also allowed for the Water Quality Performance Criteria for turbidity, as a surrogate measure of TSS, to be adjusted based on the observed site-specific empirical relationship between field measures of turbidity and laboratory measures of TSS.

In summary, the Phase 2 WQMP required intensive spatial and temporal assessment of the contractor's ability to meet stringent Water Quality Performance Criteria for turbidity and TSS in the aquatic receiving environment as a means to monitor the effectiveness of the TRBCA to prevent recontamination of previously remediated areas of the EGD Waterlot. The use of in situ measures of water quality allowed for high intensity water quality monitoring and provided rapid feedback on the contractor's ability to manage water quality. The Phase 2 WQMP was also based on an adaptive management approach that allowed PWGSC flexibility in adjusting the monitoring intensity or the in situ criteria, as appropriate.

Water Quality Results and Discussion

Azimuth conducted water quality monitoring on 220 days between November 11, 2015 and December 9, 2016. Four hundred and three rounds of water quality monitoring were completed, during which more than 22,000 in situ measurements of water quality were taken and 583 water samples were collected and submitted for laboratory measures of water quality. Exceedances of the Water Quality Performance Criteria were infrequent and low in magnitude.

Water Quality Performance Criteria were exceeded in 93 measurements for turbidity (a frequency of 0.4%), and the maximum turbidity measurement was 23.7 Nephelometric Turbidity Units. The westernmost Early Warning stations around Zones 4 and 5 had statistically significantly lower turbidity than the easternmost Early Warning stations located around Zones 2 and 3. The most frequent and greatest magnitude of exceedances of the Water Quality Performance Criteria for turbidity occurred at water quality monitoring stations EW 32 and EW 42 outside Zone 2 (see Figure 9).

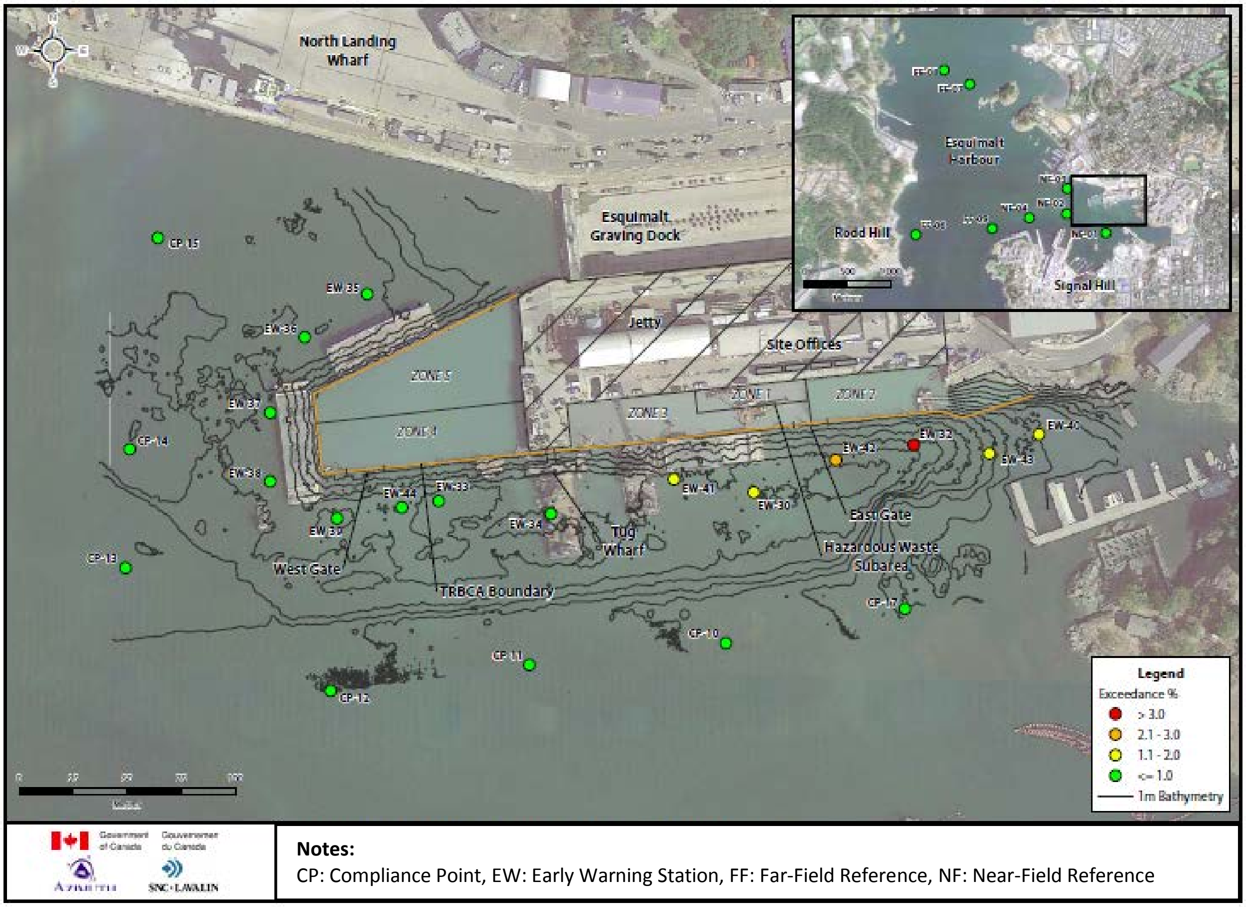

Figure 9. Frequency of Water Quality Performance Criteria turbidity exceedances.

Water Quality Performance Criteria were exceeded in 13 samples for TSS (a frequency of 2%), and the maximum TSS measurement was 16 milligrams/litre (mg/L). As was the case with turbidity, the most frequent and greatest magnitude of exceedances of the Water Quality Performance Criteria for TSS occurred at water quality monitoring stations EW 32 and EW 42 outside Zone 2.

Visible plumes of turbid water outside the TRBCA were sometimes observed by the water quality monitoring crews. The frequency of such occurrences was greater than the frequency of exceedances of the Water Quality Performance Criteria for turbidity or TSS. The visible plumes of turbid water often did not persist or extend to a distance of 25 m from the TRBCA.

There are several plausible explanations for the more frequent exceedances of the Water Quality Performance Criteria for turbidity and TSS that occurred in Zone 2, including the following:

- Water Circulation – The bathymetry and associated water circulation patterns may have caused suspended solids that were project-related or from other non-project sources to tend to flow to, and accumulate in, this area.
- Absence of Sheetpile Wall – Suspended sediment may have escaped from the TRBCA along the easternmost section where there was no sheetpile wall. In this area, the TRB was lying directly on the seafloor and may not have been fully sealed. For example, river otters were observed to enter and exit the TRBCA by diving under the TRB in this area.

- Compromised TRB – There was, on a few occasions, visual evidence that the integrity of the TRB may have been compromised in Zone 2. This evidence included tears in the TRB material observed during a dive survey, and visible plumes of turbid water escaping the TRBCA in Zones 2 and 3 observed by the water quality monitoring crews.

There is, however, insufficient information to confidently identify the cause of the more frequent exceedances of the Water Quality Performance Criteria for turbidity and TSS that occurred at the Early Warning monitoring stations outside of Zone 2.

Water Quality Performance Criteria were exceeded in three samples for total copper, and the maximum total copper measurement was 4.31 mg/L. There were 114 dissolved oxygen (DO) measurements that did not meet the Water Quality Performance Criteria for DO. However, the depressed DO was within the range of ambient conditions in Esquimalt Harbour and unlikely to have been project-related.

In summary, the Phase 2 Water Quality Performance Criteria for turbidity and TSS were quite stringent, as monitored by a spatial and temporal water quality monitoring program during Phase 2 contractor activities that had the potential to result in the release of suspended particulate from within the TRBCA. The overall frequency and magnitude of exceedances of the Water Quality Performance Criteria was low, but there were more frequent and higher magnitude exceedances of the Water Quality Performance Criteria for turbidity and TSS outside of Zone 2. Limited visual evidence suggested that the integrity of the TRBCA may have been compromised in Zones 2 and 3 on some occasions.

Sediment Sampling for Recontamination

Prior to Phase 2 work, SLR Consulting (Canada) Ltd. collected baseline sediment samples from 20 locations immediately surrounding the work area outside of the TRBCA. Surface grab samples were collected in September 2015 from the residuals management cover (RMC) sand layer placed during Phase 1B of the EGD Project to determine pre-construction conditions immediately outside of the Phase 2 work boundary, and to establish a baseline from which future samples could be compared. Samples were analyzed for total metals, PAHs, PCB, TBT, select pesticide parameters, and dioxins and furans. In addition to the surface sediment samples, diver video surveys were conducted along the armoured slope adjacent to the TRBCA for documentation purposes and to establish pre-construction conditions of the areas surrounding the Phase 2 work site.

Baseline sediment chemistry was compared to NRAOs established during Phase 1B. With the exception of three locations, results were below the NRAO thresholds during the baseline sampling event. Concentrations of total metals and/or PAHs were elevated between the 1x and 4x NRAO at the remaining three locations. Diver surveys did not observe any anomalies along the armoured slope adjacent to the TRBCA during pre-construction surveys.

Re-assessment of sediment quality at the baseline locations was conducted during the construction period and again once substantial completion of the construction period was achieved. In May 2016, due to an unscheduled opening of the TRBCA, surface sediment samples were collected from baseline locations adjacent to two TRB gate openings to aid in determining whether early opening of the TRBCA caused migration and resettling of contaminated sediments in outlying areas. Eight locations were sampled and surface sediments were submitted to the analytical laboratory for total metals, PAHs, and PCB. Results indicated elevated concentrations of contaminants of concern at locations along the eastern portion of the site, which prompted additional sampling of baseline locations to the east of the TRB gate opening. In addition, seven step-out locations approximately 20 m further south of the original baseline locations were sampled in June 2016. Step-out sample locations were selected to aid in delineation of potential sediment recontamination outside of the Phase 2 work area. Figure 10 shows locations and results compared to NRAOs for the May and June 2016 sampling events.

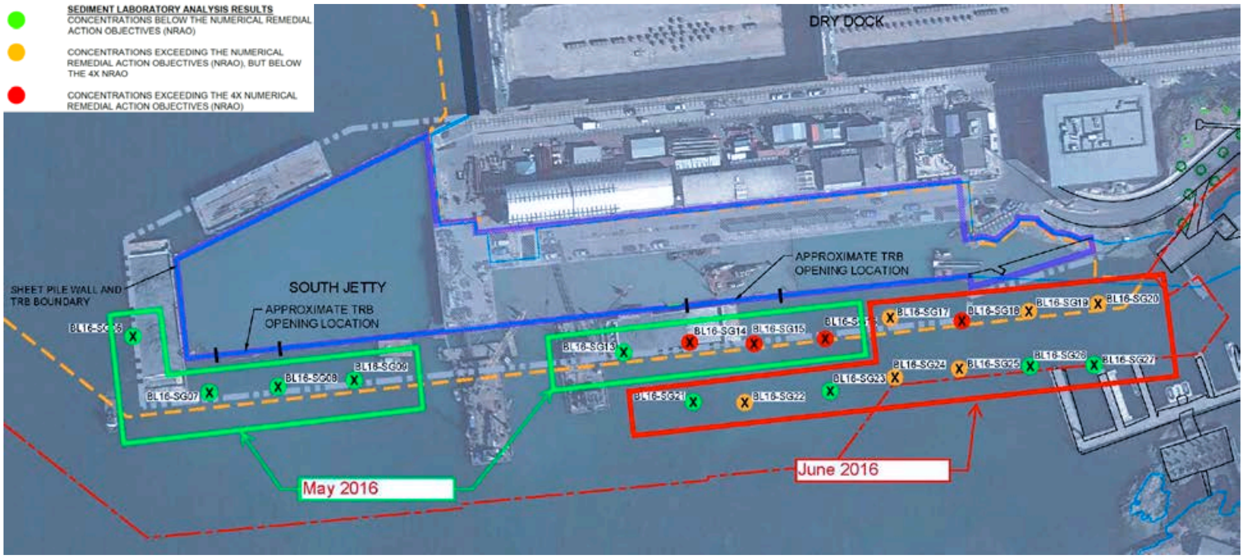

Figure 10. Interim sediment quality re-assessment locations and results compared to NRAOs.

Following substantial completion of the Phase 2 project, sediment quality was again re-assessed to determine whether recontamination occurred outside the TRBCA as a result of the Phase 2 construction work. Surface sediment samples were collected once all dredging activities were completed at each baseline and additional step-out location. Samples were submitted for analytical testing of total metals, PAHs, PCB, TBT, pesticides, and dioxins and furans, similar to the baseline sampling event. Results were compared to the Phase 1B NRAOs, as well as baseline conditions. Sediment chemistry indicated localized areas of higher concentrations of select contaminants of concern, particularly along the eastern portions of the site. The spatial extent of sediments with chemistry in excess of the remedial thresholds was limited, as shown in Figure 11. Increases in contaminant concentrations in surface sediments outside the TRB may be attributable to periodic release of suspended sediment from the Phase 2 work area; however, influx of contaminated sediments from other adjacent areas of the harbour may also have contributed to elevated contaminant concentrations. As noted above, water quality monitoring results are consistent with the observed increase in sediment contaminant concentrations within localized areas at the eastern portion of the site.

Figure 11. Post-construction sediment quality re-assessment locations and results compared to NRAOs.

Consideration of these results combined with results of the water quality and environmental monitoring program during Phase 2 aided in determining whether additional remedial action was required outside the TRBCA. Potential remedial actions that were identified during the planning stages of the project included no action, re-dredging of areas outside the Phase 2 boundary, and placement of additional RMC material outside the Phase 2 boundary, according with the following conditions:

- If results are less than NRAOs: no action;
- If results are greater than 1x NRAO but less than 4x NRAO: RMC placement; and
- If results are greater than 4x NRAO: re-dredge.

Due to scheduling and cost constraints, re-dredging of areas outside the Phase 2 boundary was not practical. In order to address the elevated concentrations of contaminants of concern observed in the interim and post-construction sampling events, the contractor placed a sand cover in areas with higher concentrations outside the Phase 2 work area to provide a clean surface at the end of construction. The sand layer was placed with a thickness of 0.30 m in areas where exceedances of the 4x NRAO multiple were noted during the May, June, or October 2016 sampling events. This sand layer is expected to mix with underlying sediments over time to achieve overall remedial targets at the site, and will be monitored for performance in the long term. Figure 12 shows sand layer placement locations.

Post-construction diver surveys were also conducted along the armoured slopes and within the Phase 2 area for comparison to baseline conditions and to document evidence of dredgeate spillage or other conditions not meeting design requirements of the project. During these surveys, it was noted that along the northern and western boundaries of the site, exposed sediments were present due to extraction of the sheetpile wall in these areas. Additional armouring was installed by the contractor to limit exposure of these sediments and provide a consistent isolation barrier between the Phase 1B and Phase 2 armouring. Figure 10 shows locations where additional armour was placed at the conclusion of the Phase 2 project.

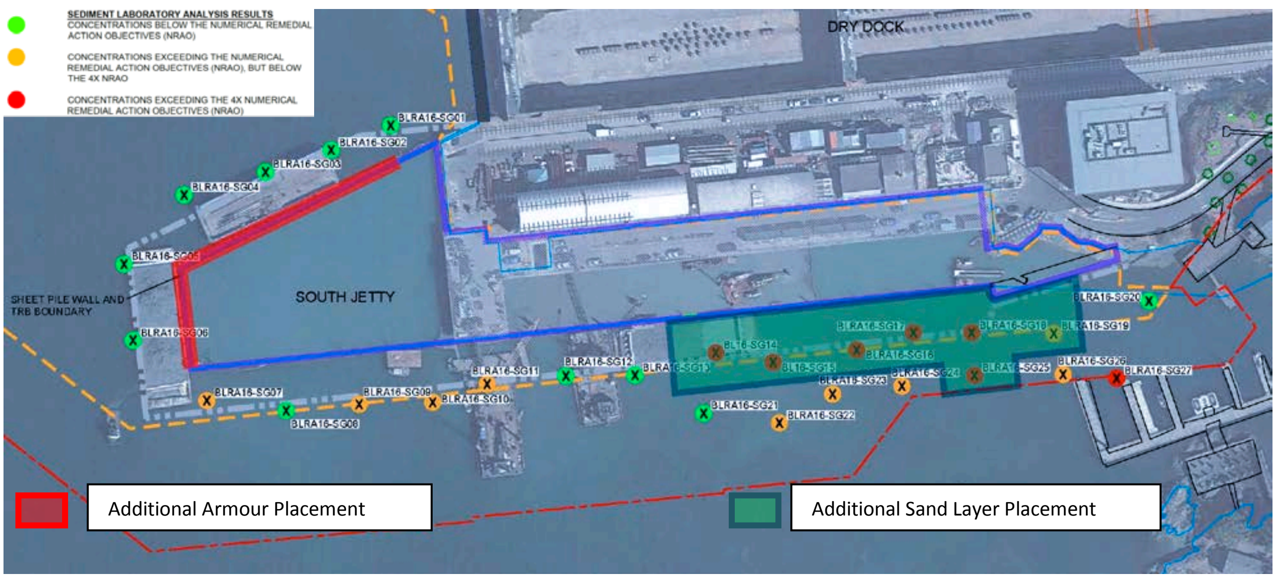

Figure 12. Locations of sand layer and additional armour placement.

Finally, a comprehensive long-term monitoring plan is anticipated to be developed by PWGSC that will include longer durations, ranging from 3 to 10 years, for different components of the remediation including condition and performance of engineered cap components, monitoring of sediment quality, and comparison to mixing predictions of applied sand layers within Phase 1B areas.

CONCLUSIONS

This paper describes the design and construction of the TRB and performance monitoring conducted during EGD Phase 2 remediation to prevent and assess recontamination of the surrounding areas that were previously remediated. The TRB design, construction, and operation controlled suspended sediments and limited potential recontamination of Phase 1B areas. The intensive water quality monitoring program was used to monitor compliance with stringent Water Quality Performance Criteria intended to protect aquatic resources and limit recontamination. The overall frequency and magnitude of exceedances of the Water Quality Performance Criteria was low, but there were more frequent and higher magnitude exceedances of the Water Quality Performance Criteria outside of Zone 2. Baseline and post-project sediment testing was used to assess the presence of recontamination outside the TRBCA and indicated localized higher concentration areas, particularly along the eastern portions of the site. While the source of the higher concentrations outside of the TRBCA is inconclusive, higher water quality monitoring results in this area are consistent with the localized increase in sediment contaminant concentrations in the eastern portion of the site. Placement of RMC material was effective in addressing these higher concentration areas. Overall, the TRB and the intensive water quality and sediment monitoring programs were effective in managing risks of recontamination during EGD Phase 2 remediation.

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CITATION

Berlin, D., N. Healey, D. McKeown, C. Major, A. Mylly, D. Osguthorpe, M. Woltman, P.E., T. Wang, P.E., R. Hill, D. Kettlewell. "Controlling Recontamination During Phase 2 Remediation at the Esquimalt Graving Dock." *Proceedings of the Western Dredging Association (WEDA) Dredging Summit & Expo 2017, Vancouver, British Columbia*, Canada, June 26-29, 2017.