Exhibit D
Interim Action Work Plan
Terminal 4 Stormwater Treatment Pond

Prepared for

Port of Vancouver
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Vancouver, WA 98660

Prepared by

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CITATION

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Terminal 4 Stormwater Treatment Pond.
Prepared for Port of Vancouver by Parametrix
Portland, Oregon. June 2023.

CERTIFICATION

The technical material and data contained in this document were prepared under the supervision and direction of the undersigned, whose seal, as a professional hydrogeologist licensed to practice as such, is affixed below.

Prepared by Richard Roché, LHG

Reviewed by Rick Malin, LHG

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1. INTRODUCTION

On behalf of the Port of Vancouver, U.S.A. (Port), Parametrix has prepared this Interim Action Work Plan (IAWP) to describe interim action activities to be conducted as part of a Remedial Investigation and Feasibility Study (RI/FS) at the Port. The actions are specific to the stormwater treatment pond located on Terminal 4 (T4).

This IAWP was prepared in accordance with the Model Toxics Control Act (MTCA) as defined in Washington Administrative Codes (WAC) 173-340-350 and 173-340-430, and pursuant to Agreed Order (AO) No. DE 18152 (AO DE 18152) between the Washington State Department of Ecology (Ecology) and the Port (the Parties). AO DE 18152 identifies the Site as the “Vancouver Port of NuStar Cadet Swan,” Facility Site Identification (FS-ID) 1026. The AO requires the Port to prepare a Feasibility Study and draft Cleanup Action Plan regarding certain hazardous substances on and in the vicinity of the Cadet Manufacturing Company and Swan Manufacturing Company portions of the Site. The extent of the Site is included on Figure 1. The AO also requires Ecology review and approval of work plans for any proposed interim actions to address site contaminants.

The Port will complete the Interim Action after Ecology approval of this IAWP and an Engineering Design Report (EDR). The overall team and responsibilities include:

- Port of Vancouver – Overall project, working with consultants to develop contractor bids and specifications, and compliance with the requirements of AO DE 18152.
- Maul Foster Alongi (MFA) – Engineering, including development of the EDR and working with Port to develop contractor bids and specifications; providing oversight of the Interim Action; and preparation of the construction report.
- Parametrix – Regulatory, including working with the Port on Ecology communications and compliance with the requirements of AO DE 18152, preparation of the Interim Action report, and communications with the technical consultant team for AO DE 18152.

1.1 Objectives

The objective of this Interim Action is to remove and properly dispose of stormwater solids impacted by Site contaminants from all portions of the T4 pond. Removal of the contaminated stormwater solids from the pond will reduce the potential threat to human health and the environment. The cleanup action will address the following objectives:

- Return of pond base to its original depth and engineered design.
- Control and removal of a pollutant source with potential to impact downstream waterbodies.
- Improve the T4 stormwater treatment system and compliance with the Industrial Stormwater General Permit (ISGP).

The work area includes removal of accumulated stormwater solids at a depth of 6 to 12 inches.

1.2 Regulatory Framework

Section VII.E of AO DE 18152 requires the Port to prepare and submit to Ecology an IAWP for any proposed interim actions to address Site contaminants. The IAWP must include a scope of work and schedule.

The Port will complete the Interim Action, and will to the maximum extent possible, share documents between Ecology and the Port; documents will include reports, approvals, and other relevant correspondence concerning the activities performed pursuant this IAWP that are shared with NuStar and Kinder Morgan Bulk Terminals (KMBT).

1.3 IAWP Organization

The remainder of this report is organized as follows:

Section 2 Port of Vancouver Stormwater System – Includes a description of the stormwater infrastructure that conveys stormwater to the pond, provides details related to the pond construction, and summarizes analytical data for contaminants in stormwater and pond sediments.

Section 3 Interim Action – Describes the approach and procedures for pre-Interim Action and Interim Action activities.

Section 4 Interim Action Report – Summarizes the general contents of the Interim Action report.

Section 5 Schedule – Provides a schedule for the Interim Action tasks.

2. PORT OF VANCOUVER STORMWATER SYSTEM

Stormwater infrastructure was initially installed at Terminals 2 and 3 in the 1960s during the terminal development and included catch basins and drainage pipes that discharged stormwater to the river as allowed by regulatory codes of the time. Terminals 2 and 3 were redeveloped by the Port from 1998 to 2003; this included the installation of a new stormwater system that collects stormwater from portions of Terminals 2 and 4, and all of Terminal 3, and conveys it to a stormwater treatment pond at Terminal 4 (Figure 2). Stormwater discharge from the Terminal 4 pond is allowed by an Ecology Industrial Stormwater General Permit (ISGP), number WAR000424.

2.1 Pond Location and History

The pond is located in Section 20, Township 2 north, Range 1 east of the Vancouver quadrangle. The pond is bounded by the Fort Vancouver Seafarers Center and NW Harborside Drive to the south, Port railroad to the east and north, and a paved parking lot to the west.

Originally constructed during the development of Terminals 3 and 4, the pond has been modified several times since its original design and installation as an infiltration facility. In 2003, the pond was modified to serve as a wet pond, rather than an infiltration facility. In 2012, the pond size was expanded to its current size of approximately 5 acres. During this expansion, the pond was reconfigured to increase the flow path length in the southern "downstream" area while maintaining the volume in the northern "forebay" areas, total volume, permanent pool surface elevation, and design capacity. After this expansion, the downstream was also temporarily used for piloting secondary treatment via a floating wetland, but this pilot has since been completed and only a few floating wetlands remain.

2.2 Pond Maintenance and Monitoring History

While maintenance and monitoring of the pond has been performed, complete removal and disposal of accumulated stormwater solids from the entire pond area has not been performed since the expansion work in 2012. The Port began to perform work associated with this removal and disposal in mid-2022, including media sampling and coordination with outside parties.

2.3 Pond Current Use

Currently, the pond's design and function remain substantially similar to the 2012 description in Section 2.1. The forebay area receives stormwater runoff from portions of Terminals 2 and 4, and all of Terminal 3, and serves as the main capture mechanism for suspended and settleable solids. The downstream area receives supernatant water from the forebay and serves as a secondary capture mechanism for suspended and settleable solids.

The stormwater basin that drains to the Terminal 4 treatment pond, and basin stormwater infrastructure , including the Terminal 4 outfall, are shown on Figure 2. Stormwater in areas shaded yellow on Figure 2 is pumped to a Port pre-treatment plant prior to discharge to the City of Vancouver wastewater system in accordance with a permit. A technical memorandum detailing the Terminal 4 pond stormwater system is included in Appendix A.

Stormwater from the NuStar Leasehold (ISGP Permit WAR308319) and KMBT Operations Area (ISGP Permit WAR308368), areas located within the Site, also discharges to the Terminal 4 treatment pond.

KMBT ceased handling bentonite and copper at the bulk terminal operational area upon the expiration of its operating agreement with the Port on December 31, 2021.

2.4 Stormwater and Pond Characterization

2.4.1 Phase I SRI Investigative Actions – Stormwater Conveyance System

Two stormwater sampling events were conducted as part of the SRI in accordance with procedures and methods detailed in the *Supplemental Remedial Investigation Work Plan* (Cascadia Associates et al. 2020).

The initial stormwater sampling event was completed between March and June of 2021 by KMBT and was subsequently reported in *Supplemental Remedial Investigation – Vancouver Bulk Terminal – Stormwater Investigation* (Antea Group 2021). The stormwater samples were collected from catch basins and stormwater conveyances in the vicinity of the KMBT Operations Area. This phase of investigation did not include sampling from areawide stormwater mains carrying stormwater from other parts of the Port to the stormwater pond. Sample locations and results are included in Appendix B.

The second stormwater sampling event was completed in December 2021, also by KMBT, and reported in *Supplemental Remedial Investigation – Vancouver Bulk Terminal – Additional Stormwater Investigation* (Antea Group 2022). The purpose of the additional stormwater investigation was to supplement the findings of the 2021 investigation with an assessment of the spatial distribution of metals at distance from the former KMBT Operations Area, as well as to ascertain if other sources of metals were present. To ascertain the spatial distribution of metals surrounding the former KMBT Operations Area and to identify other potential sources, 18 additional sample locations were added. Sample locations and results are included in Appendix B.

Stormwater data for the sampling events indicate that concentrations of total metals—arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, and zinc—exceeded the most conservative screening levels for one or more pathways (Antea Group 2022).

2.4.2 Stormwater Pond Sediment Characterization

In October 2022, the Port collected grab samples of accumulated sediments to characterize sediments for disposal. Seven grab samples were collected from the forebay on October 4, 2022, and 10 grab samples were collected from the downstream area on October 11, 2022. All samples were analyzed for Resource Conservation and Recovery Act (RCRA) 8 metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), copper, zinc, and diesel- and/or oil-range hydrocarbons. These contaminants of potential concern were selected based on the Port's understanding of operations within the drainage basin and the analytical results for stormwater samples previously collected to characterize stormwater.

The sediment data are summarized in Table 1 and Table 2 and on Figures 3 and 4. Oil-range petroleum hydrocarbons were above MTCA Method A soil cleanup levels in 7 out of 17 samples tested. The concentrations of arsenic, cadmium, chromium, copper, lead, mercury, and zinc are above the state-wide natural background soil concentrations.

3. INTERIM ACTION

3.1 Pre-Interim Action Tasks

The Port will complete the following tasks prior to the Interim Action to refine the scope of work to be included in a request for proposals from contractors.

3.1.1 Estimation of Volume of Pond Sediment

An estimate of sediment volumes of the pond will be developed. Forebay and downstream area volumes will be estimated separately. If the two areas require separate disposal locations, the volumes will be used separately; if the two areas can be disposed of at the same location, the volumes will be combined. Volumes will be estimated by multiplying the surface area of the separate areas by an assumed average depth of sediment in the individual areas. Average depths will be determined by completing a survey of the elevations of sediment surfaces in the individual areas, comparing the sediment surface elevations to pond design bottom elevations, and then using the differences between the two to assign an average depth to each area.

3.1.2 Sediment Disposal Evaluation

Sediment characterization data and volume estimates will be compiled to assess the final disposal location (or locations) for the accumulated sediment. Laboratory data will be shared with disposal facilities for the purposes of characterization, and estimated volumes of sediment from individual areas of the pond (or both, if both are able to be disposed of at the same facility) will be used to develop a request for proposals from contractors.

3.1.3 Contractor Bids and Specifications

The Port engineering team will work with MFA to develop construction specifications and obtain contractor bids for the Interim Action.

3.1.4 Engineering Design Report (EDR)

The Port will prepare and submit an EDR to Ecology for review and approval. The EDR will define the approach to implement the Interim Action and follow the requirements of WAC 173-340-400 (4) (a), including providing:

- General information on the pond, including a summary of information on the previous environmental investigations.
- Contaminant and contaminated-media characteristics and relevant cleanup standards applied to the pond.
- Identification of who will be responsible for cleanup action during and following construction.
- The proposed remedial action, including design assumptions and calculations, as well the following details:
    - Contractor mobilization and site preparation
    - Dewatering procedures

   - Solids removal and management
   - On-site best management practices
   - Off-site disposal plan
   - Airborne dust mitigation
   - Contingency planning
- Tables, figures, and drawings, including preliminary construction plans detailing the work to be performed.
- Appendices, including a Contaminated Media Management Plan (CMMP); a health and safety plan (HASP); Sampling and Analysis Plan (SAP); Compliance Monitoring Plan; and a pond amendment product sheet.

3.2 Interim Action Tasks

The Interim Action involves excavation and off-site disposal of accumulated stormwater solids. The pond will be excavated to the 2011 design elevation. The work will be completed in late summer to coincide with typical weather that best serves the required tasks. These required tasks include the following elements:

- Dewatering the pond:
   - Stormwater will be pumped from the pond and treated prior to discharge to the Columbia River in accordance with the Port's stormwater permit (ISGP).
- Desiccation of the accumulated stormwater solids:
   - After removal of the stormwater, the solids in the pond basin will be allowed to dry naturally.
- Stabilization, removal, and disposal of accumulated stormwater solids:
   - If necessary, the solids will be stabilized to further reduce moisture content.
   - Solids will be removed to the depth where underlying soil is encountered.
   - Solids will be stockpiled within the pond basin prior to loading into dump trucks for transport and disposal at an appropriate permitted landfill.
   - All work to be performed within the pond area; solids will not be stockpiled or loaded outside of the work area. Dust control methods may be used during dry weather and wind events.
- Post-solids removal soil sampling:
   - After removal of the solids, samples of the underlying soil will be collected to document the concentrations of the Site contaminants of concern and hazardous substances. Analytical data will be summarized in an Interim Action report which will include evaluation of the data to screening levels. In addition, the data will be used to further assess the nature and extent of Site contaminants as part of a Supplemental Remedial Investigation being conducted by the Port, NuStar, and Kinder Morgan. The number of soil samples will be set to ensure representativeness.

4. INTERIM ACTION REPORT

The contractor will prepare a construction completion report documenting final excavation extents, confirmation of sampling results, project photos, daily construction reports, soil disposal receipts, and other applicable cleanup action details. This report will be delivered to the Port within 30 days of completion of work, and details from this report will be included in an Interim Action Completion Report.

A draft Interim Action report will be submitted to Ecology for review within 90 days of substantial completion of the pond cleanout activities. The report will document the sediment removal activities, management and disposal of excavated materials, post-excavated conditions, and recommendations as appropriate. The data will be submitted to EIM within 90 days of receipt of lab data.

The findings of the Interim Action, including the analytical results for soil samples, will also be incorporated into a Supplemental Remedial Investigation being conducted by the Port, NuStar, and Kinder Morgan.

5. SCHEDULE OF WORK

A schedule for the Interim Action activities is summarized below.

Task	Responsible Party	Anticipated Start Date	Anticipated End Date
Submit SEPA checklist to Ecology	Port	April 10, 2023	April 27, 2023
Project permitting (grading)	Port, MFA	May 5, 2023	August 5, 2023
Submit Engineering Design Report to Ecology	Port, MFA	June 1, 2023	July 1, 2023
Public bid	Port	June 5, 2023	July 7, 2023
Dewatering of pond (performed under ISGP)	Port	June 1, 2023	August 1, 2023
Desiccation of stormwater solids	Port	June 1, 2023	August 1, 2023
Removal of stormwater solids	Contractor	August 6, 2023	September 1, 2023
Draft construction completion report	Contractor	After completion of work	Within 30 days of completion
Draft Interim Action Completion Report	Port and Parametrix	After receipt of construction completion report	Within 90 days of receipt

6. REFERENCES

Antea Group. 2021. Supplemental Remedial Investigation – Vancouver Bulk Terminal – Stormwater Investigation Technical Memorandum. Prepared for the Port of Vancouver, U.S.A.

Antea Group. 2022. Supplemental Remedial Investigation – Vancouver Bulk Terminal – Additional Stormwater Investigation Technical Memorandum. Prepared for the Port of Vancouver, U.S.A.

Cascadia Associates, LLC, Antea Group, Parametrix. 2020. Supplemental Remedial Investigation Work Plan. NuStar Vancouver Main Terminal, 2565 NW Harborside Drive, Vancouver, Washington. Prepared for NuStar Terminals Services, Inc./Kinder Morgan/Port of Vancouver. December 18, 2020.

Tables

Terminal 4 Stormwater Pond Sediment Sampling Analytical Results

Table 1

METALS

Sample ID	Sample Date	Sampler	Analysis Method	Units	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Silver	Zinc
FS-1	10/4/2022	Port	EPA 6020B	mg/kg	10.4	128	1.7	25.9	1420	88.5	ND<.257	ND<3.21	1.41	785
FS-2	10/4/2022	Port	EPA 6020B	mg/kg	9.19	118	1.41	21.9	1220	57.3	ND<.177	ND<2.21	1.38	591
FS-3	10/4/2022	Port	EPA 6020B	mg/kg	21.4	150	3.57	34.4	4030	175	ND<.336	ND<4.20	3.93	1490
FS-4	10/4/2022	Port	EPA 6020B	mg/kg	29.9	126	4.91	37.2	6470	230	0.267	ND<3.18	5.47	1810
FS-5	10/4/2022	Port	EPA 6020B	mg/kg	33.9	169	5.87	45.1	6640	276	0.301	ND<3.64	4.88	2090
FS-6	10/4/2022	Port	EPA 6020B	mg/kg	17	129	3	26.3	3090	139	ND<.242	ND<3.02	3.02	1190
FS-7	10/4/2022	Port	EPA 6020B	mg/kg	17.3	185	2.66	35	2760	107	ND<.181	ND<2.26	2.47	1030
FS-8	10/11/2022	Port	EPA 6020B	mg/kg	14.6	119	1.44	23	1420	68.3	ND<.130	ND<1.63	1.29	527
FS-9	10/11/2022	Port	EPA 6020B	mg/kg	13	146	1.76	29.7	1700	77.3	ND<.170	ND<2.13	1.43	690
FS-10	10/11/2022	Port	EPA 6020B	mg/kg	6.99	105	1.1	20.1	746	35.2	ND<.0962	ND<1.20	0.692	406
FS-11	10/11/2022	Port	EPA 6020B	mg/kg	10.1	135	1.5	25.3	894	42.7	ND<.149	ND<1.86	0.691	532
FS-12	10/11/2022	Port	EPA 6020B	mg/kg	8.51	171	1.05	25.5	746	41.2	ND<.162	ND<2.02	0.695	452
FS-13	10/11/2022	Port	EPA 6020B	mg/kg	13.7	173	1.55	30.6	1070	56.7	ND<.221	ND<2.76	0.911	565
FS-14	10/11/2022	Port	EPA 6020B	mg/kg	13.5	153	1.26	28.3	889	44.3	ND<.203	ND<2.54	0.747	494
FS-15	10/11/2022	Port	EPA 6020B	mg/kg	11.6	201	1.24	33.4	882	49.1	ND<.174	ND<2.17	0.727	526
FS-16	10/11/2022	Port	EPA 6020B	mg/kg	11.1	185	1.19	29.4	686	40.5	ND<.199	ND<2.48	0.651	458
FS-17	10/11/2022	Port	EPA 6020B	mg/kg	12.2	196	0.945	30.5	529	33	ND<.155	ND<1.94	0.46	371

ND = Not Detected above reporting limit

Terminal 4 Stormwater Pond Sediment Sampling Analytical Results

Table 2

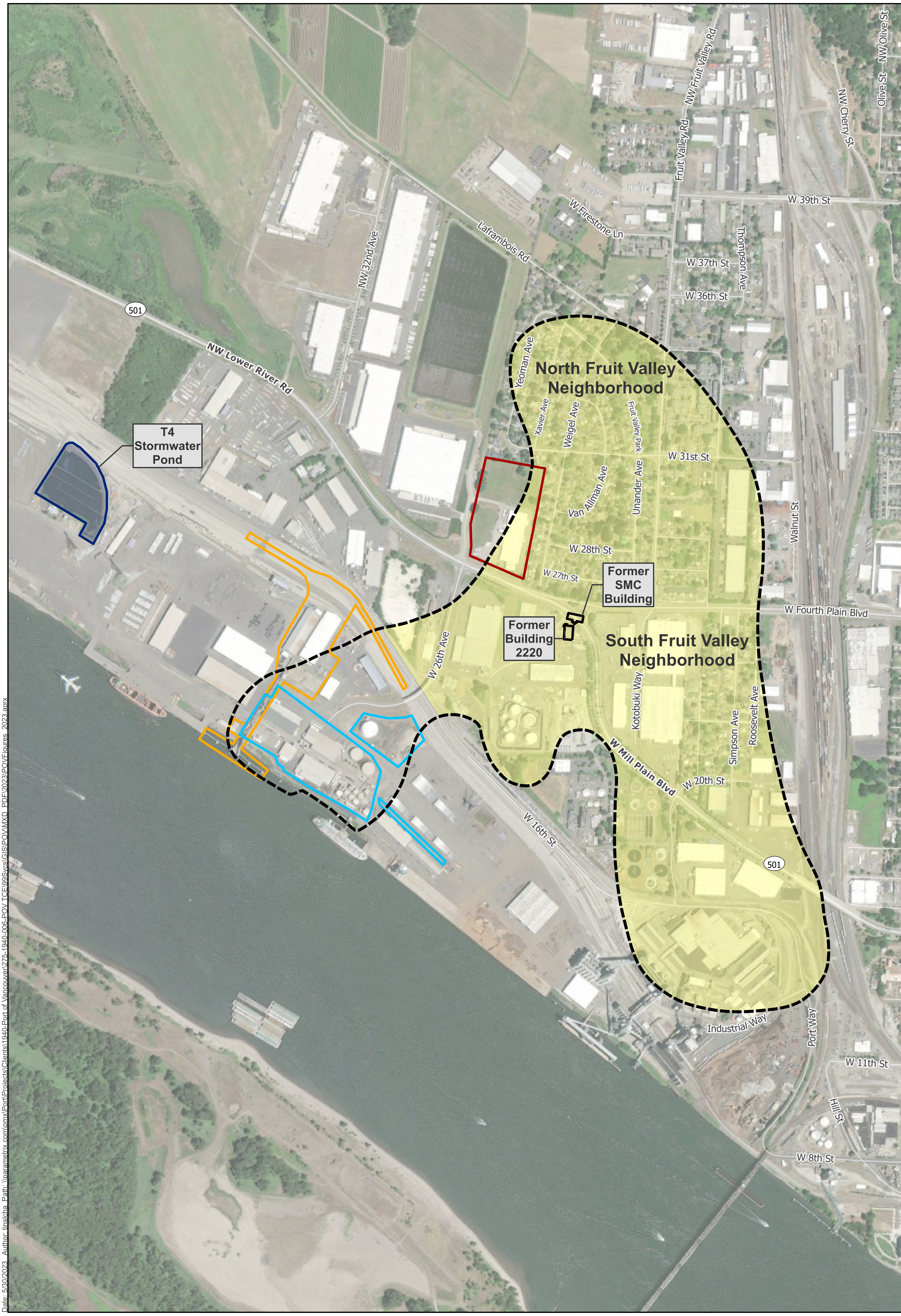
HYDROCARBONS

Sample ID	Sample Date	Sampler	Analysis Method	Units	Diesel	Oil	Gasoline
FS-1	10/4/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<648	3210	ND<32.1
FS-2	10/4/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<412	1590	ND<17.4
FS-3	10/4/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<797	4010	ND<40.9
FS-4	10/4/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<596	2970	ND<31.7
FS-5	10/4/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<698	3870	ND<36.8
FS-6	10/4/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<622	2290	ND<30.9
FS-7	10/4/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<448	2260	ND<19.0
FS-8	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<316	1410	NT
FS-9	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<432	2010	NT
FS-10	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<239	1040	NT
FS-11	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<75.1	1100	NT
FS-12	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<78.4	960	NT
FS-13	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<104	881	NT
FS-14	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<99.7	838	NT
FS-15	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<84.8	870	NT
FS-16	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<102	988	NT
FS-17	10/11/2022	Port	NWTPH _Dx/Gx	mg/kg	ND<76.9	658	NT

ND = Not Detected above reporting limit

NT= Not tested (Gasoline was not detected in any samples collected in forbay (FS-1 thru FS-7) so it was not sampled for in the remainder of the pond

Figures



Parametrix

Source: ESRI, Port of Vancouver

0 250 500 1,000 Feet

- Site - Historical Maximum Extent of HVOC Contamination
- Area of Site Included in Agreed Order 18152
- Stormwater Pond
- Cadet Facility
- Kinder Morgan Facility
- NuStar Facility

Figure 1

Site Location and Facility Map

Interim Action Work Plan

Port of Vancouver

Agreed Order DE 21295

All data shown on this map is approximate and is based on previous reports provided to the Port of Vancouver, available as-built data, Port staff knowledge, and some field verification. Some information is innaccurate due to ongoing or recently completed construction where as-builts are not available. This data may not reflect actual conditions and should not be relied upon for planning or design at the Port of Vancouver.

Background imagery ESRI

Port of Vancouver
Figure 2 - T4 Pond Drainage Basin
November 2021

0 250 500 1,000
Feet (NTS)

N

Port of Vancouver USA

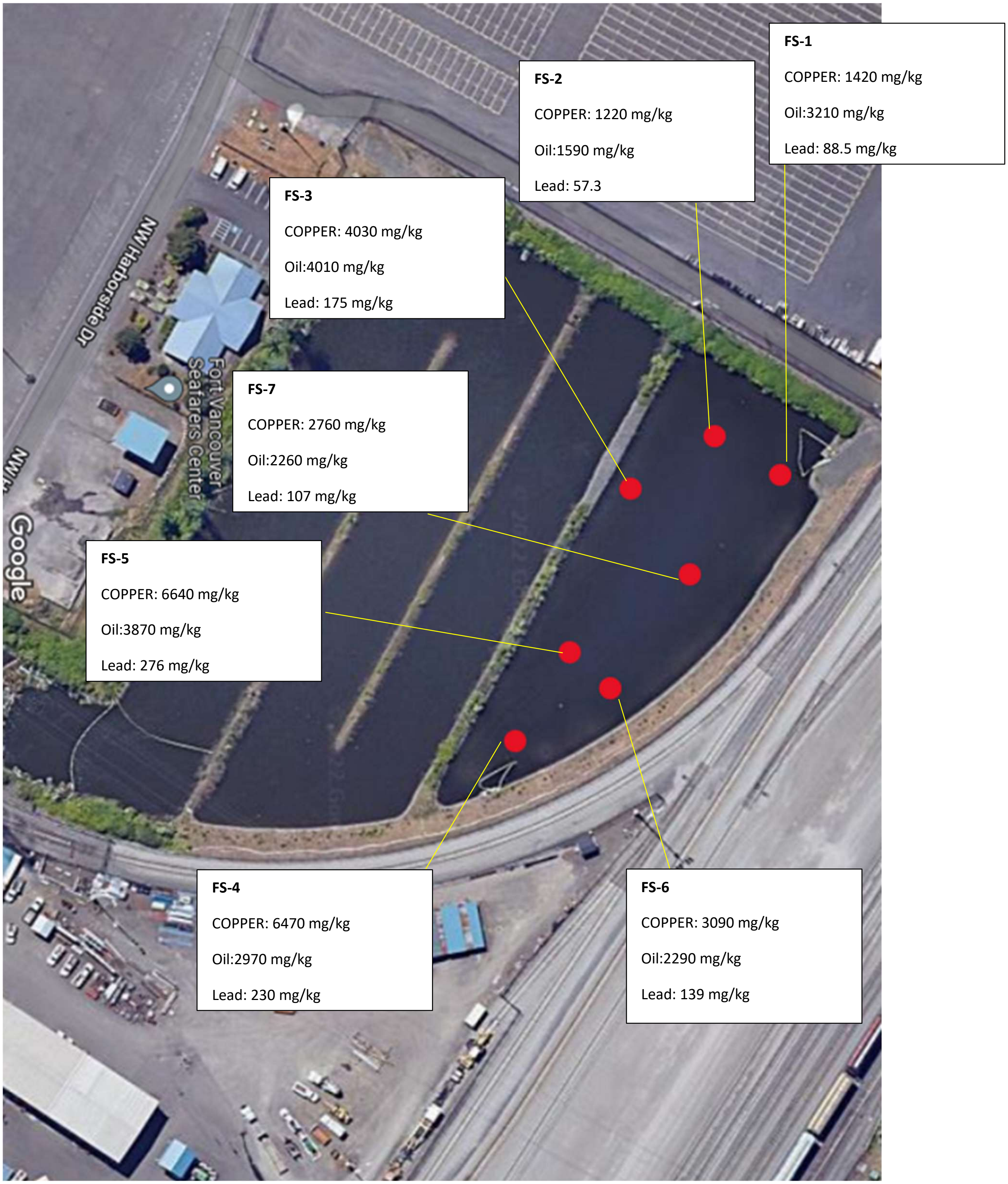


Figure 3
Terminal 4 Stormwater Treatment Facility
Forebay Sediment Investigation

Figure 4
Terminal 4 Stormwater Treatment Facility
Additional Forebay Sediment Investigation

Appendix A

T4 Pond Floating Treatment Wetland Assessment

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T4 Pond Floating Treatment Wetland Assessment

30 September 2020

Updated 24 March 2021

Prepared for

Port of Vancouver
3103 NW Lower River Road
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KJ Project No. 1896007*02 & 2165013*00

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List of Acronyms

Acronym	**Description**
%DCu	percent dissolved copper
µg/L	microgram per liter
BMP	best management practice
$CaCO_3$	calcium carbonate
City	City of Portland
COC	constituent of concern
DO	dissolved oxygen
DOC	dissolved organic carbon
EPA	U.S. Environmental Protection Agency
FTW	floating treatment wetland
ISGP	Industrial Stormwater General Permit
kg	kilogram
L	liter
mg	milligram
NTU	nephelometric turbidity unit
ORP	oxidation reduction potential
port	Port of Vancouver, USA
SM	Standard Method
T4	Terminal 4
TCu	total copper concentration
TOC	total organic carbon
TSS	total suspended solids

Section 1: Introduction and Objectives

The Port of Vancouver, USA (port), located on the Columbia River in Vancouver, Washington, is the third largest port in the State of Washington. The port encompasses over 800 acres of developed industrial land and handles a broad range of cargoes. As a part of ongoing stormwater treatment efforts at the port, a floating treatment wetland (FTW) was installed at the Terminal 4 stormwater retention pond (T4 Pond) in 2014. Kennedy Jenks assessed the current FTW configuration to provide insight into upgrades and/or expansions that may improve pollutant reduction.

1.1 Report Objectives

The objectives of this study are to characterize the current state of the FTW and evaluate its performance via sediment and water quality sampling and monitoring. It is expected that the relative concentrations of copper and zinc in dissolved, suspended sediment, and bottom sediment fractions upstream, in, and downstream of the FTW will shed light on the mechanism(s) of pollutant reduction and will inform potential modifications to the FTW that could be made to improve pollutant treatment.

1.2 Terminal 4 Stormwater Retention Pond

The T4 Pond receives runoff from approximately 189 acres of Terminals 2, 3, and 4 as shown on Figure 1. This area includes parking lots, railyards, several warehouses, and two loading bays. Terminal 3 contains a bulk copper handling and loading facility. Runoff from the bulk copper facility is diverted to a bulk copper concentrate facility and does not discharge to the T4 Pond. Most of the area draining to the T4 Pond is paved except for the railroad tracks and a few other small areas.

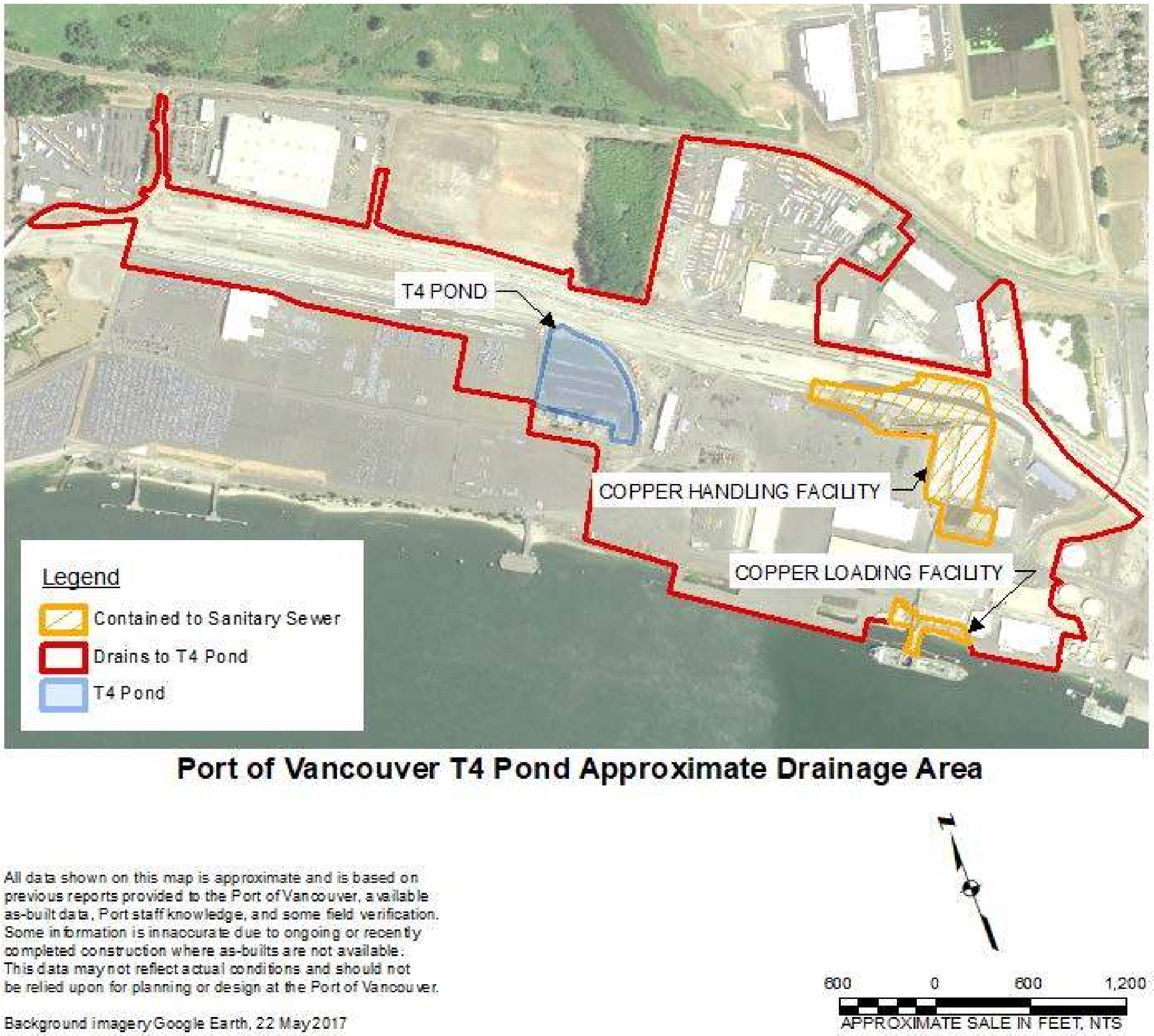


Figure 1: T4 Pond Drainage Area

The T4 Pond was originally designed and installed during the development of Terminals 3 and 4 in the 1990s to provide stormwater quality treatment and it has been modified several times over the years. It was originally designed as an infiltration basin and was modified to a wet pond in 2003. The current pond configuration, shown on Figure 2, was constructed in 2012. The T4 Pond's internal spillway and outlet structure were modified, and earthen berms were added to lengthen the flow path in the pond. The 2012 pond configuration increased the effective hydraulic residence time, promoted plug flow, and enhanced settling. The estimated average flow path length was almost tripled from approximately 500 feet to approximately 1,500 feet. The pond's water quality surface area was also increased during the reconfiguration from approximately 4.7 acres to approximately 5.3 acres. In 2015, an FTW was added to the relatively quiescent second cell of the pond across the flow path to reduce the pond's effluent metal concentrations.

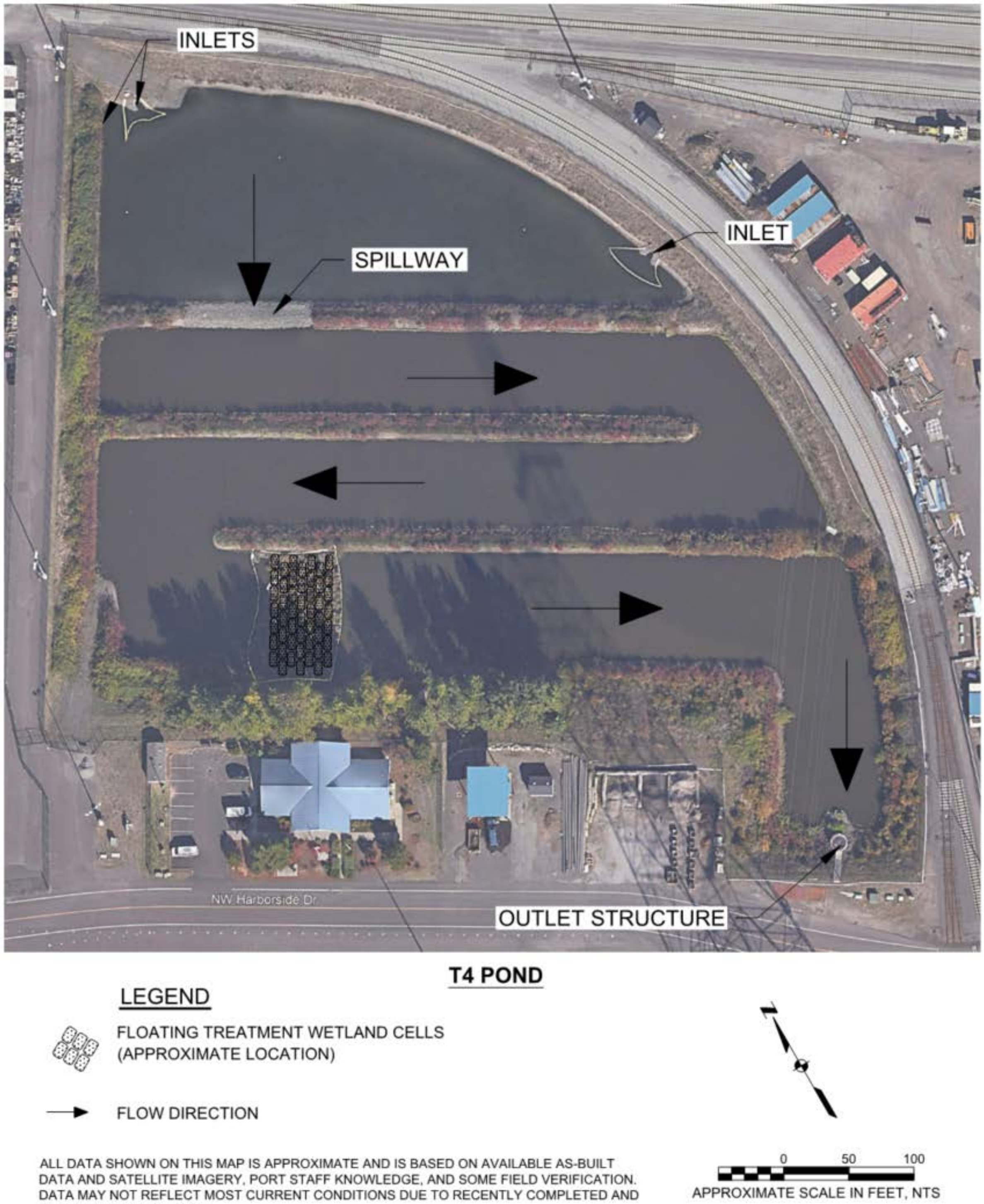


Figure 2: T4 Pond Configuration and FTW Location

Stormwater enters the T4 Pond forebay through three inlets at the northern end of the pond. Stormwater flows from the forebay over or through a spillway to the main pond and passes through a meandering section that provides quiescent conditions and time to enhance settling of particulates. Stormwater flows from the pond through an outfall structure which is designed to maintain a permanent pool and constant treatment volume. Pollutant reduction is enhanced by biological activity within the pond and through uptake of dissolved constituents by vegetation planted along the berms and pond side slopes, as well as by the FTW.

1.3 T4 Pond Stormwater

The port discharges stormwater from the T4 Pond under Washington State Department of Ecology Industrial Stormwater General Permit (ISGP) number WAR000424. Effluent benchmark values for this permit are summarized in Table 1. Corrective actions are required if the quarterly average value of any of the parameters regulated under the ISGP is exceeded. Corrective action requirements increase from Level 1 to Level 3 based on how many quarters out of the year benchmark values are exceeded.

Table 1: ISGP Sampling Benchmarks

Parameter	Units	Benchmark Value	Analytical Method	Laboratory Quantitation Level	Minimum Sampling Frequency
Turbidity	NTU	25	EPA 180.1 Meter	0.5	1/quarter
pH	Standard Units	Between 5.0 and 9.0	Meter/Paper	±0.5	1/quarter
Oil Sheen	Yes/No	No Visible Oil Sheen	N/A	N/A	1/quarter
Copper, Total	µg/L	14	EPA 200.8	2	1/quarter
Zinc, Total	µg/L	117	EPA 200.8	2.5	1/quarter

Notes:

NTU = Nephelometric turbidity unit
N/A = not applicable
µg/L = micrograms per liter
EPA = U.S Environmental Protection Agency

Between 2014 and 2017, the port acted to decrease copper discharged from T4 in response to an ISGP Level 3 corrective action triggered in 2010. This work included adding “Grattix” downspout filtration systems, jet cleaning the storm sewer in the T4 Pond drainage basin, altering the T4 Pond inlet and outlet piping, and constructing the FTW on the T4 Pond. The port and tenants also implemented negative-pressure structures with air handling equipment and baghouses to control dust emissions from a bulk copper facility in the pond’s drainage basin. The port employs regular sweeping and storm drain cleaning along with gutter cleaning, and biochar filter bags installed at storm drain inlets as copper source control.

The port has previously reported its determination that, based on monthly ISGP site inspections from the first three quarters of 2019, the likely sources of copper in T4 are brake dust from vehicles and atmospheric deposition from industrial facilities. Beginning in 2018 and continuing in 2021, investigative work required of the port, Kinder Morgan Bulk Terminals (KMBT), and NuStar under Agreed Order No. DE 15806 will be conducted. The purpose of this work is to assess the release of contaminants associated with materials handled by NuStar and materials handled by KMBT (including but not limited to copper, related metals, ammonia, and nitrate). The results of this work may identify other or additional sources of copper in T4.

1.4 FTW History in T4 Pond

The T4 FTW was constructed between May 2014 and January 2015. One hundred and twenty-six (126) 4-foot by 8-foot rectangular rafts were constructed for a combined surface area of 4,032 square feet. Each raft was made of a Styrofoam base topped with a layer of biodegradable mesh and a wooden frame around its perimeter and had 10 approximately 5-inch diameter holes through the Styrofoam for planting. Individual cells were tethered together and were planted with Slough Sedge (*Carex obnupta*). The rafts were initially attached to shore by a cable, but upstream and downstream booms were later added to keep the FTW formation together and in a fixed location in the pond. The cables and booms holding the FTW formation in place were intermittently pulled from the anchor points, allowing the individual rafts to float free and haphazardly amass in the downstream reach of the pond. This condition will be referred to as “broken up” in this report. The FTW has been broken up for a variety of reasons ranging from high winds to wildlife damaging anchors on the pond’s shore. Between July 2015 and July 2018, the FTW was intermittently broken up and put back in place but the exact dates of these events are unknown. In July 2018, the rafts were reportedly broken up and the FTW was reassembled in September 2018. The FTW was in place until the end of November 2019 when it was once again broken up. The FTW has not been documented as in place during 2020. This timeline is summarized on Figure 3.

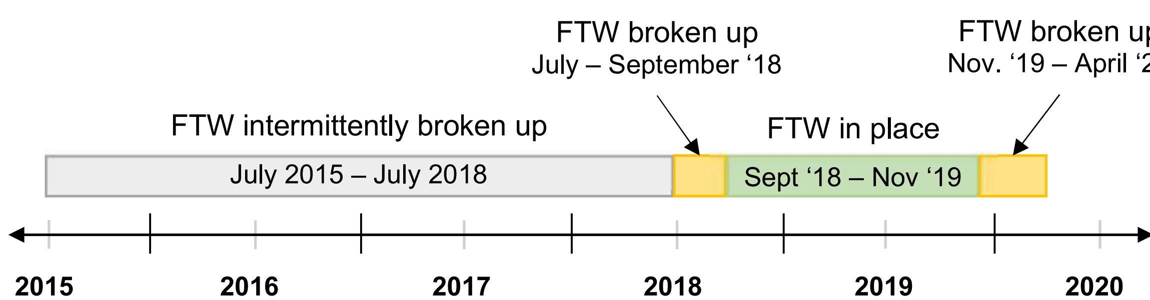


Figure 3: FTW Functionality Timeline

Section 2: Floating Treatment Wetlands

2.1 Floating Treatment Wetlands Background

Historically, constructed treatment ponds and wetlands have been used to reduce concentrations of suspended sediments and nutrients from stormwater runoff, as well as treated wastewaters and surface waters. Innovative technologies like FTWs have more recently been evaluated for the removal of constituents like metals.

FTWs utilize buoyant mats or rafts of rooted plants deployed on the surface of a constructed treatment pond or wetland. The root systems below the rafts extend multiple feet into the water column and provide removal of constituents both via uptake by roots and associated biofilms and by physical removal of particles.

Plants in FTWs uptake nutrients such as nitrogen and phosphorus, which are necessary for cellular growth. Ammonia may also be used by the biofilms growing on root structures (Pavlineri et al. 2017). Plants only uptake a small percentage of metals through their roots and this is not a major pathway of metals removal (Tanner 2011). Nutrient uptake is key to the functionality of FTWs because it keeps vegetation healthy and therefore, functional for treatment (Borne et al. 2013a).

FTWs are believed to reduce copper and zinc concentrations by enhancing particle settling and flocculation/deposition. The FTW's mesh-like root systems can act as a natural sieve, slowing water velocity, allow greater settling, and physically trapping particles. Additional removal of fine particles can occur when they bond to biofilms that form on the roots. Trapped particles eventually slough off the roots and settle to the bottom of the pond. Secretion of organic matter by the roots and biofilms also result in the complexation and flocculation of copper and zinc.

The use of FTWs has been shown to nearly double the reduction in copper concentrations when compared to open water ponds (Borne et al. 2013a). Zinc reduction in stormwater ponds is improved by the presence of FTWs, but the removal of the dissolved fraction is reduced compared to dissolved copper. This may be due to increased association of zinc with larger particles and/or the removal of colloidal copper species via complexation with organic matter released by FTWs (Borne et al. 2013a; Van de Moortel 2010).

2.2 Expected Effects of FTWs on Water and Sediment

FTWs significantly alter the chemical characteristics of the underlying and downstream reaches of a pond. FTWs have been shown to lower dissolved oxygen (DO) in the water column by acting as a physical barrier to aeration and increasing microbial activity because of carbon contributed by their roots (Borne et al. 2013a, Van de Moortel et al. 2010). Additionally, FTWs have been found to decrease pH in basic ponds towards a neutral value (Borne et al. 2014, Van de Moortel 2010). For example, Borne et al. (2014) found the pH in a pond with FTWs ranged between 7 and 8 and was on average 0.93 lower than in a parallel control pond where pH values ranged between 7.5 and 9. pH was lower in a pond with FTWs than a control pond for every measurement event (Borne et al. 2014). The more neutral pH found in FTW ponds may decrease the rate of copper adsorption to particulate matter and increase copper solubility thereby decreasing the rate of copper removal (Borne et al. 2013a, Nason et al. 2012). Although acidic pH generally decreases copper sorption rates, organic matter contributed by FTWs nets a reduction in effluent copper concentration. Additionally, FTWs have been found to moderate diurnal temperature changes in ponds by insulating a pond from changes in atmospheric temperature (Borne et al. 2014). These changes, their effects on copper removal, and observed effects of the T4 Pond FTW system on each parameter are summarized in Table 2.

Pond sediment is also affected by FTWs. Sediment samples from FTW systems show higher concentrations of both copper and organic matter when compared to open water systems (Borne et al. 2013a, Borne et al. 2013b, Borne et al. 2014). FTWs enhance metals loading to sediments because of metal sorption to organic matter contributed by their roots (Borne et al. 2014). Low DO and oxidation reduction potential (ORP) associated with FTWs tends to lead to more stable storage (less decomposition) in pond sediments underneath an FTW. FTWs do not entirely prevent metals remobilization and metals remobilization due to organic decomposition has been observed in the sediment of ponds with FTWs (Lim, Wong, and Lim 2013; Borne et al. 2014). It has also been shown that sediment can reach toxic concentrations of metals when FTWs are operated over a long period, increasing the need for sediment removal from storm ponds with FTWs (Borne et al. 2014).

Table 2: FTW Water Chemistry Effect Summary

Parameter	Literature FTW Effect	Parameter Effect on Copper	Observed T4 FTW Effects
pH	FTWs tend to neutralize pH in typically basic stormwater ponds.	Increasing pH will increase copper precipitation up to a pH of 9. Lower pH will make copper less available for treatment.	pH varies diurnally, no clear effect from FTW in probe data or grab samples.
Organic Matter	FTWs introduce larger organic debris but impacts on DOC vary.	Organic matter provides sites to which copper readily adsorbs.	Grab samples show a small increase in TOC and DOC across the FTW.
DO	FTWs lower DO by acting as a barrier to atmospheric gas exchange and by contributing organic matter that promotes oxygen consumption.	Decreased DO favors copper removal and decreases the rate of remobilization from contaminated sediment.	No clear effect by FTW on DO is observed in the T4 Pond.
Temperature	FTWs dampen diurnal temperature variation by insulating the pond from atmospheric temperature changes.	Increased temperature weakly correlates with an increased percentage of copper in the particulate fraction.	No clear effect by FTW on temperature is observed in the T4 Pond.
TSS/ Turbidity	FTWs decrease outlet TSS by slowing flow and acting as a natural baffle.	Copper is associated with suspended solids so TSS reduction by sedimentation will reduce effluent copper concentration. High outlet TSS may indicate copper export.	No clear effect by FTW on temperature is observed in the T4 Pond.

Notes:

DOC = dissolved organic carbon
TOC = total organic carbon
TSS = total suspended solids

Section 3: Sediment and Water Quality

Water and sediment sampling along with long-term water quality monitoring were performed on the T4 Pond to gather data for this study. Results of ISGP sampling events were also analyzed for correlations with precipitation data from the City of Portland's (City) HYDRA Rainfall Network to assess the performance of the T4 Pond FTW.

3.1 Sediment and Water Quality Sampling

3.1.1 Sediment and Water Quality Parameters and Sample Locations

Water and bottom sediment sampling were conducted and *in situ* water quality measurements were taken at the T4 Pond on 10 December 2018. Water depth along the middle of the channel ranged from approximately 12 inches to 24 inches. Water samples were collected at the six locations shown on Figure 4 and analyzed for the parameters listed in Table 3. Sediment samples were proposed to be collected at all sample locations but were ultimately collected only at location T4-1 as described in a subsequent paragraph. All water samples were collected as grab samples at the pond's surface from a canoe working from downstream to the upstream end of the T4 Pond to attempt to minimize disturbance prior to sampling. *In situ* water quality data, including water temperature, specific conductivity, DO concentration, pH, and ORP, were collected with a YSI 556 probe at a depth of approximately 6 inches below the surface of the water at each of the sample locations.

Table 3: Sediment and Water Quality Analyses

Sample Category	Parameter Measured	Analytical Method
Grab Water Sample	Copper, Dissolved	EPA 200.8 (Diss)
	Copper, Total	EPA 200.8
	Zinc, Dissolved	EPA 200.8 (Diss)
	Zinc, Total	EPA 200.8
	Dissolved Organic Carbon	SM 5310 C (Diss)
	Total Organic Carbon	SM 5310 C
	Alkalinity	SM 2320
	Hardness	SM 2340
	Total Suspended Solids	SM 2540 D
Sediment Sample	Copper	EPA 6020A
	Zinc	EPA 6020A
	Total Organic Carbon	SM 5310 B MOD

<u>Note:</u>

SM = Standard Method

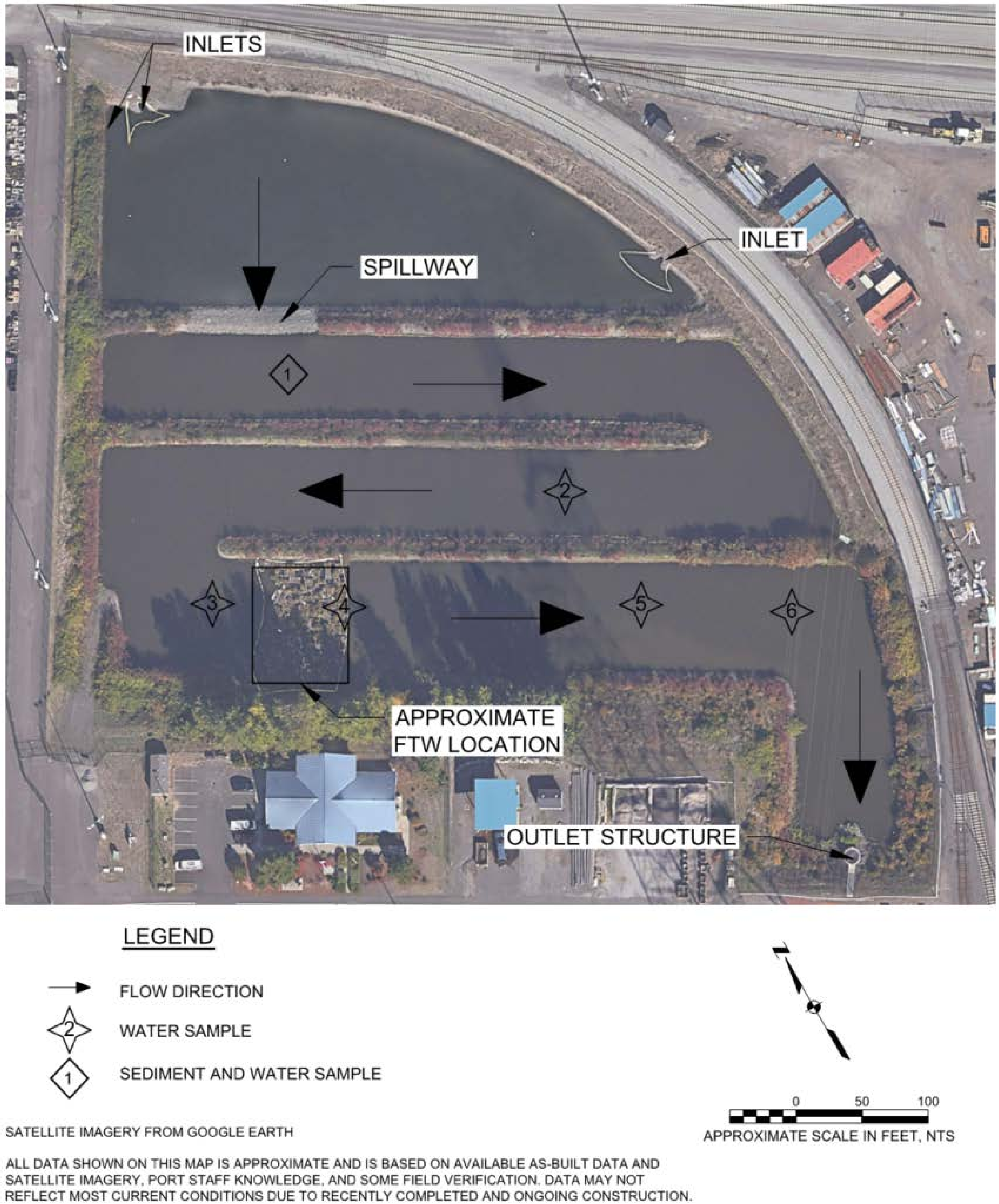


Figure 4: T4 Pond Aerial and Sample Locations

Water and bottom sediment sample locations were chosen with the intent to characterize spatial variability in water quality throughout the T4 Pond and to compare concentrations of constituents of concern (COCs) immediately and further downstream of the FTW in contrast to the upstream portions of the T4 Pond. Sample location T4-1 was selected to represent the influent to the main serpentine section of the pond. Location T4-2 represents removal efficiencies upstream of the FTW and provides a reference site that should not be influenced by the FTW, location T4-3 represents the water on the upstream edge the FTW, location T4-4 represents the water below the FTW rafts at the downstream edge, location T4-5 represents the downstream effects of the FTW, and location T4-6 represents outlet conditions. Differences in constituent concentrations from location T4-3 to location T4-6 describe the FTW's influence on water quality.

Sediment samples were proposed to be collected at all sample locations using a Russian Peat Borer. Upon attempting to collect the first sample at location T4-5, it was evident that the sediment layer at the bottom of the pond was thin (< 2 inches) which made sample collection difficult. In addition, the sediment had a very fine particle size which was prone to being rinsed away when lifting the Russian Peat Borer out of the water (Photograph 1). As a result, sediment samples were not collected at proposed sampling sites T4-2 through T4-6. A thicker 2- to 4-inch thick sediment layer was present at location T4-1, presumably attributed to particles dropping out of suspension after flowing over the inlet weir. Ten samples were collected near location T4-1 and combined to obtain sufficient material for the single composite T4-1-Sed sample identified below.

Photograph 1: Sediment Sample from Russian Peat Borer

3.1.2 Sampling Analytical Data

Analytical data from water samples collected on 10 December 2018 are presented in Table 4. Data from the sediment sample are presented in Table 5. Water samples were also analyzed for Bicarbonate Alkalinity, Carbonate Alkalinity, and Hydroxide Alkalinity but all results were below a reporting limit of 20.0 milligrams (mg) calcium carbonate per liter ($CaCO_3$/L).

Table 4: Analytical Data - Water Samples

Parameter	Units	T4-1	T4-2	T4-3	T4-4	T4-5	T4-6
Sample Date & Time		12/10/2018 13:45	12/10/2018 13:37	12/10/2018 13:30	12/10/2018 12:50	12/10/2018 12:22	12/10/2018 12:15
Calcium	mg/L	4.55	6.45	6.52	6.62	6.18	6.32
Magnesium	mg/L	1.04	1.46	1.54	1.56	1.37	1.38
Hardness	mg CaCO3/L	15.6	22.1	22.6	22.9	21.1	21.4
Total Alkalinity	mg CaCO3/L	*<10*	*<10*	*<10*	*<10*	*<10*	*<10*
Zinc, Total	µg/L	71.8	46.7	43.6	40.2	31.7	33.2
Zinc, Dissolved	µg/L	70.1	43.4	36.9	33.6	24.8	27.5
%Dissolved Zinc		97.6%	92.9%	84.6%	83.6%	78.2%	82.8%
Copper, Total	µg/L	47.6	30.4	32.2	31.4	21.4	21.8
Copper, Dissolved	µg/L	27	13.6	11.1	10.2	8.45	8.64
%Dissolved Copper		56.7%	44.7%	34.5%	32.5%	39.5%	39.6%
TSS	mg/L	5	12	2.5	8	12	2.5
Turbidity	NTU	14	12	13	14	8.6	12
Total Organic Carbon	mg/L	2.56	2.35	2.28	2.56	2.52	2.55
Dissolved Organic Carbon	mg/L	2.26	2.17	2.01	2.08	2.21	2.07

Notes:

Data in blue were at or below the detection limit for the analysis performed and are reported here as one half the detection limit.
% = percent
mg/L = milligrams per liter

Table 5: Analytical Data - Sediment Sample

Parameter	Units	T4-1-Sed
Sample Date & Time		12/10/2018 14:00
Copper	mg/kg dry	1,230
Zinc	mg/kg dry	446
TOC	mg/kg	39,000
% Solids	%	28.4

Note:

mg/kg = milligrams per kilogram

3.1.3 Sampling Data Analysis

3.1.3.1 Copper

The pollutant of greatest concern in this study is copper because the copper concentration in discharges from the T4 Pond have not consistently been below benchmarks. The data from this sampling event suggest that the FTW improves water quality for copper. The copper data from this sampling event are plotted on Figure 5. Total copper decreases from 31.4 µg/L at the immediate downstream edge of the FTW at point T4-4 to 21.4 µg/L further downstream from the FTW at point T4-5. The percentage dissolved copper in these samples increases from 32.5% to 39.5%, where it had previously been decreasing from upstream to downstream in the pond. The total dissolved copper concentration in the sample after the FTW decreases slightly from 10.2 µg/L to 8.45 µg/L but by a much smaller percentage (17.2%) than the decrease in total copper (31.8%). This result suggests that the FTW as it is implemented is enhancing removal of total copper, and it is altering the speciation of copper downstream of the FTW in the T4 Pond. This is a predicted effect of FTWs on stormwater ponds.

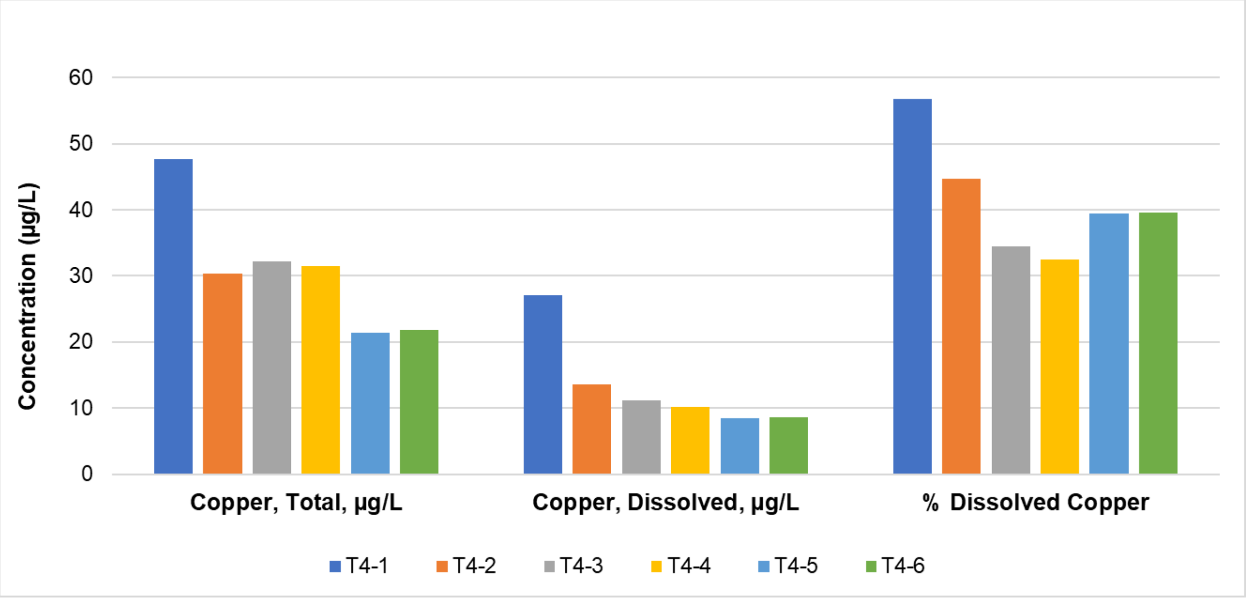
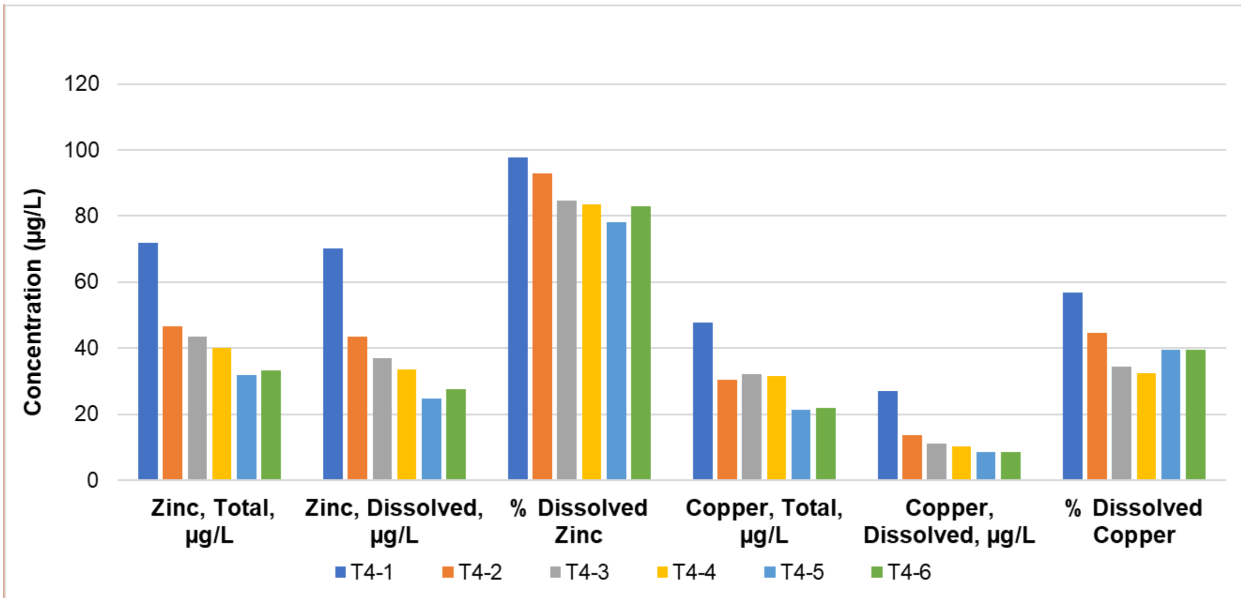


Figure 5: T4 Pond Surface Water Samples - Copper Concentration and Percentage Dissolved

For these samples, pH increased a small amount, from 6.35 before the FTW to 6.5 immediately after the FTW. Generally, copper speciation shifts towards less dissolved copper as pH increases but the opposite was observed in the T4 Pond. This effect was probably due to chemical interactions between the FTW and the underlying water. The effect of the FTW on DO was also the opposite of the expected result. Based on published research, DO would be expected to significantly decrease, but DO increased a very small amount from 7.69 mg/L before the FTW to 7.89 mg/L after. The weak influence of the FTW on pH and DO may be attributed to the low residence time of water underneath the mats, which may not allow time for the expected chemical changes to take place.

3.1.3.2 Zinc

Zinc concentrations follow a similar pattern to copper concentrations[RD1], as shown on Figure 6, which includes both the zinc concentrations and the copper concentrations that were presented on Figure 5. Total and dissolved zinc concentrations decreased consistently through the pond upstream of the FTW, decreased a larger amount just downstream of the FTW, then increased slightly at the outfall, at location T4-6. However, the changes in percentage dissolved copper are more pronounced than changes in dissolved zinc. The percentage dissolved zinc is relatively high throughout the pond. Total and dissolved zinc follow a more similar pattern than do total and dissolved copper, which suggests that the FTW has a larger effect on copper speciation than zinc speciation.



[RD2][AF3]

Figure 6: T4 Pond Surface Water Samples - Metals Concentrations and Percentage Dissolved

3.1.3.3 Organic Carbon

Published research suggests the FTW's most significant treatment pathway for copper removal is through contribution of organic matter to the pond. Copper readily binds to organic matter and is removed via sedimentation. The organic carbon data collected in this sampling event, plotted on Figure 7, show that the FTW is probably contributing a small amount of organic matter to the T4 Pond. TOC steadily decreased upstream of the FTW from 2.56 µg/l at point T4-1 to 2.28 µg/L at point T4-3 then increases to 2.56 µg/l at point T4-4 and remains high to the outlet of the pond. DOC follows a similar pattern although it increases from point T4-4 to point T4-5 before decreasing again from point T4-5 to point T4-6. The organic matter contribution of the FTW to the T4 Pond is likely limited by the relatively small proportion of the pond surface area that is covered. Expanding the T4 FTW coverage area would be expected to increase the organic matter contribution and could further enhance copper removal.

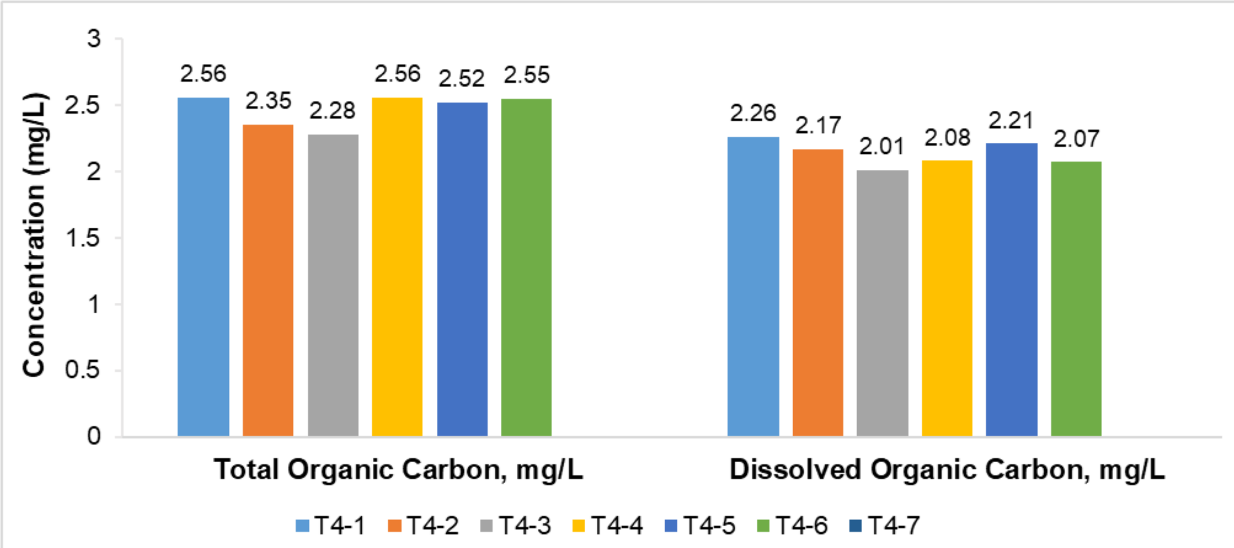


Figure 7: T4 Pond Surface Water Samples - Organic Carbon

3.1.3.4 Other Water Quality Parameters

Measured calcium, magnesium, and alkalinity were relatively constant for all water samples. Alkalinity was below the detection limit for all sampling points. TSS values range from below the detection limit to 12 mg/L with no apparent trend through the pond. The low TSS concentrations measured in these samples is as expected for surface water grab samples collected between rain events in a relatively still pond that is designed to allow solids to settle. Turbidity was measured to be relatively consistent between 12 and 14 NTU for all sampling locations except at T4-5 where turbidity was 8.6 NTU. Due to the low and relatively consistent levels of these other water quality parameters, they do not contribute significant additional information to this analysis.

3.2 Hydrologic Analysis

Potential correlations between storm characteristics and copper concentrations in T4 Pond discharges were investigated using rainfall data from the Simmons and Hayden Island rain gauges in the City's HYDRA network and available T4 Pond ISGP DMR data. Details of this correlation analysis are presented in Appendix A. Data were divided into two groups based on whether the FTW was in place or broken up when samples were taken. ISGP samples taken before July 2018 were not included in this analysis because exact records of the FTW's status are not available before that date. Based on the analysis, despite the limitations of available data, it appears the FTW on the T4 Pond does enhance copper removal in the pond. Differences in copper speciation were found between samples from the time periods with the FTW in place and with it broken up.

3.3 Long-Term Water Quality Monitoring

Additional water quality monitoring was conducted at the T4 Pond beginning in May 2019. On 21 May 2019, a Seametrics TempHion probe was deployed downstream of the FTW to collect temperature, pH, and Redox measurements at 5-minute intervals until it was removed from the pond on 7 July 2019. Unfortunately, due to algal growth on the probe, only the data from 21 May through 5 June are considered reliable and was used for detailed analysis, which is discussed in Appendix A.

Probe measurements follow the expected trend for a natural pond. During dry weather, daily pH fluctuations are driven by temperature and biological activity and range between 6 and 10. The redox potential in the pond fluctuates as the inverse of the pH data. Minimum temperature, maximum redox potential, and minimum pH occur between 6:00 a.m. and 8:00 a.m. Minimum redox potential and maximum pH occur between 2:00 p.m. and 3:00 p.m. while maximum temperature does not occur until later in the evening. Significant rainfall events on 22 May and 24 through 26 May correspond to response in pond temperature, pH, and redox potential that depend on the type of storm event, as discussed in Appendix A.

Based on the probe data, it is difficult to determine whether the FTW significantly alters the pH or temperature characteristics of the T4 Pond. FTWs are expected to decrease the pH toward neutral and moderate the temperature fluctuations in the pond, but whether this effect is occurring in T4 Pond cannot be said definitively without contemporaneous data from upstream of the FTW. The impact of the FTW on the pond's chemistry may be difficult to observe because of their limited coverage resulting in a limited residence time of water underneath them, and the 'noise' of the other environmental factors influencing the pond's water chemistry.

Section 4: Vegetation Assessment

FTW vegetation health was also evaluated during the sediment and water quality sampling event on 10 December 2018. Visual inspection showed the vegetation was growing moderately well on most rafts although some rafts were struggling more than others. The most numerous surviving plant species on the FTW rafts was Slough Sedge (*Carex obnupta*) along with common rush (*Juncus effusus*). There were a several other weed and volunteer species found on the FTW rafts as well, including Himalayan blackberry (*Rubus discolor),* dock (*Rumex spp.*), mullein (*Verbascum spp.*), ferns, and red-osier dogwood (*Cornus sericea*).

Selected plants on several rafts that were safely accessible from shore were measured to assess the height of emergent shoots above the raft and roots below. Plant heights and root depths are presented in Table 6 and photographs of these measurements can be found in Appendix B. The emergent plant height did not appear to be correlated with the root depth, rather root depths appear to be constrained by the depth of water where the raft is located. Plants on rafts closer to the shoreline generally had shallower root depths compared to plants on rafts closer to the centerline of the pond.

Table 6: FTW Vegetation Measurements

Plant	Species	Plant Height (inch)	Root Depth (inch)
1	*Carex obnupta*	40.5	14.0
2	*Carex obnupta*	21.0	13.5
3	*Carex obnupta*	33.0	11.5

The pond water level has been lowered to near the pond bottom in the past, which may have limited root development under the FTW rafts. Other challenges to vegetation establishment on the FTW rafts include wildlife disturbance and raft damage from significant storm events. Photographs from field visits are found in Appendix B.

Section 5: Results and Recommendations

5.1 Results

This assessment indicates the FTW deployed on the T4 Pond enhanced copper treatment in the T4 Pond to some extent and that adjustments to improve the function of the FTW may be an effective way to further decrease the effluent copper concentrations from the T4 Pond. Although not clearly distinguished by ISGP sampling results, the total effluent copper concentration was significantly different between periods with the FTW in place and times when the FTW was broken up, the presence of the FTW does coincide with an increase in percent dissolved copper (%DCu). The surface water grab samples taken on the T4 Pond similarly show an increase in %DCu downstream of the FTW that coincides with a decrease in total copper concentration (TCu), suggesting particulate copper removal by the FTW. The TCu does not decrease directly under the FTW but rather downstream, most likely because of downstream sedimentation of copper associated organic matter contributed by FTW.

The ability of the T4 Pond FTW to enhance copper removal in the pond is most likely limited by the relatively small area of FTW coverage relative to the size of the pond. Plants appear to be moderately well established although weeds have also established on some rafts. Lowered water levels may have limited root development, as well as facilitated resuspension of bottom sediment in the pond. Additionally, the periodic break-up of the FTW and the damage inflicted by wildlife have potentially limited the effect of the FTW on the T4 Pond and reduced the effects that were expected to be observed in this study.

5.2 Recommendations

Based on this assessment, Kennedy Jenks recommends the port continue to manage and monitor the T4 Pond FTW to further refine their understanding of the influence that the FTW has on the T4 Pond, and expand the FTW coverage on the T4 to the extent feasible. Additional data collection, including contemporaneous inlet and outlet sampling, and recording the FTW condition for each ISGP sampling event could allow a more complete assessment of FTW performance. A lower priority recommendation to help improve data quality would be to consider the use of an ion-selective probe to measure effluent free copper in order to better understand whether the measured dissolved copper is colloidally associated.

A major factor limiting FTW functionality is the FTW formation being broken up by wind and damaged by wildlife. The capacity of the booms and anchor points used to restrain the FTW rafts has been exceeded several times during wind or storm events. Kennedy Jenks recommends the total size of an FTW deployment and number of rafts in each set of booms be limited to approximately half of the current size, with the FTWs placed in bands at several points across the flow path through the pond. This approach also has the potential to improve treatment by extending the influence of changed water chemistry, enhanced sedimentation, and organic matter contribution through a greater portion of the flow path through the pond. In addition to limiting the total size of each FTW deployment, Kennedy Jenks recommends building individual FTW rafts in a hexagonal or circular shape that could allow individual rafts to rotate and move past each other during collisions and storm events. Efforts to manage beavers and other wildlife in the T4 Pond should also continue.

A relatively small fraction of the pond's surface area is covered by the FTW. Currently, less than 5% of the T4 Pond's surface area is covered. Research indicates that additional coverage increases the effect on treatment performance of FTWs. Increased residence time under the FTW for water flowing through the pond would be expected to increase the beneficial effects anticipated to be provided by the FTW. Kennedy Jenks recommends building additional FTW rafts as resources allow.

This analysis suggests that resuspension of settled sediment may be occurring in the T4 Pond. An expected effect of the FTW is to cause additional metals to accumulate in the sediment. Sediment would ideally be retained in the pond until it can be removed during regular maintenance. The current outfall from the pond discharges at the pond bottom of where suspended sediment concentrations are likely to be higher. Finer particles may not settle before reaching the outfall. Modifications to the outfall so that water is discharged from near the water surface may reduce sediment and metals concentrations in the discharges and complement the expected function of the FTW.

Finally, the port has implemented improved best management practices (BMPs) in the T4 Pond drainage basin, including targeted sweeping, which are presumed to have contributed to decreasing the copper concentration in influent to the T4 Pond. Implementation of these BMPs should continue. Sweeping should be performed using a high efficiency sweeper and care should be taken that sweeping is not performed more than necessary to keep the facility visibly clean. Excessive sweeping can mobilize fixed particles that would otherwise not be washed off in a storm event. Fixed particles tend to be fine and associated with metals so excessive sweeping could result in elevated pollutant concentrations in runoff.

5.3 Conclusions

The FTW implemented by the port appears to improve pollutant treatment in the T4 Pond, but additional efforts appear to be required to consistently meet the port's ISGP benchmarks for copper. Significant differences in copper speciation were found between the time period with the FTW in place and with it broken up. It also appears that the FTW is contributing organic carbon to the pond without associated decreases in pH or DO. Our analysis suggests that opportunities exist to expand the FTW and enhance its treatment performance.

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Appendix A

Data Analysis Detail

Appendix A: Data Analysis Detail

A.1 Analysis Overview

Available hydrologic and water quality data for the Port of Vancouver's (port) Terminal 4 Pond (T4 Pond) was reviewed to assess the factors influencing copper concentrations and floating treatment wetland (FTW) performance in the T4 Pond. The analysis used copper concentrations from Industrial Stormwater General Permit (ISGP) discharge monitoring reports (DMRs), rainfall data from the City of Portland's (City) HYDRA rainfall network, samples taken on a field visit on 10 December 2018, and continuous probe data collected between 21 May 2018 and 7 July 2018. The review was conducted to estimate what effect the FTW has on copper and water chemistry, and highlights both correlations and patterns observed in the data. The limitations of the data available for the analysis are noted.

The analysis of ISGP DMR data, rainfall data, and of the continuous probe data are presented in detail in this appendix. Analysis of the data collected during the December 2018 field visit is presented in the main report.

Based on these analyses, despite the limitations of available data, it appears the FTW on the T4 Pond does enhance copper removal in the pond. Significant differences in copper speciation were found between samples from the time periods with the FTW in place and with it broken up. Water sampling results showed that the increase in dissolved copper percentage across the FTW coincided with a decrease in total copper concentration (TCu). It also appears that the FTW is contributing organic carbon to the pond without associated decreases in pH or dissolved oxygen (DO). Overall, this analysis suggests that having the FTW rafts in place provides some additional treatment for copper over the T4 Pond without the FTW. Increasing the FTW coverage of the pond is likely to further improve treatment. Recommendations for additional data collection and analysis and actions to enhance FTW performance are provided in the report.

A.2 Correlation between Rainfall Data and Copper Concentration Reported in ISGP DMRs

A correlation analysis was performed in Excel using available T4 Pond ISGP DMRs and rainfall data from the Simmons and Hayden Island rain gauges in the City's HYDRA network. Data were limited to ISGP sampling events since 2017 when the port implemented improved source control best management practices (BMPs) at the T4 bulk copper handling facility in the T4 Pond drainage basin. Since 2017, samples have been collected while the FTW rafts were anchored in place, and while the FTW formation was broken up and the rafts were distributed along the pond shoreline and presumed not be enhancing treatment. It is known the FTW were in place from 28 November 2018 to 3 October 2019 and broken up from 8 February 2017 to 14 February 2018 and from 10 January 2020 to 6 March 2020. The entire data set from 2017 to 2020 and those distinct periods were analyzed to differentiate copper effluent with the FTW in place from the treatment provided by the T4 Pond alone.

Two rain gauges operated as part of the City's HYDRA rainfall network are located near the port and were used as the source for rainfall data. Station No. 7 is located on Hayden Island at 1740 North Jantzen Beach Center. Station No. 139 is located at 16001 North Simmons Road. The HYDRA network, and the locations of the T4 Pond and these stations are shown on Figure A.1.

Hourly rainfall data from these two gauges were downloaded from the Oregon Water Science Center website (http://or.water.usgs.gov/non-usgs/bes/). Data were reviewed to determine a single distinct rainfall event associated with each ISGP sample event, and the following were calculated: the rainfall depth for the rain event that was sampled, the antecedent dry period (ADP) or number of days between the sampled event and the previous distinct rainfall event, and the depth of the previous distinct rainfall event.

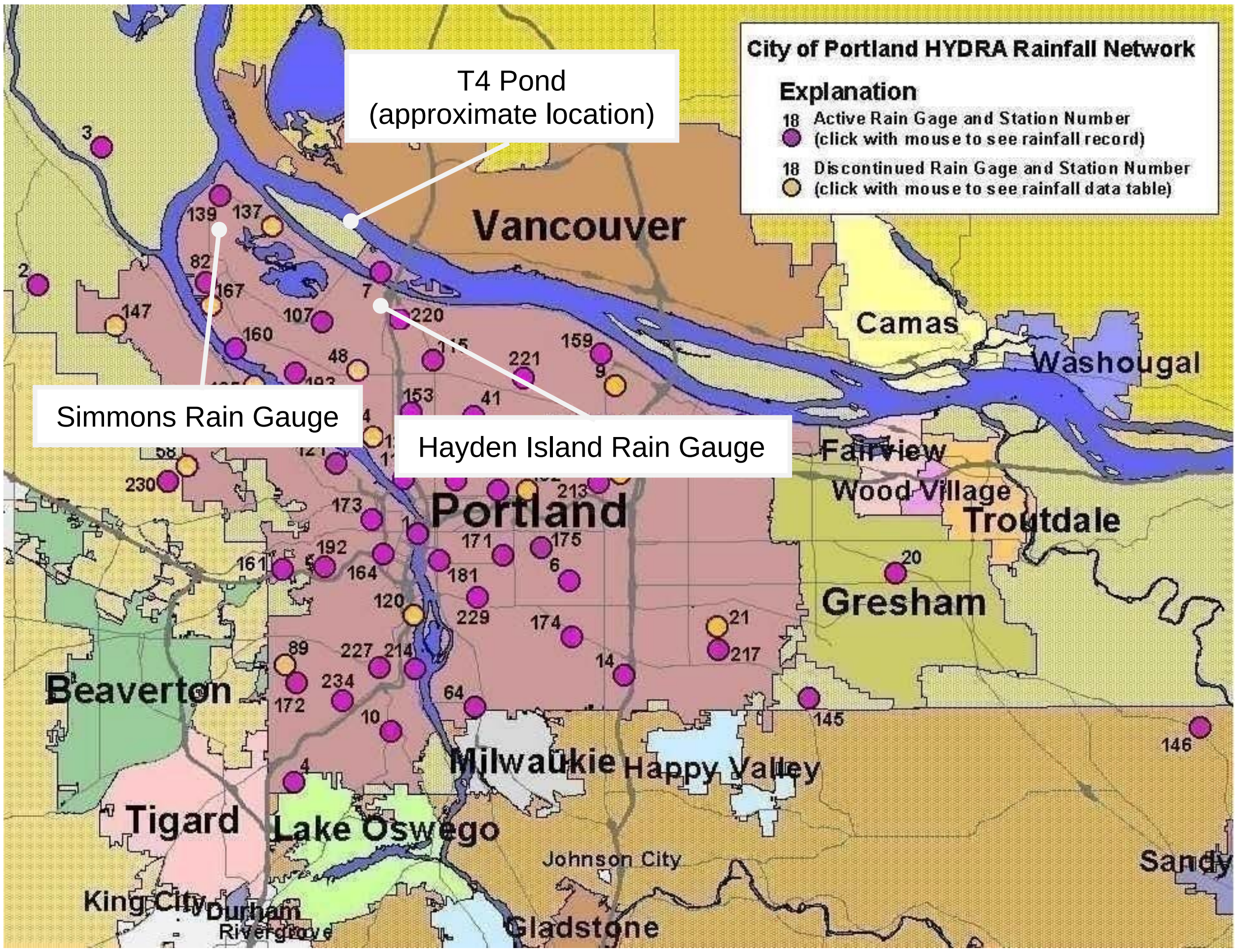


Figure A.1: Rain Gauges in the City of Portland HYDRA Network

Statistics for the rainfall data corresponding with sample events, and copper concentrations for ISGP samples are summarized in Table A.1. Mean values of TCu, dissolved copper concentration (DCu), percent dissolved copper (%DCu), rain event depth, previous rain event depth, and ADP were calculated for analyzed sample events, as well as for the two segregated periods within the data. A two tailed t-test was performed to evaluate the significance of differences between the in place and broken up periods. A significant difference is defined as two values for which the t-test resulted in a p-value less than 0.05.

Table A.1: Mean Values Compared Between the Periods with the FTW In Place and Broken Up

Property	Full Data Set Mean	Broken-Up Mean	In Place Mean	p-Value
TCu (µg/L)	21.49	22.22	21.08	0.78
DCu (µg/L)	13.20	11.38	14.20	0.21
%DCu	63 %	51 %	69 %	**0.00009**
Rain event depth (inch)	0.34	0.55	0.23	**0.02**
Previous rain event depth (inch)	30.39	37.30	26.56	0.52
ADP (Days)	3.40	4.68	2.69	0.31

Notes:
µg/L = micrograms per liter
Significant differences in bold.

A significant difference (p = 0.00009) was found between the two data sets for %DCu and for rain event depths with a greater %DCu found with the FTW in place than with it broken up. The difference in %DCu suggests that the presence of the FTW may cause the copper fractionation in the T4 Pond to shift toward dissolved. An increase in percentage dissolved copper downstream of the FTW was also observed in pond-surface grab samples collected during the 10 December 2018 sampling event. The increase may indicate chemical changes in the pond caused by the FTW or that the FTW most efficiently removes particulate copper, leaving more dissolved copper in solution. The trend could also be interpreted as the FTW releasing colloid-sized particles. Copper readily bonds to colloid-sized particles which are fine enough to pass through the filters used to separate suspended from dissolved species in laboratory tests. Colloidally associated copper would thus result in a reported DCu that is higher than the true DCu. Additional investigation is required to verify to what extent the copper reported here as dissolved may or may not be colloidally associated.

The mean sampled rain event depth for the data set also had a statistically significant difference between the broken-up and in-place data sets (p = 0.02). Sampled rain events were larger for the period when the FTW was broken up than for the period when it was in place, which may confound comparisons between the two time periods. A larger rain event may also transport more pollutants to the pond, which could be reflected in the data sets. Rain event depths, however, are measured at offsite rain gauges and may not exactly reflect rainfall in the drainage basin. Influent sampling data could allow for a more thorough understanding of the correlation between rain event data and copper concentrations.

To analyze the influence of storms on the pond's effluent copper concentration, the correlation coefficient between storm event characteristics copper concentrations was calculated. The resulting correlation coefficients (r values) are presented in Table A.2 for the comparison of ADP, sampled storm depth, and previous storm depth to total and dissolved copper concentration and percent dissolved copper in ISGP samples. The data set is presented for both the in-place and broken-up periods, as well as the combined data. Differences between correlations for in-place and broken-up periods indicate a difference in the pond's treatment performance that likely can be attributed to the FTW. The combined data set would be presumed to show correlations that are not related to the status of the FTW; however, correlations may be obscured by effects of the FTW.

Table A.2: Correlation Coefficients for Rain Event Characteristics Compared to Copper Concentrations in ISGP Samples

Data Set	Storm Characteristics	TCu	DCu	%DCu
FTW Broken Up (n = 10)	ADP	-0.229	-0.371	**-0.455**
	Sampled rain event depth	**0.736**	**0.677**	0.009
	Previous rain event depth	-0.201	-0.311	**-0.555**
FTW In Place (n = 18)	ADP	-0.238	-0.109	**0.434**
	Sampled rain event depth	0.112	0.318	0.391
	Previous rain event depth	**0.641**	**0.673**	-0.263
Combined Data (n = 28)	ADP	-0.207	-0.316	-0.222
	Sampled rain event depth	**0.452**	0.267	-0.350
	Previous rain event depth	0.172	0.055	-0.386

Notes:
TCu = total copper
DCu = dissolved copper
% DCu = percentage dissolved copper
ADP = antecedent dry period
Stronger correlations are shown in bold.

There is a positive correlation between the sampled rain event depth and both TCu and DCu with the FTW broken up, and between the previous rain event depth and both TCu and DCu with the FTW in place. For the combined data set, there is only a moderate correlation between sampled rain event depth and TCu. There is also a moderately strong negative correlation between %DCu and ADP with the FTW broken up, and moderately strong positive correlation between percentage dissolved copper and ADP with the FTW in place.

Selected data sets with stronger correlations are presented graphically and discussed in more detail in the following sections. The R^2 value shown for trendlines on the following graphs are the square of the correlation coefficients presented in Table A2. The small size of the data sets and relatively high variability limit the strength of conclusions based on these calculated correlations and observed trends. The relationship between TCu and sampled storm depth is presented first, for the FTW broken up and FTW in place, on Figure A.1.

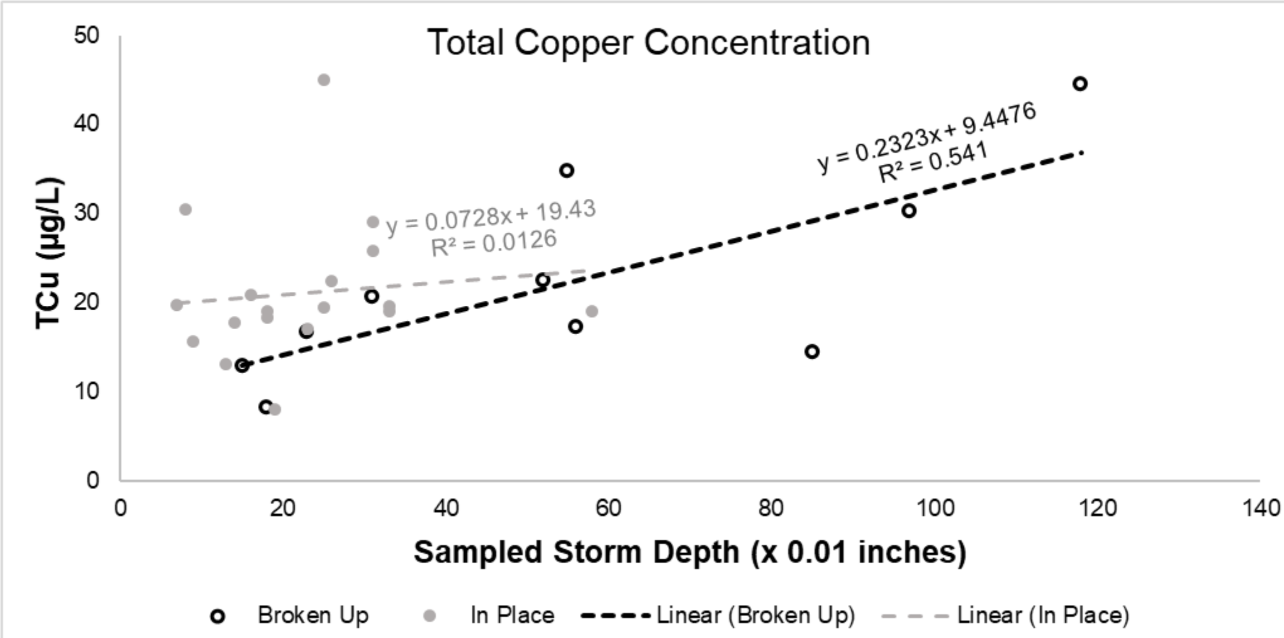


Figure A.2: TCu versus Depth of Sampled Storm for Broken-Up and In-Place Periods

The stronger correlation between TCu and sampled storm depth with the FTW broken up suggests a relationship between storm depth and influent copper concentration, presuming that particulate-associated copper passes through the T4 Pond during larger storm events. Influent copper sampling could support this supposition. The data presented on Figure A.1 suggest there is a difference between copper treatment in the pond when the FTW was in place compared to when the FTW was broken up; however, samples were collected with the FTW in place only during smaller rain events, which complicates the analysis.

The relationship between total and dissolved copper concentration and previous rain event depth with the FTW in place is shown on Figure A.2. The positive correlation, between total and dissolved copper concentrations and previous rain event depth is apparent on Figure A.2, by visual inspection of the relatively small previous rain event depths versus the relatively large rain event depths. FTWs tend to increase copper concentration in sediment by contributing suspended organic matter to the water column, which bonds to copper and falls to the sediment layer. This copper may be resuspended during subsequent events. The correlations in the data shown on Figures A.1 and A.2 may indicate that larger storms bring more copper into the pond, as would be expected, and that copper may have been remobilized during the smaller events that were sampled with the FTW in place. Because the T4 Pond discharges near the bottom of the water column, resuspended sediment can easily be discharged. Raising the outfall elevation may help prevent the discharge of resuspended sediment.

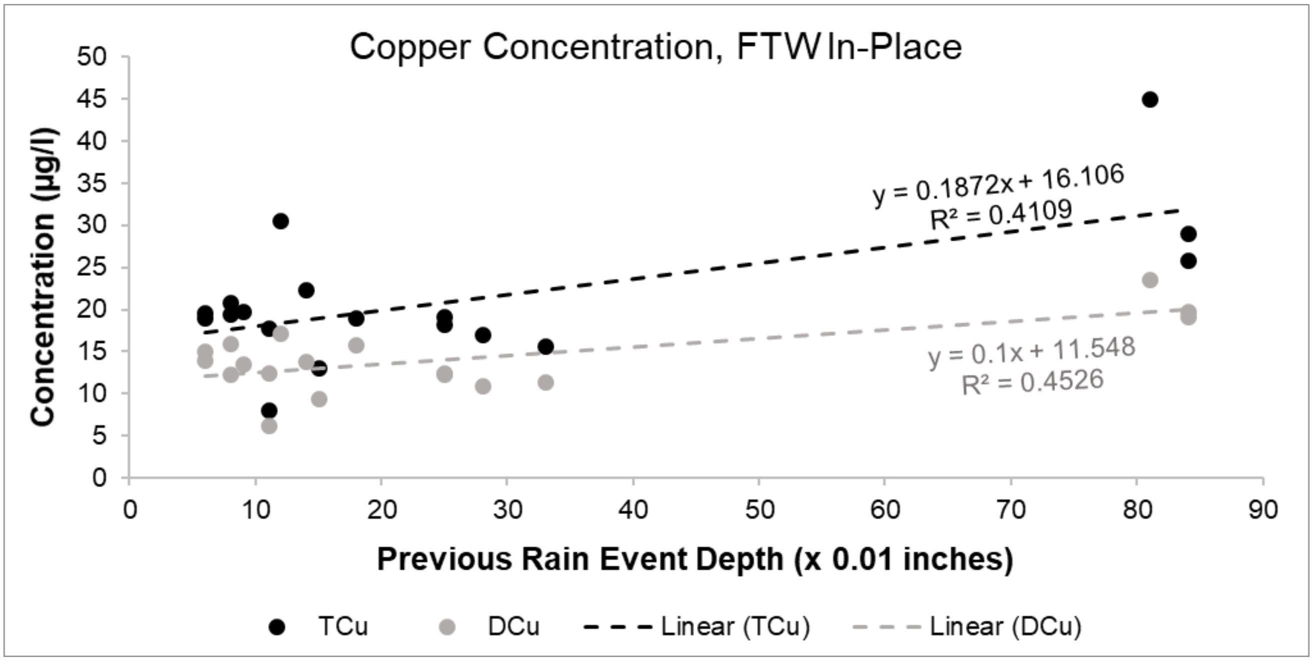


Figure A.3: Copper Concentration versus Previous Rain Event Depth for FTW In Place

The final relationship between copper concentration and rain events to be discussed herein, plotted on Figure A.3, is the moderately strong negative correlation between %DCu and ADP with the FTW broken up, and moderately strong positive correlation between %DCu and ADP with the FTW in place. These observed correlations provide further evidence that the FTW may influence the partitioning of copper between dissolved and particulate-associated species. The differing correlations corroborate the difference in mean values between the two data sets as evidence of a difference in the fractionation between dissolved and particulate copper with and without the FTW in place.

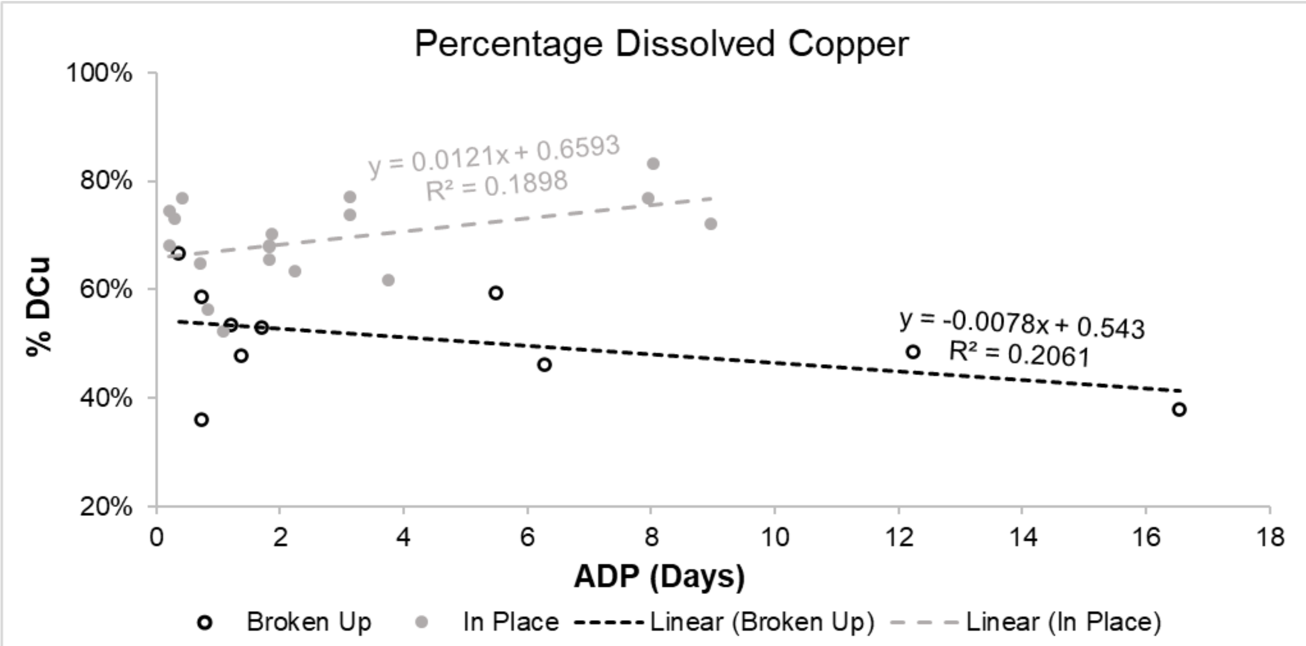


Figure A.4: Plot of the Correlation between %DCu and ADP for Both Periods with the FTW Broken Up and In Place

The analysis of storm data and ISGP sampling data suggests some interesting relationships even if the data limitations allow for only tentative conclusions to be drawn. The analysis showed that the FTW probably increased the %DCu in samples, may lead to greater copper storage in the T4 Pond's sediment and therefore, remobilization during subsequent sampling events, and may moderate the increased copper concentrations in the T4 Pond effluent as a result of larger storms. The conclusions made based on analysis of these data could be more thoroughly evaluated if influent sampling data were available for the same time periods. Unfortunately, the significant difference in storm depth between the broken up and in place periods weakens the conclusions reached based on differences in the data sets presented here. Continued analysis of the relationship between rainfall events and influent and effluent total and dissolved copper concentrations at T4 Pond could lead to a clearer understanding of the effect of the FTW on copper treatment.

A.3 Long-Term Probe Data Analysis

A Seametrics TempHion probe was deployed in the T4 Pond immediately downstream of the FTW at a depth of 12 inches below the water surface, from 21 May 2019 to 7 July 2019, to collect temperature, pH, and redox measurements at 5-minute intervals. The pH sensor on the probe was calibrated on 21 May 2019 prior to deployment. The redox sensor was calibrated on 28 March 2017 and the temperature sensor does not require calibration.

On the afternoon of 30 May 2019, the probe was checked and was immediately redeployed; the probe appeared to be clean, and the data collected so far appeared to be reasonable and following expected trends. The probe was then left in the pond from 30 May 2019 until 16 July 2019. On 16 July 2019 when the probe was recovered, it was noted that there was a thick layer of algae growing on the probe. A photograph of the probe when it was removed on 16 July 2019 is presented in Appendix B.

An inquiry was made to Seametrics, who indicated that algae may interfere with the probe's calibration and its overall readings. It appears the collected data were likely to have been affected by algae growth starting around 6 June 2019. For the initial portion of the deployment, from 21 May 2019 to 6 June 2019, the data appear to follow diurnal variation typical for natural ponds, which is controlled by temperature and photosynthetic activity. After 6 June 2019, the diurnal variation in pH and redox approximately double and the minimum pH decreases from between 6 and 9 to between 2 and 5. The measured pond temperature continues to follow the typical diurnal pattern and change as expected with the ambient air temperature. Because of this potential biofouling, only the data collected before 6 June 2019 were used in subsequent analysis.

The data collected during the entire deployment are shown on Figure A.7. The date the probe was checked and redeployed, 30 May 2019, is indicated with a vertical dotted line. The data presumed to be reliable are shaded in green while the data that suggest probable biofouling of the probe are shaded in grey.

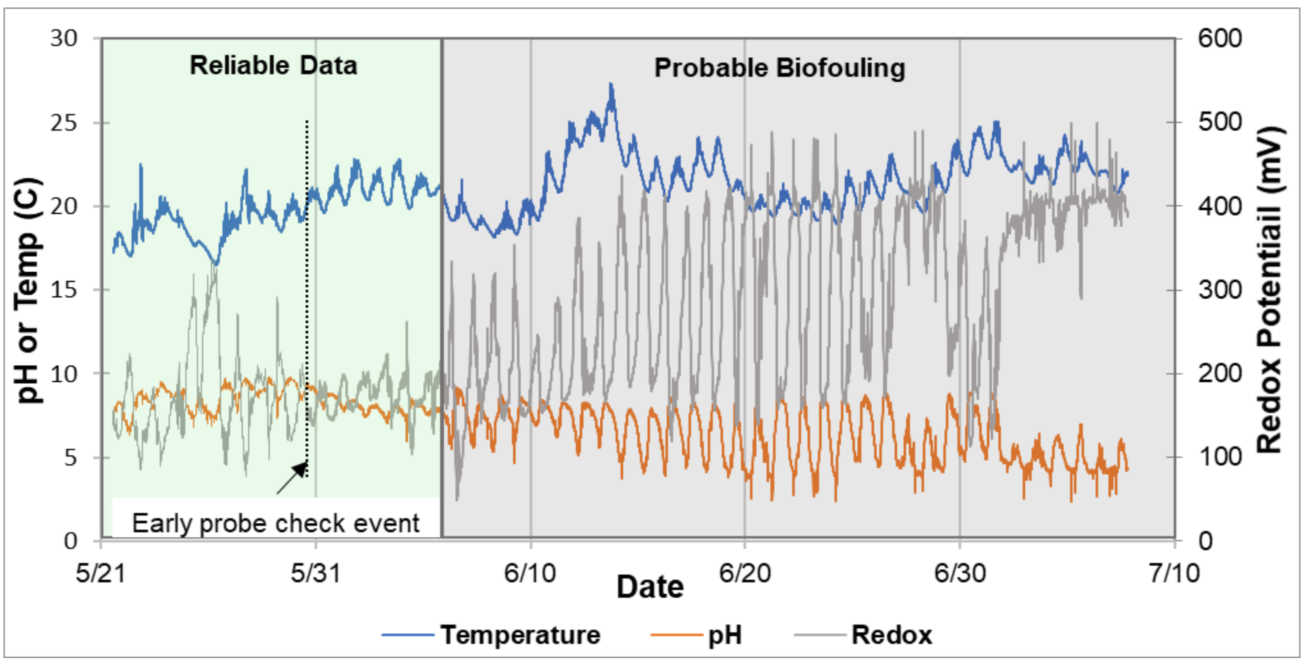


Figure A.5: Long-Term Probe Data from the T4 Pond from 21 May to 7 July 2018

Probe data collected from 21 May to 5 June 2019, which are considered reliable, are shown on Figure A.8. Rain event depths recorded at the Hayden Island and Simmons rain gauges are also shown on the figure, with the total rainfall depth symbol located at the approximate time of the end of the event. The response of the pond to rain events can be seen in the temperature, pH, and redox data. The rain event on 22 May 2019 and the event from 24 May to 26 May 2019 correspond with a change in the water temperature, a decrease in pH, and an increase in redox potential.

The temperature response may be explained by the type of rainfall event. The 22 May event was a localized thunderstorm, as indicated by the fact that the event was recorded at the Hayden Island gauge, but not the nearby Simmons gauge. Weather records indicate the day was generally sunny and hot; thus, the runoff to the T4 Pond caused an abrupt increase in temperature. The 24 to

26 May rainfall event was a slow-moving widespread system during a cloudy, cool period; thus, the runoff decreased the pond temperature. The pH response is as expected for both events because rainwater tends to have a slightly acidic pH.

It is difficult to determine the effects or lack thereof from the FTW based on this data set. As was noted during the grab sampling process, the FTW in the T4 Pond seems to be too small to produce a noticeable effect on pH in the pond. If there were contemporaneous pH or redox potential data upstream of the FTW, it might be possible to show an effect or lack thereof, but those data were not collected. Similarly, temperature data follow expected trends but do not indicate a significant effect from the FTW. Published research indicates that FTWs will often dampen diurnal temperature variation.

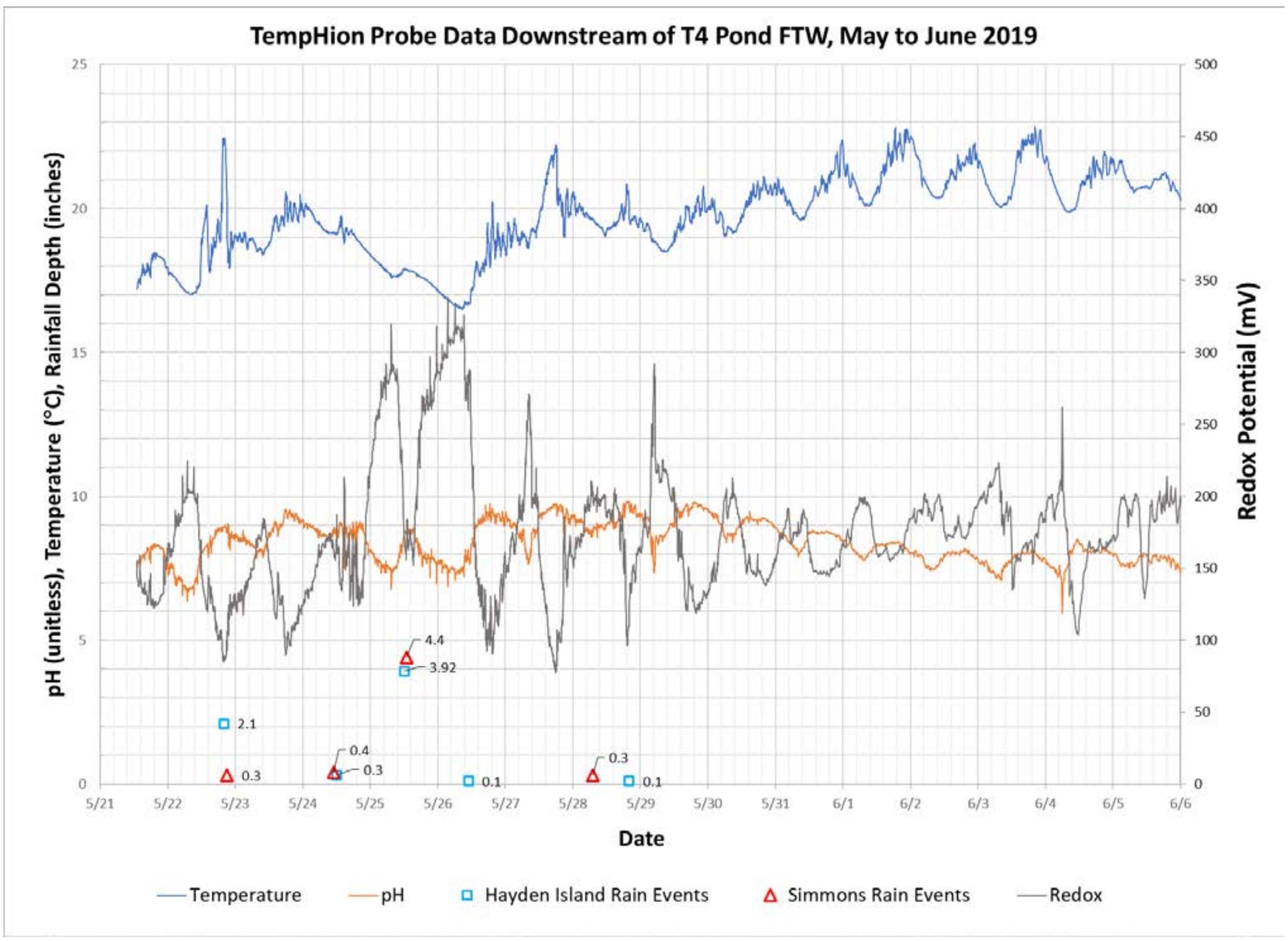


Figure A.6: TempHion Probe Data Downstream of T4 Pond FTW, 21 May through 5 June 2019

The diurnal trends for temperature, redox potential, and pH over the 21 May through 5 June 2019 probe deployment are presented on Figure A.9, which is a plot of the daily data sets by time of day, and the hourly mean over the time period, with error bars representing one standard deviation above and below the mean. Days that vary significantly from the mean are generally related to rain events. redox potential and pH are strongly negatively correlated, and both vary less from day to day than the temperature in the pond.

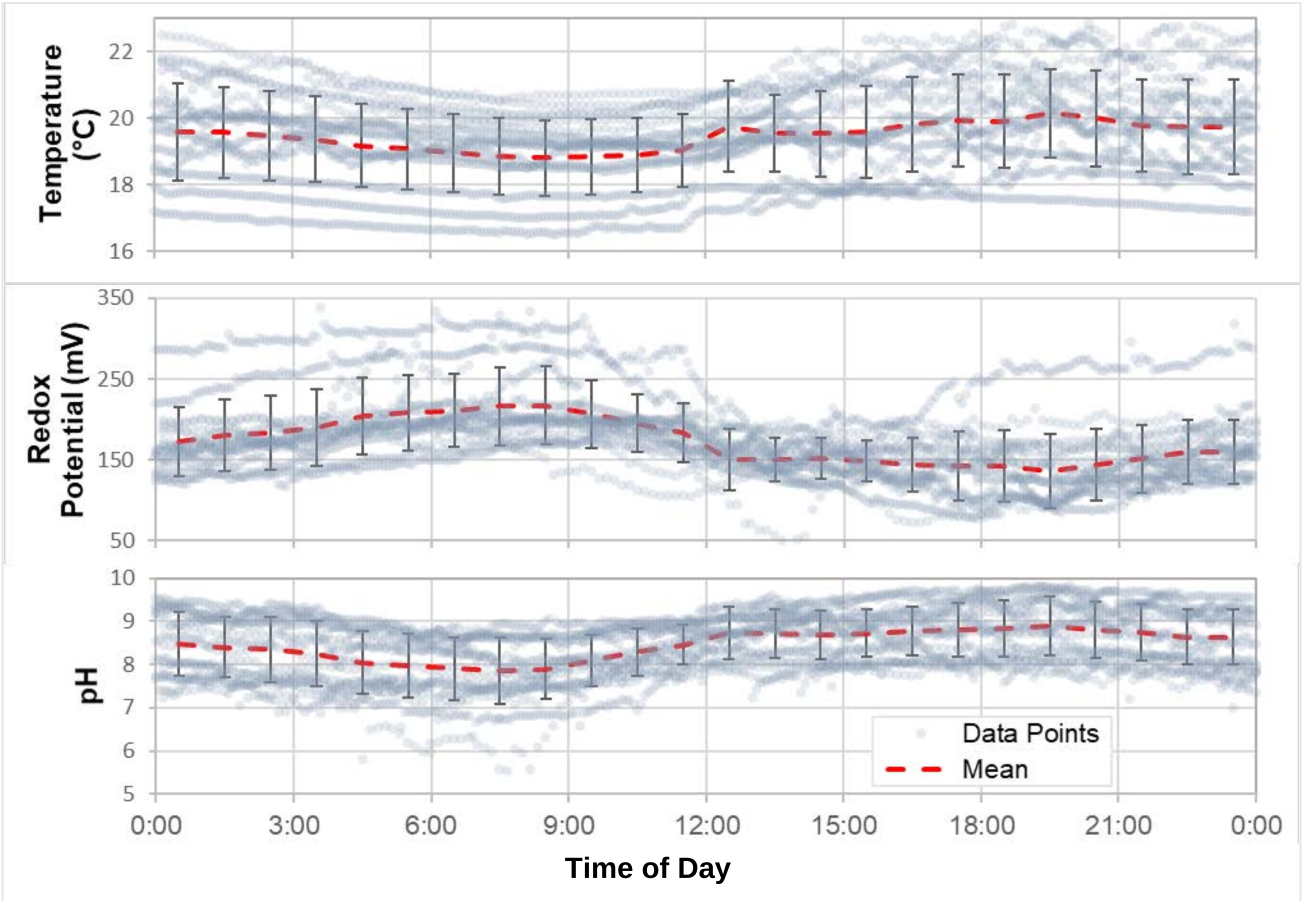


Figure A.7: Profiles of Diurnal Variation of TempHion Probe Data between 21 May and 6 June 2018

Diurnal patterns in pH and redox potential are a result of the metabolic processes of the algae and bacteria of the pond. Photosynthetic organisms that consume carbon dioxide (CO_2) and produce oxygen are dominant during sunlight hours, causing a shift in the carbonate cycle which makes the pond more acidic. When the sunlight is less intense, for example due to cloud cover, or at night the photosynthetic organisms lose their energy source so oxygen consuming, CO_2 producing organisms become dominant, causing the pond's pH to become more basic. The daily cycle of water temperature is driven more directly by air temperature and sunlight which warm the water during the day.

Appendix B

FTW Photographs

***Photo #1**:* Treatment plants: Primarily slough sedge*, Carex obnupta* and common rush, *Juncus effusus*

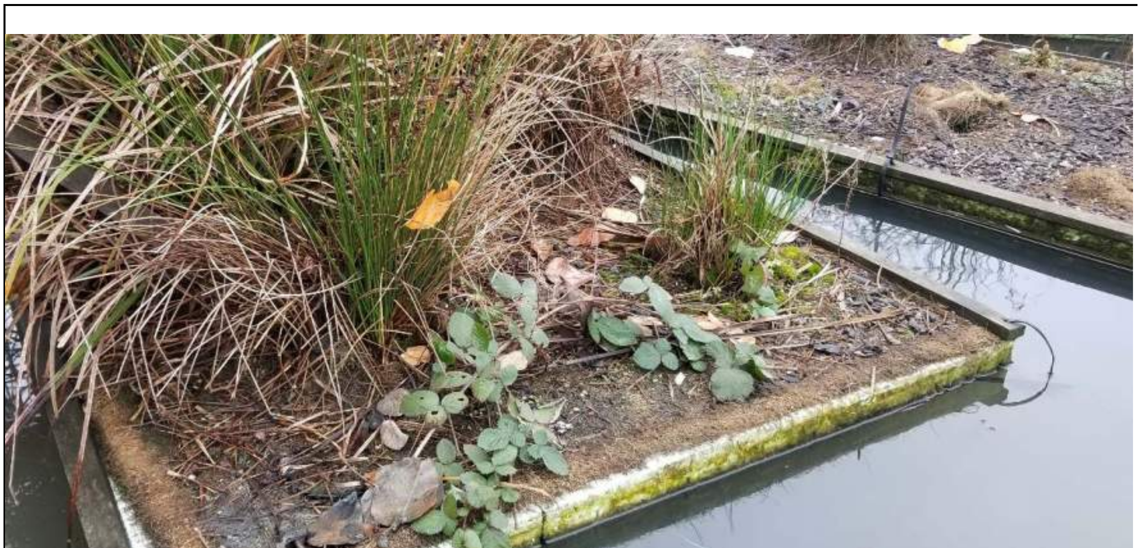


***Photo #2**:* Weeds: Himalayan blackberry, *Rubus discolor*

Photo #3*:* Weeds: Mullein, *Verbascum spp.*

Photo #4*:* Weeds: Dock, *Rumex spp.*

Photo #5:

Red-osier Dogwood, *Cornus sericea*

Photo #6:

Ferns

***Photo #7**:* Damage to FTW: Evidence of beaver activity

***Photo #8**:* Damage to FTW: Evidence of beaver activity

FTW Root Photographs

***Photo #9**:* Plant root photographs taken by contractor on 1 May 2019

***Photo #10**:* Plant root photographs taken by contractor on 1 May 2019

***Photo #11**:* Plant root picture taken during probe deployment on 21 May 2019

***Photo #12**:*

Plant 1 plant height measurements from 10 December 2018

***Photo #13**:* Plant 1 root length measurements from 10 December 2018

***Photo #14**:* Plant 2 root length and plant height measurements from 10 December 2018

***Photo #15**:* Plant 3 root length and plant height measurements from 10 December 2018

***Photo #16**:* Initial FTW deployment on 2 May 2014

***Photo #17**:* First 26 FTWs deployed on 16 December 2014

***Photo #18**:* FTWs in place on 29 January 2015

***Photo #19**:* FTWs contained inside of a boom on 4 October 2018

Probe Deployment

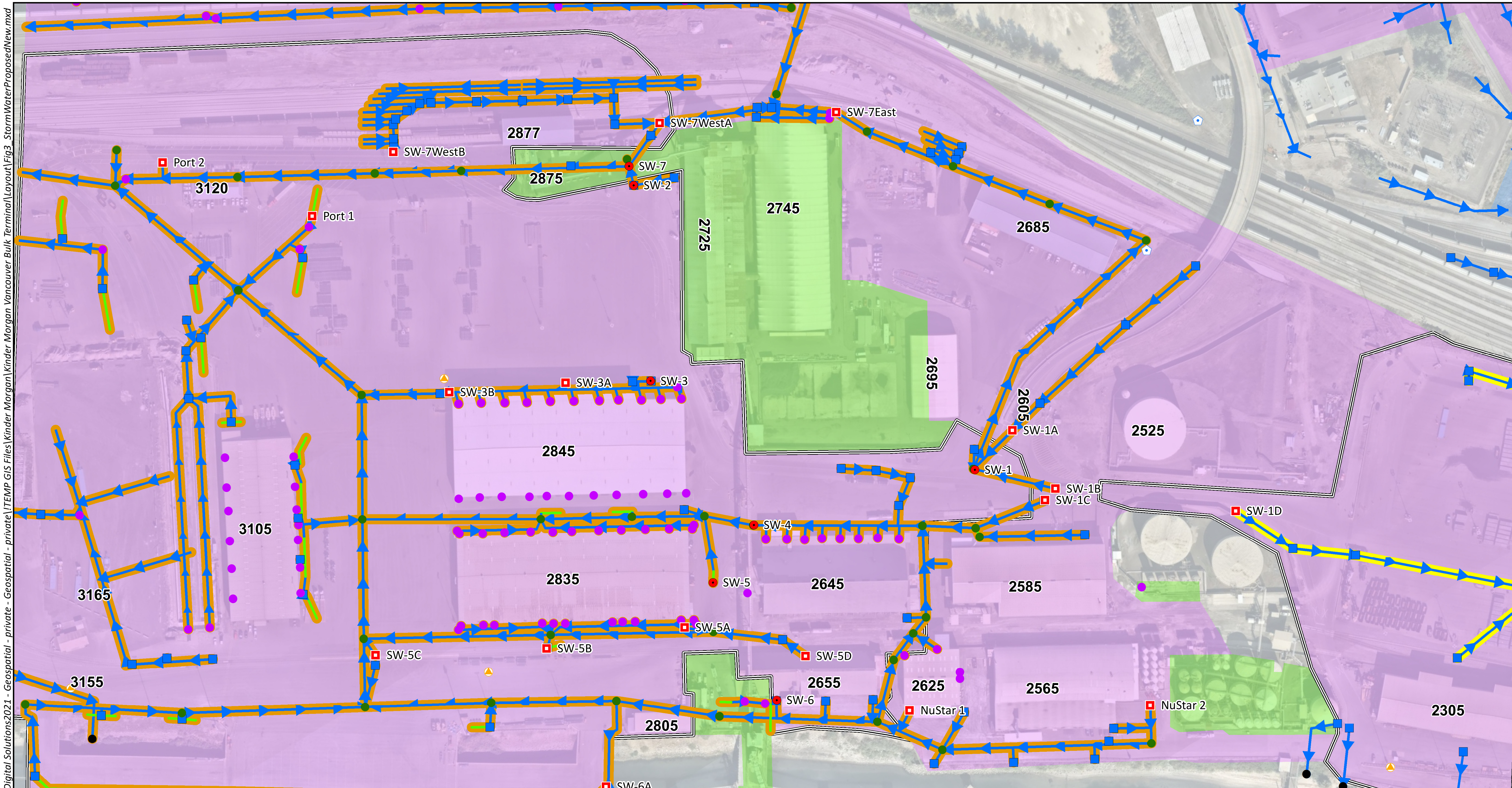
***Photo #20**:* Initial probe deployment from 21 May 2019, the probe floats below the white jug to the right of the FTWs

***Photo #21**:* Probe redeployment 30 May 2019

***Photo #22**:* Probe recovery on 16 July 2019; note the layer of green biological growth on the black probe

Appendix B

SRI Stormwater Results Figures



Legend

- Stormwater Sample Location
- Proposed Stormwater Sample Location
- Spill Kit
- Spill Containment Shed
- Other Feature
- Catch Basin
- Manhole
- Outfall
- Trench Drain
- Stormwater Pipe, Flow Direction
- East Stormwater System
- West Stormwater System
- Port ISG, 134 Acres
- Stromwater Drainage Basin
- Sanitary Sewer Drainage Basin
- Ponds

N

0 50 100 200 300 400 Feet

FIGURE 3

PROPOSED STORMWATER SAMPLE LOCATIONS MAP
PORT OF VANCOUVER, NUSTAR, AND KINDER MORGAN
VANCOUVER, WASHINGTON

antea group

DATE 12/7/2021	PROJECT NO. Kinder Morgan	PREPARED BY MB	REVIEWED BY BJ	REF SCALE 1:2,400	1 INCH = 200 FEET

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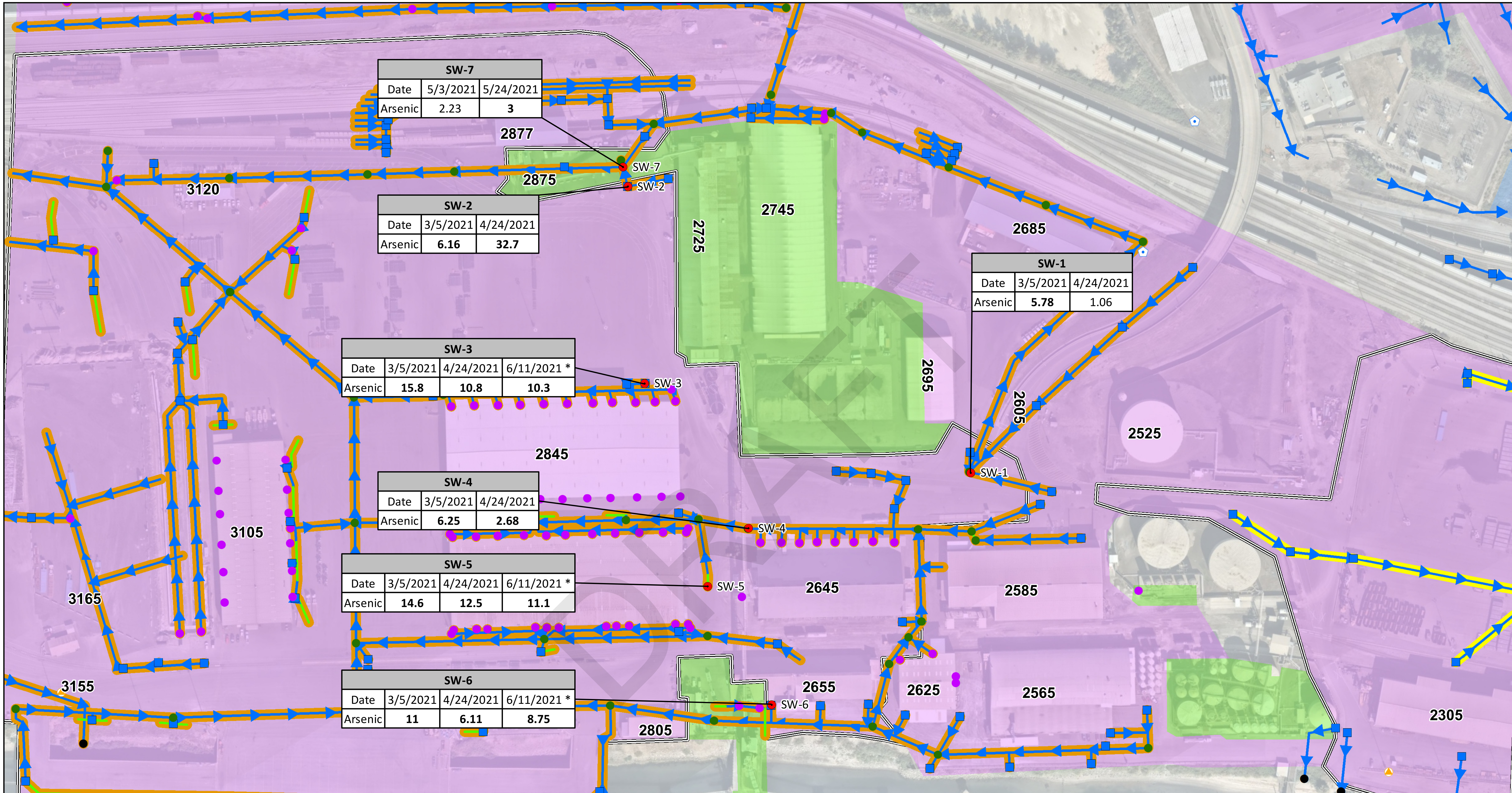

SW-7		
Date	5/3/2021	5/24/2021
Arsenic	2.23	**3**

SW-2		
Date	3/5/2021	4/24/2021
Arsenic	**6.16**	**32.7**

SW-1		
Date	3/5/2021	4/24/2021
Arsenic	**5.78**	1.06

SW-3			
Date	3/5/2021	4/24/2021	6/11/2021 *
Arsenic	**15.8**	**10.8**	**10.3**

SW-4		
Date	3/5/2021	4/24/2021
Arsenic	**6.25**	**2.68**

SW-5			
Date	3/5/2021	4/24/2021	6/11/2021 *
Arsenic	**14.6**	**12.5**	**11.1**

SW-6			
Date	3/5/2021	4/24/2021	6/11/2021 *
Arsenic	**11**	**6.11**	**8.75**

Legend

- Stormwater Sample Location
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- West Stormwater System
- Port ISG, 134 Acres
- Stromwater Drainage Basin
- Sanitary Sewer Drainage Basin
- Ponds

Notes:

SW-1, SW-2, SW-4, and SW-7 are Untreated Samples
SW-3, SW-5, and SW-6 are Post Port Filter Sock/Media Sample Locations
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see Draft Vancouver Screening Values Table
* - Sample collected prior to the StormwaterBIOCHAR catch basin insert filters

0 50 100 200 300 400 Feet

FIGURE 4

TOTAL ARSENIC STORMWATER CONCENTRATIONS
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	REVIEWED BY	MAP SCALE
8/20/2021	BJ	1 INCH = 200 FEET

anteagroup

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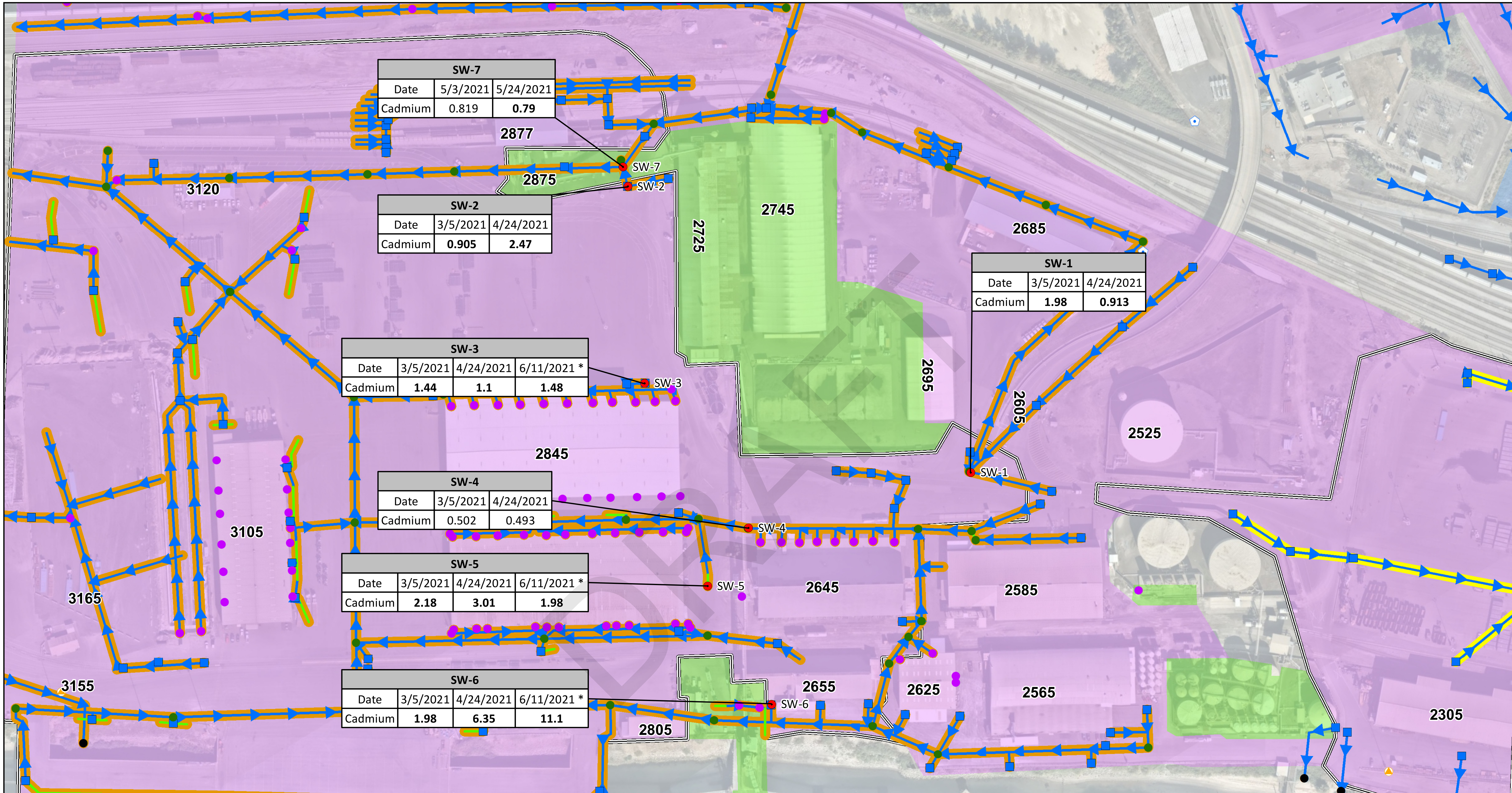

Legend

- Stormwater Sample Location
- Spill Kit
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- Other Feature
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- Ponds

Notes:
SW-1, SW-2, SW-4, and SW-7 are Untreated Samples
SW-3, SW-5, and SW-6 are Post Port Filter Sock/Media Sample Locations
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see Draft Vancouver Screening Values Table
* - Sample collected prior to the StormwaterBIOCHAR catch basin insert filters

0 50 100 200 300 400 Feet

FIGURE 5

TOTAL CADMIUM STORMWATER CONCENTRATIONS
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	REVIEWED BY	MAP SCALE
8/20/2021	BJ	1 INCH = 200 FEET

anteagroup

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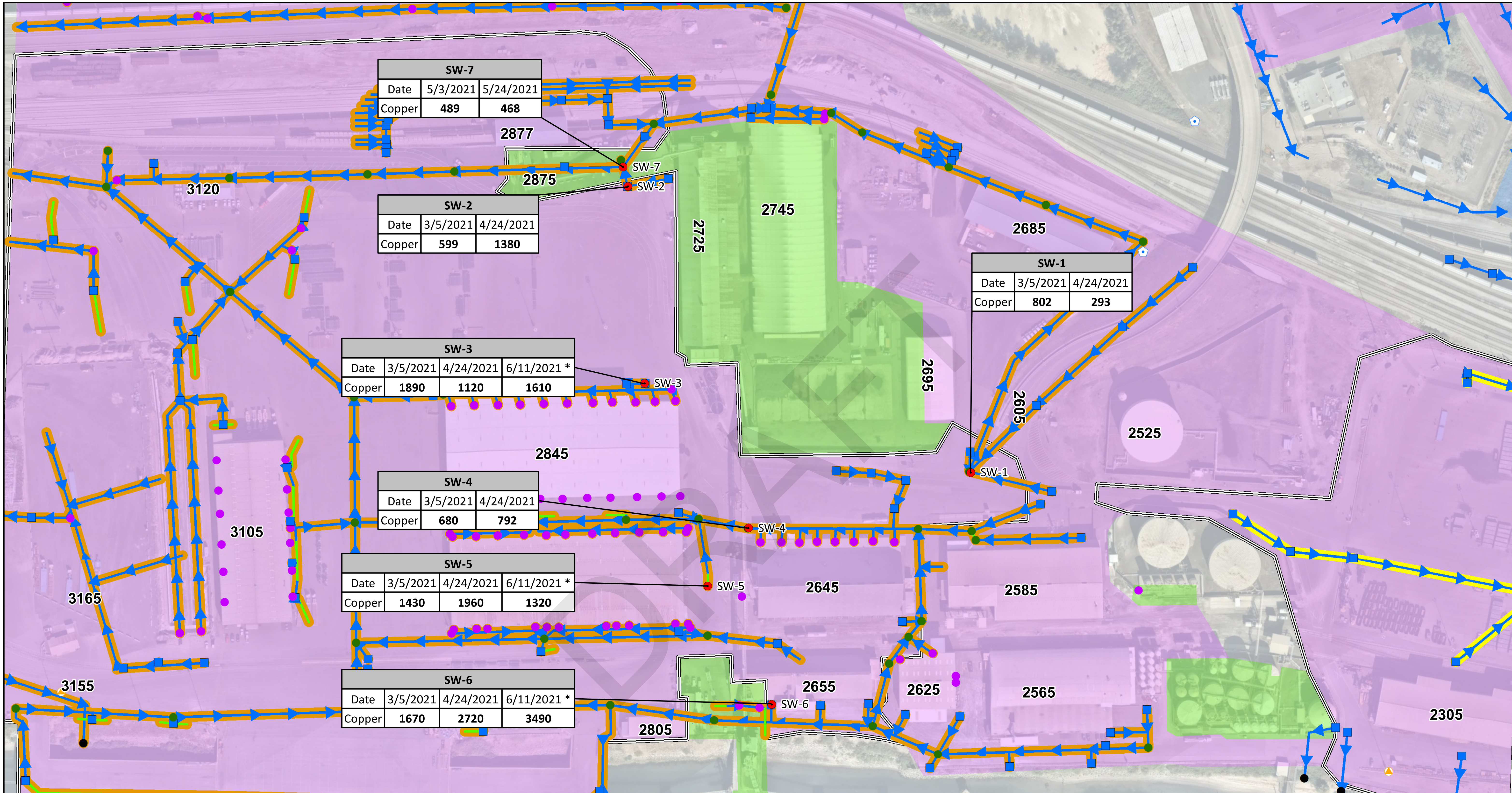

Legend

- Stormwater Sample Location
- Spill Kit
- Spill Containment Shed
- Other Feature
- Catch Basin
- Manhole
- Outfall
- Trench Drain
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- Stormwater Drainage Basin
- Sanitary Sewer Drainage Basin
- Ponds

Notes:
SW-1, SW-2, SW-4, and SW-7 are Untreated Samples
SW-3, SW-5, and SW-6 are Post Port Filter Sock/Media Sample Locations
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see Draft Vancouver Screening Values Table
* - Sample collected prior to the StormwaterBIOCHAR catch basin insert filters

0 50 100 200 300 400 Feet

FIGURE 6

TOTAL COPPER STORMWATER CONCENTRATIONS
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	REVIEWED BY	MAP SCALE
8/20/2021	BJ	1 INCH = 200 FEET

anteagroup

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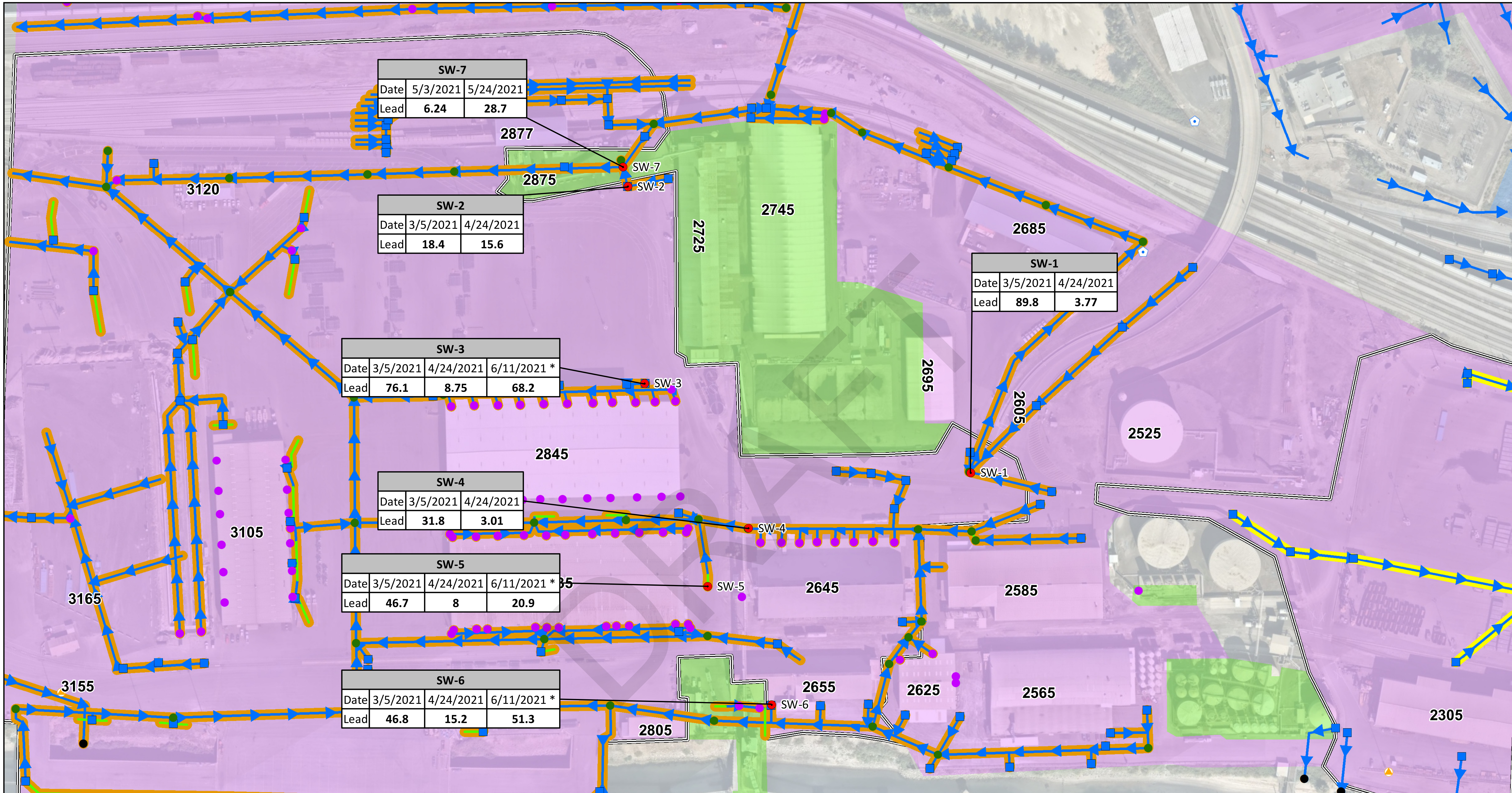

SW-7		
Date	5/3/2021	5/24/2021
Lead	**6.24**	**28.7**

SW-2		
Date	3/5/2021	4/24/2021
Lead	**18.4**	**15.6**

SW-1		
Date	3/5/2021	4/24/2021
Lead	**89.8**	**3.77**

SW-3			
Date	3/5/2021	4/24/2021	6/11/2021 *
Lead	**76.1**	**8.75**	**68.2**

SW-4		
Date	3/5/2021	4/24/2021
Lead	**31.8**	**3.01**

SW-5			
Date	3/5/2021	4/24/2021	6/11/2021 *
Lead	**46.7**	**8**	**20.9**

SW-6			
Date	3/5/2021	4/24/2021	6/11/2021 *
Lead	**46.8**	**15.2**	**51.3**

Legend

- Stormwater Sample Location
- Spill Kit
- Spill Containment Shed
- Other Feature
- Catch Basin
- Manhole
- Outfall
- Trench Drain
- Stormwater Pipe, Flow Direction
- East Stormwater System
- West Stormwater System
- Port ISG, 134 Acres
- Stromwater Drainage Basin
- Sanitary Sewer Drainage Basin
- Ponds

Notes:
SW-1, SW-2, SW-4, and SW-7 are Untreated Samples
SW-3, SW-5, and SW-6 are Post Port Filter Sock/Media Sample Locations
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see Draft Vancouver Screening Values Table
* - Sample collected prior to the StormwaterBIOCHAR catch basin insert filters

0 50 100 200 300 400 Feet

FIGURE 7

TOTAL LEAD STORMWATER CONCENTRATIONS
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	REVIEWED BY	MAP SCALE
8/20/2021	BJ	1 INCH = 200 FEET

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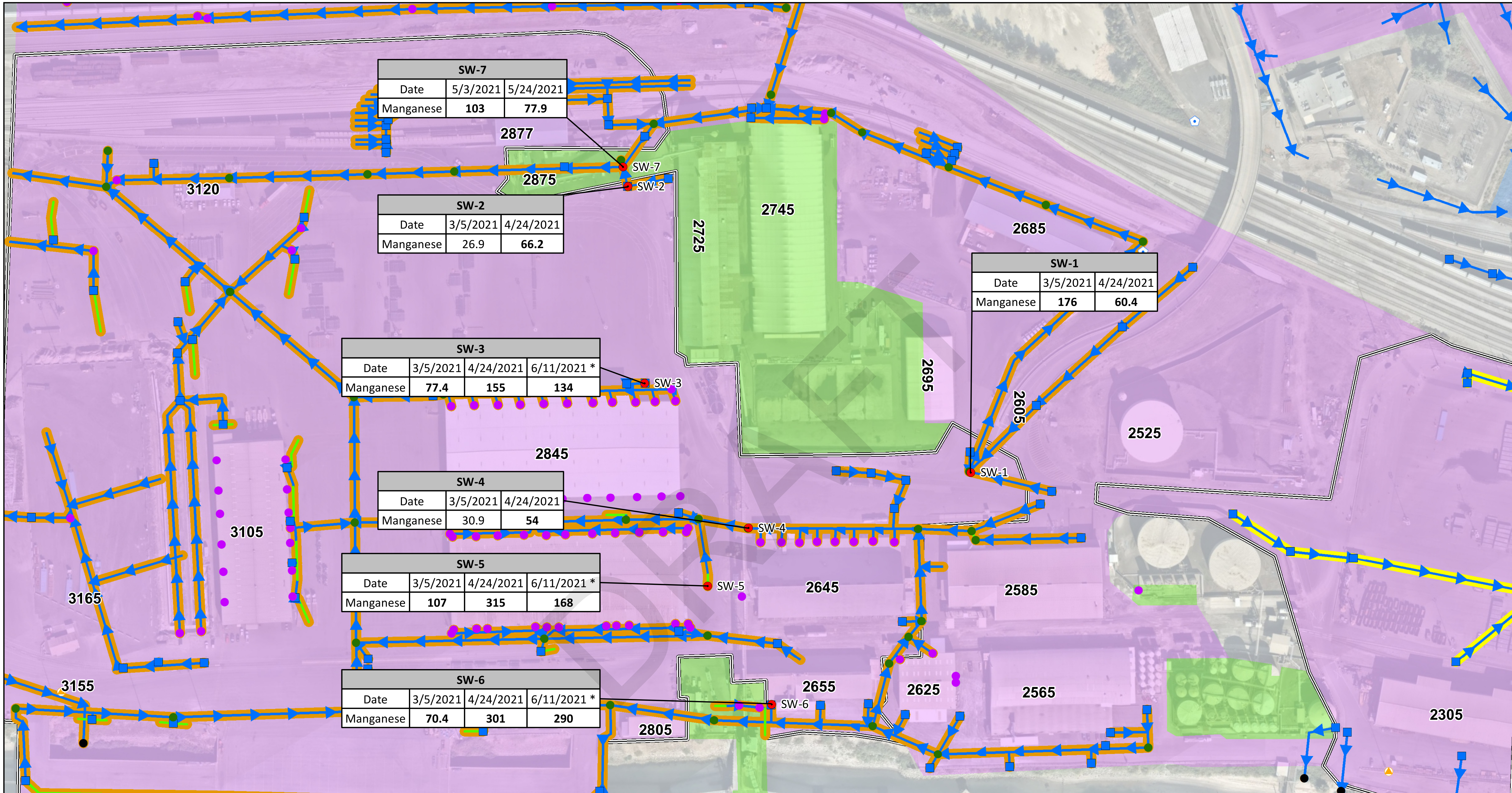

SW-7		
Date	5/3/2021	5/24/2021
Manganese	**103**	**77.9**

SW-2		
Date	3/5/2021	4/24/2021
Manganese	**26.9**	**66.2**

SW-1		
Date	3/5/2021	4/24/2021
Manganese	**176**	**60.4**

SW-3			
Date	3/5/2021	4/24/2021	6/11/2021 *
Manganese	**77.4**	**155**	**134**

SW-4		
Date	3/5/2021	4/24/2021
Manganese	**30.9**	**54**

SW-5			
Date	3/5/2021	4/24/2021	6/11/2021 *
Manganese	**107**	**315**	**168**

SW-6			
Date	3/5/2021	4/24/2021	6/11/2021 *
Manganese	**70.4**	**301**	**290**

Legend

- Stormwater Sample Location
- Spill Kit
- Spill Containment Shed
- Other Feature
- Catch Basin
- Manhole
- Outfall
- Trench Drain
- Stormwater Pipe, Flow Direction
- East Stormwater System
- West Stormwater System
- Port ISG, 134 Acres
- Stromwater Drainage Basin
- Sanitary Sewer Drainage Basin
- Ponds

Notes:
SW-1, SW-2, SW-4, and SW-7 are Untreated Samples
SW-3, SW-5, and SW-6 are Post Port Filter Sock/Media Sample Locations
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see Draft Vancouver Screening Values Table
* - Sample collected prior to the StormwaterBIOCHAR catch basin insert filters

0 50 100 200 300 400 Feet

FIGURE 8

TOTAL MANGANESE STORMWATER CONCENTRATIONS
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	**REVIEWED BY**	**MAP SCALE**
8/20/2021	BJ	1 INCH = 200 FEET

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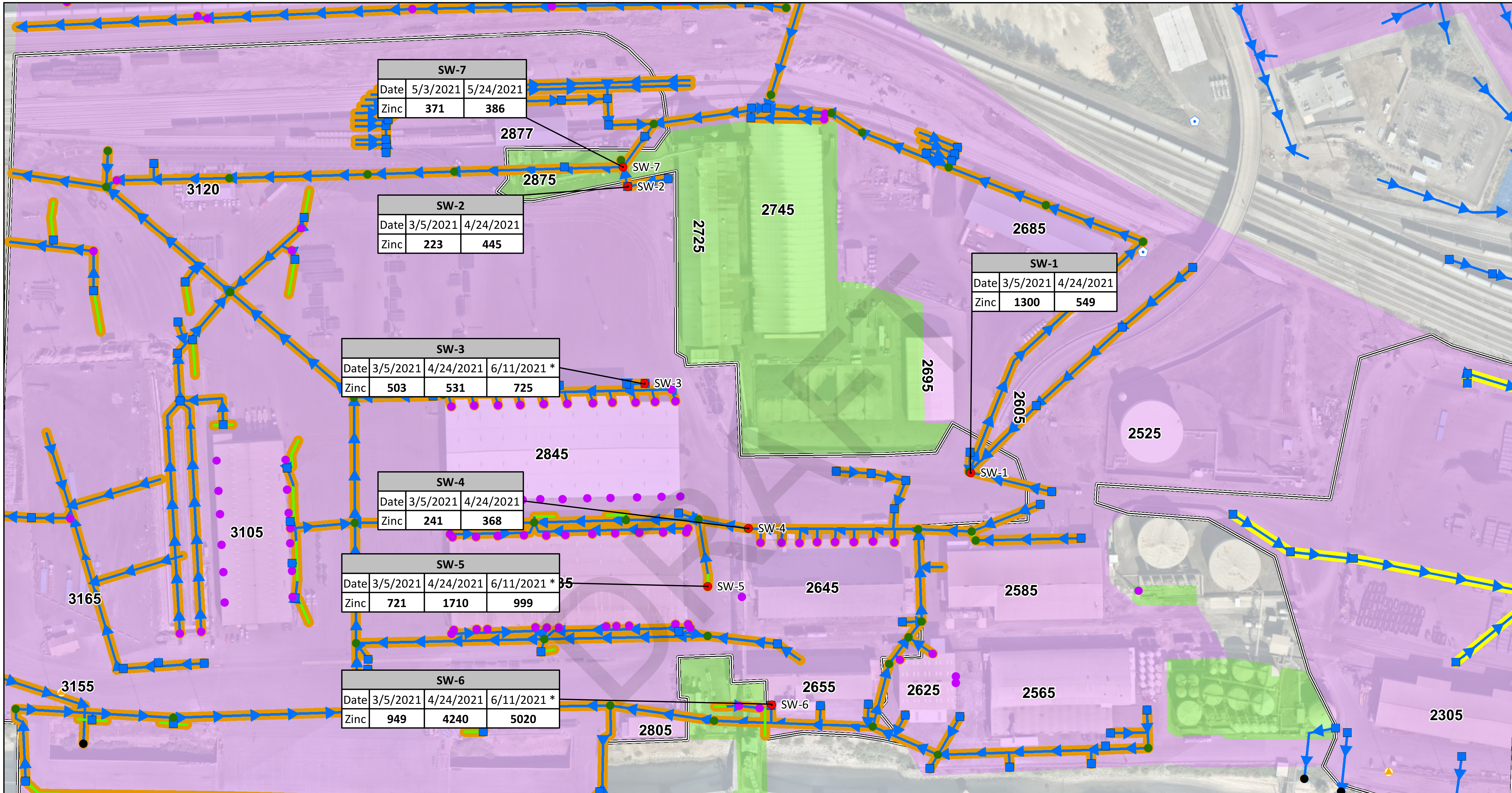

Legend

Stormwater Sample Location	Outfall	Stromwater Drainage Basin
Spill Kit	Trench Drain	Sanitary Sewer Drainage Basin
Spill Containment Shed	Stormwater Pipe, Flow Direction	Ponds
Other Feature	East Stormwater System	
Catch Basin	West Stormwater System	
Manhole	Port ISG, 134 Acres	

Notes:
SW-1, SW-2, SW-4, and SW-7 are Untreated Samples
SW-3, SW-5, and SW-6 are Post Port Filter Sock/Media Sample Locations
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see Draft Vancouver Screening Values Table
* - Sample collected prior to the StormwaterBIOCHAR catch basin insert filters

0 50 100 200 300 400 Feet

FIGURE 9

TOTAL ZINC STORMWATER CONCENTRATIONS
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	REVIEWED BY	MAP SCALE
8/20/2021	BJ	1 INCH = 200 FEET

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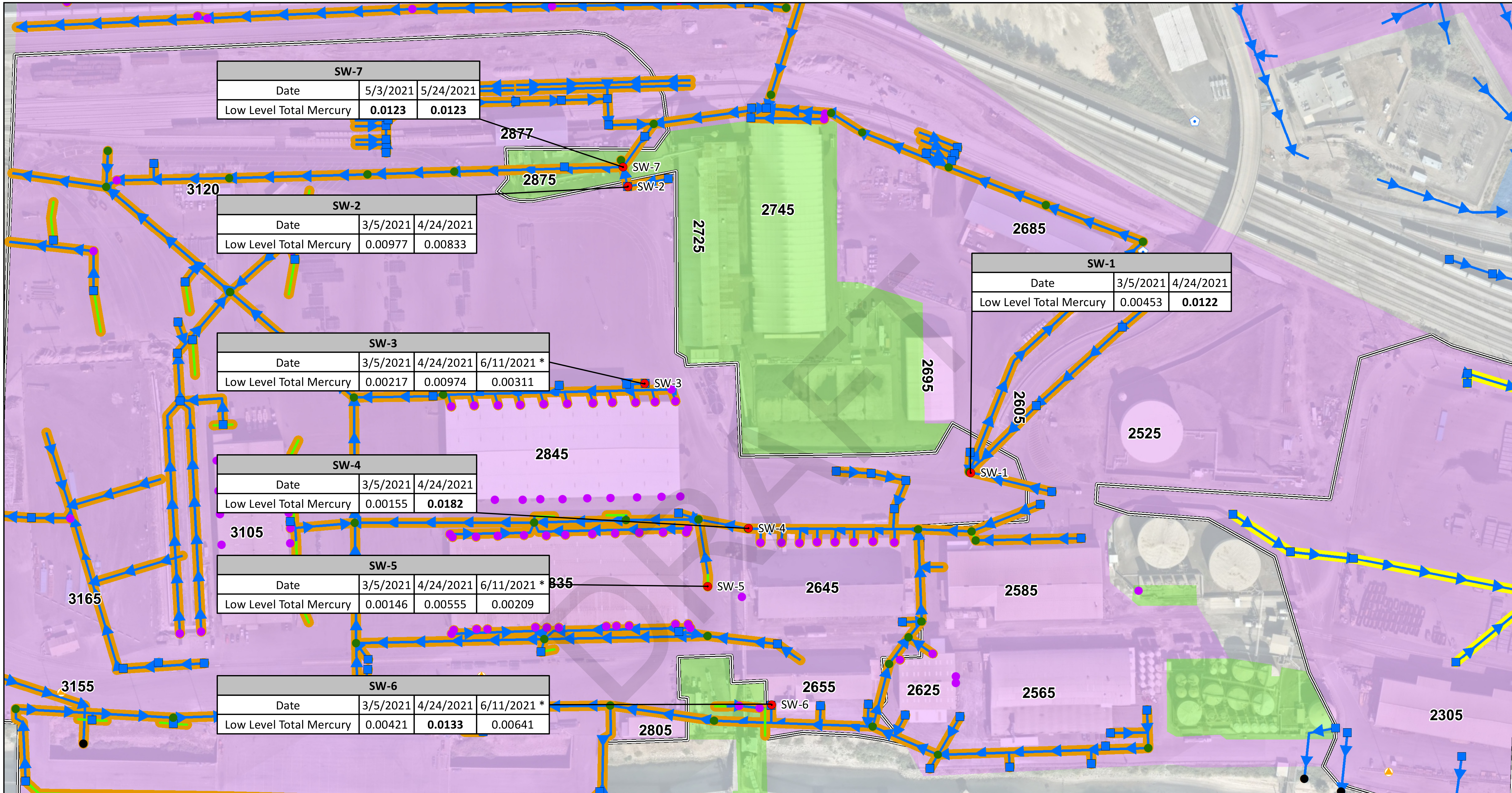

SW-7		
Date	5/3/2021	5/24/2021
Low Level Total Mercury	**0.0123**	**0.0123**

SW-2		
Date	3/5/2021	4/24/2021
Low Level Total Mercury	0.00977	0.00833

SW-1		
Date	3/5/2021	4/24/2021
Low Level Total Mercury	0.00453	**0.0122**

SW-3			
Date	3/5/2021	4/24/2021	6/11/2021 *
Low Level Total Mercury	0.00217	0.00974	0.00311

SW-4		
Date	3/5/2021	4/24/2021
Low Level Total Mercury	0.00155	**0.0182**

SW-5			
Date	3/5/2021	4/24/2021	6/11/2021 *
Low Level Total Mercury	0.00146	0.00555	0.00209

SW-6			
Date	3/5/2021	4/24/2021	6/11/2021 *
Low Level Total Mercury	0.00421	**0.0133**	0.00641

Legend

- Stormwater Sample Location
- Spill Kit
- Spill Containment Shed
- Other Feature
- Catch Basin
- Manhole
- Outfall
- Trench Drain
- Stormwater Pipe, Flow Direction
- East Stormwater System
- West Stormwater System
- Port ISG, 134 Acres
- Stromwater Drainage Basin
- Sanitary Sewer Drainage Basin
- Ponds

Notes:
SW-1, SW-2, SW-4, and SW-7 are Untreated Samples
SW-3, SW-5, and SW-6 are Post Port Filter Sock/Media Sample Locations
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see Draft Vancouver Screening Values Table
* - Sample collected prior to the StormwaterBIOCHAR catch basin insert filters

0 50 100 200 300 400 Feet

FIGURE 10

TOTAL LOW LEVEL MERCURY STORMWATER CONCENTRATIONS
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	REVIEWED BY	MAP SCALE
8/20/2021	BJ	1 INCH = 200 FEET

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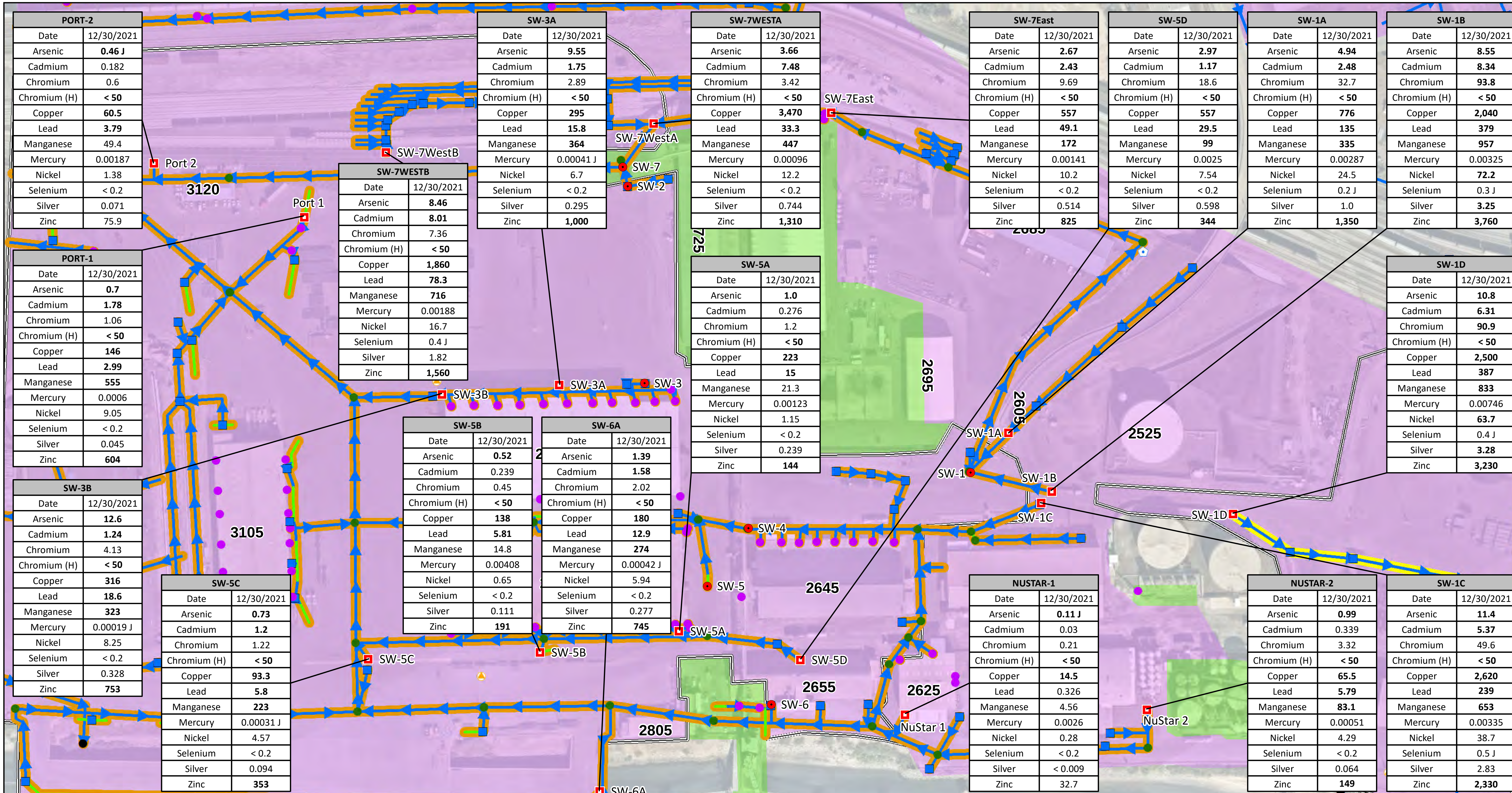

PORT-2	
Date	12/30/2021
Arsenic	**0.46 J**
Cadmium	0.182
Chromium	0.6
Chromium (H)	**< 50**
Copper	**60.5**
Lead	**3.79**
Manganese	49.4
Mercury	0.00187
Nickel	1.38
Selenium	< 0.2
Silver	0.071
Zinc	75.9

PORT-1	
Date	12/30/2021
Arsenic	**0.7**
Cadmium	**1.78**
Chromium	1.06
Chromium (H)	**< 50**
Copper	**146**
Lead	**2.99**
Manganese	**555**
Mercury	0.0006
Nickel	9.05
Selenium	< 0.2
Silver	0.045
Zinc	**604**

SW-3B	
Date	12/30/2021
Arsenic	**12.6**
Cadmium	**1.24**
Chromium	4.13
Chromium (H)	**< 50**
Copper	**316**
Lead	**18.6**
Manganese	**323**
Mercury	0.00019 J
Nickel	8.25
Selenium	< 0.2
Silver	0.328
Zinc	**753**

SW-5C	
Date	12/30/2021
Arsenic	**0.73**
Cadmium	**1.2**
Chromium	1.22
Chromium (H)	**< 50**
Copper	**93.3**
Lead	**5.8**
Manganese	**223**
Mercury	0.00031 J
Nickel	4.57
Selenium	< 0.2
Silver	0.094
Zinc	**353**

SW-7WESTB	
Date	12/30/2021
Arsenic	**8.46**
Cadmium	**8.01**
Chromium	7.36
Chromium (H)	**< 50**
Copper	**1,860**
Lead	**78.3**
Manganese	**716**
Mercury	0.00188
Nickel	16.7
Selenium	0.4 J
Silver	1.82
Zinc	**1,560**

SW-3A	
Date	12/30/2021
Arsenic	**9.55**
Cadmium	**1.75**
Chromium	2.89
Chromium (H)	**< 50**
Copper	**295**
Lead	**15.8**
Manganese	**364**
Mercury	0.00041 J
Nickel	6.7
Selenium	< 0.2
Silver	0.295
Zinc	**1,000**

SW-5B	
Date	12/30/2021
Arsenic	**0.52**
Cadmium	0.239
Chromium	0.45
Chromium (H)	**< 50**
Copper	**138**
Lead	**5.81**
Manganese	14.8
Mercury	0.00408
Nickel	0.65
Selenium	< 0.2
Silver	0.111
Zinc	**191**

SW-6A	
Date	12/30/2021
Arsenic	**1.39**
Cadmium	**1.58**
Chromium	2.02
Chromium (H)	**< 50**
Copper	**180**
Lead	**12.9**
Manganese	**274**
Mercury	0.00042 J
Nickel	5.94
Selenium	< 0.2
Silver	0.277
Zinc	**745**

SW-7WESTA	
Date	12/30/2021
Arsenic	**3.66**
Cadmium	**7.48**
Chromium	3.42
Chromium (H)	**< 50**
Copper	**3,470**
Lead	**33.3**
Manganese	**447**
Mercury	0.00096
Nickel	12.2
Selenium	< 0.2
Silver	0.744
Zinc	**1,310**

SW-5A	
Date	12/30/2021
Arsenic	**1.0**
Cadmium	0.276
Chromium	1.2
Chromium (H)	**< 50**
Copper	**223**
Lead	**15**
Manganese	21.3
Mercury	0.00123
Nickel	1.15
Selenium	< 0.2
Silver	0.239
Zinc	**144**

SW-7East	
Date	12/30/2021
Arsenic	**2.67**
Cadmium	**2.43**
Chromium	9.69
Chromium (H)	**< 50**
Copper	**557**
Lead	**49.1**
Manganese	**172**
Mercury	0.00141
Nickel	10.2
Selenium	< 0.2
Silver	0.514
Zinc	**825**

SW-5D	
Date	12/30/2021
Arsenic	**2.97**
Cadmium	**1.17**
Chromium	18.6
Chromium (H)	**< 50**
Copper	**557**
Lead	**29.5**
Manganese	**99**
Mercury	0.0025
Nickel	7.54
Selenium	< 0.2
Silver	0.598
Zinc	**344**

SW-1A	
Date	12/30/2021
Arsenic	**4.94**
Cadmium	**2.48**
Chromium	32.7
Chromium (H)	**< 50**
Copper	**776**
Lead	**135**
Manganese	**335**
Mercury	0.00287
Nickel	24.5
Selenium	0.2 J
Silver	1.0
Zinc	**1,350**

SW-1B	
Date	12/30/2021
Arsenic	**8.55**
Cadmium	**8.34**
Chromium	**93.8**
Chromium (H)	**< 50**
Copper	**2,040**
Lead	**379**
Manganese	**957**
Mercury	0.00325
Nickel	**72.2**
Selenium	0.3 J
Silver	**3.25**
Zinc	**3,760**

SW-1D	
Date	12/30/2021
Arsenic	**10.8**
Cadmium	**6.31**
Chromium	**90.9**
Chromium (H)	**< 50**
Copper	**2,500**
Lead	**387**
Manganese	**833**
Mercury	0.00746
Nickel	**63.7**
Selenium	0.4 J
Silver	**3.28**
Zinc	**3,230**

NUSTAR-1	
Date	12/30/2021
Arsenic	**0.11 J**
Cadmium	0.03
Chromium	0.21
Chromium (H)	**< 50**
Copper	**14.5**
Lead	0.326
Manganese	4.56
Mercury	0.0026
Nickel	0.28
Selenium	< 0.2
Silver	< 0.009
Zinc	32.7

NUSTAR-2	
Date	12/30/2021
Arsenic	**0.99**
Cadmium	0.339
Chromium	3.32
Chromium (H)	**< 50**
Copper	**65.5**
Lead	**5.79**
Manganese	**83.1**
Mercury	0.00051
Nickel	4.29
Selenium	< 0.2
Silver	0.064
Zinc	**149**

SW-1C	
Date	12/30/2021
Arsenic	**11.4**
Cadmium	**5.37**
Chromium	49.6
Chromium (H)	**< 50**
Copper	**2,620**
Lead	**239**
Manganese	**653**
Mercury	0.00335
Nickel	38.7
Selenium	0.5 J
Silver	2.83
Zinc	**2,330**

Legend

- Stormwater Sample Location
- Additional Stormwater Sample Location
- Spill Kit
- Spill Containment Shed
- Other Feature
- Catch Basin
- Manhole
- Outfall
- Trench Drain
- Stormwater Pipe, Flow Direction
- East Stormwater System
- West Stormwater System
- Port ISG, 134 Acres
- Stormwater Drainage Basin
- Sanitary Sewer Drainage Basin
- Ponds

Note:
(H) - Hexavalent

Notes:
All concentrations are in mircorgams per liter
Bold Text Exceeds most stringent screening value for surface water direct contact, protective of aquatic life, or protective of human health, see the Screening Values Table.

0 50 100 200 300 400 Feet

FIGURE 12

ADDITIONAL STORMWATER SAMPLE LOCATIONS
AND TOTAL ANALYTICAL DATA
SHORE TERMINALS, LLC. VANCOUVER FACILITY
VANCOUVER, WASHINGTON

PROJECT NO.	PREPARED BY	REF SCALE
Kinder Morgan	MB	1:2,400
DATE	REVIEWED BY	MAP SCALE
3/18/2022	BJ	1 INCH = 200 FEET

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