Port of Bellingham
Harris Avenue Shipyard

Remedial Investigation/ Feasibility Study

Volume I
(Text, Tables, Figures)

FINAL

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The interpretations and conclusions contained in this report are based in part on site characterization data collected by others. Floyd|Snider cannot assure the accuracy of this information.

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List of Abbreviations/Acronyms

Acronym/ Abbreviation	Definition
All American	All American Marine, Inc.
AO	Agreed Order
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirement
Arrowac	Arrowac Fisheries, Inc.
AST	Aboveground storage tank
Bay	Bellingham Bay
BAZ	Biologically active zone
bgs	Below ground surface
BMP	Best management practice
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAD	Confined aquatic disposal
CFR	Code of Federal Regulations
cm	Centimeters
COC	Contaminant of concern
COPC	Contaminant of potential concern
cPAH	Carcinogenic polycyclic aromatic hydrocarbon
CSL	Cleanup Screening Level
CSM	Conceptual Site Model
CUL	Cleanup level
CY	Cubic yards

Acronym/ Abbreviation	Definition
DAHP	Department of Archaeology and Historic Preservation
DCA	Disproportionate Cost Analysis
DGI	Data Gaps Investigation
DMMP	Dredged Material Management Program
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
EIS	Environmental Impact Statement
ENR	Enhanced natural recovery
EPH	Extractable petroleum hydrocarbon
FS	Feasibility Study
HPAH	High molecular weight polycyclic aromatic hydrocarbon
HRA	Historical Research Associates, Inc.
IHS	Indicator Hazardous Substances
JARPA	Joint Aquatic Resource Permit Application
LPAH	Low molecular weight polycyclic aromatic hydrocarbon
MCI	Maritime Contractors, Inc.
MCUL	Minimum cleanup level
µg/L	Micrograms per liter
mg/kg	Milligrams per kilogram
MIDP	Monitoring and Inadvertent Discovery Plan
MLLW	Mean Lower Low Water
MNR	Monitored natural recovery
mph	Miles per hour
m/s	Meters per second
MTCA	Model Toxics Control Act
ng/kg	Nanograms per kilogram
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NTR	National Toxics Rule
O&M	Operations and Maintenance
OMMP	Operations, Maintenance, and Monitoring Plan
PAF	Pacific American Fisheries Company
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PID	Photoionization detector
PMA	Port Management Agreement

Acronym/ Abbreviation	Definition
PNNL	Pacific Northwest National Laboratory
POC	Point of Compliance
Port	Port of Bellingham
POTW	Publicly owned treatment works
ppb	Parts per billion
ppt	Parts per thousand
PQL	Practical quantitation limit
PRB	Permeable reactive barrier
PSDDA	Puget Sound Dredged Disposal Analysis
Puglia	Puglia Engineering
QAPP	Quality Assurance Project Plan
QC	Quality control
RAL	Remedial Action Level
RAO	Remedial Action Objective
RCW	Revised Code of Washington
RETEC	The RETEC Group
RI	Remedial Investigation
SAP	Sampling and Analysis Plan
SCO	Sediment Cleanup Objective
SCUM II	Sediment Cleanup User’s Manual II
Site	Harris Avenue Shipyard
SMS	Sediment Management Standards
SMU	Sediment Management Unit
SQS	Sediment Quality Standards
SSI	Supplemental Site Investigation
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
SWAC	Surface-weighted average concentration
TBT	Tributyltin
TEE	Terrestrial Ecological Evaluation
TEQ	Toxic equivalent
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
TSCA	Toxics Substances Control Act
TTL	Target tissue level
U&A	Usual and Accustomed
USACE	U.S. Army Corps of Engineers

Acronym/ Abbreviation	**Definition**
U.S.C.	United States Code
USEPA	U.S. Environmental Protection Agency
UST	Underground storage tank
VOC	Volatile organic compound
VPH	Volatile petroleum hydrocarbon
WAC	Washington Administrative Code
Workbook	Screening Level Workbook

1.0 Introduction

This section provides an overview of the Harris Avenue Shipyard (the Site) and study area, establishes the objectives of the Remedial Investigation and Feasibility Study (RI/FS), and provides an outline of the document organization.

1.1 BACKGROUND AND OVERVIEW

This document presents the RI/FS prepared on behalf of the Port of Bellingham (the Port) for the Site in Bellingham Bay (Bay), located at 201 Harris Avenue in Bellingham, Washington (shown on Figure 1.1). The name of the Site, Harris Avenue Shipyard, is intended to include all shipyard and industrial activities that have occurred at this location, but there is not a company called Harris Avenue Shipyard. The owners and operators of the parcels within this area are discussed in further detail in Section 2.2.

The Site consists of approximately 10 acres of upland and over-water operational areas as shown on Figure 1.2. The Site consists of the upland and aquatic land currently occupied by Puglia Engineering (Puglia; operated as Fairhaven Shipyard) and a narrow strip of land to the west of these parcels that is part of Fairhaven Marine Park. Until 2017, a portion of the uplands property was previously occupied by All American Marine, Inc. (All American). The Site is bordered on the north and west sides by the Bay and on the south by Fairhaven Marine Park and the BNSF Railway rail lines, as shown on Figure 1.3. Industrial properties owned by the Port are present to the east and southeast of the Site. Properties to the east of the Site and their current uses include the former Arrowac Fisheries, Inc. (Arrowac) property, which includes an over-water building on the pier leased by Puglia for office space, a warehouse on the uplands (Warehouse No. 9), partially leased by Puglia, and the parking lot for the Arrowac property, which is used by Puglia. Farther to the east is the Bellingham Cruise Terminal, operated by the Port as the southern terminus for the Alaska State ferry (Figure 1.3).

The study area for this project includes the Site, the adjacent properties described above, and the vicinity of the Site, including the Bay to the north and west of the shipyard facility as shown on Figure 1.3. The uplands study area consists of the properties described above and the surrounding area, including the Fairhaven neighborhood, the adjacent industrial areas, and the residential areas. The in-water study area includes the area to the north of the uplands portion of Puglia and to the west, including the intertidal and subtidal sediments.

The Site is 1 of 12 cleanup sites located on and near the Bay coordinated under the Bellingham Bay Demonstration Pilot Project. The Site was identified as high priority by Washington State Department of Ecology (Ecology) in 2000 in a comprehensive strategy developed in cooperation with the Bellingham Bay Action Team.[1]

This report summarizes data from all environmental investigations conducted under the jurisdiction of the Agreed Order (AO) between Ecology and the Port for the Site. This document is being prepared in accordance with AO No. 7342 and the extension granted on December 24, 2012. Per the AO, the RI/FS presents a detailed site evaluation, defines the nature and extent of

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[1] The Bellingham Bay Action Team is a partnership of 12 federal, tribal, state, and local agencies that have developed a cooperative approach to expedite sediment cleanup, source control, and habitat restoration for sediment cleanup sites around the Bay.

identified contaminants of concern (COCs) and associated cleanup standards, and evaluates remedial alternatives.

The Port and Ecology initially entered into an AO (No. DE-03TCPBE-5670) in August 2003. The AO described the requirement to complete a final RI/FS for site sediments, pursuant to Washington Administrative Code (WAC) 173-340-350 and WAC 173-204-560.[2] On behalf of the Port, The RETEC Group (RETEC) completed a draft RI/FS for marine sediments in May 2004, which was then amended in January 2006. The RI/FS was conducted under Ecology's direction, consistent with the Washington State Model Toxics Control Act (MTCA) and the Sediment Management Standards (SMS). Work Plan development for the Draft Sediments RI/FS, and early sampling was initially conducted voluntarily by the Port while Ecology and the Port negotiated an AO.

In October 2007, Ecology and the Port agreed to expand the scope of work performed at the Site to provide a RI/FS that included both upland and sediment areas. This decision was in large part a natural progression, informed by the collection of information regarding source control at the Site and review of the draft sediment-focused work products.

A new AO (No. 7342) was signed between Ecology and the Port in March 2010 that governs completion of the upland and sediment RI/FS as one, site-wide process. The new AO was issued pursuant to the MTCA Revised Code of Washington (RCW) 70.105D.050(1) and supersedes AO No. DE-03TCPBE-5670. A Final Site-Wide RI/FS Work Plan, as specified in Exhibit B of the AO, was finalized on January 19, 2011.

The RI/FS Work Plan defined requirements for completion of a Supplemental Site Investigation (SSI) and accompanying data report (Floyd|Snider 2011b). Findings and results of the SSI field investigation completed in March and August 2011 are documented in the RI/FS Data Report. The Data Report was submitted as an interim deliverable in support of the RI/FS document and was finalized and approved by Ecology in July 2012.

In December 2012, a schedule extension request was granted by Ecology to allow a Data Gaps Investigation (DGI) to be conducted. The extension granted an additional 90 days from the submittal of the data collected during that investigation into Ecology's Environmental Information Management database. The extension required that the Port deliver the RI portions of the RI/FS to Ecology within that 90-day time period. The draft RI was submitted timely to Ecology on August 2, 2013. Final comments were received from Ecology on October 28, 2013. In March 2014, Ecology granted an extension request for submittal of the draft RI/FS to Ecology until June 6, 2014. Pursuant to the AO, the Port submitted an Agency Review Draft RI/FS to Ecology in June 2014. This RI/FS also has been prepared consistent with the revised SMS rule, which was adopted on February 22, 2013, and became effective on September 1, 2013.

Concurrent with Ecology's review of the draft RI/FS report, the Port conducted a structural assessment of the wooden portion of the Harris Avenue Pier, including the over-water Carpenter Building and its supporting Pier, and the East Marine Walkway (BergerABAM 2014). Based on the results of the structural assessment, the Port proposed an Interim Action to Ecology, including the removal of these structures, as both a source control measure and a necessary step to perform a more permanent remedy in the area of the Interim Action under MTCA. The source control measure would include removal of creosote-treated pilings and timbers from the marine environment. This would allow the removal and upland disposal of contaminated marine sediment

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[2] The upland portions of the Site were not included in the initial AO or addressed in the Sediments RI/FS (RETEC 2004).

within the footprint of those structures, as a more permanent remedy than remedies presented in the June 2014 Agency Review Draft RI/FS, including in-place sediment containment via capping. The removal of these structures was determined by the Port to be a schedule priority, due to their dilapidated condition and risk of failure during normal and ongoing shipyard operations. Only the wooden portion of the Harris Avenue Pier and the East Marine Walkway would be reconstructed in order to restore the existing function of the shipyard. The Carpenter Building and its supporting Pier would not be reconstructed, adding the additional environmental benefit of a significant reduction in over-water shading at the facility.

Based on Ecology's support for the proposed Interim Action, a Joint Aquatic Resource Permit Application (JARPA) application was submitted to the U.S. Army Corps of Engineers (USACE) in December 2014, anticipating that the work would be performed as an Ecology-approved Interim Action under an amended AO. On March 9, 2015, Ecology issued a draft AO Amendment, draft Interim Action Work Plan, and a State Environmental Policy Act determination of non-significance for a 30-day public review and comment period. On July 11, 2016, Ecology executed the AO Amendment and approved the Interim Action Work Plan as final.

In February 2015, a Proposed Interim Action Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) for implementation of investigation activities to support the design of the Interim Action was submitted to Ecology (Floyd|Snider 2015a). This groundwater, soil, and sediment investigation was conducted upon approval by Ecology in February 2015. The results from this investigation were documented in the Interim Action Basis of Design Report (Floyd|Snider 2017) approved by Ecology in February 2017.

An amendment to the JARPA application was submitted in November 2016 to account for the design changes to accommodate construction sequencing and tenant coordination. On November 17, 2016, the JARPA application was approved by the USACE. In the summer of 2017, construction of the Interim Action began and is anticipated to be completed in February 2019.

In brief, the Interim Action includes the following:

- Abatement, removal, and disposal of hazardous materials associated with those operational structures proposed to be removed.
- Demolition and removal of the wooden portion of the Harris Avenue Pier, and the Carpenter Building and its supporting Pier (including the East Marine Walkway).
- Dredging to cleanup levels (CULs) or remedial action levels (RALs) in subtidal sediments within the Interim Action area, with upland landfill disposal of dredged materials.
- Removal of contaminated intertidal sediments within the Interim Action area to approximately 3 feet deep from the surface of mudline, with upland landfill disposal of excavated materials. Capping of these removed areas with clean fill to match existing grades.
- Shallow surface soil excavation (typically less than 4 feet deep) and backfilling with clean fill in the upland area of the shipyard and in the vicinity of the Harris Avenue Pier and the Carpenter Building and its supporting Pier.
- Construction of a sheet pile bulkhead and a new concrete pier in the location of the existing wooden portion of the Harris Avenue Pier to restore existing functions and maintain shipyard operations.

- Construction of a marine railway walkway on the east side of the marine railway to restore existing functions.
- Associated utility work.

The primary remedial components and the extent of the Interim Action are shown on Figure 1.4.

This RI/FS has been prepared to address Ecology's previous comments and incorporate the Interim Action, associated sampling and the regulatory updates since the submittal of the Agency Review Draft RI/FS to Ecology in June 2014.

1.2 OBJECTIVES OF THE RI/FS

The Port has prepared the RI/FS in compliance with the investigation and cleanup requirements of MTCA and SMS. This report will be used to characterize and evaluate the remedial measures required to clean up the shipyard sediments and uplands under these regulations. The objective of this report is to conduct a comprehensive site-wide characterization, remedial assessment, and cleanup alternative evaluation including the upland and aquatic properties.

This report is designed to meet the following objectives:

- Complete a full characterization of soil, groundwater, and sediment quality, determine the compliance status of these media, and evaluate comprehensive exposure pathways.
- Define Remedial Action Objectives (RAOs), Applicable or Relevant and Appropriate Requirements (ARARs), and the site-specific CULs for COCs at the Site.
- Prepare a Conceptual Site Model (CSM) that identifies the COCs and Areas of Concern (AOCs) at the Site.
- Develop and evaluate remedial action alternatives for comprehensive cleanup of upland and sediment AOCs appropriate for implementation at the shipyard facility.
- Select a preferred remedial action for the full site that will achieve MTCA and SMS compliance under current and anticipated land uses.

The RI/FS defines RAOs for the Site as a mechanism for meeting the scoping requirements of the MTCA Cleanup Regulations (Chapter 173-340 WAC). RAOs define the objectives that must also be met by the remedy to ensure substantive compliance with ARARs. RAOs are clear statements of what the remedy needs to accomplish in order to address concerns defined in the CSM. RAOs are used to facilitate development and evaluation of remedial alternatives.

RAOs for the Site include the following:

- Remediate upland soil and groundwater to protect human health from exposure to hazardous substances via direct contact and indoor air vapor intrusion.
- Remediate marine sediments to meet MTCA and SMS requirements protective of benthic species, direct contact to humans, and bioaccumulative risks to human and higher trophic level species health.
- Control soil-to-sediment contaminant migration pathways to prevent sediment recontamination at levels of concern or at concentrations greater than CULs, and to protect surface water quality.

Additional RI/FS remedial action considerations include the following:

- Select remedial actions that can effectively be implemented and maintained within the active shipyard environment. Reduce shipyard business disturbances during remedial action implementation and minimize impacts to navigational use at and near the Site.
- Select remedial actions that will be consistent with future water-dependent industrial operations, uses, and configurations of the Site.
- Define shipyard operational or structural contamination source control actions that must be implemented prior to site cleanup to protect against recontamination of sediment, soil, or groundwater from ongoing shipyard activities.
- Develop long-term monitoring approaches, protocols, and contingency plans to be implemented following completion of site remediation.
- Consider aquatic habitat and optimize the preferred alternative to provide ancillary and permanent aquatic habitat benefit, where possible, given active shipyard use.

1.3 DOCUMENT ORGANIZATION

The RI/FS is organized as follows:

Remedial Investigation

- **Section 2.0 – Project Background and Site Setting:** Provides information on summary of site discovery, identified sources, previous studies, and objectives of the RI/FS.
- **Section 3.0 – Environmental Setting:** Provides information on the location, ownership, and current land use of the Site. Presents site bathymetry, topography, and other physical characteristics. Presents site geology and hydrogeology, natural resources, and historical and cultural resources.
- **Section 4.0 – Site Screening Levels:** Presents the current regulatory framework and MTCA requirements for the Site, exposure pathway and receptors, and site screening levels. Develops contaminants of potential concern (COPCs) to be evaluated for the Site.
- **Section 5.0 – Nature and Extent of Contamination:** Presents the primary targeted site COCs based on exceedances of developed site-specific CULs and Points of Compliance (POCs). Presents a description of type, concentration, and extent of contamination for all media.
- **Section 6.0 – Remedial Investigation Conclusions:** Presents a summary of the Site as a whole by confirming the exposure pathways, COCs, AOCs, and POCs.

Feasibility Study

- **Section 7.0 – Feasibility Study Introduction:** Presents the RAOs for the Site and identifies the site-specific ARARs for the Site.
- **Section 8.0 – Soil and Groundwater – Identification of Remedial Technologies:** Identifies and briefly describes the most commonly implemented remedial technologies for remediation of the site-specific COCs for soil and groundwater and the application and limitations of each technology.

- **Section 9.0 – Soil and Groundwater – Technology Screening and Remedial Alternative Development:** Describes the preliminary technology screening performed to eliminate technologies that do not meet site RAOs, are not technically feasible, or do not address the types of contamination present.
- **Section 10.0 – Soil and Groundwater – Alternative Evaluation and Disproportionate Cost Analysis:** Evaluates soil and groundwater alternatives against the MTCA requirements for a cleanup remedy per WAC 173-340-360.
- **Section 11.0 – Sediment – Identification of Remedial Technologies:** Identifies and briefly describes the most commonly implemented remedial technologies for remediation of the site-specific COCs for sediment and the application and limitations of each technology.
- **Section 12.0 – Sediment – Technology Screening and Remedial Alternative Development:** Describes the preliminary technology screening preformed to eliminate technologies that do not meet site RAOs, are not technically feasible, or do not address the types of contamination present.
- **Section 13.0 – Sediment – Cleanup Alternative Evaluation and Disproportionate Cost Analysis:** Evaluates sediment cleanup alternatives against the MTCA requirements for a cleanup remedy per WAC 173-340-360 and SMS.
- **Section 14.0 – Comprehensive Site-Wide Preferred Remedial Alternative:** Presents the site-wide preferred alternative for soil, groundwater, and sediment at the Site. Provides a summary of the remedial action as a whole.
- **Section 15.0 – References:** Presents the reference information for materials cited in the document.

2.0 Project Background and Site Setting

This section provides a detailed history of the Site and its operations, both historical and current. This section also provides a brief description of previous investigations that have occurred on the Site and a description of the recent investigations. Key photographs are included in Appendix A.

2.1 SITE DESCRIPTION

The Site is located at 201 Harris Avenue in Bellingham, Washington as shown on Figure 1.1. The name of the Site, Harris Avenue Shipyard, is intended to include all shipyard and industrial activities that have occurred at 201 Harris Avenue. The Site, as defined by MTCA Chapter 173-340-200 WAC as the location where contamination has come to lie, consists of portions of the upland and aquatic land occupied by Puglia (operated as Fairhaven Shipyard) and portions of the property occupied by All American (Figure 1.2). The limits of the Site have been determined by the evaluation of the contaminant characteristics within the study area, described within this document. Key features of the Site are shown on Figure 1.2.

As described in Section 1.1, the Site consists of 10 total acres, which includes approximately 5 acres of uplands and 5 acres in-water, as shown on Figure 1.2. The uplands portion of the Site consists of the properties described above and the area to the west of 201 Harris Avenue (a narrow strip of land that is part of Fairhaven Marine Park). Puglia is the only operator currently at the Site.

2.2 SITE HISTORY

The Lummi and Nooksack people, their families and relatives (Lummi Nation and Nooksack Tribe) have lived around this area with populations concentrated at the mouth of the Nooksack River, along Whatcom Creek, and on the San Juan Islands since time immemorial. Cultural resources are described in further detail in Section 3.4

The Site itself has been used by various entities for industrial purposes since the early 1900s. Prior to industrial use and development, a 60-foot-tall bluff called Deadman’s Bluff (also known as Grave Yard Point, Poe’s Point, and Deadman’s Point) existed near the Fairhaven waterfront. In 1899, this bluff was hydraulically regraded into Bellingham Bay to create Commercial Point (HRA 2011a). The 1891 shoreline, the former location of Deadman’s Bluff, and the current shoreline are shown on Figure 2.1 and are described in further detail in Section 3.2.2.

After the City of Fairhaven merged with Bellingham in 1903, fish processing facilities became prevalent along the expanding shoreline and in the vicinity of the Site (Long 2003). Based on review of Sanborn Maps from 1904, the Pacific American Fisheries Company (PAF) occupied a large property several hundred feet east of the Site and operated it as a cannery. Washington Packing Company's Salmon Cannery and the offices of the Fairhaven Land Company occupied a pier directly to the east of the Site, which is the pier that is part of the former Arrowac facility (HRA 2011a).

In May 1915, PAF leased Commercial Point from the State of Washington and built a shipyard called Commercial Point Shipyard (CPNWS 2014). In 1916, PAF purchased the land from the State of Washington and began building oceangoing wooden steamships. From 1916 to 1917, PAF constructed a total of six wooden ships for itself and a French company (Radke 2002). Sometime between 1915 and 1918, a wooden bulkhead was constructed as part of the facility upgrade that extended beyond the current uplands area along the northern shoreline

(HRA 2011a). Its location is shown on Figure 2.1. By 1917, shortly after the United States entered World War I, PAF expanded the Commercial Point Shipyard from two to five shipways to allow the simultaneous construction of five ships in anticipation of orders from the U.S. Shipping Board's Emergency Fleet Corporation. By the end of 1919, when the last contracted vessel was completed, PAF had constructed a total of seven vessels for the U.S. Shipping Board (Jewell 2008, Radke 2002).

In 1919, PAF decided to close down the shipyard. The buildings remained until 1920 when PAF dismantled the shipyard and sold the salvage to the Bellingham Junk Company (Jewell 2008, Radke 2002). The yard continued to be used for repairs and winter boat storage by PAF (Jewell 2008).

In 1937, PAF dredged and backfilled the area around Commercial Point to expand the boat yard, and brought over equipment from its cannery operations on Eliza Island in Bellingham Bay (Jewell 2008). This filling of the shoreline in the west and north portions of the Site in combination with historical filling in the late 1890s expanded the uplands from approximately 1 acre in 1891 to its current, level 4.9-acre topography, as shown on Figure 2.1. It is also believed that this activity cut back the northern shoreline from the 1918 extent defined by the wooden bulkhead to its current configuration.

During the 1930s and 1940s, a Union Oil-labeled aboveground storage tank (AST) for ship fuel was located near the main dock (Figure 1.2). The fuel tank had a reported capacity of 100,000 gallons and was removed in the late 1940s or early 1950s.

Nearly all of the Site property has been utilized at some point in the past for shipbuilding or repair. Maps from the Port's archive files, reports of historical investigations, and aerial photographs at the Site indicate that shipway structures occupied the western and northern sides of the property in the 1940s.

During World War II, Commercial Point Shipyard was used for the construction of U.S. Army tug boats and freighter passenger vessels by Northwestern Shipbuilding Company, a Seattle firm that leased the shipyard from PAF from 1942 to 1945 (Jewell 2008). Salvaging of Liberty Ships was reportedly conducted in the post-war era on the north side of the Site (in the existing Port Tenant Parcel A described in Section 2.3.1; RETEC 2004).

In 1966, the Port purchased the PAF property, including the shipyard. Since purchase of the land by the Port, the property has been leased by several different companies for use as a shipyard. Based on Port lease files and review of the RETEC investigation and Sediments RI/FS reports, the following bullets summarize the significant dates and recent history of shipyard tenants and activities:

- 1968: Post Point Marine leases the property and changes their company name to Post Point Industries in June 1970.
- 1971: Associated Venture Capital purchases Post Point Industries and changes their company name to Fairhaven Shipyard.
- 1971: Weldit Corporation purchases Fairhaven Shipyard and changes their company name to Fairhaven Industries, Inc.
- 1982: Dry Dock No. 2 is replaced with the existing dry dock structure. Records indicate that approximately 25,000 cubic yards (CY) of sediment were dredged under a USACE permit in 1982 to accommodate the existing dry dock structure. These sediments were

generally removed from the southern end of the existing dry dock and were disposed at an authorized open water disposal site.

- 1985: Maritime Contractors, Inc. (MCI), acquires the existing Weldit lease. MCI establishes a new lease agreement with the Port in 1986.
- 1991: MCI removes an underground storage tank (UST) consisting of a 3,000-gallon gasoline compartment and a 10,000-gallon diesel compartment. The removal was completed in accordance with Ecology regulations and samples were collected to show that no release had occurred (Pinner 1991). The location of the UST is shown on Figure 1.2.
- 1996: A concrete extension was built at the northern end of the Harris Avenue Pier.
- 1998: MCI terminates operations and sells the company's assets to Bellingham Bay Shipyards, which initiates a new lease agreement with the Port.
- 2002: Puglia and All American enter into leases with the Port, dividing the property into two separate operations.
- 2004: Puglia reconfigures stormwater drainage at the shipyard such that primary industrial areas of the Site (i.e., asphalt and concrete near the painting booths and the marine railway) are now collected and treated for discharge to the City's publicly owned treatment works (POTW).
- 2005: Puglia begins operating as Fairhaven Shipyards.
- 2009: Puglia permits and begins operating the submersible barge, the Faithful Servant, at the northeast end of the Harris Avenue Pier.
- 2017: All American vacates the property and Puglia vacates the Carpenter Building and moves into the All American facility.

Based on review of historical aerial and oblique photographs, the majority of the PAF buildings were removed from the Site by the 1950s with the exception of the loft and pier shops. The fabrication and maintenance building (used by All American until 2017 and now occupied by Puglia) located in the southwestern portion of the Site was constructed in the 1970s on a concrete slab and footing foundation. Since 2002, Puglia has used the loft and pier shops, dry dock, water treatment building, blasting shed, flammable storage shed, paint shop, winch house, machine shop, electrical shop, and steel fabrication shop. All of these buildings have been on the property since the 1950s for shipyard operations and are shown on Figure 1.2. Six aerial photographs spanning from 1946 to 2010 are shown on Figure 2.2.

Utilities at the Site include potable water, fire protection water, stormwater, electrical, sewer, and air. Recent improvements in 2010 were conducted to upgrade both the potable water and fire protection water lines at the Site, which included subsurface work. It is assumed that utility upgrades have occurred at the Site throughout its existence; however, little information is available about the locations of utilities prior to its current and recent configurations.

2.2.1 General Shipyard Operations and Associated Contaminants

The shipyard has a well-established history of use for shipbuilding and shipyard repair activities from 1915 until present day. Historically, most shipyards built prior to World War II employed processes and used manufactured components and basic construction materials common to the industry. While standard shipyard layouts varied, shipyard facilities typically included drydocks, marine railways, building ways, shipbuilding positions, piers and berthing positions, workshops (e.g., machine, electrical, paint and blast, metal shops), other work areas, warehouses, and offices (USEPA 1997).

Typical maintenance and repair operations included: blasting and repainting ship hulls, freeboards, superstructures, and interior tanks and work areas; rebuilding and installing machinery; overhauling systems; replacing and installing new components; repairing propellers and rudders; and creating new machinery spaces through cut outs of existing steel structures (USEPA 1997).

Contaminants commonly associated with shipyard repair and operations are described below (USEPA 1997):

- Blasting – this process involves abrasive blasting, which is the most common method for paint removal and surface preparation. Copper slag, coal slag, steel grit, and steel shot are common blasting abrasives. Air nozzle blasting (or dry abrasive blasting) is one of the most common types of blasting in the shipyard and repair industry. Prior to the mid-1980s, much of the grit used in the northwest came from the Asarco copper smelter in Tacoma. That grit contained trace amount of copper and zinc and up to 2 percent arsenic by weight.
- Solvent, Detergent, and Steam Cleaning – this process involves removing grease, oil, and other contaminants with the aid of solvents, emulsions, detergents, and other cleaning compounds. However, chlorinated solvents have never been detected at the Site.
- Hand Tool Preparation – this process involves the use of grinders, wire brushes, sanders, chipping hammers, and the like for surface preparation in areas where blasting grit would be too difficult to contain.
- Wet Abrasive Blasting and Hydroblasting – this process involves blasting with a mixture of water, air, and solid abrasives generally performed in floating dry docks, graving docks, or other building or repair position. Wet abrasive blasting does not occur throughout the shipyard like dry abrasive blasting because of the problem of water blast containment.
- Chemical Preparations – this process involves the use of paint removers, alkaline cleaning solutions, chlorinated solvents, and pickling for preparation of pipe systems and small parts for paint.
- Metal Plating and Surface Treatment – this process involves metal plating and surface treatment, including chemical and electrochemical conversion, case hardening, metallic coating, and electroplating.
- Painting Process – this process includes pigment, binder, and a solvent. Pigments that are used include zinc oxide, talc, carbon, coal tar, lead, mica, aluminum, and zinc dust. The binders can include epoxy, alkyd, urethane, vinyl, phenolic, and the like. Solvents are added to thin the paint and may include use of acetone, mineral spirits, xylene, methyl ethyl ketone, and water. Anticorrosive and antifouling paints are typically used on ship's hulls and are commonly used in the shipbuilding industry. Antifouling paints are copper-based and tributyltin- (TBT-) based. Anticorrosive paints may include vinyl, lacquer, urethane, or newer epoxy-based coating systems.

2.3 CURRENT CONDITIONS

Commercial activity at the Site all occurs in Port-owned or Port-managed property that is currently leased by Puglia (as shown on Figure 2.3).

2.3.1 Site Ownership and Leased Areas

A Port Management Agreement (PMA) with Washington State Department of Natural Resources (DNR) executed in 1997 granted primary property-management authority to the Port for multiple harbor-area parcels that are owned by the State and were previously managed by DNR. These Port parcels include Port PMA Parcels 5, 6, and 9, which extend from the inner harbor line to the outer harbor line as shown on Figure 2.3. As a result of the PMA, the Port currently manages these multiple harbor-area parcels for the State of Washington, including the aquatic and historical infill lands. The Port then sublets portions of these parcels to tenants as described below. Additionally, the Port owns the land that is landward of the inner harbor line, which is leased to Puglia.

The Puglia lease area is operated as Fairhaven Shipyards and is subdivided into four parcels, identified as Port Tenant Parcels A, B, C, and D based on Port leasehold maps dated August 31, 2006 and February 20, 2013. Port Tenant Parcel A is primarily an offshore lease parcel composed of portions of Port PMA Parcels 6 and 9 and includes both aquatic lands and lands of historical harbor infill above the high waterline that are located between the inner and outer harbor lines. Port Tenant Parcel B is located to the south of Port Tenant Parcel A and is an upland lease parcel that has been owned by the Port since 1966. Port Tenant Parcel C is an upland lease parcel owned by the Port and is located at the southeastern corner of the Site. Port Tenant Parcel D is an upland lease parcel owned by the Port located to the east of Port Tenant Parcel A and consists of the area that was occupied by Arrowac and has two structures: a pier with a two-story, 200-by-60-foot timber building that was a seafood processing plant; and a warehouse located on the uplands.

In 2017, Puglia took over the All American lease area which is located in the southwestern corner of the Site in between the four Puglia lease parcels and is composed of land owned by the Port located landward of the inner harbor line and a portion of Port PMA Parcel 6, which is land owned by the State of Washington located waterward of the inner harbor line.

As shown on Figure 2.3, the aquatic lands located immediately to the west of the former All American lease area comprise Port PMA Parcel 5, which is managed by the Port as part of the Port's PMA with DNR. No shipyard operations are being performed by Puglia within the Port PMA Parcel 5 area and no previous tenants have leased this area from the Port.

A 2007 Interlocal Agreement between DNR and the Port identified the cleanup responsibilities for DNR and the Port (DNR 2007).

2.3.2 Upland Operations and Land Use

The Site is zoned by the City of Bellingham for water-dependent industrial use. The shipyard site operates on a pier, dry dock, marine railway, and various mobile and floating cranes in addition to using upland support service shops such as a machine shop, electrical shop, steel fabrication and mechanical shop, valve shop, sandblast shed, paint shop, and water treatment building.

Puglia currently provides dry-docking and mooring capabilities and other support services for vessels. The marine railway, located in the middle of the north side of the Site, is a structure that provides vessel launching capabilities for ships. The marine railway is a structure that extends from the uplands into the water. For ease of discussion, the uplands portion of the marine railway will be identified as the “marine railway” when discussed, and the in-water portion of the marine railway will be identified as the “in-water portion of the marine railway” when discussed.

The marine railway is connected to a series of sidetracks where boats are stored during work activities. The marine railway, sidetracks, paint shop, and sandblast shed currently are some of the most heavily used portions of upland property for existing shipyard operations. The sidetracks area is currently used for sandblasting and other maintenance and repair operations. A waste oil drum storage shed is located near the entrance to the shipyard. A covered storage area, with secondary containment, is also located in this area of the shipyard, at which fuel, oil, and chemicals are stored. A former joiner shop (located in the vicinity of the current paint shed) was used for a variety of activities including painting and caulking.

An extensive network of utilities exists at the shipyard, including storm drains, sanitary sewer, natural gas, water, and electrical. Floyd|Snider inspected the shoreline to identify utilities that could act as conduits for groundwater to reach the Bay. No utilities were identified other than the following three outfalls: stormwater emergency outfall (Outfall #3) at the shipyard, the outfall to the west of the Site, and the stormwater outfall to the east of the Harris Avenue Pier, all of which appeared to be in good condition.

Upgrades to the stormwater system were conducted by Puglia in 2010. In the gravel area south of the Harris Avenue Pier, soil was excavated to approximately 3 feet below ground surface (bgs). No visual indications of contamination were identified during the upgrades. Excavated soil was either used as backfill or disposed of off-site. Soil that was disposed of off-site was sampled and contained low levels of diesel- and oil-range hydrocarbons.

Stormwater management at the Site is described in Section 2.3.4.

In 2012 to 2013, one transformer was noted by Ecology to be weeping and one transformer was noted as having stained soil around the base. Three samples were collected at the base of each transformer and analyzed for polychlorinated biphenyls (PCBs) and total petroleum hydrocarbons (TPH). PCBs were only detected in one sample at 0.20 milligrams per kilogram (mg/kg), less than the MTCA Method A screening level for unrestricted land use. One sample had elevated concentrations of diesel-range hydrocarbons. The visually impacted soil was removed and disposed of off-site in conjunction with transformer replacement.

2.3.3 Surrounding Land Use

Land use designations for the study area and surrounding landmarks are shown on Figure 1.3. The Site is located within the district of Fairhaven in an area designated as multi-use (or “Urban Village”) and consists of a commercial core, mixed use residential development, nearby single-family residential, marine industrial waterfront, ferry, bus, and train terminals, and intact historical buildings with a tourist district (City of Bellingham 2012). The primary land use designation outside of Fairhaven is residential to the east and south and some commercial and industrial to the north.

Directly to the east of the Site is the former Arrowac property, which includes a building on the pier currently leased by Puglia for office space, a warehouse on the uplands (Warehouse No. 9) that is currently partially leased by Puglia, and the parking lot for the property, which is used by Puglia. Bellingham Cruise Terminal, which is located approximately 0.15 miles to the east at 355 Harris Avenue, is a terminal with ferries that go to Alaska and the San Juan Islands. To the east of the cruise terminal is Fairhaven Station, the Amtrak train and Greyhound bus station. Further to the east is Padden Creek, which flows into Padden Creek Estuary.

To the south and east of the Site is Fairhaven Marine Park, a 1.9-acre waterfront park that is accessible to the public and used recreationally. The bank slope and intertidal sediments directly west of the Site are composed of riprap and cobbles, as shown in the Site photographs in Appendix A. Further south is the Post Point Wastewater Treatment Plant and Lagoon.

2.3.4 Stormwater Conveyance and Treatment Systems

The stormwater conveyance system is shown on Figure 2.4.

Puglia operates under an individual National Pollutant Discharge Elimination System (NPDES) Waste Discharge Permit (No. WA0031348), and has operational documents in place as part of environmental compliance. A stormwater emergency outfall, Outfall #3, located at the shipyard was plugged between 1994 and 1997, but was then extended with a diffuser and reactivated for emergency discharge. This outfall is connected to the Puglia water treatment system and is typically closed and locked. It is to be used only for emergency overflow purposes during large storm events and has not been used since it was reactivated. The outfall terminates just to the east of the dry dock ramp. Catch basins draining to this outfall historically were shared between the two site tenants. In 2004, stormwater drainage at the shipyard was reconfigured such that primary industrial areas of the Site (i.e., asphalt and concrete near the painting booths and the marine railway) are now collected and treated for discharge to the City's POTW.

The basis for the stormwater improvements is from the Engineering Report, *Stormwater Collection and Discharge System for Fairhaven Shipyard*, Bellingham, Washington (Hart Crowser 2004). This 2004 report was written as required by the NPDES permit to describe the design criteria for the stormwater collection and discharge system that discharges to the sanitary sewer. The report included the design for a future expansion of the stormwater collection system to involve the paved area of the marine railway area and sidetracks area. The expansion was subsequently constructed for the marine railway area in 2004. The Puglia stormwater treatment system has storage to hold stormwater from a 10-year, 24-hour storm event, and gravity settling prior to discharge to the sanitary sewer system.

Process water is managed separately from stormwater. Process water that is generated during hydroblasting or other industrial activities is treated with a chemical flocculant, agitated, settled, decanted, and filtrated prior to discharge to sanitary sewer. Any stormwater that comes in contact with process water is treated as process water.

Stormwater at the Puglia parcel is split between paved areas with a stormwater conveyance and treatment system, gravel areas that allow infiltration, the dry dock, submersible barge, the marine railway area, and areas that sheet flow to the Bay. Stormwater is managed as follows:

- When vessels are present and sandblasting, painting, or other industrial activities are occurring, stormwater and process water that falls on the dry dock and marine railway area is collected, conveyed to the Puglia water treatment system, treated, and then discharged to the sanitary sewer system. The stormwater from the dry dock and marine railway area drains to the Bay at other times.
- When vessels are present on the submersible barge and sandblasting, painting, or other industrial activities are occurring, stormwater is collected in on-board tanks, tested for copper, zinc, and lead, and then discharged directly to the sanitary sewer system if the stormwater meets the effluent requirements. Process water on the

submersible barge is collected separately from stormwater and treated by the Puglia water treatment system prior to discharge to sanitary sewer. The stormwater from the submersible barge drains to the Bay at other times.

- Stormwater that falls on the paved portions of the shipyard in the vicinity of Catch Basins CB-5 and CB-6 is conveyed to the stormwater treatment system where it is treated via settling prior to discharge to the sanitary sewer system. This includes stormwater that falls on the roofs of the hazmat storage area, the sandblast shed, and the spent sandblast grit storage area (refer to Figure 2.4).
- Stormwater and process water that falls on the vehicle washdown pad is treated with an oil/water separator and then discharged to the sanitary sewer.
- Stormwater that falls on the flat gravel areas of the shipyard infiltrates into the ground.
- Stormwater that falls on all other roofs in areas not discussed in the bullets above drains to gravel areas and infiltrates or sheet flows directly to the Bay.
- Stormwater that falls on a portion of the paved areas of the former Arrowac property is conveyed to the Bay through a stormwater outfall to the east of the main dock.
- Stormwater in some perimeter areas of the shipyard property sheet flows directly to the Bay.

Figure 2.4 shows the stormwater conveyance system, catch basins, approximate stormwater flow, infiltration areas, the gravel and paved areas of the Site, and identifies areas of the property that discharge directly to the Bay. Due to the flat topography of the Site and vicinity (as shown on Figure 1.3), stormwater that falls on adjacent parcels likely sheet flows away from the Site and not on or toward it.

Formerly, All American's operations were primarily indoors, and only minimal materials were stored outdoors. Because All American's fabrication was conducted indoors, Ecology did not require All American to have a stormwater discharge permit. As a result, All American received a NPDES Industrial Stormwater General Permit Conditional No Exposure Certification from Ecology. The Port is currently coordinating stormwater compliance and coverage in that area based on All American's departure.

Stormwater that falls on the former All American building, on the north half of the Fairhaven Shipyard maintenance and fabrication shop roof, and in the parking area located east of the former All American building, north of the Fairhaven Shipyard maintenance and fabrication shop and south of the sandblast shed on the Puglia parcel, drains to Catch Basins 1 through 4 and to three other catch basins that are not numbered (refer to Figure 2.4). These catch basins are part of a stormwater conveyance system that is managed by the Port. This stormwater is managed under the Port's NPDES Phase II Municipal Stormwater General Permit.

Stormwater that falls on the west side of the roof of the former All American building and in the gravel parking lot on the west side of the former All American building drains to one of four catch basins that run along the west side of the building. Stormwater from these catch basins discharges at a single outfall to the Bay located along the western portion of the shoreline, west of the former All American building. Stormwater discharge from the west side of the former All American building is covered under the Port's NPDES Phase II Municipal Stormwater General Permit. A smaller unused pipe lays immediately adjacent to and to the south of the outfall as illustrated in Photograph 14 of Appendix A. The history and use of this second pipe is not known and no discharge has been identified from this pipe.

2.3.5 Over-Water Operations and Aquatic Land Use

Current over-water shipyard activities are generally confined to the marine railway, submersible barge, dry dock, and pier areas on the north side of the Site. The submersible barge (the Faithful Servant) is currently moored at the northeast end of the Harris Avenue Pier. Source control requirements associated with operation of the Faithful Servant and the dry dock are documented in permits and have been evaluated as part of this RI/FS.

The Harris Avenue Pier was originally constructed in the 1950s and a concrete extension was built at the northern end of the pier in 1996. Since becoming a tenant at the Site, Puglia has repaired and maintained the Harris Avenue Pier, including installation of new timber decking, secured steel plates over decking, and repair/replacement of transverse diagonal bracers. At the time of initial RI development, the inner portion of the timber pile-supported Harris Avenue Pier was not in favorable condition and was known to require structural upgrades or replacement. This replacement activity was conducted as part of an Interim Action in 2017, and included removal and replacement of the wood portion of the pier in its original location.

The Carpenter Building and its supporting Pier were constructed circa 1942 by the Northwestern Shipbuilding Company to support the construction of naval vessels for the United States military during World War II. The name “Carpenter Building” likely references the building’s association with the production of primarily wood-hulled ships at the shipyard during this period. The two-story wood framed building was approximately 21,000 square feet, with a partial attic level at the north end of the building. The 54-foot by 156-foot building sat directly on the supporting pier (with the pier deck serving as its ground floor) and consisted of post and beam construction (BergerABAM 2014). In August 2014, a structural assessment was conducted by BergerABAM that evaluated the condition of the building and pier and identified the necessary building and pier structural improvements to be conducted. In 2017, the Carpenter Building and its supporting Pier were removed as part of an Interim Action and were not rebuilt.

2.4 TRIBAL USE AND AGREEMENTS

Within the Bay, two tribal groups, the Lummi Nation and Nooksack Tribe, have Usual and Accustomed (U&A) fishing rights (refer to Tribal land maps included in Appendix B). Lummi Nation and Nooksack Tribe U&A Fishing Areas include the offshore and shoreline areas of the Site.

Fishing resources for both tribes include salmon (migratory), resident finfish, and shellfish. Tribal and non-tribal commercial salmon fishing occurs throughout the Bay (Anchor 2000). Tribal fishing rights and practices are incorporated into determining appropriate CULs for evaluation of the Site in this RI/FS. Historical and cultural resources are discussed in further detail in Section 3.4.

2.5 PREVIOUS ENVIRONMENTAL INVESTIGATIONS

This section provides a summary of environmental investigations and actions that have been completed to date at the Site or adjacent to the shipyard. Upland and sediment investigations have been completed at the shipyard since approximately 1993 and have been documented in several reports prepared by Ecology, GeoEngineers, RETEC, and Floyd|Snider. Data from the previous investigations are summarized below. It should be noted that the results described below are described in relation to the SMS or MTCA CULs that were relevant at the time of the investigation. All of the results are compared to current screening levels and CULs in Sections 4.0 and 5.0, respectively. Relevant data tables from historical site investigations are included in Appendix C. Sample locations are shown on Figure 2.5.

2.5.1 Pre-1998 Sampling and Ecology Inspections

Limited sampling of upland soil and sediment was performed prior to the initial work by RETEC beginning in 1998, as described in the following paragraphs.

In March 1993, Ecology completed a Solid and Hazardous Waste Inspection and noted sandblast grit and stained soil near the sandblast shed, former joiner shop, marine railway, and sidetracks areas. Upland soil samples in visually contaminated areas were collected from shallow surface soil and had detections of metals, semivolatile organic compounds (SVOCs), PCBs, and TPH. Subtidal sediment samples were collected using a Van Veen sampler at an unspecified depth from the main shipyard area and exceeded SMS sediment quality standards (SQS) for one or more analytes. Phenol and PCBs were reported in exceedances of SMS criteria. Arsenic, copper, lead, and zinc were also reported in exceedance of the SMS criteria. TBT was detected in three samples (RETEC 2004). Because depth information is unavailable for these older samples, these are not considered further in the RI/FS.

In 1993, MCI, a former tenant, excavated an unknown amount of petroleum-contaminated soil from the marine railway area as an improvement action for stormwater control at the Site. Soil was tested and designated as non-hazardous, petroleum-contaminated soil.

In June 1996, GeoEngineers collected three sediment samples along the under-pier area of the Harris Avenue Pier as part of the pier-extension project (RETEC 2004). All samples were in compliance with the SMS sediment criteria. The sampling excluded analyses for organotins. Because depth information is unavailable for these older samples, these are also not considered further in the RI/FS.

2.5.2 RETEC Phase 2 Sampling of Sediments, August 1998

In 1998, Environmental Site Assessment Phase 2 sampling was performed in both upland and sediment areas of the Site to provide baseline information relative to a change in the leasehold at the property. The objective of the Phase 2 sediment sampling was to provide initial sediment characterization. Two primary areas were sampled, the Port PMA Parcel 5 area and the marine shipyard area. RETEC completed a site survey, diver video survey, and grab sampling at 23 locations using a hydraulic Van Veen sampler. Primary grab samples were analyzed for metals and PCBs, and secondary analyses were completed for SVOCs and organotins. SMS exceedances were reported in samples collected west of the loft and pier shops under the northern portion of the large dry dock. Samples were also collected from Port PMA Parcel 5 area west of the Site; however, no SMS SQS or minimum cleanup level (MCUL) exceedances were reported in those samples. Grab samples were collected around areas of debris. Five samples were analyzed for SVOCs. Eight grab samples were analyzed for organotins in porewater.

In addition to the grab samples, cores were advanced using a vibracore sampler at four locations in areas of known contamination to delineate vertical extent. Core samples were analyzed for metals, total organic carbon (TOC), and PCBs, with logs noting the presence of anthropogenic debris (RETEC 1998a).

2.5.3 RETEC Phase 2 Sampling of Soil and Groundwater, September 1998

In 1998, Environmental Site Assessment Phase 2 sampling was performed in both upland and sediment areas of the Site to provide baseline information relative to a change in the leasehold at the property. As part of the Phase 2 upland sampling completed in September 1998, RETEC installed five monitoring wells to define hydrogeologic properties at the facility including depth to groundwater, tidal influence on groundwater elevations, and hydraulic conductivity. Gasoline- and diesel-range hydrocarbons were detected in groundwater from a well located downgradient of the former AST at concentrations exceeding MTCA Method A CULs for TPH in groundwater (based on use as drinking water). Petroleum hydrocarbons were also detected in subsurface soil samples collected during the installation of this well. TPH was also detected in groundwater samples from two other wells but at concentrations less than the MTCA Method A CUL. Volatile organic compounds (VOCs) were generally not detected in any groundwater sample with the exception of toluene, ethylbenzene, xylenes, alkylbenzenes, and acetone in the well downgradient from the former AST, which was reported to be attributable to petroleum contamination. Dissolved metals were detected in several samples from monitoring wells. Concentrations of metals generally reflected natural background concentrations. Groundwater samples were reportedly very turbid as monitoring wells were not sampled using a low-flow sampling protocol.

Soil sampling confirmed that metals, petroleum hydrocarbons, and polycyclic aromatic hydrocarbon (PAH) compounds are present in subsurface soil at concentrations exceeding MTCA Method A CULs and, in some samples, exceeding MTCA Method C industrial CULs. Elevated concentrations of metals in shallow soils were attributable to sandblast grit and included anthropogenic debris. Petroleum hydrocarbons were detected at several locations, with the greatest concentration located in the northern area of the Site, including the former ASTs, marine railway, and northwestern corner uplands areas. In the area of the former ASTs and former joiner shop, PAH compounds are thought to be related to the hydrocarbon contamination in that area. Contamination in the area of the former joiner shop (south of the former AST in the location of the current paint shop) is reported to be derived from coal tars or treated-wood debris generated during shipbuilding activity prior to its demolition (RETEC 1998b).

2.5.4 RETEC Bioassay Testing, 2000, 2003, and 2004

Bioassay sampling was first conducted in 2000. Amphipod mortality, larval effective mortality, and juvenile polychaete tests were performed on sediment from two sample locations. For the amphipod mortality, both samples passed SQS and MCUL criteria. For the juvenile polychaete, no toxicity was measured, and the test passed SMS performance standards for growth and mortality. Based on quality control (QC) issues, a second round of larval tests was performed on the original two samples and three additional sample locations. Samples were slightly outside of the 8-week holding time and failed the reference sediment QC criteria. Sediment samples were again collected at the same locations and reference stations and analyzed for the larval bioassay test. In this third round of testing, all samples except for two showed statistical differences and MCUL failures when compared to the reference. The reference was slightly outside of the performance standard, but the control sample was acceptable (RETEC 2004).

In the fall of 2003, supplemental bioassay sediment toxicity tests at different sample locations located around the northern and western boundary of the Site were conducted to assess the survival of the amphipod *Ampelisca abdita,* the juvenile polychaete worm *Neanthes arenaceodentata*, and the larval development of the mussel *Mytilus galloprovincialis*. QC failures required a second round of sediment collection and bioassay testing conducted in late 2003 and early 2004. Porewater was centrifuged and analyzed for interstitial ammonia and total sulfides. Ammonia results were less than toxic concentrations and within the typical range for Puget Sound. Total sulfides ranged in concentrations up to 3,800 mg/kg. No correlation was noted between ammonia and total sulfides results and bioassay failures (RETEC 2004).

In initial bioassay tests conducted in September 2003, two of the sampling locations exhibited significantly decreased survival of *A. abdita* compared to the control. No adverse effects were observed in the growth or survival of juvenile polychaetes *N. arenaceodentata* or in the larval development of *M. galloprovincialis* in any sample relative to the control. Initial SMS SQS and MCUL biological criteria failure were attributable to QC failures; however, following a second round of sediment collection and additional bioassay testing in November 2003, all 2003 bioassay testing locations passed SMS biological effects criteria (RETEC 2004).

2.5.5 RETEC Working Draft Sediments RI/FS, May 2004 (amended January 2006)

The RETEC working Draft Sediments RI/FS (RETEC 2004) was completed for Ecology review in May 2004 and later amended in January 2006 (RETEC 2006) to include the findings of a supplemental sediment source control evaluation that was conducted in 2005. The supplemental source control evaluation addressed the intertidal sediments and adjacent upland marine railway area of the Site.

The updated working Draft Sediments RI/FS document was prepared for Ecology review; however, the public review process for this report was not completed, and the document was not formally approved by Ecology. All data collected during preparation of the working Draft Sediment RI/FS and supplementary sampling events are being evaluated as part of the RI/FS for development of the proposed site-wide remedial alternatives.

The working Draft Sediments RI/FS and supplemental sampling results concluded that the extent of surface and subsurface sediment contamination at the Site had been accurately delineated and sediment remediation unit boundaries were proposed as part of the remedial alternatives. The total volume of contaminated sediment was estimated at approximately 19,300 CY, including provisions for a 1-foot overdredge allowance. Remedial technologies and cleanup alternatives were evaluated consistent with MTCA and SMS criteria (at that time). The preferred remedial alternative presented in the draft document included dredging in accessible areas with Puget Sound Dredged Disposal Analysis (PSDDA) open water or upland disposal, capping in inaccessible areas (under-pier areas and the marine railway), and beneficial reuse of dredged material, as applicable. The revised preferred alternative in 2006 also proposed limited removal of exposed intertidal sediments in the marine railway area.

Principal investigation tasks involved the collection of additional chemical data in the under-pier area, dry dock, and other areas with inadequate data to determine compliance with SMS criteria. Confirmatory biological testing on surface sediment was conducted in areas that exceeded SMS criteria for samples collected in 2000. Bioassay testing was not completed in areas where PCB concentrations were less than the SMS PCB criteria of 12 parts per million TOC. Human health and ecological risk assessments for PCBs were also conducted at the Site. The evaluation concluded that the proposed PCB CUL would not adversely affect ecological receptors.

Core samples were also collected to define the depth and thickness of contaminated sediments at the Site. Sediment deposition patterns were assessed using radioisotope profiles of cesium-137 (Cs-137). Physical parameters (grain size, specific gravity, compressibility, etc.) were also analyzed to support the engineering analysis of the alternatives.

Additional core samples were collected in February 2004 as part of an effort to characterize sediment suitability for disposal at an open water disposal site. This program was completed in accordance with the PSDDA program and the Dredged Material Management Program (DMMP). Regulatory agencies provided preliminary approval for disposal of approximately 12,000 CY of dredged sediment from the Site at an open water disposal location in July 2006 and this disposal option was incorporated into the preferred remedial alternative recommended in the working Draft Sediments RI/FS.

2.5.6 RETEC Uplands Source Control Sampling, August 2005

The RETEC working Draft Sediments RI/FS was completed for Ecology review in 2006 and incorporated results of supplemental uplands source control sampling performed in August 2005. As part of this investigation, soil samples were collected from borings located adjacent to the marine railway area, a known area of contamination with elevated metals and TPH. In addition to upland soils, intertidal sediments and sediments under the paved area of the marine railway area were analyzed for site contaminants. Groundwater collected from a well located upgradient of the nearshore area was analyzed for total and dissolved metals, diesel- and motor oil-range hydrocarbons, PAHs, and PCBs. Intertidal and upland soil samples were analyzed for VOCs, PCBs, SVOCs, TBT, metals, TPH including diesel- and motor oil-range hydrocarbons and gasoline, and TOC. The well located upgradient of the nearshore area had no detections for PAHs, PCBs, or hydrocarbons. Dissolved metals were not detected or were much less than the applicable CULs.

Petroleum hydrocarbons were detected in sediment beneath the paved marine railway area and in adjacent uplands near the former AST. Concentrations of diesel-range TPH below the paved area of the marine railway area were up to 6,300 mg/kg (at 2 to 4 feet). Gasoline-range hydrocarbons were detected (up to 310 mg/kg).[3] Several PAHs, including low molecular weight PAHs (LPAHs; up to 454 mg/kg) and high molecular weight PAHs (HPAHs; up to 3,172 mg/kg), exceeded SMS SQS.

An upland soil sample between the marine railway area and the former AST contained petroleum hydrocarbons, PAHs, and low-level gasoline-range hydrocarbons contamination that appear to increase in concentration with depth, which was consistent with previous RETEC investigations.

Heavy metals, including copper (up to 2,620 mg/kg), lead (up to 942 mg/kg), zinc (up to 3,960 mg/kg), mercury (up to 26.2 mg/kg), arsenic (up to 340 mg/kg), and cadmium (up to 7.2 mg/kg) were all detected at concentrations exceeding SMS SQS values under the paved portion of the marine railway at location S-2 (collected from a depth of 0 to 2 feet bgs). All metal concentrations were less than the SMS SQS values in the nearby intertidal sediment samples at S-1 (also 0 to 2 feet bgs). Uplands samples had elevated detections of copper, mercury, and zinc, which was consistent with previous Ecology and RETEC investigations and is thought to be due to the presence of sandblast grit.

TBT analytical results were compared to the former PSDDA program screening level of 0.073 mg/kg. TBT was detected under the paved area of the marine railway (up to 6.2 mg/kg) and in both intertidal samples (up to 3 mg/kg). TBT appears to be localized to this area.

SVOCs were not detected at concentrations greater than SMS values in two intertidal sediment samples. PCBs were not detected in intertidal sediment samples but were detected in two shallow upland samples (up to 37 mg/kg total PCBs). VOCs were not detected at concentrations greater than CULs in any sample in the intertidal and uplands areas. RETEC indicated that VOCs do not appear to be significant contaminants for the Site.

2.5.7 Floyd|Snider Supplemental Site Investigation, March 2011

Following the decision by the Port and Ecology to conduct the Site-Wide RI/FS, an RI/FS Work Plan was developed by Floyd|Snider (Floyd|Snider 2011a), which included implementing a

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[3] The gasoline-range hydrocarbons detected at low concentrations in soil and sediment in the marine railway are consistent with the low-boiling end of diesel and do not indicate a gasoline release on-site.

SSI in March 2011 to gather additional data to further characterize upland site conditions, address the upland and sediment data gaps, and better define the preliminary site-wide CSM. The SSI upland investigation included soil and groundwater sample collection and analysis, and installation of additional groundwater monitoring wells. To address data gaps in marine sediments, bank/intertidal and nearshore surface sediment samples were collected to evaluate potential uplands and shoreline transport pathways to sediments, as well as to evaluate source control. The results of the SSI and all the historical data were summarized in the RI/FS Data Report (Floyd|Snider 2011b).

In the upland area, 22 soil borings were advanced via Geoprobe to further define the extent and depth of known and potentially unknown COPCs. Boring locations were determined based on interpretation and evaluation of existing analytical data, as well as recorded field conditions and site access. Additional step-out borings were completed in select locations to define vertical and horizontal extent of contamination. Select soil samples were also collected during monitoring well installation.

During installation of Monitoring Well MW-09, heavy sheen and odor was observed at approximately 3.5 feet bgs. In order to assess if any vapor risk exists on-site, a soil gas sample was collected next to MW-09 at 3.5 feet bgs. To collect the sample, a probe point was advanced via Geoprobe down to 3.5 feet bgs and the soil gas was evacuated through Teflon tubing into a Summa canister. Results were non-detect for all TPH target analytes (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]) and the C_9–C_{10} aromatic hydrocarbon ranges. There were detections of the C_5–C_8 aliphatic hydrocarbon ranges and the C_9–C_{12} aliphatic hydrocarbon ranges, with 86,000 and 36,000 micrograms per cubic meter, respectively.

Metals and TPH were previously identified along the shoreline area from the loft and pier shops to the area extending east beyond the dry dock; however, prior to the SSI, the full extent of TPH and metals had not been determined in this area and groundwater conditions had not been established along the shoreline. To fill data gaps in this area, nine soil borings (FS-01 through FS-09) were advanced to delineate the full extent of TPH and metals in soil. Four new monitoring wells (MW-02A and MW-06 through MW-08) were also installed in this area to identify COPCs in groundwater.

The SSI identified a previously unknown source of TPH and naphthalene surrounding FS-09 and surrounding step-out borings. A creosote (or similar) treated piling was found during drilling when the Geoprobe casing drilled vertically down through the piling. The analytical results from samples taken directly from the soil in surrounding step-out locations identified carcinogenic polycyclic aromatic hydrocarbons (cPAHs), naphthalene, and heavy diesel-range TPH in concentrations exceeding site screening criteria in soil ranging from 8 to 9.5 feet bgs.

FS-01, located on the eastern end of the northern shoreline area, had exceedances of site screening criteria for SVOCs and diesel-, oil-, and gasoline-range TPH in soil ranging from 14 to 25 feet bgs.

Moving west along the shoreline, a TPH detection exceeding MTCA Method A site screening criterion was found in soils sampled during installation of MW-02A. Specifically, gasoline-, diesel-and-oil-range TPH all exceeded site screening criteria in depths ranging from 1 to 7.5 feet bgs. The concentrations found in this well were expected, as this was a replacement for Monitoring Well MW-2, located approximately 25 feet west of MW-02A. The results for MW-02A are similar to MW-2, with significant diesel-range TPH down to 7.5 feet bgs.

The SSI did not identify any new areas with significant metals concentrations and the results are consistent with those seen in previous investigations (metals, primarily arsenic, and, to a lesser extent, copper and zinc, exist in the top 2 feet of surface soils, with contamination down to 4 feet in some locations).

The groundwater monitoring wells installed during the SSI provided additional data to the existing groundwater dataset and confirmed areas with known or suspected exceedances of site screening criteria. In general, groundwater exceedances of site screening criteria in the northern shoreline area are primarily limited to dissolved arsenic and diesel-range TPH. Dissolved arsenic exceeded its site screening criterion at all sampled shoreline wells, and TPH was found on the eastern portion of the Site at MW-1 and MW-06 in concentrations exceeding site screening criteria.

A more detailed description of the findings is included in the RI/FS Data Report and a detailed evaluation of the findings of the SSI is included in Sections 4.0 and 5.0 of this document.

2.6 DATA GAPS INVESTIGATION 2013

Floyd|Snider completed a DGI in February 2013 to fill data gaps identified as part of the SSI work and to collect upland and in-water data to further define nature and extent of known COCs for completion of the RI/FS. The scope of work primarily included upland sampling for petroleum hydrocarbon contamination associated with the former UST area and to assess the potential for contaminant mobility in the shoreline area and northeast corner of the study area. Nearshore and intertidal sediment sampling was completed to further define extent of contamination in the shoreline area and assess potential contaminant migration from the upland area. Sediment sampling occurred in close proximity to locations that previously exceeded SMS criteria for metals, in the eastern boundary of the study area, and where data were not previously collected. In addition, geological and hydrogeological subsurface conditions were assessed for calculating site-specific CULs. The sampling methodology and protocols are discussed in further detail in Appendix D and the findings are incorporated into this RI/FS.

2.7 PRE-INTERIM ACTION CHARACTERIZATION

Prior to the implementation of the Interim Action, Floyd|Snider conducted an investigation in February 2015 to collect additional soil, groundwater, and sediment chemistry and physical data to enable design of the Interim Action in the uplands and in the sediments. Details of the investigation activities are included in the Proposed Interim Action SAP/QAPP (Floyd|Snider 2015b) and the findings are incorporated into this RI/FS and the Interim Action Basis of Design Report (Floyd|Snider 2017).

2.7.1 Uplands Pre-Interim Action Investigation

The uplands area of the proposed Interim Action was investigated by analyzing soil samples from nineteen borings (FS-24 to FS-42) on an approximately 25-foot grid. The locations and sampling depths were used to provide a comprehensive set of data in order to define the lateral and vertical extent of the excavation completed during the Interim Action activities. In addition, two monitoring wells (MW-11 and MW-12) were installed in the shoreline area to fill data gaps identified as part of data assessment with Ecology after submittal of the agency review draft of the R/FS. Boring and monitoring well locations are shown on Figure 2.5.

Fifteen borings, FS-24 to FS-38, were advanced to depths up to approximately 4 feet bgs to delineate metals contamination in surface soils. Samples were collected across the following depth intervals: 0 to 1 foot, 1 to 2 feet, 2 to 3 feet, and 3 to 4 feet. Samples from the upper 3 feet were analyzed and the samples from the 3- to 4-foot depth were archived and analyzed if the overlying sample interval contained concentrations of metals greater than CULs.

Four borings, FS-39 to FS-42, were located in the area of the former ASTs and soil samples were collected to depths up to 12 feet to further delineate TPH contamination. Due to the tidal fluctuations, the depth to the water table varies with the daily tides and creates a smear zone that is approximately 4 to 6 feet thick near the shoreline. To determine the depth interval where the greatest concentrations are within the smear zone, samples were collected across the following depths, spanning the smear zone: the 1-foot interval above the water table, the upper 1-foot interval at the water table, the lower 1- foot interval at the water table, and the 1-foot interval below the water table.

Two monitoring wells, MW-11 and MW-12, were installed down to 15 feet bgs in accordance with Ecology's request to complete the shoreline monitoring well network. Groundwater monitoring was conducted quarterly for 1 year (four events) at these new wells and all perimeter monitoring wells were sampled during 2015. Results for the 2015 quarterly groundwater monitoring are discussed in Section 5.3.

2.7.2 Sediments Pre-Interim Action Investigation

The sediments investigation consisted of the advancement of 23 sediment cores using a vibracore, three surface grab samples using a power grab sampler, and three intertidal sediment samples using a hand auger. Locations were located throughout the proposed Interim Action area to delineate the final depths of contamination within the Interim Action area and to determine the chemical nature to the east of the sediment AOC. The analytical results were used to provide a comprehensive set of data that would supplement the existing analytical data to determine the final dredge depths and extents for the Interim Action, as discussed in the Interim Action Basis of Design Report (Floyd|Snider 2017).

For the sediment cores, samples were collected from the following depth intervals: 0 to 12 centimeters (cm; 0.4 feet), 1 to 2 feet, 2 to 3 feet, 3 to 4 feet, 4 to 5 feet, and 5 to 6 feet. For areas with known contamination, samples from 1 to 2 and 2 to 3 feet were analyzed and remaining depth intervals up to 6 feet were archived and only analyzed if the overlying sample interval contained concentrations of chemicals greater than the appropriate CULs or RALs. Additionally, in areas where there was no surface data or the data were old (i.e., greater than 10 years old), the 0- to 12-cm samples were analyzed. For the surface samples collected with a power grab sampler, sediment samples were collected from the 0- to 12-cm depth interval.

In the intertidal sediment area, three hand auger locations were advanced to a depth of 4 feet bgs. Samples from 1 to 2 and 2 to 3 feet were analyzed and the remaining interval from 3 to 4 feet was analyzed if the overlying sample interval contained concentrations of chemicals was greater than the appropriate CULs or RALs.

2.8 INTERIM ACTION CONFIRMATIONAL SAMPLING

Following implementation of the Interim Action in the uplands and sediments, confirmation samples were collected in accordance with the Confirmational Sampling Plan (Appendix E of the Interim Action Basis of Design Report). Sample results will be reported in the Interim Action Completion Report, anticipated to be submitted to Ecology in the fall of 2018.

3.0 Environmental Setting

This section provides a description of the physical environment at the Site that is derived from the historical and current investigations including geology, hydrogeology, marine environment, sea-level rise, substrate types present near the shoreline, and historical and archaeological cultural resources.

3.1 PHYSICAL ENVIRONMENT AND AQUATIC SETTING

3.1.1 Site Shoreline and Bathymetry

The Site is located in Bellingham, Washington and is surrounded to the north and west by the Bay. The Site area is low and flat, with an elevation less than 20 feet above the Mean Lower Low Water (MLLW) datum. Tidal elevations can rise to +7.5 feet MLLW during extreme tides (refer to Section 3.1.3). The upper shoreline is armored with riprap and there are concrete block bulkheads on the north side of the property. Most of the upland area is covered with gravel; however, there is some asphalt and concrete in the area of the painting booths and near the uplands portion of the marine railway structure as a result of recent stormwater management site upgrades in 2004. The shoreline slopes are generally steep and reinforced with armor material (engineered riprap slopes and concrete block bulkheads). The intertidal area north of the Site consists of larger gravel and sand mixture material. The intertidal area west of the Site consists of large cobbles. Mudline elevations in the aquatic site area range from approximate elevations 0 to -45 feet MLLW. The top of bank, armored slopes, and cobbled beach are shown in Figure 1.2.

The majority of the shoreline at the Site is armored with either an engineered riprap slope or concrete block bulkheads that are designed to prevent erosion of uplands soils to the sediments.

Over-water and in-water site feature structures include the Harris Avenue Pier, which houses the loft and pier shops; several smaller docks; one dry dock; and the in-water portion of the marine railway as shown on Figure 1.2. The marine railway extends approximately 200 feet to the north from the shoreline, is timber pile-supported, and is generally slightly elevated above the mudline except on the upland portion of the Site. Over the years a number of pile-supported structures were built on-site including a wooden bulkhead, as discussed in Section 2.2. Depending on the year of installation, some of these subsurface wooden support structures were creosote-treated. Subsurface work at the Site may encounter some of these structures; few drawings exist to locate them accurately on maps.

For the majority of the main shipyard (Port Tenant Parcels A and D and the western portion of Port PMA Parcel 6) and Port PMA Parcel 5 area, sediment surface elevations slope away from the shoreline (at approximate elevation 0 feet MLLW) to bottom elevations ranging from -30 to -35 feet MLLW at the middle of the Harris Avenue Pier. Slope grades in these areas range from 3H:1V at the steepest to as shallow as 12H:1V with shallow slopes generally located at the north end of the Site. Some eelgrass beds are present in a shallow offshore area at the southern end of Port PMA Parcel 5 (refer to Figure 2.3).

Sources of new nearshore sediments are limited in the area. There are no significant streams, rivers, or bluffs adjacent to the Site contributing to sediment deposition. Padden Creek is located east of the Site in Fairhaven, but is not a source of infill to the sediments in the vicinity of the Site.

The sediment bathymetry contours around the existing dry dock are irregular compared to the general shipyard area. As documented in the investigation reports prepared by RETEC and in

Port files, dredging was completed in 1982 in the area of the southern footprint of the existing dry dock to achieve required water depths to accommodate the structure. The footprint of this dredging event is still evident in the bathymetry data shown on Figure 1.2, which are from the 1998 RETEC documents. A more recent bathymetric survey was conducted in 2011 as part of the study related to improvements of the Harris Avenue Pier. However, the bathymetric survey is not comprehensive and does not extend to the dry dock or the portion of the Bay that is west of the Site. Although the 2011 bathymetry is similar to the 1998 bathymetry, there were differences that made it unfeasible to combine the two surveys, and the 1998 bathymetry is used in the RI sections of this document. The 2011 bathymetry is used to evaluate remedial alternatives in the FS.

General sediment stratigraphy within the study area consists of a mixture of silt and sand to an approximate depth of 5 feet below the mudline. Sediment core logs are included in Appendix E. The underlying layer consists mainly of sand and gravel and provides a firm bottom beneath the upper recent sediment deposits. Gravelly material is also present near the sediment surface in the previously dredged area at the existing dry dock and Harris Avenue Pier. Silty sediment was present in the southern portion of Port PMA Parcel 5 (Figure 2.3), in the vicinity of the eelgrass beds.

For the purpose of this RI/FS and based on information provided by Ecology, an estimate of potential sea-level rise in the Bay by 2100 is currently assumed to be up to approximately 2.4 feet above current mean sea level, with a low probability of a very high potential sea level rise of 4.16 feet (provided in a January 2008 report by the University of Washington and Ecology). This potential sea level rise is consistent with the evaluation documented in the Waterfront District Redevelopment Environmental Impact Statement (EIS; Port of Bellingham 2012) and the draft Engineering Design Report (EDR) for Whatcom Waterway (Anchor QEA 2013). While marine facilities typically are designed to operate at current sea level conditions, sea level rise has been considered during the RI/FS process.

3.1.2 Aquatic Setting and Surface Water Features

3.1.2.1 Salish Sea

The Site is located on the Bay, a marine water body that is part of the Salish Sea. Approximately 20 percent of the Site was a glacial ridge that extended into the Bay and was regraded to its current elevations in the late 1890s. As discussed in Section 3.2.2, the other 80 percent of the Site consists of filled lands, and much of the land on either side of the Site was filled in the late 1890s and early 1900s (HRA 2011a).

The Bay is located within the Puget Sound-Georgia Basin watershed, which is now officially designated as the Salish Sea. The Salish Sea is a network of coastal waterways that extends from the north end of the Strait of Georgia and Desolation Sound to the south end of Puget Sound and west to the mouth of the Strait of Juan de Fuca, including the inland marine waters of southern British Columbia, Canada, and northern Washington, USA. These separately named bodies of water form a single estuarine ecosystem (DNR 2013).

The Salish Sea is connected to the Pacific Ocean primarily via the Strait of Juan de Fuca, with only modest tidal influence from Johnstone Strait north of Vancouver Island (WWU 2013). The Bay lies just north of where the Strait of Juan de Fuca brings marine waters into the Salish Sea system. This location, in combination with the sheltered harbor of the Bay, makes Bellingham one of the major port cities on the Salish Sea (WWU 2013).

3.1.2.2 Other Surface Water Features

To the east of the Site are Padden Creek and the Padden Creek estuary. The Padden Creek watershed drains approximately 3,830 acres on the south end of Bellingham and includes the sub-basins of Lake Padden and Connelly Creek. Elevation ranges from sea level to 985 feet. The lower portion of Padden Creek meanders 2.9 miles from Lake Padden through residential development and city parks to the Bay. In 1982, approximately 2,300 feet of Padden Creek between 22nd Street and Fairhaven Marine Park was straightened and buried into a culvert to allow for railroad construction (Whatcom County 2014). In 2015, the City of Bellingham and Washington State Department of Transportation daylighted Padden Creek by removing it from the culvert and placing it back into a natural streambed to allow for fish passage of salmonids.

To the south of the Site is the Post Point Wastewater Treatment Plant and Lagoon. Post Point Lagoon is a 3-acre saltwater embayment adjacent to the Post Point Wastewater Treatment Plant. The Lagoon is surrounded by City of Bellingham property on three sides and connected to the Bay through a narrow tidal channel that passes under the BNSF Railway trestle. Post Point Lagoon was created during the 1930s when BNSF Railway predecessors constructed a stone causeway replacing a lengthy trestle across a shallow cover of the Bay. During the 1960s and 1970s, the City of Bellingham purchased much of the surrounding property and much of the Lagoon was filled in as part of the construction of the Post Point Wastewater Treatment Plant (City of Bellingham 2005).

Post Point Lagoon is one of seven remaining pocket estuaries in the Bay that provide a habitat featuring eelgrass beds, saltwater marsh with pickleweed, terrestrial vegetation, and large woody debris. Post Point Lagoon also provides habitat for Chinook salmon, bull trout, and steelhead and supports the only Great Blue Heron colony within the City of Bellingham. Restoration work was completed in 2008 to improve shoreline riparian, upper intertidal salt marsh, and the intertidal mud flat. Elements of the restoration included placement of large woody debris, removing fill from the shoreline, increasing the shoreline length and saltmarsh area, re-establishing native riparian shoreline buffer and restricting access to upland areas to protect native vegetation and habitat.

3.1.3 Bellingham Bay Tides and Currents

The Bay's tides are generally mixed and semidiurnal tidal cycles that are created by the modest overall elevation fluctuations of the Salish Sea. The mean tidal elevation is 3.4 feet MLLW and has a range of 5.44 feet.[4] Typical tidal elevations range from 0.6 feet to 6.0 feet MLLW. During spring tides, the higher high and the lower low occur consecutively, causing a range of 8.51 feet in the same tidal cycle. The low and high tide elevations during this period range between 0.8 to 7.5 feet MLLW. During neap tides, the lower high and higher low occurs consecutively, causing little fluctuation in tidal range (NOAA 2013).

As part of a hydrodynamic and transport model in April 2010, current velocity was recorded at four stations, two inside the Bay (Stations C1 [approximately 4 miles from the Site] and C2 [approximately 1.8 miles from the Site]) and outside the Bay located in the channel between Lummi Island and Lummi Peninsula (Stations C3 and C4), to assess tidal current velocity (PNNL 2010). Tidal current data indicate that currents inside the Bay are much smaller in magnitude compared to the stations outside of the Bay. Both model predictions and field observations indicate no clear tidal signals in velocities inside the Bay, likely caused by the presence of nearby islands at the mouth of the Bay that dissipate the tidal energy as tides come

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[4] It should be noted that these tidal fluctuations are less than those in Puget Sound to the south, where fluctuations of 11 to 12 feet are common (NOAA 2013).

into the Bay. Variations in observed velocities and modeled data were influenced by other factors, such as local winds, and not dominated by tidal constituents. In general, the tidal current velocity during an ebb, low, and high tide is approximately 0.98 feet per second (0.3 meters per second [m/s]) as compared to velocities greater than 6.5 feet per second (2.0 m/s) outside of the Bay. The strongest tidal current velocities occur in channels outside of the Bay (PNNL 2010).

River inflow from the Nooksack River, the major river emptying into the Bay, is continuously gauged by the U.S. Geological Survey (USGS) at Gauge Station 12213100 (USGS 2013). The mouth of the Nooksack River is located approximately 4.5 miles across the Bay north-northwest of the site. The average discharge rate is 3,853 cubic feet per second. Based on the data available and results of the predicted model, it is unlikely that the shipyard tidal current is influenced by inflow from the Nooksack River due to distance from the shipyard. In addition, at the mouth of smaller sloughs and estuaries where Squalicum, Whatcom, and Padden Creeks discharge into the Bay, there are much lower inflow rates than the Nooksack River. Circulation and water quality appear to be influenced only at the discharge points into the Bay. Therefore, the Nooksack River and smaller creeks are unlikely to have an impact on the shipyard (PNNL 2010).

Both model results and observed data indicated that, while water surface elevations inside the Bay are highly correlated to tides, velocities inside the Bay are not dominated by tidal forcing, and local factors such as wind and freshwater inflow from rivers could have an influence on water circulation (PNNL 2010) at the point of discharge into the Bay and not at the shipyard. In addition to the Pacific Northwest National Laboratory document for supporting data, the Coastal Evaluation in the February 2013 draft EDR for the Whatcom Waterway (Anchor QEA 2013) was reviewed for information regarding bay tides and currents. This study appears to be consistent with the Pacific Northwest National Laboratory (PNNL) model with regard to water surface elevations by tidal action and wind action. Flow velocities in Whatcom Waterway were simulated for the condition of a combined tidal series of neap to spring tides and 100-year storm discharge. The peak flow rate from Whatcom Waterway was consistent with National Oceanic and Atmospheric Administration (NOAA) and PNNL data. In addition, the outer waterway tidal bottom velocities in this area were near zero and the bottom velocity from a 100-year wave event was 0.6 feet per second (0.18 m/s).

Site specific data assessed by Reid Middleton indicated that tidal current speeds of 1.7 feet per second (0.5 m/s) at the Site are unlikely to cause significant erosion of mixed gravel marine sediments in the area and in deeper water offshore (Reid Middleton 2008).

3.1.4 Wave Conditions

As part of the Coastal Evaluation for the Proposed Dry Dock for the Site, Reid Middleton analyzed wind-wave conditions for the southwesterly and northerly winds over approximately 4 miles of fetch to the southwest and approximately 2.2 miles of fetch to the north using the Coastal Engineering Design and Analysis System (CEDAS) Automated Coastal Engineering System (ACES) module to predict wave height and duration at the Site. The study indicated that over 85 percent of the time wind conditions at the Site are calm (less than 4 miles per hour [mph]) or from a direction that does not generate wave conditions. Northerly wind events (45 mph sustained for an hour) occur approximately 9 percent of the time and southwesterly wind events (52 mph sustained for an hour) occur approximately 4 percent of the time (Reid Middleton 2008). The southwesterly wind condition had an average wave height of 6.1 feet for 4.0 seconds and a wave length of 83 feet. The northerly wind condition had an average wave height of 4.4 feet for 3.3 seconds and a wave length of 55 feet. Additionally, the Site is exposed to wakes from Bellingham and Alaska Ferry traffic, which produces less significant waves that typically have longer wave periods up to 5 to 6 seconds in duration. Sediment transport is localized due to limited sources of input. Some increased scour of areas during southwesterly storm events were noted as being a possibility due to increased wave conditions.

3.1.5 Seismic Hazards and Tsunami Risk

The City of Bellingham has developed maps of geologically hazardous areas that are subject to severe risk of ground shaking, rupture, soil liquefaction, and tsunamis. The general seismic hazards map indicates that the shipyard area is mapped as a very high seismic hazard area due to the presence of fill (City of Bellingham 2012). While the shipyard is in a very high seismic hazard area, the shoreline and bank are well established and unchanged since the last significant fill event in 1937. Additionally, much of the fill encountered on-site during drilling appears to be sandy glacial materials with gravel, consistent with the re-grading of the glacial ridge in the late 1890s. Three significant earthquakes have occurred in the Puget Sound region in recorded history. These include a magnitude 7.1 on April 13, 1949, a magnitude 6.5 on April 29, 1965, and most recently the Nisqually earthquake, a magnitude 6.8 on February 28, 2001 (USGS 2014). The shoreline area of the shipyard and associated infrastructure and piers appear to be unaffected by past seismic activity in Puget Sound and have not changed since the last significant fill event in 1937. Historical aerial and oblique photographs are included in Figure 2.2.

A large tsunami could be generated by a large earthquake or submarine landslide in the Pacific Ocean basin. The DNR Division of Geology and Earth Resources and NOAA completed a tsunami inundation model for the Bellingham area based on a Cascadia Subduction Zone Earthquake (Walsh et al. 2004), utilizing the Method of Splitting Tsunamis model, which is the current technology for modeling tsunamis. The model is based on a computer model of waves generated by a scenario earthquake of magnitude 9.1. This earthquake scenario adopted by the study was developed by Priest and others (Priest 1997) and has been the basis for tsunami inundation modeling for tsunami hazard mapping of the Bellingham area (Walsh et al. 2004).

The Waterfront District Redevelopment EIS and Coastal Evaluation in the draft EDR for Whatcom Waterway evaluated tsunami risk utilizing this model. The evaluation indicated that the upland areas surrounding the waterway are predicted to be inundated from 0 to 1.5 feet (0.5 meters) during the modeled tsunami event and was conservatively assumed to occur during a high tide of approximately +9 feet MLLW. As is true of tidal currents, the presence of the San Juan Islands at the mouth of the Bay and the sheltered nature of the Bay would act to dampen the potential impact of a tsunami on the Site.

3.2 GEOLOGY AND HYDROGEOLOGY

3.2.1 Regional Geology

The Site is situated in the Puget Sound Basin, west of the North Cascades mountain range and east of the Cascadia Subduction Zone. Uplands geology in this area is predominantly influenced by quaternary Vashon glaciation, with till and outwash deposited during the retreat of the Cordilleran ice sheet present in varying thicknesses throughout the region. Along the shoreline of the Bay, landslide deposits of gravel, sand, and silt, as well as marine sand deposits, commonly overlie these glacial deposits, as well. The till and outwash are underlain by the Padden Member of the Chuckanut Formation, which was formed by debris deposition in a strike-slip pull-apart basin during the Eocene period. The Padden Member consists of sandstone and conglomerate alternating with mudstone and coal deposits, and has been estimated to be up to 8,800 feet thick. Below the Padden Member are metamorphosed volcanic rocks associated with the formation of the North Cascades.

3.2.2 Site Geology

As summarized in Section 2.2, Commercial Point was formed beginning in 1899 when Deadman's Bluff, a 60-foot-tall bluff near the City of Fairhaven waterfront, was removed over a number of years by being hydraulically sluiced to fill in the adjacent tidelands (HRA 2011a [Courtney 1950:70, 72; Van Miert 2004:233]). The original bluff was a ridge of glacial outwash and till. After sluicing, the ridge was reduced from 60 feet to a generally flat area approximately 20 feet above sea level (HRA 2011a).

Approximately 20 percent of the Site exists on this flattened glacial ridge. Figure 2.1 shows the shoreline of the ridge before it was regraded. The regrading is believed to have moved almost half of the mass of the ridge to create new land; however, no map has been found to show the post-grading shoreline configuration. The rest of the Site was created in the 1930s by placing up to 15 feet of hydraulically dredged sediments along the western and northern edge of the current Site. Unfortunately, it is difficult to distinguish between the original glacial ridge material, the glacial fill from the regrading, and the hydraulic fill from the adjacent shoreline (which received some of the glacial ridge material during regrading). The presence of shell fragments in the subsurface in the western and northern extent of the shipyard is generally taken to indicate fill from the hydraulic dredging event. If so, in these areas, the fill may be up to 15 feet in thickness.

Test pit, soil boring, and monitoring well data collected during the Phase 2 Soil and Groundwater Investigation (RETEC 1998b), the Floyd|Snider SSI (Floyd|Snider 2011b), and the Floyd|Snider DGI summary (Appendix D), indicated that beneath surficial gravel and asphalt the subsurface consists of sands with silts and gravels to the depth of most borings (15 to 25 feet bgs). A few deeper borings in the area encountered glacial till. Logs of all soil borings, test pits, and monitoring wells are included in Appendix E.

In general, the majority of the soil borings indicated the subsurface was sandy with low to moderate amounts of gravels, grading to a silty sand (with gravel) at depth. The current interpretation is that silts would be present in the undisturbed sections of the glacial ridge and in the hydraulic fill, but that the regrading (using hydraulic pressure) in the late 1890s could have left behind a reworked surface that was low in fine grained material. Additionally, fill sands contained shells and were often hard to distinguish from undisturbed beach deposits. In general, anthropogenic debris, when encountered, was present only in the upper 2 feet of the Site.

During the DGI, a deeper soil boring, FS-20, was advanced to a depth of 40 feet bgs (approximately -20 feet MLLW) in the approximate center of the study area in order to better understand deeper geology. Deeper soils in that boring are similar to native soils found at shallower depths. Additionally, in 2011, GeoEngineers advanced borings, B-1 and B-2, in the shoreline and intertidal area in close proximity to the loft and pier shops for geotechnical purposes. Boring B-1 was advanced to -64.5 feet MLLW and Boring B-2 was advanced to -41 feet MLLW. Below fill, native silty sands were consistent with other nearby shallow borings completed by Floyd|Snider. Glacial till was encountered at approximately -20 feet MLLW.

Figure 3.1 presents a representative cross-section along the eastern edge of the Site. The current interpretation of the geology is that the cross-section is running along the regraded ridge from Monitoring Well MW-05 to approximately Boring FS-13. At Boring B-13, shells are first encountered at an elevation that would be consistent with an intertidal beach along the edge of the ridge. Beyond this point, the Site is likely constructed on approximately 15 feet of fill (both from the regrading and the filling with marine sediments on top of a layer of glacial deposits [the underwater extension of the ridge]), and then a glacial till layer at depths of greater than -20 feet MLLW.

3.2.3 Hydrogeologic Conditions

Based on the boring logs, groundwater is first observed within sandy soils at depths ranging between 8 and 11 feet bgs and saturated soils were observed to depths of 40 feet bgs (the deepest soil boring advanced within the study area) without evidence of an aquitard. For consistency throughout this document, the demarcation between the saturated and unsaturated zone is 8 feet bgs.

Shallow groundwater appears to be unconfined and, based on potentiometric maps produced in February 2015 and August 2015 (as shown on Figures 3.2 and 3.3), flows in a northwesterly direction toward the Bay. Groundwater is tidally influenced with variable degrees of influence depending on well location relative to the shoreline, as discussed below. A summary of water level measurements collected during these events are included on Table 3.1. A summary of monitoring well and boring installation details are summarized in Tables 3.2 and 3.3, respectively.

Hydraulic gradients were determined based on measurements collected in February 2015 and August 2015. During both events, the horizontal gradient in the southeastern portion of the Site was consistent, ranging from 0.018 to 0.0033 feet per feet in a northwesterly direction. As groundwater approaches the shoreline, mounding of groundwater was observed in the northwestern portion of the Site around Monitoring Wells MW-02A and MW-07. This effect is shown on Figures 3.2 and 3.3. The water level in the Bay at the time of sampling is indicated on Figures 3.2 and 3.3, as recorded from NOAA's Cherry Point Station 9449424.

The remnant glacial ridge, when combined with the strong tidal influences in the unconfined aquifer and the remnants of the 1918 bulkhead, complicates the determination of hydraulic gradients, including direction. Gradients to the north and west of the ridge where much of the shipyard activities occur are clearly pointing to tidally influenced radial flow off the Site into the Bay. This flow has been shown in Figures 3.2 and 3.3. Monitoring Well MW-05 was originally sited to act as an upgradient groundwater well. However, it is not clear how MW-05 fits into the flow directions. The photograph of Deadman's Bluff shown on Figure 2.1 indicates that MW-05 is located along a flank of the remnant bluff that may be more connected to groundwater to the east and south than to the Site as a whole.

Additionally, as discussed below, the tidal efficiencies and lag are different at the different wells. For example, the tidal efficiency at MW-02A is 27 percent, while the efficiency at MW-07 is only 4 percent; this means that in a synoptic measurement of water levels (all at one time), the tidal effect at MW-07 would be lagging than at MW-02A and would be less in magnitude. Therefore, the specific shape of the potentiometric surface is driven by this tidal lag. The cause of the lag is not known, but may be related to the 1918 bulkhead (shown on Figures 3.2 and 3.3), which may continue to exist in sections.

3.2.4 Groundwater and Surface Water Interactions

3.2.4.1 Tidal Studies

In March 2011, Floyd|Snider completed a 72-hour tidal study to determine tidal fluctuation and tidal efficiency in monitoring wells along the shoreline and upland area of the study area and the effects of tides on salinity concentrations in groundwater. The tidal study was completed using Monitoring Wells MW-02A, MW-04, MW-05, MW-07, MW-08, and MW-09.

Water levels were continually monitored using automated pressure transducers/conductivity sensors. Parameters logged included continuous recording of water levels, conductivity (at MW-07 and MW-09 only), and temperature. All data were corrected for barometric pressure.

Tidal fluctuation data were used to calculate the tidal efficiency value in each well, as summarized in Table 3.4. Tidal efficiency is a relative measure of tidal influence and is expressed as the ratio of feet of tidal change observed in a well to the feet of actual tidal change. To determine the average groundwater elevation across the period of the tidal study, the tidal data were reduced using the Serfes method (Serfes 1991). The tidal study graphs are included in Appendix F. A NOAA data station is not currently located in the Bay for logging real-time tidal data. Therefore, predicted NOAA tidal data for the Bay from Bellingham Bay Station 94429211 referenced to real-time NOAA certified data from the Port Townsend Station (9444900) were used. The Port Townsend data elevations have been offset to adjust for more accurate high and low tide predictions in the Bay. The dataset was then translated to mean tidal elevation to illustrate the difference between the peak elevations of the tide and of groundwater in each monitoring well.

Salinity concentrations were measured from all monitoring wells in February 2013 during the groundwater sampling event. Tidal efficiency and salinity are also shown on Figure 3.4.

Table 3.4
Overall Percentage of Tidal Efficiency in Monitoring Wells[1]

Monitoring Well[2,3]	Distance from Shoreline (feet)[4]	2011 Floyd|Snider Study	1998 RETEC Study
MW-01	65	-	9%
MW-02	30	-	40%
MW-02A	30	27%	-
MW-03	80	-	4%
MW-04	210	13%	19%
MW-05	540	6%	6%
MW-07	60	4%	-
MW-08	35	19%	-
MW-09	30	18%	-

Notes:

- \- Study not conducted.
- 1 Percent of total tide calculated after mean height correction.
- 2 Monitoring Wells MW-02A, MW-07, MW-08, and MW-09 were installed in 2011.
- 3 Monitoring Wells MW-01, MW-02, and MW-03 were unable to be located for the 2011 Floyd|Snider Tidal Study.
- 4 Approximate distance from well to shoreline toe of slope.

In general, the findings of the tidal study (March 2011) and more current tidal data (February 2013 and 2015) and salinity data (February 2013) collected during groundwater sampling include the following:

- The average overall groundwater flow direction as determined using Monitoring Wells MW-02A, MW-04, MW-05, MW-07, and MW-08 is to the northwest (toward the Bay). This is shown on Figures 3.2 and 3.3.
- Tidal data for Monitoring Wells MW-04, MW-08, and MW-09 suggest a slight tidal reversal (defined as when the tidal level rises above that of the uplands groundwater level), leading to a slight reversal of gradient during times of high tide. The remaining wells showed no reversal of gradient near high tide.
- Shoreline Monitoring Wells MW-02A, MW-08, and MW-09 had maximum tidal amplitude and tidal efficiency between 18 to 25 percent. The tidal lag, which is the time difference between tidal phases as measured in the Bay and those measured in the monitoring wells, had an average tidal lag of 74 minutes. MW-04, located further inland, had a slightly lower tidal efficiency of 13 percent.
- Salinity concentrations were the highest in shoreline Monitoring Wells MW-02A, MW-07, and MW-08 ranging from 3.8 to 6 parts per thousand (ppt), which is considered brackish. Salinity concentrations at the remaining shoreline monitoring wells further to the east (MW-01, MW-06, MW-09, and MW-10) were lower, ranging from 0.1 to 1 ppt. Upgradient Monitoring Well MW-05 had a salinity of 0.1 ppt, which is fairly fresh. For comparison, salinity in the Bay generally ranges between 25 and 30 ppt. Salinity concentrations in MW-07 and MW-09 were consistent with data collected during groundwater sampling in February 2013. Average salinity at each monitoring well location is shown on Figure 3.4. Overall the tidal data and salinity measurements indicate the groundwater beneath the site is moderately influenced by the adjacent marine embayment and is non-potable, as previously determined by Ecology.

Monitoring Well MW-04 exhibited both a medium tidal efficiency of 13 percent and a salinity measurement of 3.03 ppt. Monitoring Well MW-04 (located in the center of the study area and approximately 220 feet away from the shoreline) had a tidal efficiency greater than MW-01 and MW-07, which are located within 50 feet of the shoreline area. Higher tidal influence in MW-04 suggests high hydraulic connectivity between the well and the shoreline. No utilities, historical features, or differing soil conditions were identified along the shoreline to indicate a direct pathway from the shoreline to this well.

In addition, Floyd|Snider reviewed previous data from the 18-hour tidal study that was completed during the 1998 RETEC Phase 2 sampling event at five monitoring well locations (MW-01, MW-02, MW-03, MW-04, and MW-05). During this study, the tidal efficiency was greatest in MW-02 and had the greatest tidal influence due to the proximity to the shoreline. Tidal efficiencies in remaining wells did not vary directly with distance; for example, the tidal efficiency measured at MW-01 was twice that measured at MW-03, yet MW-01 and MW-03 are located at approximately the same distance (50 feet) away from the shoreline.

3.2.4.2 Discharge Zones

Stormwater discharges to surface water are discussed in Section 2.3.4.

The tidal study data and the salinity data confirm that groundwater at the Site discharges to the Bay through the nearshore intertidal sediments. RETEC and Floyd|Snider surveyed the shoreline area at low tide for groundwater seepage areas. No seeps were noted with adequate water production for sample collection. At low tide, water was observed moving through the riprap slope but was likely drainage of tidal waters (bank storage) mixed with groundwater seepage.

Given the salinity and elevation of marine waters in the Bay, it is likely that a salt water wedge exists at the shoreline and that shallow groundwater at the Site discharges “up and over” the marine waters at elevations between -1 feet MLLW (approximately the lowest level that tides reach during a year) and +7 feet MLLW (the average elevation of groundwater on-site). This discharge will include returning marine water (bank storage) that entered the Site when tides were above average groundwater.

3.3 NATURAL RESOURCES

This section provides a summary of the most beneficial uses of the resources in the area. This section provides the foundation for the pathways that will be evaluated in Sections 4.0 and 5.0 of this document.

3.3.1 Groundwater Resources

Groundwater in the vicinity of the Site is not potable. In order to provide consistent direction for the Bay waterfront sites, Ecology has made the following determination as provided to the Port and Floyd|Snider on November 26, 2012.

> “Ecology has considered the issue of whether ground water should be classified as potable at sites located within waterfront properties adjoining Bellingham Bay. Ecology decided that for most of these sites, the shallow ground water in fill can be classified as nonpotable based on the criteria under WAC 173-340-720(2). The conditions applicable to a nonpotable classification at a hypothetical Bellingham Bay site are as follows using language directly from WAC 173-340-720(2):
>
> (2)(a) The ground water does not serve as a current source of drinking water. Drinking water is currently supplied by the City of Bellingham. Water supply wells are not known to exist at or near the site.
>
> (2)(c) The department determines it is unlikely that hazardous substances will be transported from the contaminated ground water to ground water that is a current or potential future source of drinking water, as defined in (a) and (b) of this subsection [i.e., -720(2)], at concentrations which exceed ground water quality criteria published in chapter 173-200 WAC.
>
> Remedial investigation work at the site indicates that contaminated ground water occurs primarily in the uppermost water-bearing zone. This water-bearing zone occurs in manmade fill placed into Bellingham Bay and in the upper part of the underlying native sediments (“shallow aquifer”). The shallow aquifer discharges directly into Bellingham Bay. Contaminated ground water in the shallow aquifer will not flow laterally inland towards other aquifers that may be a current or potential future source of drinking water, because the inland aquifers are hydraulically upgradient of the shallow aquifer. Similarly, contaminated water in the shallow aquifer will not flow vertically downward into deeper aquifers that may be a current or potential future source of drinking water, because ground water flow between aquifers at the shoreline is upward, reflecting increasing hydraulic heads with depth.

> (2)(d) Even if ground water is classified as a potential future source of drinking water, the department recognizes that there may be sites where there is an extremely low probability that the ground water will be used for that purpose because of the site's proximity to surface water that is not suitable as a domestic water supply. An example of this situation would be shallow ground waters in close proximity to marine waters such as on Harbor Island in Seattle. At such sites, the department may allow ground water to be classified as nonpotable if each of the following conditions can be demonstrated. These determinations must be for reasons other than that the ground water or surface water has been contaminated by a release of a hazardous substance at the site.
>
> (2)(d)(i) There are known or projected points of entry of the ground water into the surface water.
>
> Remedial investigation work at the site demonstrates that ground water in the shallow aquifer discharges directly into Bellingham Bay.
>
> (2)(d)(ii) The surface water is not classified as a suitable domestic water supply source under chapter 173-201A WAC.
>
> Bellingham Bay is a marine surface water body, and is not suitable as a domestic water supply under chapter 173-201A WAC.
>
> (2)(d)(iii) The ground water is sufficiently hydraulically connected to the surface water that the ground water is not practicable to use as a drinking water source.
>
> Remedial investigation work at the site indicates that the shallow aquifer is directly connected with and discharges into Bellingham Bay. It is not practicable to utilize the shallow aquifer for water supply due to the potential for drawing saline water into the aquifer (salt water intrusion)."

The findings of this RI/FS are consistent with Ecology's determination and the groundwater in this area is not potable. Therefore, the highest beneficial use of groundwater in this area is protection of surface water and sediment quality. These pathways will be evaluated in Sections 4.0 and 5.0.

3.3.2 Aquatic Resources

According to the City, the Site is zoned for water-dependent industrial use, which is consistent with the Port's long-term plan for the Site. The Port's Master Plan for this area identifies the Site as part of Planning Area 5, the main deep water industrial area for the Port's Fairhaven properties. The continued industrial use of this area is documented in the Port's Fairhaven Comprehensive Scheme of Harbor Improvements (Reid Middleton 2008). This is consistent with the DNR lease for the over-water areas, which indicates that the highest beneficial use of this aquatic property is for industrial use. The nearby Ferry Terminal is part of the Alaska Marine Highway, which the State of Alaska is critically dependent on (refer to Figure 1.3).

The sediments in the area, although in an industrial area, also provide habitat to benthic creatures and provide clean water for finfish, shellfish, migratory fish, and aquatic mammals. Because the Site is part of the U&A fishing grounds for the Nooksack Tribe and Lummi Nation, the quality of the water and sediment must be sufficient to protect those resources.

3.3.3 Terrestrial Ecological Resources

According to WAC 173-340-7491, a site may be excluded from a Terrestrial Ecological Evaluation (TEE) if it meets certain criteria. The goal of the TEE process in MTCA is to evaluate the potential for terrestrial ecological exposure to contaminated soil to cause significant adverse effects to terrestrial species. The first step in the TEE process is to determine if a site qualifies for completion of a TEE, or if the Site is excluded from further evaluation based on site conditions or other factors. If a site meets one of the exclusion criteria outlined in WAC 173-340-7491(1), no additional evaluation is required, and CULs for protection of terrestrial receptors are not required. WAC 173-340-7491(1)(b) states:

> "(b). All soil contaminated with hazardous sub-stances is, or will be, covered by buildings, paved roads, pavement, or other physical barriers that will prevent plants or wildlife from being exposed to the soil contamination. To qualify for this exclusion, an institutional control shall be required by the department under WAC 173-340-440. An exclusion based on planned future land use shall include a completion date for such future development that is acceptable to the department."

As discussed in Section 2.3.2 and shown in the photos in Appendix A, the Site is zoned for industrial use and is fully paved or gravel surfaced. Where the site is gravel surfaced, it is very hard packed allowing little or no access to the surface by terrestrial species. Additionally, there is no vegetation on-site that would attract terrestrial species. An institutional control, in the form of a deed restriction, will ensure that the property remains zoned as industrial and that the surface will remain either paved or as a hard packed gravel surface in areas where buildings are not present.

Based on the use of the shipyard property as an active industrial facility, the absence of any vegetation, and the hard packed gravel or paved areas covering the property, the Site can be excluded from doing a TEE because the current ground surface serves as a "physical barrier" to any potential terrestrial species. This "physical barrier" will remain in place in the future in accordance with the deed restriction that will be placed on the Site.

3.4 HISTORICAL AND CULTURAL RESOURCES

The Bay shoreline areas are sensitive for historical and archaeological cultural resources as Native Americans, including the current Lummi Nation and Nooksack Tribe, lived around this area with populations concentrated at the mouth of the Nooksack River, along Whatcom Creek, and on the San Juan Islands since time immemorial. Historical Research Associates, Inc. (HRA) evaluated the probability of encountering cultural resources within the study area and completed a review of previous ethnographic, historical, and archaeological records, and a review of relevant background literature and maps (HRA 2011a). Proposed explorations were limited to fill soils overlaying the historical tide flats, within low to medium probability zones for archaeological material. Based on general site knowledge of historical fill soils overlying the tide flat and background research, it was determined that any ground-disturbing activities during site investigation activities had a low probability of encountering intact historical and archaeological cultural resources within the study area. Previously disturbed and undocumented historic and archaeological materials may have been imported with fill material, however, and these materials may be regulated. Figure 2.1 shows the original shoreline from the 1891 Harbor Line Commission map overlaid with the current shoreline area.

An HRA archaeologist monitored ground-disturbing activities during initial drilling activities. Although no known archaeologically significant cultural resources were identified within the study area during these activities, the southeastern portion remains moderately sensitive as there is a recorded archaeological site approximately 600 meters east and adjacent to the south and southeast portions of the shipyard (Site No. 45WH41) at the western end of Harris Avenue. HRA recommended future archaeological monitoring of ground-disturbing remedial activities in the southeastern portion of the study area at the approximate interface between historic-period fill and undisturbed native soils, to around a 3-foot depth in the native soils (HRA 2011b).

For investigation activities completed after March 2011, the following procedures were followed to address the possibility of encountering cultural artifacts:

- The soil borings were logged by a geologist and closely observed for evidence of non-soil materials.
- If apparent archaeological materials were encountered, the Port would have been notified immediately. The Port would have notified Ecology, the Department of Archaeology and Historic Preservation (DAHP), the Lummi Nation, and the Nooksack Tribe, and invited all parties to attend an on-site inspection with a professional archaeologist contracted by the Port. The archaeologist would then document the discovery in a report and submit to DAHP so that they may control access to information regarding potential sensitive-site locations, in accordance with Chapter 27.53 RCW.

In 2015, a Monitoring and Inadvertent Discovery Plan (MIDP) was prepared by HRA (HRA 2015) for monitoring ground-disturbing activities in the uplands and sediments. During the May 2017 Interim Action, archeological monitoring was conducted by HRA during excavation of areas with the potential of cultural material discovery in accordance with the MIDP. During the course of the excavation, several anticipated and one inadvertent discovery of cultural materials were documented by HRA. Coordination with the appropriate parties, including the Port, Ecology, the DAHP, and the affected Tribes, was conducted and appropriate action was taken to protect and record the findings. Following project completion, all discoveries of cultural material were recorded in an Archaeological Monitoring Report that was provided to the appropriate parties.

In the event of inadvertent discovery of potential human remains, work would have immediately been halted in the discovery area, and the apparent remains covered and secured against further disturbance. The City of Bellingham Police Department and Whatcom County Medical Examiner would have been immediately contacted, along with DAHP and authorized Tribal representatives. A treatment plan would have been developed by HRA in accordance with applicable state laws.

4.0 Site Screening Levels

This section describes the analysis of exposure pathways and receptors within air, soil, groundwater, surface water, and sediment at the Site and identifies the screening levels for each media. An adaptive CSM was developed in the RI/FS Work Plan and RI/FS Data Report. The CSM has been updated and revised based on work from recent investigations and in response to Ecology's comments on the RI/FS Data Report and Screening Level Workbook (Workbook), described below in Section 4.1.

The revised CSM, as shown in Figure 4.1, presents an updated and more accurate picture of conditions at the Site. Figure 4.2 identifies the pathways that may be present at the Site, which are evaluated in Section 4.1. The following subsections update the exposure pathways analysis from the CSM based on the incorporation of RI data, and identify the appropriate regulations for the selection and calculation of site screening levels and CULs.

The Port and Floyd|Snider worked closely with Ecology to develop the scope of analyses for the RI based on the history of the Site (as discussed in Section 2.0) and knowledge of typical waste handling processes at shipyards. This scope was formalized through a series of Ecology-approved Work Plans. The identification of exposure pathways and assumptions was also developed in close cooperation with Ecology.

The primary COCs identified in coordination with Ecology were metals and petroleum hydrocarbons, which could have been released via operations or accidental releases to uplands soil and sediments. Groundwater contamination, if present, was expected to be primarily from releases to soil and subsequent leaching by infiltrating stormwater, as large sections of the Site are or were unpaved.

Because the aquifer beneath the Site is non-potable and its highest beneficial use is discharge to the adjacent marine embayment, the majority of groundwater monitoring wells are present along the shoreline where discharge occurs. There are a few interior wells, including a well MW-01 downgradient of the former ASTs. Soil and groundwater data exist for the traditionally used "EPA Target Analyte List" of metals, VOCs, SVOCs, PCBs, and TPH; select samples have been analyzed for dioxin/furans. Sediment samples were analyzed for the SMS analyte list as well as select samples for dioxin/furans.

Section 4.2 describes the process of determining site COPCs, in which data are compared to the most stringent screening level by media. The outcome of this section is a list of applicable screening levels for various pathways and COPCs for each media. In Section 5.0, the nature and extent of contamination will be addressed, while considering which cross-media pathways are active at the Site. Section 5.0 evaluates COPCs, identifies COCs, and concludes with a list by media of the COCs along with their proposed CULs and the POCs for the CULs.

Appendix G (Attachments G.1 through G.3) contains backup information and/or rationale for the development of bioaccumulative chemicals, exposure parameters, screening levels, and TPH.

4.1 DEVELOPMENT OF SCREENING LEVELS

As discussed in Section 1.1, the Site is one of 12 cleanup sites that are being coordinated under the Bellingham Bay Demonstration Pilot Project. In 2012, the Port and its consultants for these 12 sites worked with Ecology to develop the Workbook, which could be used at all Port sites within the Bay. Following several iterations of the Workbook, Ecology and the Port determined that it was most appropriate for the Workbook to be used only as a reference and only during the development of site-specific screening levels. The last version of the Workbook, including the

Port's response and Ecology's comments, was submitted to Ecology on October 31, 2012 (Floyd|Snider 2012c). Much of the material completed during the Workbook development is relevant and appropriate to this Site. The Workbook and Ecology's comments were used as the starting point for developing the site-specific screening levels that are described below.

Figure 4.2 identifies the exposure pathways that were evaluated in this process. This pathway figure was developed in cooperation with Ecology during the development of the Workbook.

Sediment, groundwater, and soil screening levels were updated in June 2017 on the basis of new chemical partitioning factors, toxicity factors, and promulgated regulatory criteria since the last version of the RI/FS. These changes are described in more detail later in this section.

4.1.1 Exposure Pathways and Receptors

Under MTCA and SMS, two different types of exposure scenarios are considered: direct exposures and cross-media protection. Direct exposures share the following characteristics:

- Concentrations have been measured in the media and are known.
- Exposure is directly in contact with the media itself. The receptors may be ecological or human, and the route of exposure may vary. Typical direct exposures include, but are not limited to: incidental ingestion of soil or sediment, inhalation of ambient and indoor air or dust, dermal contact with soil, sediment, or water, and habitat contact, as when benthic species reside in or on the sediment.
- A direct exposure pathway is not complete when there is an actual physical or administrative barrier to contact.

Cross-media protection pathways are potential and indirect exposure pathways requiring that (1) the contaminant migrates from one media (or location) to another and that (2) an exposure occurs between a receptor and the media that is being protected. These pathways share the following characteristics:

- The migration of the chemical from one media to another is often modeled based on simple equilibrium migration models that are not usually calibrated to site-specific conditions.
- The media to be protected may or may not have been analyzed. When the media to be protected has been analyzed, it is possible to determine whether the migration has occurred and at what level, and to more accurately evaluate the potential exposure.
- Data from the media to be protected, such as contaminant concentrations in groundwater, may be used to demonstrate compliance.
- A cross-media exposure pathway is not complete when there is an actual physical barrier to migration. The physical barrier may be a natural process (e.g., site-specific conditions may act to significantly attenuate actual migration).

Table 4.1 presents an overview of the media, receptors, and exposure routes that are being considered for the Site. The following site-specific media were sampled at the Site: subtidal and intertidal sediments, groundwater, saturated and unsaturated soils (i.e., vadose zone), and soil gas. Ambient air was not sampled. Resident fish/shellfish were also not sampled. Many of the important marine species have resident ranges that are much larger than the Site. Tissue data available from investigations conducted in the Bay are discussed further in Appendix G, Attachment G.1 on Bioaccumulative Chemicals. Table 4.2 considers the key media analyzed at the Site and lists the pathways and scenarios that are being considered in establishing screening levels for the Site. Some of the pathways represent direct exposures and some represent cross-media protection. This distinction becomes more important in Section 5.0 when data from the media to be protected are used to demonstrate whether the pathway is important for specific chemicals.

4.1.2 Screening Level Development for Sediment

The SMS includes requirements for the protection of both human health and the environment. For the human health exposure pathways, the revised SMS Rule provides specific risk evaluation procedure requirements for the establishment of sediment CULs (WAC 173-204-560). The risk-based levels are used in conjunction with background concentrations and practical quantitation limits (PQLs) to derive Sediment Cleanup Objectives (SCOs) and a Cleanup Screening Level (CSL).[5] The SCO defines the lower bound of a sediment CUL and the CSL defines the upper bound, with the final site-specific CUL defined on a site-by-site basis. In order to provide a conservative approach, screening levels for human health exposure pathways are based on the SCO (the lower value) as discussed below. The CUL development is discussed further in Section 5.2.

In developing screening levels for sediments, the following direct exposures pathways were considered:

- **Protection of Benthic Species.** Numeric criteria are promulgated by Ecology to prevent benthic toxicity in Washington State. In order to provide the most conservative approach to protect benthic species, the SCO values were established as the screening levels protective of benthic species. In the Washington State SMS (WAC 173-204-562 Table III and Table 8-1 of the Sediment Cleanup User's Manual II [SCUM II; Ecology 2017a]), the SCO serve as the long-term goal for sediments of the state, and the lower end of the range within which cleanup standards for a site can be selected. The CSLs serve as the level greater than which cleanup sites are designated, and also serve as the upper end of the range within which cleanup standards for a site may be selected, based on balancing environmental protectiveness, cost, and technical feasibility. Thus, a cleanup standard for any given site may be set within a range of allowable adverse effects, from no effects to minor adverse effects, depending on site-specific considerations.

  The depth of exposure for this pathway is the biologically active zone (BAZ) typically defined as 0 to 10 cm in the SMS. However, Ecology has determined that the BAZ for the entire Bay is 0 to 12 cm and is using this BAZ throughout this evaluation.

  This pathway is applicable to intertidal sediments located within the intertidal area adjacent to the west side of the Site within Fairhaven Marine Park (i.e., "beach intertidal sediment area"), and runs north and to the east along the front of the shipyard (i.e., "shipyard intertidal sediment area").

  TBT is considered separately because, while it has the potential to cause benthic toxicity, regulatory limits protective of benthic species have not been established under SMS. A report on the evaluation of TBT relative to benthic toxicity (Michelsen et al. 1996) proposed regulatory criteria based on porewater concentrations, rather than on bulk sediment, stating that the porewater concentration

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[5] SMS is using the term CSL for the upper bound of the CUL. The current SMS uses SCO for the lower bound when both benthic protection and protection of human health are considered. However, prior to the 2013 SMS revisions, SQS was the term used and is, therefore, used here to describe previous results.

is "conceptually equivalent" to a benthic SCO. This porewater screening level value has been considered as the screening level for TBT protective of benthic species.

- **Protection of Human Direct Contact: Shipyard Workers.** Within the shipyard intertidal sediment area there is the potential for workers to be exposed to intertidal sediment, particularly in the marine railway area. This area is shown on Figure 4.3 as the shipyard intertidal sediment area. Although, the exposure levels are minimal as the exposure time here is limited, this pathway needed to be evaluated. Exposure is assumed to include both dermal contact and incidental ingestion of the intertidal sediments; details are presented in Appendix G, Attachment G.1. Exposure parameters presented in Appendix G are similar to default parameters for MTCA Method C soil CULs.

  The depth of exposure is 0 to 12 cm as it represents a depth of sediment that could be accessible by shipyard workers during routine shipyard activities. SCUM II recommends a depth of 0 to 45 cm for sediments for beach play and clamming, but neither occur in the active shipyard; instead, workers in boots cross the intertidal sediments periodically to reach operational areas and a 0 to 12 cm exposure depth is more appropriate.

- **Protection of Human Direct Contact: Beach Recreation.** To the west of the shipyard, the beach intertidal sediment area is partially armored with large riprap, and otherwise covered primarily by coarse pebbles and cobble-sized material that prevent direct contact between humans and sediment. Additionally, there is little or no "sediment" defined as silt and sand in this area. Therefore, there is no pathway for direct contact during beach recreation.

- **Protection of Human Direct Contact: Tribal Net Fishing.** As described in Section 2.4, the aquatic areas in the vicinity of the Site are U&A fishing areas for both the Lummi Nation and Nooksack Tribe. During net fishing, it is possible to have direct contact with surface sediment that has adhered to the net while the net is being pulled up. Exposure is assumed to include both dermal contact and incidental ingestion of the subtidal sediments consistent with SCUM II); details are presented in Appendix G, Attachment G.1. The depth of exposure for this pathway is the BAZ, 0 to 12 cm.

In addition to these direct exposure scenarios for sediment, two cross-media protection scenarios were also considered:

- **Protection of Seafood Quality to Support Human Consumption of Seafood.** This pathway evaluates the ingestion by humans of aquatic species (seafood) that may have accumulated toxic chemicals during their life cycle. The primary concern is the presence of a source of persistent contamination in the sediments that can accumulate in on-site organisms over a long period of time. For the Site, the following seven chemicals or chemical groups have been evaluated for their potential as bioaccumulative COCs: arsenic, cadmium, lead, mercury, cPAHs, PCBs, and dioxins/furans. The development of the appropriate screening levels for this pathway is described in detail in Appendix G, Attachment G.1. Exposure parameters are generally consistent with the SCUM II. The depth of exposure for this pathway is the BAZ, 0 to 12 cm.

- **Protection of Seafood Quality to Support Higher Trophic Level Species Consumption of Seafood.** This pathway evaluates the ingestion by higher order marine species of lower level aquatic species (seafood) that may have accumulated toxic chemicals during their life cycle as specified in WAC 173-204-564. The overall approach is to calculate sediment screening levels protective of this pathway using literature-derived target tissue levels (TTLs). TTLs are risk-based tissue concentrations below which chemicals would not be expected to pose adverse health effects to higher order marine species. TTLs are presented in guidance documents including the Sediment Evaluation Framework for the Pacific Northwest (RSET 2016), and the Oregon State Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment (ODEQ 2007). The development of the appropriate screening levels for this pathway is described in detail in Appendix G, Attachment G.1. The depth of exposure for this pathway is the BAZ, 0 to 12 cm.

Two modifying factors, natural background and PQLs, were also considered when establishing the screening levels:

- **Natural Background.** A number of the chemicals evaluated at the Site are naturally occurring in the environment or are so ubiquitous in the environment to be present in "natural" background. For sediments, Ecology has selected for use the 90th Upper Confidence Limit of the 90th percentile of DMMP's sediment sampling conducted in 2008 (DMMP 2009), commonly referred to as the OSV Bold Survey, and approved background data sets presented in Appendix I of SCUM II. For chemicals with risk-based screening levels that are less than natural background, the natural background was applied as the most stringent screening level.
- **PQLs.** No screening level will be set less than the PQLs; the derivation of the PQLs used is discussed in 4.1.7.

Table 4.3 presents the screening levels for sediments for each of these potential exposure pathways. Screening levels are presented for all chemicals that were analyzed for which there are either available ARARs (such as the SCO for benthic species protection) or toxicological information that allows for the calculation of risk-based screening levels. Blank cells are intentional in the table. When a cell is blank, no screening level is available for that specific chemical for that pathway.

It should be noted that no sediment screening level was developed for petroleum mixtures (e.g., TPH). There are no state or national standards for TPH in sediment. The aromatic components of TPH, the PAHs, are often used as Indicator Hazardous Substances (IHS) for TPH impacts. The PAHs have been well-studied and have established standards and toxicity factors. They are a soluble component of TPH that can migrate, yet prefer to adsorb to the organic content of sediment. Sediment screening levels for the PAHs have been developed and potential TPH impacts to the sediments will be assessed through their use.

4.1.3 Screening Level Development for Surface Water

Surface water is not a contaminated medium at the Site. However, in order to establish groundwater screening levels that are protective of surface water, it is necessary to define concentrations in surface water that are protective of human health and aquatic species, and then establish groundwater screening levels that are protective of these surface water concentrations.

4.1.3.1 Protection of Aquatic Species

Surface water concentrations that are protective of aquatic species can be found in three promulgated regulations:

- Ambient Water Quality Criteria established under Sections 303 and 304 of the Clean Water Act (33 United States Code [U.S.C.]; 1313–14).

- National Toxics Rule (NTR) at 40 Code of Federal Regulations (CFR) 131.36.
- Washington State Surface Water Quality Standards at RCW 90-48 and WAC 173-201A.

In using these regulations, the criteria based on chronic exposure in marine waters were selected from each regulation as the most appropriate and conservative for the Site.

4.1.3.2 Protection of Human Health

Surface water concentrations that are protective of human consumption of fish and shellfish can be found in four promulgated regulations:

- Ambient Water Quality Criteria established under Sections 303 and 304 of the Clean Water Act (33 U.S.C. 1313–14).
- NTR at 40 CFR 131.36. The NTR has not been updated since it was passed in 1992, and is based on toxicity information from the 1980s. NTR values that are based on federally withdrawn toxicity factors have been removed from the table; in all cases, newer values based on current toxicity information were available from either the Ambient Water Quality Criteria or MTCA.
- Clean Water Act-Effective Human Health Criteria Applicable to Washington (Washington Water Quality Standards; 40 CFR 131.45).
- MTCA, WAC 173-340-730, surface water CULs.

In accordance with WAC 173-340-730(3)(b)(iii), if sufficiently protective health-based criteria or standards have not been established under the above applicable state and federal laws, MTCA Method B equations for the calculation of human health screening levels based on fish consumption have been used. MTCA Method B values are most restrictive of carcinogenic or non-carcinogenic values presented in Ecology's Cleanup Levels and Risk Calculation (CLARC) Database.

The screening levels developed for surface water based on these regulations will be used in the next section in the development of screening levels for groundwater.

4.1.4 Screening Levels Development for Groundwater

As described in Section 3.3.1, the groundwater in this area has been determined to be non-potable by Ecology and the drinking water pathway is not an applicable pathway at this site. The highest beneficial use of groundwater at the Site is discharge to the Bay. Three cross-media protection pathways were considered for groundwater at the Site:

- **Protection of Air Quality for Industrial Workers.** Volatile contaminants in shallow groundwater have the potential to volatilize and rise through the soil column and discharge into indoor air. Screening levels for this pathway were developed by Ecology and published in Ecology's *Guidance for Evaluation of Soil Vapor Intrusion* (Ecology 2016a). The applicable groundwater screening levels for this pathway are the MTCA Method C values for industrial land use.
- **Protection of Surface Water.** Groundwater in the shallow aquifer at the Site has the potential to migrate to the shoreline and discharge into the Bay. Consistent with requirements in MTCA, groundwater that discharges into surface water must meet the

surface water quality standards (the screening levels developed above) at the point where the discharge occurs, without taking dilution into account.

- **Protection of Sediment.** Sediment quality must be protected at the point where groundwater is discharged to the marine sediment. As discussed in Section 3.2.4.2, groundwater at the Site discharges into the intertidal area (up and over the salt water wedge). There are two intertidal sediment areas with differing screening levels at the Site; however, in order to provide the most conservative screening level, the sediment quality target that is being protected is the lower of the screening level to protect benthic species and the screening level to protect shipyard workers that may come in contact with intertidal sediments during routine shipyard activities. Porewater concentrations were calculated using equilibrium partitioning based on the protection of this sediment quality target. This calculated porewater value was then applied to groundwater where it discharges into the Bay.

In addition, two modifying factors were considered in establishing screening levels, natural background, and PQLs:

- **Natural Background.** A number of the chemicals evaluated at the Site are naturally occurring in the environment and it is inappropriate to establish a screening level or CUL lower than the natural background concentrations. In groundwater, only one chemical, arsenic, has an established statewide background concentration. The value from WAC 173-340-900 Table 720-1 is used as the natural background value in the screening level tables. No arsenic screening level was set at a level less than the statewide arsenic background level of 5 micrograms per liter (µg/L). Because groundwater at the Site occurs in the Padden member of the Chuckanut Formation, it may be necessary to develop local background levels for arsenic, copper, and nickel in groundwater. For example, 13 of 24 water supply wells in Whatcom County have arsenic concentrations greater than 10 µg/L; the highest are in the Chuckanut Sandstone (median 32 µg/L) with the next highest in the unconsolidated aquifer near the Sandstone (Martell 2010; Aspect 2006).
- **PQLs.** Based on COCs defined at this site, no screening levels and/or CULs will be set at levels less than their PQLs; the derivation of the PQLs that are used is discussed in Section 4.1.7.

Table 4.4 presents the screening levels for groundwater for each of these potential exposure pathways. Screening levels are presented for all chemicals that were detected at the Site, and for which there are either available ARARs (such as the ambient water quality criteria) or toxicological information that allows for the calculation of risk-based screening levels. Blank cells are intentional in the table. When a cell is blank, no screening level is available for that specific chemical for that pathway.

4.1.4.1 Total Petroleum Hydrocarbons

As with sediments, no surface water screening level was developed for petroleum mixtures (TPH). There are no state or national standards for TPH in surface water. In Washington, the aromatic components of TPH (i.e., BTEX and PAHs) can be used as IHS for TPH impacts in surface water. BTEX and PAHs have been well-studied and have established standards and toxicity factors. As discussed further in Appendix G, Attachment G.3, surface water screening levels for BTEX and PAHs have been developed that are protective of surface water and sediments quality. TPH in groundwater will be regulated through the use of appropriate site-specific IHS.

The aliphatic components of TPH are not regulated in surface water and sediment. They are regulated in groundwater, but TPH was not detected in groundwater at the Site. Due to their low solubility in groundwater and the fact that they were not detected in groundwater, the vapor intrusion pathway from groundwater is not present and groundwater screening levels from Ecology's updated Table B-1 in the *Guidance for Evaluation of Soil Vapor Intrusion* (Ecology 2016a) are not applicable to the Site.

In summary, the potential for TPH contamination from uplands sources to groundwater is assessed using IHS. The advantage of this approach is that the mobile components of TPH have been well-studied, have available standards for sediments and surface water, and have available and well-researched toxicity factors.

4.1.5 Screening Level Development for Soil

In developing screening levels for soil, the following direct exposure pathway was considered:

- **Protection of Industrial Workers.** As discussed in Section 2.3.2, the Site is an industrial facility in active use in an area zoned for industrial use. The majority of the Site is unpaved, and industrial workers may come into contact with the soil within the upper 15 feet during the course of normal facility activities, including routine operations, maintenance activities at the Site, and facility upgrades that disturb the upper 15 feet of the soil column. This pathway will be evaluated using the standard MTCA Method C approach. When MTCA Method C numbers are not available, MTCA Method A numbers will be used; this specifically applies to TPH and lead. The MTCA Method C value for industrial exposures is 66 mg/kg for total PCBs. This value will be replaced by the Toxic Substances Control Act (TSCA) limit of 10 mg/kg for active industrial facilities with asphalt, concrete, or compacted dirt caps (a Federal ARAR). This was also done by Ecology in development of the MTCA Method A industrial value for PCBs.[6]

The following cross-media protection pathways were also evaluated for soil:

- **Protection of Groundwater Quality.** Contaminants within both the saturated and unsaturated soil have the potential for leaching to the groundwater. In accordance with WAC 173-340-747(3), screening levels that are protective of contaminants leaching from soil to groundwater were calculated using the fixed parameter three-phase partitioning model, MTCA Equation 747-1, with the default parameters. Screening levels were developed for both the saturated and unsaturated soil zones. As described in Section 3.2.3, groundwater has been observed between 8 and 11 feet bgs. In order to provide the most conservative approach, the saturated zone has been defined as soil below 8 feet bgs.
- **Protection of Intertidal Sediments.** Surface soil has the potential to reach surface water and intertidal sediments via direct stormwater runoff, soil erosion, or wind action along the shoreline. Due to the natural forces that are required for this pathway to be active, this pathway is only applicable to the current upper horizon of soil in select areas that are not paved and have the topographical features necessary for these physical actions to occur. However, due to the limited post-cleanup potential for soil erosion and transport to sediments at this Site, Ecology has determined CULs do not need to be developed for this exposure pathway. This is supported by the upland

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[6] For sites with surfaces that allow infiltration of stormwater, the TSCA value is 1.0 mg/kg, but this value is to protect groundwater quality, not direct contact. The value proposed in the next section to protect groundwater quality is 0.16 mg/kg (from MTCA), which is lower than the TSCA value.

cleanup within the Interim Action in which shallow soil (primarily up to 4 feet bgs) was excavated and replaced with clean backfill. The Interim Action occurred in the area of the Site that was unpaved and a portion of the area sloped toward the adjacent surface waters.

It should be noted that Site soils throughout the upper 15 feet of the Site could become of concern for this pathway if redevelopment activities expose subsurface soils to areas of the Site that have the potential to drain to sediments, or if subsurface soils are relocated to areas of the Site that have the potential to drain to sediments.

- **Protection of Air Quality for Industrial Workers.** Volatile contaminants in the unsaturated soil column have the potential to volatilize and rise through the soil column and discharge into indoor air. During the SSI, a soil gas sample was collected at MW-09; however, soil with petroleum hydrocarbon contamination in the vicinity of MW-09 was removed during the Interim Action activities, which occurred in the summer of 2017, and the soil gas data from MW-09 are no longer representative of the site. Table 4.5 shows soil gas results at MW-09.

  The degree and extent of TPH is well defined and Interim Action activities have removed a substantial volume of soil contamination containing insoluble and soluble petroleum components, which will significantly reduce dissolved-phase concentrations at the Site. Any remaining petroleum impacts will be more than 30 feet away from any occupied below-grade foundation or slab-on-grade buildings with office and work spaces. Therefore, using Ecology's 2016 updated process for initially assessing vapor intrusion and Ecology's definition of lateral inclusion zone of 30 feet, there are no current petroleum vapor risks to indoor air at the Site from the unsaturated soil column (Ecology 2016b).

In addition, two modifying factors were considered in establishing screening levels, natural background, and PQLs:

- **Natural Background.** A number of chemicals evaluated at the Site are naturally occurring in the environment, and it is inappropriate to establish a screening level or CUL lower than the natural background concentrations. In soil, background concentrations for some metals and dioxins/furans have established statewide background concentrations. Values from Ecology's *Natural Background Soil Metals Concentrations in Washington State* (Ecology 1994) are used for the metals and the value from Ecology's *Natural Background for Dioxins/Furans in Washington Soils—Technical Memorandum #8* (Ecology 2010a) is used as a natural background number for dioxins/furans. Similar to sediment and groundwater, for chemicals with screening levels that are less than natural background, the natural background was applied as the most stringent screening level.
- **PQLs.** No screening level will be set at levels less than PQLs; the derivation of the PQLs used for this project is discussed in Section 4.1.7.

Table 4.6 presents the screening levels for soil for each of these potential exposure pathways. Screening levels are presented for all chemicals that were detected at the Site, and for which there are either available ARARs or toxicological information that allows for the calculation of risk-based screening levels. Blank cells are intentional in the table. When a cell is blank, no screening level is available for that specific chemical for that pathway.

4.1.5.1 Total Petroleum Hydrocarbons

In addition to the IHS for TPH used in the other media, volatile petroleum hydrocarbon (VPH) and extractable petroleum hydrocarbon (EPH) data were collected for a number of soil samples at the Site. The results for the VPH/EPH and the IHS were then used to develop site-specific screening levels for TPH for the following pathways:

- Protection of industrial workers (via direct contact).
- Protection of groundwater quality.
- Protection of vapor intrusion.
- Prevention of the formation of free product (residual saturation).

The TPH Screening Level Report (Appendix G, Attachment G.2) presents the data and the development of the screening levels and CULs for TPH.

4.1.6 Other Exposure Pathways and Receptors

Stormwater at the Site is described in detail in Section 2.3.4. As described, stormwater in the active areas of the shipyard either infiltrates into gravel surfaced areas, or is collected for treatment and ultimate discharge to the municipal sanitary sewer system. The stormwater system within the uplands portion of the marine railway area is designed to collect stormwater for treatment and sanitary sewer discharge during active work periods. All direct discharges of stormwater from the active shipyard site to open water have been eliminated. Stormwater across the Site is managed and monitored in compliance with Puglia's individual NPDES Waste Discharge Permit or with the Port's NPDES Phase II Municipal Stormwater General Permit. Additionally, shoreline areas have been inspected to ensure that utility bedding or inactive utilities are not providing a migration corridor to sediments and open water. Due to these conditions, evaluation of exposure pathways associated with stormwater movement of soils is limited to the protection of intertidal sediment pathways described above. Stormwater source control activities are evaluated further in the FS portions of the RI/FS.

4.1.7 Practical Quantitation Limits

In addition to the screening levels identified above for each pathway, an appropriate PQL was identified for each chemical and media. The PQL is the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department-approved methods. PQL values shown in Tables 4.3, 4.4, and 4.6 are the higher of the PQLs reported from ALS Laboratory (Kelso, Washington) and Analytical Resources, Inc. (Tukwila, Washington). Because a screening level or CUL cannot be established at a concentration less than an achievable PQL, the PQL was applied as the most stringent screening level for chemicals that have other screening levels less than PQLs. PQLs for the bioaccumulatives have been selected based on the analytical method used in the Harris Avenue Shipyard DGI and were similar to PQLs identified in Table 11-1 and Appendix D of the SCUM II. These PQLs are presented in Appendix G, Attachment G.1.

4.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

A large number of environmental samples have been collected in sediment, groundwater, and soil at the Site over the previous two decades as part of the activities described in Section 2.0. Appendix C contains summary tables of all sampling results. These tables are sorted first by media, then by location. Table C.1 is a list of events for all current and historical sampling.

Table C.2 is a list of locations by media and event. Table C.3 is an analytical summary by event and media. A summary of chemicals analyzed for but not detected are in Tables C.4 through C.6. Tables C.7 through C.13 are results for all media.

Samples from sediment, groundwater, and soil throughout the Site (excluding confirmation samples collected during the Interim Action) were evaluated in a stepwise process to identify COPCs. Figures 4.4, 4.5, and 4.6 provide detailed steps by media. In general, the steps for identifying the COPCs were as follows:

Step 1: Gather data set by media; some will be limited by depth or date.

Step 2: Compare non-detected chemicals to most stringent screening level.

- If the reporting limits for a sufficient number of samples are acceptable (i.e., less than the most stringent screening level), the chemical is eliminated as a COPC.
- If the reporting limits are insufficient, retain until all media are analyzed and determine whether the chemical is retained in other media. Justify final decision to retain or eliminate.

Step 3: Evaluate the frequency with which the chemical was detected, and compare the maximum detected concentrations of each chemical to its most stringent screening level.

- If the chemical is detected in more than 5 percent of the samples and the maximum detection is greater than the screening level, retain the chemical as a COPC.
- If the chemical is detected in less than 5 percent of the samples and the maximum detection is less than 2 times the screening level, the chemical may be eliminated. Justify the final decision if retained.

Step 4: Advance the COPCs to Section 5.0, where their nature and extent are evaluated in further detail.

4.2.1 Sediment

Sediment samples were analyzed for the following chemical groups: SMS metals plus antimony, nickel, and TBT; PCB Aroclors; dioxins/furans; and SVOCs, including PAHs.

Chemicals that were detected in surface sediment within the depth of exposure (i.e., 0 to 12 cm) are presented in Table 4.7. This table shows the maximum detected value and the most stringent screening level for each chemical, and presents the determination of whether the chemical is retained as a COPC or eliminated.

A review of the screening levels in Table 4.3 and the sediment data collected prior to 2013 presented in Table 4.7 indicates the following:

- **Metals.** Arsenic, cadmium, and lead were retained as COPCs for the bioaccumulative pathway for seafood consumption. Arsenic, copper, lead, mercury, and zinc have been retained as COPCs for other sediment exposure pathways.
- **PCBs.** Total PCBs were retained as a COPC for the bioaccumulative pathway for seafood consumption, and as a COPC for protection of the benthic species pathway. Total PCBs were not retained for the direct contact via net fishing or shipyard worker pathways.

- **Dioxins/Furans.** Dioxins/furans were retained as a COPC for the bioaccumulative pathway for seafood consumption, but were not retained for other sediment exposure pathways.
- **cPAHs.** The cPAHs were retained as a group as a COPC for the bioaccumulative pathway for seafood consumption.
- **LPAHs.** Several LPAHs were retained as COPCs for protection of benthic species, but not for protection of human health.
- **HPAHs.** Several high molecular weight, but non-carcinogenic, PAHs were retained as COPCs for protection of benthic species, but not for protection of human or higher trophic level species health.
- **Other SVOCs.** Two phthalate esters and benzyl alcohol[7] were also retained as COPCs for protection of benthic species, but not for protection of human health.

Chemicals that were analyzed for but not detected in sediments are reported in Table C.4 in Appendix C, along with their method detection limit from current data and the lowest method detection limit from historical events. The detection limits from historical and current events were screened against the most stringent screening levels. Detection limits were adequate for identification of COPCs; refer to Table C.4 for details.

4.2.2 Groundwater

Groundwater samples were analyzed for the following chemical groups: petroleum hydrocarbons, using both NWTPH-Dx and NWTPH-Gx and NWTPH VPH/EPH methods; metals; PCBs; SVOCs, including cPAHs; and VOCs.

Chemicals that were detected in groundwater from site monitoring wells are presented in Table 4.8.[8] Chemicals that were not detected in groundwater are presented in Table C.5. Table 4.8 only presents groundwater data collected more recently than January 1, 2009, as historical groundwater results are not relevant and are superseded by more current data. This table shows the maximum detected value and the most stringent screening level and presents the determination of whether the chemical is retained as a COPC or eliminated.

A review of the groundwater data presented in these tables indicates the following:

- **Metals.** Several metals were retained as groundwater COPCs.
  - Arsenic was retained because it is present in groundwater at concentrations greater than its background-based screening level.
  - Copper was retained because it is present in groundwater at concentrations greater than the screening level based on marine chronic criteria, which may be lower than its background concentrations in groundwater. There is no approved background for copper in groundwater in the Bellingham area.
  - Nickel was retained for the same reason as copper. Nickel concentrations in soils at the Site appear to represent a background dataset, indicating that there is no known source of nickel to groundwater.
  - Zinc was retained because it is present in groundwater at concentrations greater than its background-based screening level.

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[7] Although benzyl alcohol has several industrial and commercial applications, it is also a naturally occurring organic chemical produced by many plants and is readily degraded in the marine environment.

[8] Groundwater data collected from probe advancement are included in Appendix C. These data were not included in the determination of site COPCs as they were collected for screening purposes only.

- **PCBs.** PCBs (including Aroclor 1016, 1254, and 1260, and total PCBs) were not detected in groundwater and are not retained as COPCs.
- **cPAHs.** cPAHs, calculated as the cPAH toxic equivalent (TEQ), are retained as a COPC. They are only detected in 5 percent of the samples, but the maximum detection is greater than 2 times the screening level.
- **LPAHs.** Four LPAHs (1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, and fluorene) were detected in approximately half of the samples and are retained as COPCs. These chemicals will be evaluated as IHS for TPH when considering protection of surface water and sediment.
- **HPAHs.** Except for the cPAHs detected in a single well, no HPAHs were detected in groundwater. Only cPAHs were retained as groundwater COPCs.
- **VOCs.** VOCs are not retained as COPCs. Only six VOCs were detected in groundwater; none of the maximum detected concentrations exceed the most stringent screening level.

Though site data was analyzed for TPH, which confirmed its presence on-site, compliance with screening levels and CULs is semiqualitative and should not be evaluated using strict quantitative methods, as performed for other contaminants in Table 4.8. TPH is evaluated relative to site-specific CULs, as described in Appendix G, Attachment G.2.

Those chemicals that were analyzed for but not detected in groundwater are reported in Table C.5 in Appendix C, along with their method detection limit from current data and the lowest method detection limit from historical events. The detection limits were screened against the most stringent screening levels. Detection limits were found to be adequate for identification of COPCs; refer to Table C.5 for details.

4.2.3 Soil

Soil samples were analyzed for the following chemical groups: petroleum hydrocarbons, using NWTPH-Dx, NWTPH-Gx, and NWTPH VPH/EPH methods; metals; PCBs; dioxins/furans; SVOCs, including cPAHs; and VOCs.

Chemicals that were detected in soil are presented in Table 4.9. This table shows the maximum detected value and the most stringent screening level and presents the determination of whether the chemical is retained as a COPC or eliminated.

A review of the soil data presented in Table 4.9 and Appendix G.2, indicates the following:

- TPH and its individual aromatic components (EPH/VPH and PAHs) were detected in a large number of samples at the Site and are retained as COPCs. The primary TPH concentrations are consistent with the presence of petroleum-based products in the diesel and oil range (typically a mixture of diesel No. 2 and oil). Gasoline is not present in samples; gasoline-range detections, when present, represented the low boiling end of diesel or a kerosene-type product. Details are discussed in Appendix G, Attachment G.2.

  The screening level for TPH in soil is based on the MTCA Method A tables for industrial sites and was developed for protection of industrial workers from direct contact, for protection of groundwater for drinking water uses, and for the prevention of the formation of free product (residual saturation). The diesel-range value is driven by protection of groundwater for drinking water uses and the oil-range value is driven by prevention of free product in a coarse sand; neither of these end-points is relevant to actual conditions at the Site.

- Metals are present throughout the Site and the following metals are retained as COPCs: antimony, arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc. Beryllium is not retained as a COPC as the maximum detection is not greater than the most stringent screening level. Chromium is not retained as there is no associated screening level.
- Total PCBs, as well as Aroclor 1254 and 1260, are retained as COPCs. Aroclor 1242, 1248, and 1268 are not retained as COPCs.
- Dioxins/furans were detected in all four sample locations. The maximum detection on-site is 57 nanograms per kilogram (ng/kg), which is significantly lower than the MTCA Method C industrial Worker CUL of 1,500 ng/kg; therefore, dioxins/furans were not retained. The maximum value (one soil sample) did exceed the direct contact via net fishing screening level, but this value was not considered relevant because soil dioxins would need to migrate hundreds of feet to the net fishing area and impact large acres of sediments, which is not possible.
- SVOCs retained as COPCs include: all of the cPAH compounds (including cPAH TEQ); four LPAHs, naphthalene, anthracene, acenaphthene, and fluorene; two HPAHs, fluoranthene and pyrene; three phthalate esters; and three miscellaneous SVOCs.
- The only VOC that was retained was ethylbenzene, which had a maximum detection greater than the most stringent screening level.

Those chemicals that were analyzed for but not detected in soil are reported in Table C.6 in Appendix C, along with their method detection limit from current data and the lowest method detection limit from historical events. The detection limits were screened against the most stringent screening levels and were found to be adequate for identification of COPCs; refer to Table C.6 for details.

4.3 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Table 4.10 provides a summary of all COPCs in sediment, groundwater, and soil, and it can be used to assess the importance of cross-media pathways. For example, most groundwater COPCs are also COPCs for soil; therefore, it will be important to evaluate the potential for soil to provide an on-going source of contamination for these groundwater COPCs. Conversely, most soil COPCs are not groundwater COPCs. For example, protection of groundwater quality is only important for some (those detected in groundwater), not all, of the soil COPCs. The most important COPCs for the evaluation of the cross-media pathways are the following:

- The metals: arsenic, copper, nickel, mercury, and zinc. All five metals occur naturally in Puget Sound soil, sediment, and groundwater, and are common contaminants at industrial sites.
- TPH and its potential IHS: acenaphthene, fluorene, 1-methylnaphthalene, and 2-methylnaphthalene.
- cPAHs (as a summed TEQ).

All the COPCs for sediment, groundwater, and soil will be evaluated further in the next section, which discusses nature and extent of contamination.

5.0 Nature and Extent of Contamination

In Section 4.0, site data for all the toxic chemicals were evaluated with the most stringent screening level for that media to generate a list of the COPCs for the Site. This section further evaluates each of the COPCs identified in Section 4.0, including consideration of each media to be protected, as well as the relevant exposure pathways associated with each media. When evaluating cross-media pathways (e.g., soil concentrations protective of the highest beneficial use of groundwater), the nature and extent of exceedances in both the target media and the media to be protected will be considered to determine whether exceedances of screening levels in the target media translate to exceedances in the media to be protected.

The evaluation performed in this section results in identification of COCs among the COPCs for each media based on complete or potentially complete exposure pathways at the Site. This evaluation considers the nature and extent of contamination and the pathway to be protected relative to proposed cleanup standards for that pathway. In soil and groundwater, the proposed cleanup standards consist of the POC for the pathway and the CUL for the pathway. In these media, the proposed CUL is typically the most stringent screening level that is protective of the pathway being considered. In some cases, however, site-specific or analytical method-based factors are considered and an alternative CUL is proposed. For sediments, the proposed cleanup standards consist of the SCOs and CSLs, which are the lower and upper bounds, respectively, of the CUL at the POC. Finally, this section identifies AOCs for each media based on the location of exceedances of the cleanup standards.

5.1 CONTAMINANTS OF CONCERN AND CLEANUP STANDARD DEVELOPMENT APPROACH BY MEDIA

In recent years, the remedial extent of shoreline cleanup sites under MTCA and SMS has been driven by screening levels for cross-media pathways, including soil screening levels protective of groundwater quality, groundwater screening levels protective of surface water and sediment quality, and surface water and sediment screening levels protective of seafood consumers. These cross-media pathways are calculated using simple equilibrium models that represent very conservative possibilities for transport and exposure; they do not include naturally occurring attenuation processes and other site-specific factors that reduce chemical partitioning between media. This means the screening levels calculated in Section 4.0 are intentionally conservative, and do not represent conditions present at most sites.

The advantage of using low screening levels in the RI stage is that it forces the selection of very sensitive analytical methods, which results in data of sufficient quality to address the questions that arise during the RI/FS process. If a chemical does not exceed its calculated screening level in a particular media, the use of these low screening levels allows an *a priori* demonstration that the target media is protective of the receiving media. In cases where the target media exceeds the screening levels for a particular COPC, data from the media being protected can be used to determine whether the target media is protective of the receiving media following the procedures for performing an empirical demonstration, which is outlined in MTCA. For example, groundwater data can be used to demonstrate that soils are protective of groundwater, even if soil concentrations exceed the screening level at some locations (WAC 173-340-747(9)). This demonstration step distinguishes chemicals that are not migrating from one media to another (i.e., incomplete pathway) from those that either are migrating from one media to another, or that may do so in the future. As a result, the RI can focus on those chemicals that may require further action to eliminate or prevent migration from one media to another.

The data are gathered in the key environmental media and then used to determine which pathways are important for which chemicals for the specific site, and to evaluate what concentrations would actually protect the pathways.

During this stage, data from other media are used to inform the selection of COCs and cleanup standards for the target media. For example, no VOCs were detected in groundwater at concentrations exceeding the most stringent screening levels; therefore, the vapor intrusion pathway from groundwater was eliminated from further consideration. For soil, volatile aliphatic chemicals (i.e., those associated with a release of diesel fuel) are present in some locations, so the vapor intrusion pathway was retained.

The remainder of Section 5.0 evaluates the media in the following order: (1) sediments, both intertidal and subtidal, (2) groundwater, and (3) soil, including both saturated and unsaturated (vadose zone) soil. This order facilitates empirical demonstrations of the protectiveness of cross-media pathways.

5.2 SEDIMENT

Sediment COPCs were identified in Section 4.2.1. In this section, the sediments are divided into two areas, based on two different direct contact exposure pathways: intertidal sediments (discussed in Section 5.2.2) and subtidal sediments (discussed in Section 5.2.3). Cleanup standards specific to each of these areas will be developed in these sections. Risks associated with sediment exposure to bioaccumulative chemicals are evaluated separately (after the intertidal and subtidal sediments are evaluated for the direct exposure pathways) in Section 5.2.4. The cleanup standards developed in Section 5.2.5 apply to all sediments across the Site.

5.2.1 Establishing Site-Specific Sediment Cleanup Objectives and Cleanup Screening Levels

In accordance with SMS and the associated SCUM II, the sediment CULs could be set between the SCOs (the lower bound) and the CSLs (the upper bound), as shown on Figure 5.1. The specific CUL for each sediment COC is based on technical possibility and net adverse environmental impacts. This section determines the SCOs and CSLs for the Site for use in selection of the final CULs for the sediment COCs. For intertidal and subtidal sediments, the screening levels and site-specific information are used to identify the COCs for the Site. The screening levels are effectively the SCOs, but are not defined as such until the COCs have been identified. After the COCs in each sediment area have been identified, the SCO and CSL are developed for each COC. For the bioaccumulative chemicals, the process is slightly different and is detailed further in Section 5.2.4. During the development of COCs, the following must also be considered:

- **Different pathways apply to different areas** of the Site, especially between the intertidal areas and the subtidal areas; therefore, different areas of the Site will have different SCOs for the same chemical. Additionally, a chemical may be a COC in one sediment area and not in others.
- **Different compliance schemes are used for different pathways**. For example, protection of benthic species is assessed point-by-point, whereas protection of human and higher trophic level species health via direct contact or seafood consumption is assessed using a surface-weighted average concentration (SWAC).

In order to implement the approach, the following step-wise approach was used:

Step 1: **Intertidal Sediment:** Identify intertidal sediment SCOs and CSLs for the protection of benthic species and human direct contact by shipyard workers (excluding the bioaccumulative pathway). To evaluate benthic species, compare the intertidal sediment data to the SCO on a point-by-point basis to establish benthic COCs for the intertidal sediment area. To evaluate human direct contact by shipyard workers, compare the intertidal sediment data to the SCO on a SWAC basis to establish human direct contact COCs for the intertidal area.

Step 2: **Subtidal Sediment:** Identify subtidal sediment SCOs and CSLs for the protection of benthic species and human direct contact through net fishing (excluding the bioaccumulative pathway). To evaluate benthic species, compare the subtidal sediment data to these values on a point-by-point basis to establish benthic COCs for the subtidal sediment area. To evaluate human direct contact by net fishers, compare the intertidal sediment data to the SCO on a SWAC basis to establish human direct contact COCs for the subtidal area.

Step 3: **Bioaccumulatives:** Identify bioaccumulative COCs and their respective SCOs and CSLs. This includes establishing natural and regional background (either Ecology-derived or on a site-specific basis, depending on the chemical), and consideration of the PQL and area-wide tissue data. This step is discussed in Section 5.2.4.

This analytical approach results in the establishment of final COCs, CULs, and their associated AOCs. Per the SCUM II, in order to determine compliance with cleanup standards, CULs based on protection of benthic species will be evaluated on a point-by-point compliance, and CULs based on protection of human health via direct contact or seafood consumption will be evaluated on a SWAC basis. This is because benthic exposure occurs over an organism's lifetime in a very limited area, while human exposure over a lifetime occurs over a much larger area, as workers spend time working throughout the beach area and fishing could occur over a much larger area than could be represented by a single point.

5.2.2 Intertidal Sediment Area

The intertidal sediment area is divided into two sub-areas: the beach intertidal sediment area and the shipyard intertidal sediment area. These two sub-areas are shown on Figure 4.3.

The POC in the intertidal sediment area for protection of benthic species and direct contact with humans during shipyard activities is 0 to 12 cm. A POC of 0 to 12 cm for direct contact is appropriate because at the shipyard, the workers access the intertidal sediment area at low tide occasionally to reach structures (such as the marine railway) that are above and just below the sediment surface; therefore, they are not digging in the sediments, rather they are walking across the sediments at low tide to reach aboveground structures. For this site-specific exposure, the POC of 0 to 12 cm is appropriate and will simplify the intertidal sediment analysis by using the same POC for both human health and benthic species pathways.

Because compliance is measured differently depending on the exposure pathway, SCO, CSL, and COC identification for benthic species and for direct contact by shipyard workers are discussed separately in the following sections.

5.2.2.1 Protection of Benthic Species

As described above, identification of the benthic COCs is determined based on comparison to the SCO on a point-by-point basis for all chemicals. The SMS benthic SCOs expressed as their dry weight equivalents were identified as the appropriate screening levels for COC identification.

COC identification is performed in Table 5.1, which is a frequency of exceedance table of all the sediment COPCs that compares their concentrations in intertidal sediments against the intertidal sediment area benthic SCOs. The table is separated into two sections: (1) COPCs that exceed the SCOs and are retained as COCs; and (2) COPCs that are not retained as COCs. Based on this evaluation, the only benthic COCs for the intertidal sediment area are arsenic, copper, and zinc.

With the exception of lead and mercury, all other COPCs were eliminated as COCs because the results are less than the benthic SCO developed for this area of the Site. Lead and mercury were eliminated for the following reasons:

- Lead was eliminated because it was considered to be in compliance with the benthic SCO for benthic protection. At HA-07, a single sample in 2011 contained lead at levels greater than the screening level with a concentration of 580 mg/kg. This location was re-sampled in 2013, which resulted in a concentration of 44 mg/kg. The average value of both these results is 310 mg/kg. The screening level for lead is 450 mg/kg. All other intertidal sediments are in compliance for lead. Given this information, lead was eliminated as a COC.
- Mercury exceeded the screening level at one location, S-2. The sample was collected from the 0- to 2-foot interval; however, only the 0- to 12-cm interval (i.e., the top 12 cm of a 60-cm sample interval) is included in the POC. The concentration of 26 mg/kg exceeds the benthic SCO. Despite this exceedance, mercury is eliminated as a COC in intertidal sediments for the following reasons: (1) mercury contamination is limited to one location and is less than the SCO at two adjacent locations, S-1 and HA-03, (2) the location of sample S-2 is currently paved, (3) the concentration is significantly less than the shipyard worker screening level of 1,100 mg/kg, and (4) the mercury exceedance in S-2 will be remediated due to other metal COCs at the location.

Once the benthic COCs were identified as arsenic, copper, and zinc, CSLs were developed for each of the COCs. The SMS benthic CSLs were selected for use.

Although there are no LPAH exceedances in intertidal sediments, four LPAHs (acenaphthene, fluorene, 1-methylnaphthalene, and 2-methylnaphthalene) are considered potential IHS to evaluate TPH migration via uplands groundwater discharge into intertidal sediments. These chemicals were selected because they are mobile constituents of diesel, have sediment and surface water ARARs, and were detected in site groundwater. However, none of the LPAHs, including the four potential IHS, were detected in sediments at levels greater than SCOs. Intertidal sediments are in compliance with LPAH screening levels, which provides an empirical demonstration that the TPH present in the uplands does not result in sediment contamination. Therefore, these four potential IHS are not retained as COCs for intertidal sediments. These data will be evaluated during the discussion of TPH contaminant transport migration in groundwater in Section 5.3. Any LPAH that is retained as a COC in groundwater will be retained as an IHS in sediment.

5.2.2.2 Protection of Human Direct Contact

As described above, identification of the human direct contact COCs is determined based on comparison to the SCO on a SWAC basis for all chemicals. This evaluation is performed in Table 5.1, which presents the human direct contact SCOs and SWAC calculated within the intertidal area for comparison. The only COPC with a maximum concentration exceeding the human direct contact SCO was arsenic; therefore, only the SWAC for arsenic was calculated.

For arsenic, the screening level for protection of shipyard workers through direct contact (9.4 mg/kg) was adjusted upward to the natural background value for arsenic in uplands soils (20 mg/kg). Consideration was also given to adjusting the SCO to the arsenic natural background value developed for Puget Sound sediments as presented in the SCUM II (11 mg/kg). However, the concentration of arsenic in naturally occurring soils and sediments is a strong function of the redox environment and iron concentrations at the time of deposit. The Puget Sound subtidal sediment data used to derive the natural background value in the SCUM II are in a much less aerobic environment than the intertidal sediments, resulting in less arsenic deposition (and more leaching after deposition) than in intertidal areas. Therefore, of the two available natural background concentrations, one for soils and one for Puget Sound deep subtidal sediments, the soil natural background concentration was considered a better representation of intertidal sediment conditions. The current arsenic SWAC in the shipyard intertidal area is greater than the SCO of 20 mg/kg; therefore, arsenic was retained as a COC for the human direct contact pathway.

Once arsenic was identified as a COC, a CSL was developed. The proposed CSL is risk-based for protection of shipyard workers through direct contact (incidental ingestion and dermal contact) while working at the shipyard (at a cancer risk of less than or equal to 1 in 100,000).

A summary of the SCOs and CSLs for each of the COCs is presented in Table 5.2. The SCO defines the lower bound of a sediment CUL and the CSL defines the upper bound. The proposed CUL is presented in Section 5.2.5.

Table 5.2
Summary of Intertidal Sediment COCs and their Proposed SCOs and CSLs for Non-Bioaccumulative Pathways

Contaminant of Concern	Proposed SCO		Proposed CSL		POC
	mg/kg	Basis	mg/kg	Basis	
Benthic					
Arsenic	57	Benthic SCO	93	Benthic CSL	0 to 12 cm
Copper	390	Benthic SCO	390	Benthic CSL	0 to 12 cm
Zinc	410	Benthic SCO	960	Benthic CSL	0 to 12 cm
Human Direct Contact					
Arsenic	20	Soil natural background	94	Human Direct Contact at 1.0 x 10^{-5} Risk	0 to 12 cm

Table 5.3 presents sampling results for all intertidal sediment COCs. When available, data in the media to be protected supports cross-media pathway discussions, particularly when an empirical demonstration is needed. Figure 5.2 shows intertidal sediment sampling locations and results for

metals that became COCs. In the beach intertidal sediment area, up to the dry dock, the COCs are less than their respective SCOs. East of the dry dock, the Site transitions to an active work area and metal concentrations increase. Location S-2 in the marine railway area is the most contaminated sample.

5.2.3 Subtidal Sediments

The subtidal sediment area is shown on Figure 4.3. The POC in the subtidal sediment area for protection of both benthic species and direct contact with humans via net fishing is 0 to 12 cm.

Because compliance is measured differently depending on the exposure pathway, COC identification for benthic species and for direct contact to shipyard workers are discussed separately below.

5.2.3.1 Protection of Benthic Species

Consistent with intertidal sediments, the SMS benthic SCOs expressed as their dry weight equivalents were identified as the appropriate screening levels for COC identification.

COC identification is performed in Table 5.4, which is a frequency of exceedance table of all the sediment COPCs that compares their concentrations in subtidal sediments against the subtidal sediment area benthic SCOs. The table is separated into two sections: (1) COPCs that exceed the SCOs and are retained as COCs and (2) COPCs that are not retained as COCs. Some COPCs were eliminated because they met the following criteria:

1. The maximum concentration is less than 2 times the SCO.
2. Less than 10 percent of the samples exceed the screening level.
3. The exceedances do not form a cluster in space (generally defined as three locations).

Cadmium, mercury, lead, and PAHs with the exceptions of fluoranthene and pyrene were eliminated using these criteria. Additional COPCs were eliminated from further consideration for the reasons identified below:

- Butyl benzyl phthalate exceeded at a single location that was sampled twice (HG-10 in 1998 and HG-38 in 2000) and is bounded by concentrations less than the applicable screening level. Concentrations had already decreased between 1998 and 2000 (as shown in Table 5.5). Therefore, further investigation at this location for this COPC is unwarranted and butyl benzyl phthalate is not retained as a COC.
- Benzyl alcohol was detected in some of the older samples at concentrations greater than screening levels. There were no exceedances in more recent samples. Benzyl alcohol is a degradation product of toluene (a major component in gasoline and a minor component of other petroleum products). Its half-life in the marine environment is measured in days under aerobic conditions and weeks under anaerobic conditions (Wibbertmann et al. 2000, Harayama et al. 1999, and USEPA 1989). It has been eliminated as a COC because the samples containing the exceedances are more than a decade old and their concentrations have had time to come into compliance, consistent with the newer data.

Therefore, COCs for the subtidal sediments for the benthic pathway are: arsenic, copper, zinc, total PCBs, fluoranthene, and pyrene. CSLs were developed for each of the COCs. The SMS benthic CSLs expressed as their dry weight equivalents were selected for use.

While LPAHs were not retained as COCs for the subtidal sediments, their status as potential IHS for TPH at the Site warrants further discussion. Three LPAHs (2-methylnaphthahlene, anthracene, and phenanthrene) were detected in the subtidal sediments, but these LPAHs did not exceed SCOs in intertidal sediments and do not exceed screening levels in shoreline groundwater wells (refer to Section 4.2.2 and Section 5.3). Therefore, their presence in subtidal sediments does not indicate a pathway for TPH in the uplands to migrate to subtidal sediments. The only LPAH that became a COC in groundwater—1-methylnaphthalene—has no sediment exceedances in either the subtidal or intertidal sediments (refer to Table 4.7), again indicating no impact to sediments from TPH in the uplands.

5.2.3.2 Protection of Human Direct Contact

As described above, identification of the human direct contact COCs is determined based on comparison to the SCO on a SWAC basis for all chemicals. This evaluation is performed in Table 5.4, which presents the human direct contact SCOs and SWAC calculated within the subtidal area for comparison against the SCO. As in the intertidal sediments, the only COPC with a maximum concentration exceeding the human direct contact SCO was arsenic; therefore, a SWAC was calculated only for arsenic. The current arsenic SWAC in the shipyard intertidal area is greater than the SCO of 11 mg/kg, based on the natural background value for arsenic in subtidal Puget Sound sediments. Therefore, arsenic was retained as a COC for the human direct contact pathway.

Once arsenic was identified as a COC, a CSL was developed. Per the SCUM II (Figure 10-1), the risk-based CSL for protection of net fishers through direct contact at a cancer risk of less than or equal to 1 in 100,000 may be selected for use as the CSL (33 mg/kg). However, for conservatism, a CSL based on arsenic's site-specific regional background (derived in Appendix G, Attachment G.1 and described further below) was selected for use (13 mg/kg).

A summary of the SCOs and CSLs for each of the COCs is presented in Table 5.6 (embedded below). The SCO defines the lower bound of a sediment CUL and the CSL defines the upper bound. The CUL considers current and potential future exposure pathways. The proposed CUL is presented in Section 5.2.5.

Table 5.6
Summary of Subtidal Sediment COCs and their Proposed SCOs and CSLs for Non-Bioaccumulative Pathways

Contaminant of Concern	Proposed SCO		Proposed CSL		POC
	mg/kg	Basis	mg/kg	Basis	
Benthic					
Arsenic	57	Benthic SCO	93	Benthic CSL	0 to 12 cm
Copper	390	Benthic SCO	390	Benthic CSL	0 to 12 cm
Zinc	410	Benthic SCO	960	Benthic CSL	0 to 12 cm
Fluoranthene	1.7	Benthic SCO	2.5	Benthic CSL	0 to 12 cm
Pyrene	2.6	Benthic SCO	3.3	Benthic CSL	0 to 12 cm
PCBs	0.13	Benthic SCO	1.0	Benthic CSL	0 to 12 cm
Human Direct Contact					
Arsenic	11	Natural Background	13	Site-Specific Regional Background	0 to 12 cm

Figure 5.3 shows subtidal sediment sampling locations and metals results; Figure 5.4 shows subtidal sediment sampling locations and organics results. The patterns are similar to those for the intertidal sediment area. Subtidal sediments in front of Fairhaven Marine Park are protective of benthic and human health exposures. Moving toward the dry dock, concentrations increase for arsenic and are greater than the natural sediment background of 11 mg/kg, but are generally near 20 mg/kg (the soil background). Within 50 feet of the dry dock and moving east into the active operational areas of the Site, concentrations increase and the other COCs are detected at levels greater than their screening levels. On the east side of the Harris Avenue Pier, metal concentrations are bounded except for minor exceedances of arsenic (with detected concentrations of 12 and 14 mg/kg, compared to a natural background of 11 mg/kg). Of the eighteen sediment locations sampled east of the Harris Avenue Pier, seven show exceedances for cPAHs and five also have minor exceedances for pyrene and fluoranthene. These results do not include samples collected within the Interim Action area for the purpose of remedial design.

The nature and extent of PCBs in the surface subtidal sediments are shown in Figure 5.4. Consistent with previous investigations, the area that contains PCBs at concentrations greater than the SCO of 0.13 mg/kg are primarily located north of the marine railway area and in between the dry dock and the Harris Avenue Pier. Concentrations in the impacted area range from 0.22 to 1.8 mg/kg.

5.2.4 Bioaccumulative Contaminants of Concern and their Sediment Cleanup Objectives and Cleanup Screening Levels

Specific bioaccumulative chemicals were identified as COPCs for a pathway from sediments to fish to consumption by humans and higher trophic level species. This pathway is discussed in detail in Appendix G, Attachment G.1. Under the SMS Rule, the development of human health and higher trophic level species risk-based levels is a component of the overall sediment CUL development. As described in Section 5.2.1, the risk-based concentrations are used in conjunction with background concentrations and PQLs to derive SCOs and CSLs. The SCO defines the lower bound of a sediment CUL and the CSL defines the upper bound, with the final site-specific CUL defined on a site-by-site basis.

For the Site, the following seven chemicals or chemical groups have been evaluated for their potential as bioaccumulative COCs: arsenic, cadmium, lead, mercury, PAHs (including cPAHs for human health and pyrene for higher trophic level species health), PCBs, and dioxins/furans. The purpose of Appendix G, Attachment G.1 is to document the step-wise bioaccumulative COC screening process for these chemicals consistent with the SMS Rule requirements, which results in the determination of the final bioaccumulative COC list and the development of their associated CSLs. The step-wise screening process is summarized below and in Figure G.1.1, and is described in detail in Sections 2.0 through 4.0 of Appendix G, Attachment G.1:

Step 1: **Determine SCO.** The bioaccumulative COPC screening process initially requires the establishment of an SCO in accordance with WAC 173-204-560(2). The SCO is established as the highest of the following levels:

- The risk-based concentration that is the lower of:
  - The concentration of the contaminant based on protection of human health (at cancer risk of less than or equal to 1 in 1,000,000 or equal to a hazard quotient of 1, as specified in WAC 173-204-561(2), with lead considered separately). Human exposure pathways include direct contact with sediments via net fishing or working in the shipyard, or seafood consumption.

    - The concentration of the contaminant based on protection of higher trophic level species from bioaccumulative impacts as specified in WAC 173-204-564.
  - Natural background
  - PQL of the laboratory analytical limit

Step 2: SCO screening assessment. Once the SCOs are developed, all study area data are screened against these levels. Consistent with the COPC screening process described in Section 4.0, chemicals are retained for further evaluation as COPCs if their SCOs are exceeded in greater than 5 percent of sediment samples collected within the study area.

Step 3: Identification of COCs based on Bellingham Bay seafood tissue data. The SCUM II allows for tissue data to be used in a weight-of-evidence approach along with sediment data to further screen COPCs. SCUM II states that: "Tissue concentrations provide an indication of whether bioaccumulative chemicals are entering the food chain at concentrations that present unacceptable risks to humans and higher trophic level species, and they are a more direct estimate of exposure than sediment data." Therefore, finfish and shellfish tissue data within Bellingham Bay are evaluated to identify which COPCs potentially pose unacceptable human or higher trophic level species health risks. The bioaccumulative COPCs that were shown to potentially pose risk based on both tissue data and an exceedance of the SCO were identified as the final bioaccumulative COCs in sediments at the Site.

Step 4: CSL Development. After determination of the final bioaccumulative COCs, a CSL for each COC is developed. The CSL for each COC is established in accordance with WAC 173-204-560(3) as the highest of the following levels:

- Risk-based concentration of CSL. The risk-based concentration of the CSL that is defined as:
  - **Human health risk.** The concentration of the contaminant is calculated based on protection of human health (at carcinogenic risk of less than or equal to 1 in 100,000 or a non-carcinogenic risk of less than or equal to a hazard quotient of 1, as specified in WAC 173-204-561(2)).
  - **Higher trophic level species risk.** The concentration of the contaminant is calculated based on protection of higher trophic level species from bioaccumulative impacts as specified in WAC 173-204-564.
- Regional background if available. Natural background may be defaulted to if regional background is not available.
- PQL of the laboratory analytical limit.

Completion of Step 4 identifies the proposed CSLs associated with the identified bioaccumulative COCs at the Site. The CUL for each of COCs does not exceed the CSL in accordance with WAC 173-204-500.

Details of this analysis are presented in Appendix G, Attachment G.1. A summary of the rationale for the development of the final bioaccumulative COC list is presented below. Table 5.7 presents the SCOs and their CSLs for the bioaccumulative COCs:

- **Arsenic.** Unacceptable human and higher trophic level species health risk based on seafood tissue sample results is indicated for arsenic; therefore, arsenic is retained as a bioaccumulative COC.

- **Cadmium.** Unacceptable human or higher trophic level species health risk is not indicated for cadmium, however, there is uncertainty in whether the shellfish tissue samples used in the risk analysis are truly representative of the study area. To be conservative, cadmium is retained as a bioaccumulative COC.
- **Lead.** Unacceptable human or higher trophic level species health risk is not indicated for lead in the evaluation of seafood tissue; therefore, lead is not retained as a bioaccumulative COC and no additional analysis is required.
- **Mercury.** The frequency of exceedance of the bioaccumulative SCO was less than 5 percent; therefore, mercury is not retained as a bioaccumulative COC and no additional analysis is required.
- **cPAHs.** Risk analysis was not conducted for cPAHs because they were not detected in seafood tissue within Bellingham Bay. However, because uncertainty exists due to the elevated detection limits used for evaluation of cPAH in seafood tissue, cPAHs are retained as bioaccumulative COCs.
- **Pyrene.** Pyrene was never detected at a concentration greater than the SCO; therefore, pyrene is not retained as a bioaccumulative COC and no additional analysis is required.
- **Total PCBs.** Unacceptable human and higher trophic level species health risk is not indicated for PCBs when shellfish or finfish tissue results from the edible muscle of finfish (rather than the liver, which is not commonly consumed) are used in the risk analysis. However, because there exists uncertainty due to the elevated detection limits used for evaluation of PCBs in shellfish tissue, PCBs are retained as a bioaccumulative COC.
- **Dioxins/Furans.** Dioxin/furan concentrations are protective of human direct contact exposures, such as net fishing, while the concentrations exceed screening levels protective of seafood consumption by human and higher trophic level species. Therefore, for human seafood consumption, the CUL ranges between the SCO of 5 ng/kg based on the PQL and the CSL of 15 ng/kg based on the regional background. Four subtidal sediment samples were collected in the study area for dioxins/furans and are shown in Figure 5.5. Two samples located within the operational area of Fairhaven Shipyard (SG-06 and SG-07) have concentrations of 36 and 5.3 ng/kg, respectively. Samples SG-12 and SG-13 are outside the area of operations and are intended to represent the site regional background conditions. They had concentrations of 12 and 25 ng/kg, relative to the regional background of 15 ng/kg presented in the *Bellingham Bay Regional Background Sediment Characterization report* (Ecology 2015).

  SG-06 is located in the marine railway area, and will be addressed for a number of COCs. The other three samples have concentrations ranging from 5 to 25 ng/kg against the regional background of 15 ng/kg, and are believed to represent ambient conditions unrelated to site activities. This is consistent with the lack of a known source or release of dioxins/furans at the Site. Because the area around SG-06 will be addressed as part of AOC-1, it is recommended that dioxins/furans be eliminated as a COC.

Table 5.7
Summary of Bioaccumulative COCs and their Proposed SCOs and CSLs

	Proposed SCO		Proposed CSL	
Bioaccumulative	**mg/kg**	**Basis**	**mg/kg**	**Basis**
Arsenic	11	Natural Background	13	Site-Specific Regional Background
Cadmium	0.8	Natural Background	0.8	Site-Specific Regional Background analysis indicated that cadmium was not elevated in Bellingham Bay and calculated value is equivalent to natural background.
cPAH TEQ	0.016	Natural Background	0.14	Seafood consumption at 10^{-5} risk
Total PCBs	0.0055	PQL (selected based on the analytical limit used in the Harris Avenue Shipyard DGI and less than the average PQL identified in SCUM II Appendix D)	0.033	PQL (SCUM II Appendix D)[9]

5.2.5 Summary of Proposed Sediment Contaminants of Concern and Their Cleanup Standards

Table 5.8 summarizes the sediment COCs and their associated cleanup standards, which are described in more detail in the sections that follow.

5.2.5.1 Intertidal Sediment Area – Non-Bioaccumulative Pathways

The intertidal sediment area consisted of two areas with different exposures: the shipyard intertidal sediment area and the beach intertidal sediment area. SCOs and CSLs are developed for the intertidal sediment COCs for both of these areas. There are three benthic COCs for the intertidal sediment area: arsenic, copper, and zinc. There is one human direct contact COC: arsenic.

The proposed POC throughout the intertidal sediment area is 0 to 12 cm; this is appropriate for benthic protection. The 0 to 12 cm POC is also appropriate for direct contact, because the

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[9] The maximum PQL identified in SCUM II was selected as the PQL for the Total PCBs CSL. This value will be compared to the sum of PCB Aroclors to evaluate CUL compliance. This is consistent with the PQLs reported for the historical sediment data that are used in conjunction with newer data to calculate SWACs. PQLs for historical data collected by RETEC between 1998 and 2005 ranged from approximately 20 parts per billion (ppb) to 40 ppb. These data are presented in Appendix C of the RI/FS.

shipyard workers are only occasionally in the intertidal sediment area to perform maintenance on over-water structures, and are walking on the sediment surface in industrial work boots.

For the intertidal sediment COCs (arsenic, copper, and zinc), the proposed CUL is the SCO for both the benthic and human direct contact exposure pathways. For human direct contact, the arsenic criterion is based on natural background for soil because the SCO protective of direct contact is less than the natural background level. Arsenic is also evaluated separately as a bioaccumulative COC, described below. Criteria in the beach intertidal sediment area are SCOs protective of benthic species. There is no human direct contact pathway in this area and none of the COCs exceed SCOs in the beach intertidal sediment area. Compliance is measured on a point-by-point basis for the benthic COCs and a SWAC basis for human direct contact.

5.2.5.2 Subtidal Sediment Area – Non-Bioaccumulative Pathways

In the subtidal sediment area, arsenic, copper, zinc, fluoranthene, pyrene, and PCBs are benthic COCs, with arsenic also a human direct contact COC. SCOs for copper, zinc, fluoranthene, pyrene, and PCBs are proposed as their CULs for benthic protection. The POC is 0 to 12 cm, and the compliance approach is point-by-point. For arsenic, the CSL based on the site-specific regional background is proposed as the CUL for the human direct contact pathway. The POC is 0 to 12 cm, and the compliance approach uses the SWAC.

5.2.5.3 All Sediment Areas – Bioaccumulative Pathway

Arsenic, cadmium, cPAHs, and PCBs are bioaccumulative COCs in both the intertidal and subtidal sediment areas. Sediment compliance is evaluated on a site-wide SWAC basis. The POC for the seafood consumption pathway is 0 to 12 cm.

Table 5.8
Summary of Sediment COCs and their Proposed CULs

Contaminant of Concern	Area	Proposed CUL		POC
		mg/kg	Basis	
Benthic COCs evaluated on a point-by-point basis at POC				
Arsenic	Site-Wide	57	SCO; Benthic protection	0 to 12 cm
Copper	Site-Wide	390	SCO; Benthic protection	0 to 12 cm
Zinc	Site-Wide	410	SCO; Benthic protection	0 to 12 cm
Fluoranthene	Subtidal	1.7	SCO; Benthic protection	0 to 12 cm
Pyrene	Subtidal	2.6	SCO; Benthic protection	0 to 12 cm
PCBs	Subtidal	0.13	SCO; Benthic protection	0 to 12 cm
Human Direct Contact COCs evaluated on a SWAC basis at POC				
Arsenic	Shipyard Intertidal	20	SCO; soil natural background for the protection of direct contact by shipyard workers	0 to 12 cm
	Subtidal	13	CSL; site-specific regional background for the protection of direct contact by net fishers	0 to 12 cm
Bioaccumulative COCs evaluated on a SWAC basis at POC				
Arsenic	Site-Wide	13	CSL; Site-specific regional background	0 to 12 cm
Cadmium	Site-Wide	0.8	CSL; Regional background equivalent to natural background	0 to 12 cm
cPAH TEQ	Site-Wide	0.14	CSL; Seafood consumption at 1.0×10^{-5} risk	0 to 12 cm
PCBs	Site-Wide	0.033	CSL; PQL (SCUM II, Appendix D)[1]	0 to 12 cm
Non-Bioaccumulative IHS evaluated on a point-by-point basis at POC				
1-Methylnaphthalene[2]	Intertidal	410	SCO; Direct contact via shipyard workers at 1×10^{-6} risk	0 to 12 cm

Notes:

1 The maximum PQL identified in SCUM II was selected as the PQL for Total PCBs. This is consistent with the PQLs reported for the historical sediment data that are used in conjunction with newer data to calculate SWACs. PQLs for historical data collected by RETEC between 1998 and 2005 ranged from approximately 20 ppb to 40 ppb. These data are presented in Appendix C of the RI/FS.

2 This IHS does not exceed SCOs, and so did not become a COC; it is included in this table because it is of interest for other pathways.

5.2.6 Proposed Sediment Areas of Concern

The AOC for sediments is defined using SCOs for the exposure pathways where compliance with CULs is based on point-by-point comparisons, consistent with the SCUM II. For the benthic

COCs, copper, zinc, fluoranthene, and pyrene, the SCO was used to determine the extent of the AOC.

For human direct contact COCs and bioaccumulative COCs, compliance with CULs is evaluated on a SWAC basis. Rather than SCOs or CSLs being selected to define the sediment AOC, RALs were selected for the human direct contact and bioaccumulative COCs; a RAL is defined as a contaminant concentration that must be addressed point-by-point to achieve the CUL on a SWAC basis.

For arsenic, a RAL of 20 mg/kg is used, which is protective of benthic species and direct contact through beach activities and results in site-wide compliance with the SWAC; for cadmium and PCBs, the SCOs protective of benthic species were used (5.1 mg/kg and 0.13 mg/kg respectively); and for cPAHs the SCO of 4.2 mg/kg for the protection of direct contact through net fishing was used. The use of RALs for the bioaccumulative COCs will be discussed further in the FS.

Figure 5.6 shows AOC 1, which, consistent with previous investigations, contains the primary areas of operations between the dry dock and the Harris Avenue Pier, including the marine railway area. It also includes the area around the dry dock extending to HG-10 and HG-38. AOC 1 will be carried into the FS for further evaluation with respect to remedial alternatives.

5.3 GROUNDWATER

Groundwater data collected from monitoring wells within the last 5 years were used to identify the COCs at the Site and determine the nature and extent of contamination. All wells are completed in the upper portion of the shallow aquifer at the Site. At Ecology's request, as part of additional groundwater monitoring, two additional shoreline wells, MW-11 and MW-12, were installed and all shoreline monitoring wells were sampled quarterly for a year for chemicals likely to become groundwater COCs for the Site. These data were intended to fill spatial gaps in the shoreline monitoring well network. This was completed and the results have been used to inform determination of COCs and AOCs in the RI and alternatives considered in the FS.

The water table across the Site varies seasonally between approximately 8 to 10 feet bgs. The water table also varies with the tide, especially near the shoreline. For consistency in this document, the demarcation line between saturated and unsaturated zones is defined as 8 feet bgs. Near the shoreline at high tide, water will rise above this line for minutes to a few hours, and then drop below it. Inland, the soil between 8 and 9.5 feet is damp, but not always fully saturated.

Ecology determined the aquifer is non-potable (Section 3.3.1) and drinking water exposure is not considered an applicable pathway (Section 4.1.4). As discussed in Section 4.0, although the cross-media pathway for groundwater for the protection of indoor air is not currently a relevant exposure pathway for the Site, it is retained for protection of future potential site uses. Based on the existing data, the only VOCs of concern at the Site are volatile components of diesel fuel. Of those, the only VOCs detected at levels of concern in soil vapor were C_9 to C_{12} aliphatics. These chemicals are present in site soils, but are not soluble in water, and are not detected in groundwater.

Groundwater cleanup standards are established in this section. Groundwater cleanup standards are composed of the proposed CUL combined with the POC, which is the location where the proposed CUL must be met.

The proposed CULs for groundwater are numerically equivalent to the screening levels developed in Section 4.1.4 for all COPCs, with the exception of LPAHs. Proposed CULs for LPAHs are based on the screening level developed for protection of surface water quality, rather than the more stringent screening level developed for protection of sediment quality. As described in Section 5.2, sediment data demonstrate that none of the LPAHs retained as COPCs in groundwater were detected in sediment. Thus, site sediment data demonstrates empirically that site groundwater is already protective of sediment for these LPAHs. The proposed CULs for all other COPCs are protective of surface water, sediment, and indoor air.

The groundwater POC is at the shoreline where groundwater discharges into surface water through the sediments. The existing shoreline monitoring wells (MW-10, MW-06, MW-09, MW-11, MW-02A, MW-12, MW-07, and MW-08) are compliance monitoring wells. Monitoring well MW-10 is located off-site and may represent groundwater quality influenced by neighboring facilities; therefore, though it is a shoreline well, it is not considered a compliance monitoring well.

Groundwater COCs were determined based on compliance with the groundwater cleanup standards, i.e., by evaluating the frequency with which COPCs exceeded the proposed groundwater CULs in conjunction with the location of groundwater exceedances.

MTCA allows groundwater compliance to be determined using the true mean concentration for each well for chemicals whose proposed CULs are based on chronic or carcinogenic effects, as long as no single sample concentration in a compliance well is more than twice the proposed CUL, and no more than ten percent of the measured concentrations exceed the proposed CUL (WAC 173-340-720(9)(e)).

This evaluation is performed in Tables 5.9 and 5.10. Table 5.9 is a frequency of exceedance table that compares results from each event for each COPC to the proposed CUL. Table 5.10 presents groundwater results for all COPCs site-wide, both individually by event and as a location-specific average concentration. Table 5.10 also identifies whether each monitoring location is an interior well or shoreline well. In both tables, COPCs that exceed the screening levels and therefore became COCs are presented separately from COPCs that are not retained as COCs. The results of this evaluation are described in the sections that follow.

5.3.1 Metals

Arsenic, copper, and zinc were retained as groundwater COCs on the basis of exceedances of their proposed CULs in several shoreline wells. Nickel was not retained as a groundwater COC. Results are discussed individually in the sections that follow, and are shown on Figure 5.7. These metals are measured in the dissolved fraction because the proposed CULs are derived from surface water ARARs that are based on chronic effects caused by dissolved metal concentrations in the water column. To assess compliance, it is appropriate for the fraction measured to match the fraction regulated.

5.3.1.1 Arsenic

The proposed CUL for arsenic is based on an Ecology-established statewide natural background concentration of 5 µg/L. This concentration was established in 1991 based on data collected in 1989; more recent sampling indicates that statewide natural background concentrations are likely closer to 10 µg/L (Ecology 2010b [pp. 14–16]). Arsenic concentrations at the Site tend to vary between 3 and 8 µg/L in many wells and likely represent area-wide background conditions.

At most locations, arsenic concentrations in groundwater typically vary around a natural background concentration that is likely between 5 and 10 µg/L. The only locations where the average arsenic concentrations exceed the state's natural background concentration of 5 µg/L are MW-01, MW-09, and MW-11.

MW-01 is an interior well that has exceeded the proposed CUL in every sampling event since 2013. The average concentration for this well is 19 µg/L. MW-09 and MW-11 are both downgradient of MW-01, and also display evidence of arsenic contamination. Average arsenic concentrations in MW-09 and MW-11 are 17 µg/L and 8.7 µg/L, respectively.

The higher arsenic concentrations in these wells is likely due to the apparent TPH release in this area surrounding the former AST, where the top of the aquifer is contaminated with petroleum, resulting in biological degradation, which has caused localized anaerobic conditions. These conditions allow the naturally occurring arsenic in the soil (or in sandblast grit co-mingled with the surface soil) to be reduced to a more soluble form that then dissolves into groundwater.

The relationship between arsenic and TPH was determined by evaluating the relationship between TPH and arsenic concentrations in groundwater samples measured across the Site (Appendix C, Table C.8). At locations where TPH concentrations are greater than 1,000 µg/L, corresponding arsenic concentrations are more elevated than locations with concentrations less than 1,000 µg/L, indicating that arsenic is liberated more in the areas with more petroleum contamination. Therefore, at levels greater than 1,000 µg/L, active remediation should be considered to reduce the arsenic concentration in groundwater; at levels less than this value there is no indication that TPH concentrations are controlling arsenic concentrations.

The most effective way to reduce arsenic concentrations in the vicinity of MW-01 and MW-09 will likely be to reduce TPH groundwater concentrations to less than 1,000 µg/L from previous concentrations of 1,300 to 4,700 µg/L in groundwater. This is discussed in more detail in Section 5.3.5, which defines groundwater AOCs.

5.3.1.2 Copper and Zinc

As shown in Table 5.10, copper exceeded the proposed CUL in all events at shoreline wells MW-02A and MW-12, with average concentrations of 7.3 and 10 µg/L, respectively. In other wells, copper exceeded the proposed CUL in a few events at MW-07 and MW-08 but the average concentrations were less than the proposed CUL.

Zinc follows a similar pattern as copper. Zinc exceeded the proposed CUL in all events (except for one) at shoreline wells MW-02A and new well MW-12, with average concentrations of 100 and 260 µg/L, respectively. In other wells, zinc is consistently measured at concentrations that are an order of magnitude less than the proposed CUL.

Site-wide, soil concentrations for copper and zinc are not predictive of groundwater concentrations (refer to Figures 5.8 and 5.9). Although there is surface contamination of copper and zinc throughout the Site in surface soils (refer to Section 5.4.2), groundwater only exceeds the proposed CULs at two shoreline wells (MW-02A and MW-12). The highest concentrations of copper and zinc in soil are typically within the upper 2 to 4 feet, in locations where sandblast grit has been entrained in soil. Areas impacted by sandblast grit are not necessarily proximate to the locations of the two shoreline groundwater wells where copper and zinc exceed the proposed CULs. Additionally, based on soil sampling logs, soil samples collected throughout the Site were often preferentially collected from soil with visible sandblast grit, rather than soil without visible sandblast grit impacts. Therefore, the soil samples with high concentrations of these metals may overestimate average soil concentrations in a particular area, which may explain the lack of apparent correlation between soil and groundwater in many areas of the Site.

At MW-12, however, soil concentrations of copper and zinc exceed the screening levels developed for protection of groundwater (which default to natural background soil concentrations of 36 and 85 mg/kg for copper and zinc, respectively) down to 14 feet bgs. The MW-12 groundwater well is screened from 5 to 15 feet bgs, so it is likely that metals in soil throughout the screened interval contribute to groundwater contamination at this location.

In the vicinity of MW-02A (extending out to FS-09), soil samples are not available as characterization of this area was prevented by the presence of large immobile equipment. This results in groundwater uncertainty in this area because the source of metals concentrations in groundwater at MW-02A is unknown. Although it may be due to soil contamination upgradient of the well, it is possible that a soil layer existed at MW-02A with elevated metals but was not sampled, as the screened interval samples are either clean (i.e., zinc) or at a concentration just greater than background (i.e., copper).

5.3.1.3 Nickel

Unlike for other metals, there are limited occurrences of elevated detections of nickel in site groundwater data. Nickel detections at concentrations exceeding the screening level of 8.2 µg/L are sporadic and do not appear to be linked to site activities or releases. Although nickel does occasionally exceed the screening level at wells MW-02A and MW-10, when groundwater data collected between 2011 and 2013 are also reviewed, nickel concentrations are believed to indicate background conditions consistent with natural variation around a background value of approximately 8 µg/L.

Elevated concentrations of nickel in well MW-02A during the March 2011 sampling event may have been caused by saline matrix interferences with the analytical method. Nickel is usually analyzed at mass 60, which has a significant sodium chloride interference in analysis methods that use a collision cell reactor, including those used by ARI to analyze for nickel in Harris groundwater samples. Sodium chloride has an atomic mass of 58.44, while nickel has an atomic mass of 58.69. This can cause a significant and possibly incurable saline matrix interference in samples with high specific conductivity (greater than approximately 10,000–12,000 µS/cm). This was addressed in February 2013 by timing the sampling event to coincide with low tide.

During the February 2013 event, the only well with elevated nickel concentrations was MW-10, where nickel was detected at a concentration of 9.0 µg/L. MW-10 is a shoreline well that is located off-site, north of the Harris property boundary. Measured specific conductivity in this well was greater than that of most other wells during the same event, indicating that saline matrix interference may have influenced sampling results. The elevated nickel result in this well may also have been caused by off-site conditions or natural variation around a background concentration of 8 µg/L resulting from the Site's location in the Padden member of the Chuckanut Formation. Regardless of the cause, Ecology agreed that sampling for nickel could be discontinued after the February 2013 event on the basis of sporadic detections that did not indicate evidence of a nickel release.

For nickel, soil data demonstrates even more clearly that there is no sign of a nickel release at the Site. Concentrations at all depths are similar and are spatially distributed across the Site similar to a typical background distribution. This is discussed further in Section 5.4.2.1 and associated figures. Because there is no soil source to groundwater, and no evidence of a nickel release or groundwater contamination issue anywhere within the Site property boundary, and because nickel exceedances were likely due to saline matrix interferences, nickel was eliminated as a groundwater COC.

5.3.1.3 Metals Summary and Recommendations

Arsenic is retained as a groundwater COC due to its elevated concentrations in the area of the TPH release, represented by shoreline wells MW-09 and MW-11.

Copper and zinc are retained as groundwater COCs due to their presence at shoreline wells MW-02A and MW-12. Site-wide, the copper and zinc groundwater data do not correlate with soil concentrations spatially to form a plume and there does not appear to be a seasonal effect on groundwater concentrations, as shown in Table 5.10.

A summary of the groundwater COCs and their CULs is presented below in embedded Table 5.11.

5.3.2 Indicator Hazardous Substances for TPH: LPAHs

As discussed in Section 4.0, TPH is evaluated in groundwater at the Site using LPAHs as IHS. The following four LPAHs were identified as COPCs in groundwater, and are candidates to become IHS in groundwater: acenaphthene, fluorene, 1-methylnaphthalene, and 2-methylnaphthalene. The proposed groundwater CULs for these potential IHS are based on protection of surface water quality for human health exposure. This pathway is protective of carcinogenicity and systemic toxicity effects; thus, it is appropriate to compare average groundwater concentrations at each well to the proposed CULs.

Figure 5.10 presents the average concentrations of all sampling events conducted between 2013 and 2015 for the LPAHs that were retained as potential IHS (1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, and fluorene). Results for cPAHs are also shown in the figure. Table 5.10 presents the groundwater concentrations from sampling events conducted between 2013 and 2015 for groundwater COPCs.

The data indicate the following:

- These four LPAHs are detected in eight of the wells at the Site, including both shoreline and interior wells. The greatest exceedances of screening levels for all of these LPAHs occur in MW-01, an interior well.
- Three of these LPAHs (2-methylnaphthalene, acenaphthene, and fluorene) only exceed the proposed CULs in one interior well, MW-01. 2-methylnaphthalene only exceeds in one sampling event at this well, with an average concentration of 33 μg/L (slightly greater than the proposed CUL of 32 μg/L). There are no exceedances of the proposed CUL at the POC (shoreline wells) for these three LPAHs. Therefore, they are eliminated as COCs.
- MW-09 and MW-11 are downgradient of the area around MW-01. 1-methylnaphthalene exceeds the proposed CUL in all sampling events at shoreline well MW-09, but is in compliance with the proposed CUL in all samples collected from MW-11. Based on these results, only 1-methylnaphthalene is retained as a groundwater COC.
- In all shoreline wells other than MW-09, average concentrations of acenaphthene, fluorene, and 1-methylnaphthalene are an order of magnitude less than the proposed CUL.

Based on these results, 1-methylnaphthalene is an appropriate chemical to use as an IHS for TPH. It is the only LPAH that is retained as a COC, and its mobility in groundwater confirms that it is an appropriate chemical to use as a surrogate for TPH in groundwater. Therefore, it is the only LPAH that is retained as an IHS in sediment.

During the 2017 Interim Action activities, soil with petroleum contamination was removed in the vicinity of MW-09 where 1-methylnaphthalene was greater than the proposed CUL in groundwater. Because the previous groundwater data for MW-09 may not represent current groundwater conditions, future compliance monitoring in this well is needed to confirm whether 1-methylnaphthalene still exceeds the proposed CUL and whether TPH in the former AST area is impacting sediment or surface water quality. Until such data are available, 1-methylnaphthalene (and by extension TPH) is considered a groundwater COC for the Site.

5.3.3 Other Organics

As shown in Table 5.10, MW-01 exceeded the proposed CUL for cPAHs in three events during 2013 and 2015. The average concentration in this well is 0.03 µg/L, which is greater than the proposed CUL of 0.01 µg/L. From previous sampling events, this well contains TPH at concentrations near its solubility limit (refer to Appendix G, Attachment G.2). Although free product is neither visible nor measureable in the well, the groundwater here likely contains finely dispersed micelles of petroleum into which the cPAHs are partitioned, allowing them to be present at higher concentrations than their chemical properties would predict. As the groundwater travels toward the Bay, passing through MW-09, concentrations of the COPCs drop, and cPAHs are either no longer detected or detected at low concentrations (Figure 5.10).

At newly installed shoreline monitoring well MW-11, however, the average cPAH concentration is 0.015 µg/L, which is slightly greater than the proposed CUL. In three sampling events, cPAHs were non-detect. In the February 2015 event, the reporting limit is elevated relative to the typical PQL, and in the December event, the measured result was 0.016 µg/L. This may indicate a seasonal trend for increased cPAHs during fall and winter months, when tidal flushing and increased rainfall result in a rise in the average depth of the water table at the Site.

MW-01 and MW-11 are located between the original 1890s shoreline and the current shoreline (refer to Figure 3.2), and it is also possible that these results are measuring groundwater concentrations influenced by a historical piling or timber that was creosote-treated, representing a very localized cPAH source. Soil samples collected at locations nearby MW-01 (FS-20) were non-detect or detected at low concentrations (less than 0.05 mg/kg). These concentrations are similar to soil concentrations measured elsewhere at the Site where cPAHs are not of concern in groundwater, indicating that soil is not the primary source to groundwater at these locations.

Although they slightly exceed at a shoreline well, cPAHs are not retained as COCs for groundwater. The presence of cPAHs in diesel is unusual, and probably not directly related. The diesel is likely facilitating the presence of cPAHs in groundwater. Remediation of diesel is therefore expected to address cPAH contamination; this final compliance is demonstrated if groundwater is in compliance at the POC shorelines wells.

5.3.4 Summary of Proposed Groundwater Contaminants of Concern and Their Cleanup Standards

Table 5.11 summarizes groundwater cleanup standards for COCs and IHS.

Table 5.11
Summary of Groundwater Cleanup Standards for COCs and IHS

Contaminant of Concern[1]	POC[2]	Proposed CUL[3] Units (µg/L)	Proposed CUL[3] Basis
Arsenic	Shoreline	5.0	Natural background.
Copper	Shoreline	3.1	Protection of surface water quality.[4]
Zinc	Shoreline	81	Protection of surface water quality.
TPH	Shoreline	NA	1-methylnaphthalene as an IHS used to evaluate compliance for TPH.[5]
1-Methylnaphthalene	Shoreline	1.5	IHS used to evaluate compliance for TPH.

Notes:

1 For metals, compliance with the proposed CULs is assessed using filtered groundwater samples; in surface water, the criteria are applicable to dissolved metals in the water column.

2 The POC for this pathway is where groundwater discharges to surface water, which is represented by shoreline monitoring wells (compliance wells). These wells are MW-06, MW-09, MW-11, MW-02A, MW-12, MW-07, and MW-08.

3 Each of the proposed CULs is based on chronic or carcinogenic effects. Therefore, groundwater compliance is determined using the true mean concentration for each well as allowed by MTCA (WAC 173-340-720(9)(e)). Accordingly, to be considered in compliance, no single sample concentration in a compliance well can be more than twice the proposed CUL, and no more than ten percent of the measured concentrations may exceed the proposed CUL.

4 The toxicity of copper in the aquatic environment is impacted by site-specific water quality variables, including temperature, dissolved organic carbon, salinity, and pH. In 2016, the U.S. Environmental Protection Agency (USEPA) published draft estuarine/marine copper Ambient Water Quality Criteria (USEPA 2016), enabling calculation of a site-specific CUL protective of aquatic life in marine waters. Ecology may approve calculation of a site-specific CUL per WAC 173-201A-240, Table 240, footnote dd.

5 Three LPAHs are already in compliance with groundwater cleanup standards throughout the Site, but were evaluated as potential IHS for TPH. Groundwater data do not indicate that cleanup is required for these chemicals.

5.3.5 Proposed Groundwater Areas of Concern

Groundwater is in compliance with the proposed cleanup standards at compliance wells throughout the Site with the exception of arsenic at MW-09 and MW-11, copper and zinc in MW-02A and MW-12, and 1-methylnaphthalene in MW-09.

Copper and zinc are present at elevated concentrations in soil at locations MW-02 and MW-12, which may be the source of elevated copper and zinc detections in groundwater in these wells. As discussed in Section 5.4, addressing copper and zinc in soil in these areas is expected to address groundwater contamination in these wells, and, therefore, separate groundwater AOCs surrounding wells MW-02A and MW-12 have not been defined.

Though arsenic in groundwater exceeds at MW-09 and MW-11, no groundwater AOC is defined based on these exceedances because the best approach to treat arsenic in groundwater is to address TPH in the soil. Elevated concentrations of arsenic are often attributable to reducing geochemical conditions in the groundwater, rather than to releases of arsenic-containing products. Reducing conditions are present at locations where TPH releases have occurred.

Additionally, at MW-09, groundwater data collected in 2015 may not represent current groundwater conditions. Soil with petroleum contamination was removed in the vicinity of MW-09 during the 2017 Interim Action activities. Therefore, future compliance monitoring in this well is needed to confirm whether arsenic still exceeds the proposed CUL and whether the TPH release in the former AST area is impacting sediment or surface water quality. This will be discussed in further detail when soils are discussed in Section 5.4.

5.4 SOIL

This section identifies soil COCs from among the COPCs identified in Section 4.0 and identifies the nature and extent of contamination for each. As described in Section 4.0, several metals were detected in virtually all soil samples. Organic chemicals frequently detected across the Site were PAHs, PCBs, and the VOC ethylbenzene. Other organics retained as COPCs were either detected in more than 5 percent of the soil samples or present at concentrations more than two times the lowest applicable screening level.

Based on historical operations at the facility discussed in Section 2.0, the primary sources of contamination to soils were expected to be metals from marine paints and sandblast grit, and petroleum components from oils and greases associated with ship and boat maintenance activities. There was also a historical diesel AST south of MW-01. The soil results are very consistent with these expectations, with metals and petroleum-related chemicals being the majority of the detections.

In order to identify the chemicals that are COCs at the Site, the standard procedure is to compare their concentrations to their cleanup standards. Cleanup standards include both a proposed CUL and a POC where the level must be met. This is complicated because each of the soil exposure pathways has its own POC, which apply to different soil depth intervals. The screening levels and their associated POCs for each pathway are listed below, and are based on screening levels developed in Section 4.0:

- Protection of industrial workers through direct contact (incidental ingestion and dermal contact). The default POC for this pathway is the top 15 feet of soil.
- Protection of soil leaching to groundwater in the unsaturated (vadose) zone. This pathway is applicable to soil above 8 feet bgs.
- Protection of soil leaching to groundwater in the saturated zone. This pathway is applicable to all soils below 8 feet bgs.

Soil COCs and their associated cleanup standards will be identified using the following steps:

Step 1: For each of the soil exposure pathways, COPC concentrations at the appropriate POC are evaluated individually. COPCs that are in compliance are eliminated as COCs for the subject pathway.

For the two leaching pathways, if soil data exceed the leaching screening levels, groundwater data is considered. If the chemical did not become a groundwater COPC (either because the chemical was never detected in groundwater or did not meet the criteria to become a COPC), then groundwater is considered “clean,” the leaching pathway is considered incomplete, and the chemical is not retained as a COC for that pathway in soil. If the chemical was retained as a COPC in groundwater, a more thorough analysis is performed.

This evaluation is shown in Table 5.12, which presents the frequency of exceedance information for soil COPCs, separated by the individual pathways.

Step 2: For the COPCs that remain, proposed CULs are developed that simplify and combine requirements associated with the individual exposure pathways.

Step 3: The nature and extent of the remaining COPCs and their proposed CULs are evaluated to develop the final list of soil COCs and their associated proposed CULs and POCs.

Soil AOCs for the Site are defined using the information in Step 3.

Soil results for soil COPCs that were retained as COCs or that are included in the discussion of the nature and extent of contamination in the subsections that follow are included in Table 5.13. PCBs are not included in Table 5.13 because soil results do not indicate that PCB contamination is present at the Site. PCBs associated with two pads with outdoor transformers were tested prior to this RI/FS and are discussed in Section 2.3.2. The data indicated that the transformers were not a source of PCBs to the rest of the Site. However, PCBs can be present in other materials that may have been encountered on-site, including marine paints and caulks; therefore, additional samples were collected around the Site. PCBs were not detected at concentrations exceeding direct contact criteria. A complete listing of all site soil data, including PCBs, is included in Appendix C.

5.4.1 Metals: Arsenic, Copper, Lead, Mercury, Nickel, and Zinc

Based on information presented in Table 5.12, arsenic, copper, and zinc are COCs and will be discussed further in this section. Lead, mercury, and nickel are not retained as COCs; the discussion of why they were eliminated is presented in this section.

5.4.1.1 Distribution

The use of sandblast grit containing metals that has become entrained in surface soils is the probable source of arsenic, copper, zinc, and other metals in surface soils. When RETEC performed their test pit soil sampling in 1998, they focused on worst case conditions; specifically, as stated in their report, “for the test pits, sampling was focused on those soils which, based on field observations (presence of debris, sand blast grit, petroleum staining, elevated photoionization detector (PID) readings, odors, etc.) had a substantial probability of chemical contamination” (RETEC 1998b). These test pit samples and a few other soils in the top 2 feet of soil borings consistently contain the highest metal concentrations on the Site. Below 3 to 4 feet bgs, the soil has significantly lower concentrations, and visually resembles a disturbed (but not contaminated) native soil horizon.

Figure 5.11 shows metals results by depth for arsenic, copper, lead, nickel, and zinc. Arsenic, copper, lead, and zinc concentrations exhibit a pattern that indicates surface impacts that rapidly attenuate with depth. In the upper 4 feet (generally the upper 2 feet), concentrations can be quite elevated. Between 4 and 8 feet bgs, concentrations drop sharply, with only two locations continuing to show exceedances. Below 8 to 9 feet, arsenic, lead, and zinc concentrations at the Site are less than Puget Sound background concentrations. Copper concentrations detected below 9 feet bgs also decrease significantly relative to the concentrations detected in the vadose zone; however, there are still some areas of the Site that exceed Puget Sound background concentrations at depth. The data for arsenic, copper, and zinc in the 0 to 4 feet bgs and 4 to 8 feet bgs depth intervals are shown spatially in Figure 5.12.

Unlike the other metals, nickel concentrations follow a normal distribution that does not vary with depth. Nickel concentrations are indistinguishable from the surface down to well into native glacial soils, expected to be encountered at 6 to 12 feet bgs across large sections of the Site. Although the nickel background level predicted by these data (73 mg/kg) is greater than the statewide nickel background developed by Ecology (38 mg/kg), the Site overlies the Chuckanut Formation, which includes nickeliferous iron deposits with nickel concentrations at the percent level (Frizzell 1979, Mills 1960). Reworking of those deposits resulting in nickel-enriched glacial soils at the Site would not be unexpected. The consistency of nickel concentrations with depth, as shown on Figure 5.11, indicates that itis at a naturally occurring background level at the Site; therefore, it is not considered a COC for soils.

Though mercury is not shown on Figure 5.11 or Figure 5.12, results in Table 5.13 show mercury follows a similar pattern as arsenic, lead, and zinc, indicating the probable source of mercury is sandblast grit. The screening level for mercury was developed based on elemental mercury. Elemental mercury is not found in sandblast grit/paint, but mercuric chloride is. Therefore, mercury concentrations are more appropriately compared to mercuric chloride standards. The MTCA Method C CUL for mercuric chloride is 1,000 mg/kg, more than an order of magnitude higher than the greatest mercury detection on-site (17.6 mg/kg at location Soil 2-A/2-B) and therefore is not considered a COC for soils.

5.4.1.2 Direct Contact Pathway for Human Health

For this pathway, soil concentrations throughout the Site are evaluated down to 15 feet bgs. The only COPC that poses a risk for direct contact to industrial workers at the Site is arsenic (Table 5.12). Figure 5.11 presents the arsenic results at various depths within the 0 to 15 feet depth interval. Figure 5.12 spatially displays the data for the upper 8 feet where the majority of the elevated arsenic concentrations are present. For convenience, the figure displays metals data in two depth intervals: 0 to 4 feet bgs and 4 to 8 feet bgs. Arsenic was detected at concentrations greater than the screening level in 10 percent of the samples; all but two of these samples are located in the upper 2 feet of the soil column. Contamination at FS-23 extends to approximately 3.5 feet bgs, while contamination at MW-11 extends to approximately 3 feet bgs. Arsenic is retained as a COC for the direct contact pathway, with a CUL of 88 mg/kg, which is the standard MTCA Method C value.

Because the existing data collection in the upper 4 feet was designed to capture worst case conditions in visually contaminated areas, the alternative to address arsenic in site soils presented in the FS will include the collection of additional surficial data (i.e., data in the upper 4 feet of the soil column) as necessary to design an appropriate areal extent for the remedial action.

Additionally, by remediating soils with arsenic concentrations greater than 88 mg/kg, a significant amount of zinc, mercury, lead, and copper is also addressed because these metals tend to co-occur with the arsenic. Copper, mercury, and zinc are in compliance with criteria developed for the protection of the direct contact pathway, but a remedial action will reduce the source mass of metals at the Site that could be leached to groundwater, as discussed in the following section.

5.4.1.3 Protection of Groundwater Quality

This exposure pathway addresses the potential for contamination present in soil to be leached to groundwater, contaminating groundwater at levels of concern. Under MTCA, this pathway is evaluated by calculating soil concentrations to protect groundwater using the 3-phase model and partitioning coefficients. The model does not consider the form of the constituent in soil, site-specific soil properties, or a number of other site-specific considerations, and many of the partitioning coefficients have never been measured, but instead are based on another uncalibrated model. For this reason, MTCA lists multiple ways to determine compliance along this pathway, including using groundwater monitoring results to demonstrate compliance.

For the purposes of this RI, groundwater monitoring results have been used to assess this pathway. Because the Site is largely unpaved and sufficient time has elapsed for soil conditions at the Site to reach equilibrium with groundwater, the groundwater results are considered representative of the actual potential for leaching to groundwater.

Section 5.3.1 discussed the distribution of metals in groundwater, identified COCs, and proposed CULs. Detection limits were low enough that most metals were detected in at least a third of the samples, consistent with the natural prevalence of metals in soil and groundwater. Four metals exceeded their respective groundwater screening levels: arsenic, copper, nickel, and zinc. Based on the groundwater results presented in Section 5.3, only arsenic, copper, and zinc need to be evaluated for compliance for this pathway. This section discusses soil results in the saturated and unsaturated zones separately before identifying the COCs and cleanup standards for this pathway. For copper and zinc, soil results are compared to the following criteria to determine if there is a correlation between measured soil concentrations and groundwater quality:

- The soil screening levels protective of groundwater quality in either saturated or unsaturated soil (Table 4.6)
- The sediment CSL, which is protective of sediment and surface water quality (Table 4.3)

Unsaturated (Vadose Zone) Soils. Arsenic, copper, and zinc results exceed screening levels developed for the protection of groundwater in unsaturated soils. A majority of soil samples that exceed these copper and zinc screening levels will be addressed through remediation of soils with arsenic concentrations greater than 88 mg/kg because these metals tend to co-occur with the arsenic:

- **Copper.** Soil concentrations exceeding the copper screening level in unsaturated soils do not appear to be predictive of copper groundwater impacts, as shown on Figure 5.8. For example, average groundwater concentrations in MW-01, MW-09, and MW-11 do *not* exceed the proposed CUL for copper, even though copper was measured at concentrations of 2,400 to 2,800 mg/kg (more than four times the sediment CSL) in several vadose zone soil samples at or in close proximity to these locations. In contrast, areas with nearby vadose zone soil concentrations *less than* the unsaturated soil screening level also do not exceed the groundwater screening level, indicating that neither the unsaturated soil screening level nor the sediment CSL is useful in identifying areas where remediation is required.
- **Zinc.** Soil concentrations exceeding the zinc screening level in unsaturated soils do not appear to be predictive of zinc groundwater impacts, as shown on Figure 5.9. Though a higher percentage of zinc results exceed the unsaturated soil screening level for zinc, there are still only two groundwater locations with average concentrations that exceed the proposed CUL (MW-02A and MW-12). Zinc in soil at MW-02A was detected at concentrations less than the unsaturated soil screening level, which indicates either that soil is not a source of groundwater contamination at this location, or that the soil source zone in in the vicinity of this well has not been identified. In contrast, zinc concentrations in soil at MW-04, MW-09, and MW-11 exceed the

unsaturated soil screening level (and the sediment CSL in some samples) but groundwater is in compliance with the proposed CUL for zinc at these locations. These results indicate that neither the unsaturated soil screening level nor the sediment CSL is useful in identifying areas where remediation is required.

- **Arsenic.** The soil-to-protect groundwater pathway is not scientifically quantifiable due to the strong impact of redox potential, which is not considered in the 3-phase model calculation. The most scientifically straightforward approach is to use the human direct contact CUL for arsenic and to remediate the mass of petroleum near MW-01 that is causing reducing geochemical conditions. Protection of groundwater for arsenic will be achieved through remediation of petroleum contamination (and hence, oxygen demand) as discussed further in Section 5.4.2.3. Remediating soil samples that exceed arsenic's direct contact criterion leaves fewer than 20 samples that exceed the screening level developed for protection of groundwater from arsenic. These samples are not clustered and are unlikely to cause elevated concentrations of arsenic in groundwater. With these two changes (source reduction of both arsenic and oxygen-demand), compliance with this pathway can be assessed using measured arsenic groundwater concentrations.

Saturated Soils. In the saturated zone (below 8 feet bgs), soil metal concentrations are essentially at background with the occasional outlier as seen in Figure 5.11 and Table 5.13. Arsenic concentrations do not exceed the screening level in this depth interval:

- **Copper and Zinc.** For copper, 11 percent of samples exceed the saturated soil screening level (natural background) in the saturated zone. These samples are all located at or near two shoreline wells that also had groundwater exceedances of copper (MW-02A and MW-12). Though soil concentrations are not predictive of groundwater concentrations in the unsaturated zone for these metals, copper and zinc are retained as COCs in the saturated zone due to collocated soil and groundwater exceedances (of the sediment CSL and proposed groundwater CUL) in the vicinity of these two shoreline wells. Because few soil samples are available in the vicinity of MW-02A, it is possible that there is additional saturated soil near MW-02A with elevated levels of copper and zinc. Elsewhere at the Site, existing data is sufficient to illustrate that this pathway is not complete.

Soil CULs need to be developed for copper and zinc for this pathway in the saturated zone. The screening level calculated from the 3-phase model is unrealistically low. As seen in Table 4.6, it would predict (1) that in order to protect surface water, soil concentrations in the vadose zone of the Site would need to be cleaner than the sediments that are in direct contact with surface water (Table 4.3), and (2) that the concentrations in groundwater would be more than an order of magnitude higher than the actual measured groundwater concentrations. Two possible approaches exist for developing an appropriate CUL:

- **Option 1:** Use the sediment CSL that has already been established for sediment as protective of sediment receptors. This value is protective of sediment and surface water quality.
- **Option 2:** Collect samples that can be used for a leaching test to develop site-specific partitioning coefficients that would enable development of a site-specific CUL for this pathway.

For the purposes of this RI, Option 1 has been used in figures and tables. However, Option 2 may be used for the final CUL development and reflected in the Cleanup Action Plan or the EDR developed for the Site.

5.4.1.4 *Summary for Metals*

Arsenic, copper, and zinc are proposed as soil COCs for the Site. The POC for metals via the direct contact pathway is 0 to 15 feet; however, contamination is generally limited to arsenic in the 0- to 4-foot horizon. Below 8 to 9 feet bgs, all metals are present at background concentrations at all locations, except for copper and zinc at MW-02 and MW-12.

5.4.2 Total Petroleum Hydrocarbons and LPAHs

5.4.2.1 *Distribution*

The distribution of TPH and the LPAH used as IHS for TPH (i.e., 1-methylnaphthalene) are shown with depth spatially in Figure 5.13; results are tabulated by sample in Table G.2.4 in Appendix G, Attachment G.2. Results in Figure 5.13 were plotted in two panels, one from 0 to 6 feet bgs (representing the unsaturated soil horizon) and the other from 6 to 12 feet bgs, representing the transition between unsaturated soils, capillary fringe (moist soils), and the water table where soils are saturated. Because petroleum contamination is generally released as a liquid product, it is assumed to move initially in the unsaturated soil column as a free product moving under gravity until concentrations drop to less than residual saturation; after that movement is limited to dissolved components moving in groundwater or infiltrating rainwater. This is a different mechanism from the metals discussed above, where the majority of the contamination is believed to come from solids (sandblast grit and debris). For metals, the 8-foot bgs demarcation between saturated and unsaturated soils worked well; however, an 8-foot demarcation splits the “smear zone” of petroleum concentrations that forms during the seasonal fluctuation of the water table. Setting a 6- to 12-foot bgs interval to cover the entire smear zone allows for a rapid assessment of TPH concentrations.

TPH contamination at the Site exists as a mixture of diesel and oil. Near and downgradient of the former ASTs (the area defined by MW-01, MW-06, MW-09, and MW-11), diesel dominates but is mixed with oil. The low-boiling components of diesel that are aromatic are soluble in groundwater and form an area with TPH in groundwater. Representative data for MW-01, MW-09, and MW-11 are included in Exhibit G.2.B of Appendix G, Attachment G.2. The concentrations observed in MW-01 and MW-09 are dominated by naphthalenes and other LPAHs. However, the soluble TPH components are biodegradable which causes a localized depression in the dissolved oxygen concentrations of the groundwater, leading to reducing conditions that release arsenic to groundwater at concentrations that are not protective of surface water quality. For ease in use, this effect is called oxygen demand. At the Site, it is the soluble components of diesel, such as BTEX and LPAHs, that are causing the demand. TPH concentrations in groundwater for MW-11 were less than laboratory detection limits during the February 2015 sampling event.

TPH also exists along the shoreline from S-3 to MW-02A and MW-12 and inland around the FS-09 cluster of soil borings. A review of the chromatograms in this area indicates that the diesel is more weathered, and that both light oils and heavy oils (such as lube oil) are present. Very little of this material is soluble in groundwater, as can be seen by comparing the soil concentrations at MW-02 and MW-02A (21,000 to 24,000 mg/kg at the water table[10]) to the groundwater concentrations of 160 to 340 µg/L.

Results at MW-12 indicate TPH contamination at the surface and deeper TPH contamination at the groundwater table. The chromatogram for MW-12 representing the surface sample collected between 1 and 2 feet bgs indicates a lack of diesel-range material, and is more consistent with a

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[10] TPH concentrations in soil for MW-02 and MW-02A are expressed to two significant figures.

lube oil, heavy oil, or hydraulic oil. However, chromatograms from deeper soil samples collected at 4 feet and 10.5 feet show weathered diesel and oils, which is similar to the rest of the Site. TPH contamination in soil exists at MW-12, just above the groundwater table, but groundwater contamination is non-detect, which is consistent with products containing little leachable hydrocarbons and also consistent with other locations at the Site, such as MW-02 and MW-02A.

TPH is evaluated for human health using VPH, EPH, BTEX, and LPAH data and Ecology's Calculation Tool for TPH, but is evaluated using only LPAHs, which are constituents of petroleum, for all other pathways. The constituents are used for monitoring TPH because there are well-established sediment and surface water criteria for these constituents (but not for TPH) that protect human health and ecological receptors. Therefore, this section will describe the nature and extent of TPH and its constituents.

BTEX constituents were analyzed for in soil and groundwater, and are at concentrations less than all screening levels. Benzene was not detected, and toluene and other alkylated benzenes were at concentrations less than screening levels and will not be discussed further.

LPAH constituents were detected everywhere TPH was detected, which is consistent with their presence in diesel and oils such as those seen on-site. LPAHs will be used to develop CULs for TPH that are protective of surface water and sediments.

5.4.2.2 Direct Contact Pathway for Human Health

Ecology's Calculation Tool for TPH was used with data for key samples from NWTPH-VPH and NWTPH-EPH methods along with BTEX and PAHs to develop the CUL for human direct contact for industrial workers (refer to Appendix G, Attachment G.2, Table G.2.2). Ecology states that the most practicable approach to establish site-specific CULs is to use data from multiple locations to calculate a median soil CUL that is representative of the site (Ecology 2016c). The calculated CULs ranged from 21,000 to 82,000 mg/kg, depending on the specific mix of diesel and oil in the sample, and the median value is 33,000 mg/kg. Therefore, we are proposing the use of a more conservative TPH CUL in soil of 24,000 mg/kg.

Prior to completion of the Interim Action[11], the only exceedance of 21,000 mg/kg (the MCUL calculated in Appendix G, Attachment G.2) was in soil in the MW-02 and MW-02A area dominated with a heavy oil, which has a higher CUL (refer to individual Soil CUL Worksheets in Attachment G.2 for soil samples dominated with heavy oil). Total TPH results, expressed to two significant figures, for MW-02 and MW-02A were 21,000 and 24,000 mg/kg, respectively. Therefore, the proposed TPH CUL of 24,000 mg/kg in this area is still less than the median of the calculated soil CULs of 33,000 mg/kg for TPH. Using a conservative direct contact CUL of 24,000 mg/kg, there were no exceedances of the direct human contact level for TPH (refer to Appendix G, Attachment G.2 for details).

Individual results for BTEX and the LPAHs, were also compared to MTCA Method C CULs for industrial workers. There were no exceedances of the CULs in soil.

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[11] Soil boring location FS-29, installed as part of the Interim Action, contained a diesel-range TPH concentration of 99,000 mg/kg; however, this elevated concentration was determined to be associated with a creosote piling, and isolated to that location and not representative of TPH in soil.

5.4.2.3 *Protection of Groundwater Quality*

Ecology's Calculation Tool for TPH can estimate TPH soil concentrations protective of groundwater only for potable aquifers. For non-potable aquifers, such as the one at the Site, protection of groundwater quality is assessed through the individual constituents of TPH, in this case LPAHs. The following findings were discussed in detail in Section 5.3:

- The lowest screening level for several LPAHs (including acenaphthene and fluorene) are based on protection of sediment quality; however, there were no sediment exceedances. Other groundwater screening levels for the LPAHs are based on protection of surface water quality. Because LPAHs were detected infrequently and at low concentrations in sediment, the proposed CULs for LPAHs are based on protection of surface water quality.
- Three of these LPAHs (2-methylnaphthalene, acenaphthene, and fluorene) only exceed the proposed CULs in one interior well, MW-01. 2-methylnaphthalene only exceeds in one sampling event at this well, with an average concentration of 33 µg/L (just greater than the proposed CUL of 32 µg/L). There are no exceedances of the proposed CUL at the POC (shoreline wells) for any of these LPAHs. Therefore, they are eliminated as COCs.
- 1-methylnaphthalene exceeds the proposed CUL at MW-01 and at a downgradient shoreline well, MW-09. 1-methylnaphthalene exceeds the proposed CUL in all sampling events at MW-09, but is in compliance with the proposed CUL in all samples collected from MW-11, which is also downgradient of MW-01. Therefore, 1-methylnaphthalene was retained as a COC. Because of its mobility in groundwater, 1-methylnaphthalene was also retained as an IHS for TPH.

The diesel-range TPH concentrations near MW-01 are sufficient to cause an oxygen demand that in turn creates anaerobic groundwater, which then leaches arsenic at unacceptable levels. Although a quantitative relationship cannot be established to set a soil CUL, remediation of TPH is necessary in the area near MW-01 to decrease the oxygen demand, in order to improve the arsenic concentration in groundwater.

TPH also exists in the smear zone along the shoreline from S-3 to MW-02A and inland around the FS-09 cluster of soil borings. A review of the chromatograms in this area indicates that the diesel is more weathered, and that both light oils and heavy oils (such as lube oil) are present. Very little of this material is soluble in groundwater, as can be seen by comparing the soil concentrations at MW-02 and MW-02A (21,000 to 24,000 mg/kg at the water table[12]) to the groundwater concentrations of 160 to 340 µg/L. Arsenic and copper concentrations are slightly elevated in groundwater at MW-02A, but not in soil.

Two wells were installed along the shoreline in 2015, MW-11 and MW-12. The chromatogram from soil samples collected at MW-11 resembles bunker fuel with an oil or a mixture of very heavily weathered diesel and oil. However, soil detections at 6 to 7 feet bgs are low with a total TPH concentration of 44 mg/kg. MW-11 is tidally influenced, and detections in soil may represent surface water sheen infiltrating into the subsurface as the tide drops and lowers the groundwater table. TPH detections in groundwater are non-detect, which is consistent with the rest of the Site where TPH contamination is not very soluble. In addition, the highest detection in monitoring well MW-12 occurs just above the groundwater table. However, TPH groundwater contamination is quite low or non-detect, which is consistent with products containing little leachable hydrocarbons.

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[12] TPH concentrations in soil for MW-02 and MW-02A are expressed to two significant figures.

Based on this evaluation, the Calculation Tool indicates that all concentrations were found to be protective of groundwater, which is confirmed by non-detections and very low TPH concentrations in groundwater samples. Therefore, soil concentrations of TPH in this area of the Site are not impacting groundwater quality and TPH is not a COC for this pathway.

Because the maximum TPH concentration on-site of samples that were not associated with elevated arsenic in groundwater was 24,000 mg/kg, the potential for the formation of free product was assessed. Groundwater wells exist in the areas with the greatest TPH concentrations and are screened across the water table in the area where the concentrations are greatest. No free product has been detected in the wells with an interface probe during multiple events. Given the fine-grained nature of site soils and presence of dominance of oil in the most contaminated samples, the absence of free product formation is consistent with work by Alaska Department of Environmental Quality (Geosphere and CH2M HILL 2006), indicating that concentrations as great as 39,000 mg/kg are needed to produce free products from oily residuals in fine grained sediments.

5.4.2.4 Vapor Intrusion for C_8 to C_{12} Aliphatic in Total Petroleum Hydrocarbons

The calculations resulting in concentrations protective of the vapor intrusion pathway have the most uncertainty, which can be seen by comparing the Calculation Tool for TPH's predictions for FS-19 and FS-20 (Appendix G, Attachment G.2, Exhibit G.2.B) to the soil gas results for adjacent location MW-09 (Table 4.5). All three locations have similar concentrations of very similar TPH components. The Calculation Tool for TPH predicts volatilization of all of the diesel fractions, including those soluble in water, whereas the results at MW-09 indicate that only the C_8 to C_{12} aliphatics were a problem (prior to the interim action, which included TPH-contaminated soil removal within the vicinity of MW-09). Despite this, there is a process for initially assessing the potential for petroleum vapor intrusion that can be applied at the Site.

USEPA's 2015 technical guidance for addressing petroleum vapor intrusion states that the lateral inclusion zone and horizontal separation must be defined to determine if current buildings are threatened by potential vapor intrusion (USEPA 2015). Ecology has recently updated their vapor intrusion guidance to include lateral and vertical separation distances and lateral inclusion zones in their memorandum, *Updated Process for Initially Assessing the Potential for Petroleum Vapor Intrusion* (Ecology 2016b). The Ecology memorandum defines the lateral inclusion zone as the area surrounding a contaminant source through which vapor phase contamination might travel and intrude into buildings. If the degree and extent of contamination is well-defined and the dissolved phase plume is stable or receding, then a horizontal separation distance of 30 feet is appropriate for establishing a lateral inclusion zone. In addition, the following site-specific conditions are noted:

- The degree and extent of TPH contamination in soil and groundwater is well-defined.
- There are no buildings in the area that overlie diesel-contaminated soil or groundwater. There are above-grade trailers, but no buildings with on-grade or below-grade foundations that contain office or work spaces. Any remaining petroleum impacts will be more than 30 feet away from any occupied below-grade foundation or slab-on-grade buildings.

The pathway that is being considered is a potential future pathway that includes the hypothetical construction of a new slab-on-grade building in the area immediately downgradient of the former ASTs and over the area with strong tidal influence. Vapor intrusion concerns are limited to the C_8 to C_{12} aliphatic fraction of the TPH in this area (MW-01, MW-06, and MW-09, and downgradient of the former ASTs). Outside this area, TPH was also detected in soil in various locations (refer to

Figure 5.13). However, this risk is not a concern at this time because there are no occupied, slab-on-grade buildings within the lateral inclusion zone of 30 feet. However, the potential for vapor intrusion should be considered if new slab-on-grade office or work space buildings are constructed in the future within 30 feet of remaining residual petroleum contamination. Expected future site use and operations is unlikely to include construction of slab-on-grade buildings for office or work spaces in the areas where TPH is present on-site.

5.4.2.5 Summary for TPH and its Constituent LPAHs

TPH is not a COC for direct contact to soil throughout the Site. However, diesel concentrations that exceed 8,000 mg/kg in soil, within the vicinity of MW-01, can leach into groundwater at sufficient levels to cause an oxygen demand that in turn creates anaerobic groundwater, which then leaches arsenic at unacceptable levels (refer to Appendix G, Attachment G.2 for details). Therefore, TPH is retained as a COC in soil for protection of groundwater purposes, not for direct contact.

The LPAHs are in compliance for protection of human health by direct contact and protection of groundwater. 1-methylnaphthalene was retained as a COC for protection of the groundwater-to-surface water pathway, and will be subject to future monitoring to verify compliance.

5.4.3 cPAHs and HPAHs

The cPAHs and their associated non-carcinogenic HPAHs are co-located and likely from the same source. Possible sources include waste oils, oil drips or leaks from vehicles and heavy equipment, and creosote-treated timbers. Different source may be relevant to different locations. Test pits and boring logs indicate that a number of creosote-treated timbers were encountered in the subsurface, and that a number of soil samples contained treated wood. For example, in the photo below of soil boring FS-21, sheen, creosote-like odor, and wood were all present at 13.5 to 14.0 feet bgs. The wood appears to have been “shaved-off” a timber by the probe corer rather than to be loose wood debris.

5.4.3.1 Distribution

The distribution of cPAHs and HPAHs are also shown with depth and spatially on Figure 5.14.

The greatest concentrations of cPAHs and HPAHs are seen at multiple depths in FS-21, beneath the area of the historical AST. FS-21 encountered wood at several depths and the visible wood (Exhibit 1; shown on the following page) is black with a creosote odor. The samples with the greatest cPAHs and HPAHs include visible wood, whereas the samples at other depths with no visible wood appear brown and sandy and have little contamination. It appears that the cPAHs, HPAHs, and the deeper LPAHs and diesel-range TPH (which was flagged by the laboratory as “diesel-range, but not diesel”) are all related to creosote-treated timbers.

Exhibit 1. Visible wood in FS-21 boring

There was also an anomalous cPAH result deep in FS-01 very close to the present day shoreline in the northeast corner of the Site. During the March 2011 investigation, a sheen with the odor identified as “hydrocarbon” was encountered in soil boring FS-01 at 24.0 to 24.8 feet bgs, immediately above the native silts. A sample was analyzed for TPH, and a diesel-range result of 260 mg/kg was reported by the laboratory. The chromatogram did not resemble a petroleum product. The sample immediately below it (24.8 to 25.0 feet bgs) had a diesel-range concentration of 78 mg/kg. In March 2013, a second boring (FS-19) was advanced approximately 10 feet away to gather additional information. No sheen or odor was detected below 15 feet bgs (this area has TPH contamination throughout the unsaturated zone and down to approximately 12 feet bgs). There was no indication of petroleum below 12 feet until 27 feet bgs when the PID reading increased. A sample was collected in the native silts at approximately 27 feet bgs and contained no detected hydrocarbons. After a new evaluation of the soil, chemical results, and aerial photographs, the most likely explanation is that this soft layer is the pre-1937 sediment mudline before this section of the Site was filled. No further action is intended.

Finally, cPAHs were detected in several of the early RETEC samples of visually contaminated soils and debris. Their report and notes (refer to Section 2.5.3) indicate that creosote-treated wood fragments were present at several of these locations and were possible sources. The co-location of cPAHs and metals in the areas with visible sandblast grit and debris is not unexpected. These cPAHs are not mobile and are unlikely to represent an ongoing source to groundwater.

5.4.3.2 Direct Contact Pathway for Human Health

No HPAH result exceeded the screening level for direct contact. None of these chemicals are COCs in soil for direct contact. No cPAH result exceeds the screening level for direct contact; locations with the highest detections of cPAHs are associated with the creosote-treated timbers. For example, samples collected at FS-21 encountered timbers at 3.5 feet bgs and again at 13.5 feet bgs, and had detected cPAH concentrations of 25 and 22 mg/kg, respectively. These results are more than an order of magnitude higher than average cPAH concentrations detected at the Site.

5.4.3.3 Protection of Groundwater Quality

Though detected in groundwater at two wells (MW-01 and MW-11), cPAHs were not retained as groundwater COCs because there was only one low-level exceedance in a shoreline well (MW-11), and they are not COCs for intertidal sediments (where groundwater discharges to the Bay). The presence of cPAHs in groundwater at MW-01 is likely facilitated by diesel, rather than caused by the soil-to-groundwater pathway. Groundwater compliance at MW-11 will be reevaluated after remediation of TPH. In soil, locations with high detections of cPAHs are associated with creosote-treated timbers; though soil in the immediate vicinity of creosote-treated timbers can be expected to have high concentrations of cPAHs, these cPAHs are not very mobile in groundwater and are unlikely to represent a significant source to groundwater.

The non-carcinogenic HPAHs, specifically pyrene and fluoranthene, were detected in MW-01, but at concentrations less than their proposed groundwater CULs. They are not detected in the shoreline wells (refer to Appendix C).

Based on this assessment, cPAHs and HPAHs are not COCs in soil for the protection of groundwater quality.

5.4.4 Summary of Proposed Soil Contaminants of Concern and Their Cleanup Standards

Table 5.14 lists the proposed soil COCs (and COPCs), POCs, and their CULs.

5.4.5 Soil Areas of Concern

Three AOCs have been defined for soil that address metals contamination (AOC 2A and 2B) and TPH contamination (AOC 3). AOCs 2A, 2B, and 3 address all potentially active exposure pathways at the Site; therefore, proposed CULs and applicable depths vary within these AOCs, as described below.

AOC 2A

This AOC is defined by the need to address surficial arsenic contamination, which is primarily found in the upper four feet of site soils. It will address both protection of the direct contact pathway as well as protection of groundwater quality. This AOC addresses contamination site-wide within the top 4 feet of soil, which is diffuse across the Site. Arsenic data within AOC 2A are shown on Figure 5.15.

All arsenic exceedances of the direct contact CUL of 88 mg/kg are shallow and are in the unsaturated zone. Arsenic concentrations and exceedances are shown on Figure 5.12. Clean samples bounding areas with known contamination to the south and east are not available. The lateral extent of surficial arsenic contamination will be determined during remedial design as needed to design the remedy selected in the FS for application at the Site.

The only locations with elevated arsenic deeper than 2 feet bgs are MW-11 and FS-23 with arsenic contamination extending to approximately 3 and 3.5 feet bgs, respectively. Otherwise, data indicate that arsenic contamination is quite shallow, but widespread, in operational areas. Remediation of arsenic in soil that exceeds 88 mg/kg in this AOC will also address the majority of soils with elevated copper and zinc because they are co-located.

Remediation of soil that exceeds the direct contact CUL for arsenic will also address a significant mass of arsenic present at the Site that exceeds arsenic natural background concentrations. This action, coupled with remediation of the source mass of TPH, is expected to bring arsenic concentrations measured in groundwater into compliance with the proposed groundwater CUL, thus addressing the soil-to-groundwater pathway for arsenic without the need to develop a separate site-specific soil CUL protective of the soil-to-groundwater pathway. Therefore, the direct contact CUL for arsenic (88 mg/kg) will also be used as the soil-to-protect groundwater CUL for arsenic.

AOC 2B

AOC 2B addresses copper and zinc concentrations in soils that may be responsible for the periodic groundwater exceedances in MW-02A and MW-12. Because it is within AOC 2A, it also addresses arsenic contamination in surficial soils that exceed the direct contact CUL of 88 mg/kg. Unlike AOC 2A, which only includes soil at depths of 0 to 4 feet, AOC 2B includes soil at all depths. AOC 2B is shown on Figure 5.15 and includes arsenic, copper, and zinc data.

Within AOC 2B, the proposed CULs for protection of the soil-to-groundwater pathway for copper and zinc are the sediment CSLs. Sediment CSLs are protective of sediment and surface water quality, and thus, by inference, soil concentrations at these levels are also presumed to be protective of surface water quality. However, because site data do not show a strong correlation between surficial soil concentrations greater than the CSL and groundwater contamination in corresponding wells, this proposed CUL is believed to be overly conservative. Within AOC 2B, an alternative site-specific value based on a leaching test may be proposed in the Cleanup Action Plan, as allowed in MTCA.

Copper and zinc were detected at elevated concentrations (i.e., concentrations more than two times greater than natural background concentrations for these metals) at MW-12 and nearby location FS-03 at depths below 8 feet bgs. These results indicate that there is a deep soil source zone in this area that may be contributing to the elevated copper and zinc groundwater concentrations at MW-12. However, only one result at these locations, collected at a depth of 8 to 8.5 feet bgs, exceeds the proposed CUL, with a detected concentration of 1,800 mg/kg for zinc and 500 mg/kg for copper.

MW-02A also has elevated groundwater concentrations for both copper and zinc. Soil results at MW-02A collected at depths of 7.5 and 13.5 feet bgs are less than natural background soil concentrations for both copper and zinc. However, results collected from a depth of 8.5 feet bgs at nearby location MW-02 are more than double natural background concentrations for these metals. Though these results are less than their proposed CULs, these results are atypical for the Site and may indicate that a soil source area with high concentrations for these metals is present nearby MW-02 and upgradient of MW-02A. Therefore, AOC 2B includes an area upgradient of MW-02 and MW-02A where no soil samples are available. Additional soil borings may be required during remedial design to fully characterize the nature and extent of contamination within saturated soils in AOC 2B.

AOC 3

AOC 3 is located within AOC 2A and, due to metals in surface soil, was remediated by the Interim Action to address the direct contact pathway. This AOC is intended to address TPH contamination where diesel is present based on site-specific protection of groundwater quality. TPH contamination at the Site exists as a mixture of heavily weathered diesel and oil. Near and downgradient of the former AST (the area defined by MW-01, MW-06, and MW-09), diesel dominates but is mixed with oil. The low-boiling components of diesel that are aromatic are soluble in groundwater and form an area with TPH in groundwater. Representative data for MW-01 and MW-09 are included in Exhibit G.2.B of Appendix G, Attachment G.2. The concentrations are dominated by naphthalenes and other LPAHs. Concentrations in groundwater are protective of surface water and sediment quality as discussed earlier. However, the soluble TPH components are biodegradable, which causes a localized depression in the dissolved oxygen concentrations of the groundwater, leading to reducing conditions that release arsenic to groundwater at concentrations that are not protective of surface water quality. The goal in this AOC is to reduce TPH concentrations sufficiently to reduce oxygen demand, allow arsenic concentrations in groundwater to return to background (5 to 10 µg/L) at the point of discharge to the Bay, downgradient of MW-09. Because in-situ conditions are too complex to model, the proposed CUL for TPH within AOC 3 is estimated as 8,000 mg/kg. This value is intended to be a practical extent of soil contamination, that when remediated will be protective of site receptors by improving conditions in the vadose zone and along the top of the water table, which are currently causing increased arsenic concentrations in groundwater.

Ecology's Calculation Tool for TPH indicates that existing measured concentrations in soil should be protective; however, the measured groundwater concentrations for arsenic along the shore at MW-09 and MW-11 still need to decrease from current averages of 17 µg/L and 9 µg/L, respectively, to background levels (5 to 10 µg/L). The FS will discuss options for doing this; however, it will probably involve decreasing the diesel content of soil and groundwater in the area. This area is shown on Figure 5.16 as AOC 3. Additionally, if the arsenic background groundwater concentration is greater than 5 µg/L, then the TPH remediation in the area may not have a measureable impact on arsenic, because it may already be at background.

TPH impacts in soil also exist along the shoreline from S-3 to MW-02A and MW-12 and inland around the FS-09 cluster of soil borings, but are not correlated with groundwater, and therefore not included in AOC 3. These are areas outside of AOC 3 but still within AOC 2A. A review of the chromatograms in these areas indicates that the diesel is more weathered, and that both light oils and heavy oils (such as lube oil) are present. Very little of this material is soluble in groundwater, as can be seen by comparing the soil concentrations at MW-02 and MW-02A (21,000 to 24,000 mg/kg at the water table) to the groundwater concentrations of 160 to 340 µg/L. Zinc and copper concentrations are slightly elevated in groundwater at MW-02A, but not in soil.

Proposed CULs of 8,000 and 24,000 mg/kg for TPH have been developed in Appendix G, Attachment G.2, Exhibit G.2.B, and are presented in Table G.2.2, that protect all of these exposure pathways including prevention of the formation of free product. The proposed 8,000 mg/kg CUL should be applied within the outlined AOC 3 with a conservative 20-foot buffer beyond AOC 3 (Figure 5.16). In addition, the proposed 8,000 mg/kg CUL should be applied in the top 10 feet bgs within AOC 3 where diesel is present in soil and can potentially leach into the groundwater at concentrations exceeding 1,000 µg/L; below 10 feet bgs, TPH concentrations are already low and protective. It should be noted that the tidal effect on water levels within the near shoreline uplands (50 to 100 feet from the top of bank), means that the "water table" varies from approximately 4 to 12 feet bgs, and the CUL needs to address this range; further inland the water table elevation is fairly stable and the zone of concern is 6 to 10 feet bgs; shallow TPH contamination that does not reach the water table is not of concern at the Site. Figure 5.16 shows available TPH data in soil to two significant figures. In the areas downgradient of the former AST where the diesel is less weathered, it may not be quite low enough to reach the proposed groundwater RAL of 1,000 µg/L (see Section 5.3.1.1).

Areas where oil dominates and the diesel component is not leaching into the groundwater, the CUL of 8,000 mg/kg is overly conservative, and the definitive decision in these areas should be the formation of free product. Therefore, outside AOC 3 but within AOC 2A, the proposed TPH CUL in soil is 24,000 mg/kg. Concentrations less than this value should be protective of all pathways except within AOC 3 at interior well MW-01 and downgradient well MW-09, where groundwater results indicate diesel-range TPH components in soil can potentially leach into the groundwater. In addition, no free product has been detected at the Site in soil or groundwater. The highest soil concentrations[13] (21,000 to 24,000 mg/kg) have been a heavy oil found near MW-02 and MW-02A at the water table and product has never been observed in MW-02 or MW-02A.

AOC 3 spans the area from near MW-06 on the east to MW-09 on the west. Although the area outside AOC 3 is contaminated, the material is heavy-range petroleum, is not a direct contact risk, and does not exceed the area-specific CUL of 24,000 mg/kg, and does not result in conditions that cause either arsenic or 1-methylnaphthalene to exceed their CULs in groundwater. The goal is to address TPH in the top 10 feet bgs to less than 8,000 mg/kg in all areas of AOC 3, which will reduce diesel concentrations in groundwater and to change the redox conditions in groundwater that are causing arsenic to leach in the area. TPH concentrations below 10 feet bgs are significantly less and are not presenting a risk to humans or ecological receptors.

A CUL of 24,000 mg/kg can be applied to all areas outside AOC 3, such as within the vicinity of TP-9, and still be protective of all pathways, including direct contact, leaching to groundwater, and formation of free product. AOC 3 is shown on Figure 5.16.

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[13] Soil boring location FS-29, installed as part of the Interim Action, contained a diesel-range TPH concentration of 99,000 mg/kg; however, this elevated concentration was determined to be associated with a creosote piling, and is isolated to that location and not representative of TPH in soil.

6.0 Remedial Investigation Conclusions

Sections 2.0 through 4.0 described in detail the setting of the Site, current and historical shipyard activities at the Site, sources of hazardous substances, the types and concentrations of chemicals detected at the Site, the impacted media at the Site, and the actual and potential exposure pathways and receptors. Section 5.0 defined COCs, CULs, and AOCs. This section provides a summary of the information that is presented in detail in the previous sections.

6.1 PHYSICAL SETTING

The upland soil beneath the surface pavement or gravel layers consists of gravelly to sandy fill soils, ranging in thickness up to 7 feet and containing anthropogenic debris including wood, brick, metal, and sandblast grit. The fill material likely originated as dredged sediments taken from the western and northern areas of the facility in the 1930s and mixed with miscellaneous fill used during property development. Underlying the fill is native soil consisting of fine to coarse grained sand with gravel.

Groundwater is first observed within sandy soils at depths from 8 to 11 feet bgs. Shallow groundwater appears to be unconfined and flows toward the Bay, which is the natural point of discharge. Groundwater elevations adjacent to the shoreline fluctuate with tidal amplitude.

General sediment stratigraphy within the study area consists of a mixture of silt and sand to an approximate depth of 5 feet below the mudline. The underlying layer consists mainly of sand and gravel and provides a firm bottom beneath the upper recent sediment deposits. Gravelly material is also present near the sediment surface in the previously dredged area at the existing dry dock and Harris Avenue Pier. Silty sediment was present in the southern portion of Port PMA Parcel 5 (Figure 2.3), in the vicinity of the existing eelgrass beds.

6.2 SOURCES OF HAZARDOUS SUBSTANCES

The main sources of contamination at the Site are associated with historical shipyard activities. The property has been actively used as a shipyard since 1915, with multiple owners and operators throughout this time performing ship construction and repair.

Primary sources for soil and groundwater contamination in the uplands include:

- Historical operations in the marine railway area. This is one of the most heavily-used areas of the property for shipyard operations and the location where the most contamination has been identified, including contaminants associated with painting and sandblasting.
- Leakage of petroleum products (consisting of hydrocarbons and LPAHs) from the former ASTs located south of the Harris Avenue Pier.
- Historical shipyard operations including painting, sandblasting, movement of sandblast grit, and ship repair activities throughout the primary shipyard property.

Primary sources for sediment contamination include the following possible pathways:

- Historical shipyard over-water and nearshore operations that resulted in spills, leaks, and releases of waste materials directly to site waters and surface sediments.
- Impacted groundwater originating from upland areas, traveling through the fill unit and then discharging to sediments.

- Historical discharge of contaminated materials to sediments from former industrial wastewater or stormwater outfalls.
- Discharge by sheet flow of surface contamination generated from former shipyard upland activities (e.g., sandblasting).
- Erosion and sloughing of contaminated nearshore fill materials onto the intertidal sediment surface (e.g., marine railway area).

Sources of contamination are primarily historical. Current shipyard practices and best management practices (BMPs) are implemented to prevent contamination and ensure regulatory compliance. The FS will include any additional source control recommendations to be coupled with site remediation to prevent recontamination.

6.3 EXPOSURE PATHWAYS AND POINTS OF COMPLIANCE

As described in detail in Section 4.0, multiple exposure pathways have been evaluated at the Site and are addressed in development of screening levels and evaluation of site conditions. Figure 4.1 presents a graphical representation of the CSM.

The exposure pathways used to develop screening levels and cleanup standards are described in detail in Table 4.2 and are reiterated below.

Exposure Pathway	POC
Sediment	
Protection of benthic species	Upper 12 cm throughout site sediments. Compliance is assessed on a point-by-point basis.
Protection of human health via direct contact (Shipyard Worker Scenario)	Upper 12 cm in the shipyard intertidal sediment area (defined as above 0 feet MLLW and beyond the toe of the bank). Compliance is assessed on a SWAC basis.
Protection of human health via direct contact (Net Fishing Scenario)	Upper 12 cm throughout the subtidal zone (defined as sediments below 0 feet MLLW). Compliance is assessed on a SWAC basis.
Protection of human and higher trophic level species health via the consumption of seafood (Seafood Consumption)	Upper 12 cm throughout site sediments. Compliance is assessed on a SWAC basis.
Groundwater	
Protection of surface water quality (Surface Water Quality)	Where groundwater discharges to surface water.
Protection of sediment quality (Sediment Quality)	Where groundwater discharges to sediments.
Protection of vapor intrusion (Vapor Intrusion)	Groundwater to protect indoor air in slab-on-grade structures that are within the lateral inclusion zone (30 feet of TPH detections in groundwater).
Soil	
Protection of human direct contact	Upper 15 feet of soil throughout the Site.
Protection of groundwater quality: unsaturated zone	Unsaturated zone soils (top 8 feet of soil throughout the Site), based on infiltrating stormwater.
Protection of groundwater quality: saturated zone	Saturated zone soils (soil below 8 feet bgs), based on groundwater migration.
Protection of vapor intrusion	Unsaturated zone soils to protect indoor air in slab-on-grade structures containing office spaces that are within the lateral inclusion zone (30 feet of soil impacts).

The pathways identified above have been used in Sections 4.0 and 5.0 for the development of screening levels and cleanup standards, in order to determine COCs, to establish the nature and extent of contamination at the Site, and to identify AOCs. COCs and AOCs are summarized in Section 6.4.

The RI is then used to gather data for contaminant concentrations in key environmental media, to demonstrate, using site-specific information, which of the pathways are important for which chemicals, and what concentrations are actually protective of exposures. Section 5.0 uses the nature and extent of contamination in the environmental media on-site in combination with the CSM and exposure pathway definitions to identify the COCs and to develop appropriate CULs for them. The exposure pathways that are used in Section 4.0 are the same exposure pathways used to evaluate the nature and extent, but the cleanup standards and COCs are adjusted based on the site-specific findings in the RI.

6.4 CONTAMINANTS OF CONCERN AND AREAS OF CONCERN

COCs, cleanup standards, and AOCs for each media are presented in Section 5.0, along with related figures and tables. Table 6.1 presents COCs and IHS by media. This section summarizes the findings of Section 5.0.

6.4.1 Sediment Contaminants of Concern and Areas of Concern

The AOC for sediments, AOC 1, which encompasses both intertidal and subtidal sediments, is shown on Figure 5.6. AOC 1 has been defined within the primary operational area of the shipyard. The AOC extends from the dry dock to just east of the Harris Avenue Pier, which contains the greatest concentrations of contamination offshore of the marine railway.

Within AOC 1, COCs for intertidal sediments and subtidal sediments are as follows:

- **Intertidal Sediments**. The intertidal sediments on the north side of the shipyard are identified within AOC 1. COCs in intertidal sediments for protection of all the benthic species or human direct contact by shipyard workers include arsenic, copper, and zinc. Bioaccumulative COCs in intertidal sediments for protection of human and higher trophic level species health via consumption of seafood include arsenic, cadmium, cPAHs, and PCBs. Sediments in this area will require cleanup to meet a POC of 12 cm deep.

  Although concentrations do not exceed the sediment screening level, 1-methylnaphthalene was retained to use as an IHS in the intertidal sediments for potential TPH discharging from the uplands via groundwater flow into the sediments.

- **Subtidal Sediments.** COCs in subtidal sediments for protection of all the benthic species or direct contact during net fishing, include arsenic, copper, zinc, fluoranthene, pyrene, and PCBs. As with intertidal sediments, bioaccumulative COCs in subtidal sediments for protection of human and higher trophic level species health via consumption of seafood include arsenic, cadmium, cPAHs, and PCBs. Sediments in this area will require cleanup to meet a POC of 12 cm deep.

The Pre-Interim Action sampling described in Section 2.7 identified a small area with surface contamination located east of the Interim Action area and north of the Former Arrowac building. Two samples east of AOC 1 have exceedances of cPAHs, but the concentrations of the cPAHs are much greater than what is seen at the Site. Additionally, these samples do not have exceedances of PCBs. Based on these reasons, these samples are not thought to be related to the Site and are therefore not included in AOC 1.

6.4.2 Groundwater Contaminants of Concern and Areas of Concern

COCs in groundwater include arsenic, copper, zinc, and 1-methylnaphthalene. The proposed CUL for arsenic is its statewide background concentration in groundwater. The proposed CULs for copper, zinc, and 1-methylnaphthalene are the most stringent screening levels developed for these chemicals, which are equivalent to surface water quality standard for marine waterbodies.

The surface water concentrations on which the copper and zinc CULs are based may be less than naturally occurring background values in site groundwater, which occasionally exceed these criteria in individual samples collected from wells across the Site. The Site is located in the Padden Member of the Chuckanut Formation, which contributes to elevated natural background levels for some metals at the Site, including nickel. Concentrations of copper and zinc measured in groundwater at two wells (MW-02A and MW-12) are significantly greater than concentrations measured elsewhere at the Site, however, and may be linked to soil contamination. This possibility is addressed in Section 6.4.3. Average copper and zinc concentrations measured at all other wells at the Site are less than their proposed CULs.

Except for arsenic within the TPH-contaminated area between MW-01, MW-09, and MW-11, average arsenic concentrations discharging to surface water comply with the proposed CUL. The data suggest that arsenic is at greater concentrations within the TPH-contaminated area because localized anaerobic conditions created by biological degradation of diesel-range TPH is causing arsenic in the soil to be reduced to a more soluble form, which then dissolves into groundwater. An Interim Action has recently been completed at MW-09, and additional remedial action will be completed to address TPH contamination in the vicinity of these wells.

1-methylnaphthalene exceeds the proposed CUL only at wells MW-01 and MW-09, coinciding with TPH impacts. Addressing TPH contamination in this area will also address 1-methylnaphthalene in groundwater.

6.4.3 Soil Contaminants of Concern and Areas of Concern

Soil COCs and AOCs vary by exposure pathway, each with their own POCs. For each COC, appropriate CULs were proposed for each of the potentially complete pathways at the Site. The cleanup standard for each COC combines each of these proposed CULs with a specific area of the Site and the depth interval where the proposed CUL must be met.

6.4.3.1 Direct Contact Pathway

Arsenic is the only COC at the Site for the direct contact pathway, which is based on protection of industrial workers. The POC for direct contact is within the top 15 feet of soil across the Site. The majority of contamination is limited to the top 4 feet of soil, with most arsenic contamination exceeding the proposed CUL for the direct contact pathway present in the upper 2 feet of soil. Remediation of arsenic for this pathway will also significantly reduce average copper and zinc concentrations at the Site, because metals contamination from sandblast grit is co-located. As shown in Figure 5.11 and 5.12, very little metals contamination exists below 4 feet bgs.

6.4.3.2 Protection of Groundwater

Arsenic, copper, and zinc are COCs for this pathway, although it is difficult to discern a measurable or quantifiable effect. Most saturated soils (i.e., soils deeper than 8 feet bgs) are present at background concentrations for all metals. However, concentrations of copper and zinc exceed background concentrations in the saturated zone at the northwest corner of the Site, at locations MW-12, MW-02, and FS-03. Elevated soil concentrations in the saturated soil zone at or in the vicinity of these locations may be influencing groundwater results at wells MW-02A and MW-12, which are the only two wells that exceed the proposed CUL for copper and zinc.

The proposed CULs for this pathway are based on the human direct contact value for arsenic (88 mg/kg) and the SMS CSL for copper and zinc (390 mg/kg and 960 mg/kg, respectively). Given the existing soil and groundwater data at the Site, which generally does not exhibit a strong correlation between locations where surficial soil results were measured in excess of these levels and downgradient groundwater wells, these values are likely very conservative. In the future, proposed CULs based on site-specific leaching data may be proposed to replace these values with site-specific values.

6.4.3.4 Vapor Intrusion

Vapor intrusion risks are not currently present at the Site because there are no buildings within the lateral inclusion zone, as defined by Ecology (Ecology 2016b). The vapor intrusion pathway is limited to C_8 to C_{12} aliphatics. However, vapor intrusion should be considered a potential pathway if there will be construction of a new slab-on-grade office or work space building within 30 feet of remaining residual petroleum contamination following remedy implementation. A RAO discussed in the FS will ensure that if C_8 to C_{12} aliphatics are present following the remedial action at soil gas screening levels that are of concern for vapor intrusion, future occupied, slab-on-grade buildings will be constructed to prevent vapor intrusion through the use of engineering and/or institutional controls.

6.4.3.5 Soil Areas of Concern

To address all of the soil exposure pathways in combination, the following AOCs have been defined at the Site:

- **AOC 2A:** Within this site-wide area, surface soil concentrations exceed proposed CULs for direct contact with arsenic and for protection of groundwater. Arsenic exceedances of the direct contact CUL are not present in deeper soils.
- **AOC 2B:** AOC 2B, located within AOC 2A, addresses copper and zinc concentrations in soils that may be responsible for the periodic groundwater exceedances in MW-02A and MW-12. Results from only one soil sample measured outside of AOC 2B at depths greater than 5 feet bgs exceed background concentrations for copper or zinc. This sample was collected at a depth of 6.5 to 7.5 feet bgs from location FS-17, an interior location of the Site that does not appear to influence groundwater quality at any location.
- **AOC 3:** Petroleum contamination in AOC 3 is based on site-specific protection of groundwater quality and is defined to address diesel contamination associated with the historical ASTs. The goal of remediating AOC 3 is to decrease oxygen demand in the area, allowing for improvement in water quality for arsenic and LPAHs. This would result in a decrease in the amount of C_8–C_{12} aliphatics in the vadose zone that would reduce the potential for vapor intrusion. Petroleum impacts in soil and groundwater outside AOC 3 are more than 30 feet from occupied, slab-on-grade buildings and no action is required in these areas.

All AOCs, for sediments, groundwater, and soil, will be evaluated in the FS during the development and analysis of comprehensive site remedial actions.

7.0 Feasibility Study Introduction

The remainder of this document presents the FS for the Site.

This FS has been developed in accordance with MTCA WAC 173-340-350(8). The FS develops and evaluates remedial action alternatives for the soil, groundwater, and sediment at the Site, and then presents a site-wide preferred remedial alternative to Ecology for consideration. The FS tasks include the following:

1. Review remedial action goals and objectives for the Site.
2. Incorporate the components of the Interim Action into the Site.
3. Define ARARs (i.e., identify applicable local, state, and federal laws) that the remedial action must comply with.
4. Compile, evaluate, and screen potentially applicable remedial technologies.
5. Develop and evaluate proposed remedial alternatives that meet the requirements outlined by MTCA.
6. Compare remedial alternatives to the MTCA requirements for a cleanup action per WAC 173-340-350(8).
7. Complete a Disproportionate Cost Analysis (DCA) procedure consistent with WAC 173-340-360(3)(e) to identify the alternative that is permanent to the maximum extent practicable.
8. Propose the site-wide preferred remedial alternative to Ecology for evaluation and concurrence in development of the Cleanup Action Plan for the Site.

In this FS, Steps 3 through 7 above are implemented separately for upland soil/groundwater and sediment areas of the Site. Those evaluations support Step 8, the selection of a proposed site-wide preferred remedial alternative.

7.1 DEFINITION OF REMEDIAL ACTION OBJECTIVES

RAOs are determined to specifically identify goals that should be accomplished to ensure compliance with ARARs and as a mechanism for meeting the scoping requirements of the MTCA Cleanup Regulations (Chapter 173-340 WAC). RAOs for the Site were presented in Section 1.2 of the RI, but, because they are used for the development and evaluation of remedial alternatives, the RAOs are repeated here.

RAOs for the Site include the following:

- Remediate upland soil and groundwater to protect human health from exposure to hazardous substances via direct contact and indoor air vapor intrusion.
- Remediate marine sediments to meet MTCA and SMS requirements protective of benthic species, direct contact to humans, and bioaccumulative risks to human and higher trophic level species health.
- Control soil-to-sediment contaminant migration pathways to prevent sediment recontamination at levels of concern or at concentrations greater than CULs, and to protect surface water quality.

The numeric criteria associated with these RAOs are presented in Section 5.2.5 for sediment, in Section 5.3.4 for groundwater, and in Section 5.4.4 for soil.

Additional FS remedial action goals include the following:

- Select remedial actions that will be consistent with future water-dependent industrial operations, uses, and configurations of the Site.
- Select remedial actions that can effectively be implemented and maintained within the active shipyard environment. Reduce shipyard business disturbances during remedial action implementation and minimize impacts to navigational use at and near the Site.
- Define shipyard operational or structural source control actions that must be implemented prior to site cleanup to protect against recontamination of sediment, soil, or groundwater from ongoing shipyard activities.
- Develop monitoring approaches to be implemented following completion of site remediation to confirm the long-term effectiveness of the selected remedy.
- Consider aquatic habitat and optimize the preferred alternative to provide ancillary aquatic habitat benefit, where possible, given active shipyard use.

The FS incorporates the fact that the Interim Action has been performed successfully in accordance with the Interim Action Basis of Design Report (Floyd|Snider 2017). As of May 2018, the environmental portions of the Interim Action have been completed and the construction of the pier is being completed. The results of the Interim Action and a detailed description of its components, including the results of the confirmation sampling will be presented in an Interim Action Completion Report, following completion of all construction activities. This document is anticipated to be submitted in the fall of 2018. The Interim Action included the following components:

- Abatement, removal, and disposal of hazardous materials associated with structures requiring removal.
- Demolition and removal of the wooden portion of the Harris Avenue Pier, and the Carpenter Building and its supporting Pier (including the East Marine Walkway).
- Dredging to CULs or RALs in subtidal sediments within the Interim Action area, with upland landfill disposal of dredged materials.
- Removal of contaminated intertidal sediments within the Interim Action area to approximately 3 feet deep from the surface of mudline, with upland landfill disposal of excavated materials. Capping of these removed areas with clean fill to match the prior grades.
- Shallow surface soil excavation (typically less than 4 feet deep) and backfilling with clean fill in the upland area of the shipyard and in the vicinity of the Harris Avenue Pier and the Carpenter Building and its supporting Pier.
- Construction of a sheet pile bulkhead and a replacement concrete pier in the location of the existing wooden portion of the Harris Avenue Pier to restore existing functions and maintain shipyard operations.
- Construction of a replacement marine railway walkway on the east side of the marine railway to restore existing functions.
- Associated utility work.

Based on the implementation of the Interim Action, the majority of AOC 3 has been addressed through source removal actions, as it is primarily within the footprint of the Interim Action area, Due to this action, remedial alternatives for the portion of AOC 3 that is within the Interim Action area, other than the implemented “excavation and landfill disposal,” will not be evaluated. Similarly, for the portion of AOC 1 that was within the footprint of the Interim Action area that was addressed through source removal actions (i.e., the subtidal sediments), no other alternatives will be evaluated. However, as the intertidal sediments were capped following excavation, a full removal alternative for these portions of AOC 1 will be evaluated.

The FS also assumes that all other existing shipyard infrastructure (buildings, piers, marine railway, and utilities) will be protected in their current condition, for continued shipyard use, unless these structures prevent a remedy from being constructed. If a structure prevents a component of the remedy from being constructed, it could be removed and replaced as part of the remedy implementation. Institutional controls will be developed to ensure that if expansion or redevelopment activities occur at the Site in the future, all exposure pathways to potentially contaminated materials will be protected. This includes preventing exposure of subsurface soils to areas of the Site that have the potential to drain to sediments or relocation of subsurface soils to those areas.

If these activities include demolition of currently existing structures, institutional controls will likely require evaluation of cleanup actions for underlying material that are permanent to the maximum extent practicable. All institutional controls will be described in an Environmental Covenant that will be periodically reviewed by Ecology. Additional discussion of coordination with potential future redevelopment is included in Section 14.0.

7.2 APPLICABLE LOCAL, STATE, AND FEDERAL LAWS

The selected cleanup alternative must comply with MTCA cleanup regulations (WAC 173-340), SMS (WAC 173-204-570), and applicable local, state, and federal laws. Together, these regulations and laws are identified as ARARs for the Site. Under WAC 173-340-350 and WAC 173-340-710, the term “applicable requirements” refers to regulatory cleanup standards, standards of control, and other environmental requirements, criteria, or limitations established under state or federal law that specifically address a remedial action, location, COC, or other circumstance at the Site. The “relevant and appropriate” requirements are regulatory requirements or guidance that do not apply to the Site under law, but have been determined to be appropriate for use by Ecology. ARARs are often categorized as location-specific, action-specific, or chemical-specific.

Remedial actions conducted under a consent decree with Ecology are exempt from the state and local ARAR procedural requirements, such as permitting and approval requirements; however, remedial actions must demonstrate compliance with the substantive requirements of those ARARs (WAC 173-340-710(9)). This exemption applies to procedural permitting requirements for the applicable state and local regulations listed in Tables 7.1 through 7.3. Remedial actions are not exempt from procedural requirements of federal ARARs.

7.2.1 Location-Specific ARARs

Location-specific ARARs are those requirements that restrict the allowable concentration of hazardous substances or the performance of activities, including remedial actions, solely because they occur in specific locations. Table 7.1 outlines the location-specific ARARs that were considered and identifies those applicable to the Site.

7.2.2 Action-Specific ARARs

Action-specific ARARs are requirements that define acceptable management practices and are often specific to certain kinds of activities that occur or technologies that are used during the implementation of cleanup actions. Activities could include excavation, grading or capping of soil and sediment, and upland disposal of excavated soil and dredged sediments. Any construction activities or excavations will require compliance with stormwater regulations. Table 7.2 identifies action-specific ARARs considered for applicability to the Site.

7.2.3 Chemical-Specific ARARs

The remediation of contaminated site media must meet the CULs developed under MTCA and SMS. These potential CULs are considered chemical-specific ARARs. Chemical-specific ARARs consist of those requirements that regulate the acceptable amount or concentration of a chemical that may be found in or released to the environment. Table 7.3 identifies chemical-specific ARARs considered for applicability to the Site.

8.0 Soil and Groundwater – Identification of Remedial Technologies

This section identifies and briefly describes the most commonly implemented remedial technologies for remediation of the site-specific COCs for soil (arsenic, copper, zinc, and TPH) and groundwater (arsenic, copper, zinc, TPH, and 1-methylnaphthalene), and the application and limitations of each technology. As described in Section 7.1, this evaluation only addresses the AOCs that are present outside of the Interim Action area.

Section 9.0 then describes the preliminary technology screening preformed to eliminate technologies that do not meet RAOs applicable to the Site, are not technically feasible, or do not address the types of contamination present.

8.1 IDENTIFICATION AND DESCRIPTION OF TECHNOLOGIES COMMON TO SOIL AND GROUNDWATER

The following technologies may be applicable for remediation of soil and groundwater contamination at the Site and for long-term protection of human and ecological receptors from exposure to soil and groundwater. Soil COCs consist of arsenic, copper, zinc, and TPH. Groundwater COCs consist of arsenic, copper, zinc, TPH, and 1-methylnaphthalene.

8.1.1 No Action

No action indicates that no active remedial technology would be implemented. No action can provide a reference for comparison of the benefits of other remedial technologies.

8.1.2 Institutional Controls

Institutional controls are physical, legal, and administrative measures that are implemented to minimize or prevent human exposure to contamination by restricting access to the Site. Institutional controls often involve deed restrictions or covenants, site advisories, use restrictions, or consent decrees, and would be implemented at the Site to limit or prohibit activities that may interfere with the integrity of any cleanup action or result in exposures to hazardous substances at the Site. Institutional controls are typically implemented in addition to other technologies when those technologies leave COCs on-site at concentrations that could pose a risk to human or ecological receptors. Institutional controls may include documents such as an Operations, Maintenance, and Monitoring Plan (OMMP) that would describe how contamination that remained on-site would be addressed if disturbed in the future.

Institutional controls are applicable to Site soil for protection of terrestrial ecological receptors and are potentially applicable to all Site soil and groundwater COCs.

8.1.3 Engineering Controls

Engineering controls are physical measures constructed to block exposure pathways and reduce or eliminate contaminant exposure to ecological and human receptors. Engineering controls focus on controlling or preventing access to the contamination. Engineering controls can be used as permanent measures or as temporary measures to prevent exposure to the contamination until a permanent cleanup is implemented.

Engineering controls vary in nature and scope. Soil engineering controls could include placement of an indicator layer on top of contaminated soil, stabilization of erosion areas, or the use of engineered equipment or access controls (e.g., fencing) to prevent or limit contact with contaminated soil. Engineering controls could also include installation of pavement (evaluated in Section 8.1.4) and a stormwater conveyance system to help minimize infiltration of stormwater through contaminated soil. Groundwater engineering controls vary in nature and scope but could include stabilization of soil that represents a source to groundwater (evaluated in Section 8.1.7) or installation of pavement and a stormwater conveyance system to help minimize infiltration of stormwater through contaminated soil. These controls would limit soil leaching to groundwater. Engineering controls require maintenance in perpetuity to assure proper function and prevent exposures.

The engineering controls technology is applicable to all Site soil COCs and is potentially applicable to all Site groundwater COCs.

8.1.4 Surface Capping

Surface capping is a containment remedy that places a cap over contaminated soil to control surface water infiltration, erosion, and wind migration of soil. Surface capping provides a physical barrier, preventing human and ecological exposures via direct contact. Surface caps can be constructed with asphalt, concrete, gravel, or clean fill. They are engineered to meet permeability requirements, prevent direct contact exposures, and withstand erosion. Building slab footprints or existing paved surfaces can also act as a capped surface. Stormwater conveyance systems may need to be installed in combination with capping if the cap is designed to minimize infiltration or if capping modifies existing grades and associated drainage. Surface capping requires maintenance to preserve integrity and is typically implemented with institutional controls that require cap maintenance and define procedures for soil and groundwater management when the cap is penetrated.

The surface capping technology is applicable to all Site soil COCs and is potentially applicable to all Site groundwater COCs.

8.1.5 Monitored Natural Attenuation

Monitored natural attenuation involves regular sampling and analysis to monitor the results of one or more naturally occurring physical, chemical, or biological process that reduce the mass, toxicity, volume, or concentration of chemicals in site soil or groundwater. These naturally occurring processes may include: biodegradation; dispersion; dilution; sorption; volatilization; and chemical stabilization, transformation, or destruction of contaminants. Monitored natural attenuation may be implemented as a stand-alone remedial technology or in combination with other remedial technologies.

In soil, natural attenuation would consist mainly of biodegradation for TPH and 1-methylnaphthalene contamination, but would not be an effective treatment for metals. Monitored natural attenuation is applicable to all groundwater contamination at the Site. Natural attenuation would consist mainly of dispersion, dilution, and sorption processes for the metals contamination and biodegradation for the TPH and 1-methylnaphthalene contamination.

8.1.6 Excavation and Landfill Disposal

Excavation of contaminated soil using standard construction equipment is a common method to achieve remediation goals. For off-site disposal, excavated contaminated soil is transported by either truck or rail to an appropriate licensed landfill. The extent of soil removal is defined by remedial design sampling or confirmation soil sampling of the excavated surface prior to backfill, compaction, and site restoration. Selection of backfill material and site restoration is dependent on site-specific considerations and is typically designed to meet future use of the site. In some circumstances, backfilled material may act as a capped surface, if contamination remains deeper than the bottom depth of the excavation. Excavation may require relocation of mobile structures or shoring to maintain sidewall stability. Dewatering or drawdown of the groundwater table may also be required if excavation is to occur below the groundwater table. Excavation depths will vary depending on the depth of contamination, presence of subsurface utilities, and site use.

Source removal as a groundwater remedial action would consist of excavation of soil contamination that is an ongoing source to groundwater contamination. Source removal through excavation and landfill disposal is typically conducted as a soil remediation technology (refer to Section 8.1.6); however, it can also effectively remediate groundwater by removing the contaminant source to groundwater. Source removal typically includes groundwater monitoring following implementation to confirm that the soil source to groundwater has been effectively removed and that groundwater concentrations are less than cleanup standards. Compliance may not occur immediately and may require a short time frame for subsurface conditions to stabilize.

Excavation is applicable to all Site soil and groundwater COCs.

8.1.7 Solidification and Stabilization

Solidification and stabilization physically bind or chemically immobilize/stabilize the contamination within the soil matrix, thereby reducing or eliminating contaminant mobility. With solidification, the contaminants are either enclosed or bound within the soil matrix via a binding agent such as cement grout. Stabilization involves adding and mixing a chemical compound with the contaminated soil to make the COC immobile through a chemical reaction that forms a new compound that is less toxic than the parent COC, or through adsorption processes.

Soil mixing with an auger is a remediation technique that can be used to implement solidification or stabilization by mixing amended soil in overlapping soil columns. The soil columns are formed by advancing a large-diameter auger into the subsurface, in combination with a series of mixing shafts. As the mixing shafts are advanced into the soil, grout or slurry containing a reactant that destroys or stabilizes the COC (for example, zero-valent iron) is pumped through the hollow stem of the shaft and injected into the soil. This process generates a large amount of spoils that are difficult to handle and can also leave wedges of untreated soil in the spaces between the installed soil columns.

Solidification or stabilization can also be accomplished in conjunction with excavation by mixing the binding agent into the soil at the base of excavation. This method can be advantageous if deeper excavation is riskier or more expensive due to structural stability.

Solidification/stabilization utilized for the protection of groundwater is typically combined with leachability testing or long-term groundwater compliance monitoring to ensure that the contaminants are immobilized and do not leach to groundwater.

The solidification and stabilization technologies are applicable to all Site soil and groundwater COCs, but are most effective for the arsenic, copper, and zinc contamination and least effective in treating TPH contamination.

8.1.8 Chemical Oxidation

Chemical oxidation involves injecting oxidizing agents, such as ozone, hydrogen peroxide, or permanganate, into the subsurface to rapidly destroy organic chemicals. Injection can be applied in both vadose and saturated zones, but is most effective in treating chemicals in the saturated zone. Applicability of chemical oxidation is dependent on aquifer characteristics, soil types, and the homogeneity of the subsurface, as injected solutions tend to follow preferential pathways through heterogeneous soil. Volumes of injected agent and rate of chemical injection are dependent on the subsurface conditions at the Site. Injection points may be installed as permanent injection wells or may be injected via temporary borings. The effectiveness of injections is quite dependent on Site conditions, which typically are heterogeneous, making it difficult to obtain an even and effective distribution of the oxidant. Further, a high soil oxidant demand (i.e., high soil organic content that consumes the added oxidant) or other oxidizer sink may significantly reduce the effectiveness of chemical oxidants.

Chemical oxidation is only applicable to the TPH and 1-methylnaphthalene contamination, but by treating the TPH contamination with chemical oxidation and restoring the natural redox conditions, the arsenic concentrations in groundwater would be reduced. Chemical oxidation is not applicable to copper or zinc groundwater contamination at the Site.

8.1.9 Thermal Treatment

Thermal treatment (which is commonly applied via electrical resistance heating or thermal conduction) is a process that quickly and evenly heats contaminated waste to volatilize chemicals with low boiling points (e.g., TPH). Vapors are then recovered and typically treated using activated carbon or thermal oxidation. Thermal treatment can be applied as an in-situ or ex-situ process.

In-situ remediation involves passing electrical current or direct heat through zones of contaminated soil and groundwater. With electrical resistance heating, a current is delivered to the subsurface through a series of closely spaced electrodes. Resistance to the flow of electricity between electrodes via the natural resistance of the soil matrix generates heat in the subsurface. Soil consisting of silt can be heated as effectively as sandier zones due to the superior electrical resistance properties of silt or clay. If heated close to the boiling point of water, the heating process volatilizes chemical droplets embedded in soil into a vapor phase. The contaminated vapors, along with steam produced by the boiling of groundwater, are removed from the subsurface through a vapor recovery network for condensation and treatment.

Ex-situ thermal treatment requires excavation and placement of the subsurface soil into a treatment cell or combustion chamber. The material is then heated through electrical resistance or application of direct heat to the temperature necessary to volatilize targeted solid and aqueous contaminants into the vapor phase. Ex-situ thermal treatment generally allows a shorter and more efficient heating process than in-situ thermal treatment because of the ability to homogenize the material inside the treatment cell, but requires additional costs in soil excavation and handling.

Thermal treatment is applicable to Site TPH soil contamination, but is not effective in treating metals contamination. Because TPH contamination greater than the CUL is only present in the vadose zone, this technology would have little impact on TPH concentrations in groundwater, and would not effectively treat groundwater at the Site for TPH. 1-methylnaphthalene has a lower boiling point, which may hinder in situ thermal treatment effectiveness. Treatment of TPH in the vadose zone soils would be expected to reduce arsenic concentrations in groundwater by changing the geochemistry of the subsurface; however, thermal treatment is not applicable to copper or zinc contamination in groundwater at the Site.

8.2 IDENTIFICATION AND DESCRIPTION OF SOIL TECHNOLOGIES

The following technologies may be applicable for remediation of soil contamination at the Site, which consists of arsenic, copper, zinc, and TPH.

8.2.1 Bioremediation and Bioventing

Bioremediation of soil involves the process of using microorganisms in situ or ex situ to degrade COCs to less- or non-toxic constituents. Microorganisms, nutrients, or oxygen are injected into soil to accelerate the natural biodegradation process and aid in the decomposition of COCs. Typical enhancements include oxygen, nitrates, or solid-phase peroxide products. Bioventing involves adding oxygen to vadose zone soil to aid microorganisms already present in breaking down COCs. Bioventing is effective in the vadose zone for degrading TPH and organic vapors, but is not effective at treating saturated soil. Mixing of microorganisms, nutrients, or oxygen with contaminated soil can also be accomplished with excavated soil in landfarms. Following degradation of COCs, the landfarmed soil can be replaced on-site.

The bioventing/bioremediation technologies are applicable to the TPH contamination, but are not effective at treating the metals contamination.

8.2.2 Soil Vapor Extraction

Soil vapor extraction (SVE) is a process that extracts soil vapor from unsaturated soil pore spaces in the vadose zone by applying a vacuum to the subsurface. Vacuum is applied by a blower connected to extraction wells screened within the unsaturated area of contamination. The controlled flow of air removes accumulated volatile vapors from the unsaturated zone, which causes additional volatilization of chemicals in the soil to the vapor phase. Soil vapor extracted from the subsurface is processed through a treatment system, typically including filters for particulate removal, condensate removal, and treatment by oxidation or carbon filtration. SVE systems may be enhanced with air sparging or groundwater extraction if contamination extends below the water table.

SVE is applicable to the volatile fraction of the TPH soil contamination located in the vadose zone, but is not effective in treating the heavy fraction of TPH (higher end of diesel- and oil-range) or metals contamination. SVE is not effective in treating metals contamination.

8.3 IDENTIFICATION AND DESCRIPTION OF GROUNDWATER TECHNOLOGIES

The following technologies may be applicable for remediation of groundwater contamination at the Site, which consists of arsenic, copper, zinc, TPH, and 1-methylnaphthalene.

8.3.1 Bioremediation

Bioremediation of groundwater involves the process of using microorganisms in situ to degrade COCs to less- or non-toxic constituents. Microorganisms, nutrients, or oxygen are injected to groundwater to accelerate the natural biodegradation process and aid in the decomposition of COCs. Typical enhancements include oxygen, nitrates, or solid-phase peroxide products. Bioremediation amendments, such as a slow oxygen release compound, can be effective in treating residual contamination over a long duration (up to 12 months) following implementation. Bioremediation amendments are typically applied to groundwater via a permanent well or temporary injection points. Bioremediation of groundwater is typically only effective once the source of the contamination is removed and is often used in combination with other remedial technologies.

Bioremediation is only applicable to the TPH and 1-methylnaphthalene contamination, but by using bioremediation to treat residual TPH contamination and restoring the natural redox conditions, the arsenic concentrations would be expected to be reduced. Bioremediation would not effectively treat the other metals contamination in groundwater.

8.3.2 Permeable Reactive Barrier Wall

Permeable reactive barrier (PRB) walls intercept and treat contaminated groundwater flowing from an upgradient source. Groundwater flows through a treatment wall of reactive material, which for metals is typically composed of zero-valent iron mixed with sand. Barrier walls are generally constructed in one of two configurations, either as a “funnel and gate” configuration that employs angled wing walls to capture and direct the contaminated groundwater to a central treatment unit, or as a linear trench intersecting the plume. Groundwater flows according to its natural gradient through the PRB, where the reactive media within the wall react with the dissolved chemicals in groundwater. The life span and effectiveness of a PRB wall is also dependent on the mass of chemicals passing through the wall. PRB walls do not remediate the source area itself, but decrease the contaminant solubility or otherwise immobilize the chemicals migrating from the source area with the groundwater.

PRB walls are applicable for remediating arsenic, TPH, and 1-methylnaphthalene groundwater contamination at the Site, and are emerging technologies for copper and zinc and may be applicable to remediate copper or zinc dependent upon Site conditions.

8.3.3 Low-Permeability Barrier Wall

Barrier wall containment technologies are implemented to contain chemicals in place and typically do not involve further source area treatment. Vertical containment barriers are placed in the subsurface to cut off groundwater flow and stop chemical migration. They can be constructed using a variety of materials such as metal sheet piling, HDPE, or a slurry mixture. The slurry wall is constructed of a low-permeability material, typically a soil and bentonite clay mixture, that does not degrade in the environment. Barrier walls are typically constructed vertically from the ground surface to a depth greater than the chemical plume in soil and groundwater, or until the wall encounters a confining layer. Containment remedies are often implemented in combination with permanent pumping remedies to maintain inward gradients within the contained area and provide hydraulic control. Barrier walls and hydraulic control require continued monitoring in perpetuity to confirm the hydraulic gradients are maintained and extensive maintenance on the systems installed to pump groundwater to maintain inward gradients. Pumping system operations would also require treatment and disposal of extracted groundwater that is contaminated.

A low-permeability barrier wall is applicable to all Site groundwater COCs.

8.3.4 Pump and Treat

Pump and treat involves pumping contaminated groundwater from the subsurface and treating it before it is discharged. Treatment is generally conducted by air stripping for VOCs, filtration via activated carbon for organic compounds, or precipitation or ion exchange for metals. Groundwater pump and treat can reduce chemical concentrations in saturated soil, but only slowly by increasing the diffusion of soil contamination into groundwater. Extraction system design and treatment are dependent on the site characteristics and chemical type. Extraction wells may be screened at different levels or intervals to maximize the system effectiveness; however, restoration time frames for pump and treat systems are often very long because pump and treat cannot significantly accelerate the removal of mass from source areas, which are often large enough to leach chemicals into groundwater for long periods of time.

The pump and treat technology is applicable to all Site groundwater COCs.

8.3.5 Air Sparging

Air sparging is typically used to treat groundwater contaminated with volatile and certain semivolatile chemicals including the volatile fraction of TPH. Air is injected into the contaminated aquifer through injection wells, where it bubbles upward through channels in the soil column, creating an air stripping effect that moves chemicals in groundwater to the air bubble, which migrates to the vadose zone where it can be recovered and treated. Air sparging is limited by contaminant depths and works best in homogenous sandy soil formations that limit preferential pathways for air flow.

The air sparging technology may be applicable to the lighter volatile fractions of TPH contamination, but would not be directly applicable to the metals contamination in groundwater at the Site. It would have some limited effect on the middle- and heavy-end fractions of TPH and 1-methylnaphthalene by supplying additional oxygen for biodegradation, which would then result in reduction in dissolved arsenic concentrations.

9.0 Soil and Groundwater – Technology Screening and Remedial Alternative Development

This section presents a screening of the remedial technologies presented in Section 8.0 that are applicable to soil and groundwater contamination at the Site. The technology screening is followed by the aggregation of the retained soil and groundwater remedial technologies into remedial alternatives for further evaluation.

9.1 REMEDIAL TECHNOLOGY PRELIMINARY SCREENING

Screening of remedial technologies is presented in Table 9.1. The preliminary screening reviews each of the technologies presented in Section 8.0 for applicability in treating the Site COCs in AOC 2A, 2B, and 3, and screens the technologies against site-specific considerations. The process retains or rejects technologies based on the applicability at the Site given: the COCs and impacted media, effectiveness and proven success at similar sites, applicability of the technology within the Site physical constraints, and the ability of the technology to achieve RAOs.

As described in Table 9.1, no action, bioremediation/bioventing, chemical oxidation, SVE, monitored natural attenuation, and thermal treatment were rejected from further evaluation for remediation of soil.

As described in Table 9.1, no action, chemical oxidation, thermal treatment, monitored natural attenuation, PRB wall, low-permeability barrier walls, pump and treat, and air sparging technologies were rejected from further evaluation for remediation of groundwater.

9.2 SUMMARY OF RETAINED TECHNOLOGIES AND CONSIDERATION OF ADDITIONAL CONDITIONS

Based on the remedial technology screening, the technologies discussed in this section were retained for aggregation into alternatives to address soil and groundwater contamination at the Site. Each technology is discussed in greater detail in the following sections with consideration of site-specific conditions that may impact the applicability and success of the technology.

9.2.1 Soil and Groundwater Technologies

9.2.1.1 Institutional Controls

Institutional controls have been retained for further evaluation as a soil and groundwater remedial technology. As a stand-alone technology, institutional controls would not reduce, destroy, or remove any chemical contamination beyond that which would occur via natural processes, but would instead be implemented in addition to other technologies to meet RAOs, ensure long-term protectiveness of the selected remedy, prevent exposure to contaminated soil and groundwater, and implement protective management procedures to be utilized during potential future site redevelopment and maintenance activities (e.g., utility work).

Institutional controls would be implemented with any technology that leaves soil contamination in place at concentrations greater than direct contact criteria or in excess of CULs. Institutional controls that may be implemented at the Site for soil could include maintenance of a containment cap over contaminated soil remaining at the Site. This would ensure current and future safety, soil management, and cap restoration requirements for subsurface excavation activities such as utility work, landscaping, or construction that disturbs the ground in areas of soil contamination. If contaminated soil is left on-site following remediation, an Ecology-approved OMMP could be implemented as an institutional control to address future subsurface work. Institutional controls could be developed to address the direct contract and erosion pathways.

Institutional controls would be implemented with any technology that leaves groundwater contamination in place. Institutional controls that may be implemented for groundwater could include current and future restrictions on groundwater withdrawals and use, and procedures for management of groundwater during dewatering or excavation. Institutional controls used in combination with other remedial technologies would successfully achieve the RAOs, and could be implemented given the Site physical conditions.

When used in combination with other remedial technologies, institutional controls would successfully achieve the Site RAOs, and could be implemented given the Site physical conditions.

9.2.1.2 Engineering Controls

Engineering controls have been retained for further evaluation for Site soil and groundwater. Although engineering controls would not reduce, destroy, or remove any metals or TPH contamination, engineering controls could be used to address the exposure pathways by preventing exposure. Engineering controls, such as using an indicator layer placed on top of contaminated soil left in place prior to backfilling, would minimize the risk of in advertent human contact with contaminated soil during future utility or other excavation work. When used in combination with other remedial technologies, engineering controls would successfully achieve the Site RAOs, and could be implemented given the Site physical conditions.

9.2.1.3 Surface Capping

Surface capping of Site soil has been retained for further evaluation. When implemented with institutional controls, capping could be used to address all of the Site soil COCs through management of the exposure pathways and erosion pathways. Surface capping design would likely vary by location and shipyard use. Existing paved areas and buildings provide effective capping if maintained. The goal of capping would be to manage the direct shipyard worker contact and erosion pathways. Cap technologies can be designed to consist of either (1) impermeable or semi-permeable paving or (2) placement of permeable clean compacted soil or gravel over contaminated soil. Cap design details would be developed during the remedial design phase of the project. Capping used in combination with groundwater remedial technologies, such as source removal, would successfully achieve the Site RAOs and could be implemented given the Site physical conditions.

9.2.1.4 Source Removal by Excavation and Landfill Disposal

Excavation and landfill disposal of Site soil has been retained for further evaluation as a soil and groundwater technology because it could be used to address all of the Site soil COCs, which would also address groundwater COCs. The technology may be implemented to remove all soil contamination to a selected soil concentration (CUL or RAL) or be implemented to a limited extent to remove focused areas of soil contamination. Soil excavation may be implemented in combination with other technologies depending on the extent of contamination left in place following a focused removal. If excavation were conducted as a focused removal, additional actions would be required to manage exposure for the contaminants remaining on the Site.

Because the presence of arsenic in groundwater in AOC 3 is associated with redox conditions caused by TPH contamination in soil, excavation of the TPH-contaminated soil would both remove TPH and reduce arsenic exceedances in groundwater. The removal of shallow soil containing arsenic would further reduce arsenic concentrations in groundwater. Similarly, source mass removal of copper and zinc in soil would be expected to reduce copper and zinc concentrations in groundwater. When used in combination with other remedial technologies, excavation would successfully achieve the RAOs, and could be implemented given the Site physical conditions.

9.2.1.5 Soil Solidification/Stabilization

Solidification and stabilization has been retained for further evaluation as a potential remedy for remediating metals in soil and groundwater in areas where soil contamination presents an ongoing source to groundwater contamination. Immobilizing COCs in soil would protect the soil to groundwater pathway and act to remediate groundwater. This technology is retained for use in combination with soil excavation. Given the technology constraints of implementing solidification/stabilization as a stand-alone remedy, such as the presence of utilities and the likelihood of leaving contaminated soil in wedges behind, soil solidification/stabilization would most likely be performed in combination with excavation, at the base of excavations in areas where removal of deeper soils is infeasible due to constructability issues such as nearby structure stability, or groundwater table elevation. Soil solidification/stabilization may be accomplished by mixing an amendment into soils at the base of an excavation (with excavation equipment). When used in combination with other remedial technologies, soil solidification/stabilization would successfully achieve the RAOs, and could be implemented given the Site physical conditions.

9.2.2 Groundwater-Specific Technologies

9.2.2.1 Bioremediation

Bioremediation of TPH groundwater contamination has been retained for further evaluation. Bioremediation has been shown to be effective in treating residual contamination in situ, following source area removal or treatment. Bioremediation can consist of injection of bioremediation amendments, such as a slow oxygen-release compound, that treat residual groundwater contamination for up to a year following application. Bioremediation amendments can also be placed at the base of an excavation area to treat any residual groundwater contamination that may remain in the saturated zone. Bioremediation can be used with source removal, or other remedial technologies. When used in combination with other remedial technologies, bioremediation would assist in successfully achieving the RAOs, and could be implemented given the Site physical conditions.

9.3 AGGREGATION OF SOIL AND GROUNDWATER REMEDIAL ALTERNATIVES

The retained technologies described above have been aggregated into remedial alternatives for the uplands portion of the Site. Each alternative presented below includes the completion of the Interim Action for the portions of AOC 3 that are within the Interim Action boundary.

The alternatives are discussed in the following sections and are presented in order from least protective to most protective. Alternative 1 is a minimum removal alternative and Alternative 3 is a full removal alternative that is consistent with the MTCA definition of a permanent cleanup action.

The alternatives were selected to address both soil and groundwater contamination at the Site. The three alternatives presented will be evaluated according to the MTCA DCA procedures in Section 10.0, to compare the costs and benefits of the cleanup alternatives, and to identify the alternative that is permanent to the maximum extent practicable.

The alternatives were developed to address the contamination within each AOC and, for the most part, the alternatives are described by AOC. However, the AOCs are interrelated in that they spatially overlap each other, the remedies to be applied within each AOC are similar, and the remedies complement one another. For example, removal of shallow metals-contaminated soil in AOC 2A is expected to have an ancillary benefit on the groundwater remedy for AOC 3 and AOC 2B. Table 9.2 summarizes these remedial alternatives and identifies the technologies applied to each AOC.

Table 9.2
Proposed Remedial Alternatives for Soil and Groundwater

AOC[1]	Alternative 1	Alternative 2	Alternative 3
Site-wide	Perimeter compliance groundwater monitoring		
	Institutional controls in the form of an Environmental Covenant will require that Site land use remain industrial and that a wildlife barrier (crushed gravel, pavement, or buildings) be present across the Site. Protection of Site users will be maintained via an OMMP.		
AOC 2A	Existing unpaved areas: ○ Excavation of 6 inches of surface material ○ Geotextile indicator layer placement ○ Cap with clean gravel surface Maintain existing building and pavement areas to provide cap: ○ Excavation of 6 inches of surface material ○ Geotextile indicator layer placement ○ Cap with clean gravel surface Maintain existing building and pavement areas to provide cap.	Existing unpaved areas: ○ Implementation of one or more of the following remedies, depending on Site conditions and extent of contamination, may be used: ○ Excavation to 2 feet bgs, placement of geotextile indicator layer and capping with clean gravel. ○ Excavation to 1 foot bgs and capping with asphalt pavement. Installation of associated stormwater infrastructure or new buildings associated with redevelopment. ○ Potential targeted excavation of deeper shallow soils (2 to 4 feet bgs) based on remedial design sampling. Maintain existing building and pavement areas to provide cap.	AOC-wide: ○ Demolition of existing pavement and buildings at Fairhaven Shipyard to allow for excavation; maintain Fairhaven Shipyard building on the southern property boundary ○ Excavation of shallow soil (as deep as 4 feet bgs) to CUL ○ Backfill with a clean fill and gravel surface
AOC 2B		Perform remedial design sampling to determine extent of deeper contaminated soil: ○ Existing unpaved areas: ○ Implementation of one or more of the following remedies may be used: ○ Excavation to 2 feet bgs, as necessary, placement of geotextile indicator layer and capping with clean gravel. ○ Excavation to 1 foot bgs and capping with asphalt pavement. Installation of associated stormwater infrastructure or new buildings associated with redevelopment. ○ Potential excavation of deeper soils (anticipated to be approximately 8 feet bgs) based on remedial investigation results. ○ Contingency solidification/stabilization at base of deep excavation. ○ Maintain existing building and pavement areas to provide cap.	Perform remedial design sampling to determine site-specific CULs and extent of deeper contaminated soil. Demolition of existing pavement and buildings at Fairhaven Shipyard to allow for excavation: ○ Excavation of deeper soils (anticipated to be approximately 8 to 10 feet bgs) to CULs ○ Backfill with a clean fill and gravel surface
AOC 3	Interim Action as completed in 2018 included: source removal to CULs with upland landfill disposal of excavated materials; and capping with clean fill overlain by gravel surface. Existing pavement and structures were left in place.		
	Monitored natural recovery.	If confirmation monitoring shows groundwater exceedances, implement contingency bioremediation amendment.	Removal of existing pavement and structures, and excavation to CULs.

Note:

[1] The AOCs are interrelated in that they spatially overlap each other, and the remedies complement one another. AOCs 2B and 3 are located within AOC 2A; AOC-wide actions described with respect to AOC 2A would also apply to AOC 2B and AOC 3.

Site images from these AOCs can be found in Appendix A. Important conclusions about current data, exposure pathways, and CULs for each AOC were discussed in the RI and are particularly germane to the discussion of the alternatives. Those conclusions and considerations are summarized here by AOC.

AOC 2A

AOC 2A includes all soil at the Site where it is necessary to address direct contact of arsenic contamination by shipyard workers. The POC for direct contact is 15 feet bgs, but the contamination is limited to surface soil, primarily within the top 2 feet. There are select areas where contamination greater than direct contact CULs may be present up to 4 feet bgs. The COC is arsenic, but the action will also decrease the mass of copper and zinc on-site that is co-located with the arsenic.

AOC 2B

AOC 2B is located within AOC 2A and was delineated to identify copper and zinc concentrations in soils that may be responsible for the groundwater exceedances in MW-02A and MW-12. Arsenic also exists in shallow soils within this area, as AOC 2B is within AOC 2A. Soil within AOC 2B will be remediated to address direct contact of arsenic by shipyard workers and leaching of copper and zinc from soil to groundwater.

AOC 3

The majority of AOC 3 was addressed in the Interim Action through a source removal to CULs of soil containing copper, zinc, arsenic, and TPH. The remaining soil within AOC 3 lies below the marine railway sidetracks and associated concrete pad.

AOC 3 is located within AOC 2A, discussed above, and therefore must address the direct contact exposure pathway for arsenic in surface soil. In addition, AOC 3 is defined as soil impacted by petroleum hydrocarbons, primarily associated with presumed releases from a historical diesel AST system. The goal of remediation of AOC 3 is the protection of groundwater. TPH concentrations in groundwater in AOC 3 are currently protective of both surface water and sediment quality (refer to Section 5.4.2 and Appendix G). However, arsenic concentrations are elevated to levels greater than its proposed CUL in groundwater in this area. The most likely cause is dissolution of arsenic from soil (both contaminated and native) due to anaerobic groundwater conditions caused by biological degradation of TPH at the water table. This process is well understood and is best remedied by removal or treatment of the biologically degradable petroleum at the water table. As the groundwater then returns to less anaerobic conditions, the arsenic re-adsorbs/precipitates on the soil, decreasing its concentrations in groundwater (refer to Sections 5.3 and 5.4 for additional discussion). Therefore, the remedy for AOC 3 must achieve the remediation of COCs in soil as measured by groundwater compliance for arsenic and 1-methylnaphthalene used as an IHS for TPH.

Finally, the diesel contamination in vadose zone soils in this area contains C_8 to C_{12} aliphatic TPH that could cause vapor intrusion issues if a future building were constructed in this area. Therefore, remediation of the diesel at the water table could include remediation of the diesel in the overlying soils to decease the potential for future vapor intrusion of C_8 to C_{12} aliphatics.

9.3.1 Alternative 1

Alternative 1 is considered the minimum removal alternative and consists of shallow surface soil excavation, engineering controls, capping, groundwater monitoring, and institutional controls. Refer to Figure 9.1.

AOC 2A and AOC 2B

For Alternative 1, all unpaved areas of AOC 2A and AOC 2B would be excavated 6 inches and restored with a 6-inch-thick gravel cap to interrupt the direct contact pathway of shipyard workers to contaminated shallow soil. A geotextile fabric layer would be placed over these excavated areas to provide an indicator layer between clean fill and underlying contaminated soil. These actions would address direct contact exposures to arsenic. Institutional controls would require procedures for future soil disruption that would be protective of the direct contact exposure pathways. AOCs 2A and 2B would be addressed in the following manner:

- Excavation of contaminated soil would be performed to a depth of 6 inches below the existing grade for the areas shown in Figure 9.1. Excavated soil would be disposed of off-site at a landfill. Excavation of metals-contaminated soil in this area would have an ancillary benefit on the groundwater remedy through the slight reduction in contaminant mass.
- A geotextile would be placed in the excavated areas to prevent mixing of clean surface gravel with subsurface contaminated material and to provide a contamination indicator layer. Excavated areas would be backfilled with compacted gravel to a surface that meets the shipyard's operational requirements. The geotextile placement and backfilling with clean surface material would address the direct contact exposure pathway in AOC 2A.
- Existing buildings and pavements would remain in place, serving as a cap for subsurface soil.
- Institutional controls would require implementation of an Ecology-approved OMMP specifying soil management procedures for future excavation and health and safety requirements for subsurface work. These procedures would be applicable to any future site redevelopment or maintenance that involves removal or disturbance of subsurface material. The OMMP would be prepared for Ecology approval concurrent with remedial design and would include specifications for the following:
  - Health and safety requirements for working in and handling site soils.
  - BMPs for soil stockpiling, dust control, and erosion control. Requirements for off-site disposal and associated recordkeeping.
  - Requirements for Ecology notification and reporting.
- Stormwater control would be considered during design to ensure that stormwater at the Site would continue to infiltrate.

AOC 3

Alternative 1 for AOC 3 includes the work that was completed during the Interim Action, which consisted of excavation and off-site disposal of accessible soil with arsenic concentrations greater than the CUL for direct contact and copper, zinc, and TPH concentrations greater than the CUL for protection of groundwater. The outline of the Interim Action area in relation to AOC 3 is shown on Figure 9.1. The AOC 3 soil not removed during the Interim Action would remain in place beneath existing structures and pavement serving as a cap for subsurface soils. Contaminated soil remaining in place would be subject to the site-wide institutional controls established for AOC 2A, including all requirements of the Ecology-approved OMMP for any future site redevelopment or maintenance.

The majority of source contamination of TPH and metals causing exceedances in MW-01 and MW-09 was removed during the Interim Action. Groundwater monitoring will be conducted during the remedial design sampling to determine the effectiveness of the Interim Action to bring the groundwater into compliance.

Site-Wide Institutional Controls

Institutional controls in the form of an Environmental Covenant limiting the Site to industrial or other use that is consistent with Site CULs would be implemented. This would include a map showing the nature and extent of residual soil contamination that remained on-site at concentrations greater than CULs.

Site-Wide Groundwater

An OMMP would be developed and implemented. The OMMP schedule would likely include 2 years of quarterly performance monitoring for TPH and metals in the downgradient perimeter monitoring wells. Groundwater samples would be collected and analyzed for 1-methylnaphthalene, arsenic, copper, and zinc. The OMMP would also include annual confirmation monitoring conducted along the downgradient perimeter compliance monitoring well network to assess remedy effectiveness and would be conducted for some duration determined in coordination with Ecology until trends in groundwater quality are sufficiently determined. The downgradient perimeter compliance monitoring well network would consist of MW-02A, MW-06, MW-07, MW-08, MW-09, MW-11, and MW-12.

Associated Cost

The estimated cost for Alternative 1 is $4.1 million and includes remedial design sampling and design; implementation; compliance groundwater monitoring; and a 30% contingency. The total alternative cost also includes the cost for the Interim Action as the Interim Action is considered part of the remedy. The cost estimate for Alternative 1 is included in Appendix H, Table H.2.

9.3.2 Alternative 2

Alternative 2 consists of soil removal for placement of a cap that prevents direct contact of shipyard workers to shallow soil contamination. Compared to Alternative 1, Alternative 2 also provides a greater degree of contaminant mass removal for protection of the soil to groundwater pathway. The cap design will vary by area and will consist of either a 2-foot excavation followed by placement of a 2-foot-thick gravel cap, or a 1-foot excavation and placement of an asphalt cap. The extent of gravel and asphalt caps will be determined during remedial design and will consider site use and future development plans. In asphalt cap areas, installation of a stormwater conveyance system would be included. Deeper excavation may occur in “hot spots” based on the results of the remedial design sampling. Additional actions for Alternative 2 include contingency bioremediation application (AOC 3), groundwater monitoring, and institutional controls. Alternative 2 is considered more protective than Alternative 1 because it proposes more contaminant mass be removed and the placement of an asphalt or thicker gravel capped surface, which would be expected to be more stable and permanent over the long term. Refer to Figure 9.2.

AOC 2A and AOC 2B

For Alternative 2, remedial design sampling would be conducted across AOC 2A and AOC 2B to delineate the horizontal and vertical extent of contamination for arsenic in AOC 2A and for arsenic, copper, and zinc in AOC 2B. No action would occur in those areas of the Site where sampling indicates soil currently meets CULs. In unpaved areas where sampling indicates that metals contamination in shallow surface soils is present at concentrations greater than CULs, one or a combination of two equally protective potential remedial actions would be implemented. The final determination for which remedy will be selected will be based upon shipyard use and future development plans:

- Removal of the top 2 feet of soil to support gravel cap placement in areas. Excavated soil would be disposed of off-site at a landfill. A geotextile indicator fabric would be placed in excavated areas to prevent mixing of clean surface gravel with subsurface contaminated material and to provide a contamination indicator layer. Excavated areas would then be capped with compacted gravel to a surface that meets the shipyard's operational requirements.

9. Removal of the top 1 foot of soil to support pavement placement. Though the minimum excavation depth is 1 foot, the specific excavation depth would vary across the Site based on geotechnical conditions and existing grades. Excavated areas would be backfilled with compacted base course material as necessary, and asphalt pavement would be placed. Stormwater infrastructure would be installed in paved areas because those areas of the Site would no longer infiltrate stormwater. The layout and functionality of the stormwater conveyance system would be developed during design.

The decision for which shallow soil remedy would be implemented would be determined during design and would be based upon the feasibility of each option across the Site and the shipyard's future operational needs. One remedy may be chosen for the entire Site or both remedies may be constructed in different areas of the Site.

In addition, if remedial design sampling indicates that deeper excavation in limited areas would result in compliance with CULs, additional soil removal may be conducted. Achieving compliance with CULs in shallow soil would reduce the footprint of the Site, requiring long-term groundwater monitoring and cap maintenance and monitoring. This benefit would be compared against the cost of soil removal during remedial design. The nature and extent of residual contamination remaining in Site soils will be documented in the Cleanup Action Plan.

In AOC 2B, remedial design sampling may include one or more of the following:

- Collection of additional saturated soil data within AOC 2B and upgradient of MW-02A and MW-12, to delineate copper and zinc concentrations contributing to groundwater exceedances at these monitoring well locations.
- Soil leachability testing to determine a CUL for copper and zinc within AOC 2B based on leaching test data. Should a leaching test be performed, the requirements in WAC 173-340-747(7) must be met. Specifically, test effluent concentrations must be less than or equal to 10 times the applicable groundwater cleanup level for zinc, and less than or equal to the applicable groundwater cleanup level established for arsenic and copper.
- Collection of porewater data downgradient of MW-02A and MW-12 to evaluate copper and zinc concentrations at the point where groundwater discharges to surface water.

These data would be used to perform an empirical demonstration to evaluate compliance with the groundwater CUL.

- Collection of data necessary to calculate a site-specific groundwater CUL for copper consistent with USEPA's 2016 *Draft Aquatic Life Ambient Estuarine/Marine Water Quality Criteria for Copper* (USEPA 2016).

Alternative 2 assumes that excavation of soil to a depth of approximately 8 to 10 feet bgs may be necessary to remove "hot spot" copper and zinc contamination in soil within the boundary of AOC 2B. Based on remedial design data, if deep contamination removal is necessary near sensitive aboveground structures and excavation may be costly or infeasible, then using a solidification/stabilization amendment mixed into the base of the excavation to stop leaching from deeper soils would be considered as an alternative during design.

Each soil remedy component would provide ancillary benefit to the groundwater remedy through the reduction in metals-contaminated soil mass. Excavation and backfilling with clean surface material or capping with pavement would address the direct contact exposure pathway. Existing buildings and pavements would remain in place, serving as a cap for subsurface soil. The remaining soil would require implementation of an Ecology-approved OMMP specifying soil management procedures for future excavation and health and safety requirements for subsurface work. These procedures would be applicable to any future Site redevelopment or maintenance that involves removal or disturbance of subsurface material. The OMMP would be prepared for Ecology approval concurrent with remedial design and would include specifications for the following:

- Health and safety requirements for working in and handling site soils.
- BMPs for soil stockpiling, dust control, and erosion control.
- Requirements for off-site disposal and associated recordkeeping.
- Requirements for Ecology notification and reporting.

Groundwater monitoring would confirm the effectiveness of the remedy, as described below.

AOC 3

Alternative 2 for AOC 3 includes the work that was completed during the Interim Action, which consisted of fully removing soil with arsenic concentrations greater than the CUL for direct contact and copper, zinc, and TPH concentrations greater than the CUL for protection of groundwater. The outline of the Interim Action area in relation to AOC 3 is shown on Figure 9.2. The remaining portion of AOC 3 is covered by existing structures and pavement serving as a cap for subsurface soils.

The majority of source contamination of TPH causing exceedances in MW-01 and MW-09 was removed during the Interim Action. Groundwater compliance monitoring conducted following the full remediation will be used to determine the effectiveness of the Interim Action to bring the groundwater into compliance. If compliance monitoring indicates source contamination is still contributing to exceedances of TPH (based on 1-methylnaphthalene) in groundwater then bioremediation via a biological amendment, such as an oxygen release compound, would be used in a series of focused injection events to treat residual TPH in groundwater. The type of biological amendment and number of injection events would be selected during design in concurrence with Ecology. Performance monitoring after the injection event would continue as part of the site-wide groundwater compliance monitoring.

Site-Wide Institutional Controls

Institutional controls in the form of an Environmental Covenant limiting the Site to industrial or other use that is consistent with Site CULs would be implemented. This would include a map showing the nature and extent of residual soil contamination that remain on-site at concentrations greater than CULs.

Site-Wide Groundwater

Similar to Alternative 1, an OMMP would be developed and implemented. The OMMP would likely include 2 years of quarterly performance monitoring for TPH and metals in the downgradient perimeter monitoring wells. Groundwater samples would be collected and analyzed for 1-methylnaphthalene (surrogate for TPH), arsenic, copper, and zinc. The OMMP would also include annual confirmation monitoring conducted along the downgradient perimeter compliance monitoring well network to assess remedy effectiveness and would be conducted for some duration determined in coordination with Ecology until trends in groundwater quality are sufficiently determined. The downgradient perimeter compliance monitoring well network would consist of MW-02A, MW-06, MW-07, MW-08, MW-09, MW-11, and MW-12.

Associated Cost

The estimated cost for Alternative 2 is $5.9 million and includes remedial design sampling and design, implementation, compliance groundwater monitoring, and a 30% contingency. Two cost estimates were developed for Alternative 2 to evaluate a full gravel cap remedy and a full asphalt cap remedy. The final cost is an average of these two estimates. The total also includes the cost for the Interim Action, as the Interim Action is considered part of the remedy. The cost estimates for Alternative 2 are included in Appendix H, Tables H.3 and H.4.

9.3.3 Alternative 3

Alternative 3 is a full removal alternative for AOCs 2A, 2B, and 3, where soil with concentrations greater than the CULs would be excavated or remediated. Alternative 3 includes a combination of excavation and off-site disposal, monitoring, and limited institutional controls. Refer to Figure 9.3. Alternative 3 is considered the most protective alternative because it proposes the largest source removal of contaminated soil.

AOC 2A and AOC 2B

Alternative 3 for AOCs 2A and 2B is a full removal alternative that involves the excavation and off-site disposal of metals-contaminated soil for the protection of the direct contact exposure pathway for shipyard workers (AOC 2A) and for protection of sediments through the soil to groundwater to sediment pathway. This would include removal or demolition of existing buildings and pavement on the Fairhaven Shipyard portion of the Site to support excavation (refer to Figure 9.3). Existing buildings on the south side of the Site (the former All American building and the machine shop) would remain; potential future disturbance of soil under these buildings would be addressed with the OMMP. AOCs 2A and 2B would be excavated to a depth where clean soil is encountered in existing unpaved areas and in areas where pavement or buildings were demolished. The contaminated soil would be disposed of off-site. This action would address the source of copper and zinc groundwater exceedances in monitoring wells MW-02A and MW-12 (AOC 2B). This action would also excavate arsenic-contaminated soil in AOC 2A for protection of the direct contact exposure pathway for shipyard workers.

Remedial design sampling would be conducted to determine the horizontal and vertical extent of soil contamination for arsenic in AOC 2A and for arsenic, copper, and zinc in AOC 2B. Depth of excavation is expected to be 2 to 3 feet bgs for most areas of the Site, except AOC 2B where copper and zinc exceedances are expected to be found in deeper soil (8 to 10 feet bgs). Alternative 3 would include the following actions:

- In AOC 2A, excavation to a depth where sampling indicates CULs would be reached (expected to be 2 to 3 feet bgs) and off-site disposal of contaminated soil at a landfill would occur. A few areas may require excavation to as deep as 4 feet bgs.
- In AOC 2B, excavation to a depth where sampling indicates CULs based on protection of groundwater would be reached (assumed to be 8 to 10 feet bgs) and off-site disposal at a landfill of contaminated soil would occur.
- Excavated areas would be backfilled with soil and compacted gravel to a surface that meets the shipyard's operational requirements.
- Following implementation of the remedy in AOCs 2A and 2B, no metals concentrations greater than the direct contact CULs would be left in place in the existing unpaved areas and areas where pavement and buildings are demolished.

Existing buildings and pavements would remain in place on the southern property boundary (the former All American building and the machine shop). If future redevelopment activities included demolition of these structures, institutional controls would require evaluation of subsurface material and of cleanup actions for underlying material that are permanent to the maximum extent practicable.

AOC 3

Alternative 3 for AOC 3 includes the work that was completed during the Interim Action, which consisted of fully removing soil with arsenic concentrations greater than the CUL for direct contact and copper, zinc, and TPH concentrations greater than the CUL for protection of groundwater. The outline of the Interim Action area in relation to AOC 3 is shown on Figure 9.3. The remaining contaminated soil in AOC 3 would be addressed by Alternative 3 through full removal of TPH-contaminated soil to CULs. This action would restore the natural redox conditions in groundwater and result in the precipitation of arsenic leading to a decrease in arsenic concentrations in groundwater. The remedy would include:

- Demolition of the existing upland portion of the marine railway to support excavation.
- Excavation and off-site disposal at a landfill of remaining TPH-contaminated soil. Depth of excavation would be determined during design based on additional sampling.
- The excavated area would be backfilled with soil and the surface would be backfilled with compacted gravel to meet shipyard requirements.

Site-Wide Groundwater

An OMMP would be developed and implemented. The OMMP schedule would likely include 2 years of quarterly performance monitoring for TPH and metals in the downgradient perimeter monitoring wells. Groundwater samples would be collected and analyzed for 1-methylnaphthalene, arsenic, copper, and zinc. The OMMP would also include annual confirmation monitoring conducted along the downgradient perimeter compliance monitoring well network to assess remedy effectiveness and would be conducted for some duration determined in coordination with Ecology until data sufficiently confirmed compliance with groundwater cleanup standards. The downgradient perimeter compliance monitoring well network would consist of MW-02A, MW-06, MW-07, MW-08, MW-09, MW-11, and MW-12.

Associated Cost

The estimated cost for Alternative 3 is $12.6 million and includes remedial design sampling, design, implementation, compliance groundwater monitoring, and a 30% contingency. The final cost also includes the cost for the Interim Action as the Interim Action is considered part of the remedy. The cost estimate for Alternative 3 is included in Appendix H, Table H.5.

10.0 Soil and Groundwater – Alternative Evaluation and Disproportionate Cost Analysis

In this section, the alternatives developed for the Site soil and groundwater in Section 9.0 are evaluated against the MTCA requirements for a cleanup remedy per WAC 173-340-360. The MTCA requirements are introduced in Section 10.1, followed by the alternatives evaluation that compares each alternative based on its ability to comply with the MTCA requirements in Section 10.2, and finally a description of the DCA evaluation and resulting preferred remedy in Section 10.3.

10.1 MTCA REQUIREMENTS AND DISPROPORTIONATE COST ANALYSIS EVALUATION CRITERIA

This section provides a summary of the requirements and criteria that each remedial alternative is evaluated against in accordance with MTCA. Each of the proposed remedial alternatives is screened relative to mandatory "MTCA Threshold Requirements" and "Other MTCA Requirements" for evaluation. A DCA is conducted to identify the alternative that is "permanent to the maximum extent practicable," using DCA evaluation criteria. Based on these evaluations, a Preferred Remedial Alternative is selected for recommendation to Ecology.

10.1.1 MTCA Threshold Requirements

MTCA WAC 173-340-360(2) mandates that all cleanup actions meet minimum requirements, including the MTCA Threshold Requirements, and when multiple cleanup action components are implemented for a single site, the overall cleanup action shall also meet the minimum requirements discussed below:

- **Protect Human Health and the Environment.** Protection of human health and the environment shall be achieved through implementation of the selected remedial action.
- **Comply with Cleanup Standards.** Cleanup standards, as defined by MTCA, consist of CULs for hazardous substances present at a site, the location, or POC where the CULs must be met, and any regulatory requirements that may apply to a site due to the type of action being implemented or the location of the site. All selected cleanup alternatives must meet cleanup standards defined for the Site.
- **Comply with Applicable State and Federal Laws.** MTCA WAC 173-340-710 states that cleanup standards shall comply with applicable ARARs. ARARs applicable to this Site are detailed in Tables 7.1 through 7.3 and consist of chemical-specific ARARs applicable to the contamination types present at the Site, location-specific ARARs that apply to the physical location of the Site, and action-specific ARARs that apply to the construction components of the remedy.
- **Provide for Compliance Monitoring.** MTCA requires that all selected cleanup alternatives provide for compliance monitoring as described in WAC 173-340-410. Compliance monitoring consists of protection monitoring, performance monitoring, and confirmation monitoring. Protection monitoring is performed during remedial implementation to monitor short-term risks and confirm protection of human health and the environment during construction activities. Performance monitoring will assess short-term remedy effectiveness and confirm compliance with the Site CULs immediately following remedial implementation. Confirmation monitoring will evaluate

long-term effectiveness of the remedial action following attainment of the cleanup standards.

10.1.2 Other MTCA Requirements

Cleanup alternatives that meet the MTCA Threshold Requirements must also fulfill other MTCA Requirements described in WAC 173-340-360(2)(b):

- **Use Permanent Solutions to the Maximum Extent Practicable.** The use of permanent solutions to the maximum extent practicable for a cleanup action is analyzed according to the DCA procedure described in WAC 173-340-360(3). Preference is given to alternatives that implement permanent solutions, defined in MTCA as actions that can meet cleanup standards "without further action being required at the site being cleaned up or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances" (WAC 173-340-200).

  The DCA process is conducted to identify the alternative that uses permanent solutions to the maximum extent practicable.

- **Provide for a Reasonable Restoration Time Frame.** Restoration time frame is defined in MTCA as "the period of time needed to achieve the required CULs at the POCs established for the site." Preference is given to alternatives that provide for a reasonable restoration time frame. For alternatives that rely on natural attenuation and degradation over time to meet cleanup standards, a restoration time frame of 10 years or less is typically accepted as "reasonable."
- **Consideration of Public Concerns.** Public involvement must be initiated according to the requirements set forth in WAC 173-340-600. Public concerns are taken into account at each step in the formal process under MTCA. Formal public comment will be received on this Draft RI/FS document, and will be taken into account when developing the Final RI/FS. Public comment will also be taken into consideration when developing the final CAP.

10.2 ALTERNATIVES EVALUATION

In the following sections, the three proposed remedial alternatives for the uplands are evaluated for compliance with the MTCA Threshold Requirements, the ability to meet a reasonable restoration time frame, and compliance with the Site RAOs defined in Section 7.0. Alternative assessment under the Other MTCA Requirement "Uses Permanent Solutions to the Maximum Extent Practicable" is reported in the following sections and as a part of the discussion of the DCA, which is described in Section 10.3 and Table 10.1 and summarized in Table 10.2.

The Other MTCA Requirement "Consideration of Public Concern" was evaluated in the DCA by estimating the benefit scoring each alternative is likely to receive, based on prior public concerns on similar projects, and the general understanding of public interest and desired project outcomes for cleanup sites in the region. Public comments on this Draft RI/FS document and any future project documents will be solicited by Ecology and the Port, and taken into account during final Ecology decision-making regarding the Preferred Remedial Alternative.

10.2.1 Alternative 1

Alternative 1 is considered the minimum removal alternative and consists of surface soil excavation, capping with a clean gravel surface, monitoring, engineering controls, and institutional controls. These actions would address the direct contact exposures to arsenic and would remove a portion of source metal contamination contributing to shoreline groundwater exceedances. Existing pavement and buildings would be maintained as a cap for surface soil throughout the Site.

10.2.1.1 MTCA Threshold Requirements

- **Protect Human Health and the Environment.** Alternative 1 would be protective of human health and the environment by removing exposed soil exceeding the CUL for direct contact and backfilling with clean material to cap the remaining contamination in place (AOCs 2A and 2B). Existing pavement or structures would be maintained as a cap to subsurface contamination. Risks would be immediately reduced as a result of capping in areas for the direct contact exposure pathway for shipyard workers. Institutional controls in the form of an Environmental Covenant including an Ecology-approved OMMP would protect workers who would potentially come in contact with contaminated soil during future development or maintenance work. The placement of a geotextile in the excavation areas would prevent mixing of clean surface material with contaminated subsurface material and provide an indication to future workers of areas where contamination remains. Protection for worker direct contact in AOC 3 has already been addressed through the mass soil excavation completed during the Interim Action. It is expected that the source removal during the Interim Action has brought the surrounding groundwater into compliance. Protection of groundwater would be assessed through groundwater monitoring and would be evaluated for long-term recovery over the duration of groundwater monitoring. An improvement in overall environmental quality would result from implementation of this alternative.
- **Comply with Cleanup Standards.** Alternative 1 for AOCs 2A and 2B complies with MTCA cleanup standards by excavating surface soil exceeding CULs for off-site disposal and through containment of COCs that remain on-site at concentrations greater than CULs with capping. The containment remedy would be consistent with WAC 173-340-740(6)(f). Institutional controls would be developed for the contamination that would remain on-site. Excavation of metals contamination in soil would reduce metals that could leach to groundwater across the Site, including in AOCs 2B and 3, and provide an ancillary benefit to site-wide groundwater quality. Groundwater performance and compliance monitoring would ensure CULs are being met across the Site.
- **Comply with Applicable State and Federal Laws.** Alternative 1 complies with all applicable state and federal laws outlined in Section 7.2 and in Tables 7.1 through 7.3 through capping, engineering controls, and institutional controls.
- **Provide for Compliance Monitoring.** Alternative 1 meets the requirements for compliance monitoring by conducting protection monitoring during implementation, performance monitoring following completion of excavation and capping, and confirmation monitoring to confirm groundwater compliance following remedy implementation.

10.2.1.2 Remedial Action Objectives

Alternative 1 would comply with all RAOs because it would remediate soil and groundwater to protect human health from exposure to contamination via direct contact and would remediate groundwater. By phasing the implementation of the remedy, the remedy could be implemented within the active shipyard environment. Placement of the geotextile between contaminated soil and the clean gravel surface would prevent soil mixing, and could be maintained within the shipyard. Long-term monitoring to assess cap integrity and groundwater compliance would be conducted.

10.2.1.3 Restoration Time Frame

Alternative 1 would address the direct contact exposure pathway within a reasonable time frame through site preparation and placement of a geotextile, capping with a clean gravel surface, and institutional controls, which include the OMMP. The direct contact exposure pathway would be addressed immediately following excavation through placement of a geotextile and compacted gravel surface. Soil compliance for AOCs 2A and 2B would be expected to occur immediately following completion of the soil cap. Groundwater compliance in AOC 2B would be addressed through the removal of source material. The restoration time frame for groundwater in AOC 2B is projected to be 20 to 25 years after construction completion.

The direct contact exposure pathway in AOC 3 has already been addressed through the Interim Action. Compliance of groundwater in AOC 3 still needs to be evaluated following the completion of the Interim Action. While it is expected that groundwater would be in compliance following the mass source removal of TPH and arsenic-contaminated soil during the Interim Action, the restoration time frame for groundwater in AOC 3 is projected to be 2 to 5 years after implementation of the final remedy to allow time for reestablishment of more natural geochemical conditions.

10.2.2 Alternative 2

Alternative 2 is a more comprehensive excavation and capping alternative, and consists of a combination of deeper soil removal up to 2 feet bgs and placement of a thicker gravel or asphalt pavement capping. This remedy is a partial removal and containment remedy that addresses the direct contact pathway to shipyard workers. This remedy also removes contaminant mass for protection of the soil to groundwater pathway. Alternative 2 also includes groundwater monitoring, contingency bioremediation in AOC 3 and contingency soil solidification/stabilization or deeper excavation in AOC 2B based on groundwater monitoring results, and institutional controls. Alternative 2 provides more protection for worker direct contact than Alternative 1 through placement of an asphalt cap and/or deeper contaminant removal with a thicker gravel cap. The asphalt or thicker gravel cap associated with Alternative 2 would be expected to have a longer life and retain a greater level of integrity over the long term for the protection of direct contact by shipyard workers. Alternative 2 is also more protective of groundwater in AOC 3 than Alternative 1 through a greater degree of source removal.

10.2.2.1 MTCA Threshold Requirements

- **Protect Human Health and the Environment.** Alternative 2 would be protective of human health and the environment by removing exposed surface soil exceeding the CUL for direct contact and placing an asphalt or clean gravel surface to cap remaining contamination in place (AOCs 2A and 2B). Existing pavement or structures would be maintained as a cap to subsurface contamination. Risks would be immediately reduced as a result of capping in areas for the direct contact exposure pathway for shipyard workers. Institutional controls in the form of an Environmental Covenant including an Ecology-approved OMMP would protect workers who would potentially come in contact with contaminated soil during future development or maintenance work. If required, geotextile would be placed in the excavation areas would prevent mixing of clean surface material with contaminated subsurface material and provide an indication to future workers of where contamination remains. Protection for worker direct contact in AOC 3 has already been addressed through the mass soil excavation completed during the Interim Action. It is expected that the source removal during the Interim Action has brought the surrounding groundwater into compliance. Protection of groundwater would be assessed through groundwater monitoring. If groundwater monitoring indicates the Interim Action was not fully protective of groundwater in AOC 3, a series of biological remediation amendments would be injected to break down residual TPH contamination and restore natural redox conditions to stop arsenic leaching. Also, if groundwater monitoring indicates further exceedances of COCs in groundwater in AOC 2B, a soil solidification/stabilization amendment would be mixed into deeper soils to eliminate contaminant mobility. An improvement in overall environmental quality would result from implementation of this alternative.

- **Comply with Cleanup Standards.** Alternative 2 for AOCs 2A and 2B complies with MTCA cleanup standards by excavating soil exceeding CULs for off-site disposal and through containment of COCs that remain on-site at concentrations greater than CULs with capping. The containment remedy would be consistent with WAC 173-340-740(6)(f). Institutional controls would be developed for the contamination that would remain on-site. Excavation of metals contamination in soil would reduce metals that could leach to groundwater across the Site, including in AOCs 2B and 3, and provide an ancillary benefit to site-wide groundwater quality.

  Alternative 2 for AOC 3 would comply with cleanup standards by monitoring groundwater to determine the effect of the Interim Action on bringing groundwater concentrations of COCs to less than CULs. If groundwater is found to not be in compliance, a bioremediation agent would be injected in a series of events as necessary to treat residual TPH contamination and change redox conditions to reduce the solubility of arsenic in groundwater.

- **Comply with Applicable State and Federal Laws.** Alternative 2 complies with all applicable state and federal laws outlined in Section 7.2 and in Tables 7.1 through 7.3 through capping, engineering controls, and institutional controls.

- **Provide for Compliance Monitoring.** Alternative 2 meets the requirements for compliance monitoring by conducting protection monitoring during implementation, performance monitoring following completion of capping, and confirmation monitoring for groundwater compliance following remedy implementation.

10.2.2.2 Remedial Action Objectives

Alternative 2 would comply with all RAOs because it would remediate soil and groundwater to protect human health from exposure to contamination via direct contact and would remediate groundwater. By phasing the implementation of the remedy, the remedy could be implemented within the active shipyard environment. The asphalt cap that may be placed on the Site would be designed to be compatible with shipyard operations and could be maintained within the shipyard. Long-term monitoring to assess cap integrity and groundwater compliance would be conducted.

10.2.2.3 Restoration Time Frame

Alternative 2 would address the direct contact exposure pathway within a reasonable time frame through implementation of capping and institutional controls. This pathway would be addressed immediately following capping.

The direct contact exposure pathway in AOC 3 has already been addressed through the Interim Action. Compliance of groundwater in AOC 3 still needs to be evaluated following the completion of the Interim Action. While it is expected that groundwater would be in compliance following the mass source removal of TPH- and arsenic-contaminated soil during the Interim Action, the restoration time frame for groundwater in AOC 3 is projected to be 2 to 5 years after implementation of the final remedy to allow time for reestablishment of more natural geochemical conditions.

10.2.3 Alternative 3

Alternative 3 is a full removal alternative, where soil contamination at concentrations greater than the CULs would be excavated or remediated in all areas of the Site except under the buildings located on the southern property boundary (the former All American building and the machine shop). Existing pavement and buildings on the Fairhaven Shipyard portion of the Site would be demolished to support the remedy. Alternative 3 is the most aggressive and protective alternative for all AOCs. These actions would address the direct contact exposure pathway for shipyard workers. Site-wide groundwater concentrations for metals would also be reduced, including in AOCs 2B and 3 as a result of the excavation of source metals in soil.

10.2.3.1 MTCA Threshold Requirements

- **Protect Human Health and the Environment.** Alternative 3 for AOCs 2A, 2B, and 3 would be protective of human health and the environment through full contaminant removal in all areas of the Site except beneath the buildings on the southern property boundary (the former All American building and the machine shop). Contaminated material would be disposed of off-site at a landfill. Risks would be immediately reduced to be protective of the direct contact exposure pathway.

  Protection for worker direct contact in AOC 3 has already been addressed through the mass soil excavation completed during the Interim Action. Removal of the remaining contamination beneath the upland portion of the marine railway would remove TPH in soil and address residual contamination in groundwater. Removal of the TPH contamination would restore the natural redox conditions of the subsurface to prevent the natural leaching of arsenic to groundwater. Risks would be reduced following implementation of the remedy. Monitoring would be conducted to ensure that contaminant concentrations continue to be protective of human health and the environment. The remedy for all AOCs would ensure that site-wide groundwater CULs would be met through source removal. There is substantial improvement of overall environmental quality at the Site resulting from the implementation of this alternative. This “full removal” alternative is considered the most protective alternative.

- **Comply with Cleanup Standards.** Alternative 3 complies with all MTCA cleanup standards in AOCs 2A, 2B, and 3 through excavation. Removal of metals in surface soil would reduce metals leaching to groundwater across the Site, including in AOCs 2B and 3, and provide an ancillary benefit to site-wide groundwater quality. Additional monitoring would ensure CULs are being met.

- **Comply with Applicable State and Federal Laws.** Alternative 3 complies with all applicable state and federal laws outlined in Section 7.2 and in Tables 7.1 through 7.3 through contaminant mass removal.

- **Provide for Compliance Monitoring.** Alternative 3 would meet the requirements for compliance monitoring by conducting protection monitoring during implementation, performance monitoring during and following excavation, and confirmation monitoring to confirm groundwater compliance following remedy implementation.

10.2.3.2 Remedial Action Objectives

Alternative 3 would comply with all RAOs because it would remediate soil and groundwater to protect human health from exposure to contamination via direct contact and would remediate groundwater. By phasing the implementation of the remedy, the remedy could be implemented within the active shipyard environment. Long-term monitoring to assess groundwater compliance would be conducted.

10.2.3.3 Restoration Time Frame

Alternative 3 would meet RAOs within a reasonable time frame. The direct contact exposure pathway in AOCs 2A, 2B, and 3 would be addressed immediately following excavation. Groundwater compliance across the Site would be expected within 2 to 5 years following remedy implementation, allowing time for reestablishment of more natural geochemical conditions.

10.3 MTCA DISPROPORTIONATE COST ANALYSIS AND IDENTIFICATION OF THE PREFERRED REMEDY

The MTCA DCA is performed to evaluate whether a cleanup action uses permanent solutions to the maximum extent practicable as determined by the level of attainment of specific criteria defined in WAC 173-340-360(3)(f). The DCA is conducted in Table 10.1 by scoring the environmental benefits of each alternative using seven evaluation criteria. Additionally, the cost of each alternative is estimated. Estimated costs for each alternative are summarized in Table 10.1 and presented in Appendix H. For each alternative, a “benefit per associated cost” is calculated by dividing the total benefit score by the cost for the alternative (in millions). A higher score indicates the most benefit for the associated cost. The alternative with the highest score provides the highest level of environmental benefit and permanence per dollar spent. The final DCA scores for the three upland alternatives are summarized in Table 10.2 and shown in Exhibit 2 (refer to Section 10.3.8).

As stated in MTCA, the cost of an individual alternative is determined disproportionate “if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative” (WAC 173-340-360(3)(e)(i)).

Evaluation of disproportionate cost allows comparison of each alternative to the most permanent alternative presented, as determined by attainment of MTCA criteria. This analysis can be qualitative or quantitative. If multiple alternatives possess equivalent benefits, the lower-cost alternative will be selected. The seven DCA criteria defined in MTCA (WAC 173-340-360(3)(f)) are as follows:

- **Protectiveness.** Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, the time required to reduce these risks, and the overall improvement in environmental quality.
- **Permanence.** The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances.

- **Cost.** The cost to implement the alternative, consisting of construction, long-term Operations and Maintenance (O&M) costs, and agency oversight costs that are recoverable[14].
- **Effectiveness over the Long-Term.** Long-term effectiveness consists of the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-site at levels greater than CULs, and the effectiveness of controls in place to control risk while contaminants remain on-site.
- **Management of Short-Term Risks.** Short-term risks consist of the risk to human health and the environment associated with the alternative during construction and implementation and the effectiveness of measures taken to control those risks.
- **Technical and Administrative Implementability.** The ability of the alternative to be implemented is based on whether the alternative is technically possible and meets administrative and regulatory requirements, and if all necessary services, supplies, and facilities are readily available.
- **Consideration of Public Concerns.** These considerations involve whether or not the community has concerns regarding the alternative and, if so, to what extent the alternative addresses those concerns.

As part of the DCA conducted for this FS, each alternative was ranked and assigned a numerical score for each DCA criterion on a scale of 1 to 10, where a score of 10 represents the highest benefit and a score of 1 represents the lowest benefit. Each numerical score was then multiplied by a weighting value and the scores were summed to determine the total alternative benefit score. Weighting values for the DCA criteria used in this FS are consistent with the weighting values recently adopted at other Port remediation sites with the explicit approval of Ecology. The weighting values used in this FS are as follows:

- Overall protectiveness: 30%
- Permanence: 20%
- Effectiveness over the long-term: 20%
- Management of short-term risks: 10%
- Implementability: 10%
- Consideration of public concerns: 10%

The following sections summarize each of the DCA criteria and discuss the alternative scoring and comparison for the three upland alternatives. A full description of the upland alternatives evaluation by the MTCA DCA criteria is discussed in Table 10.1.

10.3.1 Overall Protectiveness

Alternative 1 is moderately protective of soil by capping contaminated soil to protect shipyard workers from direct contact to arsenic. An OMMP is required to maintain the cap as long as the contaminated soil remains on-site in excess of the cleanup standards. However, Alternative 1 is less protective than Alternatives 2 and 3, because the cap is thinner and more susceptible to

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[14] Although stated in WAC 173-340-360(3)(f)(iii), long-term O&M costs were not calculated using net-present value because the costs are small compared to the overall project capital cost and the majority of long-term costs will be realized in the near term, reducing the benefit of calculating net-present value.

disturbance by the industrial operations conducted at the Site. Alternative 1 scores low for protection of groundwater because only limited contaminated mass is removed. Alternative 2 is more protective than Alternative 1 because a greater amount of contaminated soil mass is removed, reducing the degree of risk of metals leaching to groundwater. Alternative 2 also includes a more durable cap, which would be more durable under ongoing industrial operations. Alternative 2 is less protective than Alternative 3 because Alternative 2 leaves contamination in place while Alternative 3 fully removes all contamination to CULs, with the exception of potential metals contamination under existing buildings on the south side of the property. For Overall Protectiveness, Alternative 1 received a score of 3, Alternative 2 received a score of 7, and Alternative 3 received a score of 10.

10.3.2 Permanence

Alternative 1 has a low to moderate degree of permanence through the placement of a cap that would be maintained by the OMMP. However, most of the contamination would still remain at the Site beneath a gravel capped surface and indefinite upkeep and stability of the cap would rely heavily on long-term maintenance. Alternative 2 is more permanent because a much larger mass of soil contamination is removed from the site, and a more durable cap would be installed to contain contaminants remaining in place. Additionally, Alternative 2 includes use of contingency in-situ measures of solidification/stabilization in AOC 2B and bioremediation in AOC 3, if necessary, and both processes are non-reversible. Alternative 3 is the most permanent alternative because it fully removes all contamination to CULs, with the exception of potential metals contamination under existing buildings on the south side of the property, and therefore removes all currently identified risk at the Site. For Permanence, Alternative 1 received a score of 3, Alternative 2 received a score of 7, and Alternative 3 received a score of 9.

10.3.3 Effectiveness over the Long-Term

Alternative 1 provides a low degree of certainty for success over the long-term. Shipyard operations have a potential to disturb the cap, which would require more intensive maintenance efforts to avoid permanent failure and would result in potential exposures during cap disturbance events. The degree of certainty for Alternative 1 for remediating groundwater is also low because only a limited amount of contaminated soil would be removed, and it would not be expected to have an effect on groundwater conditions. Alternative 2 has a higher degree of certainty of long-term effectiveness through placement of a more durable cap and removal of more contaminated mass, which would be more likely to remediate metals in groundwater. In addition, Alternative 2 proposes deeper soil excavation within AOC 2B, contingency soil solidification/stabilization at the base of the excavation within AOC 2B, and bioremediation within AOC 3 to remediate contaminants in groundwater and increase the certainty of success, if necessary. In areas where asphalt caps are installed, stormwater collection would also be constructed, which would reduce the degree of surface water infiltration. This could also contribute to improved groundwater conditions. Long-term effectiveness is moderately certain for Alternative 2 because it does leave some contamination in place beneath the cap. Alternative 3 has the highest degree of certainty of success because it fully removes all contamination to CULs, except for potential metals contamination under existing buildings on the south side of the property; in this case, buildings cap any contamination. For Effectiveness over the Long-Term, Alternative 1 received a score of 3, Alternative 2 received a score of 6, and Alternative 3 received a score of 10.

10.3.4 Short-Term Risk Management

Alternative 1 provides a high degree of short-term risk management due to the limited amount of contaminated material handling required. This risk to construction workers would be reduced through an on-site Health and Safety Plan, and the risk to the public during transport of contaminated soil from the Site to an off-site landfill would be reduced by using licensed professionals, and disposal at a licensed facility. Alternative 2 has a similar degree of short-term risk, with a slight increase in volume of contaminated material handling; however, all the handling procedures and BMPs used for Alternative 1 would be implemented for Alternative 2 to effectively manage short-term risk. Alternative 3 has the lowest degree of short-term risk management due to the much larger volume of contaminated material handling required, the expansion of excavations into the vadose zone and groundwater table resulting in the requirement for dewatering and contaminated water handling, and the risks to workers associated with demolition activities and deeper excavations. For all three alternatives, the short-term risks associated with contaminated soil excavation and capping are commonly and effectively managed by use of common BMPs, so all alternatives score moderate to high for short-term risk management. For Short-Term Risk Management, Alternatives 1 received a score of 8, Alternative 2 received a score of 7, and Alternative 3 received a score of 5.

10.3.5 Technical and Administrative Implementability

Alternative 1 has a high degree of Implementability as it has the smallest scale compared to the other alternatives, and has the least impact to the ongoing shipyard operations. Alternative 1 would require a higher level of ongoing effort to maintain the cap in the long-term however, which decreases its Implementability over the long-term. Alternative 2 has a slightly larger scope compared to Alternative 1, which would have more impact to the shipyard operations during construction, but the caps installed with Alternative 2 are more durable and would require less long-term maintenance and repair. Alternative 3 has a significantly larger scope of work than Alternatives 1 and 2 and would cause major impacts to the current shipyard operations due the demolition and rebuilding of all site structures with the exception of the south buildings. For Technical and Administrative Implementability, Alternative 1 received a score of 8, Alternative 2 received a score of 7, and Alternative 3 received a score of 3.

10.3.6 Consideration of Public Concerns

The criteria Consideration of Public Concern was evaluated by estimating the benefit scoring based on prior public concerns on similar projects. Considering this, Alternative 1 received a score of 3, as it is anticipated the public would have concerns with a remedy that did not include enough contaminated mass removal. Alternative 2 received a score of 7, as it is anticipated the public will support a mass removal and containment remedy, but may also have concerns with the impact of construction on the community. Alternative 3 received a score of 6, as it is anticipated the public would support a full removal alternative, but would also have concerns with the cost associated with the remedy and the impact of the larger-scale construction project on the community.

10.3.7 Cost

Costs for each alternative are provided in Appendix H and included the costs for remedial design sampling, design, remedy implementation, compliance groundwater monitoring, and a 30% contingency. FS costs are developed at a conceptual design stage and are intended to be within -30% to +50% of actual remedy cost. Each alternative cost also included the cost for the Interim Action as the Interim Action is considered part of each remedy. Because Alternative 2 provides the option for either a gravel cap or an asphalt cap, or combination of the two, two separate costs were created for either a full gravel cap or full asphalt cap alternative and averaged to create the Alternative 2 cost. However, the costs developed for the two options were relatively similar, indicating the final determination of cap types across the Site will not have a measurable impact on the remedy costs provided here. The estimated cost for Alternative 1 is $4.1 million, the estimated cost for Alternative 2 is $5.9 million, and the estimated cost for Alternative 3 is $12.6 million.

10.3.8 Preferred Remedial Alternative

Based on the evaluation presented above and in Tables 10.1 and 10.2 and summarized in Exhibit 2, the total weighted unit benefit achieved for every $1M in remedy cost for Alternative 1 was 0.98, for Alternative 2 was 1.1, and for Alternative 3 was 0.65. This indicates the greatest benefit for the associated cost is highest for Alternative 2, and therefore Alternative 2 provides the greatest degree of incremental benefit for the associated cost. Alternative 2 is selected as the Preferred Remedial Alternative for recommendation to Ecology. Section 14.0 describes the Preferred Remedial Alternative in greater detail.

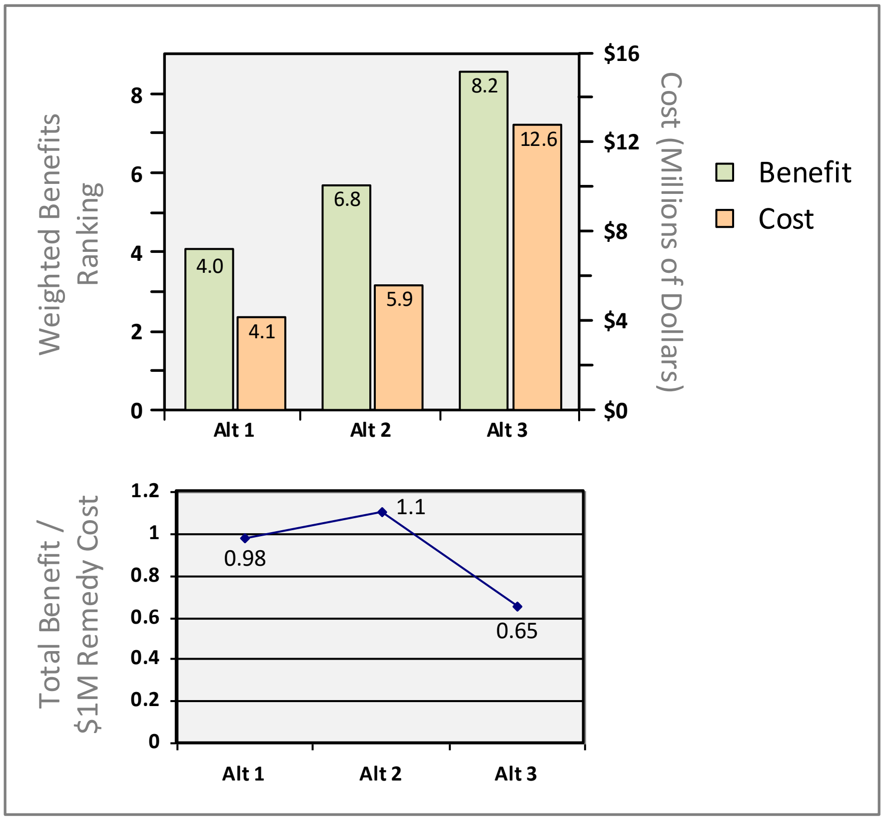

Exhibit 2. Soil and groundwater alternatives DCA summary

11.0 Sediment – Identification of Remedial Technologies

This section identifies and briefly describes the most commonly implemented remedial technologies for remediation of sediments. The COCs present in subtidal and intertidal sediment consist of arsenic, cadmium, copper, zinc, PCBs, and cPAHs. Fluoranthene, and pyrene are also COCs in the subtidal sediments. The general application and limitations of each technology are discussed in this section. Similar to the description of soil and groundwater technologies presented in Section 8.0 and as described in Section 7.1, this evaluation only addresses the portions of AOC 1 that are present outside of the Interim Action area and the intertidal sediments within the Interim Action area that were capped following excavation.

Section 12.0 then describes the preliminary technology screening preformed to eliminate technologies that do not meet RAOs applicable to the Site, or are not technically feasible. Retained technologies are described in more detail in Section 12.0.

11.1 INSTITUTIONAL CONTROLS

Institutional controls are non-engineered physical, legal, and administrative measures that are typically implemented to minimize or prevent exposure to contamination and monitor the long-term performance and protectiveness of cleanup actions that leave COCs on-site at concentrations greater than CULs. Institutional controls include deed restrictions or covenants, site advisories and use restrictions that would be implemented at a site to limit or prohibit activities that may interfere with the integrity of any element of the remedial action.

The institutional controls technology is applicable to most of the Site sediment COCs.

11.2 NATURAL RECOVERY

Natural recovery remedial technologies rely on three broad natural processes that contribute to the recovery of surface sediments over time. These processes include:

- Physical: such as sedimentation/deposition, migration/erosion, and mixing/dilution
- Chemical: including sorption and oxidation/reduction
- Biological: including biodegradation and benthic habitat recovery

Natural recovery technologies involve sediment chemical monitoring over a period of time to confirm that surface sediment contamination concentrations are declining and that the desired CUL has been or would be ultimately achieved with an appropriate restoration time frame. The two types of natural recovery processes considered for the Site are monitored natural recovery (MNR) and enhanced natural recovery (ENR), which are discussed in the following sections.

11.2.1 Monitored Natural Recovery

MNR relies solely on the natural processes discussed above to reduce exposure to human and ecological receptors through containment and attenuation.

MNR is applicable in depositional environments with low erosive forces, where the natural sedimentation process gradually buries contaminants, and in areas where the historical sedimentation rate and surface contaminant concentration data indicate that surface sediment concentrations would meet cleanup standards within an acceptable time frame. As discussed in Appendix I, cesium-137 testing and analyses of sediments at the Site determined that the sedimentation rate at the Site is between 0.65 and 0.81 cm per year (refer to Appendix I), equivalent to roughly 10 to 12 cm of projected sediment deposition over the next 15 years.

Natural recovery processes operate regardless of the selected remedy. Effective sediment remedies may incorporate MNR in combination with the other retained technologies described in this section. Factors particularly favorable to MNR include evidence that natural recovery will effectively reduce risks within an acceptable time period, the magnitude of contribution to site risk, and (where physical isolation is important) a low potential for exposure of buried contaminants. The practicability of other remedial technologies is also a factor to be considered when determining the applicability of MNR.

The MNR technology is applicable to all of the Site sediment COCs.

11.2.2 Enhanced Natural Recovery

ENR is the process of encouraging the natural recovery rate of contaminated sediments through placement of a cleaner, typically thin, sediment (e.g., sand) layer over the contaminated sediment surface. This sediment layer can range in thickness from less than 1 foot to 3 feet thick. This clean thin sediment layer does not function as a chemical containment layer (i.e., sediment cap), but is placed to accelerate the natural recovery process by mixing clean sediment with the existing contaminated surface sediments, immediately reducing the surface sediment contaminant concentrations. This reduction in contaminant concentrations reduces the time frame necessary to achieve CULs. Clean sand or sediment can be placed in a relatively uniform thin layer over a contaminated area or it can be placed in berms or windrows, allowing natural sediment transport processes to distribute the cleaner material over wider areas. ENR is usually applied in areas that are stable and not subject to scour. Following placement of the sand material on the sediment surface, monitoring would be performed to verify that natural recovery is accelerated as sediment transport, bioturbation, and resultant mixing of the cleaner material into surface sediments progresses over time. The ENR technology typically includes a greater degree of monitoring than capping to verify that recovery is being achieved in an acceptable time period. This monitoring typically consists of sampling and analysis of COCs and measurement of the cleaner thin surface material thickness.

The typical recovery time frame associated with ENR is dependent on the type and concentration of contaminants present, and is also reliant on the natural sedimentation rate at a site. The addition of clean material encourages the natural attenuation process in surface sediments, and immediately reduces surface sediment concentrations through mixing; however, the technology continues to rely on burial by cleaner material and natural attenuation of subsurface contaminants to achieve the CULs throughout a site. In some cases, if the existing chemical concentrations are low enough, the addition of clean material may achieve immediate compliance with the site-specific cleanup standards, but that is dependent on the chemical concentrations present and the site cleanup standards.

The ENR technology is applicable to all of the Site sediment COCs.

11.3 SEDIMENT CAPPING

Capping is a sediment cleanup technology that has been used at many Puget Sound cleanup sites to successfully contain and isolate contaminated sediment. Caps are designed with the objective of reducing risk through three main mechanisms: (1) physical isolation of the contaminated sediment sufficient to reduce exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the cap surface;

(2) solidification/stabilization of contaminated sediment and erosion protection of the sediment and cap, sufficient to reduce resuspension and transport of contaminants into the water column; and (3) chemical isolation that prevents contaminated sediment from solubilizing and transporting through the cap and into the water column (USEPA 2005).

In situ caps are generally constructed using granular material such as clean sand; however, in certain instances where physical conditions are not conducive to placement of a sand cap (such as below piers where access is limited, active berthing areas, or intertidal areas where erosive forces are present), caps may be constructed of or armored with larger-diameter cobbles or rock. Caps may also be constructed with low-permeability liners such as geomembranes, grout mats, or composite materials that are more feasible to construct or are more stable in the erosive environment. Capping can also be limited in areas with in-water infrastructure and analysis is typically required to ensure that the capping material does not destabilize the existing infrastructure.

If selected as part of the Site remedy, sediment caps would be designed to effectively contain and isolate contaminated sediments from the biologically active surface zone in accordance with USEPA and USACE cap design criteria (discussed below). The caps would be designed to be thick enough and of sufficient grain size to maintain their integrity under reasonable worst-case conditions. Capping is subject to USACE permit requirements. Monitoring of the constructed cap would be conducted to ensure that the contaminated sediment beneath the cap remains protected if surface erosion processes exist. Institutional controls would also be applicable to capping remedies to prohibit actions and operations that would result in damage to the cap (e.g., restrictions on ship draft size, propeller controls, anchoring, and spudding).

Cap design (which would be conducted during the remedy design phase if capping is selected) would be conducted in accordance with USEPA and USACE design guidance (Palermo et al. 1998a and 1998b, Palermo 2000, and USEPA 2005). These guidance documents provide detailed procedures for cap design, cap placement operations, and monitoring of engineered caps, and have been relied upon extensively for successful cap designs at other SMS cleanup sites. Caps designed according to the USEPA and USACE guidance have been demonstrated to be protective of human health and the environment (USEPA 2005). Design specifications for in situ engineered caps would be further refined during remedial design based on detailed analyses of the following components:

- Bioturbation/habitat quality
- Habitat compatibility
- Erosion (e.g., propeller wash, tidal currents, waves, wakes, and slope stability)
- Chemical isolation
- Consolidation
- Operational considerations (e.g., gas generation and placement inaccuracies)
- Bathymetric surveys and evaluation of geoengineering features

The sediment capping technology is applicable to all site sediment COCs. The following sections describe the general applicability and constraints for granular caps and low-permeability liners at the Site.

11.3.1 Granular Caps

Granular capping materials vary in size from sand to larger-diameter gravel and cobbles. Granular caps function by containing contaminated sediments beneath the cap while allowing for attenuation and diffusion of groundwater and contamination breakdown products (including gases) through the cap material. Granular caps can be amended with organoclays or carbon to increase the sorption capacity and increase chemical attenuation of contaminants, if determined necessary during capping design. Granular caps are frequently constructed in layers that are made up of a protective surface layer capable of providing scour and erosion protection, underlain by sand providing additional isolation. Typically, some degree of mixing occurs when the initial layers are placed on the contaminated sediment surface, which must be accounted for when determining the effective thickness of the cap.

Various equipment types and placement methods have been used for capping projects, including traditional mechanical equipment, hydraulic systems, conveyors, and hopper barges at larger sites. Mechanical methods (such as clamshells or release from a barge) rely on gravitational settling of cap materials in the water column and have been demonstrated to be effective at the depths present at the Site. Granular caps are conventionally placed in a single lift in areas with dense underlying sediments. Alternatively, thin-lift capping methods are practical in areas with soft, unconsolidated underlying sediments or in areas where resuspension of underlying materials is a concern. Construction techniques for the placement of thin-lift caps include hydraulic spraying and a telebelt conveyor method. These methods are also applicable in areas with restricted access, such as beneath over-water structures, where granular material may be “sprayed” beneath areas with over-water obstructions (Exhibit 3).

Exhibit 3. Sand shooter in limited access area

11.3.2 Low-Permeability Barriers

In situations where the construction of a granular cap is determined infeasible due the physical site constraints such as the presence of pier structures or steep slopes, the use of low permeability barriers or membranes is commonly employed to provide isolation of contaminated sediments. Low-permeability barriers are generally more expensive than granular caps, but are capable of providing chemical isolation, and are usually a fraction of the thickness of a granular cap.

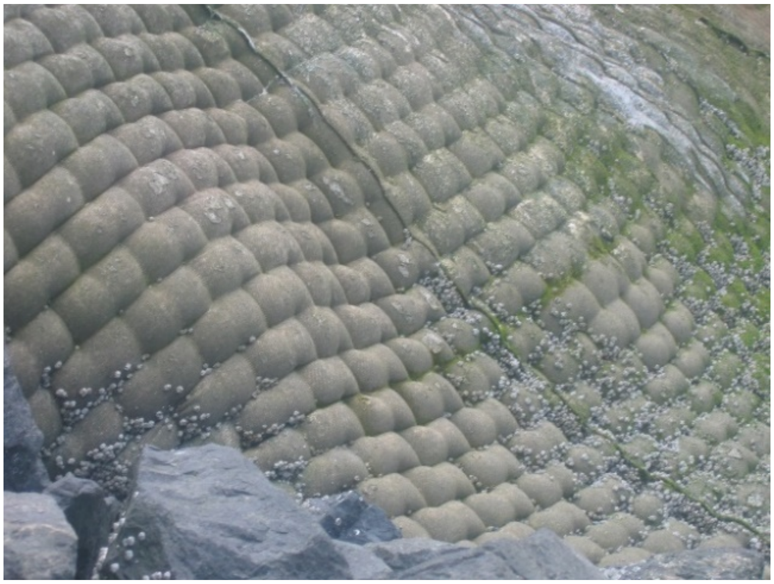

Exhibit 4. Grout mat detail

At the Site, grout mats could be considered as an alternative capping method for under-pier areas where placement of a granular cap is determined to be infeasible due to access constraints. Grout mats are commonly used in contaminated areas with steep slopes, erosional environments, and areas where access for placement of a granular cap is impeded by over-water operations or structures (Exhibits 4 and 5). Grout mats can be constructed on varying substrates, and beneath structures where placement of standard sand caps may not be feasible. Grout mats can also be implemented in deep water areas. Grout mats are constructed of a fabric “mat” similar to a deflated air mattress. The fabric mat is usually secured on the slope or cap location, sewn around pilings and pier structures, and then filled with a cement grout mix. The cement grout fills the void space of the mattress, creating a controlled, weighted, low permeability concrete barrier over the contaminated sediments. Grout mats are typically anchored in place at the edges, as required for stability. Grout mats can also be limited in placement by the presence of large structures and debris; however, grout mats can be placed over smaller-sized debris or riprap-type rock as necessary. The fill of the grout mats can also be modified to reduce or increase the permeability of the mat, as determined most appropriate during the design process to address site contaminants and groundwater flow.

Exhibit 5. Grout mat at low tide

11.4 CONTAMINATED SEDIMENT REMOVAL

Removal is a frequently used technology for contaminated sediment remediation. Removal is most commonly implemented to provide a resultant clean surface, to remove contaminated material, or to provide specific water column depths for navigation purposes. Contaminated sediment removal can be implemented using two process options: dredging and excavation. Dredging removes sediment through the water column, and can be performed using mechanical or hydraulic equipment operating from land or barge, or other floating platform. Excavation removes sediment either in the dry, or in shallow water, using typical earth-moving equipment such as excavators and backhoes operating from exposed land or wharves, or floating platform. Depending on the areas (intertidal or subtidal) of the sediments being removed, there may be some overlap in the equipment used for dredging and excavation. After removal, the sediments must be managed, a process that can include dewatering, treatment, and/or disposal.

Removal is generally applicable in open water areas where access is not constrained by over-water structures or operations. Removal is not typically feasible in areas with over-water structures, docks, and engineered shorelines (e.g., riprap slopes). Removal in these conditions would also have limited effectiveness due to the difficulty of effectively dredging around existing piers, rock, and debris. Removing, replacing, or modifying existing structures would be required to remove contaminated sediment from beneath existing structures.

The removal technology is applicable to all Site sediment COCs. The various methods for sediment removal that may be applicable at the Site are discussed in the following sections.

11.4.1 Mechanical Dredging

Mechanical dredging with a closed clamshell bucket (referred to as an environmental bucket) is commonly the preferred removal technology for contaminated sediment sites (Exhibit 6). An environmental bucket is a modified bucket to limit material loss over the top of the bucket during extraction through the water column. Environmental buckets are commonly designed to be “level cut” buckets that create a flat dredged surface and minimize dredge residuals by eliminating the scalloped surface resultant from open digging buckets. The design of the environmental bucket allows for contaminated sediments to be removed from the substrate in a somewhat dense, unmixed condition, limiting contact with the water column during bucket extraction (Exhibit 6). Bucket design also effectively reduces the degree of sediment resuspension caused during sediment extraction through the water column. This modification in bucket design, however, reduces the applicability of environmental dredge buckets for use in dense material and on sloped areas. Dredging with an environmental bucket is complicated by the presence of dense sediments, larger materials (e.g., cobbles), or debris, as debris extending out of the bucket prohibits proper closure and sealing, resulting in resuspension and sediment loss during bucket extraction through the water column.

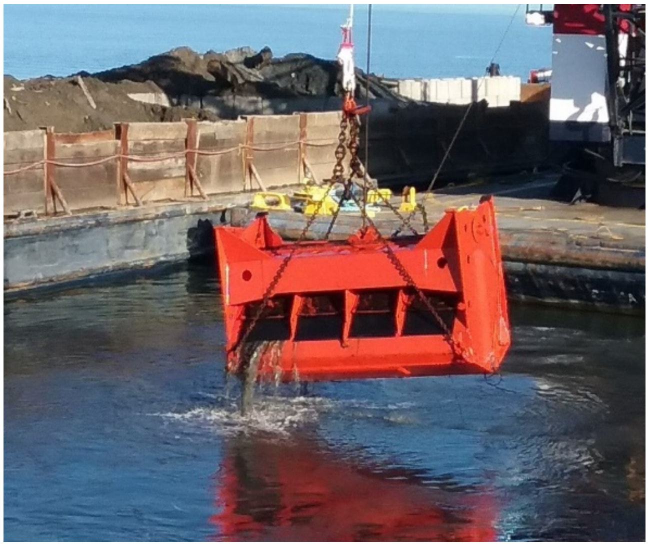

Exhibit 6. Environmental bucket

A digging bucket is a type of clamshell bucket with interlocking teeth and an open top that is used when dredging dense sediment, debris, and other large material (Exhibit 7). Previous dredging during the Interim Action exposed numerous abandoned pilings and dense rocky sediment in the area that required the use of a digging bucket to remove (Exhibit 8). Both buckets may be utilized during dredging as different conditions are encountered.

Exhibit 7. Mechanical dredge digging bucket

Exhibit 8. A digging bucket used during the Interim Action for portions of the dredge cut with larger woody debris present.

Environmental buckets and digging buckets can be connected either to a fixed arm excavator or to a cable, which is lowered to the substrate in the open position, and then closed to capture sediments in a scooping manner. Bucket placement is commonly tracked by GPS or other electronic devices. The precision of the bucket placement is dependent on the machinery operator and the precision of the tracking equipment.

11.4.2 Hydraulic Dredging

Hydraulic dredging removes sediment from the substrate through agitation and suction. Cutterhead dredges, applicable in more dense material, mix sediment with water to form a slurry, and then pump the slurry from the sediment surface through pipelines (Exhibit 9). In cases where the water content of the contaminated sediments is high enough, mixing may not be necessary prior to removal from the substrate, and the sediments are extracted via pure suction techniques. Hydraulic dredges are commonly used to remove large volumes of sediment by suction through pipelines of various sizes, depending on the material properties.

Exhibit 9. Hydraulic dredge slurry

The dredged material is typically removed from the subsurface by the dredge-head, which is lowered into the sediments, with a vacuum applied. Often, in denser materials, cutterheads are used to loosen and churn sediments into the water column, creating a slurry of contaminated sediments and water (refer to Exhibit 10). The slurry then travels through a pipeline to a hydraulic pump, which provides the suction at the dredgehead and forces the slurry material through the pipeline. If the material is soft enough (i.e., soft mud), a cutterhead is not necessary. The dredgehead is supported by a variety of methods from cables to divers to rigid hydraulic arm machinery.

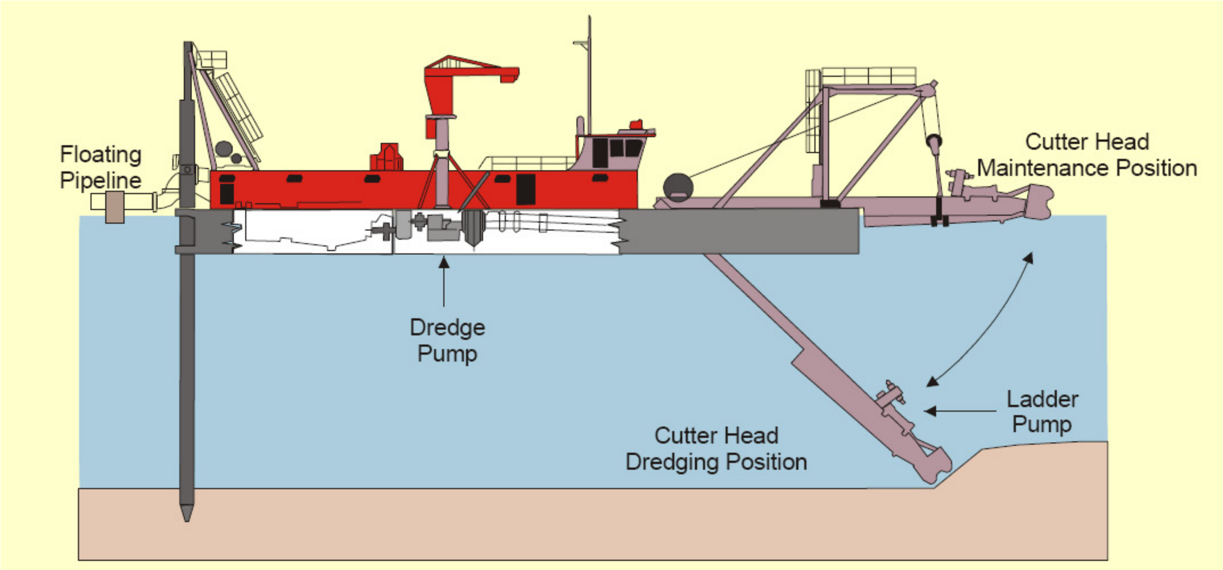

Exhibit 10. Hydraulic dredge equipment

Hydraulic dredging generates a significantly higher volume of extracted water than mechanical dredging methods, as the sediments are extracted in a slurry form, with high water content. This increase in water volume requires additional space for materials handling, increased time for dewatering of extracted materials, and substantial increases in material volumes requiring handling and disposal. Typically, dredged material from hydraulic dredging is discharged into a disposal site adjacent to the dredge area, such as a nearshore confined disposal site, at which the material can solidify over a long time frame. Hydraulic dredging is effective at dredging to a consistent elevation below water surface, but has limited effectiveness in areas with varying contaminant depths and continuity, or on slopes.

Debris substantially restricts the implementability and efficiency of all types of hydraulic dredging by jamming the dredgehead. Typically, a mechanical dredging debris removal effort must be performed before hydraulic dredging can be implemented, which can cause significant additional water quality impacts, resuspension of contaminated sediments, and added cost.

11.4.3 Excavation

Removal of unsaturated material from shoreline and intertidal sediment areas during low tide conditions is considered excavation, and could be conducted using standard excavation equipment operated from land or from a floating barge (Exhibit 11).

Excavation may also be conducted using hand methods in areas with significant operational or structural limitations, such as in the marine railway area. Hand excavation could be conducted using shovels, picks, mini-excavators, or other methods, such as use of a vacuum truck. The rate of sediment removal by hand methods is significantly slower than mechanical means, but can be applied in areas with access limitations.

Exhibit 11. Land-based mechanical excavator

11.4.4 Material Disposal

Options for disposal of marine sediments removed through dredging or excavation include upland landfill disposal, on-site confined aquatic disposal (CAD), beneficial reuse, and open water disposal. Each of these options is briefly described below.

11.4.4.1 Upland Landfill Disposal

Dredged material can be transloaded from barges to truck or rail for transportation to a landfill for disposal (Exhibit 12). Transloading requires a shoreline facility where barges can be tied up such that material can be excavated from the barge for rehandling into trucks or rail. As implemented in the Interim Action, the transload facility that would be used for work at this Site is in the Duwamish River in Seattle. Barges would be towed to this facility for offload. Once transloaded to truck or rail, dredged material would be transported for disposal at a permitted upland landfill.

Exhibit 12. Sediment transloader at Duwamish Transfer Facility

Material frequently requires dewatering or addition of a moisture-reducing admixture to meet moisture content requirements for transportation and disposal. Dewatering can occur by directly placing dredged material in a temporary upland dewatering bay designed to collect and treat water or by constructing a pump and treat system on the transport barge to remove water prior to transport. Treatment processes for dewatering water would be dictated by the necessary permit requirements and would be determined during design.

11.4.4.2 Confined Aquatic Disposal

A CAD facility is an on-site engineered containment structure that allows for dewatering and permanent storage of dredged sediments. CADs feature both solids separation and landfill characteristics, and containment of contaminated sediments in these on-site facilities is often a more cost-effective disposal option than an off-site upland landfill. CAD facilities are constructed in submerged nearshore areas and can be used to contain dredged sediment below an engineered cap. CAD facilities involve creation of a sediment containment area with final filled surface elevations that are subtidal, intertidal, or upland. Depending on site-specific designs, CADs may either involve filling of aquatic areas and conversion of those areas to upland use (e.g., nearshore fills with associated habitat mitigation requirements), or modification of the existing shoreline. However, due to lack of available space at the Site for construction of a CAD, and associated permit restrictions, this is not considered a feasible disposal option for dredged sediment from the Site.

11.4.4.3 Uplands Beneficial Reuse

In some cases, the physical and chemical properties of sediments allow these materials to be beneficially reused in upland applications. The existing sediment data for the Site indicate the significant majority of sediments to be dredged are in compliance with MTCA CULs for industrial, and in some cases unrestricted, land use. These materials may be suitable for beneficial reuse applications, and, should removal be selected as part of the final cleanup remedy, further detailed evaluations of potentially viable beneficial reuse options may be performed in accordance with MTCA during remedial design.

11.4.4.4 Puget Sound Dredge Disposal Analysis Open Water Disposal

Sediments that are determined by the Puget Sound DMMP to be suitable for open water disposal may be transported by bottom-dump barge for disposal at either a dispersive or non-dispersive unconfined open water disposal site in Puget Sound. However, because sediment concentrations of one or more COCs exceed DMMP chemical criteria, sediments removed from the Site would likely not be deemed suitable by the DMMP for open water disposal.

12.0 Sediment – Technology Screening and Remedial Alternative Development

This section presents a screening of the remedial technologies presented in Section 11.0 that are applicable to remaining sediment contamination in AOC 1 at the Site following the Interim Action. The technology screening is followed by the aggregation of the retained sediment remedial technologies into remedial alternatives for further evaluation. It should be noted that Site uses and alternatives are based on current conditions and uses of the Site. If future development or changed conditions occur, the limits of the identified units may change based upon those changes.

The Interim Action remedial components included the removal of over-water structures, removal of material through mechanical dredging to achieve RAOs within the subtidal sediments, and removal of material through excavation and granular capping within the intertidal sediments. All removed material was disposed of at an upland landfill following barge transport to a transload facility located on the Duwamish River.

12.1 REMEDIAL TECHNOLOGY SCREENING

The remedial technology screening is presented in Table 12.1. The technology screening considers the general benefits and constraints of the technology, and site-specific considerations that affect the feasibility of the technology for various areas of the sediment AOC. The process retains or rejects technologies based on the applicability at the Site given: the COCs and impacted media, effectiveness and proven success at similar sites, applicability of the technology within the site physical constraints, and the ability of the technology to achieve RAOs.

As described in Table 12.1, hydraulic dredging was rejected from further evaluation for remediation of sediments, due to inability to manage dredge slurries, debris and grain-size restrictions, and under-pier structural impacts.

12.2 SUMMARY OF RETAINED TECHNOLOGIES AND CONSIDERATION OF ADDITIONAL CONDITIONS

Based on the preliminary technology screening, institutional controls, natural recovery, capping, and removal technologies were retained for consideration and further evaluation prior to aggregation of technologies into remedial alternatives. Each of these technologies is discussed in greater detail in the following sections with consideration of site-specific conditions that may impact the applicability and success of the technology.

12.2.1 Institutional Controls

Institutional controls have been retained for further evaluation as a sediment remedial technology. As a stand-alone technology, institutional controls would not reduce, destroy, or remove any chemical contamination in addition to what would occur via natural processes, but would instead be implemented in addition to other technologies to meet RAOs, ensure long-term protectiveness of the selected remedy, and prevent exposure to contaminated sediment. At the Site, institutional controls would be implemented with any technology that contains contamination in place in excess of CULs and would be documented in the OMMP. Institutional controls that may be implemented at the Site for sediment could include monitoring and maintenance of a sediment cap or restrictions on site use that could disturb contained sediment. This would ensure current and future safety, sediment management, and cap restoration requirements for activities such as over-water structure maintenance or replacement, berth modifications or deepening that disturbs the sediment cap, and site activities with the potential to damage the cap. When used in combination with other remedial technologies, institutional controls would successfully achieve the Site RAOs, and could be implemented given the Site physical conditions.

12.2.2 Natural Recovery – Monitored Natural Recovery and Enhanced Natural Recovery

Natural recovery technologies rely on sedimentation and chemical attenuation processes to reduce contaminant concentrations in surface sediments over time. At the Site, evaluation of cesium-137 data from three core locations indicates sedimentation is occurring in areas of the Site at a rate of 0.65 to 0.81 cm per year. Given these sedimentation rates, MNR or ENR may be applicable in depositional areas of the Site. The current extent of sediment contamination is, however, mainly located in active berthing areas and shallow water areas where erosive forces from wave action and vessel movement are likely occurring. There is likely limited applicability of natural recovery technologies in these areas as sedimentation may not be occurring at rates necessary to achieve cleanup standards at the POC within a reasonable restoration time frame. Natural recovery technologies are likely most applicable to areas of deeper water or areas on the perimeter of active shipyard operations.

For these reasons, natural recovery technologies, although potentially applicable in some areas, are not carried forward as a primary remedial technology for AOC 1. However, MNR and ENR may be applicable for targeted areas in which other remedial alternatives are not practical. When used in combination with other remedial technologies, MNR and ENR would successfully achieve the Site RAOs, and could be implemented given the Site physical conditions.

12.2.3 Capping – Granular and Grout Mat Caps

Capping is a common remedial technology at contaminated sediment sites in Puget Sound. At this Site, capping in the open water areas would likely be a granular cap, and armored in shallower water areas for protection from erosive forces. Shipyard operations and related water depth requirements would be considered and would also factor into the cap design.

Beneath structures, granular caps may be placed in areas where sufficient clearance is present for material placement. Caps can often be placed to thicknesses that are acceptable given structural capacity constraints of existing piling. However, older wooden piling typically is unable to support the downdrag or differential forces applied by greater than 1 or 2 feet of capping material placement, and sometime less material.

For this FS, it is assumed that granular cap material could be placed beneath the offshore under-pier areas including the newer concrete Harris Avenue Pier and the Access Pier to the dry dock. These are newer structures that are sturdy enough to withstand the effects of placement of capping material. Caps in these areas could be adequately constructed with conveyor equipment that “sprays” the granular cap material (typically sand) beneath pier structures from barges adjacent to the structure (refer to Section 11.3.1, Photograph 2).

In nearshore intertidal areas with existing infrastructure, there are potential accessibility constraints and potentially insufficient over-water clearance for operation of the conveyor to place a granular cap. In these areas, capping is still recommended, but the cap type would be determined during design. Selection of the cap type would depend on permitting, hydrodynamics, and constructability. In addition to the granular caps discussed in Section 11.3.1, grout mats could be considered. Grout mats are quilted fabric pads that are pumped full of cementitious grout.

Grout mat caps can be custom fabricated or modified from stock material to be placed between piling and other obstructions (refer to Photographs 2 and 3 in Section 11.3).

During the cap design process, an analysis would be conducted to better understand scour and wave action within AOC 1 and determine an appropriate cap design including optimal grain size and requirements for armoring to maintain stability. Cap thickness would also be evaluated and selected during design. The shipyard operational water depth requirements will also be factored into the cap design to ensure cap placement does not impact shipyard operations.

12.2.4 Removal – Dredging and Excavation

Dredging and excavation are common technologies to address sediment contamination in intertidal and subtidal areas. Given the active use of the Site as an operational shipyard, with operational water depth requirements, prop wash, and wave action erosion considerations, dredging and excavation are applicable at the Site and are retained for detailed evaluation. Dredging actions are limited at the Site to open water and intertidal areas that are unobstructed by existing structures. Dredging in open water areas would be conducted with mechanical dredge equipment. Environmental dredge buckets would be utilized wherever possible. Mechanical digging buckets may be necessary to use in sloped areas or areas containing significant debris. During the dredging process, free water would be drained from dredged sediments, filtered, and returned to the water column within the work area. Water quality monitoring during dredging would confirm water quality protection.

Removal is not a suitable technology beneath the existing shipyard piers and over-water structures while the structures are in place, due to structural impacts and access restrictions.

Dredging and excavation are feasible in the open water subtidal and intertidal areas of the Site where over-water structures are not present. Focused excavation in the intertidal zone of the marine railway is considered feasible, as there are no overhead obstructions limiting access to the area. Focused excavation in the intertidal zone of the marine railway would be conducted by hand, or with small machinery.

Following removal, the material must be disposed of properly. Given the location of the Site and available Site access by barge, rail, and truck, both upland disposal and upland beneficial reuse are potential options for disposal of any dredged or excavated sediment. The sediment is not expected to be classified as a hazardous or state dangerous waste, and could be transloaded for disposal at a Subtitle D landfill.

Dredged material could also potentially be transloaded for upland beneficial reuse at a construction or redevelopment site close to the Bellingham Bay shoreline or in a reasonable distance of established transload facilities in the region (Duwamish Waterway in Seattle). The chemical concentrations present in Site sediment are less than MTCA Method C soil criteria for industrial upland use, with the exception of some limited exceedances of arsenic. Much of the sediment is in compliance with MTCA Method B soil unrestricted use criteria. Beneficial reuse would be a significantly reduced construction cost when compared to landfill disposal. Beneficial reuse would also significantly reduce transportation impacts associated with traffic, transportation risk, and greenhouse gas emissions. However, beneficial reuse requires identification and permitting of a reuse project site. There is minimal area at the Site for upland handling, dewatering, or storage of dredged sediment, so if material is not able to be transported immediately to a reuse site, upland reuse would likely not be possible. Additionally, salinity (sodium chloride) in the dredged sediment would need to be evaluated to determine feasibility of sediment beneficial reuse. It is also assumed that any material dewatering or handling would occur over-water on barges, as there is not an available upland area that could be used for material dewatering or handling.

For the purposes of this FS, it is assumed that dredged or excavated sediment may be either reused or disposed of at a Subtitle D landfill. For comparison of costs, it is assumed all material is transloaded for transportation and disposal at an upland Subtitle D landfill.

12.3 SEDIMENT MANAGEMENT UNIT DESCRIPTION

In order to evaluate cleanup alternatives for sediments, AOC 1 has been divided into Sediment Management Units (SMUs). It should be noted that these are identical to Sediment Management Areas as defined in SCUM II, but are called SMUs within this document for consistency with the Interim Action Basis of Design Report and previous Draft RI/FS reports. Consistent with SCUM II, SMUs within AOC 1 were primarily determined considering natural and built features of the Site, and different receptor types and exposure pathways (intertidal versus subtidal areas). SMUs defined within AOC 1 are illustrated on Figures 12.1, 12.2, and 12.3. Each SMU has characteristics unique to the application of remedial technologies. This section describes the characteristics of each SMU.

12.3.1 Sediment Management Units 1, 2, 3, and 4

These SMUs include the portions of AOC 1 that were addressed in the Interim Action and a small area northeast of the Interim Action area that has not been addressed. The four SMUs addressed in the Interim Action are categorized by whether they are subtidal or intertidal sediments, and the phase of construction in which they were addressed. The east and west sides of the Harris Avenue Pier were demolished in two separate phases to maintain accessibility to the remaining concrete portion of the pier. The SMUs addressed under the Interim Action are described as follows:

- SMU 1 – the subtidal sediments east of the Harris Avenue Pier midline
- SMU 2 – the intertidal sediments east of the Harris Avenue Pier midline
- SMU 3 – the subtidal sediments west of the Harris Avenue Pier midline
- SMU 4 – the intertidal sediments west of the Harris Avenue Pier midline

In brief, the Interim Action in these SMUs included the following components:

- Abatement, removal, and disposal of hazardous building materials associated with structures to be removed.
- Demolition and removal of the wooden portion of the Harris Avenue Pier, and the Carpenter Building and its supporting Pier (including the East Marine Walkway).
- Dredging to CULs or RALs in subtidal SMUs 1 and 3, with upland landfill disposal of dredged materials.
- Removal of contaminated intertidal sediments in SMUs 2 and 4 to approximately 3 feet deep from the surface of mudline, with upland landfill disposal of excavated materials. Capping of these removed areas with clean fill to match existing grades.
- Construction of a sheet pile bulkhead and a replacement concrete pier in the location of the existing wooden portion of the Harris Avenue Pier to restore existing functions and maintain shipyard operations.

- Construction of a marine railway walkway on the east side of the marine railway to restore existing functions.
- Associated utility work.

As of November 2018, the remedial components of the Interim Action have been completed and the pier work is complete. A detailed description of the Interim Action will be presented in an Interim Action Construction Completion Report anticipated in the January or February 2019.

The unremediated area in SMU 1 encompasses an area where interpolation of existing chemical data indicates an exceedance of the PCB CUL for protection of benthic health. Additional data collection conducted during remedial design will determine if remedial action is necessary within this area to comply with benthic health CULs/RALs.

12.3.2 SMU 5

SMU 5 is the subtidal area located beneath the concrete portion of the Harris Avenue Pier within AOC 1. This portion of the Harris Avenue Pier consists of a concrete deck structure supported by concrete piling. The width of this structure varies between 30 and 60 feet. The available data density within SMU 5 is not sufficient to determine the current status of surface sediment exceedances. During remedial design, additional data would be collected within this area to determine the necessity for remedial action.

12.3.3 SMUs 6 and 9

The open water SMUs 6 and 9 encompass the subtidal areas between the Harris Avenue Pier and the western edge of Dry Dock No. 1. The boundaries between SMU 6 and 9 are drawn based on the differing levels of available chemistry data within the SMUs, and the typical over water operations within the areas. Data were collected within SMU 6 as part of the 2015 Pre-Interim Action sampling event and reported in the Interim Action Basis of Design Report. The available data density within SMU 9 is less than within SMU 6. During remedial design, additional data will be collected within SMU 6 to determine the necessity for and extent of remedial actions.

SMU 6 is located between the Marine Railway and the Harris Avenue Pier. Operational activities in this SMU are primarily associated with operations on the Harris Avenue Pier.

Access for remediation of SMU 9 will require relocation of Dry Dock No. 1, which is a floating structure that is moored in place. The dry dock can be temporarily removed from its moorings and relocated for performance of the remedial action in SMU 9. On the eastern edge of SMU 9 is the West Marine Walkway, which runs alongside the in-water portion of the marine railway and is in disrepair. All proposed remedies will include demolition of the West Marine Walkway to access the underlying contaminated sediment and rebuilding the walkway.

Sediment mudline elevations range from 0 feet MLLW to approximately -45 feet MLLW. These are active areas of shipyard operations, where existing water depths are necessary to support shipyard activities. Sediment surfaces are subject to prop wash and ship scour associated with vessel movements. Maximum vessel draft in the area is approximately 25 feet.

12.3.4 SMU 7

SMU 7 consists of the subtidal area beneath and surrounding the offshore in-water portion of the marine railway in the subtidal sediments with sediment mudline elevations deeper than 0 feet MLLW. The marine railway structure in this area is pile-supported above the sediment surface, with clearance present between the railway girders and the sediment mudline. Clearance distances increase at farther distances offshore. Timber pilings support pile caps, which in turn support girders below the rails. Four rails are present. When ships are transported on the railway, they sit in a cradle that runs on the rails. Immediately west of the marine railway is the timber pile-supported West Marine Walkway, accessed by shipyard personnel to facilitate ship movement.

12.3.5 SMU 8

SMU 8 consists of the intertidal area beneath and surrounding the in-water portion of the marine railway that is within the shipyard intertidal sediment area higher than elevation 0 feet MLLW. The marine railway structure in this area is pile-supported, but the piling is fully subsurface, and the girders supporting the railroad sit within the sediment surface, without clearance below.

12.3.6 SMU 10

SMU 10 is the shipyard intertidal sediment area with sediment mudline elevations higher than 0 feet MLLW, between the in-water portion of the marine railway and the Access Pier to Dry Dock No. 1. An ecology block bulkhead is present along the south edge of SMU 10. In some areas, a riprap slope exists at the foot of the bulkhead. On the western portion of SMU 10, the bulkhead wall is in disrepair. As part of any remedial action, the westerly portion of the bulkhead wall would be repaired. On the eastern edge of SMU 10 is the West Marine Walkway, which runs alongside the in-water portion of the marine railway and is also in disrepair. All proposed remedies will include demolition of the West Marine Walkway to access the underlying contaminated sediment and rebuilding the walkway. An existing stormwater emergency outfall pipe is located in the intertidal area in SMU 10, with a bolted connection where the pipeline enters the bulkhead wall. The emergency outfall pipe is in good condition. As part of any remedial action, it would be temporarily disconnected for storage and would be replaced following completion of the sediment remedial action.

12.3.7 SMU 11

SMU 11 is located beneath the Access Pier to Dry Dock No. 1 and extends from the shore to approximately -30 feet MLLW, extending approximately 120 feet from the shoreline. The Access Pier is approximately 30 feet wide. At the end of the Access Pier, a gangplank extends to Dry Dock No. 1. The Access Pier is in good working condition and this FS assumes that placement of capping material between the support piling would not adversely affect the structural integrity of the pier.

12.4 AGGREGATION OF SEDIMENT REMEDIAL ALTERNATIVES

The retained technologies described above have been aggregated into remedial alternatives for AOC 1. Each remedial alternative presented here includes the Interim Action for SMUs 1 through 4. A full removal alternative is included as part of Alternative 3 for SMUs 2 and 4 as these intertidal sediments were capped following excavation in the Interim Action.

Alternative 1 is primarily a capping alternative that assumes cap placement throughout the sediment AOC. Alternative 3 is a dredging alternative that requires removal of all over-water structures for dredging access and assumes removal of contaminated sediment to the greatest degree feasible. Alternative 2 is a combination alternative that applies dredging in accessible open water areas, with capping in under-pier areas that would be maintained and at the in-water portions of the marine railway. Each of the alternatives presented in the following sections is based on current conditions. Changes because of future development could change the remedy at that time.

All three alternatives will include demolition and replacement of the West Marine Walkway and repair and armoring of a stretch of the western shoreline. A section of the shoreline west of SMU 10 has been identified as eroding and releasing sediment east toward the shipyard. For the past several years, the shipyard tenant has been required to remove accumulated sediment underneath the marine railway at periodic intervals in order to maintain necessary working depths. The eroding section of shoreline will be delineated during design and armored as part of the preferred remedy.

The three remedial alternatives presented will be evaluated according to the SMS and the MTCA DCA process presented in Section 13.0 to compare their relative costs and benefits, and identify the alternative that is permanent to the maximum extent practicable. Table 12.2 presents the alternatives and identifies the technologies applied to each area of AOC 1. AOC 1 has been divided into SMUs for application of remedial technologies. Remedial technologies applied in Alternatives 1, 2, and 3 are presented in Figures 12.1, 12.2, and 12.3, respectively.

Site images from AOC 1 and the SMUs can be found in Appendix A.

Table 12.2
Proposed Remedial Alternatives for Sediment

SMU	Alternative 1	Alternative 2	Alternative 3
SMUs 1 and 3	Interim Action as completed in 2018: • Removal of over-water structures. • Dredging to CULs or RALs, with upland landfill disposal of dredged materials. • Construction of replacement Harris Avenue Pier. Additional samples will be collected in the unremediated area of SMU 1 to determine if additional remediation is necessary to meet CULs/RALs.		
SMUs 2 and 4	Interim Action as completed in 2018: • Removal of over-water structures. • Excavation of 3 feet of contaminated intertidal sediments, with upland landfill disposal of excavated materials. • Capping with clean fill to match pre-construction grades. • Construction of replacement Harris Avenue Pier.		Interim Action as completed in 2018 and described in Alternatives 1 and 2. Collect additional samples to determine extent of additional remediation to meet CULs/RALs. Removal of 3 feet of capping materials. Excavate an additional 2- to 3-foot average depth of intertidal sediment to meet CULs/RALs. Backfill with appropriate habitat substrate to meet existing elevations.

<table>
<tr><th>SMU</th><th>Alternative 1</th><th>Alternative 2</th><th>Alternative 3</th></tr>
<tr><td rowspan="2">SMU 5</td><td colspan="3">Collect additional samples to determine extent of additional remediation to meet CULs/RALs.</td></tr>
<tr><td colspan="2">Place granular cap, 1-foot minimum thickness, if remediation is necessary.[1]</td><td>Demolish existing pier, if necessary.
Dredge approximate 2- to 3-foot depth to meet CULs/RALs.
Reconstruct pier, if necessary.</td></tr>
<tr><td rowspan="2">SMUs 6 and 9</td><td colspan="3">Collect additional samples within SMU 9 to determine extent of additional remediation to meet CULs/RALs.</td></tr>
<tr><td>Place granular cap, 3-foot minimum thickness.[1]</td><td colspan="2">Dredge 2- to 3-foot average depth to meet CULs/RALs.
Upland disposal or reuse of dredged sediment.</td></tr>
<tr><td>SMU 7</td><td colspan="2">Place granular cap, 1- to 3-feet thick, determined by clearance between existing mudline and marine railway girders.[1]</td><td>Demolish existing marine railway and West Marine Walkway.
Dredge 2- to 3-foot average depth to meet CULs/RALs.
Reconstruct marine railway and West Marine Walkway.</td></tr>
<tr><td rowspan="2">SMU 8</td><td colspan="3">Demolish existing West Marine Walkway.</td></tr>
<tr><td colspan="2">Targeted excavation and placement of 1-foot minimum thickness granular cap at marine railway.[1]</td><td>Demolish existing marine railway.
Excavate approximate 2-foot depth and backfill to maintain existing elevations.
Reconstruct marine railway and West Marine Walkway.</td></tr>
<tr><td rowspan="2">SMU 10</td><td colspan="3">Collect additional samples to determine extent of additional remediation to meet CULs/RALs.</td></tr>
<tr><td>Excavate to a maximum 3-foot depth and cap with clean fill to meet existing elevations.</td><td colspan="2">Excavate to an average 3-foot depth and backfill with appropriate habitat substrate to meet existing elevations.</td></tr>
<tr><td>SMU 11</td><td colspan="2">Place granular cap, 1-foot minimum thickness, as determined during design.[1]</td><td>Demolish existing pier.
Dredge approximate 2- to 3-foot depth to meet CULs/RALs.
Reconstruct Dry Dock Access Pier.</td></tr>
<tr><td>All SMUs</td><td colspan="3">In alternatives for which dredging to CULs/RALs are selected, if those target concentrations are unable to be achieved (e.g., due to subsurface obstructions), a 6-inch-thick layer of sand would be placed as ENR.</td></tr>
</table>

Note:

1 For alternatives in which capping under existing structures is evaluated. Institutional controls requiring evaluation of a more permanent remedy if over-water structures are removed in the future are part of the alternative.

12.4.1 Alternative 1

With the exception of the areas completed during the Interim Action (SMUs 1 through 4), Alternative 1 is considered the full capping alternative, and consists of capping in both open water and under-pier areas. A 1- to 3-foot-thick granular cap would be placed throughout all accessible open water areas. All shipyard over-water structures and the marine railway would be protected for continued use. A granular or low-permeability cap would be placed below shipyard structures that are maintained. In the shipyard intertidal sediment areas, contaminated sediments would be excavated, and the excavation would be backfilled to maintain existing elevations. In the intertidal portion of the marine railway, targeted excavation would be performed to support placement of a cap to match the surface elevation of railroad girders, to maintain operation of the railway structure.

The only material removal included in Alternative 1 would be in the intertidal sediment in SMUs 8 and 10 to accommodate placement of backfill and sediment cap without modifying intertidal area elevations or the ordinary high water line. All excavated material would be transloaded for upland landfill disposal or upland beneficial reuse. Table 12.2 lists the specific technology proposed for each SMU, and the following sections discuss the application of remedial technologies for each of the SMUs not addressed in the Interim Action. Figure 12.1 illustrates the applied technologies by SMU for Alternative 1.

SMU 1

A small area in SMU 1 northeast of the Interim Action area was not addressed as part of the Interim Action. Sampling will be conducted during remedial design to determine if any additional action is necessary within this area to meet benthic health CULs/RALs. For this FS evaluation, Alternative 1 assumes dredging is conducted in this area.

SMU 5

SMU 5 is located beneath the concrete portion of the Harris Avenue Pier. During remedial design, additional data would be collected within this area to determine the necessity for remedial action. If remedial action is required in Alternative 1, this SMU would be addressed through placement of a thick granular cap to contain sediment contamination in place, immediately addressing all exposure pathways. This SMU would be addressed in the following manner:

- A granular cap with a 1-foot minimum thickness would be placed using conveyor or telebelt capping equipment and methods to place material beneath the existing pier structure. The concrete portion of the Harris Avenue Pier is in water that is deep enough to provide the clearances necessary for this method of cap placement.
    - The cap thickness and material specifications would be determined during remedial design. The existing structural capacity of the piling supporting this pier would determine cap thickness. The concrete piling at this pier would likely be able to support a 1- to 3-foot-thick cap.
    - Institutional controls would be placed on the Site that would control future site development in capped areas, including potential shipyard operational controls such as propeller wake restrictions, if determined necessary during the design process by propeller wash analyses.
- Confirmation monitoring (e.g., bathymetric surveys) would be conducted during and following cap placement to confirm the constructed caps meet design requirements.

- Long-term monitoring would be conducted to ensure stability and effectiveness of constructed caps.

SMUs 6 and 9

The open water SMUs 6 and 9 encompass the open water areas within AOC 1 (Figure 12.1). Remedial design sampling in SMU 6 was conducted as part of the Interim Action design. During remedial design, additional data would be collected within SMU 9 to determine the necessity for remedial action. In Alternative 1, these areas would be actively remediated through placement of a thick granular cap to contain sediment contamination in place, immediately addressing all exposure pathways. These SMUs would be addressed in the following manner:

- A granular cap with 3-foot minimum thickness would be placed using standard granular capping equipment and methods.
  - The cap thickness, material specifications, and potential armoring requirements would be determined during remedial design.
- Confirmation monitoring (e.g., bathymetric surveys) would be conducted during and following cap placement to confirm the constructed cap meets the design requirements.
- Long-term monitoring would be conducted to ensure stability and effectiveness of the constructed cap.
- Institutional controls would be placed on the Site that would control future site development in capped areas, such as restrictions on maintenance dredging and water deepening actions. This could also potentially include shipyard operational controls such as propeller wake restrictions, if determined necessary during the design process by propeller wash analyses.

Placement of a thick granular cap within the open water operational areas of the shipyard would have significant negative impacts to shipyard operations. In multiple areas of the shipyard, the shallower water depths present after capping would not provide the berth depths necessary to support the depths of vessels and the dry dock that currently operate at the shipyard. In addition, operations could be significantly impacted by the propeller wake restrictions that would likely be required throughout much of the shipyard to protect the cap.

SMU 7

SMU 7 consists of the area beneath and surrounding the marine railway at depths greater than 0-feet MLLW. The marine railway structure in this area is pile supported above the sediment surface, with greater clearance between the railway girders and the sediment mudline at further distances offshore. In Alternative 1, this SMU would be actively remediated through placement of a granular cap to contain sediment contamination in place, immediately addressing all exposure pathways. SMU 7 would be addressed in the following manner:

- A granular cap would be placed, 1 to 3 feet thick, between the marine railway girders and ties, depending on the amount of clearance available between the mudline and the railroad girders. Sand or the selected material would be placed with conveyor or telebelt capping equipment or standard crane-operated equipment placing capping material through the marine railway structure, followed by a diver sweep of the structure to clear settled capping material off of the railway structure. The cap thickness, material specifications, and armoring requirements would be determined during remedial design.

- As feasible, dredging or excavation would be conducted as close as practicable to the marine railway girders on either side of the railway structure to the edge of the Carpenter Building pier and to the West Marine Walkway. This area would then be capped.
- Confirmation monitoring (e.g., bathymetric surveys) would be conducted during and following cap placement to confirm the constructed cap meets the design requirements.
- Long-term monitoring would be conducted to ensure stability and effectiveness of the constructed cap.
- Institutional controls would be implemented that would require evaluation of a more permanent remedy at the time the marine railway structure is renovated, replaced, or demolished. Institutional controls may also limit or restrict shipyard operations that cause erosive conditions on the sediment cap, as determined during the design process through a propeller wash analysis.

SMU 8

SMU 8 consists of the area beneath and surrounding the in-water portion of the marine railway within the shipyard intertidal sediment area above elevation 0 feet MLLW. The marine railway structure in this area is pile-supported and the girders supporting the railroad sit within the sediment surface without clearance below. In Alternative 1, this SMU would be actively remediated through focused excavation between the railway girders to allow placement of a granular cap and to contain sediment contamination in place, thus immediately addressing all exposure pathways. SMU 8 would be addressed in the following manner:

- Focused excavation would occur to remove material between the railway girders and from either side of the railway structure. Excavation within the marine railway would be performed by hand equipment, small excavator, or vacuum truck. Material would be removed to a minimum 1-foot depth below the top of the railway girders. Excavation in between the marine railway and the West Marine Walkway and underneath the walkway could be done with upland excavation equipment at low tides.
- A granular cap would be placed, minimum 1 foot in thickness, extending flush with the top of the railroad girders. The granular cap material placed would be selected to withstand intertidal erosive forces and marine railway operations. Likely, the cap material would be compacted crushed rock. The selection of material and finished cap elevation would be designed to allow maintenance cleaning of depositional material from the railway area without disturbing the cap material. The material specifications and compaction requirements would be determined during remedial design.
- Confirmation monitoring (e.g., bathymetric surveys) would be conducted during and following cap placement to confirm the constructed cap meets the design requirements.
- Long-term monitoring would be conducted to ensure stability and effectiveness of the constructed cap.
- Institutional controls would be implemented that would require evaluation of a more permanent remedy at the time the marine railway structure is renovated, replaced, or demolished. Institutional controls may also limit or restrict shipyard operations that cause erosive conditions on the cap, as determined during the design process through a propeller wash analysis.

SMU 10

SMU 10 encompasses the shipyard intertidal sediment areas above 0 feet MLLW that is not covered by structures. In Alternative 1, this area would be actively remediated through excavation of approximately 3 feet of sediment, followed by backfilling to return the areas to existing grade. This is similar to the remedy implemented in the intertidal sediments in the Interim Action. This removal action would immediately address all exposure pathways through contaminant mass removal. These SMUs would be addressed in the following manner:

- Excavation would be performed for a maximum of 3 feet of contaminated sediment from the intertidal areas using standard excavation equipment. Equipment may be operated either from land or from barges.
    - The excavation extent would be offset from the existing bulkhead structures by approximately 6 feet for structural stability and protection. The area between the excavation and bulkhead wall would be filled to construct a slope that would provide improved structural support to the bulkhead wall. This bulkhead slope would also provide a cap to contaminated sediment beneath it.
    - Remedial design sampling would be conducted to confirm excavation depths and to determine where in the intertidal sediment area institutional controls may be necessary. Backfill areas would require maintenance.
    - Excavated material would be transported off-site and transloaded for upland landfill disposal or upland beneficial reuse.
    - Backfill and bulkhead slope materials would be selected during the design phase to resist wave action and erosional forces, and to provide ancillary habitat benefit.
- In areas where clean sediment cannot be reached within 3 feet, backfill material placed to return the area to existing elevations would provide a granular cap for underlying contaminated material. The material specifications and compaction requirements would be determined during remedial design.
- Performance monitoring would be conducted during excavation to ensure contaminated sediment removal complies with remedial goals. Topographic surveys would be conducted to confirm that backfilled material meets design requirements.
- Upgrades to bulkhead structures would be constructed as necessary to repair and improve damaged and aging portions of the existing bulkheads. Bulkhead upgrades would be completed in a manner that minimizes the volume of soil removed from behind the bulkheads and is consistent in construction type with the sections of the bulkhead that do not require repair or improvement.
- The existing stormwater emergency outfall pipe located in the intertidal sediment area in SMU 10 would be temporarily disconnected and stored during construction of the remedial action and then re-installed.
- Long-term monitoring would be conducted to ensure stability of the constructed cap and the backfilled intertidal sediment area, as well as the bulkhead toe berms.
- Institutional controls would be implemented in the intertidal area where contaminated sediment remains in place beneath backfill and the bulkhead toe berm. These controls would manage exposure to the contaminated sediment during future redevelopment actions in the area, such as bulkhead wall replacement.

SMU 11

SMU 11 is located beneath the Access Pier to Dry Dock No. 1.

In Alternative 1, this SMU would be actively remediated through placement of an under-pier granular cap to contain sediment contamination in place, immediately addressing all exposure pathways. This SMU would be addressed in the following manner:

- A granular cap with a 1-foot minimum thickness would be placed using conveyor or telebelt capping equipment and methods to place material beneath the existing pier structure. This pier has the clearances necessary for this method of cap placement. The cap thickness and material specifications would be determined during remedial design and will include a structural evaluation of the older wooden pier to confirm the final sediment cap design does not impact the structure. This evaluation may limit the allowable cap thickness in this area.
- Institutional controls would be implemented at the Site that would control future site development in capped areas, including potential shipyard operational controls such as propeller wake restrictions, if determined necessary during the design process by propeller wash analyses. Institutional controls would also require evaluation of a more permanent remedial action at the time the pier structure is renovated, replaced, or demolished.
- Confirmation monitoring (e.g., bathymetric survey) would be conducted during and following cap placement to confirm the constructed cap meets design requirements.
- Long-term monitoring would be conducted to ensure stability and effectiveness of constructed caps.

Associated Cost

The estimated cost for Alternative 1 is $19.0 million and includes remedial design sampling, design, implementation, and a 30% contingency. The final cost also includes the cost for the Interim Action as the Interim Action is considered part of the remedy. The cost estimate for Alternative 1 is included in Appendix H, Table H.7.

12.4.2 Alternative 2

Alternative 2 includes a combination of dredging and capping, based on shipyard considerations, accessibility, and existing infrastructure. In Alternative 2, all accessible open water areas of AOC 1 would be dredged for full removal to meet cleanup standards. These contaminated sediments would be removed from the aquatic environment for upland landfill disposal or upland beneficial reuse.

In Alternative 2, as in Alternative 1, shipyard intertidal sediment areas would be excavated, and the excavation backfilled to maintain existing elevations. Excavated material would be removed from the aquatic environment for upland landfill disposal or upland beneficial reuse.

As in Alternative 1, the Interim Action has been completed in SMUs 1 through 4 and is part of this alternative. Existing over-water shipyard structures and the marine railway would be protected for continued use. Contaminated sediments below shipyard structures that remain would be capped and regulated with institutional controls.

Table 12.2 lists the specific technologies proposed for each SMU, and the following sections discuss the application of remedial technologies for each SMU with the exception of those addressed in the Interim Action. Figure 12.2 illustrates the applied technologies by SMU for Alternative 2.

SMU 1

A small area in SMU 1 northeast of the Interim Action area was not addressed as part of the Interim Action. Sampling will be conducted during remedial design to determine if any additional action is necessary within this area to meet benthic health CULs/RALs. For this FS evaluation, Alternative 2 assumes dredging is conducted in this area.

SMU 5

The proposed Alternative 2 remedy in SMU 5 is the same as Alternative 1. SMU 5 is located beneath the concrete portion of the Harris Avenue Pier. During remedial design, additional data would be collected within this area to determine the necessity for remedial action. If remedial action is required in Alternative 2, this SMU would be addressed through placement of a thick granular cap to contain sediment contamination in place, immediately addressing all exposure pathways. This SMU would be addressed in the following manner:

- A granular cap with a 1-foot minimum thickness would be placed using conveyor or telebelt capping equipment and methods to place material beneath the existing pier structure. The concrete portion of the Harris Avenue Pier is in water that is deep enough to provide the clearances necessary for this method of cap placement.
  - The cap thickness and material specifications would be determined during remedial design. The existing structural capacity of the piling supporting this pier would determine cap thickness. The concrete piling at this pier would likely be able to support a 1- to 3-foot-thick cap.
  - Institutional controls would be placed on the Site that would control future site development in capped areas, including potential shipyard operational controls such as propeller wake restrictions, if determined necessary during the design process by propeller wash analyses.
- Confirmation monitoring (e.g., bathymetric surveys) would be conducted during and following cap placement to confirm the constructed caps meet design requirements.
- Long-term monitoring would be conducted to ensure stability and effectiveness of constructed caps.

SMUs 6 and 9

The open water SMUs 6 and 9 encompass the open water areas within AOC 1 (Figure 12.2). Remedial design sampling in SMU 6 was conducted as part of the Interim Action design. During remedial design, additional data would be collected within SMU 9 to determine the necessity for remedial action. These areas are fully accessible to water-borne construction equipment. In Alternative 2, these areas would be actively remediated through dredging to a surface that meets CULs/RALs, addressing all exposure pathways. These SMUs would be addressed in the following manner:

- Dredging would occur to an average of a 3-foot depth, using mechanical dredging equipment and methods. Remedial design sampling would be conducted to confirm dredge depths and support dredge design. Existing data predicts that a 2- to 4-foot dredge depth will reach native sediments or sediments that meet CULs/RALs. Figure 12.4 presents subtidal sediment core data with bottom depths greater than 12 cm on which this prediction has been based. The specific extents and depths of dredging would be determined with a remedial design sampling effort to supplement current understanding of the thickness of contaminated sediments throughout these SMUs. Significant differences in expected thickness would be evaluated in coordination with Ecology.

- All contaminated sediments would be removed from the aquatic environment. They would be transported by barge to a suitable transload facility, where they would be transloaded to truck or rail for transportation to an upland landfill for disposal. Dredged sediments could also be considered for upland beneficial reuse with Ecology approval. That potential would be evaluated during design.
- Confirmation monitoring (e.g., bathymetric surveys) would be conducted following dredging to confirm the exposed sediment surface meets CULs/RALs. A Confirmation Monitoring Plan would be developed during design for Ecology approval. The Confirmation Monitoring Plan would be designed to confirm that the sediment surface meets CULs/RALs following dredging, given allowances for anticipated dredge residuals.

Dredging within the open water operational areas of the shipyard to achieve a sediment surface that meets CULs/RALs is supportive of continued shipyard operations. The dredged surface does not constrain operational depths or vessel movements.

SMU 7

The proposed Alternative 2 remedy in SMU 7 is the same as Alternative 1. SMU 7 consists of the area beneath and surrounding the marine railway at depths greater than 0 feet MLLW. The marine railway structure in this area is pile-supported above the sediment surface, with greater clearance between the railway girders and the sediment mudline at farther distances offshore. In Alternative 2, as in Alternative 1, this SMU would be actively remediated through placement of a granular cap to contain sediment contamination in place, immediately addressing all exposure pathways. SMU 7 would be addressed in the following manner:

- A granular cap would be placed, 1 to 3 feet thick, between the marine railway girders and ties, depending on the amount of clearance available between the mudline and the railroad girders. Sand or the selected material would be placed with conveyor or telebelt capping equipment or standard crane-operated equipment placing capping material through the marine railway structure. Capping operations would be followed by a diver sweep of the structure to clear settled capping material off of the railway structure.
    - The cap thickness, material specifications, and armoring requirements would be determined during remedial design.
- As feasible, dredging or excavation would be conducted as close as practicable to the marine railway girders on either side of the railway structure to the edge of the Carpenter Building pier and to the West Marine Walkway. This area would then be capped.
- Confirmation monitoring would be conducted during and following cap placement to confirm the constructed cap meets the design requirements.

- Long-term monitoring would be conducted to ensure stability and effectiveness of the constructed cap.
- Institutional controls would be implemented that would require evaluation of a more permanent remedy at the time the marine railway structure is renovated, replaced, or demolished. Institutional controls may also limit or restrict shipyard operations that cause erosive conditions on the sediment cap, as determined during the design process through a propeller wash analysis.

SMU 8

The proposed Alternative 2 remedy in SMU 8 is the same as Alternative 1. SMU 8 consists of the area beneath and surrounding the in-water portion of the marine railway within the shipyard intertidal sediment area above elevation 0 feet MLLW. The marine railway structure in this area is pile-supported, and the girders supporting the railroad sit on the sediment surface without clearance below. In Alternative 2, as in Alternative 1, this SMU would be actively remediated through focused excavation between the railway girders to allow placement of a granular cap and to contain sediment contamination in place, thus immediately addressing all exposure pathways. SMU 8 would be addressed in the following manner:

- Focused excavation would occur to remove material between the railway girders, and from either side of the railway structure. Excavation within the marine railway would be performed by hand equipment, small excavation equipment, or vacuum truck. Material would be removed to a minimum 1-foot depth below the top of the railway girders. Excavation in between the marine railway and the West Marine Walkway and underneath the walkway could be done with upland excavation equipment at low tides.
- A granular cap would be placed, minimum 1 foot in thickness, extending flush with the top of the railroad girders. The granular cap material placed would be selected to withstand intertidal erosive forces and marine railway operations. Likely, the cap material would be compacted crushed rock. The selection of material and finished cap elevation would be designed to allow maintenance cleaning of depositional material from the railway area without disturbing the cap material.
    - The material specifications and compaction requirements would be determined during remedial design.
- Confirmation monitoring (e.g., bathymetric surveys) would be conducted during and following cap placement to confirm the constructed cap meets the design requirements.
- Long-term monitoring would be conducted to ensure stability and effectiveness of the constructed cap.
- Institutional controls would be implemented that would require evaluation of a more permanent remedy at the time the marine railway structure is renovated, replaced, or demolished. Institutional controls may also limit or restrict shipyard operations that cause erosive conditions on the cap, as determined during the design process through a propeller wash analysis.

SMU 10

SMU 10 encompasses the shipyard intertidal sediment area above 0 feet MLLW that is not covered by structures. In Alternative 2, this area would be actively remediated through excavation of an average of 3 feet of sediment to meet the CULs/RALs, followed by backfilling with appropriate habitat substrate to return the areas to existing grade. This removal action would immediately address all exposure pathways through contaminant mass removal. This SMU would be addressed in the following manner:

- Excavation would be performed for an average of 3 feet of contaminated sediment from the intertidal areas using standard excavation equipment. Equipment may be operated from either land or barges.
    - The excavation extent would be offset from the existing bulkhead structures by approximately 6 feet for structural stability and protection. The area between the excavation and bulkhead wall would be filled to construct a slope that would provide improved structural support to the bulkhead wall. This bulkhead slope would also provide a cap to contaminated sediment beneath it.
    - Remedial design sampling would be conducted to confirm excavation depths necessary to meet CULs/RALs and to determine where in the intertidal sediment area institutional controls may be necessary. Backfill areas would require maintenance.
    - Excavated material would be transported off-site and transloaded for upland landfill disposal or upland beneficial reuse.
    - Backfill and bulkhead slope materials would be selected during the design phase to resist wave action and erosional forces, and to provide ancillary habitat benefit.
- Performance monitoring would be conducted during excavation to ensure contaminated sediment removal complies with remedial goals. Topographic surveys would be conducted to confirm that backfilled material meets design requirements.
- Upgrades to the bulkhead structures would be constructed as necessary to repair and improve damaged and aging portions of the existing bulkheads. Bulkhead upgrades would be completed in a manner that minimizes the volume of soil removed from behind the bulkheads, and is consistent in construction type with the sections of the bulkhead that do not require repair or improvement.
- The existing stormwater emergency outfall pipe located in the intertidal sediment area in SMU 10 would be temporarily disconnected and stored during construction of the remedial action and then re-installed.
- Confirmation monitoring (e.g., topographic survey) would be conducted during and following cap placement, if necessary, to confirm the constructed cap meets the design requirements.
- Long-term monitoring would be conducted to ensure stability of the backfilled intertidal sediment area and bulkhead toe berms.
- Institutional controls would be implemented in the intertidal area where contaminated sediment remains in place beneath backfill and the bulkhead toe berm. These controls would manage exposure to the contaminated sediment during future redevelopment actions in the area, such as bulkhead wall replacement.

SMU 11

The proposed Alternative 2 remedy in SMU 11 is the same as Alternative 1. SMU 11 is located beneath the Access Pier to Dry Dock No. 1.

In Alternative 2, as in Alternative 1, this SMU would be actively remediated through placement of an under-pier granular cap to contain sediment contamination in place, immediately addressing all exposure pathways. This SMU would be addressed in the following manner:

- A granular cap with 1-foot minimum thickness would be placed using conveyor or telebelt capping equipment and methods to place material beneath the existing pier structure. This pier has the clearances necessary for this method of cap placement.
    - The cap thickness and material specifications would be determined during remedial design and will include a structural evaluation of the older wooden pier to confirm the final sediment cap design does not impact the structure. This evaluation may limit the allowable cap thickness in this area.
- Institutional controls would be implemented at the Site that would control future site development in capped areas, including potential shipyard operational controls such as propeller wake restrictions, if determined necessary during the design process by propeller wash analyses. Institutional controls would also require evaluation of a more permanent remedial action at the time the pier structure is renovated, replaced, or demolished.
- Confirmation monitoring (e.g., bathymetric survey) would be conducted during and following cap placement to confirm the constructed caps meet design requirements.
- Long-term monitoring would be conducted to ensure stability and effectiveness of constructed caps.

All SMUs

For SMUs or portions of the SMUs in which dredging to CULs/RALs is an alternative, if the target concentrations are unable to be achieved (e.g., due to subsurface obstructions), a 6-inch-thick layer of sand will be placed as ENR. This is anticipated to be a small subsection of the SMUs, but provides additional protection for areas in which it is infeasible to reach the RAOs.

Associated Cost

The estimated cost for Alternative 2 is $22.4 million and includes remedial design sampling, design, implementation, and a 30% contingency. The final cost also includes the cost for the Interim Action, as the Interim Action is considered part of the remedy. The cost estimate for Alternative 2 is included in Appendix H, Table H.8.

12.4.3 Alternative 3

Alternative 3 is a full removal option, which includes demolition and replacement of existing over-water structures to allow access for sediment removal. Alternative 3 is based on current conditions following completion of the Interim Action. The concrete portion of the Harris Avenue Pier over SMU 5, the in-water portions of the marine railway, the West Marine Walkway, and the Access Pier to Dry Dock No. 1 would all be demolished to facilitate dredging below these structures. Following dredging of contaminated sediments, the infrastructure would be re-built based on the current footprint and existing uses.

Shipyard intertidal sediment areas would be excavated to CULs/RALs and backfilled to maintain existing grades, as in Alternatives 1 and 2. All dredged and excavated material would be permanently removed from the aquatic environment for upland landfill disposal or approved upland reuse. This alternative also includes additional work for the intertidal SMUs 2 and 4 that were addressed in the Interim Action to achieve full removal. In Alternative 3, as in Alternatives 1 and 2, the Interim Action completed for SMUs 1 and 3 are part of this alternative.

Alternative 3 supports continued operation of the shipyard, without providing constraints to berth depth or vessel operation. However, the construction of Alternative 3 would cause substantial impacts to shipyard operations and require multiple construction seasons. Due to the requirements for structural demolition and reconstruction, the construction duration associated with Alternative 3 would be significantly longer than Alternatives 1 or 2. With full permanent removal of contaminated material, institutional controls would not be required for Alternative 3.

Table 12.2 lists the specific technologies proposed for each SMU, and the following sections discuss the application of remedial technologies for each SMU. Figure 12.3 illustrates the applied technologies by SMU for Alternative 3.

SMU 1

A small area in SMU 1 northeast of the Interim Action area was not addressed as part of the Interim Action. Sampling will be conducted during remedial design to determine if any additional action is necessary within this area to meet benthic health CULs/RALs. For this FS evaluation, Alternative 3 assumes dredging is conducted in this area.

SMUs 2 and 4

As part of the full removal alternative, the contaminated material in the intertidal sediments that was capped during the Interim Action must be removed. In Alternative 3, the cap material would be removed as necessary to allow for excavation of contaminated material to meet the CULs/RALs. These SMUs would be addressed in the following manner:

- Complete remedial design sampling to confirm the extent of contaminated material and final excavation depths.
- Removal of approximately 3 feet of cap material placed during the Interim Action. It is assumed that upland excavation equipment could be used and would be able to reach under the recently constructed Harris Avenue Pier.
- Excavation of contaminated material would occur to meet CULs/RALS, assumed to be an average 2-foot depth, using upland excavation equipment.
- All contaminated sediments would be removed from the aquatic environment. They would be transported by barge to a suitable transload facility, where they would then be transloaded to truck or rail for transportation to an upland landfill for disposal. Dredged sediments could also be considered for upland beneficial reuse with Ecology approval. That potential would be evaluated during design.
- Confirmation monitoring (e.g., bathymetric survey) would be conducted following dredging to confirm the exposed surface meets CULs/RALs.
- Backfill with appropriate habitat substrate would be placed to return the intertidal sediment area to existing grades. Backfill material would be selected during design to resist wave action and erosional forces.

SMU 5

SMU 5 is located beneath the concrete portion of the Harris Avenue Pier. During remedial design, additional data would be collected within this area to determine the necessity for remedial action. If remedial action is required in Alternative 3, the concrete portion of the Harris Avenue Pier above SMU 5 would be demolished to allow removal of contaminated material beneath it. Alternatively, dredging of this section could potentially be accomplished through the use of divers without demolition of the pier. The cost and practicality of this option compared to structure removal and replacement will be evaluated in detail during remedial design.

This SMU would be addressed in the following manner:

- Structural demolition would occur, with appropriate BMPs to minimize effects to water quality. Treated pilings would be pulled for full removal from the aquatic environment, to the maximum extent possible.
- Following structure demolition, dredging would be conducted throughout the area to achieve a surface meeting CULs/RALs, consistent with the dredging performed in SMUs 6 and 9. Dredged material would be permanently removed from the aquatic environment.
- Confirmation monitoring would be conducted following dredging to confirm the exposed surface meets CULs/RALs. A Confirmation Monitoring Plan would be developed during design for Ecology approval. The Confirmation Monitoring Plan would be designed to confirm that the sediment surface meets CULs/RALs following dredging, given allowances for anticipated dredge residuals.

Following confirmation monitoring, the pier would be rebuilt to original dimensions and to support continued shipyard use.

SMUs 6 and 9

The proposed Alternative 2 remedy in SMUs 6 and 9 are the same as Alternative 2. The open water SMUs 6 and 9 encompass the open water areas within AOC 1 (Figure 12.3). Remedial design sampling in SMU 6 was conducted as part of the Interim Action design. During remedial design, additional data would be collected within SMU 9 to determine the necessity for remedial action. These areas are fully accessible to water-borne construction equipment. In Alternative 2, these areas would be actively remediated through dredging to a surface that meets CULs/RALs, addressing all exposure pathways. These SMUs would be addressed in the following manner:

- Dredging would occur to an average 3-foot depth, using mechanical dredging equipment and methods.
    - Existing data predict that a 2- to 4-foot dredge depth will reach native sediments, or sediments that meet CULs/RALs. Figure 12.4 presents subtidal sediment core data with bottom depths greater than 12 cm, on which this prediction has been based. The specific extents and depths of dredging would be determined with remedial design sampling to supplement current understanding of the thickness of contaminated sediments throughout SMU 9. Significant differences in expected thickness would be evaluated in coordination with Ecology.
- All contaminated sediments would be removed from the aquatic environment. They would be transported by barge to a suitable transload facility, where they would be transloaded to truck or rail for transportation to an upland landfill for disposal. Dredged

sediments could also be considered for upland beneficial reuse with Ecology approval. That potential would be evaluated during design.

- Confirmation monitoring (e.g., bathymetric surveys) would be conducted following dredging to confirm the exposed sediment surface meets CULs/RALs. A Confirmation Monitoring Plan would be developed during design for Ecology approval. The Confirmation Monitoring Plan would be designed to confirm that the sediment surface meets CULs/RALs following dredging, given allowances for anticipated dredge residuals.

Dredging within the open water operational areas of the shipyard to achieve a sediment surface that meets CULs/RALs is supportive of continued shipyard operations. The dredged surface does not constrain operational depths or vessel movements

SMU 7

SMU 7 consists of the area beneath and surrounding the marine railway at depths greater than 0 feet MLLW. In Alternative 3, the marine railway structures and adjacent West Marine Walkway would be demolished, and underlying sediments would be dredged to a surface that meets CULs/RALs, addressing all exposure pathways. This SMU would be addressed in the following manner:

- Structural demolition of the marine railway and West Marine Walkway would occur, with appropriate BMPs to minimize effects to water quality. Piling would be pulled for full removal from the aquatic environment, to the maximum extent possible.
- Following structure demolition, dredging would be conducted throughout the area to achieve a surface meeting CULs/RALs, consistent with the dredging performed in SMUs 6 and 9. Dredged material would be permanently removed from the aquatic environment.
- Consistent with SMUs 6 and 9, confirmation monitoring would be conducted following dredging to confirm the exposed surface meets CULs/RALs.
- Following confirmation monitoring, structures would be rebuilt to original dimensions and to support continued shipyard use.

SMU 8

SMU 8 consists of the area beneath and surrounding the in-water portion of the marine railway within the shipyard intertidal sediment area above 0 feet MLLW elevation. In Alternative 3, the marine railway structures and adjacent West Marine Walkway would be demolished, and underlying sediments would be dredged to a surface that meets CULs/RALs, addressing all exposure pathways. Intertidal areas would be returned to existing elevations. This SMU would be addressed in the following manner:

- Structural demolition of the marine railway and West Marine Walkway would occur, with appropriate BMPs to minimize effects to water quality. Piling would be pulled for full removal from the aquatic environment, to the maximum extent possible.
- Following structure demolition, dredging would be conducted throughout the area to achieve a surface meeting CULs/RALs, consistent with the dredging performed in SMUs 6 and 9. Dredged material would be permanently removed from the aquatic environment.

- Consistent with SMUs 6 and 9, confirmation monitoring would be conducted following dredging to confirm the exposed surface meets CULs/RALs.
- At elevations above 0 feet MLLW, backfill would be placed to return the intertidal sediment area to existing grades. Backfill material would be selected during design to resist wave action and erosional forces and to support continued operation of a marine railway in the area.

Following confirmation monitoring and sediment intertidal area backfill, structures would be rebuilt to original dimensions and to support continued shipyard use.

SMU 10

The proposed Alternative 3 remedy in SMU 10 is the same as Alternative 2. SMU 10 encompasses the shipyard intertidal sediment area above 0 feet MLLW that is not covered by structures. In Alternative 3, this area would be actively remediated through excavation of an average of 3 feet of sediment to meet the CULs/RALs, followed by backfilling with appropriate habitat substrate to return the area to existing grade. This removal action would immediately address all exposure pathways through contaminant mass removal. This SMU would be addressed in the following manner:

- Excavation would be performed for an average of 3 feet of contaminated sediment from the intertidal areas using standard excavation equipment. Equipment may be operated either from land or from barges.
    - The excavation extent would be offset from the existing bulkhead structures by approximately 6 feet for structural stability and protection. The area between the excavation and bulkhead wall would be filled to construct a slope that would provide improved structural support to the bulkhead wall. This bulkhead slope would also provide a cap to contaminated sediment beneath it.
    - Remedial design sampling would be conducted to confirm excavation depths necessary to meet CULs/RALs and to determine where in the intertidal sediment area institutional controls may be necessary. Backfill areas would require maintenance.
    - Excavated material would be transported off-site, and transloaded for upland landfill disposal or upland beneficial reuse.
    - Backfill and bulkhead slope materials would be selected during the design phase to resist wave action and erosional forces and to provide ancillary habitat benefit.
- Performance monitoring would be conducted during excavation to ensure contaminated sediment removal complies with remedial goals. Topographic surveys would be conducted to confirm that backfilled material meets design requirements.
- Upgrades to bulkhead structures would be constructed as necessary to repair and improve damaged and aging portions of the existing bulkheads. Bulkhead upgrades would be completed in a manner that minimizes the volume of soil removed from behind the bulkheads, and is consistent in construction type with the sections of the bulkhead that do not require repair or improvement.
- The existing stormwater emergency outfall pipe located in the intertidal sediment area in SMU 10 would be temporarily disconnected and stored during construction of the remedial action and then re-installed.

- Confirmation monitoring (e.g., topographic survey) would be conducted during and following cap placement, if necessary, to confirm the constructed cap meets the design requirements.
- Long-term monitoring would be conducted to ensure stability of the backfilled intertidal sediment area and bulkhead toe berms.
- Institutional controls would be implemented in the intertidal area where contaminated sediment remains in place beneath backfill and the bulkhead toe berm. These controls would manage exposure to the contaminated sediment during future redevelopment actions in the area, such as bulkhead wall replacement.

SMU 11

SMU 11 is located beneath the Access Pier to Dry Dock No. 1. In Alternative 3, this wooden pier structure would be demolished, and underlying sediments would be dredged to a surface that meets CULs/RALs, addressing all exposure pathways. This SMU would be addressed in the following manner:

- Structural demolition would occur, with appropriate BMPs to minimize effects to water quality. Piling would be pulled for full removal from the aquatic environment, to the maximum extent possible.
- Dredging would be conducted throughout the area following structure demolition to achieve a surface meeting CULs/RALs, consistent with the dredging performed in SMUs 6 and 9. Dredged material would be permanently removed from the aquatic environment.
- Consistent with SMUs 6 and 9, confirmation monitoring would be conducted following dredging to confirm the exposed surface meets CULs/RALs.

Following confirmation monitoring, the Access Pier to Dry Dock No. 1 would be rebuilt to original dimensions and to support continued shipyard use.

Associated Cost

The estimated cost for Alternative 3 is $35.4 million and includes remedial design sampling, design, implementation, and a 30% contingency. The final cost also includes the cost for the Interim Action, as the Interim Action is considered part of the remedy. The cost estimate for Alternative 3 is included in Appendix H, Table H.9.

13.0 Sediment – Cleanup Alternative Evaluation and Disproportionate Cost Analysis

In this section, the sediment cleanup alternatives developed for the Site in Section 12.0 are evaluated against the SMS requirements for a cleanup remedy per WAC 173-204-570 and under the MTCA requirements for the DCA per WAC 173-340-360(3), which are referenced by the SMS. The SMS requirements are introduced in the first section below, followed by the alternatives evaluation that compares each alternative based on its ability to comply with the SMS requirements and finishes with a discussion of the DCA process.

13.1 SEDIMENT MANAGEMENT STANDARDS MINIMUM REQUIREMENTS

This section provides a summary of the requirements and criteria that each remedial alternative is evaluated against in accordance with SMS. Each of the proposed remedial alternatives is screened relative to mandatory "minimum requirements for sediment cleanup actions" for evaluation. Following this, a DCA is conducted to identify the alternative that is "permanent to the maximum extent practicable," using DCA evaluation criteria as referenced by SMS. Based on these evaluations, a Preferred Remedial Alternative is selected for recommendation to Ecology.

13.1.1 Minimum Requirements for Sediment Cleanup Actions

SMS WAC 173-204-570(3) mandates that all cleanup actions meet minimum requirements, and, when multiple cleanup action components are implemented for a single site, the overall cleanup action shall also meet the minimum requirements discussed below:

- **Protect Human Health and the Environment.** Protection of human health and the environment shall be achieved through implementation of the selected remedial action.
- **Comply with Applicable State and Federal Laws.** SMS WAC 173-204-570 states that cleanup standards shall comply with legally applicable ARARs. ARARs applicable to this Site are detailed in Tables 7.1 through 7.3 and consist of chemical-specific ARARs applicable to the contamination types present at the Site, location-specific ARARs that apply to the physical location of the Site, and action-specific ARARs that apply to the construction components of the remedy.
- **Comply with the Sediment Cleanup Standards.** Cleanup standards, as defined by SMS, consist of sediment CULs for individual contaminants and the locations within a site or sediment cleanup unit where the sediment CULs must be met. Sediment cleanup standards may also include other regulatory requirements that apply to a cleanup action for contaminated sediment because of the type of action or location of a site (applicable laws). All selected cleanup alternatives must comply with the sediment cleanup standards specified in WAC 173-204-560 through 173-204-564 and defined for the Site.
- **Use Permanent Solutions to the Maximum Extent Practicable.** The use of permanent solutions to the maximum extent practicable for a cleanup action is analyzed according to WAC-173-204-570(4), which states that the DCA procedure described in WAC 173-340-360(3) must be followed. Preference is given to alternatives that implement permanent solutions, defined in MTCA as actions that can meet cleanup standards "without further action being required at the site being cleaned up or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances" (WAC 173-340-200). The

DCA process is conducted to identify the alternative that uses permanent solutions to the maximum extent practicable and is described in detail in Section 13.1.2.

- **Provide for a Reasonable Restoration Time Frame.** Restoration time frame is defined in SMS as “the length of time it will take for the cleanup action to achieve the sediment cleanup standards at the site of sediment cleanup unit.” Preference is given to alternatives that achieve sediment cleanup standards at a site or sediment cleanup unit sooner. WAC 173-204-570(5) states that “unless otherwise determined by the department, cleanup actions that achieve compliance with the sediment cleanup standards at the site or sediment cleanup unit within ten years of completion of the active components of the cleanup action shall be presumed to have a reasonable restoration time frame.”

- **Provide for Effective Source Control Measures.** Where source control measures are necessary, preference will be given to alternatives with source control measures that are more effective in minimizing sediment recontamination resulting from discharges.

- **Meet Requirements for Establishment of Sediment Recovery Zones.** If a Sediment Recovery Zone is determined necessary as part of the cleanup action, all requirements of WAC 173-204-590 must be met. Sediment Recovery Zones should be minimized to the maximum extent practicable through the use of more permanent cleanup remedies.

- **Develop More Permanent Cleanup Actions.** Cleanup actions for a site shall not rely exclusively on MNR or institutional controls when a more permanent cleanup remedy is technically feasible to implement. Proposed institutional controls must comply with WAC 173-340-440 and shall have the ability to control exposures and ensure the integrity of the cleanup action.

- **Consider Public Concerns.** Public involvement must be initiated according to the requirements set forth in WAC 173-204-575. Public concerns are taken into account at each step in the formal process under SMS. Affected landowners and the general public are notified. Formal public comment will be received on this Draft RI/FS document, and will be taken into account when developing the Final RI/FS and the Cleanup Action Plan.

- **Provide for Compliance Monitoring.** SMS requires that all selected cleanup alternatives provide for adequate monitoring to verify compliance with approved sediment cleanup standards (WAC 173-204-500(4)(d)) and to ensure the effectiveness of the cleanup action (WAC 173-204-570(3)(j)). These are typically referred to as performance monitoring and confirmation monitoring. Performance monitoring will assess whether or not a cleanup action has achieved, or is projected to achieve, sediment cleanup standards. Confirmation monitoring will evaluate long-term effectiveness of the remedial action following attainment of the cleanup standards.

- **Provide for Periodic Review.** Periodic review may be required to determine the effectiveness and protectiveness of cleanup actions that use containment, ENR, MNR, institutional controls, sediment CULs based on PQLs, or a sediment recovery zone. When required, the review will follow the process and requirements in WAC 173-340-420.

13.1.2 Consideration of Cleanup Standards Compliance

The sediment remedial alternatives described in Section 12.4 and evaluated for compliance with SMS in Section 13.2 provide multiple ways to achieve active remediation of AOC 1. With all three alternatives, active remediation of sediments within AOC 1 would achieve cleanup standards for protection of benthic species and for human direct contact to shipyard workers in intertidal sediments and net fishers in subtidal sediments. The active remediation of sediments within AOC 1 would reduce the average concentrations of bioaccumulative compounds within the vicinity of the Site. All three alternatives for active remediation within AOC 1 would reduce bioaccumulative risk within the area.

RALs were established for the human direct contact COCs and bioaccumulative COCs. Compliance with CULs for the human health pathway is established on a SWAC-basis, and therefore RALs are appropriate to develop in order to bring the Site-wide SWAC into CUL compliance. RALs include: 20 mg/kg for arsenic, 5.1 mg/kg for cadmium, 0.13 mg/kg for PCBs, and 4.2 mg/kg for cPAHs. These RALs were based on the non-bioaccumulative exposure pathways and were used to determine the extent of AOC 1. The definition of AOC 1 and the derivation of sediment CULs and RALs are described in Section 5.2. Sediment CULs and remedy evaluation are summarized in Table 13.1.

The selected active remedy within AOC 1 would address all benthic exposure pathways within the AOC 1 boundary. All sediments that exceed the CULs for this exposure pathway would either be capped with clean material and/or dredged to a surface meeting CULs. For human direct contact[15] and bioaccumulative exposure pathways, all sediments that exceed the RALs would either be capped with clean material and/or dredged to a surface that results in the Site-wide SWACs meeting CULs post-remediation (with the exception of cPAHs, as described below).

Bioaccumulative CULs applicable to the Site were developed based on current SMS guidance, with the development process described in Appendix G, Attachment G.1. To evaluate compliance with the bioaccumulative exposure pathway, site-wide SWACs were calculated for each of the bioaccumulative COCs, pre- and post-remediation.

To determine the SWACs, surface sediment data were interpolated using the inverse-distance weighted algorithm from the ArcGIS Geostatistical Analyst extension. Data used to generate the concentration surfaces were obtained from both the study area and Ecology's Environmental Information Management database, using the maximum concentration for each chemical at each sampling location or a value of one-half the detection limit if all of the results were non-detects.

The SWAC for each bioaccumulative COC was then calculated by assigning post-remediation concentrations to the active cleanup area within AOC 1 and then calculating a resultant SWAC for each of the bioaccumulative compounds at three separate buffer distances from the shoreline: 600 feet, 800 feet, and 1,000 feet.[16] For purposes of this evaluation it is assumed that the entire AOC 1 will be actively remediated. The actual extent of the remediation of the SMUs in AOC 1 would be based upon the remedial design sampling event. Post-remediation concentrations are based on the data available in subsurface sediments indicating the concentrations that would be

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[15] Because arsenic is the only human direct contact COC and the CUL for this exposure pathway is the same as the seafood consumption exposure pathway, the direct contact pathway is no longer discussed separately in this FS.

[16] If the buffer distance influences the calculated SWACs, it is possible that each selected buffer distance is still impacted by a contaminant source and each buffer distance is just farther from the source. When the buffer distance does not influence the SWAC, it is a good indication that there is no measurable impact from a source area (i.e., the active remediation has effectively removed the source).

left in place following remediation (i.e., the concentrations at the subsurface sample that met the RALs). The areas in which SWAC evaluations were performed and SWAC results for arsenic, cadmium, cPAHs, and PCBs are shown in Figures 13.1 through 13.4 and are summarized in Table 13.1.

As shown below, the arsenic, cadmium, and PCBs SWACs within the Site vicinity meet the bioaccumulative CUL for protection of human health through seafood consumption.

Bioaccumulative COC	**Bioaccumulative CUL (mg/kg)**	**SWACs: 600 to 1,000 feet offshore (mg/kg)**
Arsenic	13	11
Cadmium	0.8	0.83 to 0.87[1]
cPAHs	0.14	0.28 to 0.32
PCBs	0.033	0.028 to 0.030

Note:

1 Per SCUM II, cadmium is considered in compliance with the CUL because the final SWAC is within 20 percent of the CUL. SCUM II states: “Based on typical analytical relative percent differences (RPDs) and field variability, any individual or mean value within 20% of the cleanup standard is considered to be indistinguishable from the cleanup standard and in compliance.”

Following remediation of AOC 1, surface sediments within the vicinity of the Site would not meet the bioaccumulative CULs for cPAHs when evaluated using the SWAC within 600-foot, 800-foot, or 1,000-foot shoreline buffer areas. The SWAC evaluation for the various shoreline buffer areas was conducted to provide a sensitivity analysis to demonstrate that the SWAC values for these compounds do not change significantly when incrementally evaluated farther offshore of the shipyard property.

For cadmium, the shoreline buffer evaluation indicated that concentrations of the post-remediation SWAC actually increase as the buffer distance increases, with no distinguishable pattern of distribution (refer to Figure 13.2), further supporting that cadmium is not associated with Site sources. For cPAHS, a sensitivity analysis was performed to determine what post-remediation concentration was necessary to achieve the CUL for cPAHs within these shoreline buffer areas and it was determined that even if the post-remediation concentration was zero within AOC 1, the SWAC would still exceed the CUL, due to the presence of scattered samples, not associated with the Site, that have cPAH concentrations greater than the CUL within the Bay. It is impracticable and unreasonable for the Site’s responsible parties to be required to remediate areas of regional low-level sediment that are outside of the Site AOCs. Active remediation of sediments within AOC 1 addresses contamination related to historical activities at the Site. As anticipated by Ecology, cPAH regional concentrations within the Bay are expected to continue to naturally recover based on watershed-wide source control and cleanup actions.

13.2 ALTERNATIVES EVALUATION

In the following sections, the three proposed remedial alternatives for the sediments are evaluated for compliance with the minimum requirements for sediment cleanup actions under SMS and compliance with the Site RAOs defined in Section 7.0. Alternative assessment is conducted in Table 13.2, summarized in Table 13.3, and discussed further in Section 13.3.

The SMS requirement “Meet Requirements for Establishment of Sediment Recovery Zones”[17] is not evaluated in the alternatives analysis that follows as a Sediment Recovery Zone is not proposed as part of the any of the alternatives. With all three alternatives, active remediation of sediments within AOC 1 would achieve cleanup standards throughout the Site for protection of benthic species and human intertidal sediment direct contact, as well as individual direct contact and incidental ingestion during net fishing. The active remediation of sediments within AOC 1 would reduce the average concentrations of bioaccumulative compounds within the vicinity of the Site. Ubiquitous low-level cPAH concentrations present in regional sediments within the Bay are expected to continue to naturally recover due to regional source reduction efforts.

The SMS requirement “Develop More Permanent Cleanup Actions” is not evaluated in the alternatives analysis that follows as alternatives consisting only of MNR and institutional controls are not being proposed. The permanence of each alterative is evaluated under the “User Permanent Solutions to the Extent Practicable” SMS requirement.

The SMS requirement “Consider Public Concerns” is not evaluated in the alternatives analysis that follows. Public comments on this Draft RI/FS document and any future project documents will be solicited by Ecology and the Port, and taken into account during final Ecology decision-making regarding the Preferred Remedial Alternative.

13.2.1 Alternative 1

Alternative 1 is considered the full capping alternative, with the exception of the work conducted in the Interim Action, and consists of capping in both open water and under-pier areas. At the intertidal sediment areas, contaminated sediments would be excavated, and then backfilled to maintain existing elevations. In the intertidal portion of the marine railway, targeted excavation would be performed to support placement of a cap to match the surface elevation of railroad girders, to maintain operation of the railway structure.

The only material removal in Alternative 1, with the exception of the work conducted in the Interim Action, would be in the intertidal sediment areas adjacent to the bulkheads and at the marine railway to accommodate placement of backfill and a sediment cap without modifying intertidal sediment elevations or the ordinary high water line. All excavated material would be transloaded for upland landfill disposal or upland beneficial reuse. Institutional controls would require maintenance of the capped areas in perpetuity and could require dredging restrictions, development restrictions, and shipyard operation restrictions.

Alternative 1 also includes demolition and replacement of the West Marine Walkway and armoring of the eroding section of the western shoreline.

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[17] A “Sediment Recovery Zone” is an authorized area where it is determined that the cleanup action will not achieve cleanup standards within 10 years after completion of the action’s active components. Sediment recovery zones must meet the requirements in WAC 173-204-590 and be authorized by the department under WAC 173-204-575.

13.2.1.1 Sediment Management Standards Requirements

- **Protect Human Health and the Environment.** Alternative 1 is protective of human health and the environment in AOC 1 through sediment capping. Capping of the open water and understructure areas would contain contamination in place, providing a clean surface that would be protective of all exposure pathways in areas that are actively remediated. Risks would be immediately reduced following placement of the capped material. Institutional controls would ensure that the cap was maintained in perpetuity and that the remedy remained protective. There would be an improvement in overall environmental quality resulting from implementation of this remedy. Following implementation of the remedial action within AOC 1, human health risk remains within the Site vicinity associated with consumption of resident seafood at high consumption rates. This is due to the presence of ubiquitous low-level cPAH concentrations present in regional sediments within the Bay.
- **Comply with Applicable State and Federal Laws.** Alternative 1 complies with all applicable state and federal laws outlined in Section 7.2 and in Tables 7.1 through 7.3 through contaminant capping and institutional controls in capped areas.
- **Comply with the Sediment Cleanup Standards.** Alternative 1 complies with cleanup standards within AOC 1 through containment of COCs with capping and limited excavation. Because contamination would remain on-site at concentrations greater than CULs, institutional controls would require cap maintenance in perpetuity. Implementation of Alternative 1 for remediation of sediments within AOC 1 would achieve cleanup standards for all COCs for protection of benthic species and human intertidal sediment direct contact, as well as individual direct contact and incidental ingestion during net fishing. The active remediation of sediments within AOC 1 would also reduce the average concentrations of bioaccumulative compounds within the vicinity of the Site. As described above, following remediation of AOC 1, within a buffer area of 1,000 feet from the shoreline, the SWACs of arsenic, cadmium, and PCBs in surface sediments would meet the CUL for protection of human health through seafood consumption. However, due to the presence of ubiquitous low-level cPAH concentrations regionally present in the Bay sediments, the cPAH SWAC would not meet its CUL for protection of human health through seafood consumption. A description of how active remediation of AOC 1 would address cleanup standards for the bioaccumulatives is presented in Section 13.1.3.
- **Use Permanent Solutions to the Maximum Extent Practicable.** The use of permanent solutions to the maximum extent practicable in Alternative 1 is evaluated through the DCA process in accordance with WAC 173-340-360(3). The DCA process is summarized in Section 13.3.
- **Provide for a Reasonable Restoration Time Frame.** Alternative 1 would meet cleanup standards as described above within a reasonable time frame through the placement of cap material and containment of COCs. Cap material would be expected to be placed in all areas of AOC 1 with contamination greater than CULs within two in-water construction seasons. The benthic and human health exposure pathways would be addressed immediately following completion of the remedy, expected to be within 2 years from the start of construction. Residual concentrations of cPAHs in the sediment outside AOC 1 would be expected to continue to naturally recover within a reasonable time frame based on the continued watershed-wide source control efforts and cleanups of uplands and in-water sources through various regulatory programs.

- **Provide for Effective Source Control Measures.** Source control measures would be implemented as part of Alternative 1 to prevent recontamination of sediments. Alternative 1 would provide for effective source control measures through the isolation of contaminated sediment and implementation of shipyard procedures to prevent the release of contaminants to the Bay. Source control was addressed during the Interim Action through removal of creosote piling in the footprint of the Harris Avenue Pier and Carpenter Building and its supporting pier. Source control actions that could be implemented at the shipyard would be finalized during design, but could include infrastructure updates to the containment system at the marine railway or structural changes to the Dry Dock No. 1 ramp. These source control measures would prevent against any future discharge of contamination to sediments or recontamination of sediment consistent with SMS WAC 173-204-500(4) and (5) and are described further in Section 14.3.
- **Provide for Compliance Monitoring.** Alternative 1 meets the requirements for compliance monitoring by conducting performance monitoring following completion of capping and confirmation monitoring to confirm cap effectiveness. Some monitoring would be conducted in advance of implementation of the remedy, during design. This confirmation monitoring would be conducted to confirm cap placement areas in AOC 1. Performance monitoring would be conducted during construction. Confirmation monitoring would be conducted following construction and annually to ensure cap effectiveness.
- **Provide for Periodic Review.** Alternative 1 meets the requirements for periodic review because it would allow for cap inspections on a regular schedule. Requirements for long-term operation and maintenance of the capped areas would be developed and enforced through institutional controls. Long-term operation and maintenance of the capped areas could include inspections and repairs. If the capped surface were to fail, the capping material could be reevaluated and replaced if necessary.

13.2.1.2 Remedial Action Objectives

Alternative 1 would remediate marine sediments to meet SMS requirements protective of benthic species, direct contact, and incidental ingestion at the Site. Alternative 1 would be protective of human and ecological health through consumption of seafood in all the areas actively remediated within AOC 1. Due to the presence of ubiquitous low-level cPAH concentrations in regional sediments within the Bay, human health risk would remain within the Site vicinity associated with consumption of resident seafood at high consumption rates.

Alternative 1 would also address source control to protect sediment from recontamination and to protect surface water quality. By phasing the implementation of the remedy to maintain continuous shipyard operations and manage in-water work windows, the remedy could technically be implemented within the active shipyard environment. However, placement of a thick sediment cap within the operational areas of the shipyard would cause substantial negative impacts to shipyard operations and would be difficult to maintain. The shallower water depths that would be present following implementation of the remedy would not provide the berth depths necessary to support the draft depths of vessels that currently operate at the shipyard. Furthermore, shipyard operations and propeller wash have the potential to damage capped areas if stringent propeller wake restrictions are not followed. The portion of the Harris Avenue Pier that was demolished during the Interim Action to support the remedy was rebuilt following remediation to provide for continued shipyard operations. The new pier provides a safe working space for continued shipyard operations. The Carpenter Building and its supporting pier were not re-built because they are not required for continued operations.

Alternative 1 would allow for long-term monitoring to assess the cap integrity and effectiveness. Alternative 1 would also provide an ancillary benefit to habitat, by maintaining existing surface elevations in the intertidal sediment areas.

13.2.2 Alternative 2

Alternative 2 includes a combination of dredging and capping based on shipyard considerations, accessibility, and existing infrastructure. In Alternative 2, all accessible open water areas of AOC 1 would be dredged for full removal to meet cleanup standards. This includes the full removal of contaminated sediment beneath the Harris Avenue Pier and the Carpenter Building and its supporting pier completed during the Interim Action. In areas where the cleanup standard is unable to be met through dredging, a 6-inch-thick layer of sand would be placed as ENR. All contaminated sediments within accessible open water areas in AOC 1 would be removed from the aquatic environment, for upland landfill disposal or upland beneficial reuse.

In Alternative 2, intertidal sediment areas would be excavated, and the excavation would be backfilled to maintain existing elevations. Excavated material would be removed from the aquatic environment, for upland landfill disposal or upland beneficial reuse.

Shipyard structures other than those demolished as part of the Interim Action would be protected for continued use. Contaminated sediments below these shipyard structures would be capped, and institutional controls requiring maintenance of capped areas would be implemented.

Alternative 2 also includes demolition and replacement of the West Marine Walkway and armoring of the eroding section of the western shoreline.

13.2.2.1 Sediment Management Standards Requirements

- **Protect Human Health and the Environment.** Alternative 2 is protective of human health and the environment in AOC 1 through contaminant removal and disposal in a landfill and limited sediment capping. Dredging in open water areas and capping in select understructure areas would either remove or contain contamination in place, providing a surface that would be protective of all exposure pathways in areas that are actively remediated. Risks would be immediately reduced following dredging or placement of the capped material. Institutional controls would ensure that the cap areas were maintained in perpetuity and that the remedy remained protective. There would be an improvement in overall environmental quality resulting from implementation of this remedy. Following implementation of the remedial action within AOC 1, human health risk remains within the Site vicinity associated with consumption of resident seafood at high consumption rates. This is due to the presence of ubiquitous low-level cPAH concentrations present in regional sediments within the Bay.
- **Comply with Applicable State and Federal Laws.** Alternative 2 complies with all applicable state and federal laws outlined in Section 7.2 and in Tables 7.1 through 7.3 through dredging and contaminant mass removal, capping, and institutional controls in capped areas.
- **Comply with Cleanup Standards.** Alternative 2 complies with cleanup standards within AOC 1 through removal of COCs with dredging and off-site disposal or beneficial reuse and with limited containment of COCs with capping. Because contamination would remain on-site at concentrations greater than CULs in select areas with existing infrastructure, institutional controls would require cap maintenance in perpetuity or

until such time as structures are demolished and the underlying sediments become accessible for consideration of a more permanent remedy. Implementation of Alternative 2 for remediation of sediments within AOC 1 would achieve cleanup standards for all COCs for protection of benthic species and human intertidal sediment direct contact, as well as individual direct contact and incidental ingestion during net fishing. The active remediation of sediments within AOC 1 would also reduce the average concentrations of bioaccumulative compounds within the vicinity of the Site. As described above, following remediation of AOC 1, within a buffer area of 1,000 feet from the shoreline, the SWACs of arsenic, cadmium, and PCBs in surface sediments would meet the CUL for protection of human health through seafood consumption. However, due to the presence of ubiquitous low-level cPAH concentrations regionally present in Bay sediments, the cPAH SWAC would not meet its CUL for protection of human health through seafood consumption. A more thorough description of how active remediation of AOC 1 would address cleanup standards for the bioaccumulatives is presented in Section 13.1.3.

- **Use Permanent Solutions to the Maximum Extent Practicable.** The use of permanent solutions to the maximum extent practicable in Alternative 2 is evaluated through the DCA process in accordance with WAC 173-340-360(3). The DCA process is summarized in Section 13.3.
- **Provide for a Reasonable Restoration Time Frame.** Alternative 2 would meet cleanup standards as described above within a reasonable time frame through dredging and capping in select areas with existing infrastructure. Dredging would be expected to occur over two in-water construction seasons. Capping would be expected to be completed within one in-water construction season. The benthic and human health exposure pathways would be addressed immediately following completion of the remedy, expected to be within 2 years from the start of construction. Residual concentrations of cPAHs in the sediment outside AOC 1 would be expected to continue to naturally recover within a reasonable time frame based on the continued watershed-wide source control efforts and cleanups of uplands and in-water sources through various regulatory programs.
- **Provide for Effective Source Control Measures.** Source control measures would be implemented as part of Alternative 2 to prevent recontamination of sediments. Alternative 2 would provide for effective source control measures through the isolation of contaminated sediment under the over-water structures, and implementation of shipyard procedures to prevent the release of contaminants to the Bay. Source control was addressed during the Interim Action through removal of creosote piling in the footprint of the Harris Avenue Pier and the Carpenter Building and its supporting pier. Source control actions that could be implemented at the shipyard would be finalized during design, but could include infrastructure updates to the containment system at the marine railway or structural changes to the Dry Dock No. 1 ramp. These source control measures would prevent against any future discharge of contamination to sediments or recontamination of sediment consistent with SMS WAC 173-204-500(4) and (5) and are described further in Section 14.3.
- **Provide for Compliance Monitoring.** Alternative 2 meets the requirements for compliance monitoring by conducting performance monitoring during dredging and confirmation monitoring following completion of construction to confirm a sediment surface that meets CULs and confirm cap effectiveness. Some monitoring would be conducted in advance of implementation of the remedy, during design. This confirmation monitoring would be conducted to confirm dredge areas in AOC 1. Performance monitoring would be conducted during construction. Confirmation

monitoring would be conducted following construction and annually to ensure cap effectiveness in those areas that are capped.

- **Provide for Periodic Review.** Alternative 2 meets the requirements for periodic review because it would allow for cap inspections in those areas that are capped on a regular schedule. Requirements for long-term operation and maintenance of the capped areas would be developed and enforced through institutional controls. Periodic monitoring to confirm the remediated dredge surface does not become recontaminated could also be conducted.

13.2.2.2 Remedial Action Objectives

Alternative 2 would remediate marine sediments to meet SMS requirements protective of benthic species, direct contact, and incidental ingestion at the Site. Alternative 2 would be protective of human and ecological health through consumption of seafood in all the areas actively remediated within AOC 1. Due to the presence of ubiquitous low-level cPAH concentrations present in regional sediments within the Bay, human health risk would remain within the Site vicinity associated with consumption of resident seafood at high consumption rates.

Alternative 2 would also address source control to protect sediment from recontamination and to protect surface water quality. By phasing the construction of the remedy to support continuous shipyard operations and address in-water work windows, the remedy could be implemented within the active shipyard environment. Dredging within the open water operational areas of the shipyard would achieve a final surface elevation that is supportive of continued shipyard operations because the dredged surface would not constrain operational depths or vessel movements. The portion of the Harris Avenue Pier that was demolished to support the remedy was rebuilt following remediation to provide for continued shipyard operations. The new pier provides a safe working space for continued shipyard operations. The Carpenter Building and its supporting pier were not re-built because they are not required for continued operations.

Long-term monitoring to assess the cap integrity and effectiveness under structures would be conducted with Alternative 2. Alternative 2 would also provide an ancillary benefit to habitat by maintaining existing surface elevations in the intertidal sediment areas.

13.2.3 Alternative 3

Alternative 3 is a full removal option, which includes demolition and replacement of existing over-water structures to allow access for sediment removal where necessary following remedial design sampling. To allow sediment removal beneath the existing structures at the Site, Alternative 3 would include demolition of all existing shipyard structures so that contaminated sediments could be dredged. The newer concrete portion of the Harris Avenue Pier in SMU 5, the in-water portions of the marine railway, the West Marine Walkway, and the Access Pier to Dry Dock No. 1 would all be demolished. In areas where the cleanup standard is unable to be met through dredging, a 6-inch-thick layer of sand would be placed as ENR. Following dredging of contaminated sediments, the infrastructure would be re-built based on the current footprint and existing uses.

Intertidal sediment areas would be excavated to a clean surface and backfilled to maintain existing grades. This alternative includes removing the capping material placed in the intertidal areas in the Interim Action, removing any remaining material with COC concentrations exceeding the CULs/RALs, and backfilling with an appropriate substrate to existing elevations. All dredged and excavated material would be permanently removed from the aquatic environment for upland landfill disposal or approved upland reuse. With full permanent removal of contaminated material, institutional controls would not be required for Alternative 3.

Alternative 3 also includes demolition and replacement of the West Marine Walkway and armoring of the eroding section of the western shoreline.

13.2.3.1 Sediment Management Standards Requirements

- **Protect Human Health and the Environment.** Alternative 3 is protective of human health and the environment in AOC 1 through mass removal via dredging. Dredging in open water areas and beneath buildings that are demolished to support the remedy would permanently remove contamination, providing a surface that would be protective of all exposure pathways in areas that are actively remediated. Risks would be immediately reduced through dredging of contaminated areas. There would be substantial improvement in overall environmental quality resulting from implementation of this remedy. Following implementation of the remedial action within AOC 1, human health risk remains within the Site vicinity associated with consumption of resident seafood at high consumption rates. This is due to the presence of ubiquitous low-level cPAH concentrations present in regional sediments within the Bay.
- **Comply with Applicable State and Federal Laws.** Alternative 3 complies with all applicable state and federal laws outlined in Section 7.2 and in Tables 7.1 through 7.3 through dredging and contaminant mass removal.
- **Comply with Cleanup Standards.** Alternative 3 complies with cleanup standards within AOC 1 through removal of COCs with dredging and off-site disposal or beneficial reuse. Implementation of Alternative 3 for remediation of sediments within AOC 1 would achieve cleanup standards for all COCs for protection of benthic species and human intertidal sediment direct contact, as well as individual direct contact and incidental ingestion during net fishing. The active remediation of sediments within AOC 1 would also reduce the average concentrations of bioaccumulative compounds within the vicinity of the Site. As described above, following remediation of AOC 1, within a buffer area of 1,000 feet from the shoreline, the SWACs of arsenic, cadmium, and PCBs in surface sediments would meet the CUL for protection of human health through seafood consumption. However, due to the presence of ubiquitous low-level cPAH concentrations regionally present in Bay sediments, the cPAH SWAC would not meet its CUL for protection of human health through seafood consumption. A more thorough description of how active remediation of AOC 1 would address cleanup standards for the bioaccumulatives is presented in Section 13.1.3.
- **Use Permanent Solutions to the Maximum Extent Practicable.** The use of permanent solutions to the maximum extent practicable in Alternative 3 is evaluated through the DCA process in accordance with WAC 173-340-360(3). The DCA process is summarized in Section 13.3.
- **Provide for a Reasonable Restoration Time Frame.** Alternative 3 would meet cleanup standards, as described above, within a reasonable time frame through dredging. Due to the requirements for structural demolition and reconstruction with Alternative 3, the construction duration associated with Alternative 3 would be significantly longer than with Alternatives 1 or 2 and would cause substantial impacts to shipyard operations. Demolition and dredging would be expected to occur over two to three in-water construction seasons and reconstruction of structures would take additional construction seasons. In order to minimize impacts to shipyard operations, this work would need to be carefully phased. Construction of the remedy would be expected to take at least 3 years. The benthic and human health exposure pathways would be addressed immediately following implementation of the remedy in AOC 1,

with compliance expected to occur within 3 years from the start of construction. Residual sediment concentrations of cPAHs outside AOC 1 would be expected to continue to naturally recover within a reasonable time frame based on the continued watershed-wide source control efforts and cleanups of uplands and in-water sources through various regulatory programs.

- **Provide for Effective Source Control Measures.** Source control measures would be implemented as part of Alternative 3 to prevent recontamination of sediments. Source control actions that could be implemented at the shipyard would be finalized during design, but could include infrastructure updates to the containment system at the marine railway, structural changes to the Dry Dock No. 1 ramp, or other shipyard procedures to prevent the release of contaminants to the Bay. These source control measures would prevent against any future discharge of contamination to sediments or recontamination of sediment consistent with SMS WAC 173-204-500(4) and (5) and are described further in Section 14.3.
- **Provide for Compliance Monitoring.** Alternative 3 meets the requirements for compliance monitoring by conducting performance monitoring during dredging and confirmation monitoring following completion of construction to confirm that the sediment surface meets CULs.
- **Provide for Periodic Review.** Alternative 3 meets the requirements for periodic review because it would allow for periodic review to ensure sediments have not been re-contaminated.

13.2.3.2 Remedial Action Objectives

Alternative 3 would remediate marine sediments to meet SMS requirements protective of benthic species, direct contact, and incidental ingestion at the Site. In all the areas actively remediated within AOC 1, Alternative 3 would be protective of human and ecological health through consumption of seafood. Due to the presence of ubiquitous low-level cPAH concentrations present in regional sediments within the Bay, human health risk would remain within the Site vicinity associated with consumption of resident seafood at high consumption rates.

Alternative 3 would also address source control to protect sediment from recontamination and to protect surface water quality. Alternative 3 supports continued operation of the shipyard, without providing constraints to berth depth or vessel operation. However, because Alternative 3 would require demolition of existing piers and the marine railway prior to dredging and remediation, Alternative 3 would cause substantial impacts to shipyard operations, and the construction of Alternative 3 would require multiple construction seasons and careful phasing to maintain shipyard operations. Long-term monitoring to assess compliance would not be required, with the exception of monitoring to ensure recontamination of the remediated sediments does not occur. Alternative 3 would also provide an ancillary benefit to habitat by maintaining existing surface elevations in the intertidal sediment areas.

13.3 DISPROPORTIONATE COST ANALYSIS AND IDENTIFICATION OF THE PREFERRED REMEDY

The DCA criteria and process that is described in Section 10.3 also applies to the evaluation of the sediment cleanup alternatives. The only difference in the DCA criteria between what is described under MTCA and what is described under SMS (WAC 173-204-570(4)) is the consideration of long-term effectiveness. SMS provides a list of applicable sediment remedy components that are used to assess the relative degree of long-term effectiveness. This list replaces the remedy components listed in WAC 173-340-360(3)(f)(iv).

The DCA is used to evaluate whether a cleanup action uses permanent solutions to the maximum extent practicable as determined by the level of attainment of specific criteria defined in WAC 173-340-360(3)(f). The environmental benefits of each alternative are scored using seven evaluation criteria. Because some components of the alternatives provide a similar degree of compliance with a given criterion, the associated evaluation statements may be the same or similar. Additionally, the cost of each alternative is estimated. Estimated costs for each alternative are summarized in Table 13.2 and presented in more detail in Appendix H. For each alternative, a "benefit per associated remedy cost ratio" is calculated by dividing the total weighted benefit score for the alternative by the total alternative cost (in millions). A higher benefit per remedy cost value indicates the most benefit for the associated cost. The alternative with the highest benefit per associated cost ratio provides the highest level of environmental benefit and permanence per dollar spent.

As stated in MTCA, the cost of an individual alternative is determined disproportionate "if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative" (WAC 173-340-360(3)(e)(i)).

Evaluation of disproportionate cost allows comparison of each alternative to the most permanent alternative presented, as determined by attainment of MTCA criteria. This analysis can be qualitative or quantitative. If multiple alternatives possess equivalent benefits, the lower-cost alternative will be selected. The seven DCA criteria defined in MTCA (WAC 173-340-360(3)(f)) are as follows:

- **Protectiveness.** Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, the time required to reduce these risks, and the overall improvement in environmental quality.
- **Permanence.** The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances.
- **Cost.** The cost to implement the alternative consists of construction, long-term O&M costs, and agency oversight costs that are recoverable.[18]
- **Effectiveness over the Long-Term.** Long-term effectiveness consists of the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-site at levels greater than CULs, and the effectiveness of controls in place to control risk while contaminants remain on-site.
- **Management of Short-Term Risks.** Short-term risks include the risk to human health and the environment associated with the alternative during construction and implementation and the effectiveness of measures taken to control those risks.
- **Technical and Administrative Implementability.** The ability of the alternative to be implemented is based on whether the alternative is technically possible and meets administrative and regulatory requirements, and if all necessary services, supplies, and facilities are readily available.

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[18] Although stated in WAC 173-340-360(3)(f)(iii), long Term O&M costs were not calculated using net-present value because the costs are small compared to the overall project capital cost and the majority of long-term costs will be realized in the near-term, reducing the benefit of calculating net-present value.

- **Consideration of Public Concerns.** These considerations involve whether or not the community has concerns regarding the alternative and, if so, to what extent the alternative addresses those concerns.

As part of the DCA conducted for this FS, each alternative was ranked and assigned a numerical score for each of the DCA criteria on a scale of 1 to 10, where a score of 10 represents the highest benefit and a score of 1 represents the lowest benefit. Each numerical score was then multiplied by a weighting value and the scores were summed to determine the total alternative benefit score. Weighting factors for the DCA criteria were used in this FS because this approach has been used on other recent Port sites and has been acceptable to both the Port and Ecology. The weighting factors used in this FS are consistent with other recent Port sites, and are:

- Overall protectiveness: 30%
- Permanence: 20%
- Long-term effectiveness: 20%
- Short-term risk management: 10%
- Implementability: 10%
- Consideration of public concerns: 10%

The following sections go through each of the DCA criteria and discuss the rational for why each alternative was scored in relation to the other alternatives. A full description of aspects evaluated under each criteria for the sediment alternatives is discussed in Table 13.2.

13.3.1 Overall Protectiveness

Alternative 1 has the lowest degree of protectiveness compared to the other alternatives. Risk would be reduced in Alternative 1 by capping contamination in place to be protective of all exposure pathways in areas that are actively remediated. However, this alternative leaves almost all contamination within AOC 1, except for limited excavation in the intertidal area, and is therefore the least protective, given the risk associated with potential cap disturbance from ongoing industrial operations in the capped areas. Alternative 2 removes a much larger amount of contaminated mass than Alternative 1 while providing the same level of protectiveness to the contamination remaining on site by installing a cap. Alternative 3 is the fully protective alternative because it leaves no contamination on site. For Overall Protectiveness, Alternative 1 was scored a 5, Alternative 2 was scored an 8, and Alternative 3 was scored a 10.

13.3.2 Permanence

Alternative 1 has a low degree of permanence through the placement of a cap that would be maintained through institutional controls in perpetuity. Almost all contamination would still remain at the site beneath the capped surface and permanent upkeep of the cap would rely heavily on long-term maintenance to repair any damage by vessel scour or other erosional forces. Alternative 2 is much more permanent remedy because a larger mass of contamination would be removed. Contamination would only remain capped in place underneath existing structures where the cap is less susceptible to damage due to erosional forces such as propeller wash. Alternative 3 is the most permanent alternative because it fully removes all contamination to CULs/RALs and therefore removes all identified risk at the Site. For Permanence, Alternative 1 was scored a 3, Alternative 2 was scored an 8, and Alternative 3 was scored a 10.

13.3.3 Effectiveness over the Long-Term

Alternative 1 provides a low degree of certainty for success over the long-term. The cap area within the open water would be highly susceptible to damage caused by shipyard operations, propeller wash, and other tidal forces. Certainty for long-term success would rely heavily on possible restriction of shipyard operations and cap inspection and maintenance enforced through institutional controls. Alternative 2 has a higher degree of certainty of long-term effectiveness because contamination in open water areas would be removed. Capped areas for Alternative 2 would only be underneath existing structures that are more protected from erosional forces such as propeller wash. These caps would also be protected by institutional controls. Alternative 3 has the highest degree of certainty of success because it fully removes all contamination to CULs/RALs and therefore removes all identified risk at the site. For Effectiveness over the Long-Term Alternative 1 was scored a 2, Alternative 2 was scored an 8, and Alternative 3 was scored a 10.

13.3.4 Short-Term Risk Management

Alternative 1 provides a moderate degree of short-term risk due to the limited amount of contaminated material handling required. This risk to construction workers would be reduced through the use of appropriate PPE and an on-site Health and Safety Plan. Risk of contaminated sediment resuspension and transport during in-water work would be addressed through use of common BMPs such as using an environmental bucket and surrounding the work area with a turbidity curtain. The risk to the public during transport of the material would be reduced by using licensed professional boat captains. Alternative 2 has a slightly increased short-term risk due to the increased volume of contaminated sediment handling required. Alternative 3 has the highest short-term risk due to the much larger volume of contaminated material handling required than either Alternative 1 or Alternative 2. For Short-Term Risk Management, Alternative 1 was scored a 7, Alternative 2 was scored a 6, and Alternative 3 was scored a 5.

13.3.5 Technical and Administrative Implementability

Alternative 1 has the lowest degree of implementability because a thick sediment cap would negatively impact shipyard operations by resulting in shallower water depths. Berth depths are necessary to maintain to support the draft depths of vessels currently operating at the shipyard. Alternative 2 has the highest degree of implementability because it is technologically feasible, is reasonable in scope, and would not negatively impact shipyard operations. Alternative 3 has the largest scope of the three alternatives and therefore would be more difficult to implement. However, it would not negatively impact shipyard operations after construction was complete and therefore is more implementable than Alternative 1. For Technical and Administrative Implementability, Alternative 1 is scored a 2, Alternative 2 is scored an 8, and Alternative 3 is scored a 5.

13.3.6 Consideration of Public Concerns

The criteria Consideration of Public Concern was evaluated by estimating the benefit scoring based on prior public concerns on similar projects. Considering this, Alternative 1 was scored a 3, Alternative 2 was scored an 8, and Alternative 3 was scored an 8.

13.3.7 Cost

Costs for each alternative are provided in Appendix H and include the costs for remedial design sampling, design, implementation, and a 30% contingency. Each alternative cost also includes the cost for the Interim Action as the Interim Action is considered part of each remedy. The estimated cost for Alternative 1 is $19.0 million, the estimated cost for Alternative 2 is $22.4 million, and the estimated cost for Alternative 3 is $35.4 million.

13.3.8 Preferred Remedial Alternative

Based on the evaluation presented above and in Tables 13.2 and 13.3, and as shown graphically in Exhibit 13, the total weighted unit benefit achieved for every $1M in remedy cost for Alternative 1 was 0.19, for Alternative 2 was 0.35, and for Alternative 3 was 0.25. This indicates the greatest benefit for the associated cost is highest for Alternative 2, and therefore, Alternative 2 provides the greatest degree of incremental benefit for the associated cost. Alternative 2 is selected as the Preferred Remedial Alternative for recommendation to Ecology. Section 14.0 describes the Preferred Remedial Alternative in greater detail.

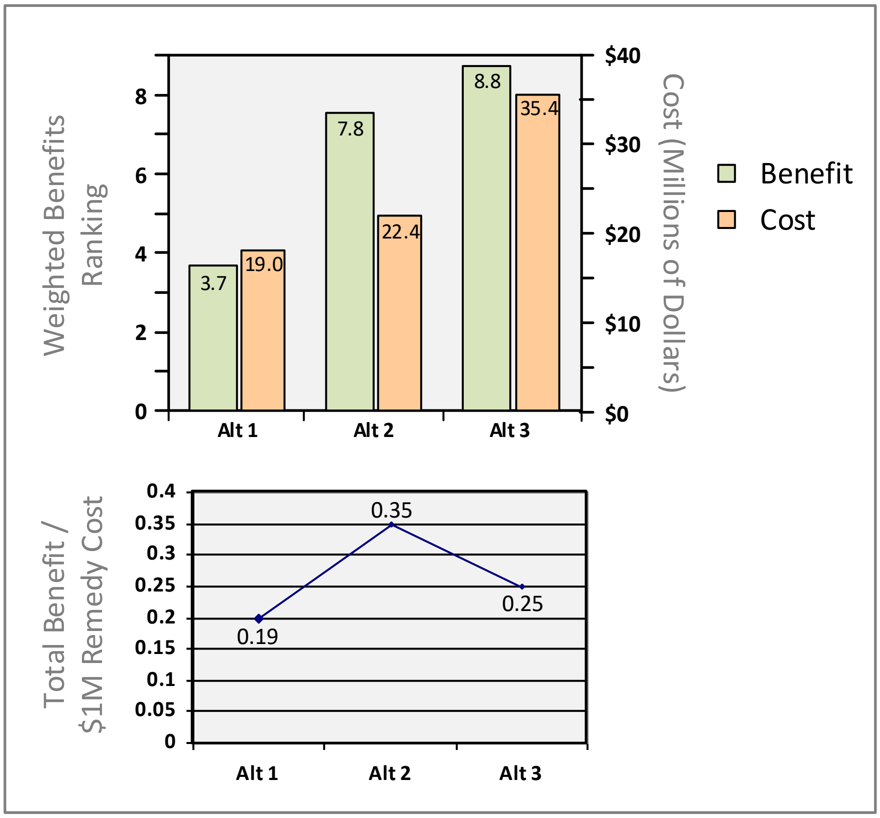

Exhibit 13. Sediment alternatives DCA summary

14.0 Comprehensive Site-Wide Preferred Remedial Alternative

In this section, the Preferred Remedial Alternative for both the uplands and sediment, which is proposed by the Port to Ecology for selection and implementation at the Site, is described in greater detail. This section explains how the Preferred Remedial Alternative complies with MTCA, Site RAOs, and associated ARARs for the greatest benefit for the associated cost, providing the highest level of environmental benefit and permanence per dollar spent, and making it the most permanent to the maximum extent practicable remedy proposed.

14.1 DESCRIPTION OF THE PREFERRED REMEDIAL ALTERNATIVE

Because remedial alternatives for the uplands and sediment were developed separately and there were two DCAs conducted, the descriptions of the two proposed alternatives are divided into separate sections, as necessary, below. The preferred remedy for all Site AOCs is shown on Figure 14.1.

Sections 9.3, 12.3, and 12.4 define the Site AOCs and present the remedial alternatives for evaluation. Sections 10.0 and 13.0 evaluate the Site remedial alternatives relative to the MTCA and SMS criteria and recommend a preferred alternative. This section presents the Preferred Remedial Alternative for both uplands and sediment in more detail. In combination, the Preferred Remedial Alternative for the uplands and sediment provides the recommended preferred cleanup action alternative for the Site.

14.1.1 Description of the Soil and Groundwater Preferred Remedial Alternative

The Preferred Remedial Alternative for the remediation of soil and groundwater at the Site is Alternative 2. Alternative 2 provides the greatest degree of benefit for the associated cost of the three alternatives discussed in Sections 9.0 and 10.0. The components of this Preferred Remedial Alternative are presented below. The Preferred Remedial Alternative for soil and groundwater is a comprehensive final remedy for the uplands portion of the Site that is in compliance with all the applicable remedy selection requirements under MTCA. Together, the individual technologies manage the exposure pathways to all contamination at the Site.

The Preferred Remedial Alternative for the uplands would remediate soil and groundwater at the Site using the following technologies:

- Institutional controls in the form of an Environmental Covenant indicating that industrial CULs were applied at the Site and that the future uses of the property need to be consistent with industrial uses and CULs.
- One of the following remedial actions would be implemented in currently unpaved areas where COC concentrations in soil are greater than CULs:
    - Removal of the top 2 feet of soil to support gravel cap placement where COC concentrations in soil are greater than CULs. Excavated soil would be disposed of off-site at a landfill. A geotextile indicator fabric would be placed in excavated areas to prevent mixing of clean surface gravel with subsurface contaminated material and to provide a contamination indicator layer. Excavated areas would then be capped with compacted gravel to a surface that meets the shipyard’s operational requirements. Removal of up to the top 2 feet of soil to support gravel cap placement may also be implemented where CULs are met.
    - Removal of the top 1 foot of soil to support pavement placement where COC concentrations in soil are greater than CULs. Excavation depth would vary across

the Site based on geotechnical conditions and existing grades. Excavated areas would be backfilled with compacted base course material as necessary, and asphalt pavement would be placed. Stormwater infrastructure would be installed in paved areas for management of stormwater runoff.

  - Potential targeted excavation of contaminated soil as deep as 3 or 4 feet bgs in limited areas, if doing so would result in compliance with the CULs and result in long-term cost savings with respect to long-term groundwater monitoring and cap maintenance and monitoring.

- Deeper excavation of copper- and zinc-contaminated soil contributing to copper and zinc exceedances in groundwater at MW-02 and MW-12. The vertical and lateral extent of soil excavation in AOC 2B will be determined based remedial design sampling. Soil solidification/stabilization is retained as a contingency in combination with deeper excavations, should excavation of soil to CULs be limited by geotechnical or other constraints.
- The Interim Action addressed the majority of AOC 3; bioremediation is retained as a groundwater contingency.
- Compliance monitoring of perimeter groundwater monitoring wells.

The Preferred Remedial Alternative supports current shipyard operations and leaves all existing buildings and pavement in place. These areas, which currently act as a cap to subsurface soil, are protective of the direct contact exposure pathway. The existing buildings and pavement would be maintained as caps, in accordance with site institutional controls in perpetuity or until those areas are redeveloped.

Remedial design sampling would be conducted on the remainder of the Site to determine the specific location and extents of capping and excavation. Following collection of the samples and evaluation of the analytical results, a comprehensive remedy would be developed for the Site. Shipyard operational needs and potential redevelopment plans that are determined prior to final remedial design would also be considered in selection of remedial actions for each area. Based on this information, the remedial actions would be selected for the unpaved areas of the Site. During design, these selected actions would be integrated into the comprehensive remedial action for the Site that makes sense for constructability and shipyard operations.

Based on the results of the remedial design sampling, excavation of deeper soils in areas may be considered during design. Deeper soils with relatively higher copper and zinc contamination may be removed if determined to be impacting groundwater quality to facilitate groundwater quality improvement. In addition, shallow areas of arsenic contamination may be excavated to CULs if limited additional soil removal is required and the added cost of excavation is balanced by the savings in reduction of the necessary long-term cap inspection and maintenance costs associated with leaving the material in place.

The determination for when 2-foot excavation and gravel capping would be considered preferential to capping with an asphalt surface would be evaluated during remedial design. The determination for 2-foot excavation and gravel capping would be based on the following guiding principles:

- Preference for 2-foot soil excavation and gravel capping areas would be given to the areas where it is simple to conduct excavation and off-site disposal or where soil contaminant concentrations greater than CULs are very shallow and easily accessible.
- Preference for asphalt capping, instead of gravel capping, would be given to those areas of the Site where future buildings or other impervious surfaces are likely.

For purposes of cost evaluation in the FS, the cost for Alternative 2 was evaluated by averaging the cost for placing a gravel cap in AOC 2A and the cost for placing asphalt pavement in AOC 2A.

Institutional controls would include a deed restriction limiting the Site to industrial or other use that is consistent with Site CULs and would include a map showing the nature and extent of residual soil contamination. Institutional controls would require implementation of an Ecology-approved OMMP specifying soil management procedures for future excavation and health and safety requirements for subsurface work in areas where a cap is present. These procedures would be applicable to any future Site redevelopment or maintenance that involves removal or disturbance of material below a cap. These are discussed in greater detail in Section 14.4. The Preferred Remedial Alternative for soil and groundwater would provide the following functions:

- Address direct contact of arsenic contamination by shipyard workers across the entire Site (AOC 2A). The POC for direct contact is 15 feet, but the contamination is limited to surface soil, primarily within the top 2 feet. There are select areas where contamination greater than direct contact CULs may be present up to 4 feet.
- Decrease the mass of copper and zinc on-site that are co-located with the arsenic. Removal of copper and zinc in surface soil is an ancillary benefit to the groundwater remedy.
- Address the periodic groundwater exceedances of copper and zinc in AOC 2B by reducing the mass of metals in deeper soil that have the potential to leach to groundwater from soil.
- Remediate TPH-contaminated soil and groundwater associated with releases from a historical diesel AST. TPH concentrations in groundwater in AOC 3 are currently protective of both surface water and sediment quality; however, arsenic concentrations in groundwater are not protective of surface water quality. Natural degradation of TPH has caused a localized depression in the dissolved oxygen concentration in groundwater, leading to reducing conditions and releasing arsenic to groundwater at concentrations not protective of surface water. Remediation of TPH would restore the natural redox conditions and reduce arsenic concentrations in groundwater. This work was completed in the Interim Action.

14.1.2 Description of the Sediment Preferred Remedial Alternative

The Preferred Remedial Alternative for the remediation of sediment at the Site is Alternative 2. Alternative 2 provides the greatest degree of benefit for the associated cost of the three alternatives discussed in Sections 12.0 and 13.0. The components of this Preferred Remedial Alternative are presented below. The Preferred Remedial Alternative for sediment is a comprehensive final remedy for the active sediment remediation area that is in compliance with all the applicable remedy selection requirements under SMS.

The Preferred Remedial Alternative includes a combination of dredging and capping, based on shipyard operational considerations, accessibility, and existing infrastructure. The wooden portion of the Harris Avenue Pier and the Carpenter Building and its supporting pier were demolished as part of the Interim Action, and the sediment beneath these structures was dredged to CULs/RALs. All accessible open water areas of the Site within the active remediation area would be dredged for full removal to meet cleanup standards (i.e., CULs and RALs). In areas where the cleanup standard is unable to be met through dredging, a 6-inch-thick layer of sand would be placed as ENR. All contaminated sediments within accessible open water areas would be removed from the aquatic environment for upland landfill disposal or upland beneficial reuse. Shipyard intertidal sediment areas would be excavated and then backfilled to maintain existing elevations.

Excavated material would be removed from the aquatic environment for upland landfill disposal or upland beneficial reuse. All permanent shipyard structures, not including the structures demolished during the Interim Action, would be retained for continued use. To facilitate dredging and capping in SMU 9 and SMU 10 the West Marine Walkway would be demolished prior to dredging and rebuilt following remedy completion.

In addition to the structural considerations above, a section of shoreline west of SMU 10 that is not within the remediation boundary has been identified as eroding and releasing sediment east toward the shipyard. For the past several years, the shipyard tenant has been required to remove accumulated sediment in the intertidal tracks of the marine railway at periodic intervals in order to maintain necessary working depths. Removing this material after capping could damage the cap and therefore is not advised. Additionally, erosion of the uplands in this area west of SMU 10 has the potential to release contaminated soil to the intertidal sediments. In order to protect the upland soil cap, the eroding section of shoreline will be delineated during design and armored as part of the preferred remedy.

Institutional controls, including a deed restriction, would ensure that the Site remains in industrial use. Contaminated sediments below these shipyard structures would be capped and institutional controls would be put in place. Monitoring would be conducted during implementation of the remedy and following completion of the remedy. A more thorough discussion of monitoring is presented in Section 14.2.

The description below of the Preferred Remedial Alternative is presented by remedial action and refers to the SMUs discussed in Sections 12.0 and 13.0 and shown on Figure 14.1. Additional detail on the SMUs is provided in Section 12.3.

This alternative includes the Interim Action, which will be completed in 2018 in SMUs 1 through 4. In brief, the Interim Action in these SMUs included the following components:

- Abatement, removal, and disposal of hazardous building materials associated with structures being removed.
- Demolition and removal of the wooden portion of the Harris Avenue Pier and the Carpenter Building and its supporting Pier (including the East Marine Walkway).
- Dredging to CULs/RALs in subtidal SMUs 1 and 3, with upland landfill disposal of dredged materials.
- Removal of contaminated intertidal sediments in SMUs 2 and 4 to approximately 3 feet deep from the surface of mudline, with upland landfill disposal of excavated materials. Capping of these removed areas with clean fill to match existing grades.
- Construction of a sheet pile bulkhead and a new concrete pier in the location of the existing wooden portion of the Harris Avenue Pier to restore existing functions and maintain shipyard operations.
- Construction of a marine railway walkway on the east side of the marine railway to restore existing functions.
- Associated utility work.

SMUs 6 and 9 encompass the open water areas in the active remediation area that would be dredged. These SMUs are located between the Harris Avenue Pier and the western side of Dry Dock No. 1. These are active areas of shipyard operations, where existing water depths are necessary to support shipyard activities. Dry Dock No. 1 is a floating structure that is moored in place and can be temporarily removed from its moorings and relocated to allow for a remedial action. Following the removal of Dry Dock No. 1, these areas would be fully accessible to water-borne construction equipment and these areas would be actively remediated through dredging to a surface that meets CULs/RALs, addressing all exposure pathways.

During remedial design, additional data within SMU 9 would be collected to determine the necessity for a remedial action. In areas of SMU 9 where remedial action is required based on additional data, active remediation would occur through dredging to a surface that meets CULs/RALs. These SMUs would be addressed in the following manner:

- Existing data predict that a 2- to 4-foot-deep dredge depth will reach native sediments or sediments that meet CULs/RALs. The specific extents and depths of dredging would be determined with a remedial design sampling effort to supplement current understanding of the thickness of contaminated sediments throughout SMU 9. Significant differences in thickness, either greater or less than expected, would be evaluated in coordination with Ecology.
- Dredging would occur to an average 3-foot depth, using mechanical dredging equipment and methods.
- All contaminated sediments would be removed from the aquatic environment. They would be transported by barge to a suitable transload facility, where they would be transloaded to truck or rail for transportation to an upland landfill for disposal. Dredged sediments could also be considered for upland beneficial reuse with Ecology approval.
- Confirmation monitoring would be conducted following dredging to confirm the exposed surface meets CULs/RALs. Monitoring is discussed in greater detail below.

SMU 10 encompasses the shipyard intertidal sediment areas between the in-water portion of the marine railway and the Access Pier to Dry Dock No. 1 that is above 0 feet MLLW, and this area would be remediated through excavation. This area would be actively remediated through excavation of approximately 2 to 3 feet of sediment, followed by backfilling with appropriate habitat substrate to return the areas to existing grade. This SMU would be addressed in the following manner:

- Remedial design sampling would be conducted to confirm excavation depths and to determine where in the intertidal sediment area institutional controls may be necessary that would require maintenance of the backfill areas.
- An average of 3 feet of contaminated sediment would be excavated from the intertidal areas using standard excavation equipment. Equipment may be operated either from land or from barges.
    - The excavation extent would be offset from the existing bulkhead structures by approximately 6 feet for structural stability and protection. The area between the excavation and the bulkhead wall would be filled to construct a slope that would provide improved structural support to the bulkhead wall. This bulkhead slope would provide a cap to contaminated sediment in this area.
    - Excavated material would be transported off-site and transloaded for upland landfill disposal or upland beneficial reuse.
    - Backfill and bulkhead slope materials would be selected during the design phase to resist wave action and erosional forces and to provide ancillary habitat benefit.

- Performance monitoring would be conducted during excavation to ensure contaminated sediment removal complies with remedial goals. Topographic surveys would be conducted to confirm that backfilled material meets design requirements.
- Upgrades to bulkhead structures would be constructed as necessary to repair and improve damaged and aging portions of the existing bulkheads. Bulkhead upgrades would be completed in a manner that minimizes the volume of soil removed from behind the bulkheads, and is consistent in construction type with the sections of the bulkhead that do not require repair or improvement.
- The existing stormwater emergency outfall pipe located in the intertidal area in SMU 10 would be temporarily disconnected and stored during construction of the remedial action and then re-installed.
- Confirmation monitoring (e.g., topographic survey) would be conducted during and following cap placement, if necessary, to confirm the constructed cap meets the design requirements.
- Long-term monitoring would be conducted to ensure stability of the backfilled intertidal sediment area and bulkhead slope.
- Institutional controls would be implemented in the intertidal sediment area where contaminated sediment remains in place beneath the structural slope adjacent to the bulkhead. Institutional controls are discussed in greater detail below.

If cleanup standards are unable to be met due to obstructions encountered during dredging in SMUs where dredging to CULs/RALs is the selected alternative, then a 6-inch-thick layer of sand would be placed as ENR.

Sediments in the active remediation area that are not dredged or excavated would be capped. This includes the areas with existing over-water shipyard infrastructure (the Access Pier to Dry Dock No. 1 and the concrete portion of the Harris Avenue Pier) and the marine railway area.

SMUs 5, 7, and 11 would be remediated through placement of a granular cap to contain sediment contamination in place. SMU 5 is located beneath the concrete portion of the Harris Avenue Pier. SMU 7 consists of the area beneath and surrounding the marine railway below 0 feet MLLW. The marine railway structure in this area is pile supported above the sediment surface, with greater clearance between the railway girders and the sediment mudline at farther distances offshore. SMU 11 is located beneath the Access Pier to Dry Dock No. 1.

Capping in SMUs 5, 7, and 11 would include the following:

- Remedial design sampling would be conducted to confirm the need for a remedial action to determine where capping would be necessary.
- A granular cap with a 1-foot minimum thickness would be placed in SMUs 5 and 11 using conveyor or telebelt capping equipment and methods to place material beneath the existing pier structure. The cap thickness and material specifications would be determined during remedial design. The existing structural capacity of the piling supporting this pier would determine cap thickness. In SMU 5, the concrete piling would likely be able to support a 1- to 3-foot-thick cap. The under-pier cap would transition to dredging in the open water approximately 5 feet off of the pier face.
- A granular cap would be placed in SMU 7, 1 to 3 feet thick, depending on the amount of clearance available between the mudline and the railroad girders. Capping material would be placed with conveyor or telebelt capping equipment or standard

crane-operated equipment placing capping material through the marine railway structure, followed by a diver sweep of the structure to clear settled capping material off of the railway structure. The cap thickness, material specifications, and armoring requirements would be determined during remedial design. Dredging would be conducted as close as practicable to the marine railway, as an extension of the dredging that would occur in the adjacent SMUs, as long as the dredging does not compromise the integrity of the structure.

- Institutional controls would be placed on the Site that would control future site development in capped areas and would require evaluation of a more permanent remedy at the time the marine railway structure is renovated, replaced, or demolished. Institutional controls are discussed in greater detail below.

SMU 8 consists of the area beneath and surrounding the in-water portion of the marine railway within the shipyard intertidal sediment area above the 0 feet MLLW elevation. The marine railway structure in this area is pile supported, and the girders supporting the railroad sit within the sediment surface, without clearance below. This SMU would be actively remediated through focused excavation between the railway girders to allow placement of a granular cap to contain sediment contamination in place. SMU 8 would be addressed in the following manner:

- Focused excavation would occur to remove material between the railway girders and from either side of the railway structure. Excavation would be performed by hand equipment, small excavator, or a vacuum truck. Material would be removed to a minimum 1-foot depth below the top of the railway girders. Beach excavation would be conducted as close as practicable to the marine railway, without compromising the integrity of the structure.
- A granular cap would be placed a minimum of 1 foot in thickness, extending flush with the top of the railroad girders. The granular cap material placed would be selected to withstand intertidal erosive forces and marine railway operations. Likely the cap material would be compacted crushed rock. The selection of material and finished cap elevation would be designed to allow maintenance cleaning of depositional material from the marine railway area without disturbing the cap material.

14.2 COMPLIANCE MONITORING REQUIREMENTS

Compliance monitoring requirements associated with remedy implementation consist of protection monitoring during construction activities, performance monitoring to ensure remedy construction in accordance with the project plans and design, and confirmation monitoring following remedy completion to confirm the long-term effectiveness of the remedy.

14.2.1 Protection Monitoring

Protection monitoring would be conducted during both remedy construction and operation and maintenance activities to confirm the protection of human health and the environment. Protection monitoring requirements for human health would be described in Health and Safety Plans addressing worker activities during remedy construction. Environmental protection monitoring would be described in the OMMP and Dredge Management Plan or equivalent documents developed as pre-construction submittals. Any activities conducted at the Site following remedy implementation that have the potential to disturb capped areas would require adherence to the OMMP and a post-remediation Health and Safety Plan that would describe worker protection monitoring requirements.

14.2.2 Performance Monitoring

Performance monitoring activities would be conducted for both the uplands and sediment during remedial design and during remedy construction. Performance monitoring for the uplands would consist of the following:

- Remedial design sampling to more accurately assess the areal extent and depth of soil excavation and to design the cap. This sampling would augment the performance monitoring that is typically conducted during remedy construction. Completing this monitoring in advance of design would allow for a more accurate remedial design, leading to cost and time savings.
- Soil sampling during construction to ensure that the excavation meets the RAOs.
- QC monitoring for construction activities, such as survey confirmation of excavation extent.

Performance monitoring for the sediments would consist of the following:

- Remedial design sampling for more accurate dredge design throughout the Site and to confirm compliance with remedial action requirements in SMUs 5, 9, 10, and 11. Completing this monitoring in advance of design would allow for a more accurate remedial design, leading to cost and time savings.
- Sediment sampling during dredging to ensure contaminated sediment removal complies with RAOs.
- Sediment monitoring during cap placement to confirm the constructed caps meet design requirements.

14.2.3 Confirmation Monitoring

Confirmation monitoring activities would be conducted for both the uplands and sediment following completion of the remedy. Confirmation monitoring would consist of the following:

- Quarterly monitoring for TPH and metals would be conducted in all Site downgradient shoreline wells beginning 1 year after completion of the Site remedy. The compliance monitoring well network is anticipated to consist of MW-06, MW-09, MW-02A, MW-07, MW-08, MW-11, and MW-12. Seasonal monitoring would assess seasonal variations. Groundwater samples would be collected and analyzed for 1-methylnaphthalene, arsenic, copper, and zinc. As described in the RI, 1-methylnaphthalene is an IHS for TPH. Compliance would be based on an annual average for each well consistent with WAC 173-340-720(9). If monitoring indicates the remedy has failed to decrease groundwater concentrations to less than CULs after a reasonable period of time, then the proposed contingency bioremediation in AOC 3 will be evaluated. Details of the groundwater monitoring would be developed as part of a groundwater monitoring plan, generally consist of quarterly monitoring followed by annual monitoring.
- Routine inspections of soil cap or paving would be conducted to verify that the constructed remedy remains effective. This is likely to be conducted through periodic reviews of the Site overseen by Ecology.
- Long-term monitoring would be conducted to ensure stability of the backfilled intertidal sediment area and bulkhead toe berms. The long-term time frame would be based on the length of time for the shoreline deposition and erosion forces to reach a steady state.

- Long-term monitoring would be conducted to ensure stability and effectiveness of constructed caps. Monitoring could include bathymetric surveys to evaluate cap thickness and regular observation for any problems or damage to the cap. Long-term monitoring in capped areas is expected to be conducted for up to 20 years, but would be based on deposition and erosion forces within the cap area and length of time for those forces to reach a steady state in the capped area.

14.3 SEDIMENT SOURCE CONTROL ACTIONS

In order to eliminate the potential for marine sediments to become recontaminated at levels of concern following implementation of the remedial action, a source control evaluation was completed. The purpose of this was to evaluate site characteristics and tenant operations relative to the physical and operational controls that are in place to prevent ongoing pollution that could re-contaminate completed upland and sediment remedial actions. The source control evaluation included review of relevant Site permits and environmental documents, an evaluation of the contaminant exposure pathways to soil, groundwater, and sediment, an interview with environmental personnel, and a site walk of both the Fairhaven Shipyard and former All American facility. No source control concerns were identified at the former All American facility; therefore, the remainder of this section focuses on Puglia's operations at the Fairhaven Shipyard.

In order to comply with Ecology requirements and Puglia environmental standards, Puglia provided the plans and documents listed below. These documents were reviewed as part of this source control evaluation:

- **NPDES Waste Discharge Permit No. WA-003134-8.** Puglia is currently operating under this permit, which allows stormwater and process water from the dry dock, submersible barge, marine railway area, and paved area of the Puglia parcel to be discharged to the City of Bellingham municipal sewer system (Ecology 2017b).
- **Industrial Wastewater Facility Wastewater Engineering Report #1.** This report was written in 1993 in response to NPDES permit requirements and primarily focuses on stormwater handling on the dry dock, marine railway area, and sidetrack. Select elements of this plan appear to have been implemented, but all of the recommended components do not appear to have been built (Mahler 1993).
- **Puglia Solid Waste Control Plan.** The Solid Waste Control Plan was written for compliance with Puglia's NPDES permit and provides guidance to shipyard employees on proper solid waste disposal procedures (Puglia 2017a).
- **Puglia Stormwater Pollution Prevention Plan.** The Stormwater Pollution Prevention Plan was written for compliance with Puglia's NPDES permit in 2017 (Puglia 2017b).
- **Puglia Spill Prevention Control and Countermeasure Plan.** The Spill Prevention Control and Countermeasure Plan was written for compliance with Puglia's NPDES permit and was revised in 2018 (Puglia 2018a).
- **Puglia Painting Operations and Training.** This plan describes the standard operating procedures and training program for painting and paint removal operations. The internal report was updated in 2011.
- **Puglia Abrasive Blasting Dust Management Plan.** This plan was written for blasting and painting operations at the marine railway area due to fugitive dust releases. Puglia was required to develop the plan by the Northwest Clean Air Agency. The internal report was updated in 2007.

- **Best Management Practices/Waste Discharge for Fairhaven Shipyard.** This plan was revised in 2016 and summarizes the BMPs and discharge requirements for the Fairhaven Shipyard NPDES Permit No. WA-003134-8. This plan describes the procedures for preventing pollutants from reaching soil, the Bay, or the City of Bellingham municipal sewer system. This plan covers painting, sandblasting, pressure washing, wastewater systems, yard maintenance, and dangerous material handling (Puglia 2016).
- **Access Agreement.** This document lists the rules that visiting vessels' crews must follow while docked at the shipyard. Crews of vessels in residence, Puglia contractors, and subcontractors are expected to follow the yard policy when working on the Puglia parcel. The document also lists contact information in the event of an emergency or an oil spill. The document lists the types of work that are and are not allowed on vessels by visiting crews (Puglia 2018b).
- **Engineering Report, Stormwater Collection and Discharge System for Fairhaven Shipyard, Bellingham, WA.** This report was written in 2004, as required by the NPDES permit, to describe the design criteria for the stormwater collection and discharge system that discharges to the sanitary sewer. The report includes the design for a future expansion of the stormwater collection system to involve the paved area of the marine railway area and side track area. As described below, part of this expansion was constructed for the marine railway area, but the expansion does not appear to have been built for the side track area (Hart Crowser 2004).
- **Puglia Lease.** The original lease between Puglia and the Port was executed in 2002 for use of the Fairhaven Shipyard site. In 2017, Puglia took over the All American lease area. The lease includes requirements and restrictions on releases of hazardous substances, environmental investigations, and stormwater control. The lease states that Puglia shall not take or permit any action that is known or should reasonably be known to exacerbate a release of a hazardous substance to the environment.

  In accordance with the lease, Puglia is responsible for the maintenance of Catch Basins 5 and 6 and the Port is responsible for Catch Basin 4. Although the lease states that the neighboring tenant (All American) is responsible for Catch Basins 1, 2, and 3, those catch basins drain to the Port's stormwater treatment system, as described in Section 2.3.4 (Port 2002).

The protocols established in the documents identified above are collectively required by numerous entities including Ecology, the Port, and Puglia to prevent negative environmental impacts due to facility operations. These protocols prevent the primary sources of potential sediment recontamination at the Site, which include the release of abrasive grit and paint from hydroblasting. The protocols identified above must be followed and continually evaluated and improved upon as necessary to keep the abrasive grit and paint isolated to work areas and collected and disposed of properly.

In addition to these already established protocols, an OMMP would be developed to include specific requirements to prevent migration of contaminated soil if subsurface soil under a cap is exposed. This plan is described in further detail in Section 14.4.

To provide better source control measures, effectively capture and contain stormwater and process water in the marine railway area, and prevent contamination from reaching the Bay, the marine railway area infrastructure would be upgraded. These upgrades could include options to channelize or funnel water to the pumps in the sumps during blasting operations. Water could be channelized to the sumps with consistent implementation of temporary diversion methods, such as sandbags, similar to what is currently used, or with a more robust structural boundary. A method to create a tight seal around the rails in order to prevent stormwater or process water from running down the track channels to the Bay should be considered during design. These upgraded measures could include use of containment coamings, curbing, or a removable gate. The structural improvements should ensure that all stormwater, pressure wash water, or other process water is effectively captured and transported to the water treatment system. The final methodology for the source control improvement would be determined during the remedial action design in coordination with Ecology and Puglia and would be implemented concurrently with the remedial action to minimize impacts to Puglia’s operations.

Another potential source of recontamination to sediment is the Access Pier to Dry Dock No. 1, located above SMU 11. This Access Pier consists of concrete with 1- to 2-inch-wide gaps in between the concrete pieces. During transport of new and spent grit to and from Dry Dock No. 1, grit could fall through the gaps and enter the Bay. Methods to address this concern and prevent recontamination of SMU 11 would be evaluated during design. This could include methods to fill in the gaps in the Access Pier, implementation of a cleaning program, or the capture of material that may fall through the gaps.

These source control measures would be implemented as part of the remedial action and would be an integral part of the successful remedy for the Site.

14.4 INSTITUTIONAL CONTROLS

The Preferred Remedial Alternative includes institutional controls to manage contamination left in place in the uplands and the sediment. Institutional controls at the Site would include the following:

- A deed restriction limiting the Site to industrial or other use that is consistent with Site CULs, which would include a map showing the nature and extent of residual contamination at concentrations greater than CULs.
- Implementation of an Ecology-approved OMMP specifying soil management procedures for future excavation and health and safety requirements for subsurface work in areas with a cap. These procedures would be applicable to any future site redevelopment or maintenance that involves removal or disturbance of subsurface material. The OMMP would be prepared for Ecology approval concurrent with remedial design and would include specifications for the following:
  - Health and safety requirements for working in and during handling of Site soils.
  - BMPs for soil stockpiling, dust control, and erosion control.
  - Requirements for off-site disposal and associated recordkeeping.
  - Requirements for Ecology notification and reporting.
- Requirements to manage the contaminated sediment that may remain in place in the intertidal sediment area beneath the bulkhead toe berm. These controls would manage exposure to the contaminated sediment during future redevelopment actions in the area, such as bulkhead wall replacement.
- Requirements that would control future site development in capped sediment areas, including potential shipyard operational controls, such as propeller wake restrictions, if determined necessary during the design process by propeller wash analyses. Institutional controls would also require evaluation of a more permanent remedial action at the time the pier and marine railway structures are renovated, replaced, or demolished.

Additionally, institutional controls would be implemented to ensure that if redevelopment activities occur at the shipyard in the future, all exposure pathways to potentially contaminated materials would be protected. If future redevelopment activities include demolition of structures, institutional controls would require evaluation of cleanup actions for underlying material that are permanent to the maximum extent practicable.

14.5 CONSTRUCTION PHASING AND COMPATIBILITY WITH FUTURE REDEVELOPMENT

Construction of the Preferred Remedial Alternative may be implemented in a phased manner to maintain active shipyard operations throughout remedial construction. Remedial construction must be conducted in a manner that minimizes shipyard business disturbances and impacts to navigational use at and near the Site. In addition, in-water work can only be conducted during the construction windows allowed by the Natural Resource Agencies for the Fairhaven Shipyard area of the Bay.

Shipyard operations are conducted in three primary areas of the property: the Harris Avenue Pier, the marine railway, and Dry Dock No. 1. All three areas are accessed from the uplands and depend on support from the uplands. Work within the vicinity of the Harris Avenue Pier was conducted during the Interim Action completed in 2018. The remainder of the construction of the remedial action should be phased in a manner that minimizes overall disruptions to shipyard operations and ensures operations in only one of these areas are disrupted at a time, such that the other two remain operational. For example, upland remedial construction that disrupts access to the marine railway must not occur at the same time that Dry Dock No. 1 is out of service. The Port would work closely with Ecology and shipyard tenants to define a phasing plan for the work that efficiently completes the remedial action, while maintaining shipyard operations. Due to this significant requirement, construction activities would occur over sequential construction seasons.

It will be important for construction documents to define BMPs and interim controls to ensure that areas of the Site that have been remediated are not affected or recontaminated by adjacent construction.

This FS assumes that all existing shipyard infrastructure (buildings, piers, marine railway, and utilities) are required for continued shipyard use. To allow for continued shipyard use, all existing infrastructure would either be protected in their current condition or rebuilt following completion of the remedy if infrastructure is demolished as part of the remedy (i.e., the Harris Avenue Pier being rebuilt as part of the Interim Action). The only existing infrastructure that would not be reconstructed following completion of the remedy is the Carpenter Building and its supporting pier, because these structures are not required for continued shipyard use.

14.6 SITE OWNERSHIP AND ACCESS

Site ownership is described in detail in Section 2.3.1. Site ownership is split between the Port and the state of Washington. Portions of the Site that are state-owned land are operated by the Port under the PMA. All proposed remedial actions would take place on Port-owned or Port-managed areas. Implementation of institutional controls and the OMMP to manage contaminated soil remaining in-place beneath existing buildings or other capped areas would be conducted by the Port and Port tenants. Shipyard operations at the Site are managed by Puglia as a tenant of the Port. The Port has access to the entire Site.

14.7 COMPLIANCE WITH THE MODEL TOXICS CONTROL ACT AND SEDIMENT MANAGEMENT STANDARDS

The Preferred Remedial Alternative for soil and groundwater meets the minimum requirements for selection of a cleanup action under MTCA WAC 173-340-360(2)(a) because it is protective of human health and the environment, complies with cleanup standards, complies with applicable state and federal laws, and provides for compliance monitoring. The evaluation of the uplands alternatives was presented in Section 10.0, and the Preferred Remedial Alternative was determined to be the permanent remedy to the maximum extent practicable in the DCA. A detailed discussion of the DCA is presented in Section 10.0 and in Tables 10.1 and 10.2. Section 10.0 also describes that the Preferred Remedial Alternative for soil and groundwater meets the Other MTCA Requirements for selection of a cleanup action, including using permanent solutions to the maximum extent practicable, providing for a reasonable restoration time frame, and considering public concerns. Exposure pathways would be addressed through contaminant removal and disposal in a landfill; excavation, placement of a contaminant indicator layer and clean surface soil; capping with asphalt or gravel; and potential contingency bioremediation and/or stabilization/solidification if warranted. Institutional controls would be developed to manage contamination that would remain on-site.

The Preferred Remedial Alternative for the uplands is a more aggressive remedial action and is a more protective and permanent remedy than Alternative 1 because there would be more contaminant mass removal. As compared to the Preferred Remedial Alternative, Alternative 3 is considered disproportionate because of its much higher cost compared to its benefit score. The Preferred Remedial Alternative for the uplands supports continued shipyard operations, minimizes future monitoring and institutional controls, and includes a compacted gravel or asphalt surface across the Site.

The Preferred Remedial Alternative for sediment meets the minimum requirements for sediment cleanup actions under SMS WAC 173-204-570(3) because it is protective of human health and the environment in the active remediation area, complies with applicable state and federal laws, and provides for compliance monitoring. The Preferred Remedial Alternative for sediment also provides for a reasonable restoration time frame, addresses source control, and would consider public comments. An evaluation of the sediments alternatives was presented in Section 13.0, based on which the Preferred Remedial Alternative was determined to be the permanent remedy to the maximum extent practicable in the DCA. A detailed discussion of the DCA is presented in Section 13.0 and in Tables 13.2 and 13.3.

The Preferred Remedial Alternative for sediment addresses exposure pathways through contaminant removal and disposal in an upland landfill or approved upland reuse, and limited sediment capping. Contamination dredging in open water areas and capping in understructure areas would either remove or contain contamination in place, providing a surface that is protective of all exposure pathways in areas that are actively remediated. Demolition of the Harris Avenue Pier and the Carpenter Building and its supporting pier in the Interim Action provided for source control through removal of creosote-treated piling and dilapidated over-water structures. Institutional controls would address contamination left in place. Compared to Alternative 1, the Preferred Remedial Alternative for sediment has a substantially higher total benefit score because it is more protective and permanent due to the increased amount of contamination that would be dredged. Although Alternative 3 is more protective, permanent, and effective over the long-term, Alternative 3 is considered disproportionate compared to the Preferred Remedial Alternative because of its significantly higher cost compared to its benefit score.

14.8 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The Preferred Remedial Alternative complies with all applicable ARARs outlined in Tables 7.1, 7.2, and 7.3. Chemical-specific ARARs are met through compliance with applicable CUL criteria. Location-specific ARARs are met through compliance with all applicable state, federal, and local regulations in place for the physical location of the Site. Applicable action-specific ARARs would be met through implementation of construction activities in compliance with all applicable construction-related requirements such as health and safety restrictions, site use and other local permits, and disposal requirements for excavated soil. Source control actions implemented as part of the remedial action would also comply with project ARARs.

14.9 COMPLIANCE WITH REMEDIAL ACTION OBJECTIVES

The Preferred Remedial Alternative for the uplands would comply with all RAOs because it would remediate soil and groundwater to protect human health from exposure to contamination via direct contact, it would protect sediments by addressing contamination in erosion areas, and would remediate groundwater. By phasing the implementation of the remedy, the remedy could be implemented within the active shipyard environment. Long-term monitoring to assess cap integrity (if necessary) and groundwater compliance would be conducted.

The Preferred Remedial Alternative for sediments would remediate marine sediments to meet SMS requirements protective of benthic species, direct contact, and incidental ingestion at the Site. In all the areas actively remediated within AOC 1, Alternative 2 would be protective of human and ecological health through consumption of seafood. Due to the presence of ubiquitous low-level cPAH concentrations present in regional sediments within the Bay, human health risk associated with consumption of resident seafood at high consumption rates would remain within the site vicinity. The Preferred Remedial Alternative would also address source control to protect sediment from recontamination and to protect surface water quality.

By phasing the construction of the remedy to support continuous shipyard operations and address in-water work windows, the remedy could be implemented within the active shipyard environment. Dredging within the open water operational areas of the shipyard would achieve a final surface elevation that is supportive of continued shipyard operations. Rebuilding of the Harris Avenue Pier provides a safe working space and access to the submersible barge in order to support continued shipyard operations. The dredged surface would not constrain operational depths or vessel movements. Long-term monitoring to assess the cap integrity and effectiveness under structures would be conducted. The Preferred Remedial Alternative would also provide an ancillary benefit to habitat by maintaining existing surface elevations in the intertidal sediment areas.

14.10 TYPES, LEVELS, AND AMOUNTS OF HAZARDOUS SUBSTANCES TO REMAIN IN PLACE

The amount of hazardous substances that would remain in place following implementation of the remedy is low, because a substantial volume of contaminated mass would be removed from the uplands and sediments.

In the uplands, arsenic, copper, and zinc may remain contained in place under caps in limited areas. Limited TPH in soil would be left on-site. The exact quantity of hazardous substances remaining in place would be determined during remedial design following the remedial design sampling.

The preferred uplands remedial action would prevent those remaining hazardous substances from migrating and being exposed to human health and the environment by being capped with gravel, new pavement, or buildings. Groundwater compliance monitoring, as described in Section 14.2, would confirm that remaining hazardous substances are not migrating to the groundwater. Additionally, an OMMP would be prepared that would identify the locations of remaining hazardous substances and specify soil management procedures for future excavation and health and safety requirements for subsurface work in areas with a cap. These procedures would be applicable to any future site redevelopment or maintenance that involves removal or disturbance of subsurface material.

In sediments within AOC 1, arsenic, copper, zinc, cPAHs, cadmium, and PCBs would remain on-site in sediment cap areas, as well as in SMUs 2, 4, and 10. The exact quantity of hazardous substances remaining in place would be better understood following the remedial design sampling. The mass of these contaminants is considered relatively low. The remaining hazardous substances would be below a cap and the caps would be routinely inspected to ensure that the hazardous substances are not migrating and remain in place.

Following implementation of the remedial action within AOC 1, human health risk remains within the Site vicinity associated with consumption of resident seafood at high consumption rates. This is due to the presence of ubiquitous low-level cPAH concentrations present in regional sediments within the Bay. As noted earlier, cPAH regional concentrations within the Bay are expected to continue to naturally recover based on the continued watershed-wide source control and cleanup actions.

14.11 RESTORATION TIME FRAME

The restoration time frame for the Preferred Remedial Alternative is as follows:

- **AOC 2A:** Soil CULs would be met within 1 year from the start of construction.
- **AOC 2B:** Soil CULs would be met within 1 year from the start of construction.
- **AOC 3:** Soil CULs are currently being met following the completion of the Interim Action.
- **Site Groundwater:** CULs would be met within 2 to 5 years from completion of construction.
- **Active Remediation Areas – Dredging:** Dredging would occur over two to three in-water construction seasons. The benthic and human health exposure pathways would be addressed immediately following completion of construction.
- **Active Remediation Areas – Capping:** Capping would occur over two in-water construction seasons. The benthic and human health exposure pathways would be addressed immediately following capping.
- **Sediment Area outside the Active Cleanup Area:** Residual sediment concentrations of cPAHs outside AOC 1 would be expected to continue to naturally recover within a reasonable time frame based on the continued watershed-wide source control efforts and cleanups of uplands and in-water sources through various regulatory programs and sediment deposition.

Construction phasing constraints were discussed in Section 14.5. Due to substantial requirements to minimize shipyard business interruption, the construction duration for implementation of the preferred alternative would be extended to occur over multiple sequential construction seasons. It is estimated that the remedial action would be complete within 3 years of construction initiation.

14.12 SUMMARY OF THE ESTIMATED REMEDY COSTS

Estimated costs for the recommended Preferred Remedial Alternative are presented in Appendix H. The costs associated with remedy implementation consist of capital construction costs, long-term monitoring costs following remedy completion, and agency oversight that would include periodic reviews of the constructed remedy.

The estimated costs for remedy construction of the uplands Preferred Remedial Alternative are as follows:

- Agency oversight, engineering design, planning, and permitting costs associated with remedy implementation are estimated to be $378,000.
- Past costs to implement the Interim Action in the uplands are approximately $1.6 million.
- Future construction capital costs that include excavation, capping, and engineering controls are estimated to be approximately $2.7 million.
- Long-term soil cap monitoring and groundwater monitoring costs are estimated to be low and consist of annual monitoring and periodic maintenance of the capped areas.
- The total project cost for the uplands Preferred Remedial Alternative, which includes a $1.0 million contingency cost, is estimated to be $5.9 million.

The estimated costs for remedy construction of the sediments Preferred Remedial Alternative are as follows:

- Agency oversight, engineering design, planning, and permitting costs associated with remedy implementation are estimated to be $697,000.
- Past costs to implement the Interim Action in the sediments are approximately $13.4 million.
- Future construction capital costs that include dredging, excavation, capping, and engineering controls are estimated to be approximately $5.5 million.
- Long-term monitoring costs are estimated to be moderate and consist of periodic maintenance of the capped areas.
- The total project cost for the sediment Preferred Remedial Alternative, which includes a $2.1 million contingency cost, is estimated to be $22.4 million.

14.13 REMEDY IMPLEMENTATION SCHEDULE

The following schedule is proposed for next steps at the Site. Estimated dates are provided for discussion and planning purposes:

Implementation Step	**Estimated Date**
Finalize RI/FS following completion of public comment	June 2019
Prepare Draft Cleanup Action Plan	Fall 2019
Amend Agreed Order for Inclusion of Remedial Design	Winter 2019
Submit Remedial Design Sampling Plan to Ecology for Approval	Spring 2020
Conduct Remedial Design Sampling and Prepare Data Report	Summer–Winter 2020
Prepare Engineering Design Report	2021
Prepare Remedial Action Construction Documents (plans and specifications)	2021
Acquire Project Permits	2021–2022
Finalize Consent Decree between the Port and Ecology for Remedy Implementation	2022
Remedial Action Construction; assume duration of 2 to 3 years (refer to construction phasing discussion)	2022–2024
Prepare Remedial Action Completion Report and Receive Ecology Approval and Initiate Compliance Groundwater Monitoring	2024
Conduct Compliance Groundwater Monitoring	2024–2029

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Harris Avenue Shipyard

Remedial Investigation/ Feasibility Study

Tables

FINAL

Table 3.1
Water Level Measurements[1]

Monitoring Event		March 2011 Water Levels before Transducer Installation Event				March 2011 Groundwater Sampling Event				July 2011 Groundwater Sampling Event				February 2013 Water Level Measurement Event			
Location	Top of Casing Elevation (feet)	Date Collected	Time	Water Level (DTW in feet)	Groundwater Elevation (feet)	Date Collected	Time	Water Level (DTW in feet)	Groundwater Elevation (feet)	Date Collected	Time	Water Level (DTW in feet)	Groundwater Elevation (feet)	Date Collected	Time	Water Level (DTW in feet)	Groundwater Elevation (feet)
MW-01	13.55	3/16/2011	11:36	6.45	7.10	3/23/2011	14:40	7.22	6.33	7/29/2011	12:11	8.04	5.51	2/14/2013	12:04	7.78	5.77
MW-2A	14.95	3/16/2011	9:38	5.21	9.74	3/23/2011	13:00	8.95	6.00	7/29/2011	13:38	10.41	4.54	2/14/2013	12:10	9.59	5.36
MW-04	15.38	3/16/2011	9:23	8.12	7.26	3/22/2011	12:50	9.24	6.14	7/29/2011	12:11	10.52	4.86	2/14/2013	12:05	9.66	5.72
MW-05	14.83	NM	NM	NM	NM	3/23/2011	10:35	6.75	8.08	7/29/2011	14:59	8.23	6.60	2/14/2013	11:58	7.82	7.01
MW-06	14.22	3/16/2011	10:43	7.11	7.11	3/22/2011	15:10	8.24	5.98	7/29/2011	10:52	8.89	5.33	2/14/2013	12:09	8.55	5.67
MW-07	14.95	3/16/2011	9:53	8.02	6.93	3/23/2011	11:45	8.29	6.66	7/29/2011	13:25	9.29	5.66	2/14/2013	12:08	9.35	5.60
MW-08	13.42	3/16/2011	9:00	6.39	7.03	3/22/2011	11:28	7.41	6.01	7/29/2011	13:00	8.10	5.32	2/14/2013	12:02	8.21	5.21
MW-09	10.58	3/16/2011	11:03	3.55	7.03	3/22/2011	14:00	4.92	5.66	7/29/2011	10:55	5.65	4.93	2/14/2013	12:14	5.07	5.51
MW-10[2]	14.31													2/14/2013	11:59	8.5	5.81
MW-11[3]	9.33																
MW-12[3]	14.50																

Notes:

▨ Gray cells indicate events that pre-date the well.

1 MW-03 could not be located.

2 MW-10 was not installed until 2013.

3 MW-11 and MW-12 were not installed until 2015.

Abbreviations:

DTW	Depth to water
NM	Not measured

Table 3.1

Water Level Measurements[1]

Monitoring Event		February 2015 Water Level Measurement Event				May 2015 Water Level Measurement Event				August 2015 Water Level Measurement Event				December 2015 Water Level Measurement Event			
Location	Top of Casing Elevation (feet)	Date Collected	Time	Level (DTW in feet)	Groundwater Elevation (feet)	Date Collected	Time	Level (DTW in feet)	Groundwater Elevation (feet)	Date Collected	Time	Level (DTW in feet)	Groundwater Elevation (feet)	Date Collected	Time	Level (DTW in feet)	Groundwater Elevation (feet)
MW-01	13.55	2/25/2015	15:34	7.62	5.93	5/28/2015	8:18	7.77	5.78	8/27/2015	8:12	7.82	5.73	12/3/2015	16:33	6.54	7.01
MW-2A	14.95	2/25/2015	15:37	9.72	5.23	5/28/2015	8:21	9.70	5.25	8/27/2015	8:14	9.79	5.16	12/3/2015	16:35	7.61	7.34
MW-04	15.38	2/25/2015	15:43	9.75	5.63	5/28/2015	8:27	9.73	5.65	8/27/2015	8:16	9.91	5.47	12/3/2015	16:40	8.22	7.16
MW-05	14.83	2/25/2015	15:51	7.6	7.23	5/28/2015	8:33	8.05	6.78	8/27/2015	8:23	8.36	6.47	12/3/2015	16:46	6.00	8.83
MW-06	14.22	2/25/2015	15:32	8.42	5.80	5/28/2015	8:16	8.57	5.65	8/27/2015	8:10	8.64	5.58	12/3/2015	16:29	7.16	7.06
MW-07	14.95	2/25/2015	15:41	9.14	5.81	5/28/2015	8:25	9.23	5.72	8/27/2015	8:15	9.16	5.79	12/3/2015	16:37	7.72	7.23
MW-08	13.42	2/25/2015	15:47	9.51	3.91	5/28/2015	8:37	8.32	5.10	8/27/2015	8:19	8.52	4.90	12/3/2015	16:44	6.51	6.91
MW-09	10.58	2/25/2015	15:33	5.07	5.51	5/28/2015	8:17	5.11	5.47	8/27/2015	8:12	5.25	5.33	12/3/2015	16:31	3.56	7.02
MW-10[2]	14.31	2/25/2015	15:31	8.27	6.04	5/28/2015	8:11	8.54	5.77	8/27/2015	8:06	8.49	5.82	12/3/2015	16:25	6.28	8.03
MW-11[3]	9.33	2/25/2015	15:35	4.65	4.68	5/28/2015	8:20	4.35	4.98	8/27/2015	8:13	4.81	4.52	12/3/2015	16:34	2.19	7.14
MW-12[3]	14.50	2/25/2015	15:39	9.78	4.72	5/28/2015	8:23	9.64	4.86	8/27/2015	11:40	10.41	4.09	12/3/2015	16:36	6.88	7.62

Notes:

▨ Gray cells indicate events that pre-date the well.

1 MW-03 could not be located.

2 MW-10 was not installed until 2013.

3 MW-11 and MW-12 were not installed until 2015.

Abbreviations:

DTW	Depth to water
NM	Not measured

Table 3.2
Monitoring Well Information

Monitoring Well	Installed By	Date Installed	Total Depth Drilled (feet bgs)	Total Depth Cased (feet bgs)	Screened Interval (feet bgs)	Casing Size & Materials (inches)	Approximate Ground Surface Elevation (feet NAVD 88)	Top of Casing Elevation (feet NAVD 88)	Northing (feet NAD 83/98)	Easting (feet NAD 83/98)	Status
MW-01	RETEC	4/28/1998	16.5	15	5–15	2-inch Schedule 40 PVC, 0.010-inch Slotted Screen, Silica Sand	14.3	13.55	632,218	1,234,576	Accessible
MW-02	RETEC	4/28/1998	16.5	15	5–15		15.32	15.05	NA	NA	Could not locate
MW-2A	Floyd|Snider	3/15/2011	15	15	4–14	2-inch Schedule 40 PVC, 0.020-inch Slotted Screen, #2/12 Monterey Sand Pack	15.37	14.95	632,258	1,234,456	Accessible
MW-03	RETEC	4/28/1998	16.5	15	5–15	2-inch Schedule 40 PVC, 0.010-inch Slotted Screen, Silica Sand	15.27	14.78	NA	NA	Could not locate
MW-04	RETEC	4/28/1998	15.5	15	5–15		16.44	15.38	632,081	1,234,506	Accessible
MW-05	RETEC	4/28/1998	16.5	15	5–15		15.67	14.83	631,749	1,234,655	Accessible
MW-06	Floyd|Snider	3/14/2011	20	20	4–19	2-inch Schedule 40 PVC, 0.020-inch Slotted Screen, #2/12 Monterey Sand Pack	14.58	14.22	632,248	1,234,636	Accessible
MW-07	Floyd|Snider	3/15/2011	15	15	4–14		15.37	14.95	632,127	1,234,337	Accessible
MW-08	Floyd|Snider	3/14/2011	20	20	4–19		13.90	13.42	631,999	1,234,273	Accessible
MW-09	Floyd|Snider	3/14/2011	15	15	4–14		11.16	10.58	632,259	1,234,582	Accessible
MW-10	Floyd|Snider	1/29/2013	26.5	20	5–20	2-inch Schedule 40 PVC, 0.010-inch Slotted Screen, #2/12 Monterey Sand Pack	14.89	14.31	632,274	1,234,715	Accessible
MW-11	Floyd|Snider	2/9/2015	13.5	13.4	3–13	2-inch Schedule 40 PVC, 0.010-inch Slotted Screen, #2/12 Monterey Sand Pack	14.89	9.33	632,256	1,234,513	Accessible
MW-12	Floyd|Snider	2/9/2015	15.03	15	5–15	2-inch Schedule 40 PVC, 0.010-inch Slotted Screen, #2/12 Monterey Sand Pack	14.89	14.50	632,222	1,234,369	Accessible

Abbreviations:

bgs	Below ground surface
NA	Not applicable or not available
NAD 83/98	North American Datum of 1983/1998
NAVD 88	North American Vertical Datum of 1988
PVC	Polyvinyl chloride
RETEC	The RETEC Group

Table 3.3
Boring Details

Location ID	Installed By	Date Installed	Total Depth Drilled (feet bgs)	Temporary Screened Interval (feet bgs)	Casing Size (inches)	Approximate Ground Surface Elevation (feet NAVD 88)	Northing (feet NAD 83/98)	Easting (feet NAD 83/98)
FS-01	Floyd|Snider	3/14/2011	25	NA[1]	NA	14.46	632,231	1,234,614
FS-02	Floyd|Snider	3/16/2011	20	NA	NA	14.79	632,248	1,234,381
FS-03	Floyd|Snider	3/16/2011	20	NA	NA	15.07	632,186	1,234,373
FS-04	Floyd|Snider	3/16/2011	20	NA	NA	14.54	632,108	1,234,312
FS-05	Floyd|Snider	3/16/2011	15	NA	NA	15.02	632,001	1,234,357
FS-06	Floyd|Snider	3/16/2011	20	NA	NA	15.73	632,072	1,234,404
FS-07	Floyd|Snider	3/16/2011	16	12–16	2	15.44	632,107	1,234,380
FS-08	Floyd|Snider	3/15/2011	25	NA	NA	15.21	632,093	1,234,458
FS-09[2]	Floyd|Snider	3/15/2011	20	13–17	2	15.23	632,128	1,234,434
FS-10	Floyd|Snider	3/15/2011	15	NA	NA	13.33	632,197	1,234,506
FS-11	Floyd|Snider	3/14/2011	20	NA	NA	10.59	632,249	1,234,544
FS-12	Floyd|Snider	3/14/2011	20	NA	NA	15.92	632,184	1,234,628
FS-13	Floyd|Snider	3/15/2011	20	NA	NA	16.50	632,101	1,234,623
FS-14	Floyd|Snider	3/15/2011	20	NA	NA	16.74	632,116	1,234,589
FS-15	Floyd|Snider	3/14/2011	25	15–19	2	16.62	632,141	1,234,569
FS-16	Floyd|Snider	3/15/2011	20	NA	NA	15.03	632,023	1,234,518
FS-17	Floyd|Snider	3/16/2011	20	13–17	2	15.91	631,940	1,234,537
FS-18	Floyd|Snider	3/16/2011	20	NA	NA	15.35	631,919	1,234,463
FS-19	Floyd|Snider	1/29/2013	30	21–26	1	13.67	632,240	1,234,608
FS-20	Floyd|Snider	1/29/2013	40	NA	NA	13.61	632,221	1,234,579
FS-21	Floyd|Snider	1/30/2013	25	20–25	1	16.46	632,178	1,234,587
FS-22	Floyd|Snider	1/30/2013	25	20–25	1	15.37	632,211	1,234,674
FS-23	Floyd|Snider	1/30/2013	25	NA	NA	16.80	632,137	1,234,613
FS-24	Floyd|Snider	2/9/2015	4	NA	NA	16.47	632,114	1,234,565
FS-25	Floyd|Snider	2/9/2015	4	NA	NA	16.92	632,133	1,234,567
FS-26	Floyd|Snider	2/9/2015	4	NA	NA	11.23	632,257	1,234,585
FS-27	Floyd|Snider	2/9/2015	4	NA	NA	16.85	632,120	1,234,594
FS-28	Floyd|Snider	2/9/2015	4	NA	NA	16.83	632,148	1,234,595
FS-29	Floyd|Snider	2/9/2015	4	NA	NA	12.74	632,250	1,234,602
FS-30	Floyd|Snider	2/9/2015	4	NA	NA	16.75	632,120	1,234,617
FS-31	Floyd|Snider	2/9/2015	4	NA	NA	16.54	632,153	1,234,618
FS-32	Floyd|Snider	2/9/2015	4	NA	NA	15.92	632,183	1,234,619
FS-33	Floyd|Snider	2/9/2015	4	NA	NA	15.07	632,213	1,234,619
FS-34	Floyd|Snider	2/9/2015	4	NA	NA	14.25	632,234	1,234,619
FS-35	Floyd|Snider	2/9/2015	4	NA	NA	13.79	632,259	1,234,620
FS-36	Floyd|Snider	2/9/2015	4	NA	NA	15.68	632,192	1,234,640
FS-37	Floyd|Snider	2/9/2015	4	NA	NA	15.32	632,212	1,234,641
FS-38	Floyd|Snider	2/9/2015	4	NA	NA	14.29	632,257	1,234,638
FS-39	Floyd|Snider	2/9/2015	12	NA	NA	16.79	632,170	1,234,590
FS-40	Floyd|Snider	2/9/2015	12	NA	NA	16.44	632,180	1,234,596
FS-41	Floyd|Snider	2/9/2015	12	NA[1]	NA	16.49	632,170	1,234,605
FS-42	Floyd|Snider	2/9/2015	12	NA	NA	16.03	632,180	1,234,606
B-1	GeoEngineers	8/4/2011	66.5	NA	NA	1 MLLW	NA	NA
B-2	GeoEngineers	8/4/2011	55.5	NA	NA	14.5 MLLW	NA	NA
TP-2	RETEC	4/27/1998	8	NA	NA	NA	631,953	1,234,574
TP-3	RETEC	4/27/1998	8	NA	NA	NA	631,986	1,234,540
TP-4	RETEC	4/27/1998	8	NA	NA	NA	631,977	1,234,485
TP-5	RETEC	4/27/1998	8	NA	NA	NA	631,983	1,234,426
TP-6	RETEC	4/27/1998	8	NA	NA	NA	631,775	1,234,262
TP-7	RETEC	4/27/1998	7	NA	NA	NA	631,933	1,234,288
TP-8	RETEC	4/27/1998	5	NA	NA	NA	632,044	1,234,318
TP-9	RETEC	4/30/1998	8.1	NA	NA	NA	632,135	1,234,404
TP-10	RETEC	4/27/1998	8	NA	NA	NA	632,176	1,234,474
TP-11	RETEC	4/30/1998	5	NA	NA	NA	632,244	1,234,477
TP-13	RETEC	4/30/1998	7	NA	NA	NA	632,231	1,234,550
TP-14	RETEC	4/30/1998	5	NA	NA	NA	632,234	1,234,594
TP-15	RETEC	4/27/1998	8.6	NA	NA	NA	632,171	1,234,601
TP-16	RETEC	4/30/1998	8.1	NA	NA	NA	631,729	1,234,558
B-1	RETEC	4/29/1998	14	NA	NA	NA	NA	NA

Notes:

1 Groundwater samples were not collected at these locations.

2 Additional step-out borings completed at FS-09a, FS-09b, FS-09c, and FS-09d.

Abbreviations:

bgs	Below ground surface
MLLW	Mean lower low water
NA	Not applicable or not available
NAD 83/98	North American Datum of 1983/1998
NAVD 88	North American Vertical Datum of 1988
RETEC	The RETEC Group

Table 4.1
Overview of Media, Receptors, and Exposure Routes

				Cross-Media Protection	
Media	**Receptors**	**Direct Exposure Description**	**Media Data Availability**	**From**	**To**
Fish and Shellfish	Humans	Tribal consumption of resident fish/shellfish	Limited data available nearby on bioaccumulatives	Sediment and Surface Water	None
	Higher Trophic Level Species	Consumption of resident fish/shellfish			None
Subtidal Sediments	Humans	Direct contact via net fishing	Good data set, including bioassays	Intertidal Sediment	Fish/Shellfish
	Benthic Species	Direct exposure by organism living in and on the sediments			
Intertidal Sediments	Humans	Industrial worker direct contact	Good data set	Groundwater and Soil (via Erosion)	Subtidal Sediment
	Benthic Species	Direct exposure by organism living in and on the sediments			
Surface Water	Humans	Limited direct exposure	No data available	Groundwater	Fish/Shellfish
	Aquatic Species	Direct exposure by living in the bay	No data available		
Groundwater	Humans	No direct exposure – non-potable	Good data set	Soil	Surface Water
	Terrestrial Species	No direct exposure – industrial site			Sediments
					Ambient Air
Saturated Soil	Humans	Limited direct exposure during construction activities	Good data set	None	Groundwater
Unsaturated Soil	Humans	Industrial worker direct contact	Good data set	None	Groundwater via Stormwater Infiltration
	Terrestrial Species	No direct exposure – industrial site			Ambient Air
Ambient Air	Humans	Industrial worker direct contact	No structures of interest; soil gas data available	Groundwater and Soil	None

Table 4.2
Overview of Relevant Exposure Pathways Used to Develop Screening Levels for the Selection of COCs

Pathway/Screening Level		Basis for Screening Level Value	Point of Compliance	Demonstration of Compliance	Site-Specific Considerations
Media: Sediment					
1a	Protection of benthic species (Benthic Toxicity)	SMS SCO and CSL expressed as dry weight for ease in comparison with screening levels from other pathways.	Upper 12 cm throughout the Site (both intertidal and subtidal areas).	Direct comparison.	The use of 12 cm, rather than the more common 10 cm, has been selected by Ecology for Bellingham Bay.
1b	Protection of human health via dermal contact and incidental ingestion: industrial worker scenario (Industrial Worker)	Risk-based calculations.	Upper 12 cm in the shipyard intertidal sediment area (defined as above 0 ft MLLW and beyond the toe of the bank).	Direct comparison of the intertidal sediment area SWAC to screening level.	Only applicable to areas where workers have access along the northern shoreline.
1c	Protection of human health via dermal contact and incidental ingestion: net fishing scenario (Direct Contact via Net Fishing)	Risk-based calculations.	Upper 12 cm throughout the subtidal zone (defined as sediments below 0 ft MLLW).	Direct comparison of the subtidal sediment SWAC to screening level.	None identified.
1d	Protection of human health via the consumption of seafood (Human Health Seafood Consumption)	Risk-based calculation limited to bioaccumulative chemicals.	Upper 12 cm throughout the Site.	Direct comparison of the Site-wide SWAC to screening level or demonstration that chemical is not a concern in tissue for primary seafood species in Bellingham Bay.	Risk-based criteria are less than background; natural background from USV Bold Survey plus data set and SCUM II. Regional background for Dioxin/furan TEQ and cPAH TEQ were developed by Ecology in 2015 (Ecology 2015). Site-specific regional background values for arsenic and cadmium were developed by Floyd|Snider in 2015 using a comprehensive EIM data pull.
1e	Protection of aquatic species via the consumption of seafood (Aquatic Higher Trophic Level Species Seafood Consumption)				
1f	Background considerations and PQLs	Natural background and PQLs are derived from the SCUM II; no screening levels will be set less than the PQL or natural background.			
Media: Groundwater					
2a	Protection of surface water quality (Surface Water Quality)	Based on WAC 173-340-730: the lowest of AWQC, NTR (except where toxicity factors are withdrawn), Clean Water Act-effective WQS for Washington, and MTCA Method B (if ARARs are not protective); protects both aquatic species and human consumption.	Where groundwater discharges to surface water.	Compliance measured in the shoreline wells; possibly with attenuations between surface water and well.	TPH was detected in site groundwater, but there are no ARARs and toxicity factors for the mixture; therefore, consideration of TPH for this pathway will use Indicator Hazardous Substances (IHS) that are constituents of TPH and that have been detected in groundwater on-site.
2b	Protection of sediment quality (Sediment Quality)	Based on equilibrium partitioning between sediments and groundwater; sediment concentration to be protected is the lowest of 1a and 1b, based on groundwater discharge to the nearshore area.	Where groundwater discharges to sediments.	Compliance in the shoreline wells; possibly with attenuation between sediment porewater and well. Nearshore sediment data may also be used to demonstrate protection.	Sediment TOC results from the Site were used to calculate an average f_{oc} for use in the partitioning calculations.
2c	Protection of vapor intrusion (Vapor Intrusion)	MTCA Method C values for industrial land use from Ecology's Guidance for Evaluation of Soil Vapor Intrusion, Revised in 2015.	Shallow groundwater to protect indoor air in structures.	Direct comparison.	No COCs were identified at the Site for this pathway using Ecology's screening levels in their Revised Vapor Intrusion Guidance (Ecology 2015).
2d	Background considerations and PQLs	Arsenic is the only chemical for which a groundwater background has been established; no criteria for arsenic will be set less than the arsenic background concentration. PQLs were developed with Ecology as part of the Bellingham Bay-wide discussions in 2012; no screening criteria will be set less than the PQL.			

Table 4.2
Overview of Relevant Exposure Pathways Used to Develop Screening Levels for the Selection of COCs

Pathway/Screening Level		**Basis for Screening Level Value**	**Point of Compliance**	**Demonstration of Compliance**	**Site-Specific Considerations**
Media: Soil					
3a	Direct contact	MTCA Method C values for industrial workers (ingestion only) and MTCA Method A values for industrial workers where a MTCA Method C value was not available.	Upper 15 ft throughout the Site.	Direct comparison.	None identified.
3b	Protection of groundwater quality: unsaturated zone	Use of the three-phase rule to calculate. Protection of the quality defined as the minimum of 2b and 2c.	Unsaturated zone soils (upper 8 ft throughout the Site), based on infiltrating stormwater.	Direct comparison to criteria or demonstration that groundwater quality in adjacent and downgradient wells is acceptable.	Demonstration using groundwater data needs to consider the conditional point of compliance at the shoreline.
3c	Protection of groundwater quality: saturated zone	Use of the three-phase rule to calculate. Protection of the quality defined as the minimum of 2b and 2c. No attenuation factor used.	Saturated zone soils (8 ft bgs and deeper), based on groundwater migration.	Direct comparison to criteria or demonstration that groundwater quality in adjacent and downgradient wells is acceptable.	Demonstration using groundwater data needs to consider the conditional point of compliance at the shoreline.
3d	Protection of vapor intrusion	MTCA Method C values for industrial land use from Ecology's April 6, 2015 Guidance for Evaluation of Soil Vapor Intrusion.	Unsaturated zone soils to protect indoor air in potential future structures; no current structures in the area of concern.	Direct comparison of soil gas results to soil gas screening levels for industrial sites.	The only COC for this pathway is a small group of aliphatic components in diesel No. 2 quantified as part of the VPH/EPH method. The soil cleanup level is adjusted downward to protect this pathway. Refer to the TPH Screening Level Development (Appendix G, Attachment G.2).
3e	Background considerations and PQLs	Background soil concentrations are available for several metals; no criteria will be set less than the natural background values for the Puget Sound Region. PQLs were developed with Ecology as part of the Bellingham Bay-wide discussions in 2012; no screening criteria will be set less than the PQL. Section 5.0 discusses site-specific naturally occurring concentrations of nickel in site soil.			

Abbreviations:

ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criteria
bgs	Below ground surface
cm	Centimeters
COC	Contaminant of concern
CSL	Cleanup Screening Level
Ecology	Washington State Department of Ecology
EPH	Extractable petroleum hydrocarbon
ft	Feet
MLLW	Mean Lower Low Water
MTCA	Model Toxics Control Act
NTR	National Toxics Rule
PQL	Practical Quantitation Limit
SCO	Sediment Cleanup Objectives
SCUM	Sediment Cleanup Users Manual
Site	Harris Avenue Shipyard
SMS	Sediment Management Standards
SWAC	Surface-weighted average concentration
TOC	Total Organic Carbon
TPH	Total petroleum hydrocarbon
VPH	Volatile petroleum hydrocarbon
WAC	Washington Administrative Code
WQS	Water Quality Standards

Table 4.3
Sediment Exposure Screening Levels for the Selection of COCs

		Modifying Criteria		Sediment Screening Levels by Exposure Pathway													Screening Levels		
				Protection of Benthic and Aquatic Species						Protection of Human Health[1]				Bioaccumulative Chemicals Only Seafood Consumption (refer to App G.1)					
				WAC 173-204 SMS (mg/kg dry wt unless otherwise note as mg/kg OCN4)				WAC 173-204 SMS5 as Dry Weight Equivalents (mg/kg dry wt)		Subtidal Direct Contact via Net Fishing (mg/kg dry wt)		Intertidal Direct Contact via Shipyard Worker Activities (mg/kg dry wt)		By Higher Trophic Levels	By Humans (tribal consumption rates) (mg/kg dry wt)		Without Seafood Consumption		With Seafood Consumption
Analyte	CAS No.	Natural Background (mg/kg dry wt)[2]	Applicable Practical Quantitation Level (PQL)3 (mg/kg dry wt)	SCO	Special Units[4]	CSL	Special Units[4]	SCO	CSL	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	(mg/kg dry wt)	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	Intertidal Sediments[6] (mg/kg dry wt)	Subtidal Sediments[7] (mg/kg dry wt)	Area-Wide Sediments per App G.1[8] (mg/kg dry wt)
Metals																			
Antimony	7440-36-0		4								1,800		1,500				1,500	1,800	
Arsenic	7440-38-2	11/20[9]	0.5	57		93		57	93	3.3	1,400	9.4	1,100	0.59	0.00038	0.16	20	11	11
Cadmium	7440-43-9	0.8	0.1	5.1		6.7		5.1	6.7		4,600		3,800	2.1		0.58	5.1	5.1	0.8
Chromium	7440-47-3	62	0.5	260		270		260	270								260	260	
Copper	7440-50-8	45	1	390		390		390	390		180,000		150,000				390	390	
Lead	7439-92-1	16	2	450		530		450	530					note 10		5.5[11]	450	450	16
Mercury	7439-97-6	0.2	0.02	0.41		0.59		0.41	0.59		1,400		1,100	1.2[12]		1.2[12]	0.41	0.41	1.2
Nickel	7440-02-0	50	1								92,000		75,000				75,000	92,000	
Silver	7440-22-4	0.24	0.5	6.1		6.1		6.1	6.1		23,000		19,000				6.1	6.1	
Zinc	7440-66-6	93	1	410		960		410	960		not toxic[13]		not toxic[13]				410	410	
Organometallics																			
Tributyltin	688-73-3			pore water[14]		pore water[14]		pore water[14]	pore water[14]		1,400		1,100				1,100	1,400	
Polychlorinated Biphenyls (PCBs)																			
Aroclor 1016	12674-11-2		0.0040							60	270	170	220		0.059	0.024	170	60	
Aroclor 1221	11104-28-2																		
Aroclor 1232	11141-16-5																		
Aroclor 1242	53469-21-9																		
Aroclor 1254	11097-69-1		0.0055							2.1	78	6.0	64		0.00018	0.0069	6.0	2.1	
Aroclor 1248	12672-29-6																		
Aroclor 1260	11096-82-5		0.0040							2.1		6.0			0.00018		6.0	2.1	
Aroclor 1268	11100-14-4																		
Total PCBs[15]	Total PCBs	0.0035	0.0055	12	mg/kg OCN	65	mg/kg OCN	0.13	1.0	2.1		6.0		0.0050	0.00018		0.13	0.13	0.0055
Dioxins/Furans																			
Dioxin/Furan TEQ[16]	2,3,7,8-TCDD	0.000004	0.000005							0.000062	0.0053	0.00018	0.0043	0.000001	0.000000032	0.0000027	0.00018	0.000062	0.000005
Semivolatile Organic Compounds (SVOCs)																			
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																			
cPAH TEQ[17, 18]	Total cPAHs TEF	0.021	0.009							4.2		12			0.014		12	4.2	0.021
Benzo(a)pyrene	50-32-8	0.015	0.006	99	mg/kg OCN	210	mg/kg OCN	1.6	1.6	4.2		12					1.6	1.6	
Benz(a)anthracene	56-55-3	0.01	0.006	110	mg/kg OCN	270	mg/kg OCN	1.3	1.6	42		120					1.3	1.3	
Benzo(b)fluoranthene	205-99-2	0.022	0.007							42		120					120	42	
Benzo(k)fluoranthene	207-08-9	0.01	0.007							420		1,200					1,200	420	
Benzofluoranthenes (total)[19]	Total Benzo.		0.06	230	mg/kg OCN	450	mg/kg OCN	3.2	3.6								3.2	3.2	
Chrysene	218-01-9	0.01	0.006	110	mg/kg OCN	460	mg/kg OCN	1.4	2.8	4,200		12,000					1.4	1.4	
Dibenzo(a,h)anthracene	53-70-3		0.006	12	mg/kg OCN	33	mg/kg OCN	0.23	0.23	4.2		12					0.23	0.23	
Indeno(1,2,3-cd)pyrene	193-39-5	0.0054	0.006	34	mg/kg OCN	88	mg/kg OCN	0.6	0.69	42		120					0.6	0.6	
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																			
1-Methylnaphthalene	90-12-0		0.05							140		410					410	140	
2-Methylnaphthalene	91-57-6		0.05	38	mg/kg OCN	64	mg/kg OCN	0.67	0.67		16,000		13,000				0.67	0.67	
Naphthalene	91-20-3		0.05	99	mg/kg OCN	170	mg/kg OCN	2.1	2.1		78,000		64,000				2.1	2.1	
Acenaphthene	83-32-9		0.05	16	mg/kg OCN	57	mg/kg OCN	0.5	0.5		240,000		190,000				0.5	0.5	
Acenaphthylene	208-96-8		0.05	66	mg/kg OCN	66	mg/kg OCN	1.3	1.3								1.3	1.3	
Anthracene	120-12-7		0.05	220	mg/kg OCN	1,200	mg/kg OCN	0.96	0.96		not toxic[13]		960,000				0.96	0.96	
Fluorene	86-73-7		0.05	23	mg/kg OCN	79	mg/kg OCN	0.54	0.54		160,000		130,000				0.54	0.54	
Phenanthrene	85-01-8	0.0091	0.05	100	mg/kg OCN	480	mg/kg OCN	1.5	1.5								1.5	1.5	
Total LPAHs[20]	Total LPAHs			370	mg/kg OCN	780	mg/kg OCN	5.2	5.2								5.2	5.2	
Benzo(g,h,i)perylene	191-24-2		0.05	31	mg/kg OCN	78	mg/kg OCN	0.67	0.72								0.67	0.67	

Table 4.3
Sediment Exposure Screening Levels for the Selection of COCs

				Sediment Screening Levels by Exposure Pathway													Screening Levels		
		Modifying Criteria		Protection of Benthic and Aquatic Species						Protection of Human Health[1]				Bioaccumulative Chemicals Only Seafood Consumption (refer to App G.1)					
		Natural Background (mg/kg dry wt)[2]	Applicable Practical Quantitation Level (PQL)3 (mg/kg dry wt)	WAC 173-204 SMS (mg/kg dry wt unless otherwise note as mg/kg OCN4)				WAC 173-204 SMS5 as Dry Weight Equivalents (mg/kg dry wt)		Subtidal Direct Contact via Net Fishing (mg/kg dry wt)		Intertidal Direct Contact via Shipyard Worker Activities (mg/kg dry wt)		By Higher Trophic Levels	By Humans (tribal consumption rates) (mg/kg dry wt)		Without Seafood Consumption		With Seafood Consumption
Analyte	CAS No.			SCO	Special Units[4]	CSL	Special Units[4]	SCO	CSL	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	(mg/kg dry wt)	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	Intertidal Sediments[6] (mg/kg dry wt)	Subtidal Sediments[7] (mg/kg dry wt)	Area-Wide Sediments per App G.1[8] (mg/kg dry wt)
Semivolatile Organic Compounds (SVOCs) (cont.)																			
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																			
Fluoranthene	206-44-0	0.016	0.05	160	mg/kg OCN	1,200	mg/kg OCN	1.7	2.5		160,000		130,000				1.7	1.7	
Pyrene	129-00-0	0.015	0.05	1,000	mg/kg OCN	1,400	mg/kg OCN	2.6	3.3		120,000		96,000	14			2.6	2.6	14[21]
Total HPAHs[22]	Total HPAH			960	mg/kg OCN	5,300	mg/kg OCN	12	17								12	12	
Other SVOCs																			
1,2,4-Trichlorobenzene	120-82-1		0.06	0.81	mg/kg OCN	1.8	mg/kg OCN	0.031	0.051	170	47,000	490	38,000				0.059	0.059	
1,2-Dichlorobenzene	95-50-1		0.06	2.3	mg/kg OCN	2.3	mg/kg OCN	0.035	0.05		420,000		340,000				0.059	0.059	
2-Chlorophenol	95-57-8		0.02								20,000		16,000				16,000	20,000	
2,3,4,6-Tetrachlorophenol	58-90-2		0.02								120,000		96,000				96,000	120,000	
2,4,5-Trichlorophenol	95-95-4		0.1								390,000		320,000				320,000	390,000	
2,4,6-Trichlorophenol	88-06-2		0.1							380	3,900	1,100	3,200				1,100	380	
2,4-Dichlorophenol	120-83-2		0.1								12,000		9,600				9,600	12,000	
2,4-Dimethylphenol	105-67-9		0.2	0.029		0.029		0.029	0.029		78,000		64,000				0.2	0.2	
2,4-Dinitrotoluene	121-14-2		0.01								7,800		6,400				6,400	7,800	
2,6-Dinitrotoluene	606-20-2		0.01								1,200		960				960	1,200	
2,4-Dinitrophenol	51-28-5		0.2								7,800		6,400				6,400	7,800	
2-Chloronaphthalene	91-58-7		0.02								310,000		260,000				260,000	310,000	
2-Methylphenol	95-48-7		0.08	0.063		0.063		0.063	0.063		200,000		160,000				0.08	0.08	
2-Nitroaniline	88-74-4		0.1								39,000		32,000				32,000	39,000	
3,3'-Dichlorobenzidine	91-94-1		0.1							9.3		27					27	9.3	
4-Chloroaniline	106-47-8		0.1							21	16,000	60	13,000				60	21	
4-Methylphenol	106-44-5	0.37	0.2	0.67		0.67		0.67	0.67		390,000		320,000				0.67	0.67	
Aniline	62-53-3		0.1							740	27,000	2,100	22,000				2,100	740	
Azobenzene	103-33-3		0.1							38		110					110	38	
Benzoic Acid	65-85-0		1.0	0.65		0.65		0.65	0.65		not toxic[13]		not toxic[13]				1	1	
Benzyl Alcohol	100-51-6		0.2	0.057		0.073		0.057	0.073		390,000		320,000				0.2	0.2	
bis(2-Chloroethyl) ether	111-44-4		0.1							4		11					11	3.8	
bis(2-Ethylhexyl) phthalate	117-81-7		0.2	47	mg/kg OCN	78	mg/kg OCN	1.3	1.9	300	78,000	860	64,000				1.3	1.3	
Butyl Benzyl Phthalate	85-68-7		0.09	4.9	mg/kg OCN	64	mg/kg OCN	0.063	0.9	2,200	780,000	6,300	640,000				0.09	0.09	
Dibenzofuran	132-64-9		0.08	15	mg/kg OCN	58	mg/kg OCN	0.54	0.54								0.54	0.54	
Diethylphthalate	84-66-2		0.1	61	mg/kg OCN	110	mg/kg OCN	0.2	1.2		not toxic[13]		not toxic[13]				0.2	0.2	
Dimethyl phthalate	131-11-3		0.08	53	mg/kg OCN	53	mg/kg OCN	0.071	0.16								0.08	0.08	
Di-n-butyl phthalate	84-74-2		0.1	220	mg/kg OCN	1,700	mg/kg OCN	1.4	1.4		390,000		320,000				1.4	1.4	
Di-n-octyl phthalate	117-84-0		0.1	58	mg/kg OCN	4,500	mg/kg OCN	6.2	6.2								6.2	6.2	
Hexachlorobenzene	118-74-1		0.06	0.38	mg/kg OCN	2.3	mg/kg OCN	0.022	0.07	3	3,100	7.5	2,600				0.06	0.06	
Hexachlorobutadiene	87-68-3		0.06	3.9	mg/kg OCN	6.2	mg/kg OCN	0.011	0.12	63	4,700	180	3,800				0.06	0.06	
Hexachlorocyclopentadiene	77-47-4		0.02								24,000		19,000				19,000	24,000	
Hexachloroethane	67-72-1		0.08							100	2,700	300	2,200				300	100	
Isophorone	78-59-1		0.1							4,400	780,000	13,000	640,000				13,000	4,400	
Nitrobenzene	98-95-3		0.02								7,800		6,400				6,400	7,800	
N-Nitrosodimethylamine	62-75-9		0.02								31	0.23	26				0.23	0.082	
N-Nitroso-di-n-propylamine	621-64-7		0.02							1		1.7					1.7	0.6	
N-Nitrosodiphenylamine	86-30-6		0.06	11	mg/kg OCN	11	mg/kg OCN	0.028	0.04	860		2,400					0.06	0.06	
Pentachlorophenol	87-86-5		0.3	0.36		0.69		0.36	0.69	10	20,000	30	16,000				0.36	0.36	
Phenol	108-95-2	0.82	0.08	0.42		1.2		0.42	1.2		not toxic[13]		960,000				0.82	0.82	
Volatile Organic Compounds (VOCs) Associated with Total Petroleum Hydrocarbon (TPH)																			
Ethylbenzene	100-41-4		0.001								470,000		380,000				380,000	470,000	

Table 4.3
Sediment Exposure Screening Levels for the Selection of COCs

		Modifying Criteria		Sediment Screening Levels by Exposure Pathway													Screening Levels		
				Protection of Benthic and Aquatic Species						Protection of Human Health[1]				Bioaccumulative Chemicals Only Seafood Consumption (refer to App G.1)					
		Natural Background (mg/kg dry wt)[2]	Applicable Practical Quantitation Level (PQL)3 (mg/kg dry wt)	WAC 173-204 SMS (mg/kg dry wt unless otherwise note as mg/kg OCN4)				WAC 173-204 SMS5 as Dry Weight Equivalents (mg/kg dry wt)		Subtidal Direct Contact via Net Fishing (mg/kg dry wt)		Intertidal Direct Contact via Shipyard Worker Activities (mg/kg dry wt)		By Higher Trophic Levels	By Humans (tribal consumption rates) (mg/kg dry wt)		Without Seafood Consumption		With Seafood Consumption
Analyte	CAS No.			SCO	Special Units[4]	CSL	Special Units[4]	SCO	CSL	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	(mg/kg dry wt)	Carcinogenic (at 10^{-6} risk)	Non-Carcinogenic	Intertidal Sediments[6] (mg/kg dry wt)	Subtidal Sediments[7] (mg/kg dry wt)	Area-Wide Sediments per App G.1[8] (mg/kg dry wt)
Volatile Organic Compounds (VOCs) Associated with Total Petroleum Hydrocarbon (TPH) (cont.)																			
Xylene (meta & para)	179601-23-1																		▨
Xylene (ortho)	95-47-6		0.001								940,000		760,000				760,000	940,000	▨
Xylene (total)	1330-20-7										940,000		760,000				760,000	940,000	▨
Other VOCs																			
1,4-Dichlorobenzene	106-46-7		0.06	3.1	mg/kg OCN	9	mg/kg OCN	0.11	0.11								0.11	0.11	▨
Pyridine	110-86-1										4,700		3,800				3,800	4,700	▨
Trichloroethene	79-01-6		0.001							110	2,300	310	1,900				310	110	▨
Tetrachloroethene	127-18-4		0.001							2,400	28,000	6,800	23,000				6,800	2,400	▨
Total Petroleum Hydrocarbons (TPH)																			
Gasoline-Range Hydrocarbons	86290-81-5																None established. Sediment screening levels are based on individual constituents of petroleum products such as xylene, pyrene, etc.		
Diesel-Range Hydrocarbons	68334-30-5		0.02																
Oil-Range Hydrocarbons	TPH-Oil		0.05																

Notes:

All blank cells are intentional.

▨ Shaded cells are not applicable.

1 Sediment screening levels for the protection of human health are calculated using the equations and input parameters provided by Ecology in the SCUM II (2017). All parameters used in these calculations are Ecology defaults with the exception of site-specific parameters identified and described in Appendix G, Attachment G.1.

2 Calculated 90/90 upper tolerance limit (UTL; i.e., the 90 percent upper confidence limit [UCL] on the 90th percentile) of data presented in OSV Bold Summer 2008 Survey Data Report and other data sets. Calculations were completed by Ecology and presented in SCUM II (Ecology 2017a; Ecology 2015).

3 PQL is the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department-approved methods. PQLs, where available, are the median value for each analyte using standard analytical methodology rounded to one significant figure. PQLs are not presented for analytes with no other criteria available.

4 Metals, phenols, benzyl alcohol, and benzoic acid are presented in mg/kg dry wt; criteria for the remaining analytes are presented in mg/kg OCN. The listed values represent concentrations in parts per million "normalized" on a TOC basis. To normalize to TOC, the dry wt concentration for each parameter is divided by the decimal fraction representing the percent TOC content of the sediment.

5 In some cases, it may be appropriate to use dry wt-based Apparent Effects Threshold (AET) sediment quality values in place of the TOC-based sediment quality criteria contained in the SMS. The use of the dry wt-based AET sediment quality values should only be done on a case-by-case basis in consultation with Ecology's Sediment Management Unit (SMU).

6 Minimum of protection of benthic and aquatic species and direct contact to human pathways (shipyard workers), modified by natural background for arsenic in soil.

7 Minimum of protection of benthic and aquatic species and direct contact to human pathways (netfishing); modified by natural background.

8 Screening levels for bioaccumulation through the consumption of fish is used in a separate process based on compliance with area-wide concentrations, rather than point-by-point concentrations.

9 Criterion based on natural background in soil.

10 Calculations could not be completed to derive a higher trophic level screening level for lead because an applicable biota accumulation factor is not readily available. Tissue concentrations discussed in Section 3.0 in Appendix G, Attachment G.1 will instead be compared against the lead target tissue level of 2 mg/kg wet wt (protective of aquatic-dependent receptors).

11 The screening level for lead is derived using the Adult Lead Model (USEPA 2003) as described in Appendix G, Attachment G.1.

12 The Whatcom Waterway Remedial Investigation/Feasibility Study (Anchor and Hart Crowser 2000) derived a site-specific mercury screening level protective of human and higher trophic level receptors, by conducting a simple regression analysis was between paired sediment and tissue data taken from Bellingham Bay and the greater Puget Sound region. The greatest bioaccumulation of mercury was found in Dungeness Crab. This tissue-sediment relationship was used to determine a screening level of 1.2 mg/kg, which is protective of both human and higher trophic level receptors. Because this screening level calculation included data from Bellingham Bay, it is appropriate to apply it in this assessment as a human health and higher trophic level risk-based level for mercury.

13 Calculated risk is greater than 1,000,000 mg/kg, therefore exerts no toxic effects.

14 Regulatory limits protective of benthic species for TBT have not been established under SMS. A report on the evaluation of TBT relative to benthic toxicity (Michelsen et al. 2006) proposed regulatory criteria based on porewater concentrations, rather than on bulk sediment, stating that the porewater concentration is “conceptually equivalent” to SMS SCO and CSL. These porewater screening level values are 0.05 µg/L (SQS) and 0.15 µg/L (CSL), and have been considered as the screening level for TBT concentrations protective of benthic species.

15 Screening levels are applicable to Total PCBs, which are calculated for this site by summing all detected Aroclors (Aroclors that are not detected are not included in the total). If no Aroclors are detected, then the Total PCB value is the greatest detection limit.

16 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

17 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

18 Since the original issuance of the Draft Remedial Investigation in 2014, the cancer potency factor for benzo(a)pyrene, used to calculate cPAH TEQ as benzo(a)pyrene equivalents, has been updated in the Integrated Risk Information System (IRIS; USEPA 2017). WAC 173-340-708 states: “For purposes of establishing cleanup levels and remediation levels for hazardous substances under this chapter, a carcinogenic potency factor established by the United States Environmental Protection Agency and available through the IRIS data base shall be used.” Therefore the new cancer slope factor from IRIS has been utilized in the calculation of risk-based screening and cleanup levels.

19 Different sediment regulatory programs regulate either total benzofluoranthenes or individual isomers; sediment screening levels are developed for both for completeness.

20 The total LPAH criterion represents the sum of the following low molecular weight polycyclic aromatic compounds: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.

21 Because the point-by-point screening levels are less than the seafood consumption screening levels for aquatic-dependent receptors, compliance by the point-by-point screening levels will also demonstrate compliance site-wide. No separate evaluation will be made.

22 The total HPAH criterion represents the sum of the following high molecular weight polycyclic aromatic compounds: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

Abbreviations:

App	Appendix
CAS	Chemical Abstracts Service
CSL	Cleanup Screening Level
Ecology	Washington State Department of Ecology
µg/L	Micrograms per liter
mg/kg	Milligrams per kilogram
OCN	Organic carbon normalized
SCO	Sediment Cleanup Objectives
SCUM II	Sediment Cleanup Users Manual II
SMS	Sediment Management Standards
TBT	Tributyltin
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TOC	Total organic carbon
WAC	Washington Administrative Code
wt	Weight

Table 4.4

Groundwater Exposure and Cross-Media Protection Screening Levels for the Selection of COCs

				Groundwater Protective of Surface Water (without attenuation between groundwater and surface water)							Protection of Sediment Quality (without attenuation)[a,b]			Protection of Sediment and Surface Water Quality	Groundwater Protective of Vapor Intrusion[3,c]		
		Modifying Criteria		Protection of Marine Aquatic Species			Protection of Human Health via Fish Consumption[2]										
				Marine Chronic Standards			Marine Consumption of Organism Only										
Analyte[1]	CAS No.	Background Groundwater Concentration (µg/L)	Applicable Practical Quantitation Level (PQL)[4] (µg/L)	Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	National Toxics Rule 40 CFR 131.36 (µg/L)	State Standards WAC 173-201A[6] (µg/L)	2015 Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	State Standards WAC 173-201A[6] (µg/L)	Washington Water Quality Standards Clean Water Act 40 CFR 131.45[7] (µg/L)	2017 MTCA Method B Formula WAC 173-340-730[8] (µg/L)	Most Stringent Intertidal Sediment Screening Level from Table 4.3[9] (mg/kg dry wt)	K_d Partitioning Coefficients Based on Harris Sediment f_{oc} of 0.018[10] (L/kg)	Porewater Screening Level Protective of Sediment (µg/L)[11]	Screening Level for Shoreline Groundwater Discharge (µg/L)	2015 MTCA Method C Ecology Guidance Industrial Land Use (µg/L)	Most Stringent Groundwater Screening Level (µg/L)[12]	
		(back)	(pql)	(mc-cwa)	(mc-ntr)	(mc-wac)	(hh-cwa)	(hh-wac)	(wa wqs)	(sw-b)			(sed)		(vi-c)		
Metals																	
Antimony	7440-36-0		0.2				640	180	37		1,500	45	33,000	37		37	(wa wqs)
Arsenic	7440-38-2	5[13]	0.5	36	36	36	0.14	10	0.0059		20	29	690	0.0059		5	(back)
Beryllium	7440-41-7		0.2							32		790		32		32	(sw-b)
Cadmium	7440-43-9		0.1	8.8	9.3	9					5.1	6.7	760	8.8		8.8	(mc-cwa)
Chromium	7440-47-3		0.5								260						
Chromium III	16065-83-1		0.5							24,000		1,000		24,000		24,000	(sw-b)
Copper	7440-50-8		0.5	3.1	withdrawn[14]	3				640	390	22	18,000	3.1		3.1	(mc-cwa)
Lead	7439-92-1		0.1	8.1	8.1	8					450	10,000	45	8.1		8.1	(mc-cwa)
Mercury (inorganic)	7439-97-6		0.001	0.94	withdrawn[15]		0.3				0.41	52	7.9	0.025	1.9	0.025	(hh-ntr)
Nickel	7440-02-0		0.5	8.2	8.2	8.2	4,600	190	39		75,000	65	1,200,000	8.2		8.2	(mc-cwa)
Selenium	7782-49-2		1	71	71	71	4,200	480	95			5		71		71	(mc-cwa)
Silver	7440-22-4		0.2	1.9	1.9	2				80	6.1	8.3	730	1.9		1.9	(mc-cwa)
Thallium	7440-28-0		0.2				0.47		0.054			71		0.054		0.2	(pql)
Zinc	7440-66-6		4.0	81	81	81	26,000	2,900	580		410	62	6,600	81		81	(mc-cwa)
Polychlorinated Biphenyls (PCBs)																	
Aroclor 1016	12674-11-2		0.01		0.03					1.1	170	2,000	85	0.03		0.03	(mc-ntr)
Aroclor 1221	11104-28-2		0.01														
Aroclor 1232	11141-16-5		0.01														
Aroclor 1242	53469-21-9		0.01														
Aroclor 1254	11097-69-1		0.01		0.03					0.044	6.0	15,000	0.4	0.03		0.03	(mc-ntr)
Aroclor 1248	12672-29-6		0.01														
Aroclor 1260	11096-82-5		0.01		0.03					0.044	6.0	15,000	0.4	0.03		0.03	(mc-ntr)
Aroclor 1268	11100-14-4		0.01														
Total PCBs[16]	Total PCBs		0.025	0.03	0.03	0.03	0.000064	0.00017	0.0000073		0.13	5,600	0.023	0.0000073		0.025	(pql)
Dioxins/Furans																	
Dioxin/Furan TEQ[17]	2,3,7,8-TCDD		0.000031				0.0000000051	0.000000064	5.9E-10		0.00018	18,000	0.00001	5.9E-10		0.000031	(pql)
Semivolatile Organic Compounds (SVOCs)																	
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																	
cPAH TEQ[18]	Total cPAHs TEF		0.01				0.00013	0.0021	0.000016		12.0	17,000	0.71	0.000016		0.01	(pql)
Benzo(a)pyrene	50-32-8		0.01				0.00013	0.0021	0.000016		1.6	17,000	0.094	0.000016		0.01	(pql)
Benz(a)anthracene	56-55-3		0.01				0.00013	0.021	0.00016		1.3	6,500	0.2	0.00013		0.01	(pql)
Benzo(b)fluoranthene	205-99-2		0.01				0.00013	0.021	0.00016		120	22,000	5.5	0.00013		0.01	(pql)
Benzo(k)fluoranthene	207-08-9		0.01				0.00013	0.21	0.0016		1200	22,000	55	0.00013		0.01	(pql)
Benzofluoranthenes (total)	Total Benzo.		0.01								3.2						
Chrysene	218-01-9		0.01				0.00013	2.1	0.016		1.4	7,200	0.19	0.00013		0.01	(pql)
Dibenzo(a,h)anthracene	53-70-3		0.01				0.00013	0.0021	0.000016		0.23	32,000	0.0072	0.000016		0.01	(pql)
Indeno(1,2,3-cd)pyrene	193-39-5		0.01				0.00013	0.021	0.00016		0.60	63,000	0.0095	0.00013		0.01	(pql)
1-Methylnaphthalene	90-12-0		0.01							1.5	410			1.5		1.5	(sw-b)
2-Methylnaphthalene	91-57-6		0.01							32	0.67			32		32	(sw-b)

Table 4.4
Groundwater Exposure and Cross-Media Protection Screening Levels for the Selection of COCs

				Groundwater Protective of Surface Water (without attenuation between groundwater and surface water)							Protection of Sediment Quality (without attenuation)[a,b]			Protection of Sediment and Surface Water Quality	Groundwater Protective of Vapor Intrusion[3,c]		
		Modifying Criteria		Protection of Marine Aquatic Species Marine Chronic Standards			Protection of Human Health via Fish Consumption[2] Marine Consumption of Organism Only										
Analyte[1]	CAS No.	Background Groundwater Concentration (µg/L)	Applicable Practical Quantitation Level (PQL)[4] (µg/L)	Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	National Toxics Rule 40 CFR 131.36 (µg/L)	State Standards WAC 173-201A[6] (µg/L)	2015 Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	State Standards WAC 173-201A[6] (µg/L)	Washington Water Quality Standards Clean Water Act 40 CFR 131.45[7] (µg/L)	2017 MTCA Method B Formula WAC 173-340-730[8] (µg/L)	Most Stringent Intertidal Sediment Screening Level from Table 4.3[9] (mg/kg dry wt)	K_d Partitioning Coefficients Based on Harris Sediment f_{oc} of 0.018[10] (L/kg)	Porewater Screening Level Protective of Sediment (µg/L)[11]	Screening Level for Shoreline Groundwater Discharge (µg/L)	2015 MTCA Method C Ecology Guidance Industrial Land Use (µg/L)	Most Stringent Groundwater Screening Level (µg/L)[12]	
		(back)	(pql)	(mc-cwa)	(mc-ntr)	(mc-wac)	(hh-cwa)	(hh-wac)	(wa wqs)	(sw-b)			(sed)		(vi-c)		
Semivolatile Organic Compounds (SVOCs) (cont.)																	
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																	
Naphthalene	91-20-3		0.01							160	2.1	22	95	95	89	89	(vi-c)
Acenaphthene	83-32-9		0.01				90	110	10		0.50	88	5.7	5.7		5.7	(sed)
Acenaphthylene	208-96-8		0.01								1.3						
Anthracene	120-12-7		0.01				400	4600	40		0.96	410	2.3	2.3		2.3	(sed)
Fluorene	86-73-7		0.01				70	610	5		0.54	140	3.9	3.9		3.9	(sed)
Phenanthrene	85-01-8		0.01								1.5						
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																	
Benzo(g,h,i)perylene	191-24-2		0.01								0.67						
Fluoranthene	206-44-0		0.01				20	16	2		1.7	880	1.9	1.9		1.9	(sed)
Pyrene	129-00-0		0.01				30	460	3		2.6	1,200	2.2	2.2		2.2	(sed)
Other SVOCs																	
1,2-Dichlorobenzene	95-50-1		1.0				3,000	2500	300		0.059	6.8	8.7	300	5,600	8.7	(sed)
2-Chlorophenol	95-57-8		1.0				800	17	80		16,000	7	2,300,000	17		17	(hh-wac)
1,3-Dichlorobenzene	541-73-1		1.0				10	16	1.0					1		1	(wa wqs)
2,3,4,6-Tetrachlorophenol	58-90-2		1.0							480	96,000	5	19,000,000	480		480	(sw-b)
2,4,5-Trichlorophenol	95-95-4		5.0				600				320,000	29	11,000,000	600		600	(hh-cwa)
2,4,6-Trichlorophenol	88-06-2		3.0				2.8	0.28	0.28		1,100	6.8	160,000	0.28		3	(pql)
2,4-Dichlorophenol	120-83-2		3.0				60	34	6.0		9,600	2.7	3,600,000	6		6	(wa wqs)
2,4-Dimethylphenol	105-67-9		4.0				3,000	97	300		0.2	3.8	53	97		53	(sed)
2,4-Dinitrotoluene	121-14-2		1.0				1.7	0.18	0.18		6,400	1.7	3,800,000	0.18		1	(pql)
2,6-Dinitrotoluene	606-20-2		1.0							0.058	960	1.2	800,000	0.058		1	(pql)
2,4-Dinitrophenol	51-28-5		20				300	610	40		6,400	0.00018	cannot exceed	40		40	(wa wqs)
2-Chloronaphthalene	91-58-7		1.0				1,000	180	100		260,000			100		100	(wa wqs)
2-Methylphenol	95-48-7		1.0							400	0.08	1.6	50	400		50	(sed)
2-Nitroaniline	88-74-4		3.0							160	32,000			160		160	(sw-b)
3,3'-Dichlorobenzidine	91-94-1		5.0				0.15	0.0033	0.015		27	13	2,100	0.0033		5.0	(pql)
4,6 Dinitro-o-cresol	534-52-1		10				30	25	3					3		10	(pql)
4-Chloro-3-methylphenol	59-50-7		3.0				2,000	36	200					36		36	(hh-wac)
4-Chloroaniline	106-47-8		5.0							0.22	60	1.2	50,000	0.22		5.0	(pql)
Aniline	62-53-3		1.0							7.7	2,100			7.7		7.7	(sw-b)
Azobenzene	103-33-3		1.0							0.8	110			0.8		1.0	(pql)
Benzoic acid	65-85-0		20							64,000	1.0	0.011	91,000	64,000		64000	(sw-b)
Benzyl alcohol	100-51-6		5.0							800	0.2			800		800	(sw-b)
Bis(2-chloroethyl) ether	111-44-4		1.0				2.2	0.06	0.24		11	1.4	7,900	0.24	260	1.0	(pql)
Bis(2-ethylhexyl) phthalate	117-81-7		3.0				0.37	0.25	0.046		1.3	2,000	0.65	0.046		3.0	(pql)

Table 4.4
Groundwater Exposure and Cross-Media Protection Screening Levels for the Selection of COCs

				Groundwater Protective of Surface Water (without attenuation between groundwater and surface water)							Protection of Sediment Quality (without attenuation)[a,b]			Protection of Sediment and Surface Water Quality	Groundwater Protective of Vapor Intrusion[3,c]		
				Protection of Marine Aquatic Species			Protection of Human Health via Fish Consumption[2]										
		Modifying Criteria		Marine Chronic Standards			Marine Consumption of Organism Only										
		Background Groundwater Concentration (µg/L)	Applicable Practical Quantitation Level (PQL)[4] (µg/L)	Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	National Toxics Rule 40 CFR 131.36 (µg/L)	State Standards WAC 173-201A[6] (µg/L)	2015 Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	State Standards WAC 173-201A[6] (µg/L)	Washington Water Quality Standards Clean Water Act 40 CFR 131.45[7] (µg/L)	2017 MTCA Method B Formula WAC 173-340-730[8] (µg/L)	Most Stringent Intertidal Sediment Screening Level from Table 4.3[9] (mg/kg dry wt)	K_d Partitioning Coefficients Based on Harris Sediment f_{oc} of 0.018[10] (L/kg)	Porewater Screening Level Protective of Sediment (µg/L)[11]	Screening Level for Shoreline Groundwater Discharge (µg/L)	2015 MTCA Method C Ecology Guidance Industrial Land Use (µg/L)	Most Stringent Groundwater Screening Level (µg/L)[12]	
Analyte[1]	CAS No.	(back)	(pql)	(mc-cwa)	(mc-ntr)	(mc-wac)	(hh-cwa)	(hh-wac)	(wa wqs)	(sw-b)			(sed)		(vi-c)		
Semivolatile Organic Compounds (SVOCs) (cont.)																	
Other SVOCs (cont.)																	
Butyl benzyl phthalate	85-68-7		1.0				0.1	0.58	0.013		0.09	250	0.36	0.013		1.0	(pql)
Carbazole	86-74-8		1.0									61					
Dibenzofuran	132-64-9		1.0							16	0.54			16		16	(sw-b)
Diethyl phthalate	84-66-2		1.0				600	5,000	80		0.2	1.5	130	80		80	(wa wqs)
Dimethyl phthalate	131-11-3		1.0				2,000	130,000	200		0.08			200		200	(wa wqs)
Di-n-butyl phthalate	84-74-2		1.0				30	510	3		1.4	29	48	3		3	(wa wqs)
Di-n-octyl phthalate	117-84-0		1.0					-		160	6.2	1,500,000	0.0041	0.0041		1.0	(pql)
Hexachlorobenzene	118-74-1		1.0				0.000079	0.000052	0.000005		0.06	1,400	0.043	0.000005		1.0	(pql)
Hexachlorobutadiene	87-68-3		3.0				0.01	4.1	0.01		0.06	970	0.062	0.01	8.1	3.0	(pql)
Hexachlorocyclopentadiene	77-47-4		5.0				4.0	630	0.4		19,000	3,600	5,300	0.4		5.0	(pql)
Hexachloroethane	67-72-1		2.0				0.1	0.13	0.02		300	32	9,400	0.02	31	2.0	(pql)
Isophorone	78-59-1		1.0				1,800	110	200		13,000	0.85	15,000,000	200		200	(wa wqs)
m,p-Cresol (2:1 ratio)	15831-10-4		1.0														
Nitrobenzene	98-95-3		1.0				600	320	60		6,400	2.2	2,900,000	60	1,600	60	(wa wqs)
N-Nitrosodimethylamine	62-75-9		3.0				3.0	0.34	0.34		0.23			0.34		0.34	(wa wqs)
N-Nitroso-di-n-propylamine	621-64-7		1.0				0.51	0.058	0.058		1.7	0.43	4,000	0.058		1.0	(pql)
N-Nitrosodiphenylamine	86-30-6		1.0				6	0.69	0.69		0.06	23	2.6	0.69		1.0	(pql)
Pentachlorophenol	87-86-5		10	7.9	7.9	7.9	0.04	0.1	0.002		0.36	11	33	0.002		10	(pql)
Phenol	108-95-2		1.0				300,000	200,000	30,000		0.82	0.52	1,600	1,600		1,600	(sed)
Volatile Organic Compounds (VOCs) Associated with Total Petroleum Hydrocarbons (TPHs)																	
Benzene	71-43-2		0.5				16	1.6	1.7			1.1		1.6	24	1.6	(hh-wac)
Ethylbenzene	100-41-4		0.5				130	270	13		380,000	3.6	110,000,000	13	6,100	13	(wa wqs)
Toluene	108-88-3		0.5				520	410	52			2.5		52	34,000	52	(wa wqs)
Xylenes (meta & para)[19]	179601-23-1		0.5														
Xylene (ortho)	95-47-6		0.5							1,600	760,000	4.3	180,000,000	1,600	960	960	(vi-c)
Xylenes (total)	1330-20-7		2.0							1,600	760,000	4.1	190,000,000	1,600		1,600	(sw-b)
1,2,4-Trimethylbenzene	95-63-6		2.0												62	62	(vi-c)
1,3,5-Trimethylbenzene	108-67-8		2.0							80				80		80	(sw-b)
Iso-Propylbenzene	98-82-8		2.0							800				800	1,600	800	(sw-b)
n-Butylbenzene	104-51-8		2.0							400				400		400	(sw-b)
n-Propylbenzene	103-65-1		2.0							800				800		800	(sw-b)
sec-Butylbenzene	135-98-8		2.0							800				800		800	(sw-b)
Other VOCs																	
1,1,1,2-Tetrachloroethane	630-20-6		0.5							1.7				1.7		1.7	(sw-b)
tert-Butylbenzene	98-06-6		2.0							1.7				1.7		2.0	(pql)
1,1,1-Trichloroethane	71-55-6		0.5					160,000	20,000			2.5		20,000	11,000	11,000	(vi-c)
1,1,2,2-Tetrachloroethane	79-34-5		0.5				3	0.46	0.3			1.4		0.3	62	0.5	(pql)

Table 4.4
Groundwater Exposure and Cross-Media Protection Screening Levels for the Selection of COCs

		Modifying Criteria		Groundwater Protective of Surface Water (without attenuation between groundwater and surface water)							Protection of Sediment Quality (without attenuation)[a,b]			Protection of Sediment and Surface Water Quality	Groundwater Protective of Vapor Intrusion[3,c]		
				Protection of Marine Aquatic Species Marine Chronic Standards			Protection of Human Health via Fish Consumption[2] Marine Consumption of Organism Only										
		Background Groundwater Concentration (µg/L)	Applicable Practical Quantitation Level (PQL)[4] (µg/L)	Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	National Toxics Rule 40 CFR 131.36 (µg/L)	State Standards WAC 173-201A[6] (µg/L)	2015 Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	State Standards WAC 173-201A[6] (µg/L)	Washington Water Quality Standards Clean Water Act 40 CFR 131.45[7] (µg/L)	2017 MTCA Method B Formula WAC 173-340-730[8] (µg/L)	Most Stringent Intertidal Sediment Screening Level from Table 4.3[9] (mg/kg dry wt)	K_d Partitioning Coefficients Based on Harris Sediment f_{oc} of 0.018[10] (L/kg)	Porewater Screening Level Protective of Sediment (µg/L)[11]	Screening Level for Shoreline Groundwater Discharge (µg/L)	2015 MTCA Method C Ecology Guidance Industrial Land Use (µg/L)	Most Stringent Groundwater Screening Level (µg/L)[12]	
Analyte[1]	CAS No.	(back)	(pql)	(mc-cwa)	(mc-ntr)	(mc-wac)	(hh-cwa)	(hh-wac)	(wa wqs)	(sw-b)			(sed)		(vi-c)		
Other VOCs (cont.)																	
1,1,2-Trichloroethane	79-00-5		0.5				8.9	2	0.9			1.4		0.9	9.9	0.9	(wa wqs)
1,1-Dichloroethane	75-34-3		0.5							7.7		0.95		7.7	110	7.7	(sw-b)
1,1-Dichloroethene	75-35-4		0.5				20,000	4,100	2,000			1.2		2,000	280	280	(vi-c)
1,2,3-Trichloropropane	96-18-4		0.5							0.0015				0.0015		0.50	(pql)
1,2,4-Trichlorobenzene	120-82-1		1.0				0.076		0.037			31		0.037	86	1.0	(pql)
1,2-Dibromoethane (EDB)	106-93-4		2.0							0.022		1.2		0.022	2.8	2.0	(pql)
1,2-Dichloroethane (EDC)	107-06-2		0.5				650	120	73			0.68		73	42	42	(vi-c)
1,2-Dichloropropane	78-87-5		0.5				31	3	3.3			0.85		3.3	39	3.3	(wa wqs)
1,2-Dibromo-3-chloropropane	96-12-8		2.00							0.055				0.055		2.0	(pql)
2-Chlorotoluene	95-49-8		2.00							0.055				0.055		2.0	(pql)
1,4-Dichlorobenzene	106-46-7		1.00				900	580	80		0.11	11	10	10	49	10	(sed)
Acetone	67-64-1		20							7,200		0.01		7,200		7,200	(sw-b)
Acrylonitrile	107-13-1		5.0				7		0.85					0.85	160	5.0	(pql)
bis(2-chloroisopropyl)ether	39638-32-9		2.0				65,000							65,000		65,000	(hh-cwa)
Bromodichloromethane	75-27-4		0.5				27	4	2.8			0.99		2.8	18	2.8	(wa wqs)
Bromoform	75-25-2		0.5				120	27	12			2.3		12	2,000	12	(wa wqs)
Bromomethane	74-83-9		0.5				10,000	2,400	1,000			0.16		1,000	28	28	(vi-c)
Carbon tetrachloride	56-23-5		0.5				5		0.5			2.7		0.5	5.4	0.5	(wa wqs)
Chloroethane	75-00-3		0.5												40,000	40,000	(vi-c)
Methyl-Tert-Butyl Ether	1634-04-4		0.5							24		0.2		24	6,100	24	(sw-b)
Carbon disulfide	75-15-0		0.5							800		0.83		800	880	800	(sw-b)
Chlorobenzene	108-90-7		0.5				800	890	80			4		80	630	80	(wa wqs)
Chloroform	67-66-3		0.5				2,000	1,200	200			0.95		200	12	12	(vi-c)
Chloromethane	74-87-3		0.5									0.11			330	330	(vi-c)
cis-1,2-Dichloroethene	156-59-2		0.5							16		0.65		16		16	(sw-b)
Cymene	99-87-6		2.0														
Dibromochloromethane	124-48-1		0.5				21	3	2.2			1.1		2.2	45	2.2	(wa wqs)
Dibromomethane	74-95-3		0.5							80				80		80	(sw-b)
Dichlorodifluoromethane	75-71-8		0.5							1,600				1,600	12	12	(vi-c)
Methyl ethyl ketone	78-93-3		20							4,800				4,800	3,800,000	4,800	(sw-b)
Methyl iso butyl ketone	108-10-1		20							640				640	1,000,000	640	(wa wqs)
Methylene chloride	75-09-2		2.0				1,000	250	100			0.18		100	11,000	100	(wa wqs)
Pyridine	110-86-1		2.0							8	3,800			8		8	(sw-b)
Styrene	100-42-5		0.5							1,600		16		1,600	18,000	1,600	(sw-b)
trans-1,2-Dichloroethene	156-60-5		0.5				4,000	5,800	400			0.68		400		400	(wa wqs)
Trichloroethene	79-01-6		0.5				7	1	0.7		310	1.7	180,000	0.7	8.4	0.7	(wa wqs)
Trichlorofluoromethane	75-69-4		0.5							2,400				2,400	260	260	(vi-c)

Table 4.4
Groundwater Exposure and Cross-Media Protection Screening Levels for the Selection of COCs

				Groundwater Protective of Surface Water (without attenuation between groundwater and surface water)							Protection of Sediment Quality (without attenuation)[a,b]			Protection of Sediment and Surface Water Quality	Groundwater Protective of Vapor Intrusion[3,c]		
		Modifying Criteria		Protection of Marine Aquatic Species			Protection of Human Health via Fish Consumption[2]										
				Marine Chronic Standards			Marine Consumption of Organism Only										
		Background Groundwater Concentration (µg/L)	Applicable Practical Quantitation Level (PQL)[4] (µg/L)	Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	National Toxics Rule 40 CFR 131.36 (µg/L)	State Standards WAC 173-201A[6] (µg/L)	2015 Ambient Water Quality Criteria Clean Water Act[5] (µg/L)	State Standards WAC 173-201A[6] (µg/L)	Washington Water Quality Standards Clean Water Act 40 CFR 131.45[7] (µg/L)	2017 MTCA Method B Formula WAC 173-340-730[8] (µg/L)	Most Stringent Intertidal Sediment Screening Level from Table 4.3[9] (mg/kg dry wt)	K_d Partitioning Coefficients Based on Harris Sediment f_{oc} of 0.018[10] (L/kg)	Porewater Screening Level Protective of Sediment (µg/L)[11]	Screening Level for Shoreline Groundwater Discharge (µg/L)	2015 MTCA Method C Ecology Guidance Industrial Land Use (µg/L)	Most Stringent Groundwater Screening Level (µg/L)[12]	
Analyte[1]	CAS No.	(back)	(pql)	(mc-cwa)	(mc-ntr)	(mc-wac)	(hh-cwa)	(hh-wac)	(wa wqs)	(sw-b)			(sed)		(vi-c)		
Other VOCs (cont.)																	
Vinyl chloride	75-01-4		0.5				1.6		0.18			0.34		0.18	3.5	0.5	(pql)
Tetrachloroethene	127-18-4		0.5				29	7	2.9		6,800	4.9	1,400,000	2.9	95	2.9	(wa wqs)
Total Petroleum Hydrocarbons (TPH)																	
Gasoline-Range Hydrocarbons	86290-81-5		50	None established. Sediment screening levels are based on individual constituents of petroleum products such as xylene, pyrene, etc.												Gasoline not detected at the Site.	
Diesel-Range Hydrocarbons	68334-30-5		150													Note 21	
Oil-Range Hydrocarbons	TPH-Oil		250													Note 21	

Numerical Criteria Notes:

Blank cells are intentional.

1 Not all analytes are analytes requiring screening levels. Analytes presented in this table were defined in coordination with Ecology, and include analytes with sediment screening levels and analytes that were detected in Site groundwater even if there are no applicable groundwater screening levels. Analytes that have not been detected in Site groundwater and for which there are no applicable screening levels are not included.

2 Human health water quality standards and ambient water quality criteria for cPAHs were developed using then-current toxicity information. In January 2017, IRIS released a new toxicity profile. Updated toxicity information from the new January 2017 IRIS profile was used to revise the most stringent of these criteria (found in 40 CFR 131.45).

3 Groundwater screening levels protective of vapor intrusion are the most restrictive of carcinogenic or non-carcinogenic values presented in Ecology's most recent vapor intrusion guidance (Ecology 2015) and were accessed using the CLARC Tool pulled on April 21, 2017. All values have been rounded to two significant figures.

4 PQL is the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department-approved methods. Values are reported from ALS Environmental (Kelso, Washington) and Analytical Resources, Inc. (Tukwila, Washington).

5 EPA Ambient Water Quality Criteria (AWQCs), Clean Water Act Section 304. National Recommended Water Quality Criteria for Human Health were updated in 2015.

6 Washington Surface Water Quality Standards; WAC 173-201A, Surface Water Quality Criteria.

7 Clean Water Act-Effective Human Health Criteria Applicable to Washington were promulgated under 40 CFR Part 131.36, and were moved into 40 CFR 131.45 to have one comprehensive human health criteria rule for Washington. They became effective on December 28, 2016.

8 In accordance with WAC 173-340-730(3)(b)(iii), if sufficiently protective health-based criteria or standards have not been established under applicable state and federal laws, MTCA Method B values have been developed. MTCA Method B values are most restrictive of carcinogenic or non-carcinogenic values presented in Ecology's Cleanup Levels and Risk Calculation (CLARC) Tool pulled on April 21, 2017. All values have been rounded to two significant figures.

9 Sediment screening levels for the protection of human health are calculated using the equations and input parameters provided by Ecology in their Draft Sediment Cleanup Users Manual (SCUM II; Ecology 2017a). All parameters used in these calculations are Ecology defaults with the exception of site-specific parameters identified and described in Appendix G, Attachment G.1.

10 The Kd Partitioning Coefficients displayed here were either taken directly from CLARC (for metals) or calculated by multiplying the analyte's Koc value by a sediment foc of 0.018. Koc and Kd factors are presented in Appendix G, Attachment G.3.1.; they were rounded to two significant figures.

11 This value takes the most stringent screening level for sediment from Table 4.3 and uses equilibrium partitioning: Cw (porewater) = (sediment screening level in dry wt)/ K_d to develop a screening level for porewater where groundwater is discharging. The value does not consider bioaccumulatives and seafood consumption, which are based on a SWAC throughout the bay. This exposure is based on direct contact with human and benthic organisms along the shoreline.

12 Most stringent of values protective of marine surface water, sediment, and vapor intrusion.

13 State-wide background arsenic concentration from WAC 173-340-900 Table 720-1.

14 The NTR value for copper requires a site-specific water effects ratio (WER). EPA has not established a method for determining a WER for marine waters and has replaced the NTR value with 3.1 ug/L in the NRWQC; Ecology's Water Quality Program uses this value as the minimum ARAR.

15 This value was derived in the document "Ambient Aquatic Life Water Quality Criteria for Mercury" (USEPA 1985). However, it was withdrawn in 1995 with the publication of the "Great Lakes Aquatic Life Criteria Guidelines" (USEPA 1995) in which USEPA revises their approach to the derivation of aquatic life criteria for mercury.

16 Screening levels are applicable to Total PCBs, which are calculated for this site by summing all detected Aroclors (Aroclors that are not detected are not included in the total). If no Aroclors are detected, then the Total PCB value is the greatest detection limit.

17 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

18 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

19 Toxicity factors were developed for individual compounds, but these analytes are analyzed and reported as a sum by the lab. Compliance will be based on compliance with total xylene and ortho-xylene standards.

20 This value has not been revised since 1992. However, the cancer slope factor on which this value is based was withdrawn in 2002.

21 The highest beneficial use of groundwater at the Site is protection of surface water; in surface water, petroleum is regulated through its constituents. LPAHs are the most mobile constituents of diesel and motor oil which are found at the Site and will be used as IHS to evaluate to evaluate risk from TPH in groundwater.

Process Notes:

a If empirical data show that sediments are in compliance with sediment screening level values, it can typically be concluded that the groundwater to sediment pathway is protective and does not require further evaluation.

b Groundwater concentrations that are protective of sediments are calculated using an equilibration partitioning method. Site-specific data (e.g., distribution coefficient [K_d], soil organic carbon water partitioning coefficient [K_{oc}], etc.) can be used to calculate if porewater is protective of sediments. In this table, the equilibrium partitioning equation is used with default parameters and is defined to achieve sediment concentrations protective of benthic species or human health via direct exposure, whichever is the lesser value.

c Values protective of vapor intrusion for an industrial site are from Ecology's Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Revised in 2015. Evaluation of this pathway is appropriate at all sites where volatile contaminants are present, per Ecology guidance.

Abbreviations:

CFR	Code of Federal Regulations
Ecology	Washington State Department of Ecology
FOC	Fraction organic carbon
IHS	Indicator hazardous substances
L/kg	Liters per kilogram
µg/L	Micrograms per liter
mg/kg	Milligrams per kilogram
MTCA	Model Toxics Control Act
Site	Harris Avenue Shipyard
SWAC	Surface Weighted Average Criteria
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
USEPA	U.S. Environmental Protection Agency
WAC	Washington Administrative Code
wt	Weight

Table 4.5
Sample MW-09 Soil Gas Results

Target Aliphatic Hydrocarbon Analytes and Hydrocarbon Ranges	**MTCA Method C Soil Gas Screening Level (µg/m³)** [1]		**Sample MW9-SG-3.5 (µg/m³)**[2]
	Noncancer	**Cancer**	
1,3-Butadiene	67	28	**32 U**[3]
Methyl-tert-butyl-ether (MTBE)	100,000	3,200	32 U
Benzene	1,000	110	32 U
Toluene	170,000	NA	41
Ethylbenzene	33,000	NA	32 U
m- & *p*-Xylenes[4]	3,300	NA	32 U
o-Xylene	3,300	NA	32 U
Naphthalene	100	25	**32 U**
C5–C8 Aliphatic hydrocarbons[5]	200,000	NA	86,000
C9–C12 Aliphatic hydrocarbons[6]	10,000	NA	**36,000**
C9–C10 Aromatic hydrocarbons	13,000	NA	270 U

Notes:

Bold Value is greater than the MTCA Method C screening levels for carcinogens. If a cancer value is not applicable, the noncancer screening level is used.

1 Screening levels are based on the more conservative sub-slab levels, and do not show screening levels for a soil gas sample collected at a depth of 3.5 feet below ground surface. Screening values are from Ecology's April 6, 2015, updated vapor intrusion table, rounded to two significant figures.

2 Detected values are the greater of the concentrations in either the sample or the laboratory duplicate of the sample; detection limits are the lesser of either the sample or the laboratory duplicate.

3 This is a component only found in gasoline; as there is no indication of a gasoline release on-site, there is no reason to suspect this chemical is present at concentrations greater than the MTCA screening levels.

4 There is no MTCA Method C screening level for p-xylene; however, since the laboratory reports m- & p-xylene results as a sum, the summed result for m- & p-xylenes is compared to the m-xylene screening level.

5 These are the C5—C8 aliphatic hydrocarbons excluding the concentration of USEPA Method Target TO-15/APH analytes eluting in that range.

6 These are the C9—C12 aliphatic hydrocarbons excluding the concentration of USEPA Method Target TO-15/APH analytes eluting in that range and the concentration of C9—C10 aromatic hydrocarbons.

Abbreviations:

µg/m³	Micrograms per cubic meter
MTCA	Model Toxics Control Act
N/A	Not applicable
USEPA	U.S. Environmental Protection Agency

Qualifier:

U The analyte was not detected at the given reporting limit

Table 4.6

Soil Exposure and Cross-Media Protection Screening Levels for the Selection of COCs[1,2,3]

Analyte[1]	CAS No.	Modifying Criteria		Soil Protective of Direct Contact by Humans[2,a]	Soil Protective of Groundwater[b,c]			Most Stringent Industrial Soil Screening Level (mg/kg)	
					Level to Protect	Calculated Values			
		Natural Background Concentration (mg/kg)[3]	Practical Quantitation Level (PQL) (mg/kg)[4]	2017 MTCA Method C Industrial Land Use (mg/kg)[5,6,7]	Most Stringent Groundwater Screening Level (µg/L)	Unsaturated Soil Screening Level (mg/kg)[8]	Saturated Soil Screening Level (mg/kg)[9]		
		(back)	*(pql)*	*(mC or gwl-mA for TPH)*	*(Table 4.4)*	*(gwl-u)*	*(gwl-s)*		
Metals									
Antimony	7440-36-0		0.5	1,400	37	33	1.7	1.7	(gwl-s)
Arsenic	7440-38-2	20	0.5	88	5	2.9	0.15	20	(back)
Beryllium	7440-41-7	0.6	0.5	7,000	32	510	25	25	(gwl-s)
Cadmium	7440-43-9	0.77	0.1	3,500	8.8	1.2	0.061	0.77	(back)
Chromium[10]	7440-47-3	48	0.5						
Copper	7440-50-8	36	0.2	140,000	3.1	1.4	0.069	36	(back)
Lead	7439-92-1	24	0.1	1,000	8.1	1,600	81	81	(gwl-s)
Mercury (inorganic)	7439-97-6	0.07	0.025	1,000	0.025	0.026	0.0013	0.07	(back)
Nickel	7440-02-0	38	0.5	70,000	8.2	11	0.54	38	(back)
Selenium	7782-49-2		1	18,000	71	7.4	0.38	1.0	(pql)
Silver	7440-22-4		0.2	18,000	1.9	0.32	0.016	0.2	(pql)
Thallium	7440-28-0		0.5	35	0.2	0.28	0.014	0.5	(pql)
Zinc	7440-66-6	85	1	1,100,000	81	100	5.0	85	(back)
Organometallics									
Butyltin	2406-65-7								
Tetrabutyltin	1461-25-2								
Tributyltin	688-73-3								
Polychlorinated Biphenyls (PCBs)									
Aroclor 1016	12674-11-2		0.033	250	0.03	0.066	0.0033	0.033	(pql)
Aroclor 1221	11104-28-2		0.033						
Aroclor 1232	11141-16-5		0.033						
Aroclor 1242	53469-21-9		0.033						
Aroclor 1254	11097-69-1		0.033	66	0.03	0.49	0.025	0.033	(pql)
Aroclor 1248	12672-29-6		0.033						
Aroclor 1260	11096-82-5		0.033	66	0.03	0.49	0.025	0.033	(pql)
Aroclor 1268	11100-14-4		0.033						
Total PCBs[11]	Total PCBs		0.05	10[5]	0.025	0.16	0.0078	0.05	(pql)
Dioxins/Furans									
Dioxin/Furan TEQ[12]	2,3,7,8-TCDD	0.0000052[13]	0.00000625	0.0017	0.000031	0.00000012	8.9E-09	0.00000625	(pql)
Semivolatile Organic Compounds (SVOCs)									
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)									
cPAH TEQ[14]	Total cPAHs TEF		0.00076	130	0.01	0.19	0.0097	0.0097	(gwl-s)
Benzo(a)pyrene	50-32-8		0.005	130	0.01	0.19	0.0097	0.0097	(gwl-s)
Benz(a)anthracene	56-55-3		0.005	1,300	0.01	0.072	0.0036	0.005	(pql)
Benzo(b)fluoranthene	205-99-2		0.005	1,300	0.01	0.24	0.012	0.012	(gwl-s)
Benzo(k)fluoranthene	207-08-9		0.005	13,000	0.01	0.24	0.012	0.012	(gwl-s)

Table 4.6
Soil Exposure and Cross-Media Protection Screening Levels for the Selection of COCs[1,2,3]

		Modifying Criteria		Soil Protective of Direct Contact by Humans[2,a]	Soil Protective of Groundwater[b,c]				
					Level to Protect	Calculated Values			
Analyte[1]	CAS No.	Natural Background Concentration (mg/kg)[3] *(back)*	Practical Quantitation Level (PQL) (mg/kg)[4] *(pql)*	2017 MTCA Method C Industrial Land Use (mg/kg)[5,6,7] *(mC or gwl-mA for TPH)*	Most Stringent Groundwater Screening Level (µg/L) *(Table 4.4)*	Unsaturated Soil Screening Level (mg/kg)[8] *(gwl-u)*	Saturated Soil Screening Level (mg/kg)[9] *(gwl-s)*	Most Stringent Industrial Soil Screening Level (mg/kg)	
Semivolatile Organic Compounds (SVOCs) (cont.)									
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs) (cont.)									
Chrysene	218-01-9		0.005	130,000	0.01	0.08	0.004	0.005	(pql)
Dibenzo(a,h)anthracene	53-70-3		0.005	130	0.01	0.36	0.018	0.018	(gwl-s)
Indeno(1,2,3-cd)pyrene	193-39-5		0.005	1,300	0.01	0.7	0.035	0.035	(gwl-s)
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)									
1-Methylnaphthalene	90-12-0		0.005	4,500	1.5			4,500	(mC)
2-Methylnaphthalene	91-57-6		0.005	14,000	32			14,000	(mC)
Naphthalene	91-20-3		0.005	70,000	89	2.5	0.13	0.13	(gwl-s)
Acenaphthene	83-32-9		0.005	210,000	5.7	0.58	0.03	0.03	(gwl-s)
Acenaphthylene	208-96-8		0.005						
Anthracene	120-12-7		0.005	1,100,000	2.3	1.1	0.054	0.054	(gwl-s)
Fluorene	86-73-7		0.005	140,000	3.9	0.62	0.031	0.031	(gwl-s)
Phenanthrene	85-01-8		0.005						
Benzo(g,h,i)perylene	191-24-2		0.005						
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)									
Fluoranthene	206-44-0		0.005	140,000	1.9	1.9	0.094	0.094	(gwl-s)
Pyrene	129-00-0		0.005	110,000	2.2	3.0	0.15	0.15	(gwl-s)
Other SVOCs									
1,2,4-Trichlorobenzene	120-82-1		0.02	4,500				4,500	(mC)
1,2-Dichlorobenzene	95-50-1		0.02	320,000	8.7	0.1	0.0058	0.02	(pql)
1,3-Dichlorobenzene	541-73-1		0.02		1.0	0.004	0.00029	0.02	(pql)
2-Chlorophenol	95-57-8		0.02	18,000	17	0.2	0.012	0.02	(gwl-s)
2,3,4,6-Tetrachlorophenol	58-90-2		0.02	110,000	480	4.6	0.27	0.27	(gwl-s)
2,4,5-Trichlorophenol	95-95-4		0.1	350,000	600	22	1.1	1.1	(gwl-s)
2,4,6-Trichlorophenol	88-06-2		0.1	3,500	3	0.035	0.002	0.10	(pql)
2,4-Dichlorophenol	120-83-2		0.1	11,000	6	0.042	0.0026	0.1	(pql)
2,4-Dimethylphenol	105-67-9		0.05	70,000	53	0.43	0.026	0.05	(pql)
2,4-Dinitrotoluene	121-14-2		0.01	420	1	0.0059	0.00038	0.01	(pql)
2,6-Dinitrotoluene	606-20-2		0.01	88	1	0.0054	0.00036	0.01	(pql)
2,4-Dinitrophenol	51-28-5		0.2	7,000	40	0.16	0.011	0.2	(pql)
2-Chloronaphthalene	91-58-7		0.02	280,000	100			280,000	(mC)
2-Methylphenol	95-48-7		0.02	180,000	50	0.29	0.019	0.02	(pql)
2-Nitroaniline	88-74-4		0.1	35,000	160			35,000	(mC)
3,3'-Dichlorobenzidine	91-94-1		0.1	290	5	0.092	0.005	0.1	(pql)
4-Chloro-3-methylphenol	59-50-7		0.1		36				
4-Chloroaniline	106-47-8		0.1	660	5	0.027	0.0018	0.1	(pql)

Table 4.6
Soil Exposure and Cross-Media Protection Screening Levels for the Selection of COCs[1,2,3]

		Modifying Criteria		Soil Protective of Direct Contact by Humans[2,a]	Soil Protective of Groundwater[b,c]				
					Level to Protect	Calculated Values			
Analyte[1]	CAS No.	Natural Background Concentration (mg/kg)[3] *(back)*	Practical Quantitation Level (PQL) (mg/kg)[4] *(pql)*	2017 MTCA Method C Industrial Land Use (mg/kg)[5,6,7] *(mC or gwl-mA for TPH)*	Most Stringent Groundwater Screening Level (µg/L) *(Table 4.4)*	Unsaturated Soil Screening Level (mg/kg)[8] *(gwl-u)*	Saturated Soil Screening Level (mg/kg)[9] *(gwl-s)*	Most Stringent Industrial Soil Screening Level (mg/kg)	
Semivolatile Organic Compounds (SVOCs) (cont.)									
Other SVOCs (cont.)									
4-Methylphenol	106-44-5		0.02	350,000				350,000	(mC)
Aniline	62-53-3		0.1	23,000	7.7			23,000	(mC)
Azobenzene	103-33-3		0.1	1,200	1.0			1,200	(mC)
Benzoic Acid	65-85-0		0.1	14,000,000	64,000	260	18	18	(gwl-s)
Benzyl Alcohol	100-51-6		0.1	350,000	800			350,000	(mC)
Bis(2-chloroethyl) Ether	111-44-4		0.1	120	1.0	0.0055	0.00036	0.1	(pql)
Bis(2-ethylhexyl) Phthalate	117-81-7		0.02	9,400	3.0	6.6	0.33	0.33	(gwl-s)
Butyl benzyl Phthalate	85-68-7		0.2	69,000	1.0	0.28	0.014	0.2	(pql)
Bis(2-chloro-1-methylethyl) ether	108-60-1		0.1	1,900				1,900	(mC)
Dibenzofuran	132-64-9		0.1	3,500	16			3,500	(mC)
Diethylphthalate	84-66-2		0.02	2,800,000	80	0.45	0.029	0.029	(gwl-s)
Dimethyl Phthalate	131-11-3		0.02		200				
Di-n-butyl Phthalate	84-74-2		0.02	350,000	3.0	0.11	0.0057	0.02	(pql)
Di-n-octyl phthalate	117-84-0		0.02	35,000	1.0	1700	83	83	(gwl-s)
Hexachlorobenzene	118-74-1		0.02	82	1.0	1.6	0.08	0.08	(gwl-s)
Hexachlorobutadiene	87-68-3		0.02	1,700	3.0	3.3	0.16	0.16	(gwl-s)
Hexachlorocyclopentadiene	77-47-4		0.02	21,000	5.0	20	1.0	1.0	(gwl-s)
Hexachloroethane	67-72-1		0.02	2,500	2.0	0.081	0.0042	0.02	(pql)
Isophorone	78-59-1		0.1	140,000	200	1.0	0.067	0.10	(pql)
Nitrobenzene	98-95-3		0.02	7,000	60	0.38	0.024	0.024	(gwl-s)
N-Nitrosodimethylamine	62-75-9		0.02	2.6	0.34			2.6	(mC)
N-Nitroso-di-n-propylamine	621-64-7		0.02	19	1.0	0.0045	0.00031	0.02	(pql)
N-Nitrosodiphenylamine	86-30-6		0.1	27,000	1.0	0.03	0.0016	0.1	(pql)
Pentachlorophenol	87-86-5		0.1	330	10	0.16	0.0088	0.1	(pql)
Phenol	108-95-2		0.02	1,100,000	1,600	7.3	0.51	0.51	(gwl-s)
Volatile Organic Compounds (VOCs) Associated with Diesel- and Oil-Range TPH									
Benzene	71-43-2		0.005	2,400	1.6	0.009	0.00056	0.005	(pql)
Ethylbenzene	100-41-4		0.005	350,000	13	0.11	0.0063	0.0063	(gwl-s)
Toluene	108-88-3		0.005	280,000	52	0.38	0.022	0.022	(gwl-s)
Xylene (meta & para)[15]	179601-23-1		0.005						
Xylene (ortho)	95-47-6		0.005	700,000	960	8.8	0.51	0.51	(gwl-s)
Xylene (total)	1330-20-7		0.02	700,000	1,600	15	0.83	0.83	(gwl-s)
1,3,5-Trimethylbenzene	108-67-8		0.02	35,000	80			35,000	(mC)
Iso-propylbenzene	98-82-8		0.02	350,000	800			350,000	(mC)
n-Propylbenzene	103-65-1		0.02	350,000	800			350,000	(mC)

Table 4.6
Soil Exposure and Cross-Media Protection Screening Levels for the Selection of COCs[1,2,3]

		Modifying Criteria		Soil Protective of Direct Contact by Humans[2,a]	Soil Protective of Groundwater[b,c]				
					Level to Protect	Calculated Values			
		Natural Background Concentration (mg/kg)[3]	Practical Quantitation Level (PQL) (mg/kg)[4]	2017 MTCA Method C Industrial Land Use (mg/kg)[5,6,7]	Most Stringent Groundwater Screening Level (µg/L)	Unsaturated Soil Screening Level (mg/kg)[8]	Saturated Soil Screening Level (mg/kg)[9]	Most Stringent Industrial Soil Screening Level (mg/kg)	
Analyte[1]	**CAS No.**	*(back)*	*(pql)*	*(mC or gwl-mA for TPH)*	*(Table 4.4)*	*(gwl-u)*	*(gwl-s)*		
Other VOCs									
1,1,1,2-Tetrachloroethane	630-20-6		0.005	5,000	1.7			5,000	(mC)
1,1,1-Trichloroethane	71-55-6		0.005	7,000,000	11,000	88	4.7	4.7	(gwl-s)
1,1,2 - Trichlorotrifluoroethane	76-13-1		0.005	110,000,000				110,000,000	(mC)
1,1,2,2-Tetrachloroethane	79-34-5		0.005	660	0.5	0.0028	0.00018	0.005	(pql)
1,1,2-Trichloroethane	79-00-5		0.005	2,300	0.9	0.005	0.00033	0.005	(pql)
1,1-Dichloroethane	75-34-3		0.005	23,000	7.7	0.042	0.0026	0.005	(pql)
1,1-Dichloroethene	75-35-4		0.005	180,000	280	2.0	0.098	0.098	(gwl-s)
1,2,3-Trichloropropane	96-18-4		0.005	4.4	0.5			4.4	(mC)
1,2-Dibromoethane (EDB)	106-93-4		0.02	66	2	0.011	0.00071	0.02	(pql)
1,2-Dichloroethane (EDC)	107-06-2		0.005	1,400	42	0.2	0.014	0.014	(gwl-s)
1,2-Dichloropropane	78-87-5		0.005	3,600	3.3	0.017	0.0011	0.005	(pql)
1,2-Dibromo-3-chloropropane	96-12-8		0.02	160	2			160	(mC)
2-Chlorotoluene	95-49-8		0.02	70,000	2			70,000	(mC)
1,4-Dichlorobenzene	106-46-7		0.02	24,000	10	0.17	0.0091	0.02	(pql)
Acetone	67-64-1		0.02	3,200,000	7,200	29	2.1	2.1	(mC)
Acrolein	107-02-8		0.1	1,800				1,800	(mC)
Acrylonitrile	107-13-1		0.02	240				240	(mC)
bis(2-chloroisopropyl)ether	39638-32-9		0.1		65,000	260	19	19	(gwl-s)
Bromodichloromethane	75-27-4		0.005	2,100	2.8	0.015	0.00096	0.005	(pql)
Bromoform	75-25-2		0.005	17,000	12	0.08	0.005	0.005	(gwl-s)
Bromomethane	74-83-9		0.005	4,900	28	0.13	0.0083	0.0083	(gwl-s)
Carbon Tetrachloride	56-23-5		0.005	1,900	0.5	0.0046	0.00022	0.005	(pql)
Carbon Disulfide	75-15-0		0.005	350,000	800	5.6	0.27	0.27	(gwl-s)
Chlorobenzene	108-90-7		0.005	70,000	80	0.69	0.041	0.041	(gwl-s)
Chloroform	67-66-3		0.005	4,200	12	0.064	0.0041	0.005	(pql)
Chloromethane	74-87-3		0.005		330	1.4	0.097	0.097	(gwl-s)
cis-1,2-Dichloroethene (DCE)	156-59-2		0.005	7,000	16	0.08	0.0052	0.0052	(gwl-s)
Dibromochloromethane	124-48-1		0.005	1,600	2.2	0.012	0.00077	0.005	(pql)
Dibromomethane	74-95-3		0.005	35,000	80			35,000	(mC)
Dichlorodifluoromethane	75-71-8		0.005	700,000	12			700,000	(mC)
Methyl Ethyl Ketone	78-93-3		0.02	2,100,000	4,800			2,100,000	(mC)
Methyl Iso Butyl Ketone	108-10-1		0.02	280,000	640			280,000	(mC)
Methyl-tert-butyl ether	1634-04-4		0.05	73,000	24	0.1	0.0071	0.05	(pql)
Methylene chloride	75-09-2		0.01	21,000	100	0.44	0.03	0.03	(gwl-s)
Pyridine	110-86-1			3,500	8			3,500	(mC)
Styrene	100-42-5		0.005	700,000	1,600	36	1.9	1.9	(gwl-s)

Table 4.6

Soil Exposure and Cross-Media Protection Screening Levels for the Selection of COCs[1,2,3]

		Modifying Criteria		Soil Protective of Direct Contact by Humans[2,a]	Soil Protective of Groundwater[b,c]				
					Level to Protect	Calculated Values			
		Natural Background Concentration (mg/kg)[3]	Practical Quantitation Level (PQL) (mg/kg)[4]	2017 MTCA Method C Industrial Land Use (mg/kg)[5,6,7]	Most Stringent Groundwater Screening Level (µg/L)	Unsaturated Soil Screening Level (mg/kg)[8]	Saturated Soil Screening Level (mg/kg)[9]	Most Stringent Industrial Soil Screening Level (mg/kg)	
Analyte[1]	**CAS No.**	*(back)*	*(pql)*	*(mC or gwl-mA for TPH)*	*(Table 4.4)*	*(gwl-u)*	*(gwl-s)*		
Other VOCs (cont.)									
trans-1,2-Dichloroethene	156-60-5		0.005	70,000	400	2.2	0.13	0.13	(gwl-s)
Trichloroethene	79-01-6		0.005	1,800	0.7	0.0046	0.00027	0.005	(pql)
Trichlorofluoromethane	75-69-4		0.005	1,100,000	260			1,100,000	(mC)
Vinyl Acetate	108-05-4		0.02	3,500,000				3,500,000	(mC)
Vinyl Chloride	75-01-4		0.005	88	0.5	0.0031	0.00015	0.005	(pql)
Tetrachloroethene	127-18-4		0.005	21,000	2.9	0.031	0.0016	0.005	(pql)
Total Petroleum Hydrocarbons (TPH)									
Gasoline-Range Hydrocarbons	86290-81-5		5	MTCA Method A values are defined for the protection of drinking water, not for direct contact, and are not relevant here.			100	100	(gwl-s)
Diesel-Range Hydrocarbons	68334-30-5		25				2,000	2,000	(gwl-s)
Oil-Range Hydrocarbons	TPH-Oil		100				2,000	no free product	
Site-Specific TPH (EPH/VPH)	TPH-Harris		25	24,000	250		8,000	8,000	(gwl-s)

Numerical Criteria Notes:

Blank cells are intentional.

1 Not all analytes are analytes requiring screening levels. Analytes presented in this table were defined in coordination with Ecology, and include analytes detected in Site soils even if there are no applicable soil screening levels. Analytes that have not been detected at the Site and for which there are no applicable screening levels are not included.

2 Direct contact criteria applicable for soils to 15-foot depth.

3 Values are specific to Puget Sound and are from Ecology's Natural Background Soil Metals Concentrations in Washington State (Ecology 1994), with the exception of arsenic; for arsenic, MTCA established 20 mg/kg as background (WAC 173-340-900 Table 740-1, Footnote b).

4 PQL is the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department-approved methods. Values are reported from ALS Environmental (Kelso, Washington) and Analytical Resources, Inc. (Tukwila, Washington). Blank cells indicate the laboratories did not provide a quantitative PQL.

5 The MTCA Method C value for Total PCBs has been replaced by the lesser Federal ARAR of 10 mg/kg for an industrial-type site. The MTCA Method C value for mercury is based on mercuric chloride as the potential source of mercury at a shipyard would be from paints containing inorganic mercury.

6 Because site groundwater is not potable, many MTCA Method A soil cleanup levels are not applicable. MTCA Method A industrial cleanup levels are used only if there are no corresponding MTCA Method C direct contact values (as for lead). Soil leachability to groundwater is addressed separately. MTCA Method A values for diesel- and oil-range TPH are based on accumulation of free product, not direct contact, and are not relevant.

7 MTCA Method C values are most restrictive of carcinogenic or non-carcinogenic values presented in Ecology's CLARC Tool pulled on April 21, 2017. As the CLARC Tool does not report a value for vinyl chloride, the MTCA C Industrial value reported here was taken from Ecology guidance (https://fortress.wa.gov/ecy/clarc/FocusSheets/VinylChloride.pdf). All values have been rounded to two significant figures.

8 Calculated values from three-phase model, per MTCA Equation 747-1, with groundwater value (C_w) as most stringent value from groundwater screening level process (Table 4.3), and Dilution Factor = 20. K_d are the same as shown in Table 4.4.

9 Calculated values from three-phase model, per MTCA Equation 747-1, with groundwater value (C_w) as most stringent value from groundwater screening level process (Table 4.3), and Dilution Factor = 1. K_d are the same as shown in Table 4.4.

10 There are no standards for total chromium. Cr(VI) is not stable under normal soil conditions and no K_d has been used for Cr(VI) partitioning between media; Cr(III) is stable and its K_d could be used, but it is not an analyte of interest due to its low toxicity.

11 Screening levels are applicable to Total PCBs, which are calculated for this site by summing all detected Aroclors (Aroclors that are not detected are not included in the total). If no Aroclors are detected, then the Total PCB value is the greatest detection limit.

12 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

13 Value from Dave Bradley's Natural Background for Dioxins/Furans in Washington Soils—Technical Memorandum #8 (Ecology 2010).

14 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

15 Toxicity is developed for individual compounds but these values are analyzed as a sum by the lab. Compliance with screening levels and cleanup levels will be based on compliance with total xylene and ortho-xylene standards.

Process Notes:

a Appropriate screening levels for the protection of human health through direct contact with soil pathway are based on a site's land use category (i.e., unrestricted or industrial). The point of compliance is established from the ground surface to 15 feet below ground surface only. This represents a reasonable estimate of the depth of soil that could be excavated during typical site activities (WAC 173-340-740(6)(d)).

b Under WAC 173-340-747(3)(e), if empirical site-specific groundwater data are available, they may be used to show that measured soil concentrations are protective of groundwater and will not cause an exceedance of the applicable groundwater cleanup level criteria.

c Soil concentrations that are protective of groundwater are calculated using either of the methods listed in WAC 173-340-747(3). Concentrations may be derived from either saturated or unsaturated soil. The fixed parameter three-phase partitioning model is used with default parameters.

Abbreviations:

ARAR	Applicable or Relevant and Appropriate Requirement
BTEX	Benzene, toluene, ethylbenzene, and xylene
CAS	Chemical Abstracts Service
CLARC	Cleanup Levels and Risk Calculation
Ecology	Washington State Department of Ecology
EPH/VPH	Extractable petroleum hydrocarbon/volatile petroleum hydrocarbon
mg/kg	Milligrams per kilogram
MTCA	Model Toxics Control Act
Site	Harris Avenue Shipyard
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
WAC	Washington Administrative Code

Table 4.7
Frequency of Detection and Maximum Concentrations Detected in Sediment

Analyte[1]	CAS No.	Screening Level[2]	Units	Number of Results[3]	Number Detected	Percent Detected	Minimum Detected Value	Maximum Detected Value	Location of Maximum Detect	Date of Maximum Detect	Percent of Detected Results Exceeding Criteria	Exceedance Factor[4]	Retain as COPC?[5]	Comment
Bioaccumulatives[6]														
Arsenic	7440-38-2	11	mg/kg	53	39	74%	3.8	158	HG-42	8/23/2000	53%	14	Yes	All bioaccumulatives retained as COPCs are discussed in detail in Appendix G, Attachment G.1, which screens the data against a more complex set of criteria. Those that are retained in Appendix G, Attachment G.1 are then discussed and displayed on maps in Section 5.0.
Cadmium	7440-43-9	0.8	mg/kg	51	36	1%	0.3	3.6	HG-12	3/24/1998	41%	4.5	Yes	
Lead	7439-92-1	16	mg/kg	51	51	100%	8	580	HA-07	3/22/2011	88%	36	Yes	
Mercury	7439-97-6	1.2	mg/kg	61	55	90%	0.014	0.51	HV-6	3/26/1998	None	None	No	
Total PCBs[7]	Total PCBs	0.0055	mg/kg dry wt	59	39	66%	0.0053	1.8	HG-4	3/24/1998	64%	330	Yes	
Dioxins/Furans TEQ[8]	2,3,7,8-TCDD	0.000005	mg/kg dry wt	5	5	100%	0.00000532	0.0000356	SG-06	1/31/2013	100%	7.1	Yes	
cPAH TEQ[9]	Total cPAHs TEF	0.021	mg/kg dry wt	46	42	91%	0.017	2.4	HG-30	8/22/2000	89%	110	Yes	
Pyrene	129-00-0	14	mg/kg dry wt	46	41	89%	0.02	6.4	HG-30	8/22/2000	None	None	No	
Metals														
Antimony	7440-36-0	1,500	mg/kg	30	7	23%	4	21	HG-42	8/23/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
Arsenic	7440-38-2	11	mg/kg	53	39	74%	3.8	158	HG-42	8/23/2000	53%	14	Yes	
Cadmium	7440-43-9	5.1	mg/kg	51	36	71%	0.3	3.6	HG-12	3/24/1998	None	None	No	Not retained; bioaccumulative effects are evaluated separately; refer to comment above on bioaccumulatives.
Copper	7440-50-8	390	mg/kg	51	51	100%	24	959	HG-38	8/22/2000	18%	2.5	Yes	
Lead	7439-92-1	450	mg/kg	51	51	100%	8	580	HA-07	3/22/2011	3.9%	1.3	Yes	
Mercury	7439-97-6	0.41	mg/kg	61	55	90%	0.014	0.51	HV-6	3/26/1998	4.9%	1.2	Yes	
Nickel	7440-02-0	140	mg/kg	44	44	100%	9	105	HG-16	3/24/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Silver	7440-22-4	6.1	mg/kg	51	7	14%	0.5	0.72	HA-02	3/16/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Zinc	7440-66-6	410	mg/kg	51	51	100%	37	1,620	HG-42	8/23/2000	18%	4.0	Yes	
Organometallics														
Tributyltin[10]	688-73-3	1,100	mg/kg dry wt	16	10	63%	0.0045	0.32	SG-04	7/28/2011	None	None	No	Not retained; maximum detected value is less than the screening level.[10]
Polychlorinated Biphenyls														
Aroclor 1242	53469-21-9	2.1	mg/kg dry wt	59	1	1.7%	0.0053	0.0053	HA-03	3/16/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Aroclor 1254	11097-69-1	2.1	mg/kg dry wt	59	34	58%	0.0026	1.8	HG-4	3/24/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Aroclor 1260	11096-82-5	2.1	mg/kg dry wt	59	19	32%	0.003	0.7	HV-4	3/26/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Total PCBs[7]	Total PCBs	0.13	mg/kg dry wt	59	39	66%	0.0053	1.8	HG-4	3/24/1998	15%	14	Yes	Retained for benthic; bioaccumulative effects are evaluated separately; refer to comment above on bioaccumulatives.
Dioxins/Furans														
Dioxin/Furan TEQ[8]	2,3,7,8-TCDD	0.000062	mg/kg dry wt	5	5	100%	0.00000532	0.0000356	SG-06	1/31/2013	None	None	No	Bioaccumulative effects are evaluated separately; refer to comment above on bioaccumulatives.
Semivolatile Organic Compounds (SVOCs)														
Carcinogenic Polycyclic Aromatic Hydrocarbons														
cPAH TEQ[9]	Total cPAHs TEF	4.2	mg/kg dry wt	46	42	91%	0.017	2.4	HG-30	8/22/2000	None	None	No	Not retained; bioaccumulative effects are evaluated separately; refer to comment above on bioaccumulatives.
Benzo(a)pyrene	50-32-8	1.6	mg/kg dry wt	46	40	87%	0.011	1.8	HG-30	8/22/2000	2.2%	1.1	Yes	
Benz(a)anthracene	56-55-3	1.3	mg/kg dry wt	46	40	87%	0.011	2.0	HG-30	8/22/2000	4.4%	1.5	Yes	
Benzo(b)fluoranthene	205-99-2	42	mg/kg dry wt	35	29	83%	0.040	1.6	HG-30	8/22/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
Benzo(k)fluoranthene	207-08-9	420	mg/kg dry wt	35	29	83%	0.047	1.5	HG-30	8/22/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
Benzofluoranthenes (total)	Total Benzo.	3.2	mg/kg dry wt	39	33	85%	0.031	3.6	HG-30	8/22/2000	2.6%	1.1	Yes	
Chrysene	218-01-9	1.4	mg/kg dry wt	46	42	91%	0.015	2.3	SG-08	1/31/2013	6.5%	1.6	Yes	
Dibenzo(a,h)anthracene	53-70-3	0.23	mg/kg dry wt	46	29	63%	0.004	0.26	SG-08	1/31/2013	2.2%	1.1	Yes	
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	mg/kg dry wt	46	37	80%	0.011	0.74	HG-30 SG-08	8/22/2000 1/31/2013	4.4%	1.2	Yes	
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs) (may be used as Indicator Hazardous Substances for TPH)														
Total LPAH[11]	Total LPAHs	5.2	mg/kg dry wt	46	40	87%	0.093	4.2	HG-42	8/23/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
1-Methylnaphthalene	90-12-0	140	mg/kg dry wt	19	9	47%	0.013	0.48	SG-04	7/28/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
2-Methylnaphthalene	91-57-6	0.67	mg/kg dry wt	46	28	61%	0.018	0.77	SG-04	7/28/2011	2.2%	1.1	Yes	
Naphthalene	91-20-3	2.1	mg/kg dry wt	46	33	72%	0.022	0.41	SG-10	1/31/2013	None	None	No	Not retained; maximum detected value is less than the screening level.

Table 4.7
Frequency of Detection and Maximum Concentrations Detected in Sediment

Analyte[1]	CAS No.	Screening Level[2]	Units	Number of Results[3]	Number Detected	Percent Detected	Minimum Detected Value	Maximum Detected Value	Location of Maximum Detect	Date of Maximum Detect	Percent of Detected Results Exceeding Criteria	Exceedance Factor[4]	Retain as COPC?[5]	Comment
Semivolatile Organic Compounds (SVOCs) (cont.)														
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs) (may be used as Indicator Hazardous Substances for TPH) (cont.)														
Acenaphthene	83-32-9	0.50	mg/kg dry wt	46	29	63%	0.014	0.22	HG-42	8/23/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
Acenaphthylene	208-96-8	1.3	mg/kg dry wt	46	22	48%	0.015	0.31	HG-30	8/22/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
Anthracene	120-12-7	0.96	mg/kg dry wt	46	37	80%	0.022	0.97	HG-39	8/22/2000	2.2%	1.0	Yes	
Fluorene	86-73-7	0.54	mg/kg dry wt	46	31	67%	0.022	0.42	HG-39	8/22/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
Phenanthrene	85-01-8	1.5	mg/kg dry wt	46	40	87%	0.059	2.8	HG-42	8/23/2000	4.4%	1.9	Yes	
High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)														
Total HPAH[12]	Total HPAH	12	mg/kg dry wt	46	42	91%	0.1	23	HG-30	8/22/2000	6.5%	1.9	Yes	
Benzo(g,h,i)perylene	191-24-2	0.67	mg/kg dry wt	46	36	78%	0.0094	0.79	SG-08	1/31/2013	2.2%	1.2	Yes	
Fluoranthene	206-44-0	1.7	mg/kg dry wt	46	41	89%	0.024	5.9	HG-30	8/22/2000	11%	3.5	Yes	
Pyrene	129-00-0	2.6	mg/kg dry wt	46	41	89%	0.02	6.4	HG-30	8/22/2000	6.5%	2.5	Yes	
Other SVOCs														
1,2-Dichlorobenzene	95-50-1	0.06	mg/kg dry wt	37	2	5.4%	0.0026	0.0029	SG-07	1/31/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
2,4-Dimethylphenol	105-67-9	0.2	mg/kg dry wt	44	6	14%	0.0045	0.031	HG-30	8/22/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
2-Methylphenol	95-48-7	0.08	mg/kg dry wt	44	5	11%	0.0038	0.024	SG-09	1/31/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
4-Methylphenol	106-44-5	0.67	mg/kg dry wt	36	31	86%	0.02	0.56	HG-18	3/23/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Benzoic acid	65-85-0	1.0	mg/kg dry wt	44	2	4.6%	0.15	0.25	SG-13	1/31/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Benzyl alcohol	100-51-6	0.2	mg/kg dry wt	44	9	20%	0.027	0.31	HG-32	8/31/2000	2.3%	1.6	Yes	
Bis(2-ethylhexyl) Phthalate	117-81-7	1.3	mg/kg dry wt	44	30	68%	0.024	2.4	HG-30	8/22/2000	4.6%	1.8	Yes	
Butyl benzyl Phthalate	85-68-7	0.09	mg/kg dry wt	44	9	20%	0.0036	1.5	HG-10	3/24/1998	4.6%	17	Yes	
Dibenzofuran	132-64-9	0.54	mg/kg dry wt	46	30	65%	0.026	0.17	SG-05	1/31/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Diethylphthalate	84-66-2	0.2	mg/kg dry wt	44	1	2.3%	0.065	0.065	HB-2	7/24/2003	None	None	No	Not retained; maximum detected value is less than the screening level.
Dimethyl Phthalate	131-11-3	0.08	mg/kg dry wt	44	12	27%	0.0082	0.076	HG-16	3/24/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Di-n-butyl Phthalate	84-74-2	1.4	mg/kg dry wt	44	6	14%	0.021	0.045	HG-44	11/9/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
N-Nitrosodiphenylamine	86-30-6	0.06	mg/kg dry wt	44	4	9.1%	0.0025	0.014	SG-08	1/31/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Pentachlorophenol	87-86-5	0.36	mg/kg dry wt	44	6	14%	0.017	0.21	HG-33	8/31/2000	None	None	No	Not retained; maximum detected value is less than the screening level.
Phenol	108-95-2	0.82	mg/kg dry wt	44	18	41%	0.021	0.5	SG-04	7/28/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Volatile Organic Compounds (VOCs)														
1,4-Dichlorobenzene	106-46-7	0.11	mg/kg dry wt	37	5	14%	0.0024	0.014	SG-08	1/31/2013	None	None	No	Not retained; maximum detected value is less than the screening level.

Notes:

Yes Indicates that constituent was retained as a COPC.

1 This table includes only those analytes that were detected at the Site. Information about non-detect results can be found in Appendix C, Attachment C.4.

2 Screening levels for all analytes of interest were developed and presented in Table 4.3 and are based on the lower of the screening levels for protection of benthic and human health. This table compares site data to the screening levels developed for sediment analytes of interest.

3 Only sediment samples collected prior to January 1, 2013, with a sampled depth interval falling between 0–12 cm were considered part of the data set. Field samples and field duplicate results are counted as unique results. Location REF-1 was excluded.

4 The exceedance factor is calculated by dividing the maximum detected value by the screening level. Only values greater than one (indicating an exceedance of the screening level) are displayed. Exceedance factors have been rounded to two significant digits.

5 If the exceedance factor was ≤ 2 and percent detected was ≤ 5%, the constituent was eliminated as a COPC.

6 For bioaccumulatives, the screening level is the sediment cleanup objective identified in Appendix G, Attachment G.1. This is the greatest value of (1) natural background, (2) risk-based calculated values, and (3) Practical Quantitation Limit.

7 Screening levels are applicable to Total PCBs, which are calculated for this site by summing all detected Aroclors (Aroclors that are not detected are not included in the total). If no Aroclors are detected, then the Total PCB value is the greatest detection limit.

8 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

9 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

10 Historical TBT porewater concentrations were also compared against the recommended porewater screening level of 0.05 µg/L, described in Section 4.1.2. Comparison against this screening level is consistent with the approach presented in the Squalicum Harbor TBT Investigation conducted by Ecology in 2007. Based on the porewater data available (RETEC 1998a and 2004), TBT was not retained as a COPC for the protection of benthic species. Porewater concentrations were analyzed during three sampling events by RETEC. In total, RETEC has analyzed 16 porewater samples for TBT between 1998 and 2004. RETEC concluded in their Sediment RI/FS (RETEC 2004) that TBT is not a COPC at the Site because all porewater concentrations were less than the recommended screening level of 0.05 µg/L.

11 Total LPAH is the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.

12 Total HPAH is the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzofluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

Abbreviations:

CAS	Chemical Abstracts Service	PCB	Polychlorinated biphenyl	TEF	Toxic equivalent factor
COPC	Contaminant of potential concern	RETEC	The RETEC Group	TEQ	Toxic equivalent
cPAH	Carcinogenic polycyclic aromatic hydrocarbon	RI/FS	Remedial Investigation/Feasibility Study	TPH	Total petroleum hydrocarbon
Ecology	Washington State Department of Ecology	Site	Harris Avenue Shipyard	WAC	Washington Administrative Code
µg/L	Micrograms per liter	TBT	Tributyltin	wt	Weight
mg/kg	Milligrams per kilogram	TCDD	Tetrachlorodibenzodioxin		

Table 4.8

Frequency of Detection and Maximum Concentrations Detected in Groundwater[1]

Analyte	CAS No.	Screening Level[2]	Units	Number of Results[3]	Percent Detected	Maximum Detected Value	Location of Maximum Detect	Date of Maximum Detect	Percent of Detected Results Exceeding Criteria	Exceedance Factor[4]	Retain as COPC?[5]	Comment
Dissolved Metals												
Antimony	7440-36-0	37	µg/L	11	100%	1.99	MW-02A	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Arsenic	7440-38-2	5	µg/L	62	97%	29	MW-01	7/29/2011	44%	5.8	Yes	
Cadmium	7440-43-9	8.8	µg/L	29	31%	0.276	MW-02A	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Chromium	7440-47-3	--	µg/L	29	48%	2.9	MW-05	7/29/2011	None	None	No	Not retained; no screening level.
Copper	7440-50-8	2.4	µg/L	62	73%	13.1	MW-12	12/3/2015	31%	5.5	Yes	
Lead	7439-92-1	8.1	µg/L	29	24%	4	MW-02A	3/23/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Nickel	7440-02-0	8.2	µg/L	29	93%	19	MW-02A	3/23/2011	14%	2.3	Yes	
Selenium	7782-49-2	71	µg/L	11	36%	0.396	MW-04	2/14/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Silver	7440-22-4	1.9	µg/L	29	14%	0.0164	MW-02A	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Thallium	7440-28-0	0.2	µg/L	11	73%	0.0147	MW-02A	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Zinc	7440-66-6	81	µg/L	62	34%	387	MW-12	8/27/2015	13%	4.8	Yes	
Total Metals												
Mercury (inorganic)	7439-97-6	0.15	µg/L	11	73%	0.035	MW-05	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Semivolatile Organic Compounds (SVOCs)												
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)												
cPAH TEQ[6]	Total cPAHs TEF	0.01	µg/L	63	12.7%	0.032	MW-01	2/15/2013	4.8%	3.2	Yes	Detected in less than 5% of samples, but at more than 2 times the screening level.
Benzo(a)pyrene	50-32-8	0.01	µg/L	62	8.1%	0.028	MW-01	2/15/2013	3.2%	2.8	No	These will be included in the cPAH TEQ, which is being retained. They will not be retained individually.
Benz(a)anthracene	56-55-3	0.01	µg/L	62	3.2%	0.027	MW-01	12/3/2015	3.2%	2.7	No	
Benzofluoranthenes (total)[7]	Total Benzo.	--	µg/L	52	3.8%	0.024	MW-11	12/3/2015	None	None	No	
Chrysene	218-01-9	0.01	µg/L	62	11.3%	0.023	MW-11	12/3/2015	3.2%	2.3	No	
Dibenzo(a,h)anthracene	53-70-3	0.01	µg/L	62	1.6%	0.012	MW-01	2/15/2013	1.6%	1.2	No	
Indeno(1,2,3-cd)pyrene	193-39-5	0.01	µg/L	62	3.2%	0.0087	MW-01	2/15/2013	None	None	No	
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs) (Indicator Hazardous Substances for TPH)												
1-Methylnaphthalene	90-12-0	1.5	µg/L	65	57%	93	MW-01	2/15/2013	26%	62	Yes	
2-Methylnaphthalene	91-57-6	32	µg/L	62	50%	67	MW-01	2/15/2013	3.2%	2.1	Yes	Detected in less than 5% of samples, but at more than 2 times the screening level.
Naphthalene	91-20-3	89	µg/L	65	54%	18	MW-01	12/3/2015	None	None	No	Not retained; maximum detected value is less than the screening level.
Acenaphthene	83-32-9	5.7	µg/L	62	50%	35	MW-01	12/3/2015	8.1%	6.1	Yes	
Acenaphthylene	208-96-8	--	µg/L	62	26%	0.41	MW-01	8/27/2015	None	None	No	
Anthracene	120-12-7	2.3	µg/L	62	44%	0.44	MW-01	12/3/2015	None	None	No	Not retained; maximum detected value is less than the screening level.
Fluorene	86-73-7	3.9	µg/L	62	45%	17	MW-01	12/3/2015	8.1%	4.4	Yes	
Phenanthrene	85-01-8	--	µg/L	62	35%	10	MW-01	3/23/2011	None	None	No	
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)												
Benzo(g,h,i)perylene	191-24-2	--	µg/L	62	2%	0.0054	MW-11	12/3/2015	None	None	No	Not retained; no screening level.
Fluoranthene	206-44-0	1.9	µg/L	62	31%	1.3	MW-01	12/3/2015	None	None	No	Not retained; maximum detected value is less than the screening level.
Pyrene	129-00-0	2.2	µg/L	62	31%	0.68	MW-01	12/3/2015	None	None	No	Not retained; maximum detected value is less than the screening level.

Table 4.8
Frequency of Detection and Maximum Concentrations Detected in Groundwater[1]

Analyte	CAS No.	Screening Level[2]	Units	Number of Results[3]	Percent Detected	Maximum Detected Value	Location of Maximum Detect	Date of Maximum Detect	Percent of Detected Results Exceeding Criteria	Exceedance Factor[4]	Retain as COPC?[5]	Comment
SVOCs (cont.)												
Other SVOCs												
Bis(2-ethylhexyl) Phthalate	117-81-7	3	µg/L	28	3.6%	2.8	MW-02A	2/15/2013	None	None	No	Retained at Ecology's request for further evaluation in newly installed wells MW-11 and MW-12; it was non-detect during four quarters of additional monitoring, and therefore has not been retained as a COPC.
Carbazole	86-74-8	--	µg/L	28	21%	49	MW-01	2/15/2013	None	None	No	Not retained; no screening level.
Dibenzofuran	132-64-9	16	µg/L	62	45%	11	MW-01	12/3/2015	None	None	No	Not retained; maximum detected value is less than the screening level.
Di-n-butyl Phthalate	84-74-2	3	µg/L	28	3.6%	3.3	MW-02A	2/15/2013	3.6%	1.1	No	Fewer than 5% detections; maximum detection less than 2 times the screening level.
m,p-Cresol (2:1 ratio)	15831-10-4	--	µg/L	28	3.6%	40	MW-06	7/29/2011	None	None	No	Not retained; no screening level.
Volatile Organic Compounds (VOCs) Associated with TPH												
Xylenes (meta & para)	108-38-3/106-42-3	--	µg/L	31	3.2%	2.1	MW-01	3/23/2011	None	None	No	Not retained; no screening level. Compliance assessed using total xylenes.
Xylenes (total)	1330-20-7	1,600	µg/L	28	3.6%	2.1	MW-01	3/23/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Iso-Propylbenzene	98-82-8	800	µg/L	28	21%	3.1	MW-01	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
n-Butylbenzene	104-51-8	400	µg/L	28	14%	8.6	MW-01	7/29/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
n-Propylbenzene	103-65-1	800	µg/L	28	11%	2.7	MW-01	3/23/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
sec-Butylbenzene	135-98-8	800	µg/L	28	14%	2.1	MW-09	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Other VOCs												
Acetone	67-64-1	7,200	µg/L	28	29%	14	MW-01	7/29/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Chlorobenzene	108-90-7	80	µg/L	28	11%	3.3	MW-09	2/15/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Chloroform	67-66-3	12	µg/L	28	7.1%	1.2	MW-01 MW-08	7/29/2011 7/29/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Cymene	99-87-6	--	µg/L	28	21%	120	MW-06	7/29/2011	None	None	No	Not retained; no screening level.
Methylene chloride	75-09-2	100	µg/L	28	25%	2.5	MW-02A	7/29/2011	None	None	No	Not retained; maximum detected value is less than the screening level.

Notes:

Yes Indicates that constituent was retained as a COPC.

1 This table includes only those analytes that were detected at the Site. Information about non-detect results can be found in Appendix C, Attachment C.5.

2 Screening levels for all analytes of interest were developed and presented in Table 4.4. This table compares site data to the screening levels developed for groundwater analytes of interest; however, this analysis does not include TPH. Though TPH was retained as an analyte of interest, compliance with screening levels and cleanup levels is semi-qualitative and should not be evaluated using strict quantitative methods, as performed in this table. TPH is evaluated relative to applicable screening levels and cleanup levels in Appendix G, Attachment G.2.

3 Only groundwater samples from wells that were collected from January 2009 to December 2015 were considered part of the data set. Field samples and field duplicate results are counted as unique results.

4 The exceedance factor is calculated by dividing the maximum detected value by the screening level. Only values greater than one (indicating an exceedance of the screening level) are displayed. Exceedance factors have been rounded to two significant digits.

5 If the exceedance factor was ≤ 2 and percent exceeding was ≤ 5%, the constituent was eliminated as a COPC.

6 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

7 Historical groundwater monitoring well results collected prior to 2011 were reported by the laboratory only as total benzoflouranthenes, not as individual b and k isomer results; these historical results are the only results with detections. Monitoring well results collected after 2011 were analyzed and reported as individual isomers, in addition to being summed into a total benzofluoranthene result; however, all results for individual isomers were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COPC	Contaminant of potential concern
Ecology	Washington State Department of Ecology
µg/L	Micrograms per liter
TEF	Toxic equivalent factor
TEQ	Toxic equivalent quotient
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 4.9

Frequency of Detection and Maximum Concentrations Detected in Soil[1,2]

Analyte	CAS No.	Screening Levels[3]	Units	Number of Results	Percent Detected	Maximum Detected Value	Location of Maximum Detect	Date of Maximum Detect	Percent of Detected Results that Exceed Criteria	Exceedance Factor[4]	Retain as COPC?[5]	Comment
Metals												
Antimony	7440-36-0	1.7	mg/kg	48	29%	70	TP-10	4/27/1998	27%	41	Yes	
Arsenic	7440-38-2	20	mg/kg	86	98%	1240	TP-10	4/27/1998	28%	62	Yes	
Beryllium	7440-41-7	25	mg/kg	38	37%	0.6	TP-10	4/27/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Cadmium	7440-43-9	0.77	mg/kg	86	29%	12.6	TP-10	4/27/1998	22%	16	Yes	
Chromium	7440-47-3	--	mg/kg	86	100%	438	Soil 3-A/3-B	8/1/1993	None	None	No	Not retained; there is no screening level.
Copper	7440-50-8	36	mg/kg	86	100%	4690	Soil 2-A/2-B	8/1/1993	50%	130	Yes	
Lead	7439-92-1	81	mg/kg	86	99%	1680	TP-8	4/27/1998	33%	21	Yes	
Mercury	7439-97-6	0.07	mg/kg	86	69%	17.6	Soil 2-A/2-B	8/1/1993	35%	250	Yes	
Nickel	7440-02-0	38	mg/kg	86	100%	426	Soil 3-A/3-B	8/1/1993	64%	11	Yes	
Selenium	7782-49-2	1.0	mg/kg	38	3%	8	MW-04	4/28/1998	3%	8	Yes	Detected in less than 5% of samples, but at more than 2 times the screening level.
Silver	7440-22-4	0.2	mg/kg	86	8%	3	TP-8TP-10	4/27/1998 4/27/1998	8%	15	Yes	
Zinc	7440-66-6	85	mg/kg	86	100%	12600	TP-10	4/27/1998	44%	150	Yes	
Organometallics												
Tributyltin	688-73-3	--	mg/kg	20	65%	14	Soil 2-A/2-B	8/1/1993	None	None	No	Not retained; there is no screening level.
Polychlorinated Biphenyls (PCBs)												
Aroclor 1242	53469-21-9	--	mg/kg	26	3.8%	0.018	MW-02A	3/15/2011	None	None	No	Not retained; there is no screening level.
Aroclor 1248	12672-29-6	66	mg/kg	32	38%	4.8	Soil 2-A/2-B	8/1/1993	None	None	No	Not retained; maximum detected value is less than the screening level.
Aroclor 1254	11097-69-1	0.033	mg/kg	32	38%	0.072	FS-11	3/14/2011	31%	2.2	Yes	
Aroclor 1260	11096-82-5	0.033	mg/kg	32	19%	1.7	Soil 2-A/2-B	8/1/1993	16%	52	Yes	
Aroclor 1268	11100-14-4	--	mg/kg	22	9.1%	1.7	Soil 1-A/1-B	8/1/1993	None	None	No	Not retained; there is no screening level.
Total PCBs[6]	Total PCBs	0.05	mg/kg	32	47%	6.5	Soil 2-A/2-B	8/1/1993	41%	130	Yes	
Dioxins/Furans												
Dioxin/Furan TEQ[7]	2,3,7,8-TCDD	0.000031	mg/kg	4	100%	0.0000573	SFS-02	1/29/2013	25%	1.8	No	The maximum detected value is much less than the industrial worker exposures for both soil and intertidal sediments. To exceed the screening levels, site soil dioxins/furans would need to migrate hundreds of feet to the net fishing area and impact large acres of sediments, which is not possible. The maximum detection on-site is approximately 1/3 of the industrial worker screening level.
Semivolatile Organic Compounds (SVOCs)												
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)												
cPAH TEQ[8]	Total cPAHs TEF	0.0097	mg/kg	86	52%	25	FS-21	1/29/2013	52%	2600	Yes	
Benzo(a)pyrene	50-32-8	0.0097	mg/kg	86	44%	16	FS-21	1/29/2013 1/30/2013	42%	1600	Yes	
Benz(a)anthracene	56-55-3	0.005	mg/kg	86	48%	38	FS-21	1/29/2013	48%	7600	Yes	
Benzo(b)fluoranthene	205-99-2	0.012	mg/kg	72	36%	20	FS-21	1/29/2013	36%	1700	Yes	
Benzo(k)fluoranthene	207-08-9	0.012	mg/kg	72	32%	23	FS-21	1/29/2013	32%	1900	Yes	
Benzofluoranthenes (total)	Total Benzo.	--	mg/kg	67	45%	11	FS-09	3/15/2011	None	None	Yes	
Chrysene	218-01-9	0.005	mg/kg	86	52%	38	FS-21	1/29/2013	52%	7600	Yes	
Dibenzo(a,h)anthracene	53-70-3	0.018	mg/kg	86	27%	4.7	FS-21	1/30/2013	22%	260	Yes	
Indeno(1,2,3-cd)pyrene	193-39-5	0.035	mg/kg	86	35%	4.3	FS-17	3/16/2011	30%	120	Yes	
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)												
1-Methylnaphthalene	90-12-0	4500	mg/kg	70	31%	80	FS-21	1/29/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
2-Methylnaphthalene	91-57-6	14000	mg/kg	86	36%	140	FS-21	1/29/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Naphthalene	91-20-3	0.13	mg/kg	96	31%	320	FS-21	1/30/2013	20%	2500	Yes	
Acenaphthene	83-32-9	0.03	mg/kg	86	44%	150	FS-21	1/29/2013	42%	5000	Yes	
Acenaphthylene	208-96-8	--	mg/kg	84	17%	2	FS-17	3/16/2011	None	None	No	Not retained; there is no screening level.
Anthracene	120-12-7	0.054	mg/kg	86	41%	63	FS-21	1/29/2013	34%	1200	Yes	
Fluorene	86-73-7	0.031	mg/kg	86	42%	130	FS-21	1/29/2013	41%	4200	Yes	
Phenanthrene	85-01-8	--	mg/kg	86	57%	450	FS-21	1/29/2013	None	None	No	Not retained; there is no screening level.

Table 4.9

Frequency of Detection and Maximum Concentrations Detected in Soil[1,2]

Analyte	CAS No.	Screening Levels[3]	Units	Number of Results	Percent Detected	Maximum Detected Value	Location of Maximum Detect	Date of Maximum Detect	Percent of Detected Results that Exceed Criteria	Exceedance Factor[4]	Retain as COPC?[5]	Comment
Semivolatile Organic Compounds (SVOCs) (cont.)												
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)												
Benzo(g,h,i)perylene	191-24-2	--	mg/kg	86	37%	8.1	FS-21	1/30/2013	None	None	No	Not retained; there is no screening level.
Fluoranthene	206-44-0	0.094	mg/kg	86	59%	200	FS-21	1/29/2013	51%	2100	Yes	
Pyrene	129-00-0	0.15	mg/kg	86	60%	190	FS-21	1/29/2013	45%	1300	Yes	
Other SVOCs												
1,2-Dichlorobenzene	95-50-1	0.02	mg/kg	74	1.4%	0.011	FS-09A	3/17/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
2,4-Dimethylphenol	105-67-9	0.05	mg/kg	71	2.8%	1.4	TP-15	4/27/1998	2.8%	28	Yes	Detected in less than 5% of samples, but at more than 2 times the screening level.
4-Chloro-3-methylphenol	59-50-7	--	mg/kg	68	1.5%	0.43	S-3	8/19/2005	None	None	No	Not retained; there is no screening level.
4-Methylphenol	106-44-5	350000	mg/kg	16	6.3%	0.15	Soil 2-A/2-B	8/1/1993	None	None	No	Not retained; maximum detected value is less than the screening level.
Benzoic Acid	65-85-0	18	mg/kg	73	2.7%	0.53	Soil 2-A/2-B	8/1/1993	None	None	No	Not retained; maximum detected value is less than the screening level.
Bis(2-ethylhexyl) Phthalate	117-81-7	0.33	mg/kg	77	16%	1.6	Soil 1-A/1-B	8/1/1993	6.5%	4.8	Yes	
Butyl benzyl Phthalate	85-68-7	0.2	mg/kg	74	2.7%	1	S-4	8/19/2005	1.4%	5	Yes	Detected in less than 5% of samples, but at more than 2 times the screening level.
Dibenzofuran	132-64-9	3500	mg/kg	85	29%	94	FS-21	1/29/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
Dimethyl Phthalate	131-11-3	--	mg/kg	74	2.7%	0.23	Soil 2-A/2-B	8/1/1993	None	None	No	Not retained; there is no screening level.
Di-n-butyl Phthalate	84-74-2	0.02	mg/kg	74	4.1%	0.15	MW-02A	3/15/2011	4.1%	7.5	Yes	Detected in less than 5% of samples, but at more than 2 times the screening level.
Isophorone	78-59-1	0.1	mg/kg	68	1.5%	0.11	MW-09	3/14/2011	1.5%	1.1	No	Fewer than 5% detections; maximum detection less than 2 times the screening level.
N-Nitrosodiphenylamine	86-30-6	0.1	mg/kg	74	5.4%	1.9	FS-09C	3/17/2011	5.4%	19	Yes	
Pentachlorophenol	87-86-5	0.1	mg/kg	74	1.4%	3.4	Soil 2-A/2-B	8/1/1993	1.4%	34	Yes	Detected in less than 5% of samples, but at more than 2 times the screening level.
Volatile Organic Compounds (VOCs) Associated with TPH												
Ethylbenzene	100-41-4	0.0063	mg/kg	66	10.6%	0.22	TP-9	4/30/1998	11%	35	Yes	
Toluene	108-88-3	0.022	mg/kg	63	1.6%	0.033	FS-09A	3/17/2011	1.6%	1.5	No	Fewer than 5% detections; maximum detection less than 2 times the screening level.
Xylene (meta & para)	179601-23-1	--	mg/kg	57	14.0%	0.31	TP-9	4/30/1998	None	None	No	Not retained; there is no screening level.
Xylene (ortho)	95-47-6	0.51	mg/kg	57	10.5%	0.12	TP-9	4/30/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Xylene (total)	1330-20-7	1	mg/kg	52	7.7%	0.6	FS-21	1/30/2013	None	None	No	Not retained; maximum detected value is less than the screening level.
1,3,5-Trimethylbenzene	108-67-8	35,000	mg/kg	59	8.5%	0.34	TP-9	4/30/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Iso-Propylbenzene	98-82-8	350,000	mg/kg	53	13%	0.18	TP-9	4/30/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
n-Propylbenzene	103-65-1	350,000	mg/kg	59	11.9%	0.43	FS-11	3/14/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Other VOCs												
1,1,2-Trichlorotrifluoroethane	76-13-1	110,000,000	mg/kg	12	8.3%	0.0058	MW-03	4/28/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Acetone	67-64-1	2	mg/kg	59	22%	0.25	TP-9	4/30/1998	None	None	No	Not retained; maximum detected value is less than the screening level.
Carbon Disulfide	75-15-0	0.27	mg/kg	55	7.3%	0.054	FS-11	3/14/2011	None	None	No	Not retained; maximum detected value is less than the screening level.
Methyl ethyl ketone	78-93-3	2,100,000	mg/kg	49	4.1%	0.021	S-3	8/19/2005	None	None	No	Not retained; maximum detected value is less than the screening level.
Methylene Chloride	75-09-2	0.03	mg/kg	55	3.6%	0.011	MW-01	4/28/1998	None	None	No	Not retained; maximum detected value is less than the screening level.

Notes:

Yes Indicates that constituent was retained as a COPC.

1 Only in situ soil samples collected prior to May 2017 within the point of compliance (from 0 to 15 feet below ground surface) were included; however, samples collected during the February 2015 Interim Action event were not included. Field samples and field duplicate samples are counted as unique results.

2 This table includes only those analytes that were detected at the Site. Information about non-detect results can be found in Appendix C, Attachment C.6.

3 Screening levels for all analytes of interest were developed and presented in Table 4.6. This table compares site data to the screening levels developed for soil analytes of interest; however, this analysis does not include TPH. Though TPH was retained as an analyte of interest, compliance with screening levels and cleanup levels is semi-qualitative and should not be evaluated using strict quantitative methods, as performed in this table. TPH is evaluated relative to applicable screening levels and cleanup levels in Appendix G, Attachment G.2.

4 The exceedance factor is calculated by dividing the maximum detected value by the screening level. Only values greater than one (indicating an exceedance of the screening level) are displayed. Exceedance factors have been rounded to two significant digits.

5 If the exceedance factor was ≤ 2 and percent exceeding was ≤ 5%, the constituent was eliminated as a COPC as allowed by MTCA soil compliance rules for screening constituents in soil found in WAC 173-340-740(7)(e)(i-ii).

6 Screening levels are applicable to Total PCBs, which are calculated for this site by summing all detected Aroclors (Aroclors that are not detected are not included in the total). If no Aroclors are detected, then the Total PCB value is the greatest detection limit.

7 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

8 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COPC	Contaminant of potential concern
mg/kg	Milligrams per kilogram
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 4.10
Analytes Retained as Contaminants of Potential Concern[1,2]

Analyte	CAS No.	COPC Outcome		
		Sediment	Groundwater	Soil
Metals				
Antimony	7440-36-0			X
Arsenic	7440-38-2	X	X	X
Cadmium	7440-43-9	X		X
Copper	7440-50-8	X	X	X
Lead	7439-92-1	X		X
Mercury	7439-97-6			X
Nickel	7440-02-0		X	X
Selenium	7782-49-2			X
Silver	7440-22-4			X
Zinc	7440-66-6	X	X	X
Polychlorinated Biphenyls (PCBs)				
Aroclor 1254	11097-69-1			X
Aroclor 1260	11096-82-5			X
Total PCBs[3]	Total PCBs	X		X
Dioxins/Furans				
Dioxin/Furan TEQ[4]	2,3,7,8-TCDD	X		
Semivolatile Organic Compounds (SVOCs)				
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)				
cPAH TEQ[5]	Total cPAHs TEF	X	X	X
Benzo(a)pyrene	50-32-8	X	Ecology regulates cPAHs using the cPAH TEQ.[6]	X
Benz(a)anthracene	56-55-3	X		X
Benzo(b)fluoranthene	205-99-2			X
Benzo(k)fluoranthene	207-08-9			X
Benzofluoranthenes (total)	Total Benzo.	X		X
Chrysene	218-01-9	X		X
Dibenzo(a,h)anthracene	53-70-3	X		X
Indeno(1,2,3-cd)pyrene	193-39-5	X		X
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)				
1-Methylnaphthalene	90-12-0		X	
2-Methylnaphthalene	91-57-6	X	X	
Naphthalene	91-20-3			X
Acenaphthene	83-32-9		X	X
Anthracene	120-12-7	X		X
Fluorene	86-73-7		X	X
Phenanthrene	85-01-8	X		
Non-carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)				
Benzo(g,h,i)perylene	191-24-2	X		
Fluoranthene	206-44-0	X		X
Pyrene	129-00-0	X		X
Total HPAH[7]	Total HPAH	X		
Other SVOCs				
2,4-Dimethylphenol	105-67-9			X
Benzyl alcohol[8]	100-51-6	X		
Bis(2-ethylhexyl) Phthalate	117-81-7	X		X
Butyl benzyl Phthalate	85-68-7	X		X
N-Nitrosodiphenylamine	86-30-6			X
Pentachlorophenol	87-86-5			X
Volatile Organic Compounds (VOCs) Associated with TPH				
Ethylbenzene	100-41-4			X
Other VOCs				
There are no other volatile COPCs at this site.				

Notes:

1 This table includes only those chemicals that were retained as a COPC in at least one environmental media.

2 Though TPH was retained as a COPC, compliance with screening levels and cleanup levels is semi-qualitative and should not be evaluated using strict quantitative methods. TPH is evaluated relative to applicable screening levels and cleanup levels in Appendix G, Attachment G.2.

3 Screening levels are applicable to Total PCBs, which are calculated for this site by summing all detected Aroclors. If no Aroclors are detected, the Total PCB value is the greatest detection limit.

4 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

5 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

6 For more information on regarding risk assessment as related to the cPAH TEQ, refer to WAC 173-340-708 or https://fortress.wa.gov/ecy/clarc/FocusSheets/tef.pdf.

7 Total HPAH is a regulated analyte in sediment, and is calculated as the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzofluoranthene, benzo(a)pyrene, indeno(1,2,3,-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

8 In addition to having commercial and industrial uses, benzyl alcohol is a naturally-occurring organic chemical produced by plants and algae that is readily degraded in the marine environment.

Abbreviations:

CAS	Chemical Abstracts Service
COPC	Contaminant of potential concern
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
WAC	Washington Administrative Code

Table 5.1
Frequency of Exceedance of Screening Levels for Intertidal Sediment Samples

Contaminants of Potential Concern	CAS No.	Benthic SCO for Intertidal Sediments	Human Direct Contact SCO for Intertidal Sediments	Units	Number of Results[1]	Number of Detected Results Exceeding Benthic SCO	Percent of Detected Results that Exceed Benthic SCO	Information about Maximum Detection			Current SWAC	Comment
								Value	Location	Date		
COPCs Retained as COCs for Intertidal Sediments (Seafood consumption pathway for bioaccumulations is considered separately)												
Metals												
Arsenic	7440-38-2	57	20[2]	mg/kg	11	2	18%	110	S-2	8/19/2005	49	COC based on protection of benthic species, shipyard worker direct contact (current SWAC is greater than the human health SCO), and bioaccumulation. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Copper	7440-50-8	390	150,000	mg/kg	11	4	36%	2,620	S-2	8/19/2005	NC	COC based on protection of benthic species .
Zinc	7440-66-6	410	NA	mg/kg	11	5	45%	1,690	S-2	8/19/2005	NC	COC based on protection of benthic species .
COPCs Not Retained as COCs for Intertidal Sediments												
Metals												
Cadmium	7440-43-9	5.1	3,800	mg/kg	11	None	None	1.5	S-2	8/19/2005	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Lead	7439-92-1	450	NA	mg/kg	11	1	9.1%	580	HA-07	3/22/2011	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Mercury	7439-97-6	0.41	1,100	mg/kg	11	1	9.1%	26	S-2	8/19/2005	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Polychlorinated Biphenyls (PCBs)												
Total PCBs[3]	Total PCBs	0.13	6.0	mg/kg dry wt	9	None	None	0.0243	HA-04	3/17/2011	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Dioxins/Furans												
Dioxin/Furan TEQ[4]	2,3,7,8-TCDD	NA	0.00018	mg/kg dry wt	No data collected along intertidal area.							Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Semivolatile Organic Compounds (SVOCs)												
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)												
cPAH TEQ[5]	Total cPAHs TEF	NA	12	mg/kg dry wt	9	None	None	0.32	HA-04	3/17/2011	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Benzo(a)pyrene	50-32-8	1.6	12	mg/kg dry wt	9	None	None	0.21	HA-04	3/17/2011	NC	No exceedances; not retained.
Benz(a)anthracene	56-55-3	1.3	120	mg/kg dry wt	9	None	None	0.25	HA-04	3/17/2011	NC	No exceedances; not retained.
Benzofluoranthenes (total)	Total Benzo.	3.2	120	mg/kg dry wt	9	None	None	0.65	HA-04	3/17/2011	NC	No exceedances; not retained.
Chrysene	218-01-9	1.4	1,200	mg/kg dry wt	9	None	None	0.57	HA-04	3/17/2011	NC	No exceedances; not retained.
Dibenzo(a,h)anthracene	53-70-3	0.23	12	mg/kg dry wt	9	None	None	0.004	HA-09	1/30/2013	NC	No exceedances; not retained.
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	120	mg/kg dry wt	9	None	None	0.14	HA-04	3/17/2011	NC	No exceedances; not retained.
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)[6]												
1-Methylnaphthalene	90-12-0	NA	140	mg/kg dry wt	7	None	None	None	None	None	NC	No exceedances; retained as a TPH IHS only, refer to Section 5.3.
2-Methylnaphthalene	91-57-6	0.67	13,000	mg/kg dry wt	9	None	None	None	None	None	NC	No exceedances; evaluated as potential TPH IHS but not retained as COPC or IHS.
Acenaphthene	83-32-9	0.5	190,000	mg/kg dry wt	9	None	None	None	None	None	NC	No exceedances; evaluated as potential TPH IHS but not retained as COPC or IHS.
Anthracene	120-12-7	0.96	960,000	mg/kg dry wt	9	None	None	None	None	None	NC	No exceedances; evaluated as potential TPH IHS but not retained as COPC or IHS.

Table 5.1
Frequency of Exceedance of Screening Levels for Intertidal Sediment Samples

Contaminants of Potential Concern	CAS No.	Benthic SCO for Intertidal Sediments	Human Direct Contact SCO for Intertidal Sediments	Units	Number of Results[1]	Number of Detected Results Exceeding Benthic SCO	Percent of Detected Results that Exceed Benthic SCO	Information about Maximum Detection			Current SWAC	Comment
								Value	Location	Date		
COPCs Not Retained as COCs for Intertidal Sediments (cont.)												
SVOCs (cont.)												
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)[6]												
Fluorene	86-73-7	0.54	130,000	mg/kg dry wt	9	None	None	None	None	None	NC	No exceedances; not retained.
Phenanthrene	85-01-8	1.5	NA	mg/kg dry wt	9	None	None	0.73	HA-04	3/17/2011	NC	No exceedances; not retained.
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)												
Total HPAH[7]	Total HPAH	12	NA	mg/kg dry wt	9	None	None	4.4	HA-04	3/17/2011	NC	No exceedances; not retained.
Benzo(g,h,i)perylene	191-24-2	0.67	NA	mg/kg dry wt	9	None	None	0.15	HA-04	3/17/2011	NC	No exceedances; not retained.
Fluoranthene	206-44-0	1.7	130,000	mg/kg dry wt	9	None	None	1.2	HA-04	3/17/2011	NC	No exceedances; not retained.
Pyrene	129-00-0	2.6	96,000	mg/kg dry wt	9	None	None	1.2	HA-04	3/17/2011	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Other SVOCs												
Benzyl Alcohol	100-51-6	0.2	320,000	mg/kg dry wt	9	None	None	None	None	None	NC	No exceedances; not retained.
bis(2-Ethylhexyl) Phthalate	117-81-7	1.3	64,000	mg/kg dry wt	9	None	None	0.24	HA-04	3/17/2011	NC	No exceedances; not retained.
Butyl Benzyl Phthalate	85-68-7	0.09	640,000	mg/kg dry wt	9	None	None	None	None	None	NC	No exceedances; not retained.

Notes:

🟧 Banner color indicates COPCs retained as COCs.

🟩 Banner color indicates COPCs eliminated as COCs.

NA Screening level is not available or in the case of zinc, not toxic to humans.

NC The SWAC was not calculated for these compounds because either (1) the maximum detection was less than the human direct contact SCO or (2) no human direct contact SCO was available.

1 For conservatism in evaluation of potential bioaccumulative impacts, the two intertidal samples collected from a depth deeper than the point of compliance of 0 to 12 centimeters (samples S-1 and S-2 collected from 0 to 2 feet) are included in the intertidal sediment data set.

2 Arsenic screening level shown is for the shipyard intertidal sediment area. The screening level for the beach intertidal sediment area is 57 mg/kg based on protection of benthic species.

3 The SCO is applicable to Total PCBs, which at the Site is performed by summing all detected Aroclors; Aroclors that are not detected are not included in the total. If no Aroclors were detected, then the Total PCB value is the greatest detection limit.

4 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

5 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

6 TPH is evaluated in groundwater at the Site using LPAHs as IHS. Four LPAHs were identified as COPCs in groundwater (acenaphthene, fluorene, 1-methylnaphthalene, and 2-methylnaphthalene); sediment data for these four LPAHs are included in this table, even if these analytes did not meet the criteria to become sediment COPCs in Section 4.0. Inclusion of these sediment data demonstrates that existing groundwater conditions are protective of the groundwater-to-sediment pathway.

7 Total HPAH is the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzofluoranthene, benzo(a)pyrene, indeno(1,2,3,-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

Abbreviations:

CAS	Chemical Abstracts Service	SWAC	Surface-weighted average concentration
COC	Contaminant of concern	TCDD	Tetrachlorodibenzodioxin
COPC	Contaminant of potential concern	TEF	Toxic equivalent factor
IHS	Indicator Hazardous Substances	TEQ	Toxic equivalent
mg/kg	Milligrams per kilogram	TPH	Total petroleum hydrocarbon
SCO	Sediment Cleanup Objective	WAC	Washington Administrative Code
Site	Harris Avenue Shipyard	wt	Weight

Table 5.3

Intertidal Sediment Results for Select Contaminants of Potential Concern[1]

Intertidal Contaminants of Potential Concern	CAS No.	SCO for Intertidal Sediments[2]	Location	Shipyard Intertidal Sediment Area						Beach Intertidal Sediment Area				
				HA-02	**HA-03**	**HA-04**	**HA-09**	**S-1**	**S-2**	**HA-05**	**HA-06**	**HA-07**	**HA-10**	**HA-11**
			Depth	0–12 cm	0–12 cm	0–12 cm	0–10 cm	0–2 ft	0–2 ft	0–12 cm	0–12 cm	0–12 cm	0–10 cm	0–10 cm
			Date	03/16/2011	03/16/2011	03/17/2011	01/30/2013	08/17/2005	08/19/2005	3/22/2011	3/22/2011	03/22/2011	01/30/2013	01/30/2013
			Units											
Metals														
Arsenic	7440-38-2	20/57[3]	mg/kg	**39**	**50**	**26**	**100**	**30**	**110**	21	30	9.7	6	10 U
Cadmium	7440-43-9	5.1	mg/kg	1 U	1 U	1 U	1.2	0.7 U	1.5	1 U	1 U	1 U	0.4	0.6 U
Copper	7440-50-8	390	mg/kg	**400**	**450**	270	**682**	289	**2,620**	130	76	100	53.4	24
Lead	7439-92-1	450	mg/kg	73	91	55	125 J	67	208	54	54	580	44	8
Mercury	7439-97-6	0.41	mg/kg	0.02	0.02 U	0.032	0.019	0.08	26	0.25	0.02 U	0.02 U	0.016	0.014
Zinc	7440-66-6	410	mg/kg	**530**	**690**	**620**	**1,440**	402	**1,690**	220	280	190	129	61
Polychlorinated Biphenyls (PCBs) and Dioxin/Furans														
Total PCBs	Total PCBs	0.13	mg/kg dry wt	0.0135	0.0053	0.0243	0.0058 J	0.044 U	0.04 U	0.0039 U	0.012 UY	0.0038 U	--	--
Dioxin/Furan TEQ[4]	2,3,7,8-TCDD	0.00018	mg/kg dry wt	No data collected along the intertidal sediment area.										
Semivolatile Organic Compounds (SVOCs)														
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)														
cPAH TEQ[5]	Total cPAHs TEF	12	mg/kg dry wt	0.21	0.077	0.32	0.017 J	0.17	0.25	0.076 U	0.076 U	0.076 U	--	--
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)														
Pyrene	129-00-0	2.6	mg/kg dry wt	0.26	0.1 U	1.2	0.02	--	--	0.1 U	0.1 U	0.1 U	--	--
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAHs) that became TPH Indicator Hazardous Substances in Groundwater														
1-Methylnaphthalene	90-12-0	140	mg/kg dry wt	0.1 U	0.1 U	0.1 U	0.019 U	--	--	0.1 U	0.1 U	0.1 U	--	--

Notes:

-- Not analyzed.

RED Concentration exceeds the proposed SCO.

1 This table includes all chemicals that were retained as COCs in Table 5.1 and chemicals that are included in the nature and extent discussion in Section 5.0 (e.g., chemicals with the potential to bioaccumulate or that are retained as TPH indicator hazardous substances for groundwater).

2 SCOs presented here are the lesser of screening levels for protection of benthic health and direct contact by shipyard workers. Arsenic is both a benthic and human direct contact COC; therefore, SCOs for both exposure pathways are presented here.

3 Although the SCO for the shipyard intertidal sediment area based on protection of direct contact by shipyard workers (20 mg/kg) must be met on a surface-weighted average concentration basis, exceedances of individual sample locations are identified in this table for informational purposes.

4 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

5 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COC	Contaminant of concern
cm	Centimeters
ft	Feet
mg/kg	Milligrams per kilogram
SCO	Sediment Cleanup Objective
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code
wt	Weight

Qualifiers:

J	Analyte was detected, value is considered an estimate.
U	Analyte was not detected at the given reporting limit.
UY	Not detected, with an elevated reporting limit.

Table 5.4
Frequency of Exceedance of Screening Levels for Subtidal Sediment Samples

Contaminants of Potential Concern	CAS No.	Benthic SCO for Subtidal Sediments	Human Direct Contact SCO for Subtidal Sediments	Units	Number of Results	Number of Detected Results Exceeding Subtidal Benthic SCO	Percent of Detected Results that Exceed Subtidal Benthic SCO	Information about Maximum Detection			Current SWAC	Comment
								Value	Location	Date		
COPCs Retained as COCs for Subtidal Sediments (Seafood consumption pathway for bioaccumulatives is considered separately)												
Metals												
Arsenic	7440-38-2	57	11	mg/kg	44	22	50%	158	HG-42	8/23/2000	16	COC based on protection of benthic species, netfishing direct contact (current SWAC is greater than the human health SCO), and bioaccumulation. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Copper	7440-50-8	390	180,000	mg/kg	42	6	14%	959	HG-38	8/22/2000	NC	COC based on protection of benthic species.
Zinc	7440-66-6	410	NA	mg/kg	42	5	12%	1,620	HG-42	8/23/2000	NC	COC based on protection of benthic species.
Polychlorinated Biphenyls (PCBs)												
Total PCBs[1]	Total PCBs	0.13	2.1	mg/kg dry wt	52	9	17%	1.8	HG-4	3/24/1998	NC	COC based on protection of benthic species and bioaccumulation. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Semivolatile Organic Compounds (SVOCs)												
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)												
Fluoranthene	206-44-0	1.7	160,000	mg/kg dry wt	39	5	13%	5.9	HG-30	8/22/2000	NC	COC based on protection of benthic species.
Pyrene	129-00-0	2.6	120,000	mg/kg dry wt	39	3	7.7%	6.4	HG-30	8/22/2000	NC	COC based on protection of benthic species.
COPCs Not Retained as COCs for Subtidal Sediments												
Metals												
Cadmium	7440-43-9	5.1	4,600	mg/kg	42	None	None	3.6	HG-12	3/24/1998	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Lead	7439-92-1	450	NA	mg/kg	42	1	2.4%	512	HG-2	3/24/1998	NC	Not retained; less than 10%, less than 2 times the SCO, and less than the SMS CSL; and at a single location. Will be evaluated for bioaccumulation pathway separately, see Appendix G, Attachment G.1.
Mercury	7439-97-6	0.41	1,400	mg/kg	52	3	5.8%	0.51	HV-6	3/26/1998	NC	Not retained; less than 10%, less than 2 times the SCO, and less than the SMS CSL; and detected in two separated locations.
Dioxins/Furans												
Dioxin/Furan TEQ[2]	2,3,7,8-TCDD	NA	0.000062	mg/kg dry wt	5	None	None	0.000036	SG-06	1/31/2013	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Semivolatile Organic Compounds (SVOCs)												
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)[3]												
1-Methylnaphthalene	90-12-0	NA	140	mg/kg dry wt	12	None	None	0.48	SG-04	7/28/2011	NC	No exceedances; not retained.
2-Methylnaphthalene	91-57-6	0.67	16,000	mg/kg dry wt	39	1	2.6%	0.77	SG-04	7/28/2011	NC	Not retained; less than 10% and less than 2 times the SCO; and at a single location.
Acenaphthene	83-32-9	0.5	240,000	mg/kg dry wt	39	None	None	0.22	HG-42	8/23/2000	NC	No exceedances; not retained.
Anthracene	120-12-7	0.96	NA	mg/kg dry wt	39	1	2.6%	0.97	HG-39	8/22/2000	NC	Not retained; less than 10% and less than 2 times the SCO.
Fluorene	86-73-7	0.54	160,000	mg/kg dry wt	39	None	None	0.42	HG-39	8/22/2000	NC	No exceedances; not retained.
Phenanthrene	85-01-8	1.5	NA	mg/kg dry wt	39	2	5.1%	2.8	HG-42	8/23/2000	NC	Not retained; less than 10% and less than 2 times the SCO.

Table 5.4
Frequency of Exceedance of Screening Levels for Subtidal Sediment Samples

Contaminants of Potential Concern	CAS No.	Benthic SCO for Subtidal Sediments	Human Direct Contact SCO for Subtidal Sediments	Units	Number of Results	Number of Detected Results Exceeding Subtidal Benthic SCO	Percent of Detected Results that Exceed Subtidal Benthic SCO	Information about Maximum Detection			Current SWAC	Comment
								Value	Location	Date		
COPCs Not Retained as COCs for Subtidal Sediments (cont.)												
SVOCs (cont.)												
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)												
cPAH TEQ[4]	Total cPAHs TEF	NA	4.2	mg/kg dry wt	39	None	None	2.4	HG-30	8/22/2000	NC	Not retained for this pathway; considered separately under bioaccumulatives. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Benzo(a)pyrene	50-32-8	1.6	4.2	mg/kg dry wt	39	1	2.6%	1.8	HG-30	8/22/2000	NC	Not retained; less than 10% and less than 2 times the SCO. Will be evaluated for bioaccumulation using cPAH TEQ. See Appendix G, Attachment G.1 for bioaccumulative evaluation.
Benz(a)anthracene	56-55-3	1.3	42	mg/kg dry wt	39	2	5.1%	2.0	HG-30	8/22/2000	NC	
Benzofluoranthenes (total)	Total Benzo.	3.2	42	mg/kg dry wt	32	1	3.1%	3.6	HG-30	8/22/2000	NC	
Chrysene	218-01-9	1.4	4,200	mg/kg dry wt	39	3	7.7%	2.3	SG-08	1/31/2013	NC	
Dibenzo(a,h)anthracene	53-70-3	0.23	4.2	mg/kg dry wt	39	1	2.6%	0.26	SG-08	1/31/2013	NC	
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	42	mg/kg dry wt	39	2	5.1%	0.74	HG-30 SG-08	8/22/2000 1/31/2013	NC	
Non-Carcinogenic HPAHs												
Total HPAH[5]	Total HPAH	12	NA	mg/kg dry wt	39	3	7.7%	23	HG-30	8/22/2000	NC	Not retained; less than 10%, less than 2 times pathway screening level, and less than the SMS CSL; and detected in two separated locations.
Benzo(g,h,i)perylene	191-24-2	0.67	NA	mg/kg dry wt	39	1	2.6%	0.79	SG-08	1/31/2013	NC	Not retained; less than 10% and less than 2 times the SCO.
Other SVOCs												
Benzyl alcohol	100-51-6	0.2	390,000	mg/kg dry wt	37	1	2.7%	0.31	HG-32	8/31/2000	NC	Not retained; less than 10% and less than 2 times the SCO; and due to short half life and compliance of more recent samples.
bis(2-Ethylhexyl) Phthalate	117-81-7	1.3	78,000	mg/kg dry wt	37	2	5.4%	2.4	HG-30	8/22/2000	NC	Not retained; less than 10%, less than 2 times the SCO, and less than the SMS CSL; and detected in two separated locations.
Chemicals in This Area Where Detection Limits Were Inadequate												
Butyl Benzyl Phthalate	85-68-7	0.09	780,000	mg/kg dry wt	37	2	5.4%	1.5	HG-10	3/24/1998	NC	Not retained; refer to text for details.

Notes:

🟧 Banner color indicates COPCs retained as COCs.

🟩 Banner color indicates COPCs eliminated as COCs.

NA Screening level is not available or in the cases of zinc and anthracene, not toxic to humans.

NC The SWAC was not calculated for these compounds because either (1) the maximum detection was less than the human direct contact SCO or (2) no human direct contact SCO was available.

1 Screening levels are applicable to Total PCBs, which at the Site is performed by summing all detected Aroclors; Aroclors that are not detected are not included in the total. If no Aroclors were detected, then the Total PCB value is the greatest detection limit.

2 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

3 TPH is evaluated in groundwater at the Site using LPAHs as Indicator Hazardous Substances. Four LPAHs were identified as COPCs in groundwater (acenaphthene, fluorene, 1-methylnaphthalene, and 2-methylnaphthalene); sediment data for these four LPAHs are included in this table, even if these analytes did not meet the criteria to become sediment COPCs in Section 4.0. Inclusion of these sediment data demonstrates that existing groundwater conditions are protective of the groundwater-to-sediment pathway.

4 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

5 Total HPAH is the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzofluoranthene, benzo(a)pyrene, indeno(1,2,3,-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

Abbreviations:

CAS	Chemical Abstracts Service
COC	Contaminant of concern
COPC	Contaminant of potential concern
CSL	Cleanup screening level
mg/kg	Milligrams per kilogram
SCO	Sediment Cleanup Objectives
Site	Harris Avenue Shipyard
SMS	Sediment Management Standards
SWAC	Surface-weighted average concentration
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code
wt	Weight

Table 5.5

Subtidal Sediment Results for Select Contaminants of Potential Concern[1]

Subtidal Contaminants of Potential Concern	CAS No.	SCO for Subtidal Sediments[2]	Location	HG-2	HG-3	HG-4	HG-5	HG-7	HG-8	HG-9	HG-10	HG-11	HG-12	HG-13	HG-14
			Depth	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm
			Date	03/24/1998	03/23/1998	03/24/1998	03/24/1998	03/24/1998	03/24/1998	03/24/1998	03/24/1998	03/24/1998	03/24/1998	03/24/1998	03/23/1998
			Units												
Metals															
Arsenic	7440-38-2	11/57[3]	mg/kg	**20 U**	--	--	11	--	--	--	23	--	15	16	--
Copper	7440-50-8	390	mg/kg	207	--	--	68.8	--	--	--	397	--	311	152	--
Zinc	7440-66-6	410	mg/kg	226	--	--	117	--	--	--	290	--	250	199	--
Polychlorinated Biphenyls (PCBs)															
Total PCBs[4]	Total PCBs	0.13	mg/kg dry wt	0.044	0.8	1.8	0.038 U	0.11	0.75	0.056 U	0.039 U	0.032	0.058	0.039 U	0.041
Dioxins/Furans															
Dioxin/Furan TEQ[5]	2,3,7,8-TCDD	0.000047	mg/kg dry wt	--	--	--	--	--	--	--		--	--	--	--
Semivolatile Organic Compounds (SVOCs)															
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)															
cPAH TEQ[6]	Total cPAHs TEF	4.2	mg/kg dry wt	0.75	--	--	0.34	--	--	--	0.42	--	--	--	--
Benzo(a)pyrene	50-32-8	1.6	mg/kg dry wt	0.52	--	--	0.24	--	--	--	0.3	--	--	--	--
Benz(a)anthracene	56-55-3	1.3	mg/kg dry wt	0.71	--	--	0.3	--	--	--	0.29	--	--	--	--
Benzofluoranthenes (total)	Total Benzo	3.2	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--	--
Chrysene	218-01-9	1.4	mg/kg dry wt	0.95	--	--	0.4	--	--	--	0.38	--	--	--	--
Dibenzo(a,h)anthracene	53-70-3	0.23	mg/kg dry wt	0.095	--	--	0.051	--	--	--	0.077	--	--	--	--
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	mg/kg dry wt	0.25	--	--	0.12	--	--	--	0.18	--	--	--	--
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)															
Fluoranthene	206-44-0	1.7	mg/kg dry wt	1.3	--	--	0.85	--	--	--	0.65	--	--	--	--
Pyrene	129-00-0	2.6	mg/kg dry wt	2	--	--	0.91	--	--	--	0.79	--	--	--	--
Other SVOCs															
Butyl Benzyl Phthalate	85-68-7	0.09	mg/kg dry wt	0.019 U	--	--	0.02 U	--	--	--	1.5	--	--	--	--
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAHs) that Became TPH Indicator Hazardous Substances in Groundwater															
1-Methylnaphthalene	90-12-0	140	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--	--

Notes:

--	Not analyzed.
RED	Concentration exceeds the proposed SCO.
BOLD	Reporting limit is greater than the proposed SCO.

[1] This table includes all chemicals that were retained as COCs in Table 5.4, as well as chemicals that were retained for bioaccumulative analysis or as TPH indicator hazardous substances for groundwater.

[2] SCOs presented here are the lesser of screening levels for protection of benthic health and direct contact by net fishers. Arsenic is both a benthic and human direct contact COC, therefore SCOs for both exposure pathways are presented here.

[3] Although the SCO for the subtidal sediment area based on protection of direct contact by net fishers (11 mg/kg) must be met on a surface-weighted average concentration basis, exceedances of individual sample locations are identified in this table for informational purposes.

[4] Screening levels are applicable to Total PCBs, which at the Site is performed by summing all detected Aroclors; Aroclors that are not detected are not included in the total. If no Aroclors were detected, then the Total PCB value is the greatest detection limit.

[5] Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

[6] Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

[7] Although there was a historical exceedance of PCBs at HG-44, the sample data were greater than 10 years old, and the location was re-occupied during the interim action sampling. The results for the sample collected during the interim action sampling, SC-09, now supersede the results for HG-44.

Abbreviations:

CAS	Chemical Abstracts Service
cm	Centimeters
COC	Contaminant of concern
mg/kg	Milligrams per kilogram
PQL	Practical Quantitation Limit
SCO	Sediment Cleanup Objective
Site	Harris Avenue Shipyard
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code
wt	Weight

Qualifiers:

J	Analyte was detected, given result should be considered an estimate.
U	Analyte was not detected at the given reporting limit.

Table 5.5

Subtidal Sediment Results for Select Contaminants of Potential Concern[1]

			Location	HG-15	HG-16	HG-17	HG-18	HG-19	HG-20	HG-22	HG-23	HV-3	HV-4	HV-6	HV-8	HG-30
			Depth	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–12 cm
			Date	03/24/1998	03/24/1998	03/24/1998	03/23/1998	03/23/1998	03/23/1998	03/24/1998	03/24/1998	03/26/1998	03/26/1998	03/26/1998	03/26/1998	08/22/2000
Subtidal Contaminants of Potential Concern	**CAS No.**	**SCO for Subtidal Sediments[2]**	**Units**													
Metals																
Arsenic	7440-38-2	11/57[3]	mg/kg	--	**14**	10	**17**	**14**	10	--	--	**18**	**21**	**21**	10	**13**
Copper	7440-50-8	390	mg/kg	--	65.7	69.6	99.2	136	99.4	--	--	286	199	69.4	37	149
Zinc	7440-66-6	410	mg/kg	--	116	116	136	150	128	--	--	276	266	134	37	194
Polychlorinated Biphenyls (PCBs)																
Total PCBs[4]	Total PCBs	0.13	mg/kg dry wt	0.095	0.049 U	0.039 U	0.048 U	0.081	0.039 U	0.019	0.039 U	**0.25**	**1.3**	0.073 U	0.011 J	**0.52**
Dioxins/Furans																
Dioxin/Furan TEQ[5]	2,3,7,8-TCDD	0.000047	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--	--	--
Semivolatile Organic Compounds (SVOCs)																
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																
cPAH TEQ[6]	Total cPAHs TEF	4.2	mg/kg dry wt	--	0.064	--	0.35	0.6	0.37	--	--	--	--	--	--	2.4
Benzo(a)pyrene	50-32-8	1.6	mg/kg dry wt	--	0.047	--	0.25	0.42	0.26	--	--	--	--	--	--	**1.8**
Benz(a)anthracene	56-55-3	1.3	mg/kg dry wt	--	0.039	--	0.27	0.45	0.31	--	--	--	--	--	--	**2**
Benzofluoranthenes (total)	Total Benzo	3.2	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--	--	**3.6**
Chrysene	218-01-9	1.4	mg/kg dry wt	--	0.067	--	0.4	0.67	0.46	--	--	--	--	--	--	**2.1**
Dibenzo(a,h)anthracene	53-70-3	0.23	mg/kg dry wt	--	0.02 U	--	0.055	0.097	0.052	--	--	--	--	--	--	0.21
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	mg/kg dry wt	--	0.028	--	0.13	0.22	0.13	--	--	--	--	--	--	**0.74**
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																
Fluoranthene	206-44-0	1.7	mg/kg dry wt	--	0.1	--	0.72	1	0.78	--	--	--	--	--	--	**5.9**
Pyrene	129-00-0	2.6	mg/kg dry wt	--	0.1	--	0.87	1.2	0.84	--	--	--	--	--	--	**6.4**
Other SVOCs																
Butyl Benzyl Phthalate	85-68-7	0.09	mg/kg dry wt	--	0.02 U	--	0.019 U	0.02 U	0.034 U	--	--	--	--	--	--	0.019 U
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAHs) that Became TPH Indicator Hazardous Substances in Groundwater																
1-Methylnaphthalene	90-12-0	140	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:

--	Not analyzed.
🟥 **RED**	Concentration exceeds the proposed SCO.
BOLD	Reporting limit is greater than the proposed SCO.
1	This table includes all chemicals that were retained as COCs in Table 5.4, as well as chemicals that were retained for bioaccumulative analysis or as TPH indicator hazardous substances for groundwater.
2	SCOs presented here are the lesser of screening levels for protection of benthic health and direct contact by net fishers. Arsenic is both a benthic and human direct contact COC, therefore SCOs for both exposure pathways are presented here.
3	Although the SCO for the subtidal sediment area based on protection of direct contact by net fishers (11 mg/kg) must be met on a surface-weighted average concentration basis, exceedances of individual sample locations are identified in this table for informational purposes.
4	Screening levels are applicable to Total PCBs, which at the Site is performed by summing all detected Aroclors; Aroclors that are not detected are not included in the total. If no Aroclors were detected, then the Total PCB value is the greatest detection limit.
5	Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.
6	Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.
7	Although there was a historical exceedance of PCBs at HG-44, the sample data were greater than 10 years old, and the location was re-occupied during the interim action sampling. The results for the sample collected during the interim action sampling, SC-09, now supersede the results for HG-44.

Abbreviations:

CAS	Chemical Abstracts Service
cm	Centimeters
COC	Contaminant of concern
mg/kg	Milligrams per kilogram
PQL	Practical Quantitation Limit
SCO	Sediment Cleanup Objective
Site	Harris Avenue Shipyard
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code
wt	Weight

Qualifiers:

J	Analyte was detected, given result should be considered an estimate.
U	Analyte was not detected at the given reporting limit.

Table 5.5

Subtidal Sediment Results for Select Contaminants of Potential Concern[1]

Subtidal Contaminants of Potential Concern	CAS No.	SCO for Subtidal Sediments[2]	Location	(Duplicate)	HG-31	HG-32	HG-33	HG-34	HG-35	HG-36	HG-37	HG-38	HG-39	(Duplicate)	HG-40
			Depth	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm
			Date	08/22/2000	08/22/2000	08/31/2000	08/31/2000	08/23/2000	08/22/2000	08/31/2000	08/31/2000	08/22/2000	08/22/2000	08/22/2000	08/31/2000
			Units												
Metals															
Arsenic	7440-38-2	11/57[3]	mg/kg	10	**13**	**20 U**	**30**	10 U	10 U	**20 U**	10 U	**30**	7 U	7	**20**
Copper	7440-50-8	390	mg/kg	**428**	107	115	**608**	76.3	84.3	69.7	74	**959**	99.9	**657**	96.3
Zinc	7440-66-6	410	mg/kg	166	191	138	**536**	141	126	127	90	**901**	184	372	233
Polychlorinated Biphenyls (PCBs)															
Total PCBs[4]	Total PCBs	0.13	mg/kg dry wt	**0.68**	0.039 U	0.038	**0.22**	0.072	0.025	0.022	0.019	0.039 U	0.021	0.037 U	0.0096 J
Dioxins/Furans															
Dioxin/Furan TEQ[5]	2,3,7,8-TCDD	0.000047	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--	--
Semivolatile Organic Compounds (SVOCs)															
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)															
cPAH TEQ[6]	Total cPAHs TEF	4.2	mg/kg dry wt	1.2	0.094	0.42	1.3	0.23	0.13	0.52	0.35	0.31 J	0.25	0.58	0.014 U
Benzo(a)pyrene	50-32-8	1.6	mg/kg dry wt	0.88	0.066	0.28	0.9	0.16	0.088	0.34	0.26	0.22	0.16	0.4	0.019 U
Benz(a)anthracene	56-55-3	1.3	mg/kg dry wt	0.81	0.066	0.43	1.2	0.19	0.12	0.63	0.22	0.26	0.32	0.56	0.019 U
Benzofluoranthenes (total)	Total Benzo	3.2	mg/kg dry wt	2.0	0.16	0.78	2.1	0.43	0.24	0.93	0.54	0.54	0.47	1.01	0.019 U
Chrysene	218-01-9	1.4	mg/kg dry wt	0.97	0.11	0.63	**1.7**	0.24	0.18	1.1	0.36	0.34	0.52	0.62	0.019 U
Dibenzo(a,h)anthracene	53-70-3	0.23	mg/kg dry wt	0.058	0.02 U	0.023	0.071	0.02 U	0.02 U	0.024	0.02	0.019 J	0.019 U	0.029	0.019 U
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	mg/kg dry wt	0.29	0.027	0.12	0.41	0.065	0.034	0.11	0.094	0.092	0.048	0.12	0.019 U
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)															
Fluoranthene	206-44-0	1.7	mg/kg dry wt	1.6	0.15	0.58	**2**	0.52	0.3	0.87	0.58	0.55	0.98	1.2	0.019 U
Pyrene	129-00-0	2.6	mg/kg dry wt	1.9	0.18	0.52	2.4	0.46	0.24	0.72	0.54	0.53	1	0.89	0.019 U
Other SVOCs															
Butyl Benzyl Phthalate	85-68-7	0.09	mg/kg dry wt	0.02 U	0.02 U	0.036	0.049	0.02 U	0.02 U	0.019 U	0.019 U	**0.23**	0.019 U	0.015 U	0.019 U
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAHs) that Became TPH Indicator Hazardous Substances in Groundwater															
1-Methylnaphthalene	90-12-0	140	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--	--

Notes:

-- Not analyzed.

RED Concentration exceeds the proposed SCO.

BOLD Reporting limit is greater than the proposed SCO.

1 This table includes all chemicals that were retained as COCs in Table 5.4, as well as chemicals that were retained for bioaccumulative analysis or as TPH indicator hazardous substances for groundwater.

2 SCOs presented here are the lesser of screening levels for protection of benthic health and direct contact by net fishers. Arsenic is both a benthic and human direct contact COC, therefore SCOs for both exposure pathways are presented here.

3 Although the SCO for the subtidal sediment area based on protection of direct contact by net fishers (11 mg/kg) must be met on a surface-weighted average concentration basis, exceedances of individual sample locations are identified in this table for informational purposes.

4 Screening levels are applicable to Total PCBs, which at the Site is performed by summing all detected Aroclors; Aroclors that are not detected are not included in the total. If no Aroclors were detected, then the Total PCB value is the greatest detection limit.

5 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.

6 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

7 Although there was a historical exceedance of PCBs at HG-44, the sample data were greater than 10 years old, and the location was re-occupied during the interim action sampling. The results for the sample collected during the interim action sampling, SC-09, now supersede the results for HG-44.

Abbreviations:

CAS	Chemical Abstracts Service
cm	Centimeters
COC	Contaminant of concern
mg/kg	Milligrams per kilogram
PQL	Practical Quantitation Limit
SCO	Sediment Cleanup Objective
Site	Harris Avenue Shipyard
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
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TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code
wt	Weight

Qualifiers:

J	Analyte was detected, given result should be considered an estimate.
U	Analyte was not detected at the given reporting limit.

Table 5.5

Subtidal Sediment Results for Select Contaminants of Potential Concern[1]

Subtidal Contaminants of Potential Concern	CAS No.	SCO for Subtidal Sediments[2]	Location	HG-41	HG-42	HG-44[7]	HB-1	HB-2	HB-3	HB-4	SG-01	SG-03	(Duplicate)	SG-04
			Depth	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm	0–12 cm
			Date	08/22/2000	08/23/2000	11/09/2000	07/24/2003	07/24/2003	07/24/2003	07/24/2003	07/28/2011	07/28/2011	07/28/2011	07/28/2011
			Units											
Metals														
Arsenic	7440-38-2	11/57[3]	mg/kg	10	**158**	**20 U**	10 U	10 U	10 U	**20 U**	3.8	**21**	**20**	**17**
Copper	7440-50-8	390	mg/kg	238	**669**	372	69.7	106	114	90.1	44	150	160	220
Zinc	7440-66-6	410	mg/kg	267	**1,620**	155	104	145	129	151	64	290	280	400
Polychlorinated Biphenyls (PCBs)														
Total PCBs[4]	Total PCBs	0.13	mg/kg dry wt	0.098	0.085	**0.21**	0.039 U	0.076 U	0.039 U	0.039 U	0.0078	--	--	0.1
Dioxins/Furans														
Dioxin/Furan TEQ[5]	2,3,7,8-TCDD	0.000047	mg/kg dry wt	--	--	--	--	--	--	--	--	--	--	--
Semivolatile Organic Compounds (SVOCs)														
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)														
cPAH TEQ[6]	Total cPAHs TEF	4.2	mg/kg dry wt	0.87	1.2	0.14	0.21	0.12	0.1	0.29	0.076	--	--	0.91
Benzo(a)pyrene	50-32-8	1.6	mg/kg dry wt	0.61	0.79	0.1	0.15	0.088	0.072	0.2	0.1 U	--	--	0.66
Benz(a)anthracene	56-55-3	1.3	mg/kg dry wt	0.61	1.1	0.12	0.13	0.1	0.072	0.33	0.1 U	--	--	0.8
Benzofluoranthenes (total)	Total Benzo	3.2	mg/kg dry wt	1.59	2.19	0.214	0.32	0.195	0.153	0.41	0.1 U	--	--	1.41
Chrysene	218-01-9	1.4	mg/kg dry wt	1	1.2	0.17	0.23	0.16	0.14	0.39	0.13	--	--	1.1
Dibenzo(a,h)anthracene	53-70-3	0.23	mg/kg dry wt	0.054	0.074	0.02 U	0.021	0.02 U	0.02 U	0.035	0.1 U	--	--	0.1 U
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	mg/kg dry wt	0.25	0.34	0.062	0.097	0.044	0.048	0.086	0.1 U	--	--	0.17
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)														
Fluoranthene	206-44-0	1.7	mg/kg dry wt	1.3	**3**	0.34	0.3	0.18	0.2	0.69	0.19	--	--	1.6
Pyrene	129-00-0	2.6	mg/kg dry wt	1.5	2.5	0.39	0.31	0.15	0.15	0.51	0.2	--	--	1.7
Other SVOCs														
Butyl Benzyl Phthalate	85-68-7	0.09	mg/kg dry wt	0.033	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	**0.1 U**	--	--	**0.1 U**
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAHs) that Became TPH Indicator Hazardous Substances in Groundwater														
1-Methylnaphthalene	90-12-0	140	mg/kg dry wt	--	--	--	--	--	--	--	0.1 U	--	--	0.48

Notes:

-- Not analyzed.

RED Concentration exceeds the proposed SCO.

BOLD Reporting limit is greater than the proposed SCO.

1 This table includes all chemicals that were retained as COCs in Table 5.4, as well as chemicals that were retained for bioaccumulative analysis or as TPH indicator hazardous substances for groundwater.

2 SCOs presented here are the lesser of screening levels for protection of benthic health and direct contact by net fishers. Arsenic is both a benthic and human direct contact COC, therefore SCOs for both exposure pathways are presented here.

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Table 5.5

Subtidal Sediment Results for Select Contaminants of Potential Concern[1]

Subtidal Contaminants of Potential Concern	CAS No.	SCO for Subtidal Sediments[2]	Location	SG-05	(Duplicate)	SG-06	SG-06	SG-07	SG-08	SG-09	SG-10	SG-11	SG-12	SG-13
			Depth	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm	0–10 cm
			Date	01/31/2013	01/31/2013	01/31/2013	01/31/2013	01/31/2013	01/31/2013	01/31/2013	01/31/2013	01/31/2013	01/31/2013	01/31/2013
			Units											
Metals														
Arsenic	7440-38-2	11/57[3]	mg/kg	**30**	**50**	--	--	--	**30 U**	**13**	**14 J**	10.6 J	--	--
Copper	7440-50-8	390	mg/kg	280	292	--	--	--	143	78.9	--	--	--	--
Zinc	7440-66-6	410	mg/kg	**535**	**594**	--	--	--	153	122	--	--	--	--
Polychlorinated Biphenyls (PCBs)														
Total PCBs[4]	Total PCBs	0.13	mg/kg dry wt	0.0056 J	0.031	--	--	--	0.04	0.05	0.029	0.055	--	--
Dioxins/Furans														
Dioxin/Furan TEQ[5]	2,3,7,8-TCDD	0.000047	mg/kg dry wt	--	--	0.000036 J	0.000034 J	0.0000053 J	--	--	--	--	0.000025 J	0.000012 J
Semivolatile Organic Compounds (SVOCs)														
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)														
cPAH TEQ[6]	Total cPAHs TEF	4.2	mg/kg dry wt	0.073	0.63	0.63	--	0.27	2.2	0.16	1.5	0.13	0.15	0.13 J
Benzo(a)pyrene	50-32-8	1.6	mg/kg dry wt	0.054	0.48	0.47	--	0.2	1.6	0.11	1.1	0.096	0.1	0.091
Benz(a)anthracene	56-55-3	1.3	mg/kg dry wt	0.06	0.44	0.47	--	0.2	**1.7**	0.11	1.1	0.1	0.14	0.094
Benzofluoranthenes (total)	Total Benzo	3.2	mg/kg dry wt	0.11	0.83	0.92	--	0.4	2.6	0.23	1.7	0.19	0.28	0.22
Chrysene	218-01-9	1.4	mg/kg dry wt	0.082	0.52	0.82	--	0.37	**2.3**	0.2	1.2	0.12	0.27	0.18
Dibenzo(a,h)anthracene	53-70-3	0.23	mg/kg dry wt	0.0078	0.058	0.043	--	0.017	**0.26**	0.027	0.13	0.013 J	0.011	0.01
Indeno(1,2,3-cd)pyrene	193-39-5	0.6	mg/kg dry wt	0.019 U	0.12	0.081	--	0.042	**0.74**	0.063	0.57	0.048 J	0.023	0.011 J
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)														
Fluoranthene	206-44-0	1.7	mg/kg dry wt	0.18	1.4	1.7	--	1	**3.5**	0.49	**3**	0.32	0.88	0.3
Pyrene	129-00-0	2.6	mg/kg dry wt	0.13	1.1	1.3	--	0.82	**3.7**	0.41	**4**	0.38	0.6	0.26
Other SVOCs														
Butyl Benzyl Phthalate	85-68-7	0.09	mg/kg dry wt	0.0094 J	0.0047 U	0.028 J	--	0.0037 J	0.024 U	0.0047 U	--	--	0.0036 J	0.0049 U
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAHs) that Became TPH Indicator Hazardous Substances in Groundwater														
1-Methylnaphthalene	90-12-0	140	mg/kg dry wt	0.019 U	0.091	0.036	--	0.069	0.082 J	0.022	0.01	0.032	0.013 J	0.02 U

Notes:

-- Not analyzed.
RED Concentration exceeds the proposed SCO.
BOLD Reporting limit is greater than the proposed SCO.
1 This table includes all chemicals that were retained as COCs in Table 5.4, as well as chemicals that were retained for bioaccumulative analysis or as TPH indicator hazardous substances for groundwater.
2 SCOs presented here are the lesser of screening levels for protection of benthic health and direct contact by net fishers. Arsenic is both a benthic and human direct contact COC; therefore, SCOs for both exposure pathways are presented here.
3 Although the SCO for the subtidal sediment area based on protection of direct contact by net fishers (11 mg/kg) must be met on a surface-weighted average concentration basis, exceedances of individual sample locations are identified in this table for informational purposes.
4 Screening levels are applicable to Total PCBs, which at the Site is performed by summing all detected Aroclors; Aroclors that are not detected are not included in the total. If no Aroclors were detected, then the Total PCB value is the greatest detection limit.
5 Calculation of dioxin/furan TEQ is performed using World Health Organization 2005 TEFs (Van den Berg et al. 2006). Calculation is performed using detected dioxin/furan concentrations plus one-half the detection limit for dioxins/furans that were not detected.
6 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.
7 Although there was a historical exceedance of PCBs at HG-44, the sample data were greater than 10 years old, and the location was re-occupied during the interim action sampling. The results for the sample collected during the interim action sampling, SC-09, now supersede the results for HG-4

Abbreviations:

CAS	Chemical Abstracts Service
cm	Centimeters
COC	Contaminant of concern
mg/kg	Milligrams per kilogram
PQL	Practical Quantitation Limit
SCO	Sediment Cleanup Objective
Site	Harris Avenue Shipyard
TCDD	Tetrachlorodibenzodioxin
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code
wt	Weight

Qualifiers:

J	Analyte was detected, given result should be considered an estimate.
U	Analyte was not detected at the given reporting limit.

Table 5.9
Frequency of Exceedance of Screening Levels for Groundwater

Contaminants of Potential Concern[1]	CAS No.	Proposed Groundwater Cleanup Level[2]	Unit	Number of Results[3]	Number of Detections	Number of Detected Results Exceeding Groundwater Screening Level	Percent of Detected Results Exceeding Groundwater Screening Level	Information About Maximum Detection			Comment
								Value	Location	Date	
COPCs Retained as COCs for Groundwater											
Dissolved Metals[4]											
Arsenic	7440-38-2	5.0	µg/L	44	44	18	41%	25.1	MW-01	8/27/2015	COC for protection of surface water quality at POC.
Copper[5]	7440-50-8	3.1	µg/L	44	39	12	27%	13.1	MW-12	12/3/2015	COC for protection of surface water quality at POC.
Zinc	7440-66-6	81	µg/L	44	15	8	18%	387	MW-12	8/27/2015	COC for protection of surface water quality at POC.
Low molecular weight polycyclic aromatic hydrocarbons (LPAHs)											
1-Methylnaphthalene	90-12-0	1.5	µg/L	47	32	12	26%	93	MW-01	2/15/2013	COC for protection of surface water quality at POC; also used as an Indicator Hazardous Substance (IHS) for TPH.
COPCs Not Retained as COCs for Groundwater											
Dissolved Metals[4]											
Nickel	7440-02-0	8.2	µg/L	11	11	1	9.1%	8.97	MW-10	2/14/2013	Eliminated; refer to Section 5.3 for details.
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)											
cPAH TEQ[6]	Total cPAHs TEF	0.01	µg/L	45	8	3	6.7%	0.032	MW-01	2/15/2013	Eliminated; refer to Section 5.3 for details.
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)											
2-Methylnaphthalene	91-57-6	32	µg/L	44	27	1	2.3%	67	MW-01	2/15/2013	Eliminated; refer to Section 5.3 for details.
Acenaphthene	83-32-9	10	µg/L	44	27	3	6.8%	35	MW-01	12/3/2015	Eliminated. There are no intertidal or subtidal sediment exceedances for these LPAHs; therefore, sediment data demonstrate that existing groundwater concentrations are protective. The proposed cleanup level is based on screening levels developed for protection of surface water, and must be met at point of compliance wells.
Fluorene	86-73-7	5.0	µg/L	44	24	3	6.8%	17	MW-01	12/3/2015	

Notes:

1 Only chemicals identified as groundwater COPCs in Table 4.8 are retained presented in this table. Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2.

2 Proposed groundwater cleanup level is the lesser of the screening levels to protect surface water quality, sediment quality, and vapor intrusion, as modified by natural background for arsenic and PQLs for cPAHs.

3 Only groundwater samples from wells that were collected from January 2013 to December 2015 were considered part of the data set. Field samples and field duplicate results are counted as unique results.

4 Metals are measured in the dissolved fraction because the proposed CULs are derived from surface water ARARs that are based on the dissolved fraction. To assess compliance, it is appropriate for the fraction measured to match the fraction regulated.

5 The toxicity of copper in the aquatic environment is impacted by site-specific water quality variables, including temperature, dissolved organic carbon, salinity, and pH. In 2016, EPA published draft estuarine/marine copper Ambient Water Quality Criteria (AWQC; EPA 2016), which enable calculation of a site-specific CUL protective of aquatic life in marine waters. Ecology may approve calculation of a site-specific CUL per WAC 173-201A-240, Table 240, footnote dd.

6 Calculation of cPAH TEQ concentrations was performed using the California Environmental Protection Agency 2005 Toxic Equivalency Factors as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculated using detected cPAH concentrations plus one-half the reporting limit for cPAHs that were not detected.

Abbreviations:

ARAR	Applicable or Relevant and Appropriate Requirement
CAS	Chemical Abstracts Service
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
µg/L	Micrograms per liter
POC	Point of Contact
PQL	Practical Quantitation Limit
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.10

Groundwater Results for Select Contaminants of Potential Concern[1, 2]

			Location	MW-01 (Interior Well)				MW-02A (Shoreline Well)					
			Sample Date	02/15/2013	08/27/2015	12/03/2015	3 events[4]	02/15/2013	02/25/2015	05/23/2015	08/27/2015	12/03/2015	5 events[4]
		Proposed Groundwater Cleanup Level[3]	Sample ID										
Contaminants of Potential Concern	CAS No.		Units	MW-01-GW-021513	MW-01-GW-082715	MW-01-GW-120315	MW-01 Average[5]	MW-02A-GW-021513	MW-02A-GW-022515	MW-02A-GW-052815	MW-02A-GW-082715	MW-02A-GW-120315	MW-02A Average
COCs for Groundwater													
Dissolved Metals													
Arsenic	7440-38-2	5.0	µg/L	**14**	**25**	**18**	**19**	1.5	4.2	3.1	**6.2**	2.8 JQ	3.6 J
Copper	7440-50-8	3.1	µg/L	0.24 U	1.2	1.2	0.8	**9.1**	**5.2**	**4.8**	**6.9**	**10**	**7.2**
Zinc	7440-66-6	81	µg/L	8.3 U	5.0 U	5.0 U	5.0 U	71	**94**	**120**	**93**	**140**	**100**
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)													
1-Methylnaphthalene[6]	90-12-0	1.5	µg/L	**93**	**25**	**28**	**49**	0.026	0.0051 JQ	0.0053 JQ	0.0035 JQ	0.010 U	0.0090 J
COPCs Eliminated as Groundwater COCs, but are discussed in text													
Dissolved Metals													
Nickel	7440-02-0	8.2	µg/L	4.2	--	--	4.2	4.7	--	--	--	--	4.7
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)													
cPAH TEQ[7]	Total cPAHs TEF	0.010	µg/L	**0.032 J**	**0.076 U**	**0.014 J**	**0.028 J**	0.0073 UB	0.0076 U	0.0076 U	0.0076 U	0.0076 U	0.0073 UB
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)													
2-Methylnaphthalene	91-57-6	32	µg/L	**67**	9	22	**33**	0.027	0.010 U	0.0093 JQ	0.010 U	0.010 U	0.010 J
Acenaphthene	83-32-9	10	µg/L	**25**	**32**	**35**	**31**	0.020 U	0.010 U	0.0040 JQ	0.010 U	0.0040 JQ	0.0058 J
Fluorene	86-73-7	5.0	µg/L	**14**	**14**	**17**	**15**	0.020 U	0.010 U	0.0078 JQ	0.010 U	0.01 U	0.0076 J

Notes:

--	Not analyzed.
RED	Concentration exceeds the proposed cleanup level.
BOLD	Reporting limit is greater than the proposed cleanup level.

1 All results and averages are presented to two significant figures. The individual results were rounded to two significant figures prior to calculating the average result for the well.

2 Only groundwater samples from wells that were collected in the past 5 years were considered part of the data set for determining COCs.

3 Proposed groundwater cleanup levels are the lowest of the screening levels to protect surface water quality, sediment quality, and vapor intrusion, as modified by natural background for arsenic and the PQL for cPAHs.

4 Overall event count; dissolved nickel was not analyzed after the February 2013 event by agreement with Ecology and has fewer events for MW-01, MW-02, and MW-06 through MW-09.

5 When calculating averages, 1/2 the reporting limit was used for non-detect results, unless all results at that well were non-detect; in these cases, the lowest reporting limit was used as the result for the well.

6 1-methylnaphthalene is also retained as an indicator hazardous substances for TPH, as described in Section 5.3.

7 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
µg/L	Micrograms per liter
PQL	Practical Quantitation Limit
TEF	Toxicity equivalency factor
TEQ	Toxic equivalency quotient
WAC	Washington Administrative Code

Qualifiers:

J	The analyte was detected and the result should be considered an estimate.
JQ	The analyte was detected between the method detection limit and reporting limit and should be considered an estimate.
U	The analyte was not detected at the given reporting limit.
UJ	The analyte was not detected and the reporting limit is considered an estimate.

Table 5.10

Groundwater Results for Select Contaminants of Potential Concern[1, 2]

Contaminants of Potential Concern	CAS No.	Proposed Groundwater Cleanup Level[3]	Location	MW-04 (Interior Well)	MW-05 (Interior Well)	MW-06 (Shoreline Well)							
			Sample Date	02/14/2013	02/15/2013	02/14/2013	02/14/2013	02/15/2013	02/25/2015	05/28/2015	08/27/2015	12/03/2015	6 Events[4]
			Sample ID	MW-04-GW-021413	MW-05-GW-021413	MW-06-GW-021413 (low tide)	MW-94-GW-021413 (low tide)	MW-06-GW-021513 (high tide)	MW-06-GW-022515	MW-06-GW-052815	MW-06-GW-082715	MW-06-GW-120315	MW-06 Average
			Units										
COCs for Groundwater													
Dissolved Metals													
Arsenic	7440-38-2	5.0	µg/L	1.8	0.38	4.2	4.3	3.5	4.4	5.7	4.7	1.7 JQ	4.1 J
Copper	7440-50-8	3.1	µg/L	2.1	0.84	1.6	1.5	1.6	1.2	0.90	0.71 JQ	2.6	1.4 J
Zinc	7440-66-6	81	µg/L	8.3 U	8.3 U	8.3 U	8.3 U	8.3 U	0.050 U	0.54	5.0 U	5.0 U	2.6
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)													
1-Methylnaphthalene[6]	90-12-0	1.5	µg/L	0.020 U	0.020 U	0.020 U	0.020 U	--	0.026	0.0061 JQ	0.032	0.0043 JQ	0.013 J
COPCs Eliminated as Groundwater COCs, but are discussed in text													
Dissolved Metals													
Nickel	7440-02-0	8.2	µg/L	1.9	1.6	1.2	1.1	1.2	--	--	--	--	1.2
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)													
cPAH TEQ[7]	Total cPAHs TEF	0.010	µg/L	0.0071 U	0.0071 U	0.0071 U	0.0071 U	--	0.0071 JQ	0.0076 U	0.0076 U	0.0076 U	0.0071 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)													
2-Methylnaphthalene	91-57-6	32	µg/L	0.020 U	0.020 U	0.020 U	0.020 U	--	0.015	0.0085 JQ	0.020	0.010 U	0.011 J
Acenaphthene	83-32-9	10	µg/L	0.020 U	0.020 U	0.031	0.039	--	0.010 U	0.0057 JQ	0.020	0.0050 JQ	0.015 J
Fluorene	86-73-7	5.0	µg/L	0.020 U	0.020 U	0.020 U	0.020 U	--	0.0071 JQ	0.0077 JQ	0.034	0.010 U	0.013 J

Notes:

--	Not analyzed.
RED	Concentration exceeds the proposed cleanup level.
BOLD	Reporting limit is greater than the proposed cleanup level.
1	All results and averages are presented to two significant figures. The individual results were rounded to two significant figures prior to calculating the average result for the well.
2	Only groundwater samples from wells that were collected in the past 5 years were considered part of the data set for determining COCs.
3	Proposed groundwater cleanup levels are the lowest of the screening levels to protect surface water quality, sediment quality, and vapor intrusion, as modified by natural background for arsenic and the PQL for cPAHs.
4	Overall event count; dissolved nickel was not analyzed after the February 2013 event by agreement with Ecology and has fewer events for MW-01, MW-02, and MW-06 through MW-09.
5	When calculating averages, 1/2 the reporting limit was used for non-detect results, unless all results at that well were non-detect; in these cases, the lowest reporting limit was used as the result for the well.
6	1-methylnaphthalene is also retained as an indicator hazardous substances for TPH, as described in Section 5.3.
7	Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
µg/L	Micrograms per liter
PQL	Practical Quantitation Limit
TEF	Toxicity equivalency factor
TEQ	Toxic equivalency quotient
WAC	Washington Administrative Code

Qualifiers:

J	The analyte was detected and the result should be considered an estimate.
JQ	The analyte was detected between the method detection limit and reporting limit and should be considered an estimate.
U	The analyte was not detected at the given reporting limit.
UJ	The analyte was not detected and the reporting limit is considered an estimate.

Table 5.10

Groundwater Results for Select Contaminants of Potential Concern[1, 2]

			Location	MW-07 (Shoreline Well)						MW-08 (Shoreline Well)					
			Sample Date	02/14/2013	02/25/2015	05/28/2015	08/27/2015	12/03/2015	5 Events[4]	02/14/2013	02/25/2015	05/28/2015	08/27/2015	12/03/2015	5 Events[4]
			Sample ID	MW-07-GW-021413	MW-07-GW-022515	MW-07-GW-052815	MW-07-GW-082715	MW-07-GW-120315	MW-07 Average	MW-08-GW-021413	MW-08-GW-022515	MW-08-GW-052815	MW-08-GW-082715	MW-08-GW-120315	MW-08 Average
Contaminants of Potential Concern	CAS No.	Proposed Groundwater Cleanup Level[3]	Units												
COCs for Groundwater															
Dissolved Metals															
Arsenic	7440-38-2	5.0	μg/L	0.83	1.7	3.1	6.0	1.8 JQ	2.7 J	0.92	1.9	1.5	4.3	2.1 JQ	2.1 J
Copper	7440-50-8	3.1	μg/L	1.5	1.4	0.25	0.29 JQ	2.5	1.2 J	1.2	1.1	1.2	3.7	3.9	2.2
Zinc	7440-66-6	81	μg/L	11	2.5 U	2.0	5.0 U	5.0 U	3.8	8.3 U	2.5 U	1.0 U	5.0 U	5.0 U	1.0 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)															
1-Methylnaphthalene[6]	90-12-0	1.5	μg/L	0.020 U	0.0064 JQ	0.0035 JQ	0.0080 JQ	0.010 U	0.0066 J	0.020 U	0.0089 JQ	0.0043 JQ	0.0092 JQ	0.010 U	0.0075 J
COPCs Eliminated as Groundwater COCs, but are discussed in text															
Dissolved Metals															
Nickel	7440-02-0	8.2	μg/L	7.1	--	--	--	--	7.1	1.4	--	--	--	--	1.4
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)															
cPAH TEQ[7]	Total cPAHs TEF	0.010	μg/L	0.0071 U	0.0076 U	0.0076 U	0.0076 U	0.0076 U	0.0071 U	0.0071 U	0.0076 U	0.0071 U	0.0076 U	0.0076 U	0.0071 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)															
2-Methylnaphthalene	91-57-6	32	μg/L	0.020 U	0.0055 JQ	0.0047 JQ	0.0097 JQ	0.010 U	0.0070 J	0.020 U	0.010 U	0.010	0.016	0.010 U	0.0092
Acenaphthene	83-32-9	10	μg/L	0.96	0.010 U	0.010 U	0.0073 JQ	0.010 U	0.20 J	0.020 U	0.010 U	0.010 U	0.0078 JQ	0.010 U	0.0066 J
Fluorene	86-73-7	5.0	μg/L	0.020 U	0.010 U	0.010 U	0.022	0.010 U	0.0094	0.020 U	0.010 U	0.010 U	0.018	0.010 U	0.0086

Notes:

-- Not analyzed.
RED Concentration exceeds the proposed cleanup level.
BOLD Reporting limit is greater than the proposed cleanup level.
1 All results and averages are presented to two significant figures. The individual results were rounded to two significant figures prior to calculating the average result for the well.
2 Only groundwater samples from wells that were collected in the past 5 years were considered part of the data set for determining COCs.
3 Proposed groundwater cleanup levels are the lowest of the screening levels to protect surface water quality, sediment quality, and vapor intrusion, as modified by natural background for arsenic and the PQL for cPAHs.
4 Overall event count; dissolved nickel was not analyzed after the February 2013 event by agreement with Ecology and has fewer events for MW-01, MW-02, and MW-06 through MW-09.
5 When calculating averages, 1/2 the reporting limit was used for non-detect results, unless all results at that well were non-detect; in these cases, the lowest reporting limit was used as the result for the well.
6 1-methylnaphthalene is also retained as an indicator hazardous substances for TPH, as described in Section 5.3.
7 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
μg/L	Micrograms per liter
PQL	Practical Quantitation Limit
TEF	Toxicity equivalency factor
TEQ	Toxic equivalency quotient
WAC	Washington Administrative Code

Qualifiers:

J	The analyte was detected and the result should be considered an estimate.
JQ	The analyte was detected between the method detection limit and reporting limit and should be considered an estimate.
U	The analyte was not detected at the given reporting limit.
UJ	The analyte was not detected and the reporting limit is considered an estimate.

Table 5.10

Groundwater Results for Select Contaminants of Potential Concern[1, 2]

Contaminants of Potential Concern	CAS No.	Proposed Groundwater Cleanup Level[3]	Location	MW-09 (Shoreline Well)										MW-10 (Shoreline Well)
			Sample Date	02/15/2013	02/25/2015	02/25/2015	05/28/2015	05/28/2015	08/27/2015	08/27/2015	12/03/2015	12/03/2015	5 Events[4]	02/14/2013
			Sample ID	MW-09-GW-021513	MW-09-GW-022515	MW-25-GW-022515 (09 dup)	MW-09-GW-052815	MW-25-GW-052815 (09 dup)	MW-08-GW-082715	MW-25-GW-082715 (09 dup)	MW-09-GW-120315	MW-25-GW-120315 (09 dup)	MW-09 Average	MW-10-GW-021413
			Units											
COCs for Groundwater														
Dissolved Metals														
Arsenic	7440-38-2	5.0	µg/L	4.6	**22**	--	**19**	**21**	**20**	**19**	**16**	**17**	**17**	3.9
Copper	7440-50-8	3.1	µg/L	0.24 U	0.36	--	0.52	0.41	0.35 JQ	0.25 JQ	1.0 U	1.0 U	0.37 J	0.44
Zinc	7440-66-6	81	µg/L	8.3	1.1	--	2.6	2.5	5.0 U	5.0 U	5.0 U	5.0 U	2.6	8.3 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)														
1-Methylnaphthalene[6]	90-12-0	1.5	µg/L	**52**	**60**	**52**	**39**	**39**	**48**	**47**	**35**	**35**	**47**	0.020 U
COPCs Eliminated as Groundwater COCs, but are discussed in text														
Dissolved Metals														
Nickel	7440-02-0	8.2	µg/L	1.4	--	--	--	--	--	--	--	--	1.4	**9.0**
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)														
cPAH TEQ[7]	Total cPAHs TEF	0.010	µg/L	0.0071 U	0.0076 J	0.0076 U	0.0076 U	0.0076 U	0.005 J	0.0053 J	0.0075 J	0.0076 J	0.0053 J	0.0076 UB
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)														
2-Methylnaphthalene	91-57-6	32	µg/L	4.3	12	10	8.6	8.1	8.3 J	7.7 J	5.7	5.4	7.8 J	0.020 U
Acenaphthene	83-32-9	10	µg/L	2.0	2.8	2.6	2.2	2.2	3.3	3.0	2.6	2.4	2.6	0.020 U
Fluorene	86-73-7	5.0	µg/L	3.9	3.9	3.6	2.7	2.5	3.6	3.7	1.9	1.8	3.2	0.020 U

Notes:

--	Not analyzed.
RED	Concentration exceeds the proposed cleanup level.
BOLD	Reporting limit is greater than the proposed cleanup level.
1	All results and averages are presented to two significant figures. The individual results were rounded to two significant figures prior to calculating the average result for the well.
2	Only groundwater samples from wells that were collected in the past 5 years were considered part of the data set for determining COCs.
3	Proposed groundwater cleanup levels are the lowest of the screening levels to protect surface water quality, sediment quality, and vapor intrusion, as modified by natural background for arsenic and the PQL for cPAHs.
4	Overall event count; dissolved nickel was not analyzed after the February 2013 event by agreement with Ecology and has fewer events for MW-01, MW-02, and MW-06 through MW-09.
5	When calculating averages, 1/2 the reporting limit was used for non-detect results, unless all results at that well were non-detect; in these cases, the lowest reporting limit was used as the result for the well.
6	1-methylnaphthalene is also retained as an indicator hazardous substances for TPH, as described in Section 5.3.
7	Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
µg/L	Micrograms per liter
PQL	Practical Quantitation Limit
TEF	Toxicity equivalency factor
TEQ	Toxic equivalency quotient
WAC	Washington Administrative Code

Qualifiers:

J	The analyte was detected and the result should be considered an estimate.
JQ	The analyte was detected between the method detection limit and reporting limit and should be considered an estimate.
U	The analyte was not detected at the given reporting limit.
UJ	The analyte was not detected and the reporting limit is considered an estimate.

Table 5.10

Groundwater Results for Select Contaminants of Potential Concern[1, 2]

			Location	MW-11 (Shoreline Well)					MW-12 (Shoreline Well)				
		Proposed Groundwater Cleanup Level[3]	Sample Date	02/25/2015	05/28/2015	08/27/2015	12/03/2015	4 Events	02/25/2015	05/28/2015	08/27/2015	12/03/2015	4 Events
			Sample ID	MW-11-GW-022515	MW-11-GW-052815	MW-11-GW-082715	MW-11-GW-120315	MW-11 Average	MW-12-GW-022515	MW-12-GW-052815	MW-12-GW-082715	MW-12-GW-120315	MW-12 Average
Contaminants of Potential Concern	**CAS No.**		**Units**										
COCs for Groundwater													
Dissolved Metals													
Arsenic	7440-38-2	5.0	µg/L	**8.1**	**8.6**	**12**	**5.6**	**8.6**	3.9	4.2	**5.2**	2.2 JQ	3.9 J
Copper	7440-50-8	3.1	µg/L	0.09 JQ	0.11 U	1.0 U	1.4	0.52 J	**6.8**	**8.7**	**11.9**	**13**	**10**
Zinc	7440-66-6	81	µg/L	2.5 U	0.50 U	5.0 U	5.0 U	0.5 U	**130**	**280**	**390**	**230**	**260**
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)													
1-Methylnaphthalene[6]	90-12-0	1.5	µg/L	0.22	1.0	0.73	0.14	0.52	0.10 U	0.0042 JQ	0.0062 JQ	0.010 U	0.016 J
COPCs Eliminated as Groundwater COCs, but are discussed in text													
Dissolved Metals													
Nickel	7440-02-0	8.2	µg/L	--	--	--	--	--	--	--	--	--	--
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)													
cPAH TEQ[7]	Total cPAHs TEF	0.010	µg/L	**0.071 U**	0.0076 U	0.0076 U	**0.016 J**	**0.015 J**	**0.071 U**	0.0076 U	0.0076 U	0.0076 U	0.0076 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)													
2-Methylnaphthalene	91-57-6	32	µg/L	0.010 U	0.34	0.024	0.010	0.095	0.10 U	0.0076 JQ	0.010 JQ	0.010 U	0.018 J
Acenaphthene	83-32-9	10	µg/L	0.51	2.1	3.0	1.2	1.70	0.10 U	0.0032 JQ	0.0062 JQ	0.010 U	0.016 J
Fluorene	86-73-7	5.0	µg/L	0.11	0.54	0.59	0.46	0.42	0.10 U	0.0054 JQ	0.013	0.010 U	0.018 J

Notes:

-- Not analyzed.

RED Concentration exceeds the proposed cleanup level.

BOLD Reporting limit is greater than the proposed cleanup level.

1 All results and averages are presented to two significant figures. The individual results were rounded to two significant figures prior to calculating the average result for the well.

2 Only groundwater samples from wells that were collected in the past 5 years were considered part of the data set for determining COCs.

3 Proposed groundwater cleanup levels are the lowest of the screening levels to protect surface water quality, sediment quality, and vapor intrusion, as modified by natural background for arsenic and the PQL for cPAHs.

4 Overall event count; dissolved nickel was not analyzed after the February 2013 event by agreement with Ecology and has fewer events for MW-01, MW-02, and MW-06 through MW-09.

5 When calculating averages, 1/2 the reporting limit was used for non-detect results, unless all results at that well were non-detect; in these cases, the lowest reporting limit was used as the result for the well.

6 1-methylnaphthalene is also retained as an indicator hazardous substances for TPH, as described in Section 5.3.

7 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
µg/L	Micrograms per liter
PQL	Practical Quantitation Limit
TEF	Toxicity equivalency factor
TEQ	Toxic equivalency quotient
WAC	Washington Administrative Code

Qualifiers:

J	The analyte was detected and the result should be considered an estimate.
JQ	The analyte was detected between the method detection limit and reporting limit and should be considered an estimate.
U	The analyte was not detected at the given reporting limit.
UJ	The analyte was not detected and the reporting limit is considered an estimate.

Table 5.12

Frequency of Exceedance of Screening Levels for Soil[1]

Contaminant of Potential Concern	Units	Soil Sample Results (All Depths)			Soil Screening Levels for Possible Pathways and Frequency of Exceedance for Those Pathways									Included in Nature and Extent Discussion
					Direct Contact (POC: 0–15 ft bgs)			Protection of Groundwater (POC: 0–8 ft bgs)			Protection of Groundwater (POC: ≥ 8 ft bgs)[2]			
		Number of Results	Percent Detected	Maximum Detected Value	Screening Level (Table 4.6)	Percent Exceeding[3]	COC for this pathway?	Screening Level (Table 4.6)	Percent Exceeding[3]	COC for this pathway?[4]	Screening Level (Table 4.6)	Percent Exceeding[3]	COC for this pathway?[4]	
Metals														
Antimony	mg/kg	48	29%	70	1,400	None	No	33	8%	GW Clean	1.7	None	No	No
Arsenic	mg/kg	86	98%	1,240	88	10%	**Yes**	20	40%	**Yes**	20	None	No	Yes
Cadmium	mg/kg	86	29%	12.6	3,500	None	No	1.2	18%	GW Clean	0.77	2%	No	No
Copper	mg/kg	86	100%	4,690	140,000	None	No	36	63%	**Yes**	36	11%	**Evaluated in Section 5.0.**	Yes
Lead[5]	mg/kg	86	99%	1,680	1,000	2.3%	No	1,600	2%	GW Clean	81	2%	GW Clean	Yes
Mercury[5]	mg/kg	86	69%	17.6	1,000	None	No	0.16	28%	GW Clean	0.07	4%	GW Clean	Yes
Nickel	mg/kg	86	100%	426	Nickel is present at a site-specific background in soil and is not a COC. Refer to Section 5.0 and Figure 5.11 for details.									Yes
Selenium	mg/kg	38	2.6%	8	18,000	None	No	7.4	3%	GW Clean	1	None	No	No
Silver	mg/kg	86	8.1%	3	18,000	None	No	0.32	12%	GW Clean	0.2	None	No	No
Zinc	mg/kg	86	100%	12,600	1,100,000	None	No	100	58%	**Yes**	85	4%	**Evaluated in Section 5.0.**	Yes
Polychlorinated Biphenyls (PCBs)[6]														
Aroclor 1254	mg/kg	32	38%	4.8	Only total PCBs regulated in this pathway.			0.49	13%	GW Clean	No detections.			Yes
Aroclor 1260	mg/kg	32	19%	1.7				0.49	4%	GW Clean	0.033	None	No	
Total PCBs	mg/kg	32	47%	6.5	10	None	No	Regulated by Aroclor			Regulated by Aroclor			
Semivolatile Organic Compounds (SVOCs)														
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)														
cPAH TEQ[7,8]	mg/kg	78	47%	25	130	None	No	0.19	45%	No. Refer to note 9.	0.0097	17%	No. Refer to note 9.	Yes
Benzo(a)pyrene	mg/kg	78	38%	16	Only cPAH TEQ regulated in this pathway.			0.19	42%		0.0097	9%		
Benz(a)anthracene	mg/kg	78	42%	38				0.072	45%		0.005	17%		
Benzo(b)fluoranthene	mg/kg	72	36%	20				0.24	36%		0.012	11%		
Benzo(k)fluoranthene	mg/kg	72	32%	23				0.24	34%		0.012	9%		
Chrysene	mg/kg	78	47%	38				0.08	51%		0.005	17%		
Dibenzo(a,h)anthracene	mg/kg	78	21%	4.7				0.36	8%		0.018	7%		
Indeno(1,2,3-cd)pyrene	mg/kg	78	28%	4.3				0.7	11%		0.035	7%		
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)														
Acenaphthene	mg/kg	78	40%	150	210,000	None	No	0.58	13%	No. Refer to note 10.	0.03	35%	No. Refer to note 10.	Yes
Fluorene	mg/kg	78	38%	130	140,000	None	No	0.62	19%		0.031	28%		
Naphthalene	mg/kg	84	26%	320	70,000	None	No	GW Clean (only detected at concentrations below SLs).						
Anthracene	mg/kg	78	35%	63	1,100,000	None	No							
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)														
Fluoranthene	mg/kg	78	55%	200	140,000	None	No	GW Clean (only detected at concentrations below SLs).						Yes
Pyrene	mg/kg	78	56%	190	110,000	None	No							

Table 5.12

Frequency of Exceedance of Screening Levels for Soil[1]

Contaminant of Potential Concern	Units	Soil Sample Results (All Depths)			Soil Screening Levels for Possible Pathways and Frequency of Exceedance for Those Pathways									Included in Nature and Extent Discussion
					Direct Contact (POC: 0–15 ft bgs)			Protection of Groundwater (POC: 0–8 ft bgs)			Protection of Groundwater (POC: ≥ 8 ft bgs)[2]			
		Number of Results	Percent Detected	Maximum Detected Value	Screening Level (Table 4.6)	Percent Exceeding[3]	COC for this pathway?	Screening Level (Table 4.6)	Percent Exceeding[3]	COC for this pathway?[4]	Screening Level (Table 4.6)	Percent Exceeding[3]	COC for this pathway?[4]	
SVOCs (cont.)														
Other SVOCs														
2,4-Dimethylphenol	mg/kg	71	2.8%	1.4	70,000	None	No	GW Clean (not detected in groundwater).						No
Bis(2-ethylhexyl) Phthalate	mg/kg	77	16%	1.6	9,400	None	No							No
Butyl benzyl Phthalate	mg/kg	74	2.7%	1	69,000	None	No							No
N-Nitrosodiphenylamine	mg/kg	74	5.4%	1.9	27,000	None	No							No
Pentachlorophenol	mg/kg	74	1.4%	3.4	330	None	No							No
Volatile Organic Compounds (VOCs) Associated with TPH														
Ethylbenzene	mg/kg	62	11%	0.22	350,000	None	No	0.11	5%	GW Clean	0.0063	7%	GW Clean	No

Notes:

▨ Not applicable. Refer to table cells for further detail.

Yes Indicates that constituent was retained as a COPC or COC for that pathway.

1 Only analytes identified as COPCs for soil in Table 4.9 are retained presented in this table.

2 The point of compliance for this pathway is saturated soil, which includes soil samples collected at depths deeper than eight feet bgs. Soil deeper than fifteen feet bgs is generally present at concentrations below the applicable screening level, and is not shown on figures. Soil results from all depths are reported in Table 5.13.

3 If the exceedance factor is less than 2 and percent exceeding is less than 10%, the constituent may be eliminated as a COC as allowed by WAC 173-340-740(7)(e)(i-ii).

4 Groundwater data was evaluated to determine whether soil is a potential source to groundwater using WAC 173-340-747(3)(e) as described in Table 4.6. If the contaminant did not become a groundwater COPC on the basis of infrequent and low-level detections, groundwater is considered clean and the soil to protect groundwater pathway is incomplete. A more robust analysis is performed for contaminants that were identified as groundwater COPCs.

5 Lead and mercury co-occur with the arsenic, copper, and zinc contamination but are very heterogeneous. Monitoring and remediation of arsenic, copper, and zinc will cleanup lead and mercury.

6 PCBs are only above the proposed CUL in two samples of visually contaminated debris and likely represent flecks of marine paints or caulks that contained PCB; soils on-site are in compliance.

7 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

8 Calculated using detected cPAH concentration plus one-half the reporting limit for cPAHs that were not detected.

9 Groundwater data is generally in compliance; among shoreline wells, cPAHs were only detected in one event (at MW-11). The presence of cPAHs in groundwater at this well is likely facilitated by diesel, rather than the soil-to-groundwater pathway. Compliance will be reevaluated after remediation of diesel. In soil, samples with elevated detections of cPAHs generally occur in samples containing fragments of creosote-treated timbers and wood debris. Soil containing cPAHs associated with creosote treated timbers does not represent a source to groundwater . Debris will be addressed in the FS.

10 LPAHs on-site are associated with petroleum; all LPAHs are in compliance with proposed groundwater CULs in shoreline wells with the exception of 1-methylnaphthalene. 1-methylnaphthalene will be monitored in groundwater as an indicator hazardous substance for TPH.

Abbreviations:

bgs	Below ground surface	mg/kg	Milligrams per kilogram
COC	Contaminant of concern	NA	Not applicable
COPC	Contaminant of potential concern	POC	Point of compliance
CSL	Cleanup Screening Level	Site	Harris Avenue Shipyard
CUL	Cleanup level	TEF	Toxic equivalent factor
ft	Feet	TEQ	Toxic equivalent
GW	Groundwater	TPH	Total petroleum hydrocarbons
IHS	Indicator hazardous substance	WAC	Washington Administrative Code

Table 5.13

Soil Results for Select Contaminants of Potential Concern[1]

		Location	B-1	FS-01				FS-02		FS-03		FS-04		FS-05		FS-06		FS-07		FS-08	
		Sample Date	4/29/1998	3/14/2011				3/16/2011		3/16/2011		3/16/2011		3/16/2011		3/16/2011		3/16/2011		3/15/2011	
		Sample Depth	6.5 ft	2.5–3.5 ft	14–15 ft	24–24.8 ft	24.8–25 ft	2.5–3.5 ft	18–19 ft	1.5–2.5 ft	11–12 ft	5–6 ft	11.5–12.5 ft	2.5–3.5 ft	13–14 ft	2.5–3.5 ft	19–20 ft	2–3 ft	12.5–13.5 ft	2–3 ft	21–22 ft
		Sample ID																			
Soil Contaminants of Potential Concern[2]	Proposed CUL[3]	Units	B-1 6.5'	FS01-2.5-031411	FS01-14-031411	FS01-24-031411	FS01-24.8-031411	FS02-2.5-031611	FS02-18-031611	FS03-1.5-031611	FS03-11-031611	FS04-5-031611	FS04-11.5-031611	FS05-2.5-031611	FS05-13-031611	FS06-2.5-031611	FS06-19-031611	FS07-2-031611	FS07-12.5-031611	FS08-2-031511	FS08-21-031511
Metals																					
Arsenic	88	mg/kg	--	14	2.9	5.5	4.6	17	3.1	82	14	16	4.6	3.2	2.2	4.1	3.7	2.7	3.4	3.2	3.6
Copper	390	mg/kg	--	130	24	26	21	**930**	19	**460**	160	95	15	11	23	38	23	13	19	23	18
Lead	NA	mg/kg	--	190	3.9	1.9	3.2	47	4.8	120	37	31	5.8	1.8	3	85	5.6	3.5	1.9	1.9	1.9
Mercury	NA	mg/kg	--	0.078	0.03	0.02 U	0.023	0.034	0.066	0.06	0.028	0.02 U	0.02 U	0.021	0.025	0.058	0.03	0.02 U	0.024	0.02	0.02 U
Nickel	NA[4]	mg/kg	--	64	41	69	48	39	35	72	24	46	36	23	39	31	44	26	40	54	40
Zinc	960	mg/kg	--	280	38	27	37	**3,700**	32	**1,500**	250	180	37	23	38	120	32	180	31	31	27
Semivolatile Organic Compounds																					
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																					
cPAH TEQ[5]	NA	mg/kg	--	0.32	0.076 U	7.2	0.076 U	0.24	0.076 U	0.076 U	0.076 U	0.076 U	0.076 U	0.076 U	0.076 U	0.82	0.08 U	0.076 U	0.076 U	0.08 U	0.076 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																					
1-methylnaphthalene	4,500	mg/kg	--	0.1 U	0.48	0.22	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Naphthalene	NA	mg/kg	--	0.01 UJ	0.01 U	0.91	0.081 J	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01	0.01 U
Acenaphthene	NA	mg/kg	--	0.1 U	0.15	3.8	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.41	0.1 U	0.1 U
Anthracene	NA	mg/kg	--	0.1 U	0.1 U	11	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.15	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Fluorene	NA	mg/kg	--	0.1 U	0.2	14	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.22	0.1 U	0.1 U
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																					
Fluoranthene	NA	mg/kg	--	0.38	0.1 U	48	0.15	0.41	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	1.3	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Pyrene	NA	mg/kg	--	0.43	0.1 U	36	0.15	0.42	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	1.4	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U

Notes:

--	Not analyzed.
🟨	Samples collected between 0 and 4 ft bgs; samples include samples of visible debris.
🟪	Samples collected between 4 and 8 ft bgs.
🟦	Samples collected from greater than 8 ft bgs (saturated zone) but less than 15 ft bgs (point of compliance).
▨	Samples collected from greater than 15 ft bgs (below the point of compliance).
RED/BOLD	Concentration exceeds proposed cleanup level. Though all exceedances of the proposed CUL are illustrated in this table, the proposed CUL for copper and zinc applies only to locations where copper and zinc exceedances groundwater CULs.
1	Results from all depths are shown; results are rounded to two significant figures.
2	Only soil COPCs that are included in the nature and extent discussion in text are included in this table (refer to Table 5.12). Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2. Soil results for all other chemicals are included in Appendix C. Data collected in 2015 within the Interim Action Area are presented in the Basis of Design Report.
3	Proposed cleanup levels were not developed for COPCs that did not become soil COCs (refer to Table 5.12). Proposed cleanup levels are protective of direct contact and the soil-to-protect groundwater pathway; refer to Section 5.4.5 for more information.
4	Nickel concentrations are at a site-specific, natural background; refer to Section 5.4.1 for details.
5	Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Qualifiers:

J	Analyte was detected, value should be considered an estimate.
JB	Analyte was detected, value should be considered an estimate due to blank contamination.
JM	Analyte was detected, value should be considered an estimate due to poor chromatographic match to the oil and/or diesel standard.
JQ	Analyte was detected, value should be considered an estimate due to the concentration being reported between the method detection limit and reporting limit.
U	Analyte was not detected at given reporting limit.
UJ	Analyte was not detected, given reporting limit is considered an estimate.

Abbreviations:

bgs	Below ground surface
ft	Feet
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
in	Inches
mg/kg	Milligrams per kilogram
NA	Not applicable
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.13

Soil Results for Select Contaminants of Potential Concern[1]

		Location	FS-09		FS-09A	FS-09A(2)		FS-09B	FS-09C	FS-09D	FS-10		FS-11		FS-12			FS-13		FS-14	
		Sample Date	3/15/2011		3/17/2011	3/17/2011		3/17/2011	3/17/2011	3/17/2011	3/15/2011		3/14/2011		3/14/2011			3/15/2011		3/15/2011	
		Sample Depth	8–8.5 ft	18.5–20 ft	6–7 ft	5–6 ft	14–15 ft	14–15 ft	8.5–9.5 ft	5–6 ft	2–3 ft	13–14 ft	1–2 ft	12.5–13.5 ft	2–3 ft	17–18 ft	17–18 ft	4–5 ft	16–17 ft	7–8 ft	17–19 ft
		Sample ID																			
Soil Contaminants of Potential Concern[2]	**Proposed CUL[3]**	**Units**	**FS09-8-031511**	**FS09-18.5-031511**	**FS09A-6-031711**	**FS09A(2)-5-031711**	**FS09A(2)-14-031711**	**FS09B-15-031711**	**FS09C-8.5-031711**	**FS09D-5-031711**	**FS10-2-031511**	**FS10-14-031511**	**FS11-2-031411**	**FS11-12.5-031411**	**FS12-2-031411**	**FS12-17-031411**	**FS12A-17-031411**	**FS13-4-031511**	**FS13-16-031511**	**FS14-7-031511**	**FS14-17-031511**
Metals																					
Arsenic	88	mg/kg	3.2	3.3	--	--	--	--	--	--	3.4	9.2	7.2	4	61	5.1	4.4	45	3.1	3.8	5.3
Copper	390	mg/kg	24	15	--	--	--	--	--	--	24	22	310	32	**410**	21	30	370	21	28	23
Lead	NA	mg/kg	2.6	6.3	--	--	--	--	--	--	2.4	2.9	35	4.4	690	2.9	2.8	170	2.6	2.7	2.9
Mercury	NA	mg/kg	0.02 U	0.023	--	--	--	--	--	--	0.039	0.03	0.48	0.026	**1.4**	0.028	0.028	2.7	0.027	0.029	0.032
Nickel	NA[4]	mg/kg	53	26	--	--	--	--	--	--	53	42	59	61	65	57	80	52	69	66	59
Zinc	960	mg/kg	40	36	--	--	--	--	--	--	33	32	250	48	840	35	37	750	36	36	40
Semivolatile Organic Compounds																					
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																					
cPAH TEQ[5]	NA	mg/kg	9.7	0.076 U	0.62 J	0.076 UJ	0.076 UJ	0.076 UJ	3.9 J	0.15 UJ	--	0.076 U	0.52 J	0.076 U	0.59	0.076 U	0.076 U	0.64	0.076 U	0.076 U	0.076 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																					
1-methylnaphthalene	4,500	mg/kg	27	0.1 U	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	25 J	0.2 UJ	--	0.1 U	3.8 J	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.1 U	0.1 U	0.1 U
Naphthalene	NA	mg/kg	160	0.01 U	6.9 J	0.01 UJ	0.01 UJ	0.01 UJ	40 J	0.011 J	--	0.01 U	1.3	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Acenaphthene	NA	mg/kg	70	0.1 U	0.14 J	0.1 UJ	0.3 J	0.13 J	29 J	0.2 UJ	--	0.1 U	0.98 J	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.1 U	0.1 U	0.1 U
Anthracene	NA	mg/kg	21	0.1 U	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	6.1 J	0.2 UJ	--	0.1 U	0.36 J	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.1 U	0.11 J	0.1 U
Fluorene	NA	mg/kg	61	0.1 U	0.1 UJ	0.1 UJ	0.17 J	0.1 UJ	28 J	0.86 J	--	0.1 U	1.5 J	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.1 U	0.46 J	0.1 U
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																					
Fluoranthene	NA	mg/kg	110	0.1 U	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	31 J	0.2 UJ	--	0.1 U	0.72 J	0.1 U	0.66	0.1 U	0.1 U	0.43	0.1 U	0.1 U	0.1 U
Pyrene	NA	mg/kg	68	0.1 U	0.17 J	0.1 UJ	0.1 UJ	0.1 UJ	23 J	0.2 UJ	--	0.1 U	0.99 J	0.1 U	0.75	0.1 U	0.1 U	0.68	0.1 U	0.1 U	0.1 U

Notes:

--	Not analyzed.
🟨	Samples collected between 0 and 4 ft bgs; samples include samples of visible debris.
🟪	Samples collected between 4 and 8 ft bgs.
🟦	Samples collected from greater than 8 ft bgs (saturated zone) but less than 15 ft bgs (point of compliance).
▨	Samples collected from greater than 15 ft bgs (below the point of compliance).
RED/BOLD	Concentration exceeds proposed cleanup level. Though all exceedances of the proposed CUL are illustrated in this table, the proposed CUL for copper and zinc applies only to locations where copper and zinc exceedances groundwater CULs.

[1] Results from all depths are shown; results are rounded to two significant figures.

[2] Only soil COPCs that are included in the nature and extent discussion in text are included in this table (refer to Table 5.12). Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2. Soil results for all other chemicals are included in Appendix C. Data collected in 2015 within the Interim Action Area are presented in the Basis of Design Report.

[3] Proposed cleanup levels were not developed for COPCs that did not become soil COCs (refer to Table 5.12). Proposed cleanup levels are protective of direct contact and the soil-to-protect groundwater pathway; refer to Section 5.4.5 for more information.

[4] Nickel concentrations are at a site-specific, natural background; refer to Section 5.4.1 for details.

[5] Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Qualifiers:

J	Analyte was detected, value should be considered an estimate.
JB	Analyte was detected, value should be considered an estimate due to blank contamination.
JM	Analyte was detected, value should be considered an estimate due to poor chromatographic match to the oil and/or diesel standard.
JQ	Analyte was detected, value should be considered an estimate due to the concentration being reported between the method detection limit and reporting limit.
U	Analyte was not detected at given reporting limit.
UJ	Analyte was not detected, given reporting limit is considered an estimate.

Abbreviations:

bgs	Below ground surface
ft	Feet
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
in	Inches
mg/kg	Milligrams per kilogram
NA	Not applicable
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.13

Soil Results for Select Contaminants of Potential Concern[1]

Location			FS-15		FS-16		FS-17			FS-18		FS-19				FS-20			FS-21			
Sample Date			3/14/2011		3/15/2011		3/16/2011			3/16/2011		1/29/2013				1/29/2013			1/29/2013			
Sample Depth			13–14 ft	23–24 ft	2–2.5 ft	19–20 ft	6.5–7.5 ft	18–19 ft	18–19 ft	3–4 ft	14–15 ft	3–3.5 ft	7–7.5 ft	11.5–12 ft	27–27.5 ft	2.5–3 ft	10.5–11 ft	15.5–16 ft	3.5–4 ft	8–9 ft	13.5–14 ft	22–22.5 ft
Sample ID Soil Contaminants of Potential Concern[2]	Proposed CUL[3]	Units	FS15-13-031411	FS15-23-031411	FS16-2-031511	FS16-19-031511	FS17-6.5-031611	FS17-18-031611	FS17A-18-031611	FS18-3-031611	FS18-14-031611	FS-19-3.0-3.5-012913	FS-19-7.0-7.5-012913	FS-19-11.5-12.0-012913	FS-19-27.0-27.5-012913	FS-20-2.5-3.0-012913	FS-20-10.5-11.0-012913	FS-20-15.5-16.0-012913	FS-21-3.5-4.0-013013	FS-21-8.0-9.0-013013	FS-21-13.5-14.0-013013	FS-21-22.0-22.5-013013
Metals																						
Arsenic	88	mg/kg	5.2	5	3.6	5.6	9.4	5.6	3.2	3	3.6	29	2.5	1.9	3.6	9.2	2.4	2.6	24	3.1	4	3
Copper	390	mg/kg	26	23	20	30	240	31	23	5.6	22	**490**	20	14	21	19	19	10	37	21	24	17
Lead	NA	mg/kg	16	2.2	2.1	3	710	2.9	2	1.2	33	260	2.2	1.5	2	2.5	3.9	1.7	9.4	2.4	15	1.6
Mercury	NA	mg/kg	0.02 U	0.022	0.02 U	0.021	0.097	0.024	0.03	0.02 U	0.027	**3.1**	0.02 U	0.02 U	0.02 U	0.024	0.028	0.02 U	0.047	0.033	0.026	0.02 U
Nickel	NA[4]	mg/kg	52	62	38	51	57	100	44	17	29	80	42	31	52	40	37	29	54	44	32	47
Zinc	960	mg/kg	44	34	30	33	**1,700**	35	26	17	32	400	29	23	24	30	32	24	66	36	34	24
Semivolatile Organic Compounds																						
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																						
cPAH TEQ[5]	NA	mg/kg	0.076 U	0.076 U	0.08 U	0.076 U	7.9	0.076 U	0.08 U	0.08 U	0.076 U	0.84	0.015	0.014	0.013 U	0.013 U	0.034	0.013 U	25	0.46	22	0.015
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																						
1-methylnaphthalene	4,500	mg/kg	0.1 U	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.1 U	0.1 U	0.1 U	0.22	1.8	0.22	0.02 U	0.02 U	6.6	0.033	80	0.43	73	0.02 U
Naphthalene	NA	mg/kg	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.23	0.031	0.02 U	0.02 U	0.02 U	0.5 U	0.022	300	0.87	320	0.024
Acenaphthene	NA	mg/kg	1.1	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.1 U	0.1 U	0.1 U	0.19	0.28	0.089	0.041	0.017 U	1.6	0.14	150	0.91	120	0.036
Anthracene	NA	mg/kg	0.31	0.1 U	0.1 U	0.1 U	1	0.1 U	0.1 U	0.1 U	0.1 U	0.23	0.02 U	0.024	0.02 U	0.02 U	0.5 U	0.02 U	63	0.47	40	0.021
Fluorene	NA	mg/kg	1.1	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.72	0.12	0.02 U	0.02 U	2.9	0.031	130	0.79	100	0.044
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																						
Fluoranthene	NA	mg/kg	0.4	0.1 U	0.1 U	0.1 U	8.2	0.1 U	0.1 U	0.1 U	0.11	1.2	0.054	0.068	0.02 U	0.02 U	1.4	0.02 U	200	2.1	130	0.12
Pyrene	NA	mg/kg	0.31	0.1 U	0.1 U	0.1 U	9.9	0.1 U	0.1 U	0.1 U	0.13	2.6	0.02 U	0.073	0.02 U	0.02 U	1.3	0.02 U	190	2	120	0.098

Notes:

-- Not analyzed.

🟨 Samples collected between 0 and 4 ft bgs; samples include samples of visible debris.

🟪 Samples collected between 4 and 8 ft bgs.

🟦 Samples collected from greater than 8 ft bgs (saturated zone) but less than 15 ft bgs (point of compliance).

▨ Samples collected from greater than 15 ft bgs (below the point of compliance).

RED/BOLD Concentration exceeds proposed cleanup level. Though all exceedances of the proposed CUL are illustrated in this table, the proposed CUL for copper and zinc applies only to locations where copper and zinc exceedances groundwater CULs.

1 Results from all depths are shown; results are rounded to two significant figures.

2 Only soil COPCs that are included in the nature and extent discussion in text are included in this table (refer to Table 5.12). Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2. Soil results for all other chemicals are included in Appendix C. Data collected in 2015 within the Interim Action Area are presented in the Basis of Design Report.

3 Proposed cleanup levels were not developed for COPCs that did not become soil COCs (refer to Table 5.12). Proposed cleanup levels are protective of direct contact and the soil-to-protect groundwater pathway; refer to Section 5.4.5 for more information.

4 Nickel concentrations are at a site-specific, natural background; refer to Section 5.4.1 for details.

5 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Qualifiers:

J	Analyte was detected, value should be considered an estimate.
JB	Analyte was detected, value should be considered an estimate due to blank contamination.
JM	Analyte was detected, value should be considered an estimate due to poor chromatographic match to the oil and/or diesel standard.
JQ	Analyte was detected, value should be considered an estimate due to the concentration being reported between the method detection limit and reporting limit.
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Abbreviations:

bgs	Below ground surface
ft	Feet
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
in	Inches
mg/kg	Milligrams per kilogram
NA	Not applicable
F	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.13
Soil Results for Select Contaminants of Potential Concern[1]

		Location	FS-22			FS-23		MW-01		MW-02	MW-02A		MW-03	MW-04		MW-05	MW-06		
		Sample Date	1/30/2013			1/30/2013		4/28/1998		4/28/1998	3/15/2011		4/28/1998	4/28/1998		4/29/1998	3/14/2011		
		Sample Depth	3–3.5 ft	7–8 ft	7–8 ft	3–3.5 ft	7–7.5 ft	10 ft	10 ft	8.5 ft	7.5 ft	13.5 ft	7.5 ft	2.5 ft	8 ft	7.5 ft	10 ft	14.5 ft	14.5 ft
		Sample ID																	
Soil Contaminants of Potential Concern[2]	**Proposed CUL[3]**	**Units**	**FS-22-3.0-3.5-013013**	**FS-22-7.0-8.0-013013**	**FS-78-7.0-8.0-013013**	**FS-23-3.0-3.5-013013**	**FS-23-7.0-7.5-013013**	**MW-1 10'**	**MW-1 10' Dup**	**MW-2 8.5'**	**MW02A-7.5-031511**	**MW02A-13.5-031511**	**MW-3 7.5'**	**MW-4 2.5'**	**MW-4 8'**	**MW-5 7.5'**	**MW06-10-031411**	**MW06-14.5-031411**	**MW06-14.5-031411-D**
Metals																			
Arsenic	88	mg/kg	3.2	3.8	3.1	**150**	2.3	8	7	11	4.7	6.5	6	53	8	11	2.8	2.2	2.4
Copper	390	mg/kg	20	23	19	**470**	15	18.5	18.1	114	14	48	9.2	**400**	43.1	37	20	14	14
Lead	NA	mg/kg	3.8	2.9	2.3	200	31	4	4	188	3.2	7.2	2 U	203	5	5	2.3	2	2.1
Mercury	NA	mg/kg	0.023	0.025	0.025	0.11	0.021	0.05 U	0.05 U	0.19	0.033	0.074	0.04 U	0.29	0.04 U	0.05 U	0.02 U	0.02 U	0.02 U
Nickel	NA[4]	mg/kg	39	43	37	45	27	38	38	32	32	76	25	47	45	64	45	35	36
Zinc	960	mg/kg	33	43	35	**1,500**	30	31.7	32.5	281	45	71	24	900	51	40	34	26	28
Semivolatile Organic Compounds																			
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																			
cPAH TEQ[5]	NA	mg/kg	0.013 U	0.015 U	0.015 U	1.7	0.11	--	--	--	0.39 J	0.076 U	--	--	--	--	0.076 U	0.076 U	0.076 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																			
1-methylnaphthalene	4,500	mg/kg	0.02 U	0.02 U	0.02 U	1.3	0.026	--	--	--	0.5 U	0.1 U	--	--	--	--	0.1 U	0.1 U	0.1 U
Naphthalene	NA	mg/kg	0.02 U	0.02 U	0.02 U	1.2	0.12	--	--	--	0.3	0.01 U	--	--	--	--	0.042	0.01 U	0.01 U
Acenaphthene	NA	mg/kg	0.017 U	0.017 U	0.017 U	3.5	0.017 U	--	--	--	1.2 J	0.1 U	--	--	--	--	0.22 J	0.1 U	0.1 U
Anthracene	NA	mg/kg	0.02 U	0.02 U	0.02 U	2	0.02 U	--	--	--	0.5 U	0.1 U	--	--	--	--	0.1 J	0.1 U	0.1 U
Fluorene	NA	mg/kg	0.02 U	0.02 U	0.02 U	3	0.02 U	--	--	--	0.5 U	0.1 U	--	--	--	--	0.58 J	0.1 U	0.1 U
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																			
Fluoranthene	NA	mg/kg	0.02 U	0.02 U	0.02 U	5.6	0.11	--	--	--	1.4 J	0.1 U	--	--	--	--	0.1 U	0.1 U	0.1 U
Pyrene	NA	mg/kg	0.02 U	0.02 U	0.02 U	6.5	0.13	--	--	--	1.5 J	0.1 U	--	--	--	--	0.1 J	0.1 U	0.1 U

Notes:

--	Not analyzed.
🟨	Samples collected between 0 and 4 ft bgs; samples include samples of visible debris.
🟪	Samples collected between 4 and 8 ft bgs.
🟦	Samples collected from greater than 8 ft bgs (saturated zone) but less than 15 ft bgs (point of compliance).
▨	Samples collected from greater than 15 ft bgs (below the point of compliance).
RED/BOLD	Concentration exceeds proposed cleanup level. Though all exceedances of the proposed CUL are illustrated in this table, the proposed CUL for copper and zinc applies only to locations where copper and zinc exceedances groundwater CULs.

[1] Results from all depths are shown; results are rounded to two significant figures.

[2] Only soil COPCs that are included in the nature and extent discussion in text are included in this table (refer to Table 5.12). Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2. Soil results for all other chemicals are included in Appendix C. Data collected in 2015 within the Interim Action Area are presented in the Basis of Design Report.

[3] Proposed cleanup levels were not developed for COPCs that did not become soil COCs (refer to Table 5.12). Proposed cleanup levels are protective of direct contact and the soil-to-protect groundwater pathway; refer to Section 5.4.5 for more information.

[4] Nickel concentrations are at a site-specific, natural background; refer to Section 5.4.1 for details.

[5] Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Qualifiers:

J	Analyte was detected, value should be considered an estimate.
JB	Analyte was detected, value should be considered an estimate due to blank contamination.
JM	Analyte was detected, value should be considered an estimate due to poor chromatographic match to the oil and/or diesel standard.
JQ	Analyte was detected, value should be considered an estimate due to the concentration being reported between the method detection limit and reporting limit.
U	Analyte was not detected at given reporting limit.
UJ	Analyte was not detected, given reporting limit is considered an estimate.

Abbreviations:

bgs	Below ground surface
ft	Feet
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
in	Inches
mg/kg	Milligrams per kilogram
NA	Not applicable
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.13
Soil Results for Select Contaminants of Potential Concern[1]

		Location	MW-07		MW-08		MW-09			MW-10		MW-11						
		Sample Date	3/15/2011		3/14/2011		3/14/2011			1/29/2013		2/9/2015						
		Sample Depth	5.5 ft	14 ft	4 ft	13.5 ft	4 ft	6–6.5 ft	10 ft	2–3 ft	11–11.5 ft	0–1 ft	1–2 ft	2–3 ft	5–6 ft	6–7 ft	7–8 ft	8–9 ft
Soil Contaminants of Potential Concern[2]	Proposed CUL[3]	Sample ID Units	MW07-5.5-031511	MW07-14-031511	MW08-4-031411	MW08-13.5-031411	MW09-4-031411	MW09-6-031411	MW09-10-031411	MW-10-2.0-3.0-012913	MW-10-11.0-11.5-012913	MW-11-0-1-020915	MW-11-1-2-020915	MW-11-2-3-020915	MW-11-5-6-020915	MW-11-6-7-020915	MW-11-7-8-020915	MW-11-8-9-020915
Metals																		
Arsenic	88	mg/kg	5.3	7.3	5.1	2.2	30	5.6	2.8	5.2	1.7	**250**	**330**	**100**	--	--	--	--
Copper	390	mg/kg	17	47	37	6.1	350	18	21	35	16	**2,800**	**2,400**	**1,400**	27	130	21	30
Lead	NA	mg/kg	3.8	6.2	9.6	1.2	180	3.1	3.1	28	2.1	--	--	--	--	--	--	--
Mercury	NA	mg/kg	0.02 U	0.056	0.02 U	0.02 U	0.55	0.02 U	0.029	0.063	0.02 U	--	--	--	--	--	--	--
Nickel	NA[4]	mg/kg	28	77	27	18	53	32	44	44	38	--	--	--	--	--	--	--
Zinc	960	mg/kg	39	69	130	17	790	36	39	75	29	**3,400**	**5,000**	**1,700**	36	110	50	37
Semivolatile Organic Compounds																		
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																		
cPAH TEQ[5]	NA	mg/kg	0.076 U	0.076 U	0.076 U	0.076 U	0.14	0.076 U	0.076 U	0.047	0.013 U	--	0.7	--	--	0.043	--	--
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																		
1-methylnaphthalene	4,500	mg/kg	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	2.5	0.1 U	0.02 U	0.02 U	--	0.059	--	--	0.0086	--	--
Naphthalene	NA	mg/kg	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.02 U	0.02 U	--	0.016	--	--	0.0086	--	--
Acenaphthene	NA	mg/kg	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.52	0.1 U	0.017 U	0.017 U	--	0.081	--	--	0.011	--	--
Anthracene	NA	mg/kg	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.15	0.1 U	0.02 U	0.02 U	--	0.11	--	--	0.01	--	--
Fluorene	NA	mg/kg	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	1.6	0.1 U	0.02 U	0.02 U	--	0.037	--	--	0.0061	--	--
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																		
Fluoranthene	NA	mg/kg	0.1 U	0.1 U	0.1 U	0.1 U	0.19	0.22	0.1 U	0.029	0.02 U	--	2.5	--	--	0.14	--	--
Pyrene	NA	mg/kg	0.1 U	0.1 U	0.1 U	0.1 U	0.23	0.21	0.1 U	0.038	0.02 U	--	1.8	--	--	0.097	--	--

Notes:

--	Not analyzed.
🟨	Samples collected between 0 and 4 ft bgs; samples include samples of visible debris.
🟪	Samples collected between 4 and 8 ft bgs.
🟦	Samples collected from greater than 8 ft bgs (saturated zone) but less than 15 ft bgs (point of compliance).
▒	Samples collected from greater than 15 ft bgs (below the point of compliance).
RED/BOLD	Concentration exceeds proposed cleanup level. Though all exceedances of the proposed CUL are illustrated in this table, the proposed CUL for copper and zinc applies only to locations where copper and zinc exceedances groundwater CULs.
1	Results from all depths are shown; results are rounded to two significant figures.
2	Only soil COPCs that are included in the nature and extent discussion in text are included in this table (refer to Table 5.12). Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2. Soil results for all other chemicals are included in Appendix C. Data collected in 2015 within the Interim Action Area are presented in the Basis of Design Report.
3	Proposed cleanup levels were not developed for COPCs that did not become soil COCs (refer to Table 5.12). Proposed cleanup levels are protective of direct contact and the soil-to-protect groundwater pathway; refer to Section 5.4.5 for more information.
4	Nickel concentrations are at a site-specific, natural background; refer to Section 5.4.1 for details.
5	Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Qualifiers:

J	Analyte was detected, value should be considered an estimate.
JB	Analyte was detected, value should be considered an estimate due to blank contamination.
JM	Analyte was detected, value should be considered an estimate due to poor chromatographic match to the oil and/or diesel standard.
JQ	Analyte was detected, value should be considered an estimate due to the concentration being reported between the method detection limit and reporting limit.
U	Analyte was not detected at given reporting limit.
UJ	Analyte was not detected, given reporting limit is considered an estimate.

Abbreviations:

bgs	Below ground surface
ft	Feet
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
in	Inches
mg/kg	Milligrams per kilogram
NA	Not applicable
F	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.13

Soil Results for Select Contaminants of Potential Concern[1]

		Location	**MW-12**									**S-3**		**S-4**		**S-4**		**S-5**			
		Sample Date	**2/9/2015**									**8/19/2005**		**8/19/2005**		**8/19/2005**		**8/19/2005**			
		Sample Depth	**0–1 ft**	**1–2 ft**	**2–3 ft**	**4–5 ft**	**8–8.5 ft**	**10.5–11 ft**	**11–12 ft**	**13–14 ft**	**14–15 ft**	**0–2 ft**	**2–4 ft**	**0–2 ft**	**2–4 ft**	**4-6–ft**	**6–8 ft**	**0–2 ft**	**2–4 ft**	**4–6 ft**	**6–8 ft**
		Sample ID																			
Soil Contaminants of Potential Concern[2]	**Proposed CUL[3]**	**Units**	**MW-12-0-1-020915**	**MW-12-1-2-020915**	**MW-12-2-3-020915**	**MW-12-4-5-020915**	**MW-12-8-8.5-020915**	**MW-12-10.5-11-020915**	**MW-12-11-12-020915**	**MW-12-13-14-020915**	**MW-12-14-15-020915**	**HAS-S3-0-2**	**HAS-S3-2-4**	**HAS-S4-0-2**	**HAS-S4-2-4**	**HAS-S4-4-6**	**HAS-S4-6-8**	**HAS-S5-0-2**	**HAS-S5-2-4**	**HAS-S5-4-6**	**HAS-S5-6-8**
Metals																					
Arsenic	88	mg/kg	**180**	10 U	10 U	--	--	--	--	10	10 U	**340**	70	50	35	6	6	20	19	30	6
Copper	390	mg/kg	**1,000**	81	79	--	**500**	73	45	75	79	**2,400**	**790**	**880**	350	24	52	**570**	**590**	160	20
Lead	NA	mg/kg	--	--	--	--	--	--	--	--	--	450	160	160	68	4	13	120	200	40	3
Mercury	NA	mg/kg	--	--	--	--	--	--	--	--	--	**10**	**4.7**	0.42	0.17	0.05 U	0.15	0.43	3.1	0.11	0.05 U
Nickel	NA[4]	mg/kg	--	--	--	--	--	--	--	--	--	62	64	48	21	39	34	57	73	54	40
Zinc	960	mg/kg	**2,400**	270	170	--	**1,800**	130	98	260	160	**4,000**	**4,200**	**1,600**	510	41	89	410	400	180	36
Semivolatile Organic Compounds																					
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																					
cPAH TEQ[5]	NA	mg/kg	--	0.01	--	0.49	--	0.028 J	--	0.011 J	--	2.2	1.9	0.022 U	0.06	0.062 U	0.062 U	0.37	1.4	0.19	0.69
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																					
1-methylnaphthalene	4,500	mg/kg	--	0.0047 U	--	1.4	--	0.085	--	0.0026 JQ	--	--	--	--	--	--	--	--	--	--	--
Naphthalene	NA	mg/kg	--	0.0047 U	--	0.2	--	0.021	--	0.0043 JQ	--	0.078 U	0.085 U	0.073 U	0.08 U	0.082 U	0.082 U	0.072 U	0.075 U	0.77	12
Acenaphthene	NA	mg/kg	--	0.0047 U	--	0.6	--	0.032	--	0.0032 JQ	--	0.27	0.21	0.073 U	0.08 U	0.082 U	0.082 U	0.072 U	0.097	0.11	4.1
Anthracene	NA	mg/kg	--	0.004 JQ	--	1.1	--	0.032	--	0.0044 JQ	--	0.46	0.65	0.073 U	0.08 U	0.082 U	0.082 U	0.072 U	0.097	0.072 U	1.2
Fluorene	NA	mg/kg	--	0.0047 U	--	0.83	--	0.049	--	0.0048 U	--	0.18	0.095	0.073 U	0.08 U	0.082 U	0.082 U	0.072 U	0.24	0.46	4.1
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																					
Fluoranthene	NA	mg/kg	--	0.015	--	2	--	0.078	--	0.019	--	3.1	3.7	0.11	0.17	0.082 U	0.12	0.6	1.8	0.44	6.1
Pyrene	NA	mg/kg	--	0.013	--	2	--	0.065	--	0.014	--	2.9	3	0.12	0.21	0.082 U	0.12	0.44	2.7	0.44	3.8

Notes:

--	Not analyzed.
🟨	Samples collected between 0 and 4 ft bgs; samples include samples of visible debris.
🟪	Samples collected between 4 and 8 ft bgs.
🟦	Samples collected from greater than 8 ft bgs (saturated zone) but less than 15 ft bgs (point of compliance).
▨	Samples collected from greater than 15 ft bgs (below the point of compliance).
RED/BOLD	Concentration exceeds proposed cleanup level. Though all exceedances of the proposed CUL are illustrated in this table, the proposed CUL for copper and zinc applies only to locations where copper and zinc exceedances groundwater CULs.

1 Results from all depths are shown; results are rounded to two significant figures.

2 Only soil COPCs that are included in the nature and extent discussion in text are included in this table (refer to Table 5.12). Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2. Soil results for all other chemicals are included in Appendix C. Data collected in 2015 within the Interim Action Area are presented in the Basis of Design Report.

3 Proposed cleanup levels were not developed for COPCs that did not become soil COCs (refer to Table 5.12). Proposed cleanup levels are protective of direct contact and the soil-to-protect groundwater pathway; refer to Section 5.4.5 for more information.

4 Nickel concentrations are at a site-specific, natural background; refer to Section 5.4.1 for details.

5 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Qualifiers:

J	Analyte was detected, value should be considered an estimate.
JB	Analyte was detected, value should be considered an estimate due to blank contamination.
JM	Analyte was detected, value should be considered an estimate due to poor chromatographic match to the oil and/or diesel standard.
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UJ	Analyte was not detected, given reporting limit is considered an estimate.

Abbreviations:

bgs	Below ground surface
ft	Feet
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
in	Inches
mg/kg	Milligrams per kilogram
N	Not applicable
F	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.13

Soil Results for Select Contaminants of Potential Concern[1]

		Location	Soil 1-A/1-B		Soil 2-A/2-B		Soil 3-A/3-B		TP-10	TP-13	TP-15		TP-3	TP-4	TP-6	TP-8	TP-9	
		Sample Date	8/1/1993		8/1/1993		8/1/1993		4/27/1998	4/30/1998	4/27/1998		4/27/1998	4/27/1998	4/27/1998	4/27/1998	4/30/1998	
		Sample Depth	0–4 in	4–8 in	0–4 in	4–8 in	0–4 in	4–8 in	1.2 ft	4 ft	0.7 ft	6 ft	4 ft	0.9 ft	0.9 ft	0.9 ft	1.8 ft	6 ft
		Sample ID																
Soil Contaminants of Potential Concern[2]	Proposed CUL[3]	Units	1-A	1-B	2-A	2-B	3-A	3-B	TP-10 1.2'	TP-13 4'	TP-15 0.7'	TP-15 6'	TP-3 4'	TP-4 0.9'	TP-6 0.9'	TP-8 0.9'	TP-9 1.8'	TP-9 6'
Metals																		
Arsenic	88	mg/kg	**240**	21 UJ	**160**	41	**362**	63 UJ	**1,200**	30	25	28	9	**750**	**210**	**1,100**	8	10
Copper	390	mg/kg	**2,700**	290	**2,300**	**4,700**	**2,100**	**700**	**3,600**	**1,400**	370	43	74	**3,200**	**700**	**2,400**	30	27
Lead	NA	mg/kg	340 J	190 J	230 J	390 J	710 J	120 J	1,200	440	200	16	67	670	260	1,700	7	3
Mercury	NA	mg/kg	0.14	0.078	0.24 J	18	0.043 J	0.038 UJ	0.09	0.43	**2.9**	0.06	0.09	0.33	0.09	0.12	0.05 U	0.05 U
Nickel	NA[4]	mg/kg	36 J	73 J	48 J	110 J	54 J	430 J	38	51	55	52	54	35	54	51	26	48
Zinc	960	mg/kg	**2,700**	300	**2,400**	925	**5,300**	684	**13,000**	440	160	70	490	**8,500**	**3,700**	**10,000**	49	44
Semivolatile Organic Compounds																		
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)																		
cPAH TEQ[5]	NA	mg/kg	0.48	0.8	1.2	2.4 J	0.43 J	0.085 U	--	--	--	6.4	5.3 J	--	--	--	0.092	0.091 U
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)																		
1-methylnaphthalene	4,500	mg/kg	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Naphthalene	NA	mg/kg	0.12 U	1.3	0.17	0.14 U	0.12 U	0.12 U	--	--	--	62	0.25 J	--	--	--	0.11 U	0.9
Acenaphthene	NA	mg/kg	0.12 U	0.52	0.12	0.18	0.12 U	0.12 U	--	--	--	35	0.11 UJ	--	--	--	0.89	0.46
Anthracene	NA	mg/kg	0.048 J	0.096 J	0.27	0.5	0.072 J	0.12 U	--	--	--	10	0.74 J	--	--	--	0.19	0.12 U
Fluorene	NA	mg/kg	0.12 U	0.19	0.15	0.21	0.12 U	0.12 U	--	--	--	28	0.3 J	--	--	--	3.8	1.3
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAHs)																		
Fluoranthene	NA	mg/kg	0.69	1.8	2.8	5.3	1.2	0.05 J	--	--	--	37	5.9 J	--	--	--	0.44	0.17
Pyrene	NA	mg/kg	0.47	1.2	1.4	3.9	0.57	0.06 J	--	--	--	44	8.5 J	--	--	--	0.5	0.15

Notes:

--	Not analyzed.
🟨	Samples collected between 0 and 4 ft bgs; samples include samples of visible debris.
🟪	Samples collected between 4 and 8 ft bgs.
🟦	Samples collected from greater than 8 ft bgs (saturated zone) but less than 15 ft bgs (point of compliance).
▨	Samples collected from greater than 15 ft bgs (below the point of compliance).
RED/BOLD	Concentration exceeds proposed cleanup level. Though all exceedances of the proposed CUL are illustrated in this table, the proposed CUL for copper and zinc applies only to locations where copper and zinc exceedances groundwater CULs.

1 Results from all depths are shown; results are rounded to two significant figures.

2 Only soil COPCs that are included in the nature and extent discussion in text are included in this table (refer to Table 5.12). Though TPH is a COPC at the Site, TPH is evaluated relative to applicable cleanup levels in Appendix G, Attachment G.2. Soil results for all other chemicals are included in Appendix C. Data collected in 2015 within the Interim Action Area are presented in the Basis of Design Report.

3 Proposed cleanup levels were not developed for COPCs that did not become soil COCs (refer to Table 5.12). Proposed cleanup levels are protective of direct contact and the soil-to-protect groundwater pathway; refer to Section 5.4.5 for more information.

4 Nickel concentrations are at a site-specific, natural background; refer to Section 5.4.1 for details.

5 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Qualifiers:

J	Analyte was detected, value should be considered an estimate.
JB	Analyte was detected, value should be considered an estimate due to blank contamination.
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Abbreviations:

bgs	Below ground surface
ft	Feet
COC	Contaminant of concern
COPC	Contaminant of potential concern
CUL	Cleanup level
in	Inches
mg/kg	Milligrams per kilogram
NA	Not applicable
TEF	Toxic equivalent factor
TEQ	Toxic equivalent
TPH	Total petroleum hydrocarbon
WAC	Washington Administrative Code

Table 5.14
Summary of Proposed Soil Contaminants of Concern, Retained Contaminants of Potential Concern, and Their Cleanup Levels

		Direct Contact (POC = 0–15 ft bgs)		Protection of Groundwater (POC = 0–8 ft bgs)		Protection of Groundwater (POC = Any Depth)		Protection of Groundwater (POC = Any Depth)	
		AOC Definition: AOC 2A Site-wide, 0–4 ft bgs, where exceedances are present		AOC Definition: AOC 2A Site-wide, 0–4 ft bgs, where exceedances are present		AOC Definition: AOC 2B Upgradient of MW-02A and MW-12, all depths, where exceedances are present		AOC Definition: AOC 3 In vicinity of historical ASTs, all depths, where exceedances are present[3]	
Soil Contaminants of Concern[1, 2]	**Units**	**Proposed CUL**	**COC for this Pathway?**	**Proposed CUL[4]**	**COC for this Pathway?**	**Proposed CUL[4,5]**	**COC for this Pathway?**	**Proposed CUL[4]**	**COC for this Pathway?**
Metals									
Arsenic	mg/kg	88	**Yes**	88	**Yes**	88	**Yes**	88	**Yes**
Copper	mg/kg	▨	No	▨	No	390	**Yes**	▨	No
Zinc	mg/kg	▨	No	▨	No	960	**Yes**	▨	No
Total Petroleum Hydrocarbons (TPH)									
Total TPH	mg/kg	▨	No	▨	No	▨	No	8,000	**Yes**

Notes:

▨ Pathway in compliance.

1 This table includes only those soil COPCs that were identified as COCs for at least one pathway in Table 5.13 or Appendix G.2.

2 There are elevated detections of cPAHs and HPAHs in AOC 2A and 2B; however, they are associated with creosote-treated wood pilings, timbers, and debris. They will not be used to set the limits of excavation or compliance, but will be removed where they are co-located with metals, which includes visible debris, but not in-place timbers.

3 AOC 3 addresses diesel contamination associated with historical ASTs. The intent is a mass removal or treatment action to decrease oxygen demand in the area, improving water quality, and to decrease the amount of C8-C12 aliphatics in the vadose zone to reduce the potential for vapor intrusion.

4 For arsenic, soil at concentrations calculated to be protective of groundwater using the three-phase model do not show correlation to areas of the Site with groundwater exceedances. Removing soil with arsenic concentrations that exceed the direct contact criterion for arsenic will also remove soil in most areas where arsenic was detected at concentrations greater than natural background concentrations. This action, coupled with source mass removal of TPH, is expected to bring arsenic concentrations measured in groundwater into compliance with the proposed groundwater CUL. Therefore, the direct contact CUL is also be used as the soil-to-protect groundwater CUL for arsenic.

5 In AOC 2B, the proposed CULs for protection of the soil-to-groundwater pathway are the sediment cleanup screening levels (CSLs), which are protective of sediment and surface water quality. Soil concentrations at these levels are also presumed to be protective of surface water quality. Elsewhere at the Site, groundwater is in compliance; copper and zinc concentrations in unsaturated soils are not predictive of groundwater concentrations.

Abbreviations:

AOC	Area of concern
AST	Aboveground storage tank
bgs	Below ground surface
COC	Contaminant of concern
COPC	Contaminant of potential concern
cPAH	Carcinogenic polycyclic aromatic hydrocarbon
CUL	Cleanup level
ft	Feet
HPAH	High molecular weight polycyclic aromatic hydrocarbon
mg/kg	Milligrams per kilogram
POC	Point of compliance

Table 6.1

Analytes Retained as Contaminants of Concern[1]

		Contaminant of Concern Outcome					
		Sediment			Groundwater	Soil	
Contaminants of Concern	CAS No.	Intertidal Sediment Protective of Benthic and/or Direct Contact	Subtidal Sediment Protective of Benthic and/or Direct Contact	Site-wide Sediments: Bioaccumulative Pathway	Shoreline Wells	Surficial Soils Protective of Direct Contact	All Soil for Protection of Groundwater
Metals							
Arsenic	7440-38-2	X	X	X	X	X	X
Cadmium	7440-43-9			X			
Copper	7440-50-8	X	X		X		X
Zinc	7440-66-6	X	X		X		X
Polychlorinated Biphenyls (PCBs)							
Total PCBs	Total PCBs		X	X			
Semivolatile Organic Compounds (SVOCs)							
Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)							
cPAH TEQ[2]	Total cPAHs TEF			X			
Non-Carcinogenic High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAH)							
Fluoranthene	206-44-0		X				
Pyrene	129-00-0		X				
Total Petroleum Hydrocarbon (TPH) as its Associated Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAHs)							
Total TPH	TPH				X		X
1-methylnaphthalene	90-12-0				X		

Notes:

1 This table includes only those contaminants of potential concern that were retained as a contaminant of concern in at least one environmental media.

2 Calculation of Total cPAH TEQ concentration is performed using the California Environmental Protection Agency 2005 TEFs as presented in Table 708-2 of WAC 173-340-900 (Ecology 2007). Calculation is performed using detected cPAH concentrations plus one-half the detection limit for cPAHs that were not detected.

Abbreviations:

CAS	Chemical Abstracts Service
TEF	Toxic equivalent factor
TEQ	Toxic equivalent

Table 7.1
Potential Location-Specific ARARs

Standard, Requirement, or Limitation	Description	Applicability
Shoreline, Wetlands, and Other Critical Areas		
Coastal Zone Management Act (16 USC 1451 et seq.)	Construction activities requiring federal approval must be consistent with the state's Coastal Zone Management Program.	Applicable; implemented through Washington State Shoreline Master Program.
City of Bellingham—Shoreline Master Program (BMC Title 22) (Implements the Washington Shoreline Management Act)	Implements the requirements imposed on the City of Bellingham by the Washington Shoreline Management Act (RCW 90.58) and ensures that development under the program will not cause a net loss of ecological functions.	Applicable; Harris Avenue Shipyard is located within the waters of Washington State in the City of Bellingham.
City of Bellingham—Critical Areas Regulations (BMC Chapter 16.55)	This chapter establishes regulations pertaining to the development within or adjacent to critical areas, which include areas that provide a variety of biological and physical functions that benefit the City of Bellingham and its residents, including water quality protection, fish and wildlife habitat, food chain support, etc.	Applicable; the presence of Bull trout, Puget Sound Chinook salmon, Puget Sound Coho salmon, marbled murrelets, and sand lance spawning areas designate the area as a fish and wildlife habitat conservation area.
Executive Order 11988, Protection of Floodplains (40 CFR 6.302(b) and Appendix A); Federal Emergency Management Agency (FEMA) National Flood Insurance Program Regulations (44 CFR 60.3)	In 100-year floodplains, actions must be taken to reduce the risk of flood loss, minimize the impact of floods on human safety, and restore and preserve the natural beneficial values of floodplains.	Applicable; Harris Avenue Shipyard is located within a designated floodplain.
Washington Floodplain Management Plan (RCW 86.16; WAC 173-158)	Directs Ecology (1) to establish minimum state requirements for floodplain management, which equal the National Flood Insurance Program (NFIP) minimum standards; (2) to provide technical assistance and information to local governments related to administration of their floodplain management ordinances and the NFIP; and (3) to provide assistance to local governments in identifying the location of the 100 year (base) floodplain. Also allows for the issuance of regulatory orders.	
City of Bellingham—Construction in Floodplains (BMC Chapter 17.76)	Upland development or construction within any area of special flood hazard within the City of Bellingham must undergo review by the Director of Public Works and Utilities to ensure that the proposed work would not adversely affect the flood carrying capacity of the area of special flood hazard. A development permit must be issued before construction or development begins.	
In-Water		
Washington State Hydraulic Code (RCW 77.55, WAC 220-110)	This statute and its implementing regulations apply to any work conducted within the designated shoreline that changes the natural flow or bed of the water body (and, therefore, has the potential to affect fish habitat). The requirements include bank protections and prohibited work times based on life stages of endangered or threatened fish species.	Substantive requirements are applicable. Model Toxics Control Act remedial actions are exempt from the procedural requirements of this law, but must comply with the substantive requirements.

Table 7.1
Potential Location-Specific ARARs

Standard, Requirement, or Limitation	Description	Applicability
In-Water (cont.)		
Section 10 of the Rivers and Harbors Act (33 USC 401 et seq.; Rivers and Harbors Act, Section 10; 33 CFR Parts 320 to 322)	This act prohibits unauthorized activities that obstruct or alter a navigable waterway. Section 10 applies to all structures or work below the mean high water mark of navigable tidal waters and the ordinary high water mark of navigable fresh waters. Actions in wetlands within these limits are subject to Section 10 provisions. U.S. Army Corps of Engineers permits are needed for the alteration or the modification of the course, condition, location, or capacity of a navigable water of the United States.	Applicable; Bellingham Bay is a navigable water, any alternatives involving in-water work will require compliance with Rivers and Harbors Act.
Section 404 of the Clean Water Act (33 USC 1311-1341; 33 CFR 320, 323, and 330; 40 CFR Parts 230-231)	Regulates activities that may result in any discharge into navigable waters, and permits for discharge of dredged or fill material into navigable waters.	Applicable; the selected alternative may include dredging or filling along the shoreline or within Bellingham Bay.
Protection of Wildlife and Habitat		
Endangered Species Act (16 USC Chapter 35 §1531 et seq.; 50 CFR Part 17; 50 CFR Part 402; Title 77 or 79 RCW)	Section 7 of Endangered Species Act requires that federal agencies consult with Natural Resources Trustees if listed threatened or endangered species are present in or near the project area, before making any decisions that may affect these species.	Listed species migrate through Bellingham Bay; therefore, agency consultation and compliance with the Endangered Species Act are required.
Magnuson-Stevens Act (16 USC § 1801 et seq.)	The Magnuson-Stevens Act (MSA) governs marine fisheries management in the United States. The MSA mandates the identification of essential fish habitat for federally managed species and development of measures to conserve and enhance the habitat necessary for the fish life cycles.	Applicable.
Migratory Bird Treaty Act (16 USC 703-712.)	Establishes federal responsibility for the protection of the international migratory bird resource and requires continued consultation with the USFWS during remedial design and construction to ensure that the cleanup of the site does not unnecessarily impact migratory birds.	Applicable.
Bald Eagle Protection Act (16 USC 668 et seq.)	Requires continued consultation with USFWS during remedial design and construction to ensure that any cleanup of the site does not unnecessarily adversely affect the bald or golden eagle.	Applicable.
Tribal and Cultural Protections		
Native American Graves Protection and Repatriation Act (25 USC Chapter 32 §3001 through 3113; 43 CFR Part 10) Protection of Indian Graves (RCW 27.44) Archaeological Sites and Resources (RCW 27.53)	These statutes prohibit the destruction or removal of Native American cultural items and require written notification of inadvertent discovery to the appropriate agencies and Native American tribe. These programs are applicable to the remedial action if cultural items are found. The activities must cease in the area of the discovery; a reasonable effort must be made to protect the items discovered; and notice must be provided.	Applicable.
Archaeological Resources Protection Act (16 USC 470aa et seq.; 43 CFR Part 7)	This program sets forth requirements that are triggered when archaeological resources are discovered. These requirements only apply if archaeological items are discovered during implementation of the selected remedy.	Applicable.

Table 7.1
Potential Location-Specific ARARs

Standard, Requirement, or Limitation	**Description**	**Applicability**
Tribal and Cultural Protections (cont.)		
National Historic Preservation Act (16 USC 470 et seq.; 36 CFR Parts 60, 63, and 800)	This program sets forth a national policy of historic preservation and provides a process that must be followed to ensure that impacts of actions on archaeological, historic, and other cultural resources are protected.	Applicable.
Other Regulations to be Considered		
State Aquatic Lands Management Laws (RCW 79.105 through 79.140; WAC 332-30)	Sediment management on state-owned lands must comply with state regulations and rules for management of state-owned aquatic lands.	Applicable.

Abbreviations:

ARAR	Applicable or Relevant and Appropriate Requirement
BMC	Bellingham Municipal Code
CFR	Code of Federal Regulations
Ecology	Washington State Department of Ecology
RCW	Revised Code of Washington
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code

Table 7.2
Potential Action-Specific ARARs

Standard, Requirement, or Limitation	Description	Applicability
Evaluate Environmental Impacts		
State Environmental Policy Act (RCW 43.21C, WAC 197-11, BMC Chapter 16.20)	Establishes the state's policy for protection and preservation of the natural environment.	Applicable; implemented during design and permitting phase to comply with state and City of Bellingham codes. Coordination with federal agencies may be necessary to ensure the SEPA process will meet NEPA requirements. SEPA and MTCA are integrated processes per WAC 197-11-250 through 197-11-268.
Uplands Construction and Grading		
Clean Water Act — NPDES (40 CFR 122)	In areas that could potentially erode or release soil, controls and BMPs are to be used to control runoff from construction activities. Requires permits for the discharge of pollutants from any point source into waters of the United States. Washington state has been delegated authority to issue NPDES permits. CWA Sections 401, 402, and 404 require states to adopt water quality standards and implement a NPDES permitting process. The Washington Water Pollution Control Law and regulations address this requirement.	Applicable; any construction or regarding activity will require compliance with NPDES.
Washington Water Pollution Control Law (RCW 90.48; WAC 173-216; WAC 173-226)		
City of Bellingham—Construction Codes for Grading (adopted from the State Building Code WAC 51-50/International Building Code)	The provisions of the grading chapter (Appendix J, International Building Code) apply to grading, excavation, and earthwork construction, including fills and embankments.	Substantive requirements are applicable. MTCA remedial actions are exempt from the procedural requirements of this law but must comply with the substantive requirements.
Dredging, Filling, and In-water Construction		
Dredged Material Management Program Guidelines (RCW 79.105.500-520; WAC 332-30-166)	Establishes a characterization and permitting process for sediments destined for unconfined open-water disposal.	Not applicable; the selected alternative will not include open water disposal of dredged sediments.
Marine Protection, Research and Sanctuaries Act (MPRSA; PL 92-532; 33 USC 1401-1445) and Ocean Dumping of Dredged Materials Regulations (40 CFR 227; 33 CFR Part 324)	Regulates the open-water disposal of dredged sediments.	Not applicable; the selected alternative will not include open water disposal of dredged sediments.
Solid Waste Management/Minimum Functional Standards for Solid Waste Handling (RCW 70.95 and WAC 173-304)	Establishes minimum standards for handling and disposal of solid waste. Solid waste includes wastes that are likely to be generated as a result of site remediation (e.g., contaminated sediments, construction and demolition wastes, and garbage). Sets minimum functional standards for the proper handling of all solid waste materials originating from residences, and commercial, agricultural, and industrial operations, as well as other sources.	Applicable.
Washington State Hydraulic Code (HPA; RCW 77.55, WAC 220-110)	This statute and its implementing regulations apply to any work conducted within the designated shoreline that changes the natural flow or bed of a water body (and therefore has the potential to affect fish habitat). The requirements include bank protections and prohibited work times based on life stages of endangered or threatened fish species.	Applicable.

Table 7.2
Potential Action-Specific ARARs

Standard, Requirement, or Limitation	**Description**	**Applicability**
Dredging, Filling, and In-water Construction (cont.)		
Section 10 of the Rivers and Harbors Act (33 USC 401 et seq.; Rivers and Harbors Act, Section 10; 33 CFR Parts 320 to 322)	This act prohibits unauthorized activities that obstruct or alter a navigable waterway. Section 10 applies to all structures or work below the mean high water mark of navigable tidal waters and the ordinary high water mark of navigable fresh waters. Actions in wetlands within these limits are subject to Section 10 provisions. U.S. Army Corps of Engineers permits are needed for the alteration or the modification of the course, condition, location, or capacity of a navigable water of the United States.	Applicable; Bellingham Bay is a navigable water, any alternatives involving in-water work will require compliance with Rivers and Harbors Act.
Section 404 of the Clean Water Act (33 USC 1311-1341; 33 CFR 320, 323, and 330; 40 CFR Parts 230 to 231)	Regulates activities that may result in any discharge into navigable waters, and permits for discharge of dredged or fill material into navigable waters.	Applicable; the selected alternative may include dredging or filling along the shoreline or within Bellingham Bay.
City of Bellingham – Building Codes (BMC Chapter 17.10)	The provisions of the building codes chapter apply to erection, demolition and moving of buildings, structures and building service equipment.	Applicable.
Upland Disposal of Soils and Dredged Sediments		
Resource Conservation and Recovery Act (RCRA; 42 USC Chapter 82 §6901 et seq.), Title D, Solid Waste, and Title C, Solid Hazardous Waste	Establishes requirements for the identification, handling, and disposal of hazardous and non-hazardous waste.	Applicable.
Resource Conservation and Recovery Act (40 CFR Parts 260 to 268)	Dredged material may be subject to RCRA regulations if it contains a listed waste, or if it displays a hazardous waste characteristic (e.g., under Toxicity Characteristic Leaching Procedure).	Applicable only if waste is generated from selected alternative, and contains listed waste, or displays hazardous waste characteristics.
Hazardous Waste Management (RCW 70.105) Dangerous Waste Regulations (WAC 173-303)	Establishes regulations that are the state equivalent of RCRA requirements for determining whether a solid waste is a state dangerous waste. This regulation also provides requirements for the management of dangerous wastes if dangerous wastes are generated during the cleanup action.	Applicable.
Solid Waste Disposal Act (42 USC Sec. 325103259, 6901-6991; 40 CFR 257,258) Federal Land Disposal Requirements (40 CFR Part 268)	Protects health and the environment and promotes conservation of valuable material and energy resources.	Applicable.
Minimum Functional Standards for Solid Waste Handling (WAC 173-304)	Sets minimum functional standards for the proper handling of all solid waste materials originating from residences, commercial, agricultural, and industrial operations as well as other sources.	Applicable.
Solid Waste Handling Standards (WAC 173-350)	Establishes minimum standards for handling and disposal of solid waste. Solid waste includes wastes that are likely to be generated as a result of site remediation, including contaminated soils, construction and demolition wastes, and garbage.	Applicable.
Health and Safety for Hazardous Waste Operations and Emergency Response (WAC 296-62; and Health and Safety 29 CFR 1901.120)	The HAZWOPER regulates health and safety operations for hazardous waste sites. The health and safety regulations describe federal requirements for health and safety training for workers at hazardous waste sites.	Applicable; any cleanup work will require compliance with OSHA and WISHA.

Table 7.2
Potential Action-Specific ARARs

Standard, Requirement, or Limitation	Description	Applicability
Worker Safety		
Occupational Safety and Health Act (29 USC 653, 655, 657) Occupational Safety and Health Standards (29 CFR 1910)	Employee health and safety regulations for construction activities and general construction standards as well as regulations for fire protection, materials handling, hazardous materials, personal protective equipment, and general environmental controls. Hazardous waste site work requires employees to be trained prior to participation in site activities, medical monitoring, monitoring to protect employees from excessive exposure to hazardous substances, and decontamination of personnel and equipment.	Applicable; any cleanup work will require compliance with OSHA.
Washington Industrial Safety and Health Act (WISHA; RCW 49.17) Washington Industrial Safety and Health Regulations (WAC 296-62, WAC 296-155, WAC 296-800)	Adopts the OSHA standards that govern the conditions of employment in all work places. The regulations encourage efforts to reduce safety and health hazards in the work place and set standards for safe work practices for dangerous areas such as trenches, excavations, and hazardous waste sites.	Applicable; any cleanup work will require compliance with WISHA.
Air Quality Controls		
Federal, State, and Local Air Quality Protection Programs State Implementation of Ambient Air Quality Standards NWCAA Ambient and Emission Standards Regional Standards for Fugitive Dust Emissions Toxic Air Pollutants	Regulations promulgated under the federal Clean Air Act (42 USC 7401) and the Washington State Clean Air Act (RCW 70.94) govern the release of airborne contaminants from point and non-point sources. Local air pollution control authorities such as the NWCAA have also set forth regulations for implementing these air quality requirements. These requirements may be applicable to the Site for the purposes of dust control should the selected remedial alternatives require excavation activities. WAC 173-460 establishes ambient source impact levels for arsenic.	Applicable; the selected alternative will require compliance with air quality regulations and BMPs for dust control during structural demolition.
Miscellaneous		
Noise Control Act of 1974 (RCW 70.107, WAC 173-60) (Adopted by City of Bellingham)	Establishes maximum noise levels.	Applicable; the selective alternative will need to comply with local and state noise pollution requirements. Construction and other activities will need to be limited to normal working hours.
National Electrical Code (NFPA 70) and the Seattle Electric Code Supplement for Class 1 Division 2 Environments	Establishes restrictions and guidelines for temporary and/or permanent electrical installations.	Applicable; compliance required should the selected alternative require temporary electrical power.

Abbreviations:

ARAR	Applicable or Relevant Appropriate Requirement
BMC	Bellingham Municipal Code
BMP	Best management practice
CFR	Code of Federal Regulations
CWA	Clean Water Act
HAZWOPER	Health and Safety for Hazardous Waste Operations and Emergency Management
HPA	Hydraulic Project Approval
MTCA	Model Toxics Control Act
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NPDES	National Pollutant Discharge Elimination System
NWCAA	Northwest Clean Air Agency
OSHA	Occupational Safety and Health Act
PL	Public Law
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
SEPA	State Environmental Policy Act
Site	Harris Avenue Shipyard Site
USC	United States Code
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife

Table 7.3
Potential Chemical-Specific ARARs

Standard, Requirement, or Limitation	**Description**	**Applicability**
Sediment Requirements		
Sediment Management Standards (SMS; WAC 173-204)	Establishes standards for the quality of surface sediment in Washington state. These standards provide chemical concentration criteria, which identify surface sediment without adverse effects on biological resources and no significant health risk to humans.	Applicable.
Groundwater Requirements		
Model Toxics Control Act (MTCA; WAC 173-340)	Establishes Washington state administrative processes and standards to identify, investigate, and clean up facilities where hazardous substances are located.	Applicable; Site is regulated under MTCA and must meet MTCA standards.
Drinking Water Standards—State MCLs (WAC 246-290-310)	Establishes standards for contaminant levels in drinking water for water system purveyors.	Not applicable; highest potential future beneficial use at the Site is not drinking water.
Washington State Maximum Contaminant Levels (WAC 246-290-310)	Washington state maximum contaminant levels (MCLs) are presented in WAC 246-290-310. These are standards that are generally promulgated by the United States Environmental Protection Agency (USEPA) and adopted by Washington State to protect for drinking water quality. An MCL is the legal threshold limit on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act.	Not applicable; maximum containment levels pertain to protection of groundwater for drinking water. Groundwater at the Site has been determined to be non-potable.
Water Quality Standards for Groundwaters of the State of Washington (WAC 173-200)	Implements the Water Pollution Control Act and the Water Resources Act of 1971 (90.54 RCW).	Not applicable to sites undergoing cleanup actions under MTCA, according to WAC 173-200-010(3)(c).
Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A)	The Surface Water Standards establish water quality standards for surface waters of the State of Washington. Water quality standards require that toxic substances shall not be introduced beyond the mixing zone greater than levels that have the potential to adversely affect characteristic water users, cause acute or chronic toxicity to the most sensitive biota, or adversely affect public health.	Applicable.
Total Maximum Daily Loads Established under Section 303(d) of the Clean Water Act (CWA; 40 CFR Part 130)	Requirements for water quality planning, management and implementation, and non-construction management sections of the Clean Water Act.	Not applicable; the water surrounding the Site is not on the 303(d) list and is not subject to total maximum daily load.
Water Quality Criteria Established under Section 304(a)(1) of the Clean Water Act (33 USC 1314)	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §121(d)(2) requires the USEPA to consider whether nationally recommended Ambient Water Quality Criteria should be relevant and appropriate requirements at a site. Section 401 of the Clean Water Act requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to the waters of the United States. Section 401 of the Clean Water Act requires the state to certify that federal permits are consistent with RCW 90.48 and WAC 173-201A. This may include the issuance of a 401 Water Quality Certification. Section 402 establishes the NPDES, which provides for the issuance of permits to regulate discharges to navigable waters.	Section 401 is applicable. Requirements under Section 402 are discussed under action-specific ARARs for NPDES issues related to construction.

Table 7.3
Potential Chemical-Specific ARARs

Standard, Requirement, or Limitation	Description	Applicability
Groundwater Requirements (cont.)		
National Toxics Rule (NTR; 40 CFR 131.36 et seq)	NTR promulgates for 14 states (Washington included) the chemical-specific, numeric criteria for priority toxic pollutants necessary to bring states into compliance with Section 303(c)(2)(B) of the Clean Water Act.	Applicable.
Washington Water Quality Standards Clean Water Act (40 CFR 131.45)	Clean Water Act-Effective Human Health Criteria Applicable to Washington were promulgated under 40 CFR Part 131.36 and were moved into 40 CFR 131.45 to have one comprehensive human health criteria rule for Washington. They became effective on December 28, 2016.	Applicable.
MTCA Method B Surface Water Cleanup Standards (WAC 173-340-730(3))	WAC 173-340-730(3)(b)(iii) establishes that MTCA Method B values should be considered when sufficiently protective health-based criteria or standards have not been established under applicable state and federal laws.	Applicable only if sufficiently protective health-based criteria or standards have not been established under applicable state and federal laws.
Sediment Management Standards (SMS; WAC 173-204)	Establishes standards for the quality of surface sediment in Washington state. These standards provide chemical concentration criteria, which identify surface sediment without adverse effects on biological resources and no significant health risk to humans.	Applicable.
Vapor Intrusion	Ecology's Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, as revised in 2015, identifies volatile organic compounds (as defined by WAC 173-340-200) and other substances and their respective screening levels that may pose a vapor intrusion threat. This pathway must be evaluated at sites where volatile contaminants are present within the vertical separation distances and lateral inclusion zone.	Not applicable; there are currently no slab-on-grade buildings within the vertical separation distance and lateral inclusion zone.
Soil Requirements		
Model Toxics Control Act (WAC 173-340)	Establishes Washington state administrative processes and standards to identify, investigate, and clean up facilities where hazardous substances are located.	Applicable; Site is regulated under MTCA and must meet MTCA standards.
Vapor Intrusion	Ecology's Updated Process for Initially Assessing the Potential for Petroleum Vapor Intrusion memorandum establishes TPH and BTEX concentrations in soil to quantify the total vapor phase concentrations of hydrocarbons within the vertical separation distance. This pathway must be evaluated at sites where volatile contaminants are present within the vertical separation distances and lateral inclusion zone.	Not currently applicable; there are currently no slab-on-grade buildings within the vertical separation distance and lateral inclusion zone. May be applicable in the future if new building construction occurs over areas of contamination.

Abbreviations:

ARAR	Applicable, Relevant, and Appropriate Requirement
BTEX	Benzene, Toluene, Ethylbenzene, and Total Xylenes
CFR	Code of Federal Regulations
MCL	Maximum Contaminant Level
NPDES	National Pollutant Discharge Elimination System
RCW	Revised Code of Washington
TPH	Total Petroleum Hydrocarbons
USC	United States Code
WAC	Washington Administrative Code

Table 9.1
Preliminary Screening of Technologies for Soil and Groundwater

Remedial Technology	Applicable Media	COCs and AOCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
No Action	• Soil • Groundwater	• None, there is no treatment or removal of COCs associated with this technology. This is included in the technology screening for comparative purposes.	• No cost to implement. • No long-term monitoring cost. • Does not cause substantial impacts to site operations.	• Does not reduce or remove chemical concentrations. • Does not protect human health and the environment. • Does not meet cleanup goals in a reasonable restoration time frame. • Technology does not have proven success at sites with similar conditions.	• Not impacted by site physical conditions. • Does not contribute to achievement of RAOs. • Does not affect shipyard operations.	The no action technology does not address any of the site COCs or achieve RAOs. No action is **Rejected** from further evaluation for the following: • Remediation of soil • Remediation of groundwater
Institutional Controls	• Soil • Groundwater	• Applicable to all site soil and groundwater COCs. • Applicable to all AOCs.	• Low cost to implement. • Protective of exposure pathways through requirements for maintenance and property restrictions. • Technology has proven success at sites with similar conditions.	• Does not reduce or remove chemical concentrations. • Limits future site operations through restrictive covenants or administrative measures. • Implements requirements for future ground disturbances. • As a standalone technology, institutional controls are not protective of any soil exposure pathways present at the Site.	• Can be implemented in combination with other technologies to ensure future site maintenance and/or redevelopment are conducted properly. • Contributes to achievement of RAOs when used in combination with other technologies. • Not limited by site physical conditions. • Can be implemented and maintained in an active shipyard with minimal disturbances.	Institutional controls are applicable to all COCs and all media, achieve RAOs when used in combination with other technologies, and can be implemented given site conditions. The technology of institutional controls is **Retained** for further evaluation for the following: • Remediation of soil • Remediation of groundwater
Engineering Controls	• Soil	• Applicable to all site soil COCs. • Applicable to all AOCs.	• Typically low cost to implement. • Protective of direct contact or erosion pathways through physical measures, such as an indicator layer. • Technology has proven success at sites with similar conditions.	• Chemicals remain in place and are not removed or destroyed. • Requires maintenance in perpetuity. • Accompanied by institutional controls.	• Not limited by site physical conditions. • Contributes to the achievement of RAOs when used in combination with other technologies. • Can be implemented and maintained in an active shipyard with minimal disturbances.	Engineering controls are applicable to all COCs in soil, achieve RAOs when used in combination with other technologies, and can be implemented given site conditions. The technology of engineering controls is **Retained** for further evaluation for the following: • Remediation of soil
Surface Capping	• Soil	• Applicable to all site soil COCs. • Applicable to all AOCs.	• Provides containment of contaminated soil below the ground surface with surface controls or barrier caps. • Technology has proven success at sites with similar conditions.	• Chemicals remain in place and are not removed or destroyed. • Surface cap or barrier maintenance required in perpetuity.	• Not limited by site physical conditions. • Contributes to achievement of RAOs. • Would impact shipyard operations during implementation.	Surface capping is applicable to all COCs in soil, achieves RAOs when used in combination with other technologies, and can be implemented given site conditions. Surface capping is **Retained** for further evaluation for: • Remediation of soil

Table 9.1
Preliminary Screening of Technologies for Soil and Groundwater

Remedial Technology	Applicable Media	COCs and AOCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
Solidification and Stabilization	- Soil - Groundwater (by protection of soil to groundwater pathway)	- Applicable to arsenic, copper, and zinc. - Not applicable for remediation of TPH. - Applicable to AOC 2A and AOC 2B.	- Technology reduces the mobility of soil contamination through physical or chemical immobilization by addition, for example, of zero-valent iron. - Controls contaminant migration and/or leaching to groundwater. - Can reach deep soil contamination. - Soil mixing is a common remediation technique typically used to implement solidification and stabilization, and can be implemented with augers to mix vertically into the subsurface, or with standard construction equipment to manually mix into open soils, such as the base of an excavation.	- Requires long-term groundwater compliance testing to ensure the immobilization of contaminants. - Chemicals remain in place and are immobilized but not removed. - When applied by the use of an auger, the technology can leave wedges of untreated soil in the spaces between treated soil columns. - Technology requires disturbance of the entire treated area subsurface and inhibits other operations. - When installed by auger soil mixing, technology results in generation of excess contaminated soil that must be disposed of in a landfill facility. - Technology does not have proven success at sites with similar conditions (e.g., primarily small and isolated areas of surface contamination).	- Would be difficult to implement for shallow contamination due to the large footprint of metals contamination. - Would substantially impact shipyard operations. - Substantial subsurface utilities are present, limiting the applicability of auger-mixing from the current ground surface throughout the depth of contamination. - Some implementation methods, such as mixing into the base of open excavations with standard construction equipment, may contribute to achievement of RAOs when used in combination with other technologies.	Due to the limited applicability for TPH contamination, the feasibility concerns given the widespread shallow contamination, and interruptions that would be caused to the shipyard, solidification and stabilization is **Rejected** from further evaluation for: - Remediation of shallow soil throughout the Site Due to the known conditions of multiple utilities, and tight spaces with limited access, auger-method solidification and stabilization has been **Rejected** from further evaluation**.** Due to the effectiveness in reducing metals in groundwater by immobilizing metals in soil and the potential use to be applied at the base of excavations, solidification and stabilization is **Retained** for further evaluation of the following: - Remediation of soil in combination with excavation - Remediation of groundwater in combination with excavation
Bioremediation/ Bioventing	- Soil (bioremediation and bioventing) - Groundwater (bioremediation)	- Applicable to remediation of TPH and 1-methylnaphthalene. - Not applicable for remediation of arsenic, copper, or zinc in soil. - Applicable to arsenic in groundwater by treating TPH and restoring redox conditions - Applicable to AOC 3	- Treats contamination by accelerating the natural biodegradation process. - Can use microorganisms already present in the subsurface. - Bioremediation amendments can be effective in treating residual groundwater contamination, if used with a source control technology.	- May require several rounds of injections of microorganisms, nutrients, or oxygen. - Does not treat inorganics. - Bioventing is limited to vadose zone soil. - May be limited in breaking down the heavier TPH components. - The restoration time frame is unknown.	- Technology would impact shipyard operations during implementation. - May contribute to the achievement of RAOs when used in combination with other technologies.	Due to the uncertainty of the effectiveness of bioremediation/bioventing for the Site soil COCs and its inability to effectively treat the metals contamination, bioventing/bioremediation is **Rejected** from further evaluation for the following: - Remediation of soil Due to the effectiveness in treating residual TPH and 1-methylnaphthalene groundwater contamination when used in conjunction with other technologies, bioremediation is **Retained** for further evaluation of the following: - Remediation of groundwater
Source Removal by Excavation and Landfill Disposal	- Soil - Groundwater	- Applicable to all site soil and groundwater COCs. - Applicable to all AOCs.	- Results in immediate removal of chemicals from the site, reducing mass in a short time frame. - Effectively removes all COCs in excavation area. - Removal of soil contamination in areas of impacted groundwater removes the ongoing source of contaminants to groundwater. - Does not require long-term monitoring and maintenance. - Technology has proven success at sites with similar conditions.	- Can be expensive to implement because of landfill disposal costs. - Technology is limited by contaminant depth. - May require shoring for stability depending on depth and constraints of excavation. - Dewatering may be required for excavations extending below the groundwater table, which generates liquid waste streams that would require treatment and disposal.	- Technology would substantially inhibit shipyard operations during implementation. - Contributes to achievement of RAOs when used in combination with other technologies.	Source removal addresses all COCs, is implementable given site conditions, and achieves RAOs when combined with other remedial technologies; therefore, source removal by excavation is **Retained** for further evaluation for the following: - Remediation of soil - Remediation of groundwater

Table 9.1
Preliminary Screening of Technologies for Soil and Groundwater

Remedial Technology	Applicable Media	COCs and AOCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
Chemical Oxidation	• Soil • Groundwater	• Applicable to 1-methylnaphthalene contamination. • Not applicable to TPH contamination as it is only in the vadose zone. • Not applicable to copper, or zinc contamination.	• Technology reduces contaminant concentrations and mass in place. • Low cost associated with implementation (i.e., no landfill disposal fees). • Technology has proven success at sites with saturated TPH conditions.	• Effectiveness limited by subsurface conditions and site heterogeneity as injected solutions can follow preferential pathways. • Requires multiple rounds of injection. • Contaminant rebound may be observed when source concentrations and volume are elevated and insufficient source treatment has occurred. • Success depends on matching the oxidant and in situ delivery system to contaminant concentrations and site conditions. • Oxidants used in technology can be corrosive and explosive. Implementation would require additional health and safety measures and trained professionals.	• Technology could cause significant impacts to shipyard activities during implementation. • May contribute to achievement of RAOs when used in combination with other remedial technologies. • Is typically not suitable for a point-of-discharge "curtain" application.	Due to the limited applicability of the TPH within the vadose zone, the technology of chemical oxidation is **Rejected** for further evaluation for the following: • Remediation of soil • Remediation of groundwater
Soil Vapor Extraction	• Soil	• Applicable to the volatile fraction of TPH contamination. • Not applicable to arsenic, copper, zinc, or and the heavier fraction of the TPH contamination. • Potentially applicable to AOC 3.	• Can be implemented with limited disturbance to surface activities. • System can be easily turned on and off to optimize performance and cost.	• Limited to treatment of vadose zone soil and volatile contaminants. • Requires surface capping to prevent short-circuiting. • Relatively expensive to install and maintain. • Does not address groundwater contamination for site COCs. • Technology does not have proven success at sites with similar conditions.	• Does not address contamination in the saturated zone or metals contamination. • Does not contribute to achievement of RAOs when used in combination with other remedial technologies.	Because soil vapor extraction is limited in applicability to vadose zone volatile contamination and is only effective on the lighter ends of petroleum, soil vapor extraction is **Rejected** from further evaluation for the following: • Remediation of soil
Thermal Treatment	• Soil • Groundwater	• Applicable to TPH and potentially 1-methylnaphthalene contamination. • Not applicable to arsenic, copper, or zinc. • Potentially applicable to AOC 3.	• Can be implemented in a short time frame. • Can be implemented at greater depths than other technologies. • Treats both soil and groundwater contamination simultaneously. • No long-term maintenance required.	• High cost associated with implementation. • Requires large loads of on-site power. • Requires substantial surface infrastructure for operation. • Technology does not have proven success at sites with similar conditions (e.g., heavy oils).	• Would impact shipyard operations during installation and treatment. • Technology not limited by site physical conditions and can be implemented in coordination with future use conditions. • Contributes to achievement of RAOs when used in combination with other technologies.	Because thermal treatment is only applicable to TPH and potentially 1-methylnaphthalene contamination, and does not treat any of the other site COCs, thermal treatment is **Rejected** from further evaluation for the following: • Remediation of soil • Remediation of groundwater
Monitored Natural Attenuation	• Soil • Groundwater	• Applicable to TPH, 1-methylnaphthalene, and arsenic contamination. • Applicable to AOCs 2A, 2B and 3.	• Low cost associated with implementation. • Does not cause impacts to site operations. • Technology has proven success for groundwater at sites with similar conditions when used in combination with other technologies.	• Long-term monitoring required until compliance conditions are obtained. • Does not control chemical migration. • Relies on natural degradation processes.	• Would not impact shipyard operations. • Is limited by site physical conditions, and the short distance between contamination and the shoreline. • Contributes to achievement of RAOs when used in combination with other remedial technologies. • Natural degradation processes have not been demonstrated at the Site.	Because Monitored Natural Attenuation would not significantly reduce contaminant mass and because natural degradation processes have not been demonstrated at the Site, monitored natural attenuation is **Rejected** from further evaluation for the following: • Remediation of soil Because Monitored Natural Attenuation would be applicable to achieving RAOs for TPH and subsequently arsenic in groundwater when used in combination with other technologies, it is **Retained** for further evaluation for the following: • Remediation of groundwater

Table 9.1
Preliminary Screening of Technologies for Soil and Groundwater

Remedial Technology	Applicable Media	COCs and AOCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
Permeable Reactive Barrier (PRB) Wall	• Groundwater	• Applicable to TPH, 1-methylnaphthalene, and arsenic contamination. • Potentially applicable to copper and zinc contamination. • Applicable to AOC 3 and AOC 2B.	• Passively treats contaminated groundwater as it passes through the reactive barrier area. • Can be straightforward to implement, except at significant depths. • Is relatively feasible to implement at shallow depths and does not cause significant disruption to site operations.	• A PRB wall can become "clogged" by migration of fines in groundwater and can be costly to maintain. • Depending on the concentrations in groundwater, the PRB wall may require replacement once the reaction capacity of the material in the wall is reached or the wall pores become clogged. • Dependent upon site conditions.	• Limited applicability given the physical conditions at the Site: site COCs are generally not mobile and arsenic concentrations are low compared to other sites where PRBs are installed. • Would cause substantial impacts to shipyard operations. • There is limited space between the shoreline and contaminant area for installation. This would limit the potential for long-term groundwater monitoring. • The Interim Action addressed the majority of AOC 3. • The PRB would be installed in a tidally influenced area. • Does not contribute to achievement of RAOs when used in combination with other remedial technologies. • An underlying confining layer to anchor a barrier wall is not known to exist.	PRB walls do not have proven success with TPH-contaminated sites with similar conditions, and have limited applicability given physical conditions and the majority of AOC 3 has been addressed in the Interim Action; therefore, a PRB wall is **Rejected** from further evaluation for the following: • Remediation of groundwater
Low Permeability Barrier Wall	• Groundwater	• Applicable to all site groundwater COCs. • Applicable to AOC 3 and AOC 2B.	• Contains soil and groundwater contaminants and restricts continued migration of contaminated groundwater.	• Is relatively costly to implement. • May impact future site operations, and require relocation of existing utilities. • Requires hydraulic control (pumping) inside the barrier wall to maintain an inward gradient of groundwater in perpetuity. • Does not address contamination that has already migrated past the point of treatment.	• Would cause substantial impacts to shipyard operations. • Limited applicability given the physical conditions at the Site: groundwater contamination is primarily limited to AOC 3 and AOC 2B. • There is limited space between the shoreline and contaminant area for installation. This would limit the potential for long-term groundwater monitoring • Does not contribute to achievement of RAOs when used in combination with other remedial technologies.	Low permeability barrier wall does not have proven success at sites with similar conditions, has limited applicability given physical conditions, and the majority of AOC 3 has been addressed in the Interim Action; therefore, the technology of a low permeability barrier wall is **Rejected** from further evaluation for the following: • Remediation of groundwater

Table 9.1
Preliminary Screening of Technologies for Soil and Groundwater

Remedial Technology	Applicable Media	COCs and AOCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
Pump and Treat	• Groundwater	• Applicable to all site COCs. • Applicable to AOCs 2B and 3.	• Removes dissolved-phase or solid-phase chemicals from groundwater. • Typically causes minimal impact to site operations.	• Does not treat soil source contamination. • High groundwater pumping rates may be required resulting in high volumes of groundwater for treatment and disposal. • Significant cost associated with treatment and discharge of treated waste stream. • Long-term operation and maintenance required for extraction system in perpetuity.	• Pumping wells would have to be installed along the shoreline, in a tidally influenced area that would result in excessive water volumes requiring treatment and disposal in perpetuity. • The majority of AOC 3 has been addressed by the Interim Action. • Could be implemented with current shipyard operations and would only cause minimal impacts. • May contribute to achievement of RAOs when used in combination with other remedial technologies.	Because pump and treat has historically been shown to be ineffective at treating similar sites, and given the Site conditions, concentrations of COCs, and long restoration time frame expected, pump and treat is **Rejected** from further evaluation for: • Remediation of groundwater
Air Sparging	• Groundwater	• Applicable to TPH, arsenic and 1-methylnaphthalene contamination. • Not applicable to copper or zinc. • Applicable to AOC 3.	• Flushed volatiles rise to the surface for extraction. • Air sparging is a proven technology for TPH-G.	• Although air sparging is a proven technology for VOCs and TPH-G, the effectiveness for the treatment of heavier TPH and PAH compounds is not well documented. • Would likely require a vapor extraction system to capture stripped volatiles	• Success depends on soil heterogeneity and other site specific factors. • Would cause some disruption to shipyard operations. • Does not contribute to achievement of RAOs when used in combination with other remedial technologies.	Because air sparging would not be expected to effectively treat the TPH and 1-methylnaphthalene contamination, would not address the metals contamination, and would not contribute to the achievement of RAOs, air sparging is **Rejected** from further evaluation for the following: • Remediation of groundwater

Note:

[1] RAOs refer to the Remedial Action Objectives and additional RI/FS remedial action considerations discussed in Section 7.1.

Abbreviations:

AOC	Area of Concern
COC	Contaminant of concern
RAO	Remedial Action Objective
RI/FS	Remedial Investigation/Feasibility Study
Site	Harris Avenue Shipyard
TPH	Total petroleum hydrocarbons
THP-G	Gasoline-range total petroleum hydrocarbons
VOC	Volatile organic compound

Table 10.1
Harris Avenue Shipyard Uplands Alternatives Disproportionate Cost Analysis

Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Alternative Description	Alternative 1 consists of engineering controls, removal of shallow surface soils, placement of a geotextile and capping with a clean gravel surface, groundwater monitoring, and institutional controls. These actions would address the direct contact exposures to arsenic and support site-wide groundwater recovery throughout AOC 2A and 2B. Alternative 1 includes the completed Interim Action remedy, which addressed direct contact exposure to arsenic and removed the majority of TPH and metals contamination in AOC 3 and a portion of AOC 2A. Alternative 1 will protect existing pavement and structures in all AOCs, which will serve as a cap to subsurface contamination and require institutional controls. Institutional controls would require implementation of an OMMP that would protect all exposure pathways during future excavation or site redevelopment.	Alternative 2 is either a 2-foot excavation and gravel cap or a 1-foot excavation and placement of an asphalt cap, and deeper “hot spot” excavation to address elevated groundwater concentrations of copper and zinc. A stormwater conveyance system will be installed as necessary. This alternative also includes groundwater monitoring, and institutional controls. These actions would address the direct contact exposures to arsenic and support site-wide groundwater recovery throughout AOC 2A and 2B. Alternative 2 includes the completed Interim Action remedy, which addressed direct contact exposure to arsenic and removed the majority of TPH and metals source material in AOC 3 and a portion of AOC 2A. Alternative 2 includes the contingency for use of a bioremediation amendment to address residual TPH in AOC 3 if groundwater exceedances are found during monitoring and deeper soil excavation or stabilization/solidification in excavation bases to address elevated zinc and copper in AOC 2B based on remedial design sampling. Alternative 2 will protect existing pavement and structures in all AOCs, which will serve as a cap to subsurface contamination and require institutional controls. Institutional controls would require implementation of an OMMP that would protect all exposure pathways during future excavation or site redevelopment. As with all alternatives, Alternative 2 includes the demolition and removal of the West Marine Walkway and armoring of the eroding section of the western shoreline.	Alternative 3 is a full removal alternative, where soil contamination at concentrations greater than the CUL would be excavated or remediated in all areas of the Site except under the buildings located on the south property boundary (former All American Marine building and the machine shop). Existing pavement and buildings on the Fairhaven Shipyard portion of the Site would be demolished to support the remedy. Alternative 3 includes the completed Interim Action remedy, which addressed direct contact exposure to arsenic and removed the majority of TPH and metals source material in AOC 3 and a portion of AOC 2A. These actions would address the direct contact exposure pathway for shipyard workers and support site-wide groundwater recovery. Institutional controls would be implemented to require evaluation of subsurface material and of cleanup actions for material under the remaining buildings if they are ever to be demolished. As with all alternatives, Alternative 3 includes the demolition and removal of the West Marine Walkway and armoring of the eroding section of the western shoreline.	

Table 10.1
Harris Avenue Shipyard Uplands Alternatives Disproportionate Cost Analysis

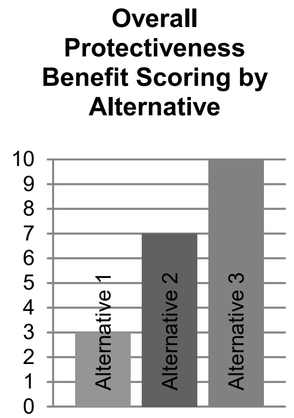
Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative Benefit Scoring**
Overall Protectiveness • Degree to which existing risks are reduced • Time required to reduce risks and attain cleanup standards • On- and off-site risks resulting from alternative implementation • Improvement in overall environmental quality	Alternative 1 is the minimum removal/capping alternative and is considered the least protective alternative. • Risks would be reduced through control of the direct contact exposure pathway through placement of a geotextile and clean gravel surface. • Stormwater at the Site would still be able to infiltrate, but the mass of metals contamination in surface soil available to leach to groundwater would be reduced through shallow excavation. This would provide a reduction in risk from groundwater contamination. • Risks in AOC 3 of direct contact exposure to soil and groundwater contamination were reduced by the completed Interim Action. • The time frame to reduce risk for the direct contact exposure pathway in soil would be immediate, following remedy implementation. The time frame for achievement of groundwater cleanup levels in AOCs 2B and AOC 3 is estimated to be 20 to 25 years from implementation. Maintenance of the cap and site institutional controls would be required in perpetuity. • There is an on-site risk that the remedy would not actually be protective of groundwater, because insufficient metals contamination in soil would have been removed. No other on-site or off-site risks result from implementation of this alternative. • There is an improvement in overall environmental quality resulting from implementation of this alternative through capping, treatment of TPH, monitoring, and implementation of institutional controls. However, because there would be less excavation than Alternatives 2 and 3 and because the cap would have less integrity than the cap associated with Alternative 2, the improvement in environmental quality is lower with Alternative 1 than the other alternatives.	Alternative 2 is considered more protective than Alternative 1 and is a capping/additional contaminant mass removal alternative. • Risks for the direct contact exposure pathway would be reduced through contaminant removal with an asphalt or thick (2 to 4 feet) gravel cap. The capped surface would be expected to have a longer life and retain more integrity over the long term than the cap with Alternative 1. Capping and installation of a stormwater conveyance system, if necessary, would reduce infiltration of stormwater and reduce leaching of metals into groundwater site-wide. • Risks to groundwater in AOC 2B would be addressed through removal of deeper contaminated soil as determined necessary by additional sample analysis and tests conducted during remedial design sampling. Tests may include leachability testing, speciation testing, and evaluation of porewater and seep data. • Risks in AOC 3 of direct contact exposure to soil and groundwater contamination were reduced by the completed Interim Action. • Risks to groundwater contamination if source removal is not enough to bring groundwater into compliance would be reduced by contingency bioremediation amendment in AOC 3. • The time frame to reduce risk for the direct contact exposure pathway in soil would be immediate, following remedy implementation; however, contamination would remain on-site greater than cleanup levels, requiring cap maintenance and institutional controls in perpetuity. • The time frame for achievement of groundwater cleanup levels in AOC 2B and AOC 3 would be up to 2 to 5 years after implementation. • There is a small risk that groundwater in AOC 2B and AOC 3 would not recover to levels in compliance with cleanup standards within a reasonable timeframe. No other on-site or off-site risks result from implementation of this alternative. • There is an improvement in overall environmental quality resulting from implementation of this alternative through source removal, capping, treatment of TPH, monitoring, and implementation of institutional controls. There is a large improvement in overall environmental quality compared to Alternative 1.	Alternative 3 is a full removal alternative and is the most aggressive and permanent alternative. • Risks would be reduced through contaminant mass removal. Because excavation is considered a permanent remedy under MTCA, this alternative is considered the most permanent alternative to the maximum extent. Comparing Alternatives 1 and 2 to Alternative 3, risks would be reduced across the Site in all AOCs. Excavation of metals contamination in surface soil would provide a reduction in risk to groundwater. • Risks in AOC 3 of direct contact exposure to soil and groundwater contamination were reduced by the completed Interim Action. • The time frame to reduce risk for the direct contact exposure pathway in soil would be immediate, following remedy implementation. Contamination would only potentially remain under those existing buildings that would continue to serve as a cap. • The time frame for achievement of groundwater cleanup levels in AOC 2B and AOC 3 would be 2 to 5 years. • There is a small risk that groundwater in AOC 2B and AOC 3 would not recover to levels in compliance with cleanup standards within a reasonable timeframe. No on- or off-site risks result from implementation of this alternative. • There is a substantial improvement in overall environmental quality resulting from implementation of this alternative through excavation and implementation of institutional controls. This is a full removal alternative and would provide the highest improvement in environmental quality.	

Table 10.1
Harris Avenue Shipyard Uplands Alternatives Disproportionate Cost Analysis

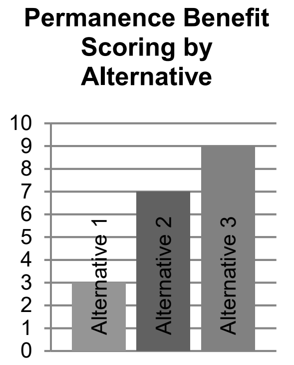
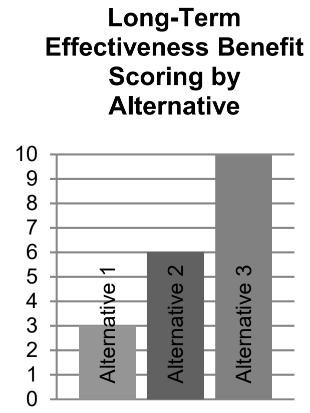
Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Permanence • Degree of reduction of contaminant toxicity, mobility, and volume • Adequacy of destruction of hazardous substances • Reduction or elimination of substance release, and source of release • Degree of irreversibility of waste treatment processes • Volume and characteristics of generated treatment residuals	• This alternative provides a slight reduction in contaminant toxicity or volume. There would be a reduction in contaminant volume through excavation of surface soil to support the placement of capping material. Capping could reduce contaminated soil mobility from erosion. Removal of surface contamination would reduce metals available to leach to groundwater. • Limited metals contamination would be removed from the Site, but not destroyed. Most contamination at the Site would be left in place beneath a capped surface. • Primary operational release mechanisms of metals contamination have been removed, and are periodically updated through improved shipyard operational BMPs. The primary release mechanisms of TPH contamination have been removed. • Waste treatment processes include excavation of metals contamination, which is irreversible. Capping is reversible, but would be maintained with institutional controls. • There are no treatment residuals associated with implementation of this technology.	• This alternative provides a significant reduction in contaminant toxicity or volume. There would be a reduction in contaminant volume through excavation of surface soil to support the placement of the cap. Additional reduction in mobility of metals in soil would be accomplished through capping. There would be a reduction of TPH in AOC 3 by bioremediation if this remedy is necessary. • The destruction of hazardous substances associated with this alternative is accomplished through removal of metals- and TPH-contaminated soil and is adequate and irreversible. Contamination at the Site not removed through excavation would be left in place beneath a capped surface and require institutional controls. • Primary operational release mechanisms of metals contamination have been removed and are periodically updated through improved shipyard operational BMPs. The primary release mechanisms of TPH contamination have been removed. • Deeper excavation in AOC 2B, if necessary to implement, would reduce the release of zinc and copper into groundwater. • Waste treatment processes include excavation of metals contamination and bioremediation of TPH contamination, both of which are irreversible. Capping is reversible, but would be maintained with institutional controls. • There are no treatment residuals associated with implementation of this technology.	• This alternative provides the highest degree of reduction in contaminant toxicity, mobility, and volume as all contamination, with the exception of potential metals contamination under existing buildings on the south side of the property, would be excavated and disposed of off-site. Remaining TPH in AOC 3 would be excavated for off-site disposal. Removal of source metals in soil would reduce mobility of metals and support the groundwater remedy in AOC 2B and AOC 3. • The destruction of hazardous substances associated with this alternative is accomplished through removal, which is both adequate and irreversible. • Primary operational release mechanisms of metals contamination have been removed, and are periodically updated through improved shipyard operational BMPs. The primary release mechanisms of TPH contamination have been removed. • The waste treatment processes associated with this alternative include excavation and maintenance of building caps. Excavation is irreversible. Capping is a reversible technology, unless maintained with institutional controls. • There are no treatment residuals associated with implementation of this technology.	
Effectiveness over the Long-Term • Degree of certainty of alternative success • Reliability while contaminants remain on-site greater than cleanup levels • Magnitude of residual risk • Effectiveness of controls implemented to manage residual risk	• This alternative provides a low degree of certainty of success. Gravel capping, placement of a geotextile to prevent soil mixing, and institutional controls are common technologies that would control exposure pathways, but require maintenance in perpetuity. Because of shipyard operations, there would be a risk that the cap would fail prematurely. • Degree of certainty for success to remediate groundwater is high in AOC 3, because the Interim Action removed the majority of TPH contaminated soil. • Degree of certainty to remediate groundwater in AOC 2B is low, because a limited amount of source material will be removed. • This alternative is reliable as long as the cap is properly maintained and institutional controls are followed. Multiple rounds of groundwater monitoring would likely be required to confirm the Site is in compliance. • Residual risk is moderate to high, as most metals contamination would remain on-site. • Risks are controlled through the enforcement of institution controls and an OMMP, which are considered to be effective at managing risk.	• This alternative provides a moderate degree of certainty of success. Both excavation and capping are common technologies that would either remove contaminants or block exposure pathways; however, caps require maintenance and institutional controls in perpetuity. • Degree of certainty for success to remediate groundwater is high in AOC 3, because the Interim Action removed the majority of TPH contaminated soil. Contingency application of bioremediation amendment increases the certainty of success. • Degree of certainty to remediate groundwater in AOC 2B is moderate, because not all source material will be removed. Deeper "hot spot" excavation of copper- and zinc-contaminated soil increases the certainty of success. • This alternative is reliable as long as the cap is properly maintained and institutional controls are followed. Multiple rounds of groundwater monitoring would likely be required to confirm the Site is in compliance. • The magnitude of residual risk associated with this alternative is moderate to low, because much of the surface contamination would be excavated or capped. Some residual risk would remain because not all contaminants are removed from the Site. • Risks are controlled through the enforcement of institutional controls and an OMMP, which are considered to be effective at managing risk.	• This alternative provides a high degree of certainty of success. Excavation is a common technology that would permanently remove contamination from the Site. • Excavation is a reliable technology with measurable success for similar excavation and disposal projects. • The magnitude of residual risk associated with this alternative is low, because nearly all site contamination would be removed, and all remaining potential contamination would be contained under existing buildings that would not be demolished. • Residual risks below the remaining buildings would be controlled through the enforcement of institutional controls, which are considered to be effective at managing risk.	

Table 10.1
Harris Avenue Shipyard Uplands Alternatives Disproportionate Cost Analysis

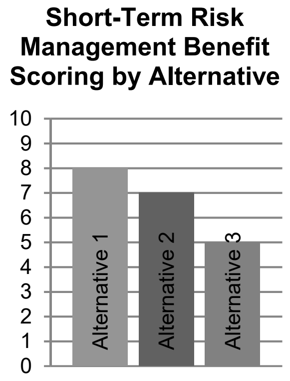
Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Short-Term Risk Management • Risk to human health and the environment associated with alternative construction • The effectiveness of controls in place to manage short-term risks	• With Alternative 1, limited contaminated surface soil is handled and removed from the Site. • There is moderate short-term risk to human health and the environment during implementation. Excavation to support the placement of a clean gravel surface requires some contaminated materials handling. There is also a low risk for public exposure with this alternative as contaminated soil would be removed and transported from the Site for disposal over public roadways; however, the excavated soil would be managed by licensed professionals. • Site activities would require appropriate PPE, BMPs, and appropriate training requirements for management of risk. These controls are highly effective and anticipated to adequately manage short-term risk.	• With Alternative 2, limited contaminated surface soil is handled and removed from the Site to support cap placement. • There is moderate short-term risk to human health and the environment during implementation. Excavation to support the placement of a capped surface requires some contaminated materials handling. There is also a low risk for public exposure with this alternative as contaminated soil would be removed and transported from the Site for disposal over public roadways; however, the excavated soil would be managed by licensed professionals. • There is a low risk to site workers during handling of bioremediation product for contingency injection into AOC 3. • Site activities would require appropriate PPE, BMPs, and appropriate training requirements for management of risk. These controls are highly effective and anticipated to adequately manage short-term risk.	• Alternative 3 is a full removal alternative consisting of excavation and off-site disposal of a large volume of contaminated soil. • This alternative has a moderate short-term risk associated with worker direct-contact during excavation and handling, and disposal of contaminated soil. • There is a low, but increased, risk compared to Alternatives 1 and 2 for worker safety during demolition activities. • There is a low, but increased, risk compared to Alternatives 1 and 2, for public exposure with this alternative as a greater volume of contaminated soil would be removed and transported from the Site for disposal over public roadways; however, the excavated soil would be managed by licensed professionals. • Site activities would require appropriate PPE, BMPs, and training requirements for management of risk. These controls are highly effective and anticipated to adequately manage short-term risk.	

Table 10.1
Harris Avenue Shipyard Uplands Alternatives Disproportionate Cost Analysis

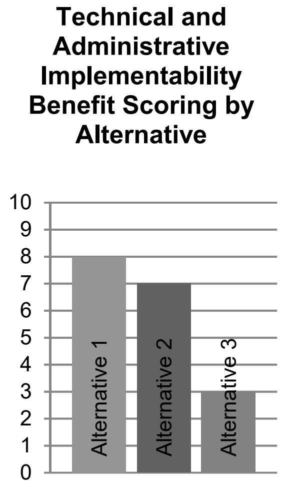
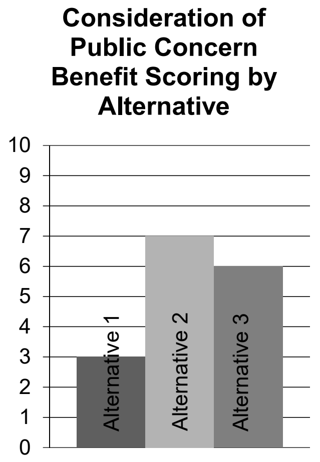
Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Technical and Administrative Implementability *Ability of alternative to be implemented considering:* • Technical possibility • Availability of off-site facilities, services, and materials • Administrative and regulatory requirements • Schedule, size, and complexity of construction • Monitoring requirements • Site access for construction, operations, and monitoring • Integration with existing site operations or other current and potential future remedial action	• This alternative is technically possible to implement and involves common technologies. This alternative is also conducive with an active shipyard environment. • All necessary off-site facilities, materials, and services are available within the region. • This alternative complies with all applicable administrative and regulatory requirements. • This alternative is moderate in scale. This alternative would be managed and constructed by specialty professionals familiar with the type of work, and this alternative can easily be implemented in a single construction season. • Monitoring requirements include soil cap monitoring in perpetuity and groundwater monitoring following implementation. Because of the nature of the cap material and the active shipyard environment, the cap would be difficult to maintain and there would be risk of cap disturbance. • Site access would not be impeded for the implementation and construction of this alternative. Implementation of this alternative may be phased to minimize impacts to the active shipyard. • Future site access would be required for groundwater monitoring, soil cap monitoring, and maintenance. • This alternative is consistent with current conditions, but implementation can be integrated with both existing and proposed future site uses.	• This alternative is technically possible to implement and involves common technologies. This alternative is also conducive with an active shipyard environment. • All necessary off-site facilities, materials, and services are available within the region. Specialized materials are required for injection of bioremediation amendments, but this equipment is available locally. • This alternative complies with all applicable administrative and regulatory requirements. • This alternative is moderate in scale. This alternative would be managed and constructed by specialty professionals familiar with the type of work, and this alternative can easily be implemented in a single construction season. • Monitoring requirements include soil cap monitoring in perpetuity and groundwater monitoring following implementation. • Site access would not be impeded for the implementation and construction of this alternative. Implementation of this alternative may be phased to minimize impacts to the active shipyard. • Future site access would be required for groundwater monitoring, soil cap monitoring, and maintenance. • This alternative is consistent with current conditions, but implementation can be integrated with both existing and proposed future site uses.	• Alternative 3 is technically possible to implement and involves common technologies, but, due to the number of existing and functional structures that would be demolished to support the remedy, it is much more difficult to implement in the active shipyard environment. • All necessary off-site facilities, materials, and services are available within the region. • This alternative complies with all applicable administrative and regulatory requirements. • This alternative is anticipated to achieve compliance with regulatory requirements in a short time frame. This alternative is very large in scale. This alternative would be managed and constructed by specialty professionals familiar with the type of work. Due to construction phasing required to support shipyard operations, this alternative would likely require multiple construction seasons to implement. • Monitoring requirements include groundwater monitoring and cap monitoring in those locations where existing buildings would be maintained and act as a cap. • Site access would not be impeded for the implementation and construction of this alternative because buildings would be demolished. Implementation of this alternative may be phased to minimize impacts to the active shipyard. • Future site access would be required for groundwater monitoring, soil cap monitoring, and maintenance. • This alternative is consistent with current conditions, but implementation can be integrated with both existing and proposed future site uses.	
Consideration of Public Concerns • Whether the community has concerns • Degree to which the alternative addresses those concerns	Public concerns will be reviewed following the public comment period and addressed in the final remedial alternative selection and design. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects. It is anticipated the public would have concern with a remedy that did not provide some degree of source removal.	Public concerns will be reviewed following the public comment period and addressed in the final remedial alternative selection and design. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects. It is anticipated the public would have concerns with the construction impact on the community.	Public concerns will be reviewed following the public comment period and addressed in the final remedial alternative selection and design. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects. It is anticipated the public would have concerns with the cost associated with this remedy and the greater degree of impact on the community during construction.	

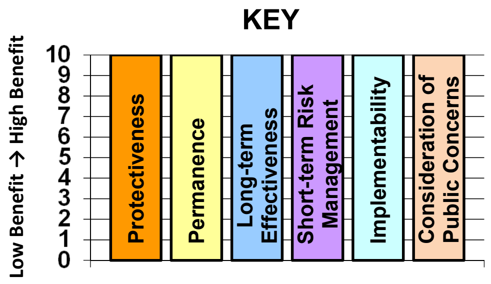
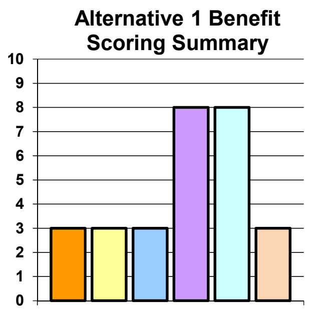
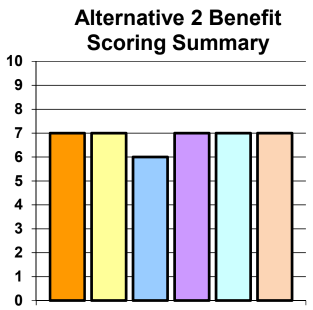
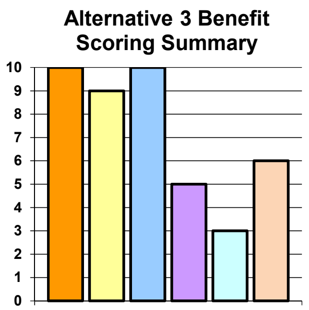
Table 10.1
Harris Avenue Shipyard Uplands Alternatives Disproportionate Cost Analysis

Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Cost • Cost of construction • Long-term monitoring, operations, and maintenance costs • Agency oversight costs	• Interim Action Cost (same for all alternatives) = $1.6 M • Construction Cost = $992 K • Total Alternative Cost (including completed Interim Action, design, and contingency) = $4.1 M • Long-term monitoring, operations, and maintenance costs would be high with Alternative 1. Annual monitoring and annual maintenance of the gravel cap would be required in perpetuity. • Agency oversight costs would be high with Alternative 1 and would include costs associated with oversight activities during construction and during annual groundwater and cap monitoring. Although construction oversight would likely consist of only one season, oversight of annual monitoring would be conducted in perpetuity.	• Interim Action Cost (same for all alternatives) = $1.6 M • Construction Cost = $2.7 M • Total Alternative Cost (including completed Interim Action, design, and contingency) = $5.9 M • Long-term monitoring, operations, and maintenance costs would be moderate with Alternative 2. Annual monitoring and periodic maintenance of the cap would be required in perpetuity. • Agency oversight costs would be moderate with Alternative 2 and would include costs associated with oversight activities during construction and during annual groundwater and cap monitoring. Although construction oversight would likely consist of only one season, oversight of annual monitoring would be conducted in perpetuity.	• Interim Action Cost (same for all alternatives) = $1.6 M • Construction Cost = $7.5 M • Total Alternative Cost (including design and contingency) = $12.6 M • Long-term monitoring, operations, and maintenance costs would be low with Alternative 3. Groundwater monitoring would only be conducted until groundwater cleanup levels are achieved, expected to be within a short time frame. Long-term monitoring and maintenance would only be required for the areas of the Site that are currently capped with buildings. • Agency oversight costs would be moderate with Alternative 3 and would include oversight activities during construction and during groundwater and cap monitoring. Costs for agency oversight during construction is expected to be higher with Alternative 3 than the other alternatives because there would be multiple construction seasons and the remedy would likely require Ecology certification of the full removal of contamination. However, there would be less agency oversight after construction, due to the reduction in long-term monitoring.	

Abbreviations:

AOC	Area of Concern
BMP	Best Management Practice
M	Million
MTCA	Model Toxics Control Act
OMMP	Operations, Maintenance, and Monitoring Plan
PPE	Personal Protective Equipment
Site	Harris Avenue Shipyard Site
TPH	Total petroleum hydrocarbons

Table 10.2
Harris Avenue Shipyard Uplands Disproportionate Cost Analysis Summary

Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**
Alternative Description	Alternative 1 consists of engineering controls, removal of shallow surface soils, placement of a geotextile and capping with a clean gravel surface, groundwater monitoring, and institutional controls. These actions would address the direct contact exposures to arsenic and support site-wide groundwater recovery throughout AOC 2A and 2B. Alternative 1 includes the completed Interim Action remedy which addressed direct contact exposure to arsenic and removed the majority of TPH and metals contamination in AOC 3 and a portion of AOC 2A. Alternative 1 will protect existing pavement and structures in all AOCs which will serve as a cap to subsurface contamination and require Institutional controls. Institutional controls would require implementation of an OMMP that would protect all exposure pathways during future excavation or site redevelopment.	Alternative 2 is either excavation to CULs with gravel backfill or a 1-foot excavation and placement of an asphalt cap, and deeper hot spot excavation as needed for groundwater protection. A stormwater conveyance system will be installed as necessary. This alternative also includes groundwater monitoring and institutional controls. These actions would address the direct contact exposures to arsenic and support site-wide groundwater recovery throughout AOC 2A and 2B, Alternative 2 includes the completed Interim Action remedy which addressed direct contact exposure to arsenic and removed the majority of TPH and metals source material in AOC 3 and a portion of AOC 2A. Alternative 2 includes the contingency for use of a bioremediation amendment to address residual TPH in AOC 3 and deeper soil solidification/stabilization of excavation bases to address elevated zinc and copper in AOC 2B based on the results of remedial sampling. Alternative 2 will protect existing pavement and structures in all AOCs which will serve as a cap to subsurface contamination and require Institutional controls. Institutional controls would require implementation of an OMMP that would protect all exposure pathways during future excavation or site redevelopment.	Alternative 3 is a full removal alternative, where soil contamination at concentrations greater than the CUL would be excavated or remediated in all areas of the Site except under the buildings located on the south property boundary (former All American Marine building and the machine shop). Existing pavement and buildings on the Fairhaven Shipyard portion of the Site would be demolished to support the remedy. Alternative 3 includes the completed Interim Action remedy, which addressed direct contact exposure to arsenic and removed the majority of TPH and metals source material in AOC 3 and a portion of AOC 2A. These actions would address the direct contact exposure pathway for shipyard workers and support site-wide groundwater recovery. Institutional controls would be implemented to require evaluation of subsurface material and of cleanup actions for material under the remaining buildings if they are eve to be demolished.
	 Alternative 1 Benefit Scoring Summary	 Alternative 2 Benefit Scoring Summary	 Alternative 3 Benefit Scoring Summary
Compliance with MTCA Threshold Requirements	Yes	Yes	Yes
Restoration Time Frame (to achieve remediation goals)	5 Years Following Construction	3 Years Following Construction	2 to 3 Years Following Construction
Benefit Scoring			
Overall Protectiveness (30%)	3	7	10
Permanence (20%)	3	7	9
Long-Term Effectiveness (20%)	3	6	10
Short-Term Risk Management[1] (10%)	8	7	5
Implementability (10%)	8	7	3
Consideration of Public Concerns[2] (10%)	3	7	6
Total Benefit Score (weighted)	**4.0**	**6.8**	**8.2**
Estimated Alternative Cost[3]	$4.1 M	$5.9 M	$12.6 M
Unit Benefit per $M [4]	**0.98**	**1.1**[5]	**0.65**

Notes:

1 Higher scores equate to a higher level of relative benefit. Fewer risks result in a higher score.

2 Public comment has not been received on the RI/FS. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects.

3 Specific cost estimate information is provided in Appendix H.

4 Unit Benefit per Million Dollars calculated by dividing the alternative Total Benefit Score by the total alternative cost (in millions). Highest value indicates the most benefit for the associated cost.

5 With the highest benefit per million dollars of remedy cost, Alternative 2 provides the greatest degree of benefit for the associated cost of all the alternatives, making it the preferred remedial alternative.

Abbreviations:

AOC	Area of Concern
CUL	Cleanup level
M	Million
MTCA	Model Toxics Control Act
OMMP	Operations, Maintenance, and Monitoring Plan
RI/FS	Remedial Investigation/Feasibility Study
Site	Harris Avenue Shipyard

Table 12.1
Preliminary Screening of Technologies for Sediment

Remedial Technology	COCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
Institutional Controls	Applicable to all Site sediment COCs.	• Low cost to implement. • Does not impact site operations. • Addresses human exposure pathways through administrative controls and restrictions.	• Does not reduce or remove chemical concentrations. • Limits future site operations through restrictive covenants or administrative measures. • Does not address benthic toxicity to ecological receptors.	• Not limited by site physical conditions. • Contributes to achievement of RAOs when used in combination with other technologies.	Institutional controls are applicable to all COCs, achieve RAOs when used in combination with other technologies, and can be implemented given site conditions. The technology of institutional controls is **Retained** for further evaluation for the following: • All sediment areas
Natural Recovery: Monitored Natural Recovery	Applicable to all Site sediment COCs.	• Low implementation cost. • Does not impact site operations. • Achieves compliance with cleanup standards over time.	• Long-term monitoring required. • COCs remain in place and are not removed or destroyed. • Does not immediately achieve chemical containment or attenuation. • Relies on natural sedimentation for dilution or containment of contaminants. • Not applicable in erosive areas.	• Natural degradation processes do not occur for PCBs or metals contamination; therefore, MNR would be reliant on sedimentation processes for effectiveness. • Evaluation of site sedimentation indicates natural recovery will occur over time in depositional areas of the Site. • The expected sedimentation rate in site depositional areas is approximately 0.65 to 0.81 cm/year. Settlement of 12 cm of clean sediment would not be expected within a 10-year timeframe, and may not achieve restoration timeframe goals as a stand-alone technology.	Monitored natural recovery is applicable in depositional areas of the Site, and has proven success at sites with similar conditions; therefore, monitored natural recovery is **Retained** for further evaluation for the following: • Depositional areas
Natural Recovery: Enhanced Natural Recovery	Applicable to all Site sediment COCs.	• Low implementation cost. • Accelerates the rate of natural recovery of contaminants through placement of a thin sand layer on the existing sediment. • Mixing of the clean sand may reduce COC concentrations in the surface sediments, and increase the rate of cleanup standard compliance.	• Long-term monitoring required. • COCs remain in place and are not removed or destroyed. • Does not immediately achieve chemical containment or attenuation. • Relies on natural sedimentation or placement of clean material for dilution or containment of contaminants. • Not applicable in erosive areas. • May impact site operations, and slightly reduce water depth.	• Natural degradation processes do not occur for metals and PCB contamination; therefore ENR, would be reliant on limited material placement and sedimentation processes for effectiveness. • Would cause minimal impacts to shipyard operations during implementation. • Given the estimated site sedimentation rate, could result in achievement of cleanup standards within a 10-year restoration time frame. • Would not be applicable in erosive areas of the Site.	Enhanced natural recovery is applicable in depositional areas of the Site, and has proven success at sites with similar conditions; therefore, enhanced natural recovery is **Retained** for further evaluation for the following: • Depositional areas
Sediment Capping: Granular Caps	Applicable to all Site sediment COCs.	• Physically separates contaminants from the overlying water column. • Contains the sediment contamination but also allows for attenuation and diffusion of groundwater through the cap material. • Cap amendments (such as organo-clays or carbon) can increase chemical attenuation. • Thin lift cap placement strengthens the sediment surface and minimizes resuspension.	• Chemicals generally remain in place and are not removed or destroyed. • Cap maintenance may be required in perpetuity. • Caps are typically constructed in layers and typically some degree of mixing occurs with underlying sediments during cap placement. • Cap placement in limited access areas requires alternative placement methods, and is typically substantially slower, and more expensive. • Cap placement can be limited by structural considerations of over-water structures.	• Applicable at the Site given physical conditions, but may require alternative material placement methods in some areas due to over-water structures. Conventional clamshell bucket placement methods would not be suitable under piers. • Would substantially impact shipyard operations during implementation. • Resuspension and migration of contaminated sediments during cap placement is possible. • Due to bottom scour potential from marine vessels, large diameter cap material would likely be required. • Cap design will need to address operational, habitat, and hydrodynamic considerations.	Granular sediment capping is applicable to all Site COCs, but is limited in some areas by over-water structures and limited accessibility. Granular sediment capping is **Retained** for further evaluation for the following: • Open water areas • Under-pier areas where adequate access and clearance exists for cap material placement • Under-pier areas where capping would not destabilize the integrity of the over-water structures

Table 12.1
Preliminary Screening of Technologies for Sediment

Remedial Technology	COCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
Sediment Capping: Low-Permeability Barrier (Grout Mat)	Applicable to all Site sediment COCs.	• Physically separates contaminants from the overlying water column. • Contains sediment contamination. • Is implementable in areas with limited access and obstructions. • Results in minimal disturbance to underlying sediment during placement.	• Chemicals generally remain in place and are not removed or destroyed. • Cap maintenance may be required in perpetuity. • Requires labor-intensive installation. • Depending on grout permeability, can redirect groundwater seepage/discharge. • Surface is not ideal for support of benthic communities, and may require placement of material on the mat surface. • Is typically more expensive than granular cap placement.	• Beneath pile-supported structures, would require by hand and diver installation including seaming and patching of the mat around piling structures. • Can be installed in areas where sand capping is not feasible due to access limitations. • May require debris removal prior to placement in the intertidal area.	Grout mat capping is applicable to all Site COCs, and is **Retained** for further evaluation for the following: • Under-pier areas where granular cap placement is infeasible due to access limitations Due to the increased cost, grout mat caps are not retained for areas of the Site where sand capping is applicable.
Removal: Mechanical Dredging	Applicable to all Site sediment COCs.	• Permanent removal of contaminated material. • Does not typically require long-term monitoring and maintenance. • Effective for removal of large materials, dense sediment, and debris. • Is implementable in sloped areas. • Dredged material has less water content than other dredge methods. • Closed bucket mechanical dredges can reduce resuspension during dredging.	• Dredging can cause resuspension, and redeposition of contaminated sediments. • May require a follow-up remedial action (capping, ENR, etc.) if dredging alone does not achieve site cleanup requirements due to dredging residuals. • Requires significant BMPs to control turbidity, and area for material handling and dewatering. • Dredging is limited by the presence of over-water structures, docks, pilings, outfalls, debris, and underwater utilities.	• Resuspension and migration of contaminated sediments during dredging is possible and BMPs would be required. • Would substantially impact shipyard operations during implementation. • Dredging could likely be conducted mechanically with a clamshell (environmental or digging) bucket. A large volume of dredge material would require dewatering and treatment, if necessary, prior to disposal. • Contributes to achievement of RAOs. • Would be designed to address adequate habitat, given shipyard use. • Is not applicable beneath or immediately adjacent to over-water structures. Would require demolition of over-water structures prior to dredging sediments currently below structures.	Mechanical dredging achieves RAOs, and is applicable to all Site COCs; therefore, mechanical dredging is **Retained** for further evaluation for the following: • Open-water areas
Removal: Hydraulic Dredging	Applicable to all Site sediment COCs.	• Permanent removal of contaminated material. • Does not typically require long-term monitoring and maintenance. • Removes material in a more consistent manner to achieve a flatter dredged surface.	• Generates a large volume of sediment slurry requiring handling and dewatering prior to disposal. • Cannot be implemented in areas with significant debris, or requires debris removal prior to dredging. • May require a follow-up remedial action (capping, ENR, etc.) if dredging alone does not achieve site cleanup requirements due to dredging residuals. • Requires significant BMPs to control turbidity, and a greater area for material handling and dewatering than mechanical dredging. • Cannot be implemented beneath over-water structures or docks, around pilings, or outfalls without significant concern of damage or impact.	• Resuspension and migration of contaminated sediments during dredging is possible and BMPs would be required. • Would substantially impact shipyard operations during implementation. • Hydraulic dredging would generate a substantially increased volume of material requiring dewatering than mechanical dredging. • Contributes to achievement of RAOs. • Would be designed to address adequate habitat, given shipyard use. • Is not applicable beneath or immediately adjacent to over-water structures. Would require demolition of over-water structures prior to dredging sediments currently below structures.	Hydraulic dredging can achieve RAOs, and is applicable to all Site COCs, but requires a significant increased area for management of dredged slurry over mechanical dredge options. Areas for management of hydraulic dredge slurries are not available at the active shipyard site. Hydraulic dredging is not feasible for under-pier implementation, due to adverse impacts that sediment removal would have on structural capacity, incompatibility with debris and large material, and access restrictions. Hydraulic dredging is **Rejected** from further evaluation.

Table 12.1
Preliminary Screening of Technologies for Sediment

Remedial Technology	COCs Addressed	General Technology Benefits	General Technology Constraints	Consideration of Site Physical Conditions and RAOs[1]	Technology Retained for or Rejected from Further Evaluation
Removal: Excavation	Applicable to all Site sediment COCs.	• Permanent removal of contaminated material. • Does not typically require long-term monitoring and maintenance. • Mechanical excavation can be conducted from upland or floating barge. • Sediment is removed while unsaturated, and requires less dewatering and handling prior to disposal. • Can be effectively implemented in sloped areas. • Hand excavation can be completed in areas with access limitations to mechanical means. • Is not impacted by the presence of debris. • Has limited water quality impacts.	• Excavation will generally occur above the waterline, and is, therefore, restricted by tidal cycles, which limits work windows. • If conducted adjacent to structures, may require off-sets, or other shoring to stabilize and protect structures. • Requires overhead clearance, and has limited applicability in areas with limited access or clearance. • Hand excavation of areas with significant access limitations is labor-intensive, resulting in high cost.	• Could impact shipyard operations depending on location of excavation work. • Contributes to achievement of RAOs. • Mechanical excavation is applicable in intertidal sediment areas, and can be conducted from land or barge, if areas are accessible by water. • Could allow for improvement of existing poor-condition bulkheads. • If excavation is conducted in intertidal sediment areas, impacts to the ordinary high water line should be considered. • Excavation of sediment from areas of significant access limitations, such as the marine railway, would be expected to be completed by hand removal. • Removal of material beneath larger areas of over-water access limitations would likely require structure removal to allow access to the underlying sediment area, and would not be feasible to address with hand methods.	Excavation is applicable to all Site COCs, achieves RAOs, and can be implemented through various methods given site conditions. The technology of excavation is **Retained** for further evaluation for the following: • Areas above 0 feet MLLW where over-water structures are not present using mechanical methods • Limited areas above 0 feet MLLW where structural impediments are present (e.g., Marine Railway) using hand methods.
Material Disposal: Upland Landfill Disposal	Applicable to all Site sediment COCs.	• Disposal is a permanent disposal option, with limited future risk.	• Requires material dewatering prior to transport. • Requires transportation to an off-site transload facility, for transload to truck or rail. • Cost of material transport and disposal can be significant, depending on the volume of material to be disposed. • Costs are elevated compared to re-use options.	• Transload facilities are not currently available in Bellingham Bay. Sediment transload is not feasible at the Site due to site physical layout and ongoing shipyard operations.	Upland landfill disposal is applicable to all Site COCs, and is **Retained** for further evaluation for the following: • All dredged and excavated sediment
Material Disposal: Uplands Beneficial Reuse	Applicable to all Site sediment COCs.	• Could provide significant disposal fee cost savings. • Re-use is considered an environmentally-conscious option, and eliminates need for landfilling.	• May require temporary storage of material to align with schedule of the beneficial reuse. • Likely to require significant laboratory analytical testing. • Requires a project willing to accept the material for reuse. • Ability to reuse material is limited by the chemical concentrations. • Material dewatering is required.	• Storage of dredged material on-site for temporary stockpiling of material prior to reuse is not feasible.	Upland beneficial reuse is applicable to all Site COCs, and is **Retained** for further evaluation for the following: • All dredged and excavated sediments with chemical concentrations less than the cleanup standards applicable to the re-use application • Because a reuse site has not been identified, upland landfill disposal of all dredged material has been assumed in this FS and for associated cost estimating

Note:

1 RAOs refer to the Remedial Action Objectives and additional RI/FS remedial action considerations discussed in Section 7.1.

Abbreviations:

BMP	Best Management Practice
cm	Centimeter
COC	Chemical of concern
ENR	Enhanced natural recovery
MLLW	Mean Lower Low Water
MNR	Monitored natural recovery
PCB	Polychlorinated biphenyl
RAO	Remedial Action Objective
RI/FS	Remedial Investigation/Feasibility Study
Site	Harris Avenue Shipyard

Table 13.1
Proposed Sediment Cleanup Levels and Remedy Evaluation

									Post-Remediation Outcomes (measured on a point-by-point basis)		Post-Remediation Outcomes (measured on a SWAC basis)		
		SCO		CSL		Proposed CUL	Proposed RAL						
Contaminant of Concern	**Area**	**mg/kg**	**Basis**	**mg/kg**	**Basis**	**mg/kg**	**mg/kg**	**Point of Compliance**	**Do All Samples Meet RAL?**	**Do All Samples Meet CUL?**	**Post-Remediation SWAC (mg/kg)**	**Does the SWAC Meet the CUL?**	**Rationale for CULs and RALs**
Benthic Exposure Pathway													
Arsenic	Site-wide Sediment	57	Benthic SCO	93	Benthic CSL	57	NA	0 to 12 cm	NA	Yes	NA	NA	CUL = SCO; no RAL proposed.
Copper	Site-wide Sediment	390	Benthic SCO	390	Benthic CSL	390	NA	0 to 12 cm	NA	Yes	NA	NA	CUL = SCO; no RAL proposed.
Zinc	Site-wide Sediment	410	Benthic SCO	960	Benthic CSL	410	NA	0 to 12 cm	NA	Yes	NA	NA	CUL = SCO; no RAL proposed.
Fluoranthene	Subtidal Sediment	1.7	Benthic SCO	2.5	Benthic CSL	1.7	NA	0 to 12 cm	NA	Yes	NA	NA	CUL = SCO; no RAL proposed.
Pyrene	Subtidal Sediment	2.6	Benthic SCO	3.3	Benthic CSL	2.6	NA	0 to 12 cm	NA	Yes	NA	NA	CUL = SCO; no RAL proposed.
Total PCBs	Subtidal Sediment	0.13	Benthic SCO	1.0	Benthic CSL	0.13	NA	0 to 12 cm	NA	Yes	NA	NA	CUL = SCO; no RAL proposed.
Human Health Direct Contact Exposure Pathway													
Arsenic	Intertidal Sediment	20	Soil Natural Background	94	Human Health Direct Contact at 1.0x10^{-5} Risk	20	NA	0 to 12 cm	NA	Yes	9.3	Yes	CUL = SCO; no RAL proposed.
	Subtidal Sediment	11	Natural Background	13	Site-specific Regional Background	13	20	0 to 12 cm	Yes	NA	600' buffer = 11 800' buffer = 11 1,000' buffer = 11	Yes	CUL = CSL (Regional background). The RAL is based on natural soil background.
Bioaccumulation Exposure Pathway													
Arsenic	Site-wide Sediment	11	Natural Background	13	Site-specific Regional Background	13	20	0 to 12 cm	Yes	NA	600' buffer = 11 800' buffer = 11 1,000' buffer = 11	Yes	CUL = CSL (Regional background). The RAL is based on natural soil background.
Cadmium	Site-wide Sediment	0.8	Natural Background	0.8	Natural Background (Regional Background was equivalent to Natural Background)	0.8	5.1	0 to 12 cm	Yes	NA	600' buffer = 0.83 800' buffer = 0.87 1,000' buffer = 0.87	Yes[1]	CUL = CSL (Regional background); equivalent to natural background. The RAL is based on the benthic SCO of 5.1 mg/kg.
cPAH TEQ	Site-wide Sediment	0.021	Natural Background	0.14	Seafood Consumption at 1.0x10^{-5} Risk	0.14	4.2	0 to 12 cm	Yes	NA	600' buffer = 0.32 800' buffer = 0.30 1,000' buffer = 0.28	No[2]	CUL = CSL (Seafood consumption at 10^{-5} risk). The RAL is based on direct contact via netfishing at 10^{-6} risk.
Total PCBs	Site-wide Sediment	0.0055	Site-Specific PQL	0.033	PQL derived from SCUM II	0.033	0.13	0 to 12 cm	Yes	NA	600' buffer = 0.030 800' buffer = 0.029 1,000' buffer = 0.028	Yes	CUL = CSL (PQL). The RAL is based on the benthic SCO of 0.13 mg/kg.

Notes:

1 Per SCUM II, cadmium is considered in compliance with the CUL because the final SWAC is within 20 percent of the CUL. SCUM II states: “Based on typical analytical relative percent differences (RPDs) and field variability, any individual or mean value within 20% of the cleanup standard is considered to be indistinguishable from the cleanup standard and in compliance.”

2 Exceedance due to regional sediment concentration. See Section 13.1.3 for details

Abbreviations:

cm	Centimeters	PCB	Polychlorinated biphenyl
COC	Contaminant of concern	PQL	Practical Quantitation Limit
COPC	Contaminant of potential concern	RAL	Remedial Action Level
CPAH	Carcinogenic polycyclic aromatic hydrocarbor	SCO	Sediment Cleanup Objective
CSL	Cleanup screening level	SCUM II	Sediment Cleanup User's Manual II
CUL	Cleanup level	SWAC	Surface-weighted average concentration
mg/kg	Milligrams per kilogram	TEQ	Toxic equivalent
NA	Not applicable		

Table 13.2
Harris Avenue Shipyard Sediment Cleanup Alternatives Disproportionate Cost Analysis

Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Alternative Description	Alternative 1 is considered the full capping alternative plus the Interim Action completed in 2018. This alternative consists of capping in both open water and under-pier areas. A thick granular cap would be placed throughout all accessible open-water areas. Select shipyard structures would be protected for continued use. A cap would be placed below shipyard structures that remain. At the shipyard intertidal sediment area, contaminated sediments will be excavated, and then backfilled to maintain existing elevations. In the intertidal portion of the marine railway, targeted excavation will be performed to support placement of a cap to match the surface elevation of railroad girders, to maintain operation of the railway structure. The only material removal included in Alternative 1, with the exception of the Interim Action, would be in the intertidal sediment areas adjacent to the bulkheads and at the marine railway to accommodate placement of backfill and sediment cap without modifying intertidal area elevations or the ordinary high water line. All excavated material would be transloaded for upland landfill disposal or upland beneficial reuse. Institutional controls would require maintenance of the capped areas in perpetuity and would require dredging restrictions, development restrictions, and shipyard operation restrictions. All alternatives include the demolition and removal of the West Marine Walkway and armoring of the eroding section of the western shoreline.	Alternative 2 includes a combination of dredging and capping, based on shipyard considerations, accessibility, and existing infrastructure plus the Interim Action completed in 2018. In Alternative 2, all accessible open water areas of AOC 1, including the sediment areas where existing over-water infrastructure is demolished, would be dredged for full removal to meet CULs/RALs. In areas where the cleanup standard is unable to be met through dredging, a 6-inch layer of sand will be placed as ENR. All contaminated sediments within accessible open water areas in AOC 1 would be removed from the aquatic environment, for upland landfill disposal or upland beneficial reuse. With Alternative 2, shipyard intertidal sediment areas would be excavated, and the excavation would be backfilled to maintain existing elevations. Excavated material would be removed from the aquatic environment, for upland landfill disposal or upland beneficial reuse. Select shipyard structures would be protected for continued use. Contaminated sediments below these shipyard structures would be capped, and institutional controls requiring maintenance of capped areas would be developed. Institutional controls would also be developed to restrict development or dredging in capped areas. All alternatives include the demolition and removal of the West Marine Walkway and armoring of the eroding section of the western shoreline.	Alternative 3 is a full removal option, which includes demolition and replacement of existing overwater structures to allow access for sediment removal. To allow sediment removal beneath the existing structures at the Site, Alternative 3 would include demolition of all existing shipyard structures so that contaminated sediments could be dredged to meet CULs/RALs. In areas where the cleanup standard is unable to be met through dredging, a 6-inch layer of sand will be placed as ENR. The newer concrete portion of the Harris Avenue Pier, the in-water portions of the marine railway, the marine railway catwalk, and the access pier to Dry Dock No. 1 would all be demolished. Following dredging of contaminated sediments, the infrastructure would be re-built based on the current footprint and existing uses. Shipyard intertidal sediment areas would be excavated and backfilled to maintain existing grades. This alternative includes removing the capping material placed in the intertidal areas in the Interim Action, removing any remaining material with COC concentrations exceeding the CULs/RALs and backfilling with an appropriate substrate to existing elevations. All dredged and excavated material would be permanently removed from the aquatic environment for upland landfill disposal or approved upland reuse. With full permanent removal of contaminated material, institutional controls would not be required for Alternative 3. All alternatives include the demolition and removal of the West Marine Walkway and armoring of the eroding section of the western shoreline.	

Table 13.2
Harris Avenue Shipyard Sediment Cleanup Alternatives Disproportionate Cost Analysis

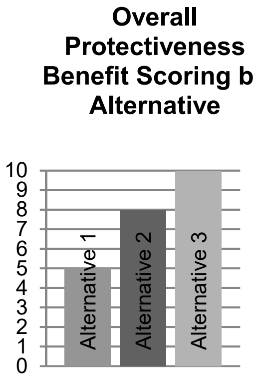
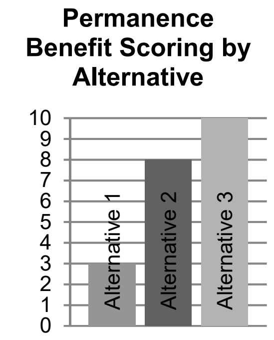
Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Overall Protectiveness • Degree to which existing risks are reduced • Time required to reduce risks and attain cleanup standards • On- and off-site risks resulting from alternative implementation • Improvement in overall environmental quality	Alternative 1 is the capping alternative and is considered the least protective alternative. • Risks would be reduced by providing a capped surface that is protective of all exposure pathways in areas that are actively remediated. • The time frame to reduce risk for exposure pathways in sediment would be immediate, following remedy completion, with construction assumed to be two in-water construction seasons. Maintenance of the cap and site institutional controls would be required in perpetuity. • Following implementation of the remedial action within AOC 1, human health risk remains within the site vicinity associated with consumption of resident seafood at high consumption rates. This is due to the presence of ubiquitous low-level cadmium and cPAH concentrations present in regional sediments within Bellingham Bay. • No other on- or off-site risks result from implementation of this alternative. • There is an improvement in overall environmental quality resulting from implementation of this alternative through capping, limited excavation, and implementation of institutional controls. However, because there would be less mass removal than Alternatives 2 and 3 and because there are substantial risks associated with capping in an active shipyard environment, the improvement in environmental quality is lower with Alternative 1 than the other alternatives.	Alternative 2 is considered to be more protective than Alternative 1 because all of the open water area would be dredged to a surface that meets CULs. • Risks would be reduced through contaminant mass removal. Alternative 2 provides for a permanent remedy because all contamination mass is being dredged and hauled off-site in the active remediation area where it is technically practicable to do so and contamination in areas with existing built structures that will not be demolished as part of the remedy and cannot reasonably be dredged are being capped to address exposure pathways. • The time frame to reduce risk for exposure pathways in sediment would be immediate, following remedy, following remedy completion, with construction assumed to be two in-water construction seasons. Maintenance of the capped areas and institutional controls would be required in perpetuity. • Following implementation of the remedial action within AOC 1, human health risk remains within the site vicinity associated with consumption of resident seafood at high consumption rates. This is due to the presence of ubiquitous low-level cadmium and cPAH concentrations present in regional sediments within Bellingham Bay. • No other on- or off-site risks result from implementation of this alternative. • There is an improvement in overall environmental quality resulting from implementation of this alternative through dredging, capping, and implementation of institutional controls. Because there is contaminant mass removal with Alternative 2, there is a large improvement in overall environmental quality compared to Alternative 1.	Alternative 3 is a full removal alternative and is the most aggressive and permanent alternative. • Risks would be reduced through contaminant mass removal. Because all contaminant mass would be being dredged and hauled off-site, including in areas with existing infrastructure, this alternative is considered the most permanent alternative to the maximum extent. Risks would be reduced across the Site in the active remediation area and risks would be reduced to a greater degree with Alternative 3 than with Alternatives 1 and 2. • The time frame to reduce risk for exposure pathways in sediment would be immediate, following remedy completion. However, the demolition and reconstruction of shipyard facilities required for this alternative would require careful phasing. Implementation of the remedy is assumed to take three or more in-water construction seasons. • Following implementation of the remedial action within AOC 1, human health risk remains within the site vicinity associated with consumption of resident seafood at high consumption rates. This is due to the presence of ubiquitous low-level cadmium and cPAH concentrations present in regional sediments within Bellingham Bay. • No other on- or off-site risks result from implementation of this alternative. • There is a substantial improvement in overall environmental quality resulting from implementation of this alternative through dredging and removal of all sediment contamination within the active remediation area. This is a full removal alternative and would provide the highest improvement in environmental quality of the alternatives.	
Permanence • Degree of reduction of contaminant toxicity, mobility, and volume • Adequacy of destruction of hazardous substances • Reduction or elimination of substance release, and source of release • Degree of irreversibility of waste treatment processes • Volume and characteristics of generated treatment residuals	• This alternative provides a low reduction in contaminant toxicity or volume compared to Alternatives 2 and 3. There would be a reduction in contaminant volume through limited excavation in the shipyard intertidal sediment area. In SMUs 8 and 10, excavation would be conducted and the areas would be backfilled to maintain the existing grade. Capping across the remainder of the active remediation area would reduce contaminant mobility. • Hazardous substances within the intertidal sediment area would be permanently removed from the Site. Contamination would not be reduced or eliminated in the other areas of the Site that would be capped. Most contamination in the active remediation area would be left in place beneath a capped surface. • Primary release mechanisms of contamination have been removed. Continued releases of contamination to sediments would be eliminated through improved shipyard operational source control. • There are no treatment residuals associated with implementation of this technology.	• This alternative provides a high degree of reduction in contaminant toxicity or volume through dredging. Contaminated sediments within the active remediation area that are not dredged would be capped, which would provide a reduction in contaminant mobility. • Hazardous substances within both open-water and intertidal sediment areas would be permanently removed from the Site. Sediment contamination in areas with existing infrastructure would be dredged or capped, depending on if the over-water structures are demolished. • Primary release mechanisms of contamination have been removed. Continued releases of contamination to sediments would be eliminated through improved shipyard operational source control. • There are no treatment residuals associated with implementation of this technology.	• This alternative provides a high degree of reduction in contaminant toxicity, mobility, and volume as all sediment contamination in the active remediation areas would be dredged and disposed of off-site. • Hazardous substances within all sediment units would be permanently removed from the Site. • Primary release mechanisms of contamination have been removed. Continued releases of contamination to sediments would be eliminated through improved shipyard operational source control. • There are no treatment residuals associated with implementation of this technology.	

Table 13.2
Harris Avenue Shipyard Sediment Cleanup Alternatives Disproportionate Cost Analysis

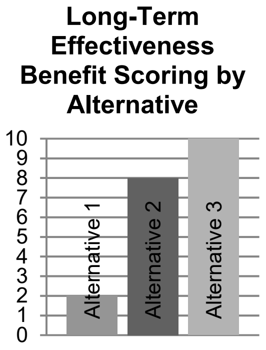
Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Effectiveness over the Long-Term • Degree of certainty of alternative success • Reliability while contaminants remain on-site greater than cleanup levels • Magnitude of residual risk • Effectiveness of controls implemented to manage residual risk	• This alternative provides a low degree of certainty of success. Although capping is a common technology that has been implemented at several sites in the Puget Sound, placement of a thick sediment cap within the open water operational areas of the shipyard would be difficult to maintain. Shipyard operations and propeller wash would have the potential to damage capped areas, if stringent propeller wake restrictions are not followed. Tidal forces would also need to be considered with cap design for Alternative 1. Capped areas would require maintenance in perpetuity. Institutional controls would be developed to require maintenance of the cap, to restrict maintenance dredging and to potentially restrict shipyard operations. Because of the current operations of the active shipyard, there would be a risk that the sediment cap would fail prematurely. The remedy would be expected to be successful in the intertidal sediment areas that would be excavated and backfilled. • This alternative is likely reliable as long as the cap is properly maintained and institutional controls are followed. However, capping is not supportive of shipyard operations because the shallower water depths that would be present following implementation of the remedy would not provide the berth depths necessary to support the draft depths of vessel that currently operate in the shipyard. To ensure reliability of the remedy, shipyard operational restrictions would need to be implemented. • The magnitude of residual risk is moderate to high, as most contamination within the active remediation area would remain on-site and there is a high risk for cap failure. • Residual risks would be controlled through the enforcement of institution controls and restrictions on shipyard operations, which would likely not be effective at managing risk in an active shipyard.	• This alternative provides a high degree of certainty of success. Dredging is a common technology for removal of sediment contamination that has been implemented at several sites in the Puget Sound. Capping in areas that are not dredged would also provide a high degree of certainty of success because the caps would be maintained with institutional controls and the capping would only occur in the under-structure areas where the existing over-water structures are not demolished as part of the remedy. Additionally, there is less impact from shipyard and vessel operations in these capped areas. • This alternative is reliable because dredging would leave a surface that meets CULs/RALs. The alternative would be reliable in capped areas as long as the cap is properly maintained and institutional controls are followed. • The magnitude of residual risk is low, as most contamination would be removed from the Site. • Residual risks would be controlled through the enforcement of institutional controls for capped areas, which are considered to be effective at managing risk.	• This alternative provides a high degree of certainty of success. Dredging is a common technology that would permanently remove contamination from the Site and be effective over the long-term. • This alternative is reliable because dredging would leave a surface that meets CULs/RALs. • The magnitude of residual risk is low, as all contamination would be removed from the Site. • Following implementation, there would be no residual risks in the active remediation area that would need to be controlled.	

Table 13.2
Harris Avenue Shipyard Sediment Cleanup Alternatives Disproportionate Cost Analysis

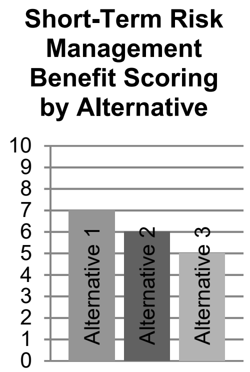
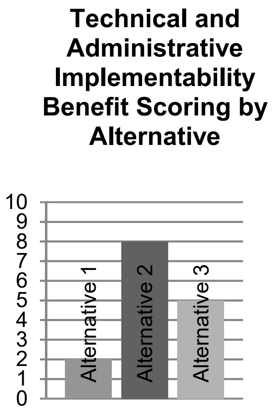
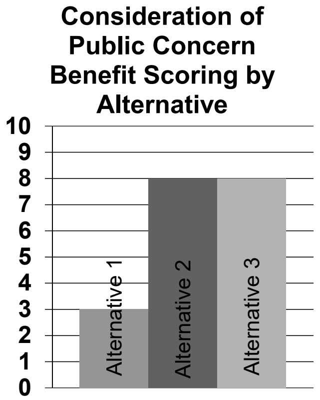
Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Short-Term Risk Management • Risk to human health and the environment associated with alternative construction • The effectiveness of controls in place to manage short-term risks	With Alternative 1, limited contaminated sediment is handled and removed from the Site. • There is low short-term risk to human health and the environment during implementation. Excavation and backfilling to return the intertidal sediments to existing grade and excavation to support capping in SMU 8 requires some contaminated materials handling. The excavation in the marine railway may be accomplished by hand. • There is low risk for public exposure with this alternative. Contaminated sediment that is excavated would likely be transloaded via barge for either disposal at a landfill or for beneficial reuse. This could require transport of contaminated sediment over public roadways; however, handling of the contaminated sediment would be managed by licensed professionals. • There is a risk of contaminated sediment resuspension and transport during sediment cap placement. Common BMPs would be implemented to minimize turbidity and control sediment migration. The sediment cap would be placed in lifts to minimize resuspension of contamination. • Site activities would require appropriate PPE, BMPs, and training requirements for management of risk. These controls are highly effective and anticipated to adequately manage short-term risk.	With Alternative 2, a substantial volume of contaminated sediment would be dredged, handled, and removed from the Site. • There would be moderate short-term risk to human health and the environment during implementation. Dredging contaminated sediment would require contaminated materials handling. • Additionally, excavation in SMU 8 would be accomplished by hand labor. There is a moderate risk for public exposure with Alternative 2. Contaminated sediment would be towed by barge from the Site to a transloading facility, likely located on the Duwamish Waterway in Seattle. Contaminated material would then be loaded onto trucks or trains for off-site disposal at a landfill. This could require transport of contaminated sediment over public roadways; however, the excavated sediment would be managed by licensed professionals. • Site activities would require appropriate PPE, BMPs, and training requirements for management of risk. These controls are highly effective and anticipated to adequately manage short-term risk.	Alternative 3 is a full removal alternative consisting of dredging and off-site disposal of a large volume of contaminated sediment. • There would be moderate short-term risk to human health and the environment during implementation. Dredging contaminated sediment would require contaminated materials handling. There is a moderate risk for public exposure with Alternative 3. Contaminated sediment would be towed by barge from the Site to a transloading facility, likely located on the Duwamish Waterway in Seattle. Contaminated material would then be loaded onto trucks or trains for off-site disposal at a landfill. This could require transport of contaminated sediment over public roadways; however, the excavated sediment would be managed by licensed professionals. • There would be moderate short-term risk to human health and the environment during demolition of the structures. This work requires removal and disposal of potentially creosote-treated piles. • Site activities would require appropriate PPE, BMPs, and training requirements for management of risk. These controls are highly effective and anticipated to adequately manage short-term risk.	 **Short-Term Risk Management Benefit Scoring by Alternative**
Technical and Administrative Implementability *Ability of alternative to be implemented considering:* • Technical possibility • Availability of off-site facilities, services, and materials • Administrative and regulatory requirements • Schedule, size, and complexity of construction • Monitoring requirements • Site access for construction, operations, and monitoring • Integration with existing site operations or other current and potential future remedial action	• This alternative is technically possible to implement and involves common technologies. This alternative is not supportive of active shipyard operations because placement of a thick sediment cap would negatively impact shipyard operations by resulting in shallower water depths that would not provide the berth depths necessary to support the draft depths of vessels that currently operate at the shipyard. • All necessary off-site facilities, materials, and services are available within the region. Specialized equipment for cap placement in the understructure areas in the marine railway may be required. • This alternative complies with all applicable administrative and regulatory requirements. • This alternative is large in scale. This alternative would be managed and constructed by specialty professionals familiar with the type of work. Implementation of this alternative may require two construction seasons in order to minimize impacts to shipyard operations. • Monitoring requirements include sediment cap monitoring in perpetuity. Because of the active shipyard environment, the cap would be difficult to maintain and there would be risk of cap disturbance and/or failure. • Site access would not be impeded for the implementation and construction of this alternative. Implementation of this alternative would likely be phased to minimize impacts to the active shipyard. Future site access would be required for sediment cap monitoring and maintenance. • This alternative is not consistent with or supportive of active shipyard operations or continued shipyard use.	• This alternative is technically possible to implement as dredging and capping are common technologies. This alternative is also supportive of the active shipyard environment because it would maintain or deepen berth depths in the open water areas. • All necessary off-site facilities, materials, and services are available within the region, but sediment may have to be barged as far as the Duwamish Waterway in Seattle for transloading. Specialized equipment for cap placement in the understructure areas and in the marine railway may be required. • This alternative complies with all applicable administrative and regulatory requirements. • This alternative is large in scale. This alternative would be managed and constructed by specialty professionals familiar with the type of work. Implementation of this alternative would likely require two construction seasons in order to minimize impacts to shipyard operations. • Monitoring requirements would include sediment cap monitoring in perpetuity for those areas that are capped. • Site access would not be impeded for the implementation and construction of this alternative. Implementation of this alternative would likely be phased to minimize construction impacts to the active shipyard. Future site access would be required for under-pier sediment cap monitoring and maintenance. • This alternative is consistent with current conditions, but implementation can be integrated with both existing and proposed future site uses.	• Alternative 3 is technically possible to implement and involves common technologies, but, due to the demolition of existing structures to support the remedy, it is very difficult to implement in the active shipyard environment. • All necessary off-site facilities, materials, and services are available within the region, but sediment may have to be barged as far as the Duwamish Waterway in Seattle for transloading. • This alternative complies with all applicable administrative and regulatory requirements. • This alternative is very large in scale. This alternative would be managed and constructed by specialty professionals familiar with the type of work. Due to construction phasing required to support shipyard operations, this alternative would likely require more than three construction seasons to implement. • There would be no long-term monitoring requirements with Alternative 3. • Site access would not be impeded for the implementation and construction of this alternative. Implementation of this alternative may be phased to minimize impacts to the active shipyard. • This alternative is consistent with current conditions, but would cause substantial impacts to shipyard operations during construction.	 **Technical and Administrative Implementability Benefit Scoring by Alternative**

Table 13.2

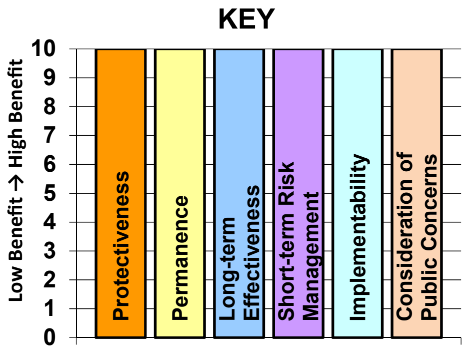
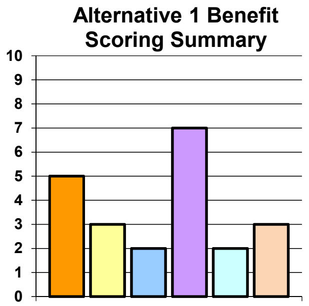
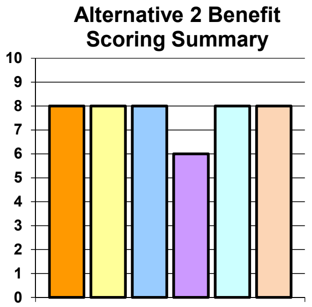
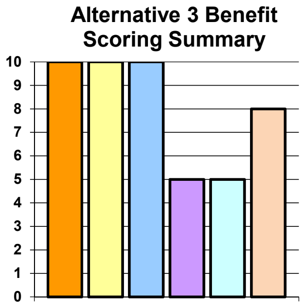
Harris Avenue Shipyard Sediment Cleanup Alternatives Disproportionate Cost Analysis

Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative Benefit Scoring
Consideration of Public Concerns • Whether the community has concerns • Degree to which the alternative addresses those concerns	Public concerns will be reviewed following the public comment period and addressed in the final remedial alternative selection and design. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects.	Public concerns will be reviewed following the public comment period and addressed in the final remedial alternative selection and design. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects.	Public concerns will be reviewed following the public comment period and addressed in the final remedial alternative selection and design. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects.	 Consideration of Public Concern Benefit Scoring by Alternative
Cost • Cost of construction • Long-term monitoring, operations, and maintenance costs • Agency oversight costs	• Interim Action Cost (same for all alternatives) = $13.4 M • Construction Cost = $2.9 M • Total Alternative Cost (including completed Interim Action, design, and contingency) = $19.0 M • Long-term monitoring, operations, and maintenance costs would be very high with Alternative 1. Annual monitoring and annual maintenance of the sediment cap would be required in perpetuity. • Agency oversight costs would be high with Alternative 1 and would include costs associated with oversight activities during construction and during annual cap monitoring.	• Interim Action Cost (same for all alternatives) = $13.4 M • Construction Cost = $5.5 M • Total Alternative Cost (including completed Interim Action, design, and contingency) = $22.4 M • Long-term monitoring, operations, and maintenance costs would be moderate with Alternative 2. Annual monitoring and periodic maintenance of the capped areas would be required in perpetuity. • Agency oversight costs would be moderate with Alternative 2 and would include costs associated with oversight activities during construction and cap monitoring. Although construction oversight would likely consist of two seasons, oversight of annual cap monitoring would be conducted in perpetuity.	• Interim Action Cost (same for all alternatives) = $13.4 M • Construction Cost = $15.0 M • Total Alternative Cost (including completed Interim Action, design, and contingency) = $35.4 M • Long-term monitoring, operations, and maintenance costs would be low with Alternative 3. No annual monitoring would be conducted because this is a full removal alternative. • Agency oversight costs would be moderate with Alternative 3 and would include oversight activities during remedial action implementation construction. Costs for agency oversight is expected to be higher with Alternative 3 than the other alternatives because there would be multiple construction seasons and the remedy would likely require Ecology certification of the full removal of contamination.	

Abbreviations:

AOC	Area of Concern
BMP	Best Management Practice
ENR	Enhanced natural recovery
M	Million
MTCA	Model Toxics Control Act
PPE	Personal Protective Equipment
Site	Harris Avenue Shipyard
SMU	Sediment Management Unit
TPH	Total petroleum hydrocarbons

Table 13.3
Harris Avenue Shipyard Sediment Cleanup Alternatives Disproportionate Cost Analysis Summary

Alternative	Alternative 1	Alternative 2	Alternative 3
Alternative Description	Alternative 1 is considered the full capping alternative plus the Interim Action completed in 2018. This alternative consists of capping in both open water and under-pier areas. A thick granular cap would be placed throughout all accessible open-water areas. Select shipyard structures would be protected for continued use. A cap would be placed below shipyard structures that remain. At the shipyard intertidal sediment area, contaminated sediments will be excavated, and then backfilled to maintain existing elevations. In the intertidal portion of the marine railway, targeted excavation will be performed to support placement of a cap to match the surface elevation of railroad girders, to maintain operation of the railway structure. The only material removal included in Alternative 1, with the exception of the Interim Action, would be in the intertidal sediment areas adjacent to the bulkheads and at the marine railway to accommodate placement of backfill and sediment cap without modifying intertidal area elevations or the ordinary high water line. All excavated material would be transloaded for upland landfill disposal or upland beneficial reuse. Institutional controls would require maintenance of the capped areas in perpetuity and would require dredging restrictions, development restrictions, and shipyard operation restrictions.	Alternative 2 includes a combination of dredging and capping, based on shipyard considerations, accessibility, and existing infrastructure plus the Interim Action completed in 2018. In Alternative 2, all accessible open water areas of AOC 1, including the sediment areas where existing over-water infrastructure is demolished, would be dredged for full removal to meet CULs/RALs. In areas where the cleanup standard is unable to be met through dredging, a 6-inch layer of sand will be placed as ENR. All contaminated sediments within accessible open water areas in AOC 1 would be removed from the aquatic environment, for upland landfill disposal or upland beneficial reuse. With Alternative 2, shipyard intertidal sediment areas would be excavated, and the excavation would be backfilled to maintain existing elevations. Excavated material would be removed from the aquatic environment, for upland landfill disposal or upland beneficial reuse. Select shipyard structures would be protected for continued use. Contaminated sediments below these shipyard structures would be capped, and institutional controls requiring maintenance of capped areas would be developed. Institutional controls would also be developed to restrict development or dredging in capped areas.	Alternative 3 is a full removal option, which includes demolition and replacement of existing overwater structures to allow access for sediment removal. To allow sediment removal beneath the existing structures at the Site, Alternative 3 would include demolition of all existing shipyard structures so that contaminated sediments could be dredged to meet CULs/RALs. In areas where the cleanup standard is unable to be met through dredging, a 6-inch layer of sand will be placed as ENR. The newer concrete portion of the Harris Avenue Pier, the in-water portions of the marine railway, the marine railway catwalk, and the access pier to Dry Dock No. 1 would all be demolished. Following dredging of contaminated sediments, the infrastructure would be re-built based on the current footprint and existing uses. Shipyard intertidal sediment areas would be excavated and backfilled to maintain existing grades. This alternative includes removing the capping material placed in the intertidal areas in the Interim Action, removing any remaining material with COC concentrations exceeding the CULs/RALs and backfilling with an appropriate substrate to existing elevations. All dredged and excavated material would be permanently removed from the aquatic environment for upland landfill disposal or approved upland reuse. With full permanent removal of contaminated material, institutional controls would not be required for Alternative 3.
			
Compliance with MTCA Threshold Requirements	Yes	Yes	Yes
Restoration Time Frame (to achieve remediation goals)	Following Construction	Following Construction	Following Construction
Benefit Scoring			
Overall Protectiveness (30%)	5	8	10
Permanence (20%)	3	8	10
Long-Term Effectiveness (20%)	2	8	10
Short-Term Risk Management[1] (10%)	7	6	5
Implementability (10%)	2	8	5
Consideration of Public Concerns[2] (10%)	3	8	8
Total Benefit Score (weighted)	**3.7**	**7.8**	**8.8**
Estimated Alternative Cost[3]	$19.0 M	$22.4 M	$35.4 M
Unit Benefit per $M[4]	**0.19**	**0.35[5]**	**0.25**

Notes:

1 Higher scores equate to a higher level of relative benefit. Fewer short-term risks result in a higher score.

2 Public comment has not been received on the RI/FS. The benefit scoring for public concerns are estimated based on prior public concerns on similar projects.

3 Specific cost estimate information is provided in Appendix H.

4 Unit Benefit per Million Dollars calculated by dividing the alternative Total Benefit Score by the total alternative cost (in millions). Highest value indicates the most benefit for the associated cost.

5 With the highest benefit per million dollars of remedy cost, Alternative 2 provides the greatest degree of benefit for the associated cost of all the alternatives, making it the preferred remedial alternative.

Abbreviations:

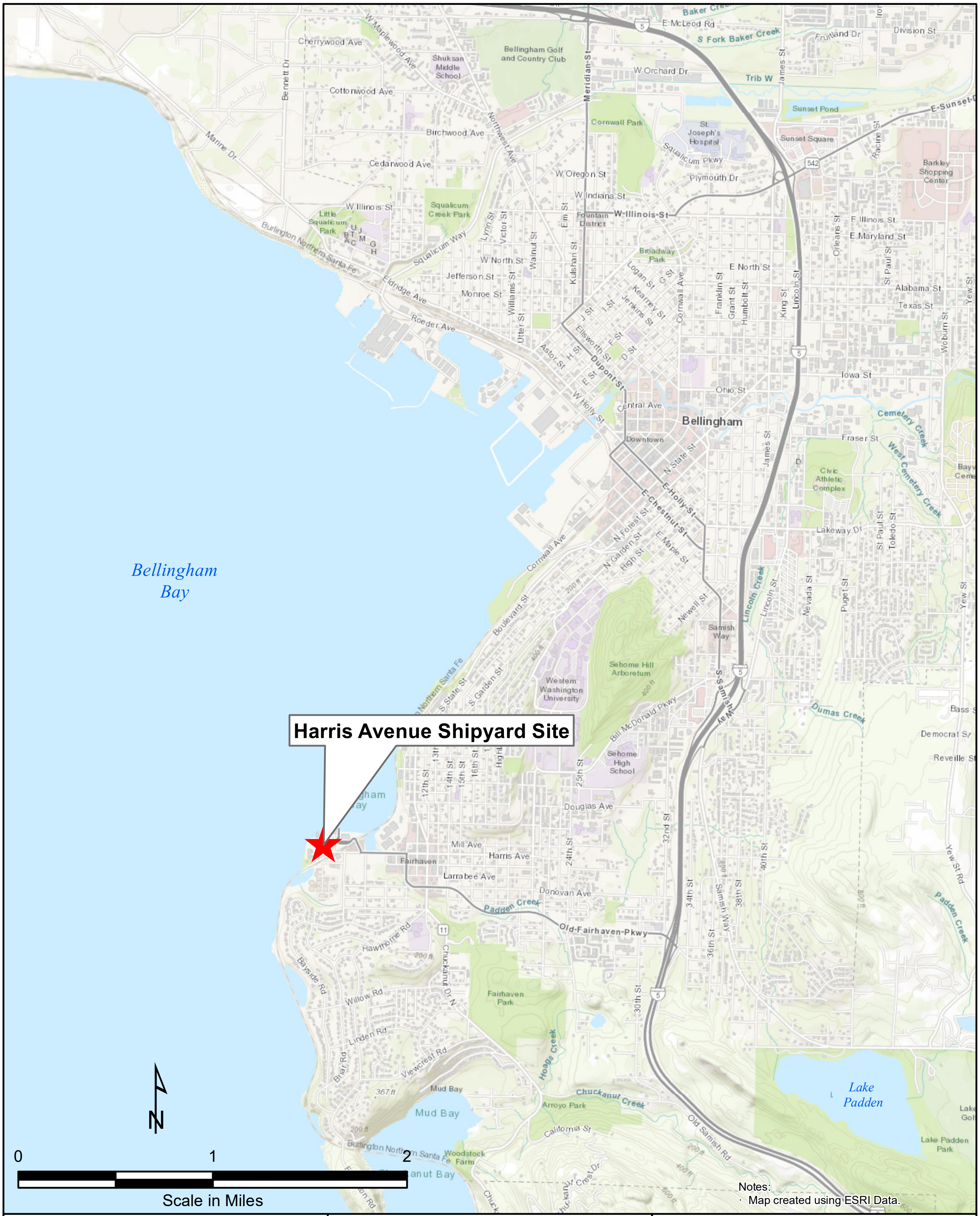
AOC	Area of Concern
CUL	Cleanup level
ENR	Enhanced natural recovery
M	Million
MTCA	Model Toxics Control Act
RAL	Remedial Action Level
RI/FS	Remedial Investigation/Feasibility Study
Site	Harris Avenue Shipyard

Harris Avenue Shipyard

Remedial Investigation/ Feasibility Study

Figures

FINAL



Notes:
· Map created using ESRI Data.

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Remedial Investigation/
Feasibility Study
Harris Avenue Shipyard
Bellingham, Washington

Figure 1.1
Vicinity Map

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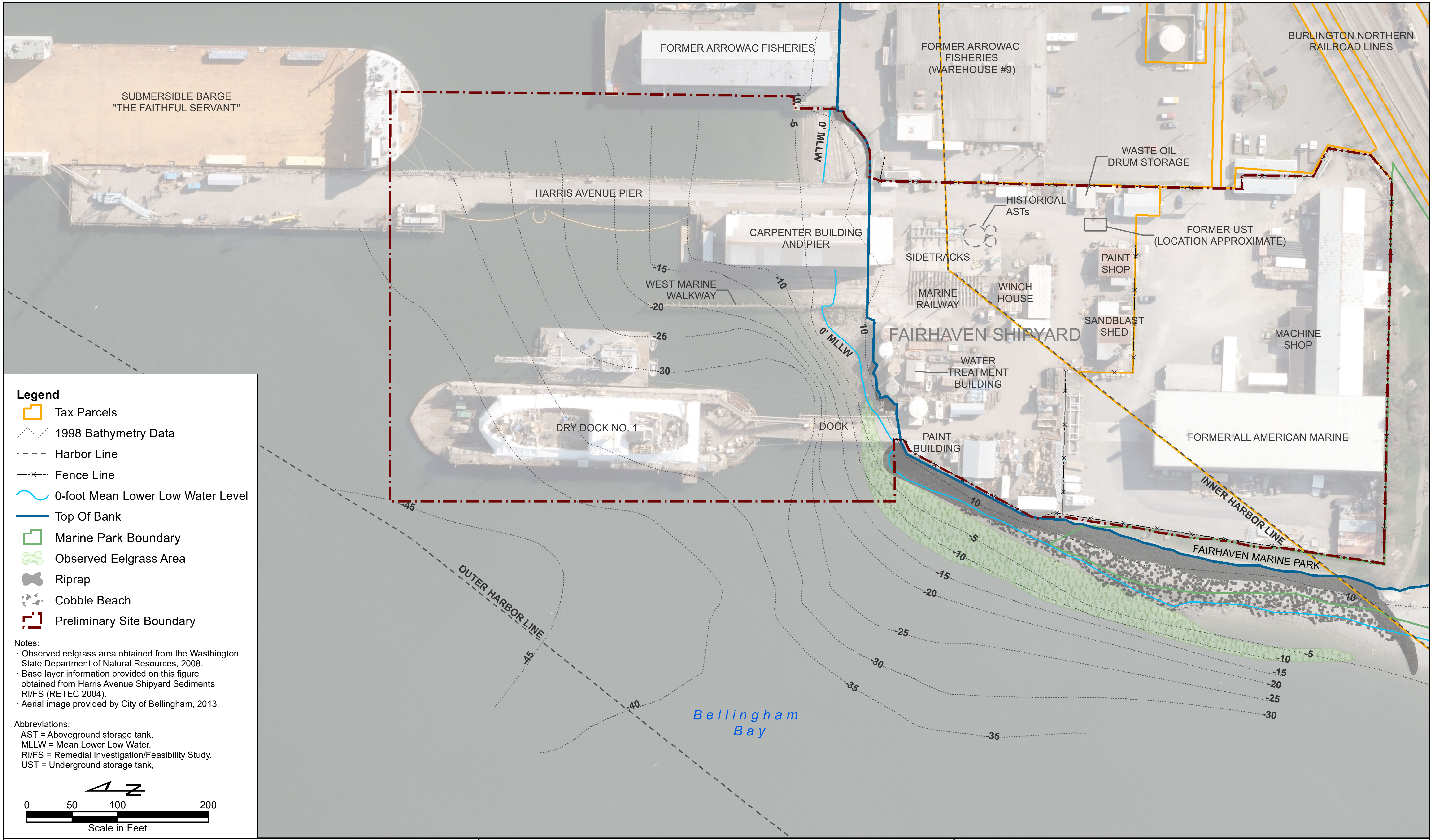
6/7/2019



Legend

- 🟧 Tax Parcels
- 1998 Bathymetry Data
- Harbor Line
- Fence Line
- 0-foot Mean Lower Low Water Level
- Top Of Bank
- 🟩 Marine Park Boundary
- Observed Eelgrass Area
- Riprap
- Cobble Beach
- Preliminary Site Boundary

Notes:
- Observed eelgrass area obtained from the Wasthington State Department of Natural Resources, 2008.
- Base layer information provided on this figure obtained from Harris Avenue Shipyard Sediments RI/FS (RETEC 2004).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:

AST = Aboveground storage tank.
MLLW = Mean Lower Low Water.
RI/FS = Remedial Investigation/Feasibility Study.
UST = Underground storage tank,

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Remedial Investigation/Feasibility Study
Harris Avenue Shipyard
Bellingham, Washington

Figure 1.2
Site Map and Key Features

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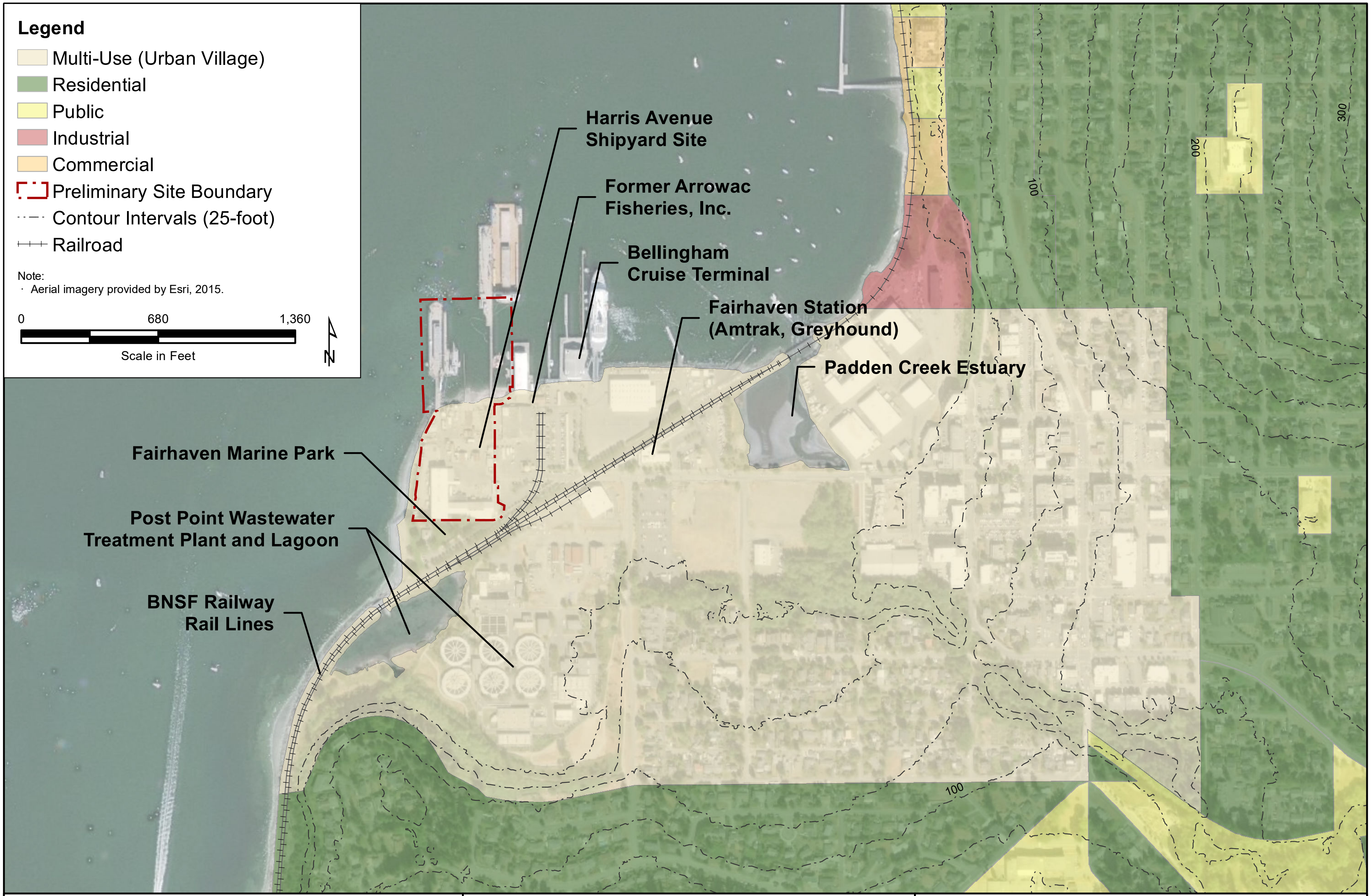
6/7/2019



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Harris Avenue Shipyard
Bellingham, Washington**

Figure 1.3
Study Area

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Date: 6/7/2019

Legend

Sediment Interim Action Components

▨ **Remove Overwater Structures**

Demolition of existing piers and buildings.

🟩 **Subtidal Sediments: Dredge to CULs/RALs**
(SMU 1 and 3)

🟩 **Intertidal Sediments: Excavate and Backfill**
(SMU 2 and 4)

Excavation, approximately 3-foot thickness, with backfill to maintain existing grades. Material selected for hydrodynamic stability and ancillary habitat benefit.

Revised Sediment Interim Action Area[1]

🟦 Upland Interim Action Area - Excavate to depths between 1 and 4 feet bgs.

▨ Paved Area

1998 Bathymetry Data

—×— Fence Line

- - - - Inner Harbor Line

0-feet Mean Lower Low Water Level

Riprap

Notes:
1. The interim action boundary is offset by 6 feet from the area where dredging will occur to account for sloughing.
· Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
CUL = Cleanup Level.
MLLW = Mean Lower Low Water.
NAVD 88 = North America Vertical Datum of 1988.
NOAA = National Oceanic and Atmospheric Administration.
RAL = Remedial Action Level.
SMU = Sediment Management Unit.

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Harris Avenue Shipyard
Bellingham, Washington

Figure 1.4
Proposed Interim Action Components

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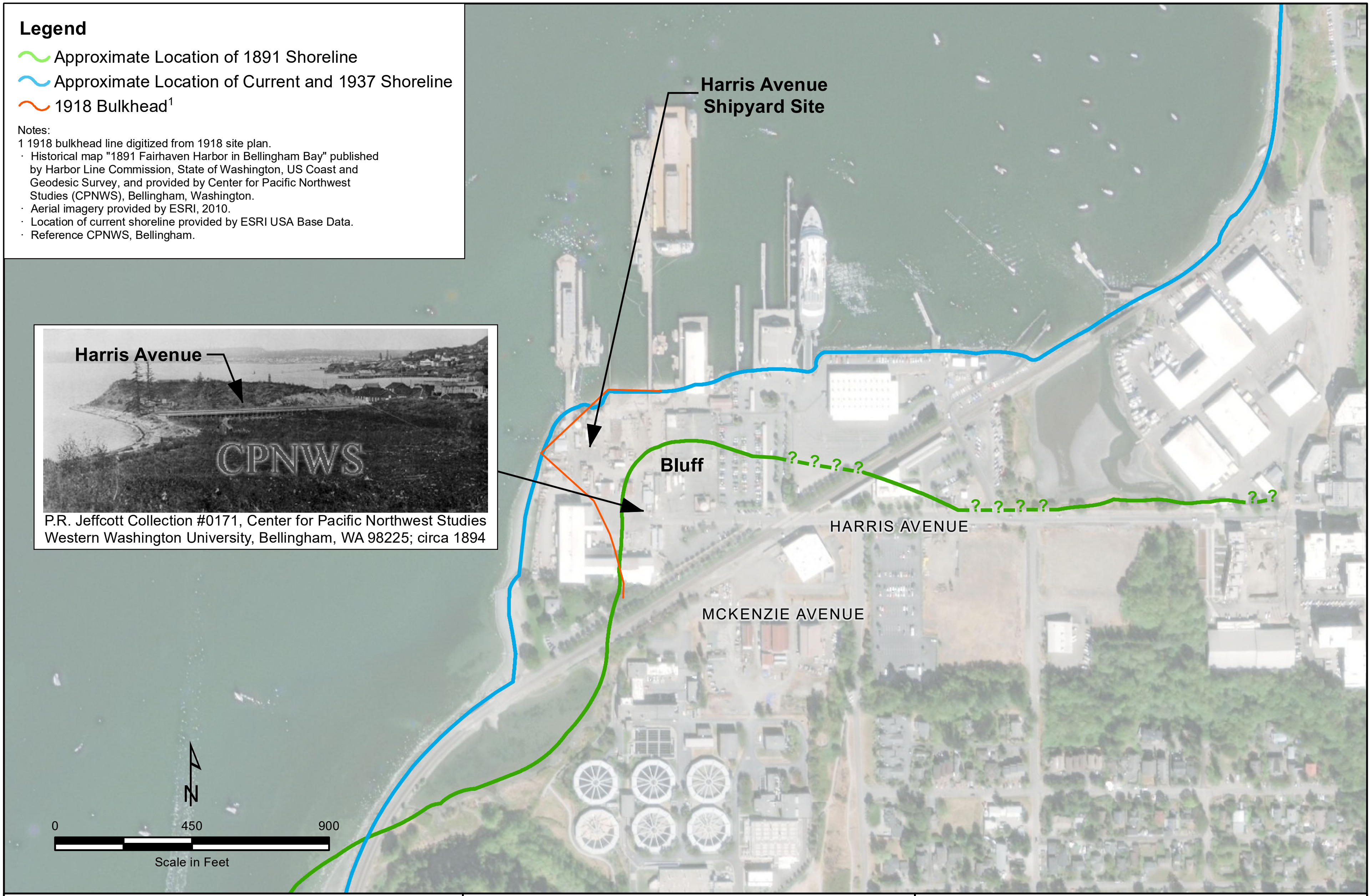

Legend

- Approximate Location of 1891 Shoreline
- Approximate Location of Current and 1937 Shoreline
- 1918 Bulkhead[1]

Notes:
1 1918 bulkhead line digitized from 1918 site plan.

- Historical map "1891 Fairhaven Harbor in Bellingham Bay" published by Harbor Line Commission, State of Washington, US Coast and Geodesic Survey, and provided by Center for Pacific Northwest Studies (CPNWS), Bellingham, Washington.
- Aerial imagery provided by ESRI, 2010.
- Location of current shoreline provided by ESRI USA Base Data.
- Reference CPNWS, Bellingham.

P.R. Jeffcott Collection #0171, Center for Pacific Northwest Studies Western Washington University, Bellingham, WA 98225; circa 1894

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Harris Avenue Shipyard
Bellingham, Washington

Figure 2.1
Historical and Current Shoreline

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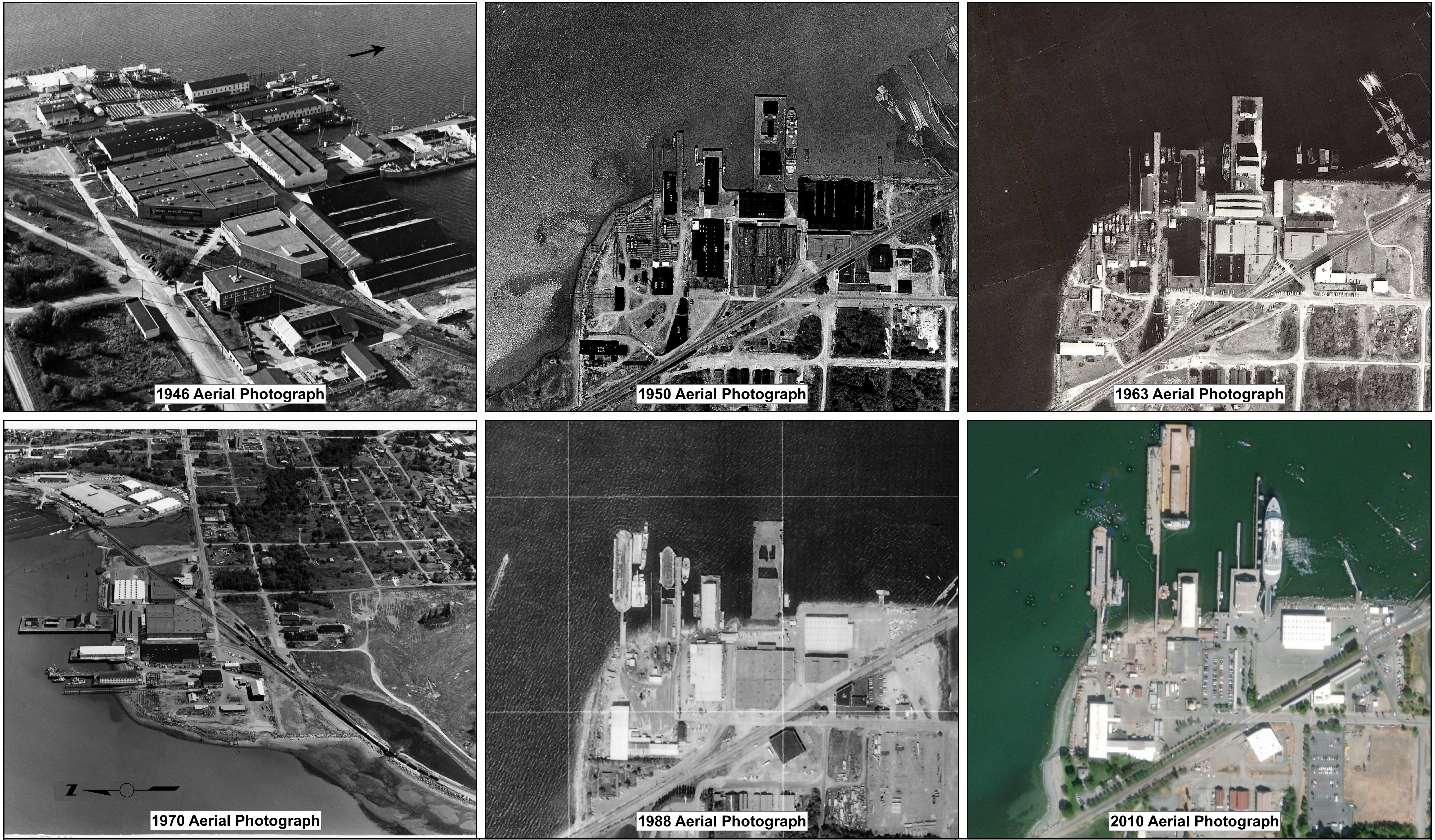
Date: 6/7/2019


1946 Aerial Photograph

1950 Aerial Photograph

1963 Aerial Photograph

1970 Aerial Photograph

1988 Aerial Photograph

2010 Aerial Photograph

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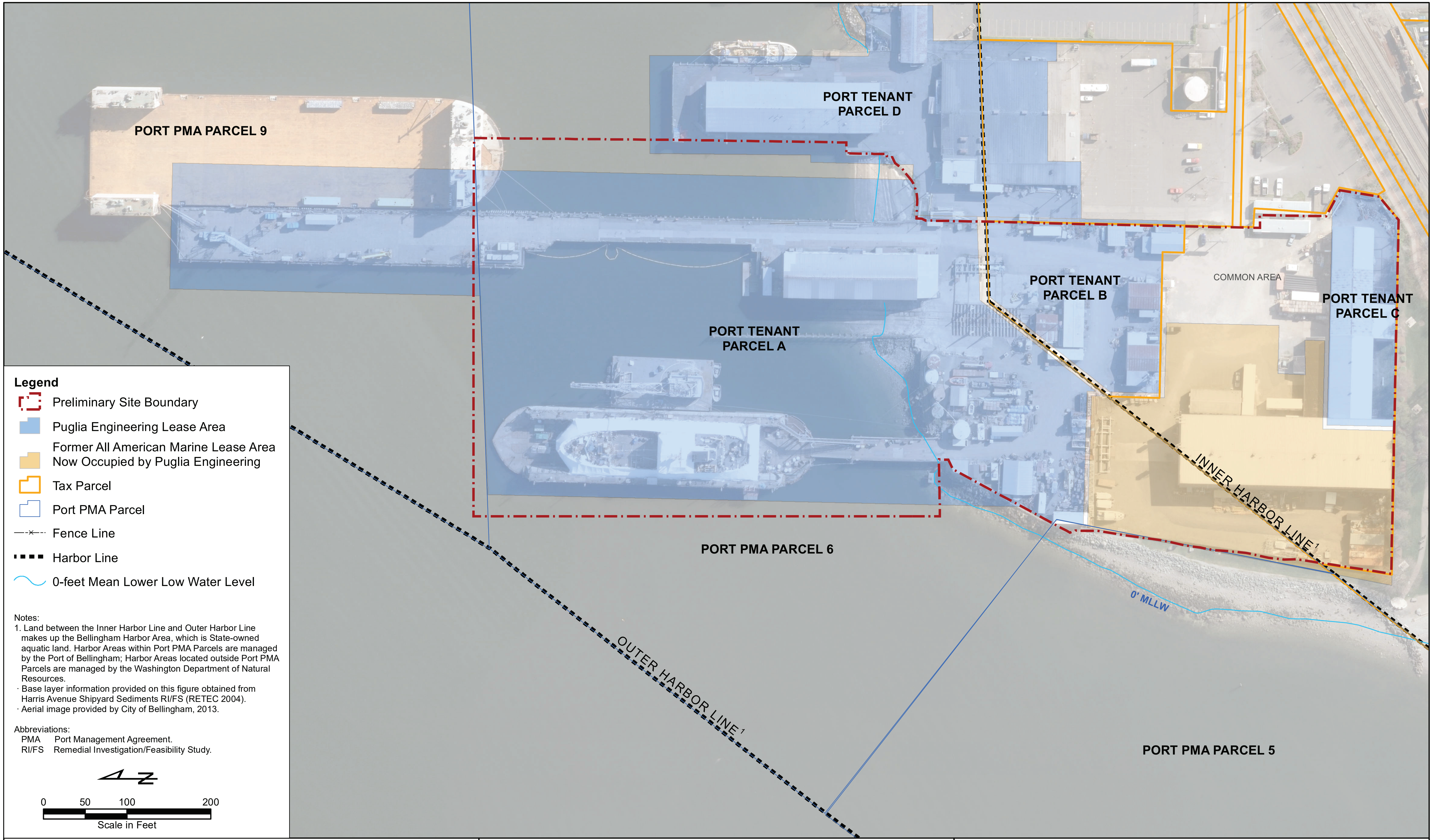
Remedial Investigation/Feasibility Study
Harris Avenue Shipyard
Bellingham, Washington

Figure 2.2
Historical Aerial Photographs

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 2.2 Historical Aerial Photographs.mxd
6/7/2019



Notes:
1. Land between the Inner Harbor Line and Outer Harbor Line makes up the Bellingham Harbor Area, which is State-owned aquatic land. Harbor Areas within Port PMA Parcels are managed by the Port of Bellingham; Harbor Areas located outside Port PMA Parcels are managed by the Washington Department of Natural Resources.
- Base layer information provided on this figure obtained from Harris Avenue Shipyard Sediments RI/FS (RETEC 2004).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:

PMA	Port Management Agreement.
RI/FS	Remedial Investigation/Feasibility Study.

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Harris Avenue Shipyard
Bellingham, Washington

Figure 2.3
Site Parcel Boundaries and Lease Areas

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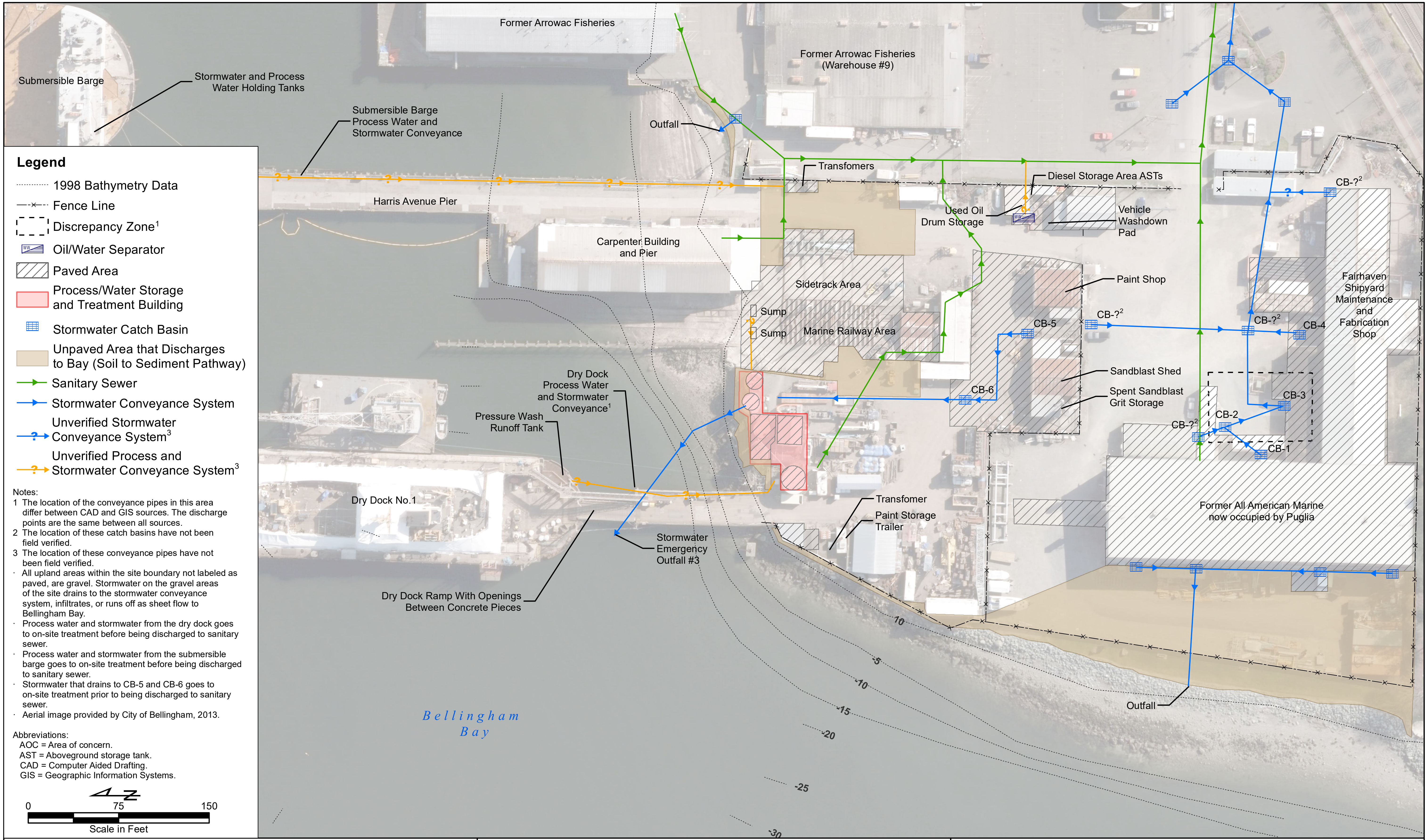
6/7/2019



Notes:

1 The location of the conveyance pipes in this area differ between CAD and GIS sources. The discharge points are the same between all sources.

2 The location of these catch basins have not been field verified.

3 The location of these conveyance pipes have not been field verified.

- All upland areas within the site boundary not labeled as paved, are gravel. Stormwater on the gravel areas of the site drains to the stormwater conveyance system, infiltrates, or runs off as sheet flow to Bellingham Bay.
- Process water and stormwater from the dry dock goes to on-site treatment before being discharged to sanitary sewer.
- Process water and stormwater from the submersible barge goes to on-site treatment before being discharged to sanitary sewer.
- Stormwater that drains to CB-5 and CB-6 goes to on-site treatment prior to being discharged to sanitary sewer.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:

AOC = Area of concern.
AST = Aboveground storage tank.
CAD = Computer Aided Drafting.
GIS = Geographic Information Systems.

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Figure 2.4
Stormwater Conveyance System

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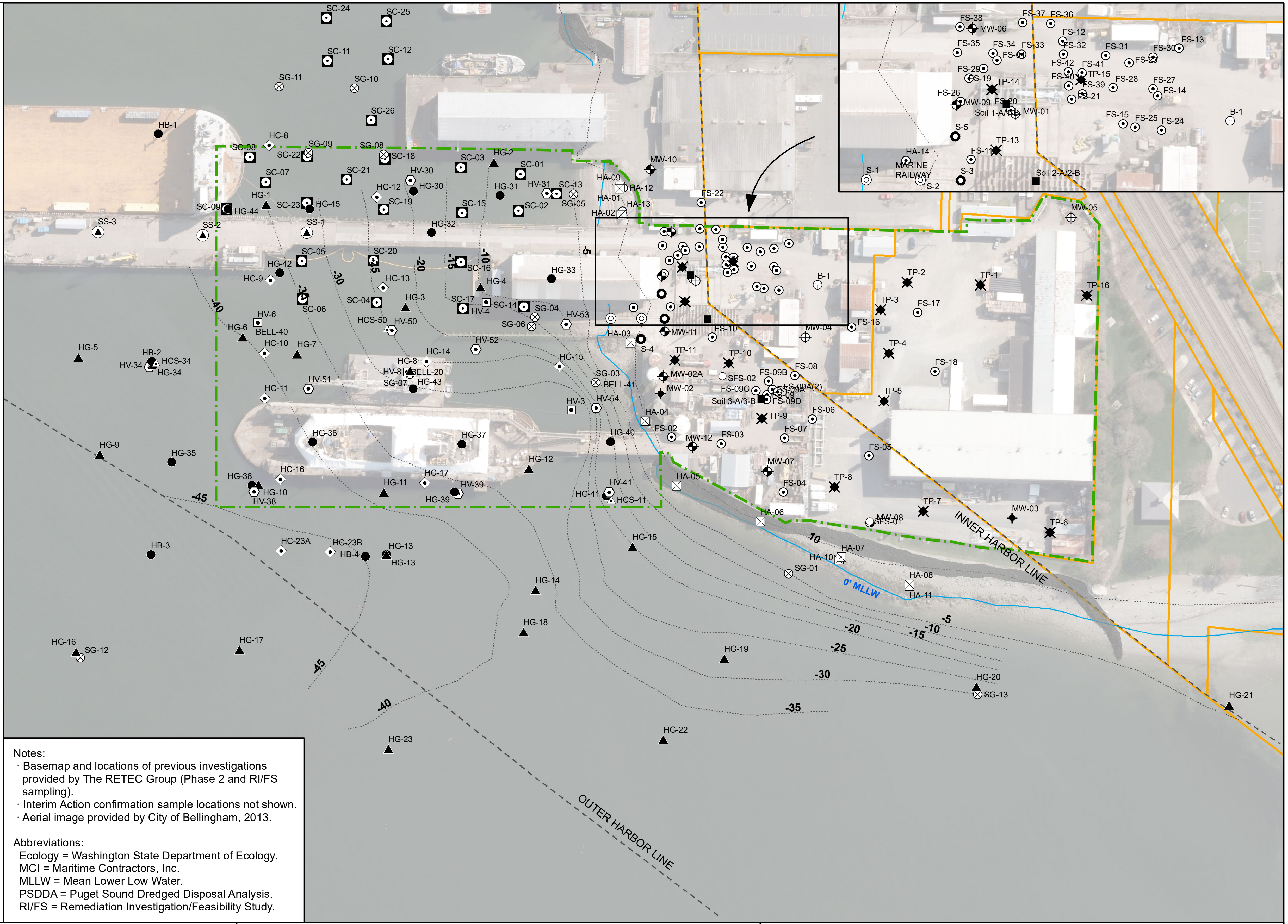
6/7/2019

Legend

- ⊡ Floyd|Snider Vibracore Location (2015)
- ⊙ Floyd|Snider Geoprobe Location (2011, 2013, 2015)
- ⊗ Floyd|Snider Grab Sample Location (2011, 2013)
- ⊠ Floyd|Snider Hand Auger Location (2011, 2013)
- ⊕ Floyd|Snider Monitoring Well (2011, 2013, 2015)
- ○ Floyd|Snider Surface Soil Sample Location (2013)
- ▲ Geoengineers Grab Sample Location (1996)
- ✦ Inaccessible or Decommissioned Monitoring Well
- ■ MCI and Ecology Upland Grab Sample Location (1993)
- ⊕ RETEC Monitoring Well
- ◇ RETEC PSDDA Vibracore Sample Location (2004)
- ○ RETEC Phase 2 Boring Location (1998)
- ▲ RETEC Phase 2 Grab Sample Location (1998)
- ✱ RETEC Phase 2 Test Pit Location (1998)
- ⊡ RETEC Phase 2 Vibracore Sample Location (1998)
- △ RETEC RI/FS Cesium Core Sample Location (2000)
- ● RETEC RI/FS Grab Sample Location (2000, 2003)
- ◎ RETEC RI/FS Offshore Sample Location (2005)
- ○ RETEC RI/FS Upland Sample Location (2005)
- ⊙ RETEC RI/FS Vibracore Sample Location (2000)
- 🟧 Tax Parcel
- 1998 Bathymetry Data
- Harbor Line
- 0-feet Mean Lower Low Water Level
- Riprap
- 🟩 Preliminary Site Boundary

0 62.5 125 250
Scale in Feet



Notes:
- Basemap and locations of previous investigations provided by The RETEC Group (Phase 2 and RI/FS sampling).
- Interim Action confirmation sample locations not shown.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
Ecology = Washington State Department of Ecology.
MCI = Maritime Contractors, Inc.
MLLW = Mean Lower Low Water.
PSDDA = Puget Sound Dredged Disposal Analysis.
RI/FS = Remediation Investigation/Feasibility Study.

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Harris Avenue Shipyard
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Figure 2.5
Historical and Current Sample Locations

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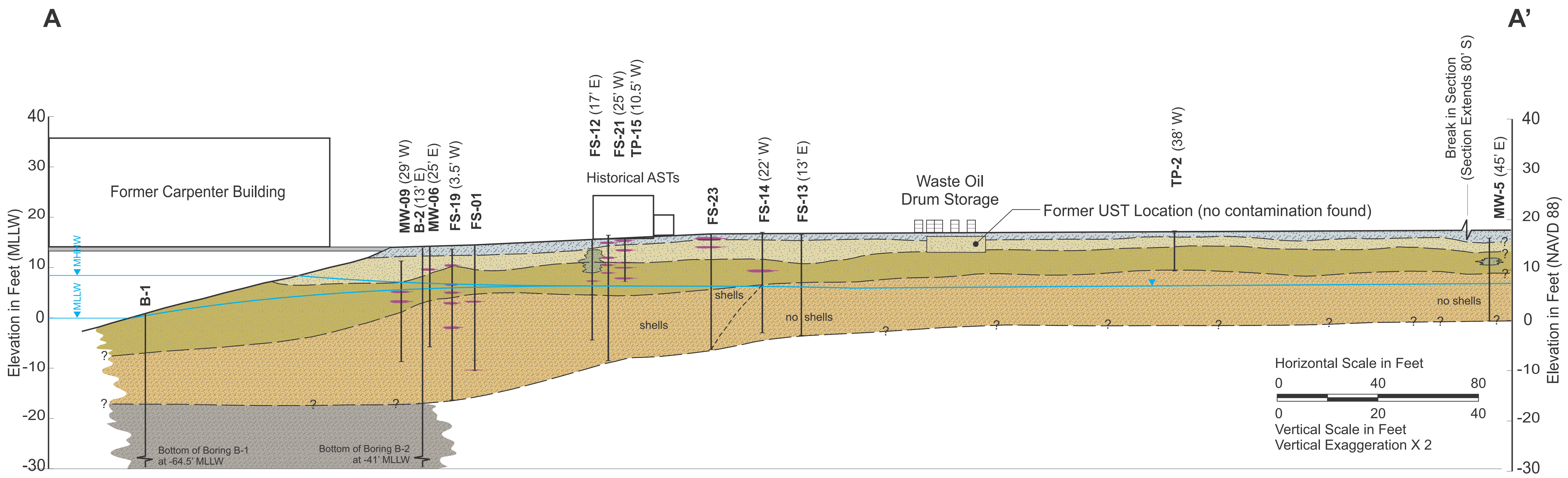
6/7/2019



▨ Gravel Base

▨ Sand with Gravel

▨ Sand with Gravel, Increased Silt

▨ Silty Sand

▨ Silty Sand with Gravel (TILL)

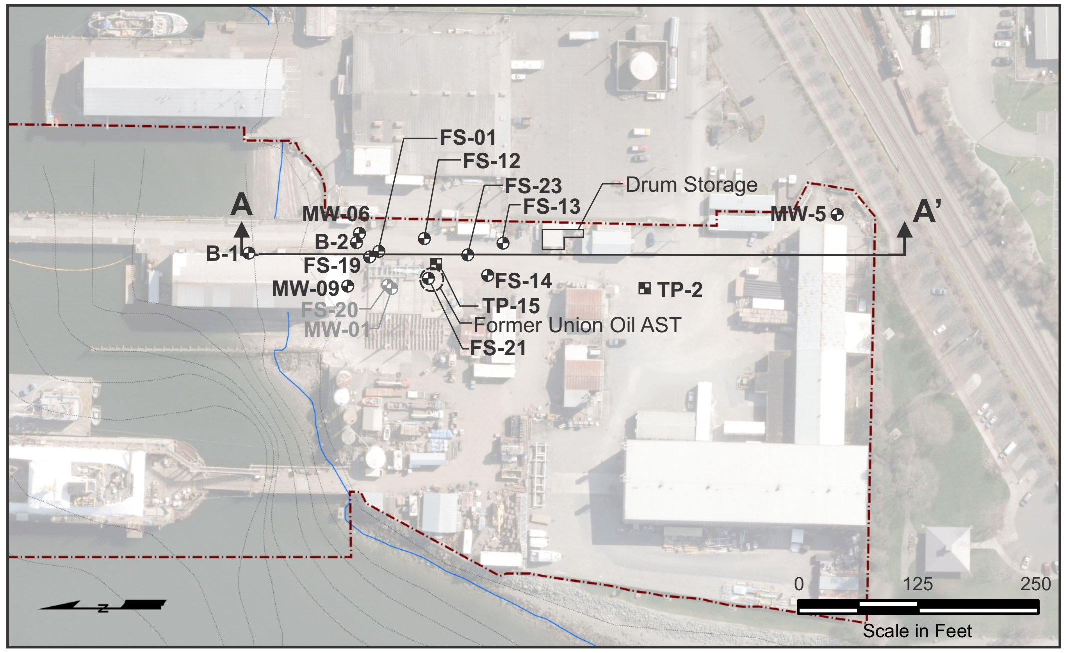
▨ Silt Lense

━ Petroleum Indications in Soil Samples
(sheen, odor, TPH concentration, > MTCA Method A)

▼ Groundwater Surface

Ι Monitoring Well or Soil Boring Location

(17' E) Offset Distance and Direction



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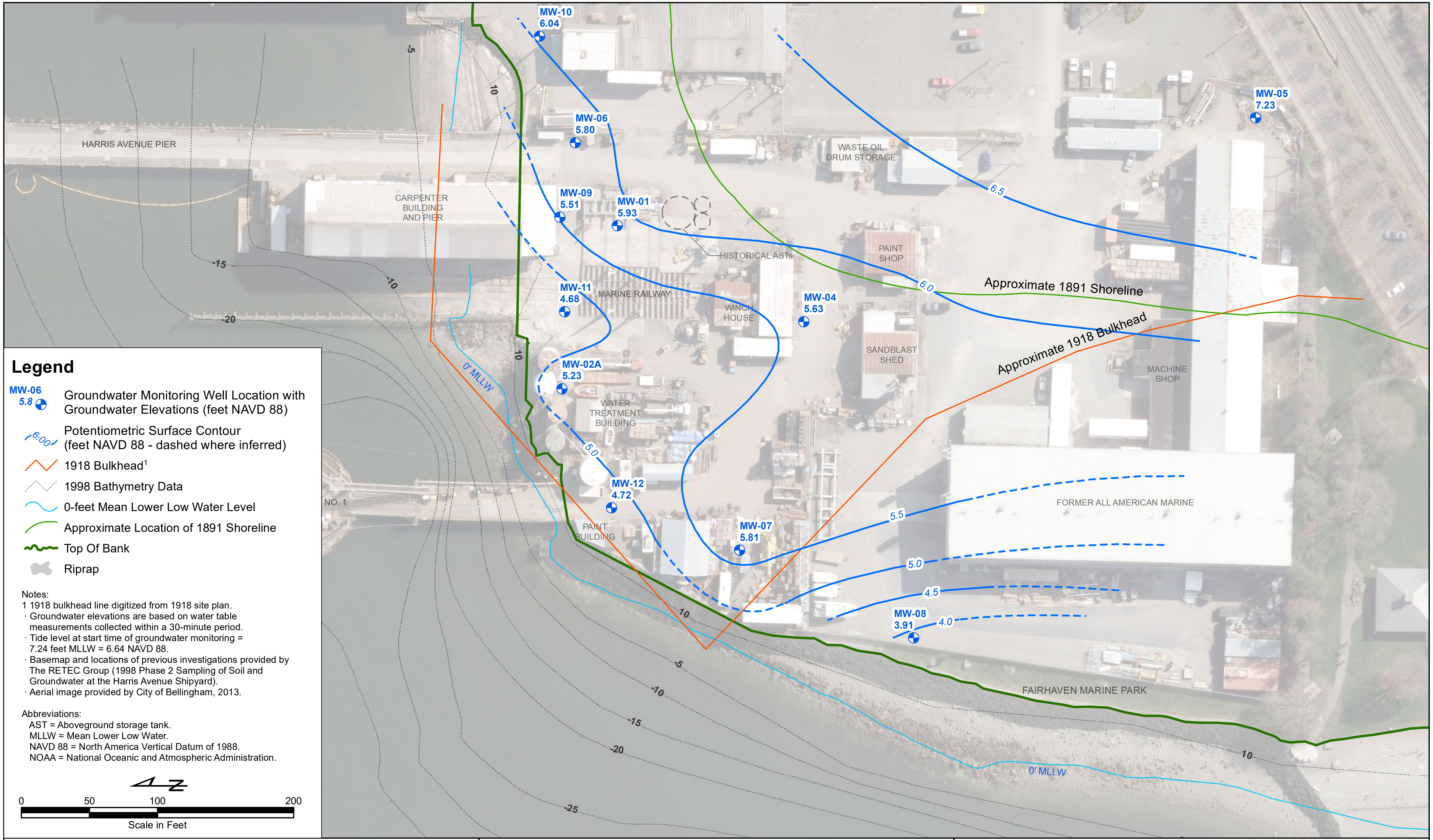
Harris Avenue Shipyard
Bellingham, Washington

Figure 3.1
Site Geology Cross Section A-A'



Notes:
1 1918 bulkhead line digitized from 1918 site plan.
- Groundwater elevations are based on water table measurements collected within a 30-minute period.
- Tide level at start time of groundwater monitoring = 7.24 feet MLLW = 6.64 NAVD 88.
- Basemap and locations of previous investigations provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
MLLW = Mean Lower Low Water.
NAVD 88 = North America Vertical Datum of 1988.
NOAA = National Oceanic and Atmospheric Administration.

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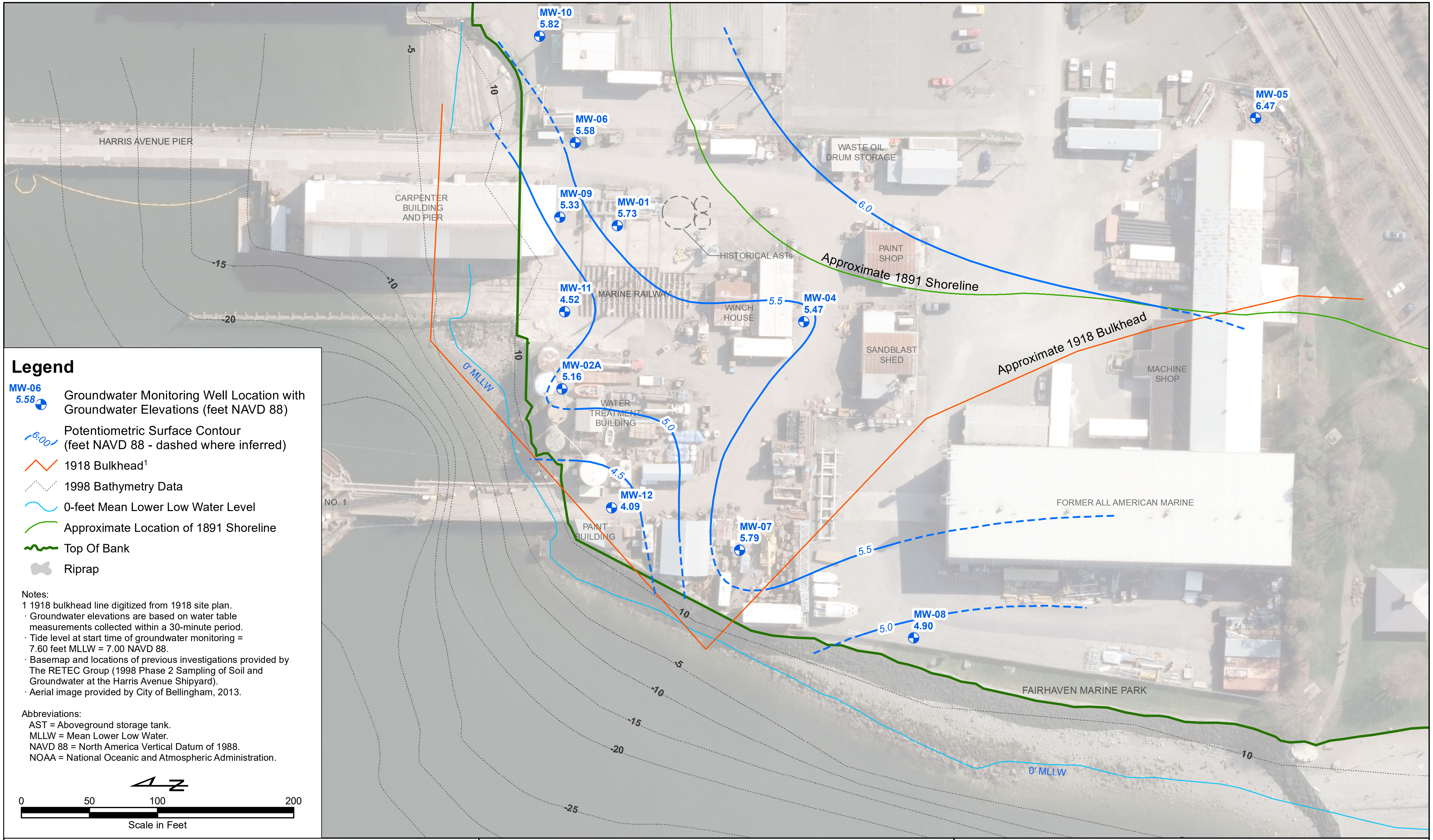
Harris Avenue Shipyard
Bellingham, Washington

Figure 3.2
Potentiometric Surface Map Groundwater Elevations
February 25, 2015



Legend

- Groundwater Monitoring Well Location with Groundwater Elevations (feet NAVD 88)
- Potentiometric Surface Contour (feet NAVD 88 - dashed where inferred)
- 1918 Bulkhead[1]
- 1998 Bathymetry Data
- 0-feet Mean Lower Low Water Level
- Approximate Location of 1891 Shoreline
- Top Of Bank
- Riprap

Notes:
1 1918 bulkhead line digitized from 1918 site plan.
· Groundwater elevations are based on water table measurements collected within a 30-minute period.
· Tide level at start time of groundwater monitoring = 7.60 feet MLLW = 7.00 NAVD 88.
· Basemap and locations of previous investigations provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
· Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
MLLW = Mean Lower Low Water.
NAVD 88 = North America Vertical Datum of 1988.
NOAA = National Oceanic and Atmospheric Administration.

N

0 50 100 200
Scale in Feet

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Figure 3.3
Potentiometric Surface Map Groundwater Elevations
August 27, 2015

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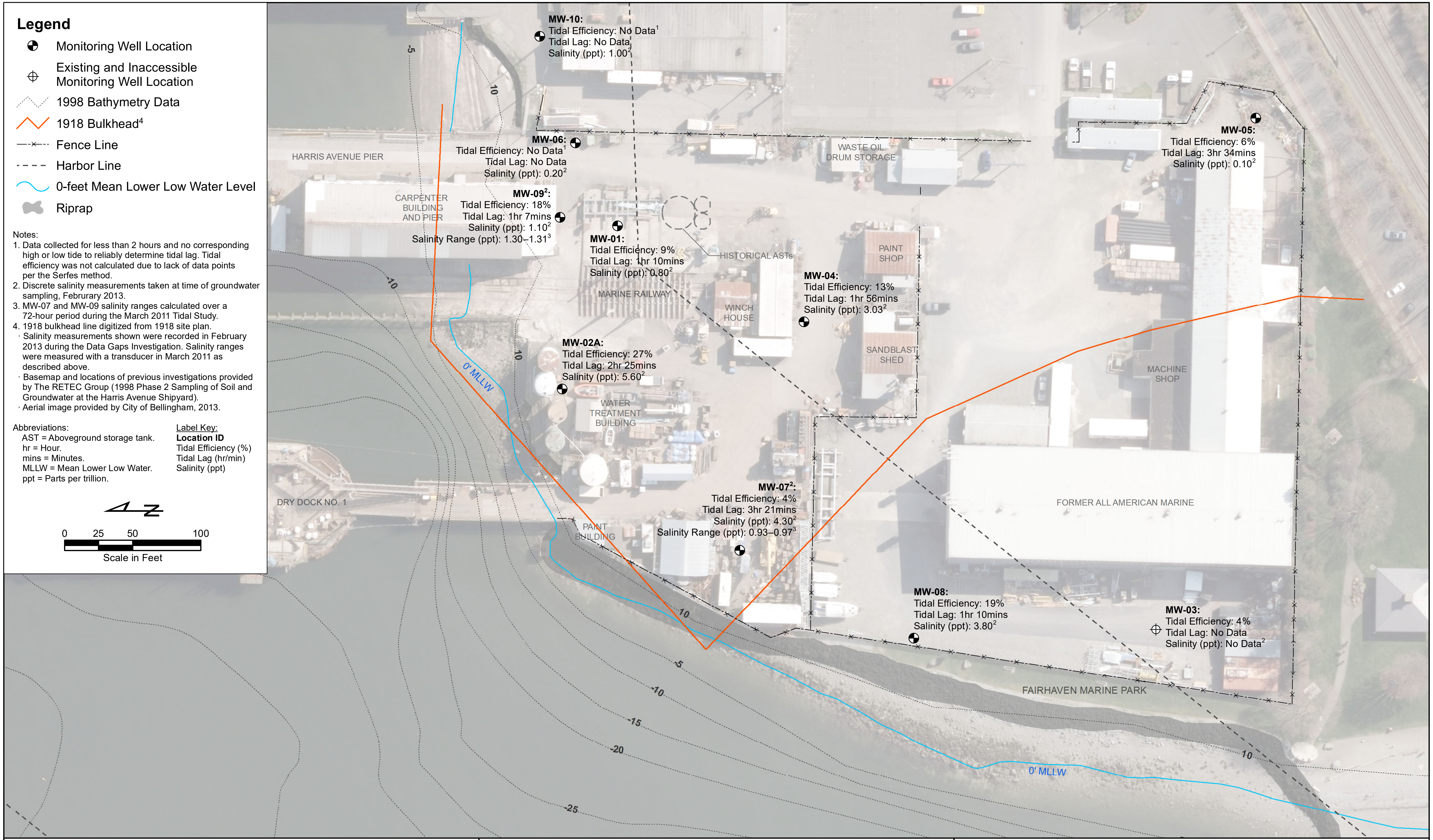
6/7/2019



Legend

- ● Monitoring Well Location
- ⊕ Existing and Inaccessible Monitoring Well Location
- 1998 Bathymetry Data
- 1918 Bulkhead[4]
- Fence Line
- Harbor Line
- 0-feet Mean Lower Low Water Level
- Riprap

Notes:
1. Data collected for less than 2 hours and no corresponding high or low tide to reliably determine tidal lag. Tidal efficiency was not calculated due to lack of data points per the Serfes method.
2. Discrete salinity measurements taken at time of groundwater sampling, Februrary 2013.
3. MW-07 and MW-09 salinity ranges calculated over a 72-hour period during the March 2011 Tidal Study.
4. 1918 bulkhead line digitized from 1918 site plan.

- Salinity measurements shown were recorded in February 2013 during the Data Gaps Investigation. Salinity ranges were measured with a transducer in March 2011 as described above.
- Basemap and locations of previous investigations provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
hr = Hour.
mins = Minutes.
MLLW = Mean Lower Low Water.
ppt = Parts per trillion.

Label Key:
Location ID
Tidal Efficiency (%)
Tidal Lag (hr/min)
Salinity (ppt)

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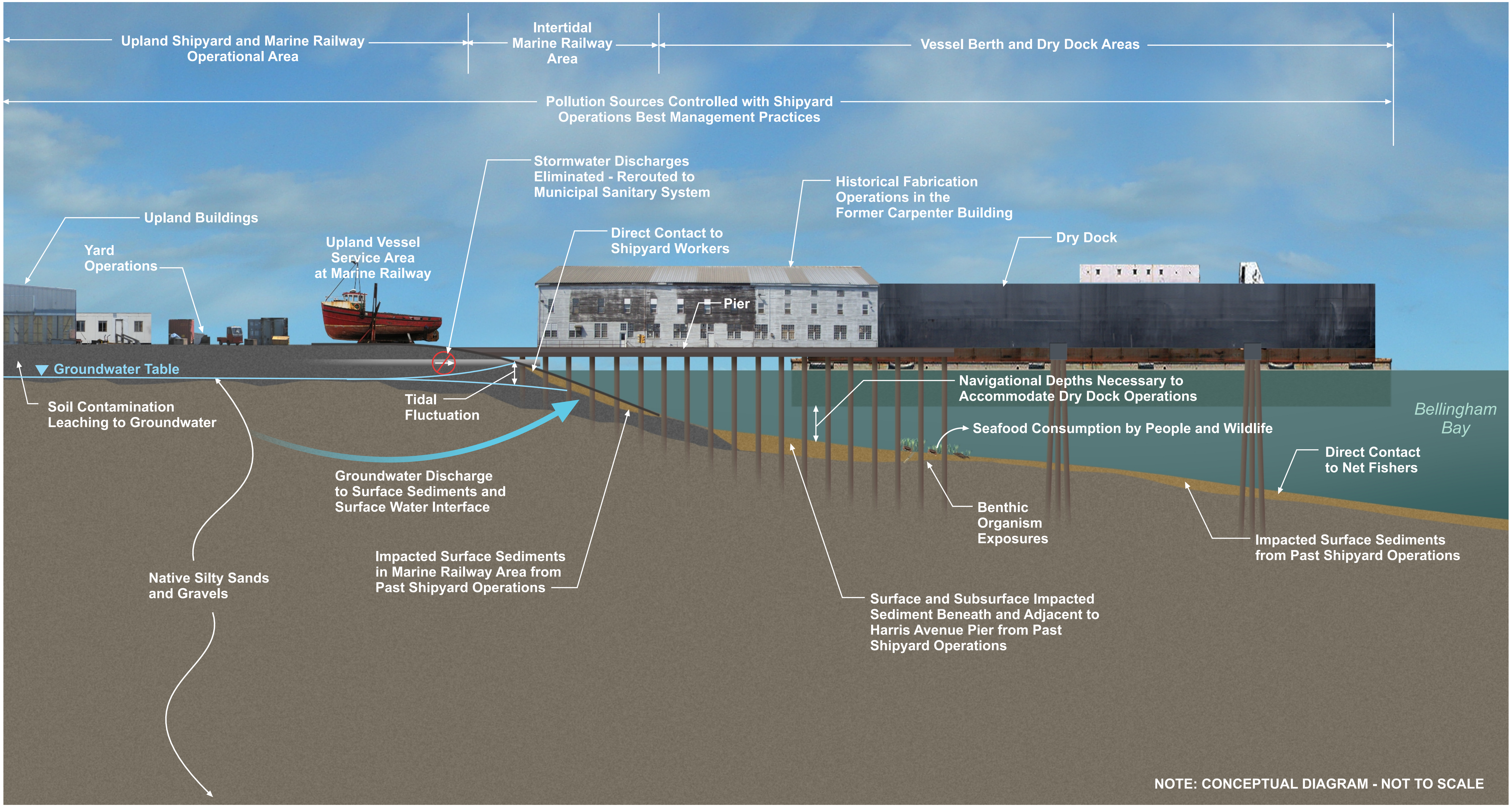
Harris Avenue Shipyard
Bellingham, Washington

Figure 3.4
Tidal Data and Average Salinity



NOTE: CONCEPTUAL DIAGRAM - NOT TO SCALE

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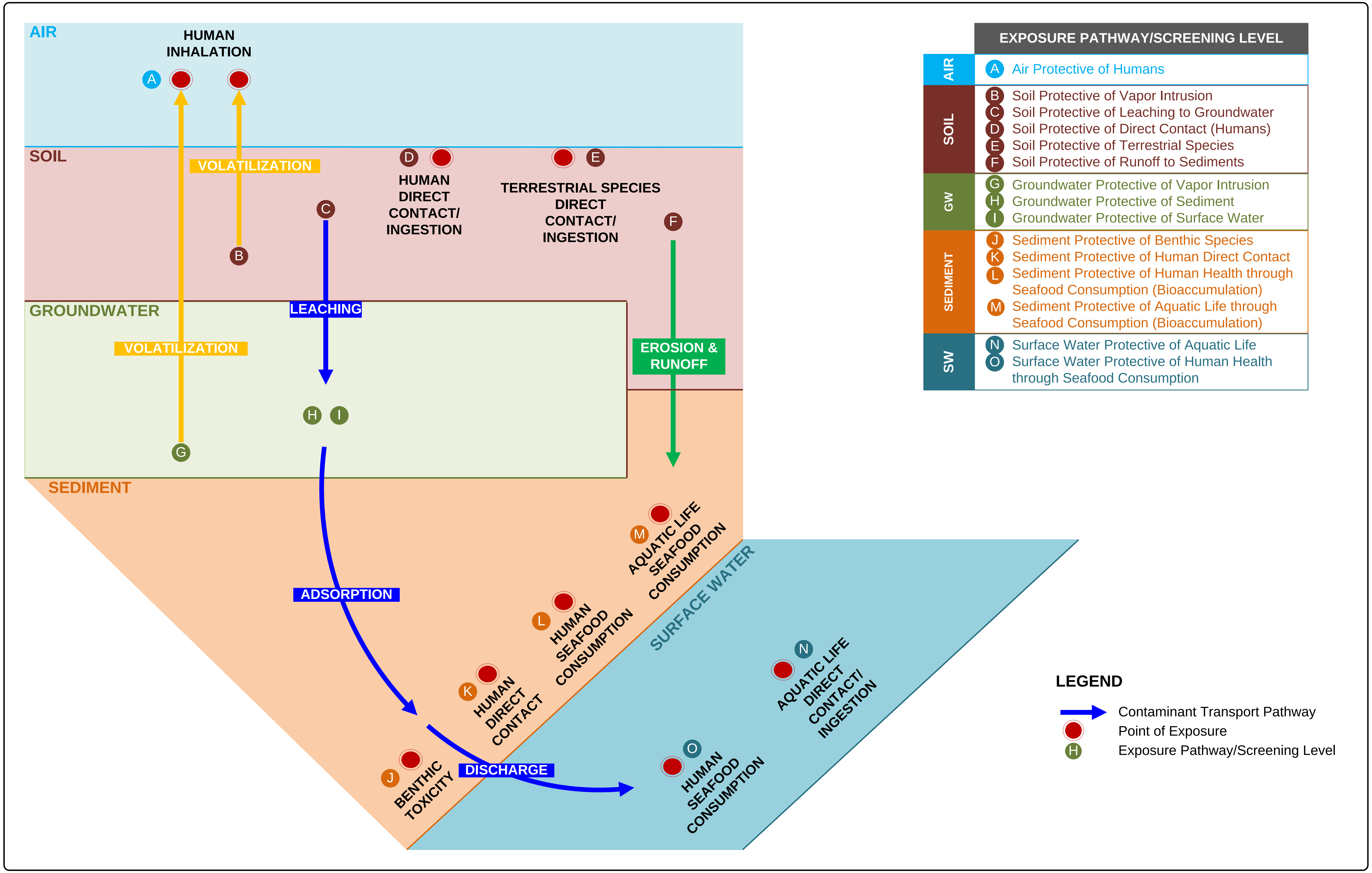
Figure 4.1
Conceptual Site Model

g:projects/clients/floydsnider/harrisavenue/2018/Figure 4.1.cdr



	EXPOSURE PATHWAY/SCREENING LEVEL
AIR	A Air Protective of Humans
SOIL	B Soil Protective of Vapor Intrusion C Soil Protective of Leaching to Groundwater D Soil Protective of Direct Contact (Humans) E Soil Protective of Terrestrial Species F Soil Protective of Runoff to Sediments
GW	G Groundwater Protective of Vapor Intrusion H Groundwater Protective of Sediment I Groundwater Protective of Surface Water
SEDIMENT	J Sediment Protective of Benthic Species K Sediment Protective of Human Direct Contact L Sediment Protective of Human Health through Seafood Consumption (Bioaccumulation) M Sediment Protective of Aquatic Life through Seafood Consumption (Bioaccumulation)
SW	N Surface Water Protective of Aquatic Life O Surface Water Protective of Human Health through Seafood Consumption

LEGEND

→ Contaminant Transport Pathway
● Point of Exposure
H Exposure Pathway/Screening Level

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Harris Avenue Shipyard
Bellingham, Washington

Figure 4.2
Evaluated Exposure Pathways

08/27/2018

Legend

- ▦ Beach Intertidal Sediment Area
- 🟩 Shipyard Intertidal Sediment Area
- ⁙ Subtidal Sediment Area
- ⋰ 1998 Bathymetry Data
- —×— Fence Line
- - - - Harbor Line
- ∼ 0-feet Mean Lower Low Water Level
- ● Riprap

Notes:
- Basemap provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
MLLW = Mean Lower Low Water.
RI = Remedial Investigation.
Site = Harris Avenue Shipyard.

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Figure 4.3
Sediment Study Areas

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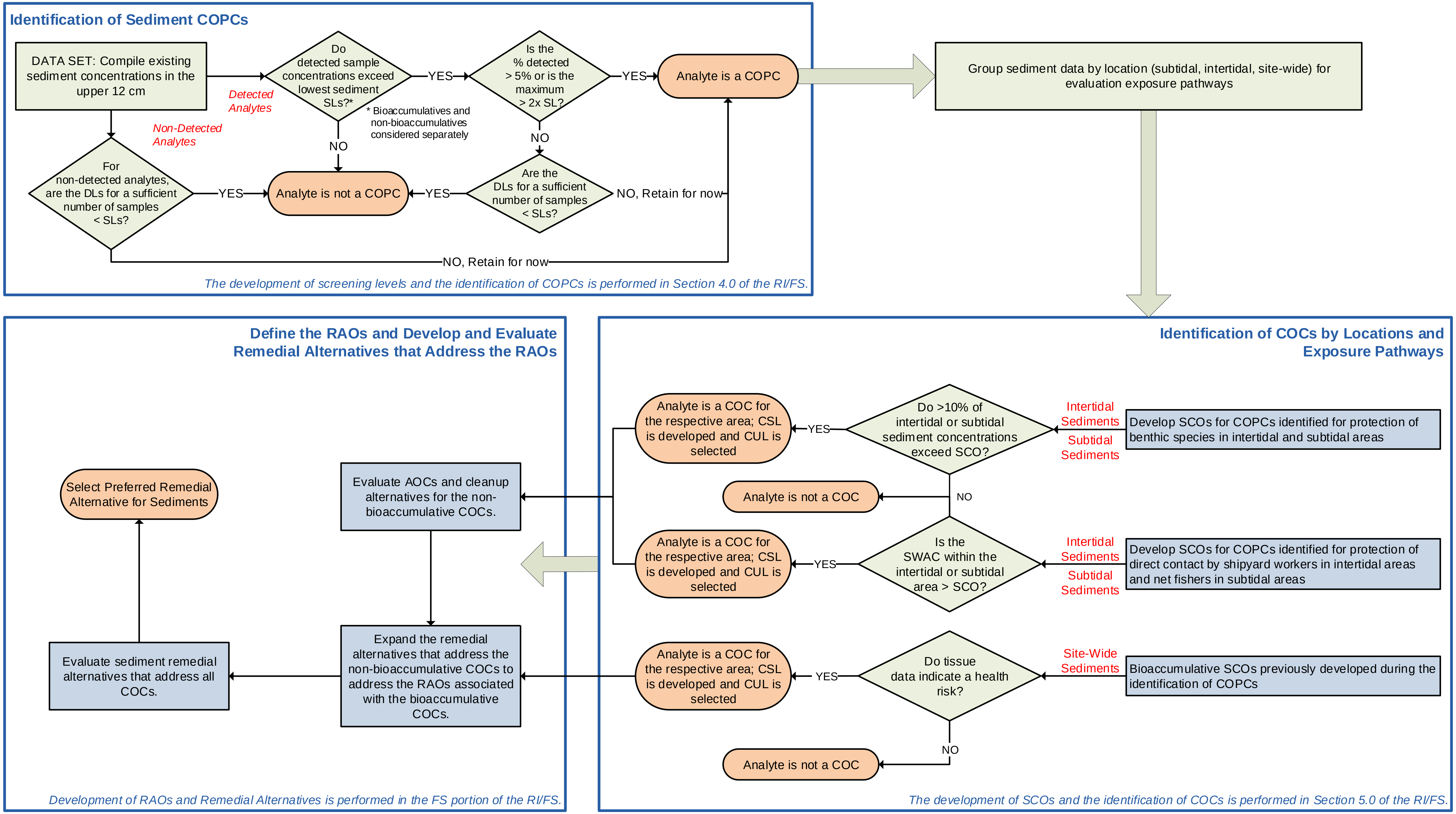
6/7/2019



Abbreviations: AOC = Area of Concern, cm = Centimeters, COC = Contaminant of concern, COPC = Contaminant of potential concern, CSL = Cleanup screening level, CUL = Cleanup level, DL = Detection limit, RAO = Remedial Action Objective, RI/FS = Remedial Investigation/Feasibility Study, SCO = Sediment Cleanup Objective, SL = Screening level, SMS = Sediment Management Standards, SQS = Sediment Quality Standards

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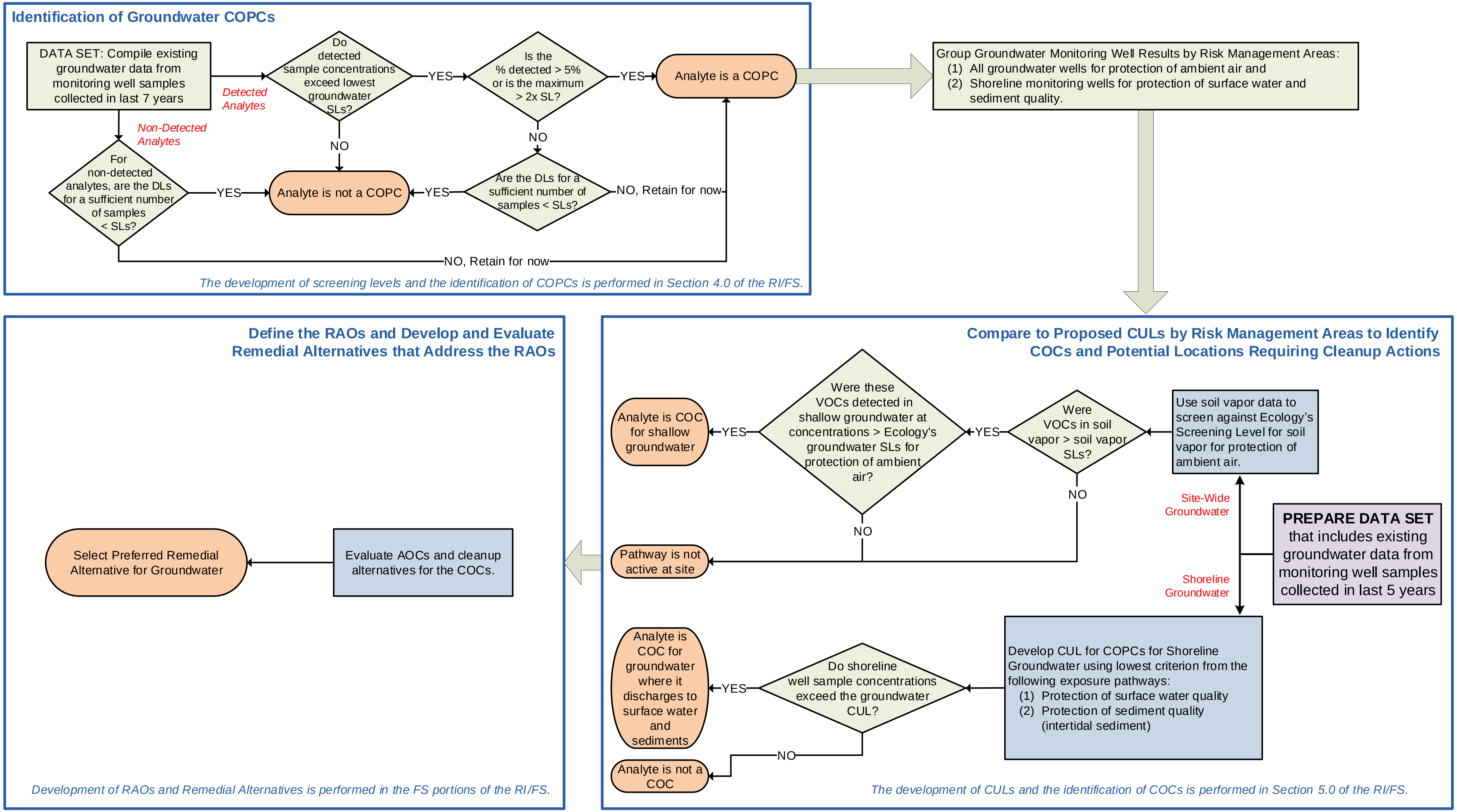
Harris Avenue Shipyard
Bellingham, Washington

Figure 4.4
Contaminant of Concern and Cleanup Level Development Flowchart — Sediment

4/11/2018



Abbreviations: AOC = Area of Concern, COC = Contaminant of concern, COPC = Contaminant of potential concern, CUL = Cleanup level, DL = Detection limit, Ecology = Washington State Department of Ecology, RAO = Remedial Action Objective, RI/FS = Remedial Investigation/Feasibility Study, Site = Harris Avenue Shipyard, SL = Screening level, VOC = Volatile organic compound.

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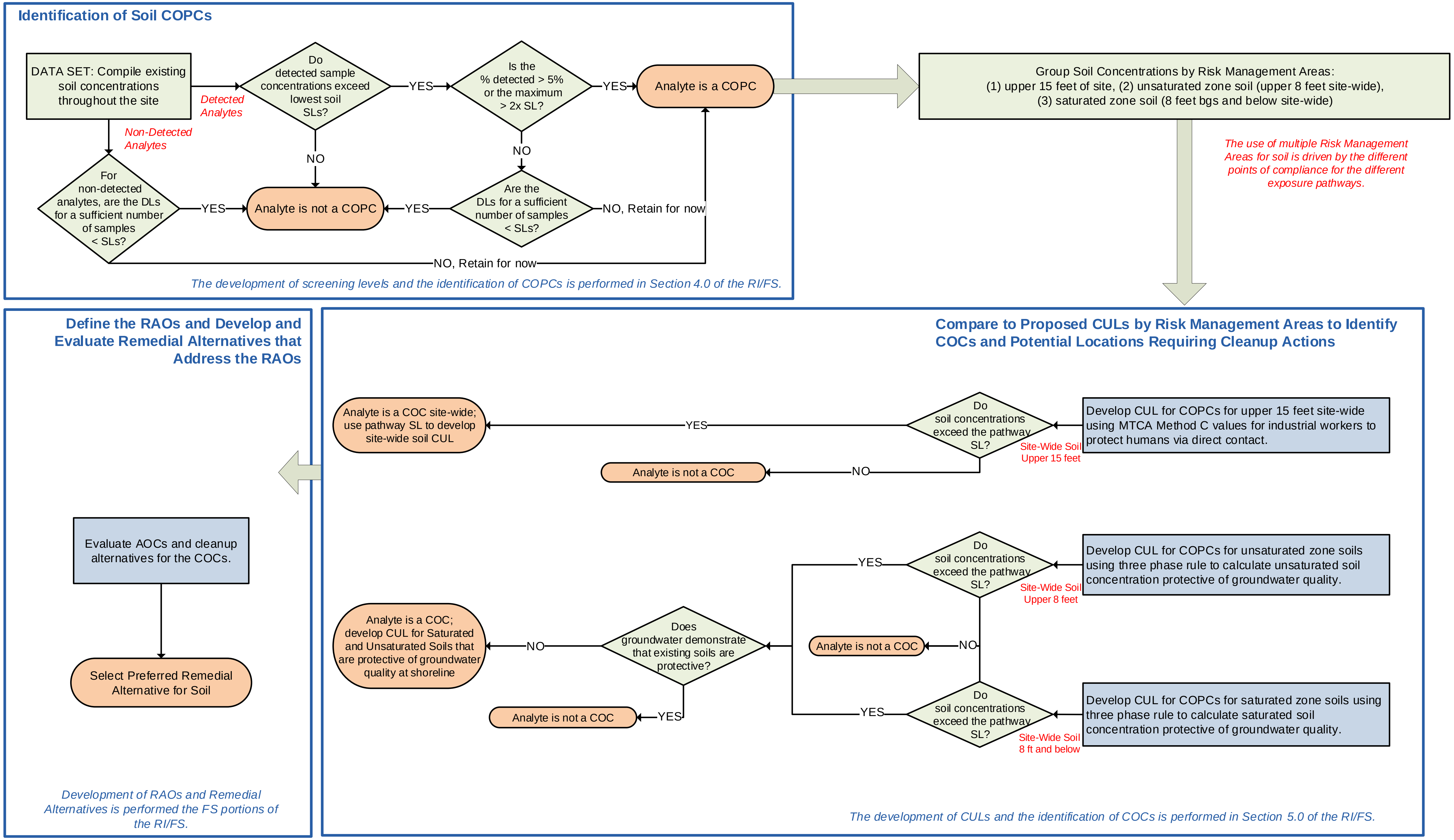
Figure 4.5
Contaminant of Concern and
Cleanup Level Development Flowchart — Groundwater

08/27/2018



Abbreviations: AOC = Area of Concern, bgs = Below ground surface, COC = Contaminant of concern, COPC = Contaminant of potential concern, CUL = Cleanup level, DL = Detection limit, MTCA = Model Toxics Control Act, RAO = Remedial Action Objective, RI/FS = Remedial Investigation/Feasibility Study, SL = Screening level, SMS = Sediment Management Standards, SQS = Sediment Quality Standards, WWAC = Washington Administrative Code

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Harris Avenue Shipyard
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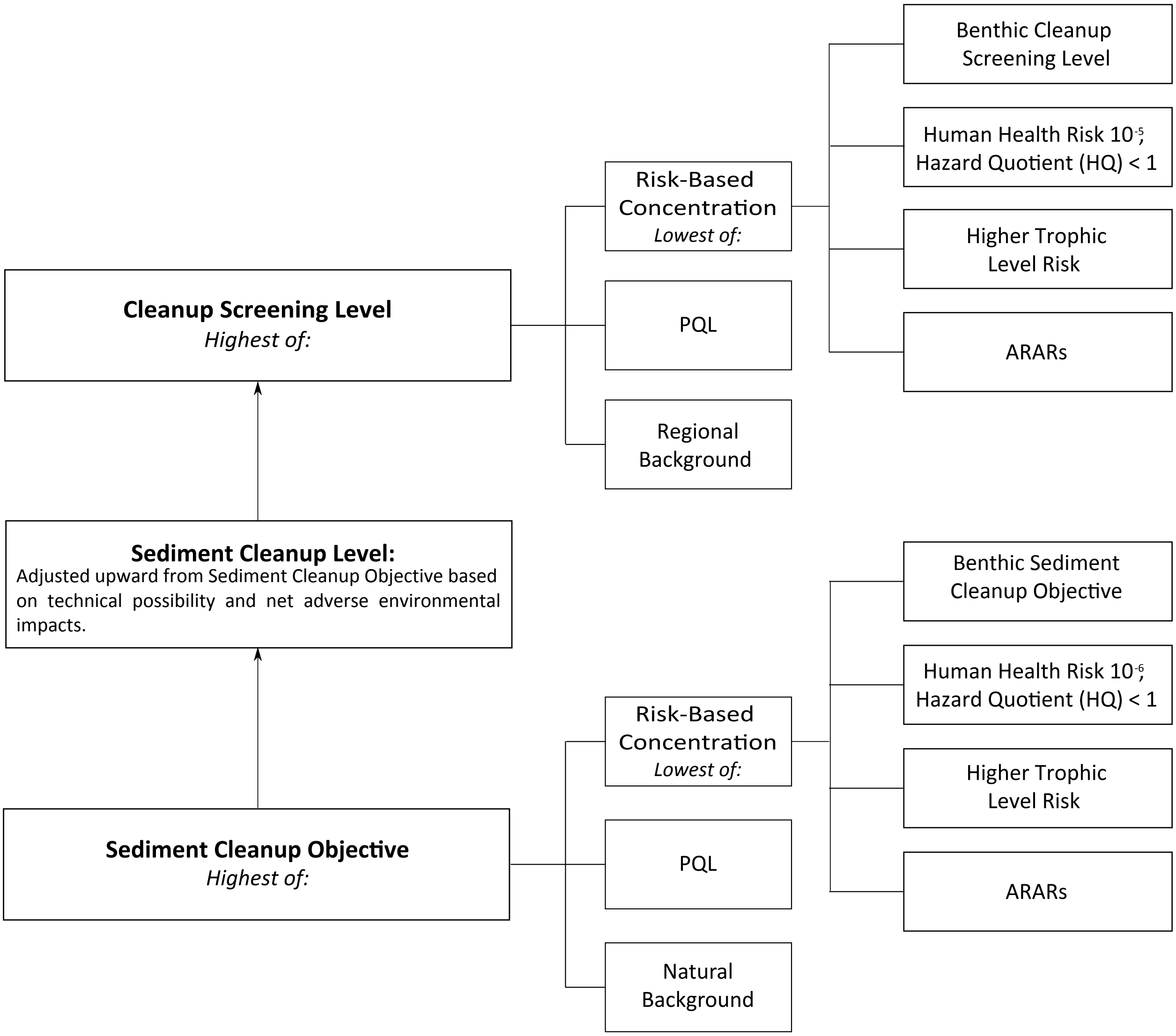
Figure 4.6
Contaminant of Concern and
Cleanup Level Development Flowchart — Soil

08/27/2018



Source: 2017. *Sediment Cleanup Users Manual II: Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards.* Chapter 173-204 WAC. Publication No. 12-09-057. April.

Acronyms: ARARs = Applicable or Relevant and Appropriate Requirements; PQL = Practical quantitation limit.

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Figure 5.1
Sediment Cleanup Level
Development Process

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08/27/2018

Legend

- 🟥 Greater Than Criterion
- 🟩 Less Than Criterion
- 🟦 Not Detected
- ● Intertidal Sediment Location
- ▢ Beach Intertidal Sediment Area
- ▢ Shipyard Intertidal Sediment Area
- 1998 Bathymetry Data
- Fence Line
- Harbor Line
- 0-feet Mean Lower Low Water Level
- Riprap

	Location ID	
	Analyte	**Criteria (mg/kg)**
■	Arsenic (As)	20[1] / 57[2]
■	Copper (Cu)	390
■	Zinc (Zn)	410

Notes:
1 Criterion is applied to the shipyard intertidal sediment area and is protective of benthic species and direct contact to shipyard workers.
2 Criterion is applied to the beach intertidal sediment area and is protective of benthic species. There is no human direct contact exposure pathway in this area.

- Data shown represents site conditions prior to completion of the Interim Action.
- Surface sediment depths are 0- to 12- centimeters, with the exception of S-1 and S-2, which have a lower depth of 2 feet.
- Results shown here are the maximum detected concentrations in the sample depth interval.
- Basemap provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- All results are reported in mg/kg dry weight.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
mg/kg = Milligrams per kilogram
MLLW = Mean Lower Low Water.

Qualifier:
U = The analyte was not detected at the given reporting limit.

0 25 50 100
Scale in Feet

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Bellingham, Washington

Figure 5.2
Arsenic, Copper, and Zinc in Intertidal Surface Sediments

Legend

🟥 Greater Than Criteria
🟩 Less Than Criteria
🟦 Not Detected
☐ Not Analyzed
● Sediment Sample Location
1998 Bathymetry Data
Fence Line
Harbor Line
0-feet Mean Lower Low Water Level
Riprap

Location ID	
Analyte	Criteria (mg/kg)
Arsenic (As)	11
Copper (Cu)	390
Zinc (Zn)	410

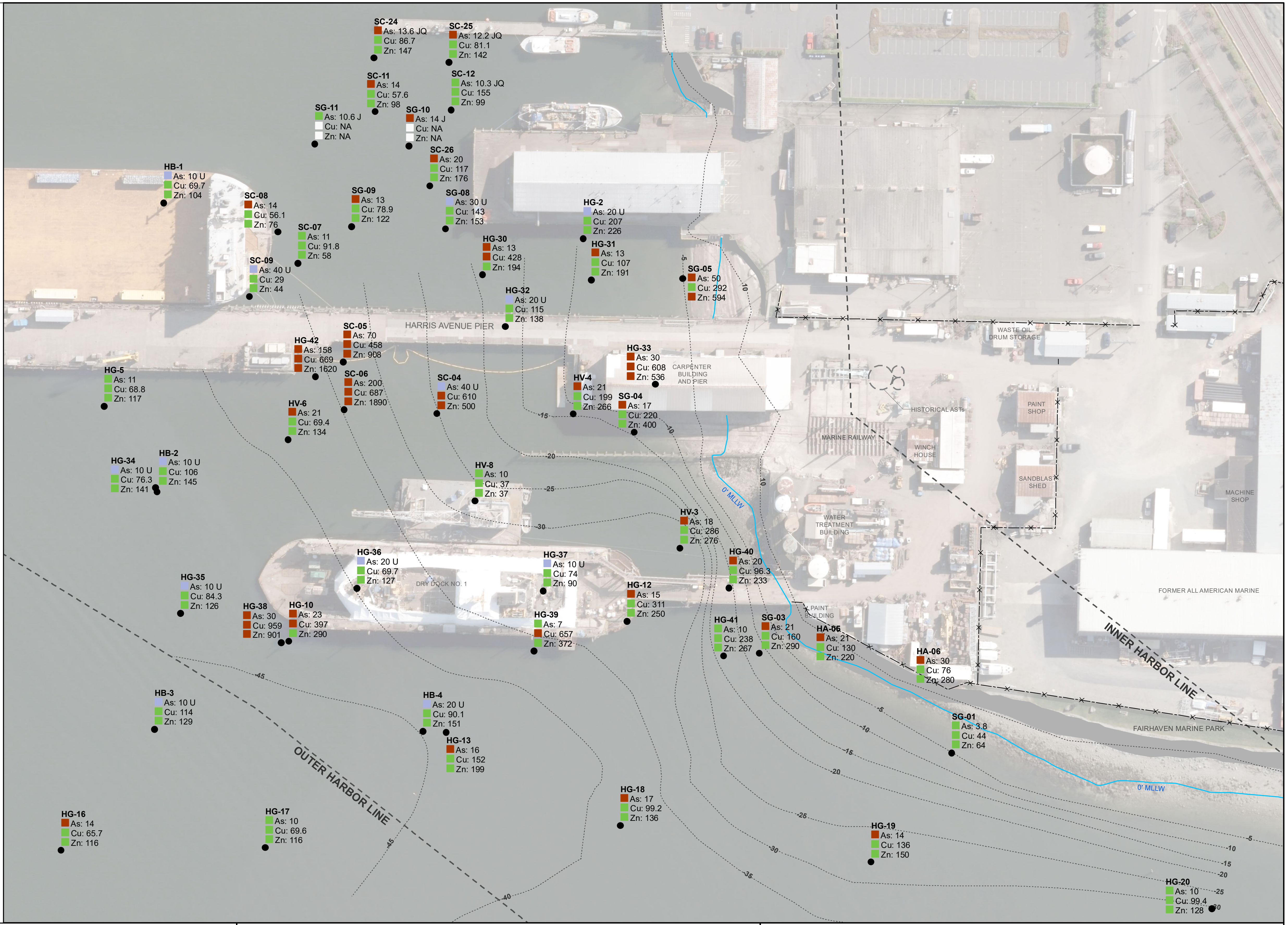
Notes:
- Criteria are screening levels protective of benthic species and human health for direct contact via net fishing.
- For clarity purposes, sample locations and data collected in 2015 within the Interim Action Area are not shown unless they help define the nature and extent of contamination. All locations and data within the vicinity of the Interim Action Area are shown in the Basis of Design Report (Floyd|Snider 2017).
- Data shown represents site conditions prior to completion of the Interim Action.
- Arsenic criterion is based on an estimate of natural background for sediment.
- Results shown here are the maximum detected concentrations in the 0- to 12-cm interval.
- Basemap and locations of investigations prior to 2011 provided by The RETEC Group.
- All results are reported in mg/kg dry weight.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
cm = Centimeters.
mg/kg = Milligrams per kilogram.
MLLW = Mean Lower Low Water.
NA = Not analyzed.

Qualifier:
U = Analyte was not detected at given reporting limit.

N

0 50 100 200
Scale in Feet



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Harris Avenue Shipyard
Bellingham, Washington

Figure 5.3
Arsenic, Copper, and Zinc in Subtidal Surface Sediments

Legend

- 🟥 Greater Than Criteria
- 🟩 Less Than Criteria
- ▨ Not Detected
- ☐ Not Analyzed
- ● Sediment Sample Location
- 1998 Bathymetry Data
- Fence Line
- Harbor Line
- 0-feet Mean Lower Low Water Level
- Riprap

	Location ID	
	Analyte	**Criteria (mg/kg)**
■	cPAH	4.2
■	Fluoranthene (Fl)	1.7
■	PCB	0.13
■	Pyrene (Pyr)	2.6

Notes:

- Criteria are screening levels protective of benthic species and human health for direct contact via net fishing, and and exclude the bioaccumulative screening levels for PCBs and cPAH TEQ protective of seafood consumption.
- cPAH TEQ calculated using detected concentrations plus one-half the detection limit for those not detected.
- Results shown here are the maximum detected concentrations in the 0- to 12-cm interval.
- For clarity purposes, sample locations and data collected in 2015 within the Interim Action Area are not shown unless they help define the nature and extent of contamination. All locations and data within the vicinity of the Interim Action Area are shown in the Basis of Design Report (Floyd|Snider 2017).
- Data shown represents site conditions prior to completion of the Interim Action.
- Basemap and locations of investigations prior to 2011 provided by The RETEC Group
- All results are reported in mg/kg dry weight.
- Aerial image provided by City of Bellingham, 2013.

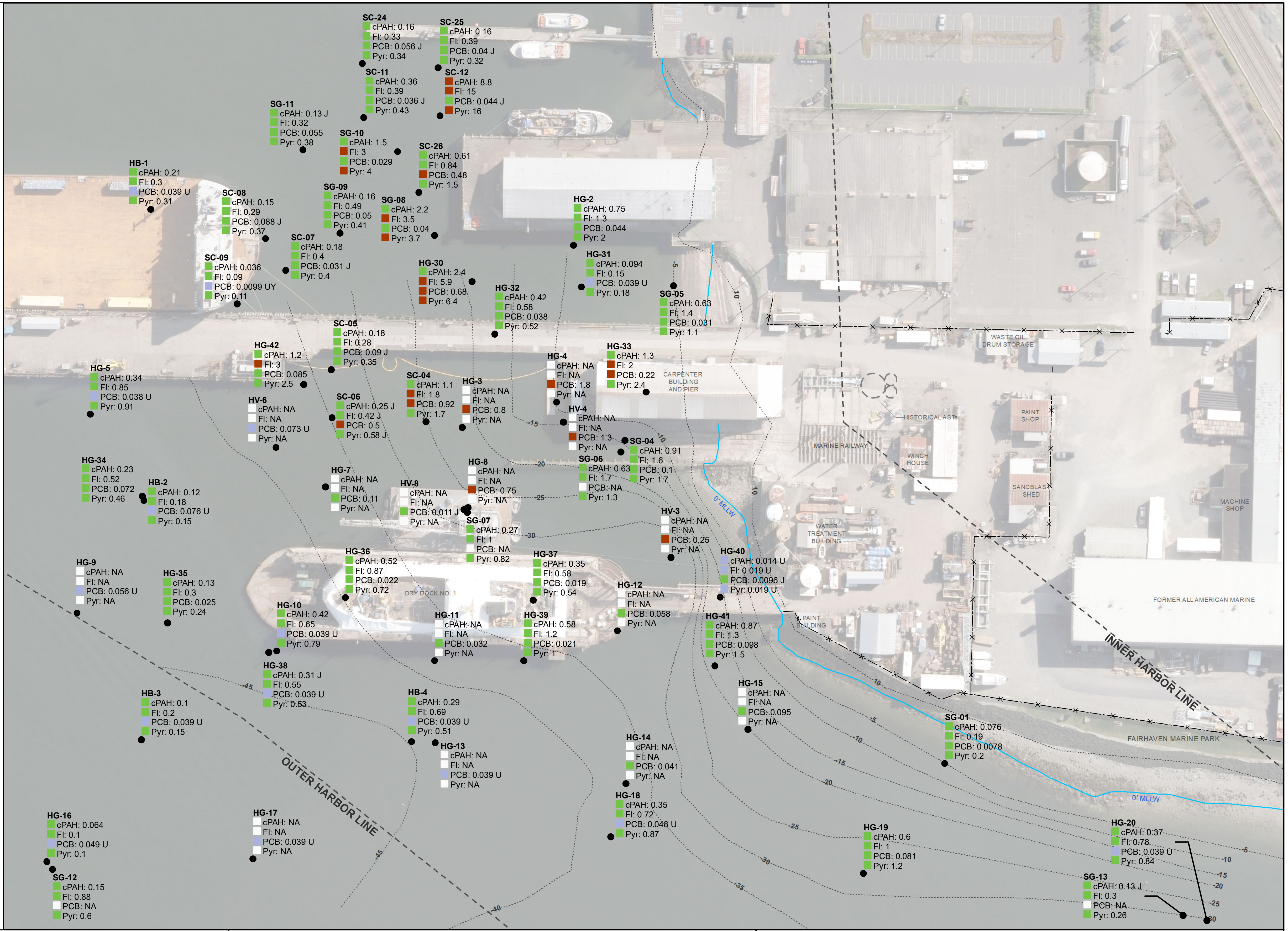
Abbreviations:

AST = Above ground storage tank.
cm= Centimeter.
cPAH = Carcinogenic polycyclic aromatic hydrocarbon.
HPAH = High molecular weight polycyclic aromatic hydrocarbon.
mg/kg = Milligrams per kilogram.
MLLW = Mean Lower Low Water.
NA = Not analyzed.
PAH = Polycyclic aromatic hydrocarbon.
PCB = Total polychlorinated biphenyl.
TEQ = Toxic equivalency quotient.

Qualifiers:

J = Analyte was detected, value should be considered an estimate.
U = Analyte was not detected at given reporting limit.

0 50 100 200
Scale in Feet



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Harris Avenue Shipyard
Bellingham, Washington

Figure 5.4
cPAHS, HPAHs, and PCBs in Subtidal Surface Sediments

Legend

- 🟥 Greater Than Direct Contact via Net Fishing Screening Level
- 🟧 Greater Than CSL[1]
- 🟩 Less Than Either Criterion
- ● Sediment Sample Location
- 1998 Bathymetry Data
- Fence Line
- Harbor Line
- 0-feet Mean Lower Low Water Level
- Riprap

	Location ID	
	Analyte	**Criteria[1] (ng/kg)**
■	Dioxin/Furans TEQ Net Fishing	62
■	Dioxin/Furans TEQ CSL	15

Notes:
1. Screening level based on tribal seafood consumption modified for Regional Background (CSL).
- Sample results are from within the 0- to 12-cm interval.
- Results calculated using detected concentrations plus one-half the detection limit for those not detected.
- Basemap provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
CSL = Cleanup screening level.
ng/kg = Nanograms per kilogram.
TEQ = Toxic equivalency quotient.

Qualifier:
J = Analyte was detected, value should be considered an estimate.

0 50 100 200
Scale in Feet

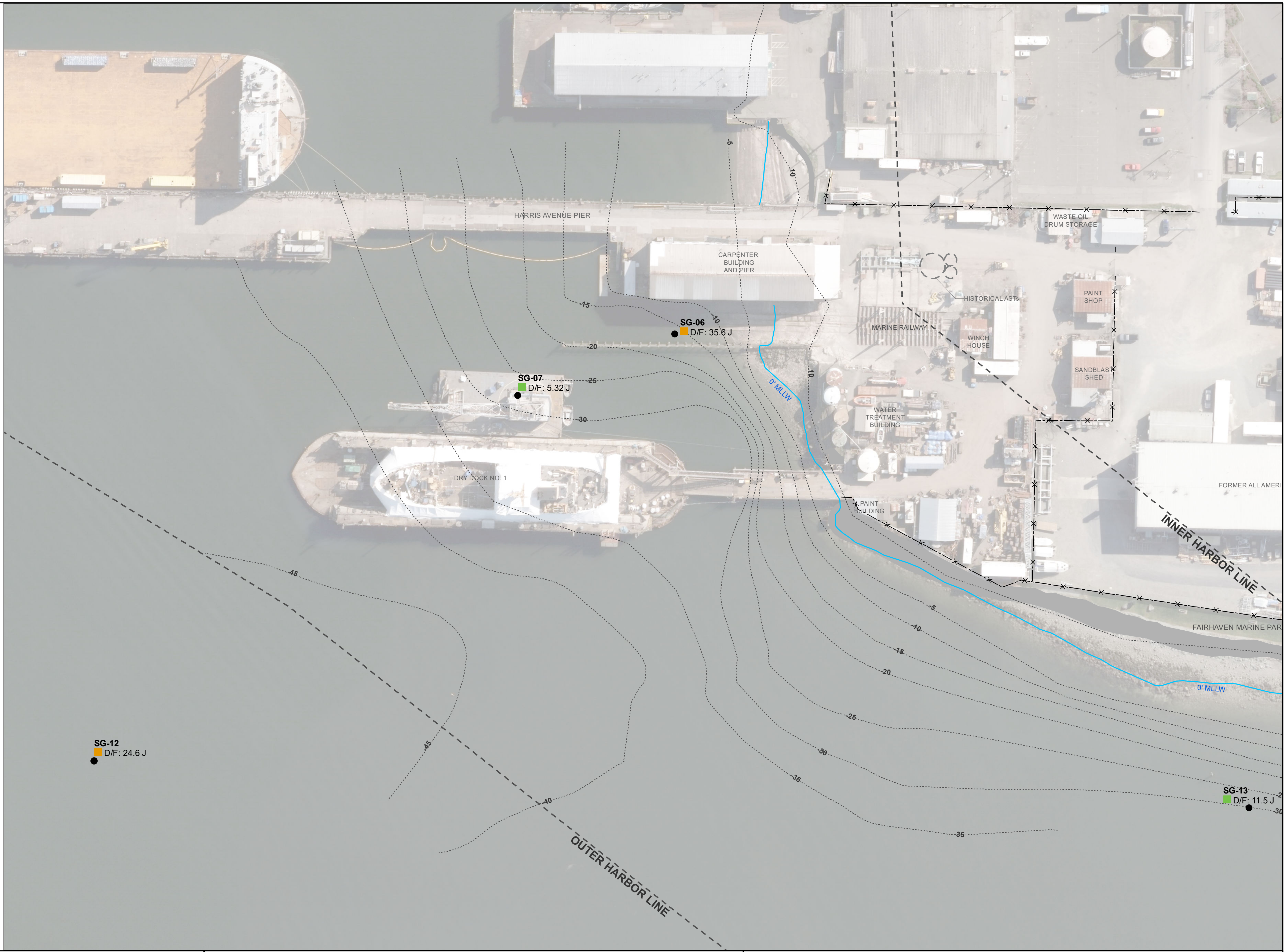

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Figure 5.5
Dioxins/Furans in Subtidal Surface Sediments

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6/7/2019

Legend

● Sediment Sample Location
🟥 Greater Than Criterion
🟩 Less Than Criterion
🟪 Not Detected
☐ Not Analyzed
1998 Bathymetry Data
Fence Line
Harbor Line
0-feet Mean Lower Low Water Level
Riprap
AOC 1

Location ID	
Analyte	**Criteria (mg/kg)**
▨ cPAH TEQ	$12^{1,2}$;4.2^{3}
▨ Fluoranthene	1.7
▨ Total PCBs	0.13
▨ Pyrene	2.6
▨ Arsenic	57^{1};20^{2};13^{3}
▨ Cadmium	5.1
▨ Copper	390
▨ Zinc	410

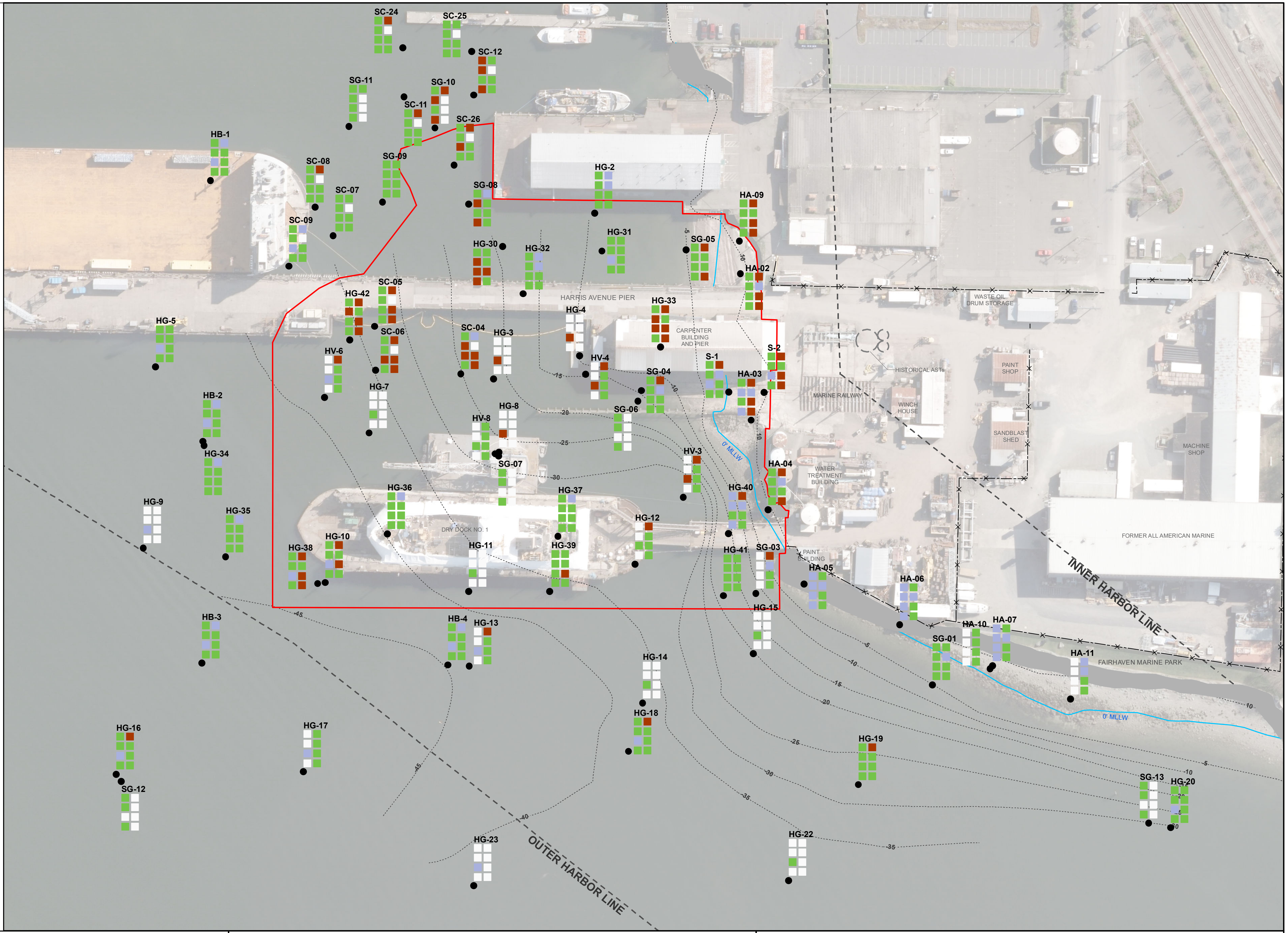
Organics		Metals
cPAH TEQ	☐☐	Arsenic
Fluroanthene	☐☐	Cadmium
Total PCBs	☐☐	Copper
Pyrene	☐☐	Zinc

Notes:
1 Beach intertidal sediment area.
2 Shipyard intertidal sediment area.
3 Subtidal sediment.

- Cleanup area has been delineated based on the eight chemicals above, but with the bounding criterion for arsenic set to 20 mg/kg rather than natural background. The arsenic criterion is based on an estimate of natural background based on deep basin sediment samples. Nearshore sediments may have a higher natural background due to arsenic geochemistry.
- Sample results are from within the 0- to 12-cm depth interval with the exceptions of S-1 and S-2 in the intertidal area, which have a bottom depth of 2 feet.
- For clarity purposes, sample locations and data collected in 2015 within the Interim Action Area are not shown unless they help define the nature and extent of contamination. All locations and data within the vicinity of the Interim Action Area are shown in the Basis of Design Report (Floyd|Snider 2017).
- Data shown represents site conditions prior to completion of the Interim Action.
- Basemap and locations of investigations prior to 2011 provided by The RETEC Group
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of concern.
AST = Above ground storage tank.
cPAH = Carcinogenic polycyclic aromatic hydrocarbon.
mg/kg = Milligrams per kilogram.
PCB = Polychlorinated biphenyl.
TEQ = Toxic equivalent.

0 55 110 220
Scale in Feet



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Harris Avenue Shipyard
Bellingham, Washington

Figure 5.6
Proposed Sediment Area of Concern – AOC 1

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.6 Proposed Sediment Area of Concern – AOC 1.mxd
6/7/2019

Legend

🟥 More Than Two Times Greater Than Criteria

🟧 Greater Than Criteria

🟩 Less Than Criteria

▨ Not Detected

⊕ Monitoring Well

1998 Bathymetry Data

Fence Line

Harbor Line

0-feet Mean Lower Low Water Level

Riprap

	Analyte	Proposed CULs (µg/L)[1]
■	Arsenic (As)	5
■	Copper (Cu)	3.1
■	Zinc (Zn)	81

Notes:
1. Proposed CULs are the lowest of the screening levels to protect surface water quality and sediment quality as modified by natural background for arsenic.
- Results shown are the average concentrations from all 2013 and 2015 sampling events.
- Results are in dissolved fraction.
- Basemap and locations of previous investigations provided by the RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- All results are reported in µg/L.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
CUL = Cleanup level.
MLLW = Mean Lower Low Water.
µg/L = Micrograms per liter.

Qualifiers:
J = The analyte was detected and the result should be considered an estimate.
U = Analyte was not detected at given reporting limit.

0 30 60 120
Scale in Feet

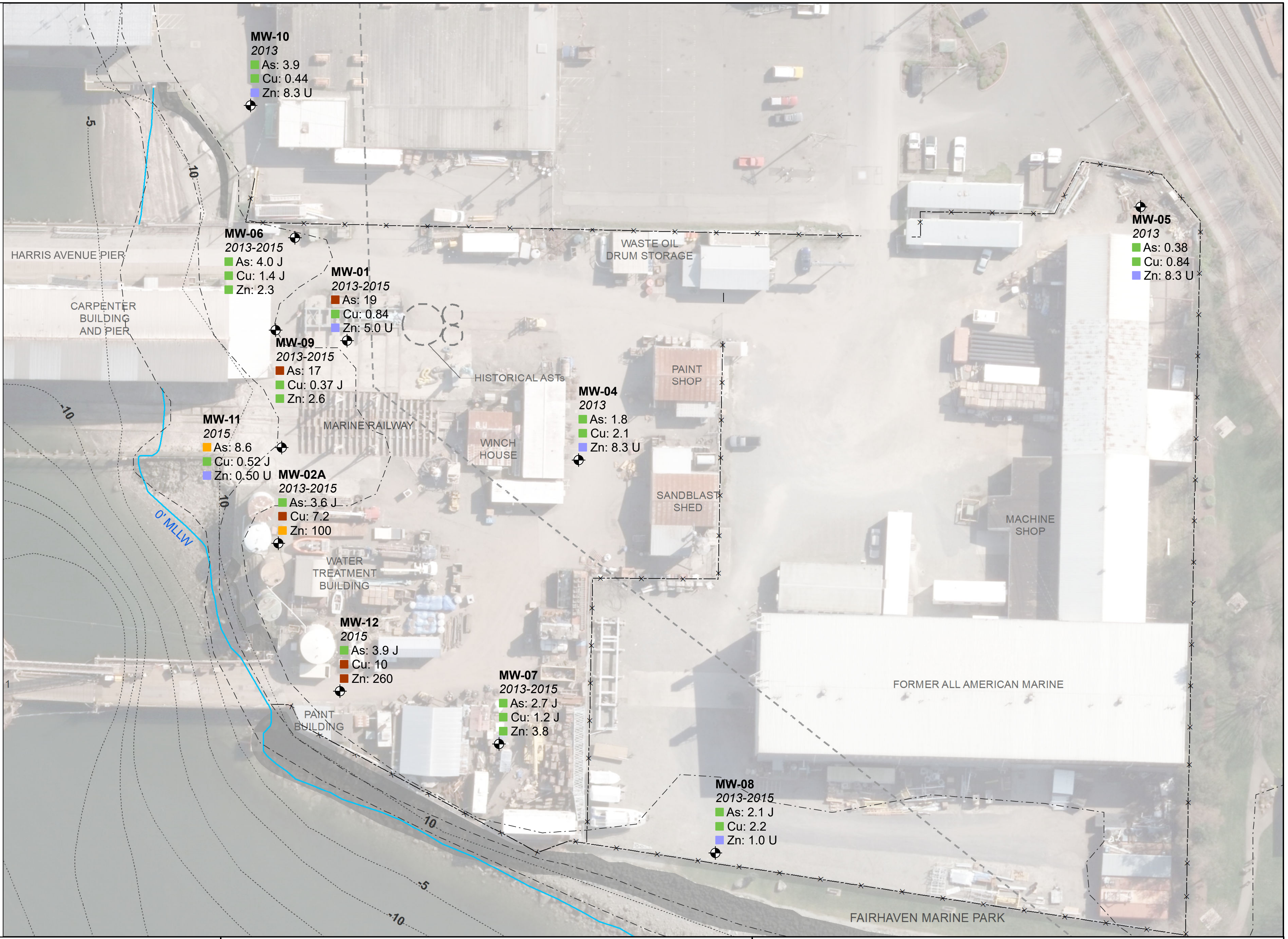

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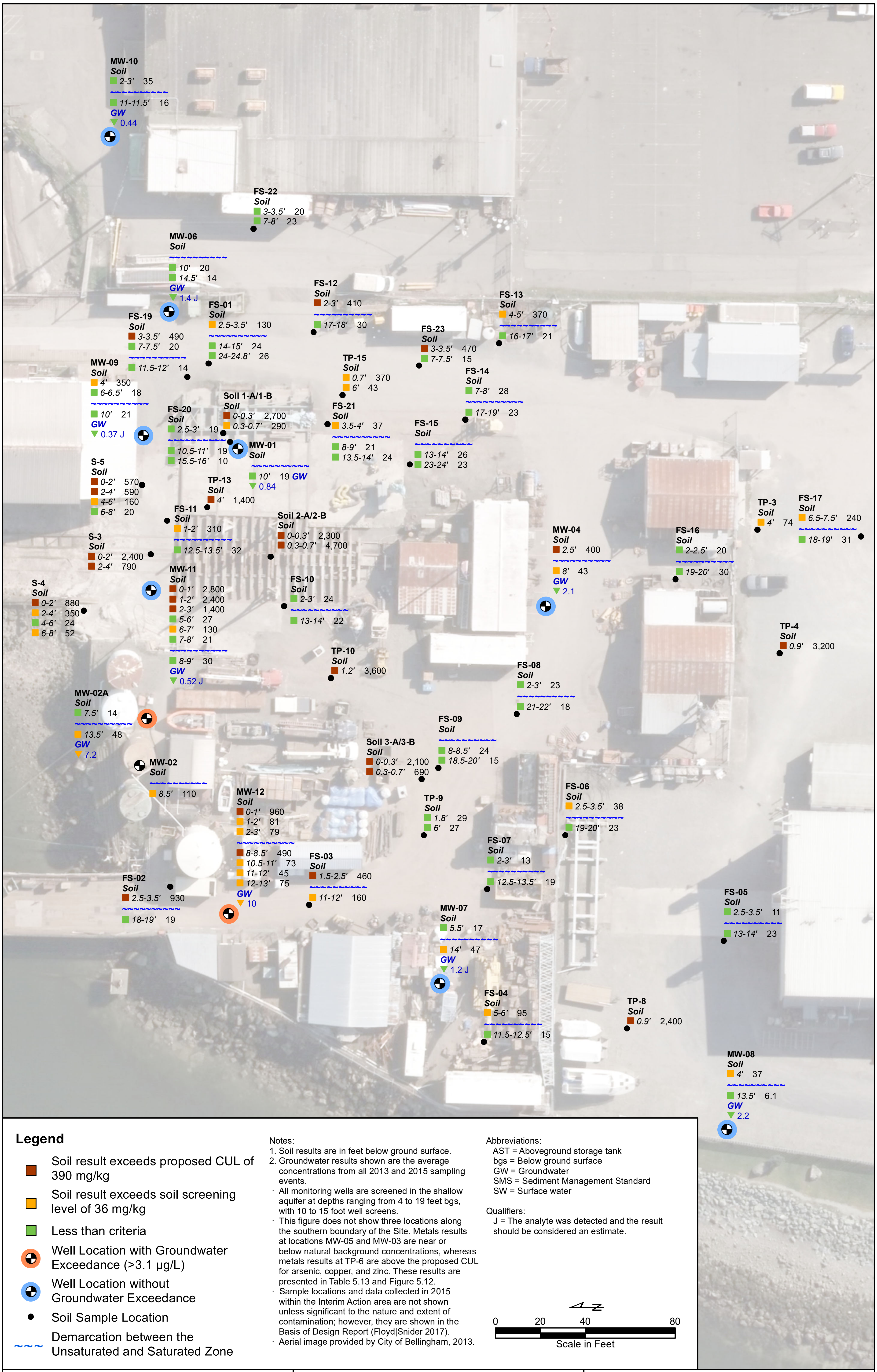
Figure 5.7
Average Arsenic, Copper, and Zinc Concentrations in Groundwater

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.7 Average Arsenic, Copper, and Zinc Concentrations in Groundwater.mxd
6/7/2019



Legend

🟥 Soil result exceeds proposed CUL of 390 mg/kg

🟧 Soil result exceeds soil screening level of 36 mg/kg

🟩 Less than criteria

⊕ Well Location with Groundwater Exceedance (>3.1 µg/L)

⊕ Well Location without Groundwater Exceedance

● Soil Sample Location

~~~ Demarcation between the Unsaturated and Saturated Zone

Notes:
1. Soil results are in feet below ground surface.
2. Groundwater results shown are the average concentrations from all 2013 and 2015 sampling events.

- All monitoring wells are screened in the shallow aquifer at depths ranging from 4 to 19 feet bgs, with 10 to 15 foot well screens.
- This figure does not show three locations along the southern boundary of the Site. Metals results at locations MW-05 and MW-03 are near or below natural background concentrations, whereas metals results at TP-6 are above the proposed CUL for arsenic, copper, and zinc. These results are presented in Table 5.13 and Figure 5.12.
- Sample locations and data collected in 2015 within the Interim Action area are not shown unless significant to the nature and extent of contamination; however, they are shown in the Basis of Design Report (Floyd|Snider 2017).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank
bgs = Below ground surface
GW = Groundwater
SMS = Sediment Management Standard
SW = Surface water

Qualifiers:
J = The analyte was detected and the result should be considered an estimate.

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Figure 5.8
Groundwater and Soil Comparison—Copper
~~~

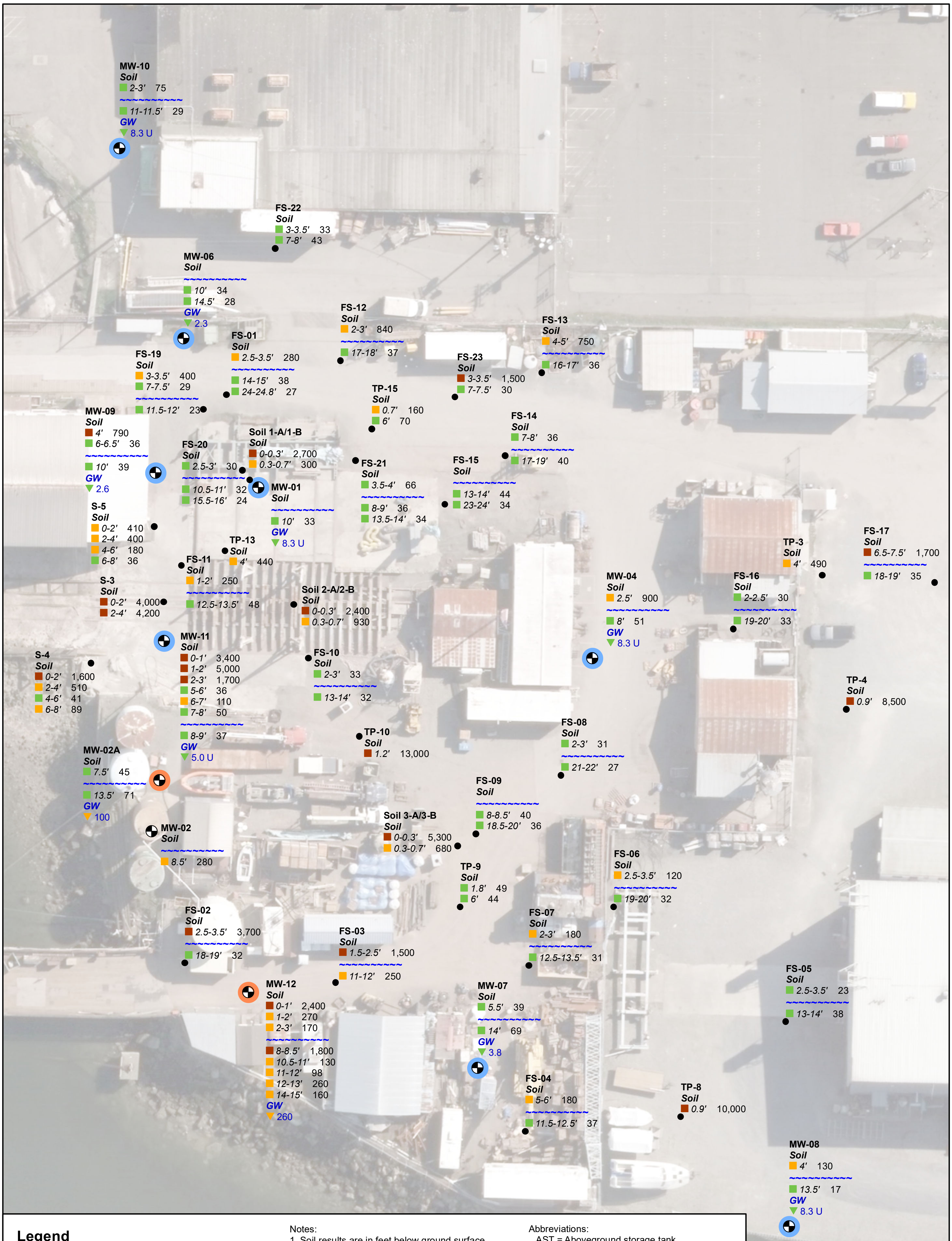

Legend

🟥 Soil result exceeds proposed CUL of 960 mg/kg

🟧 Soil result exceeds soil screening level of 85 mg/kg

🟩 Less than criteria

🟠 Well Location with Groundwater Exceedance (>81 µg/L)

🔵 Well Location without Groundwater Exceedance

● Soil Sample Location

∼∼∼ Demarcation between the Unsaturated and Saturated Zone

Notes:
1. Soil results are in feet below ground surface.
2. Groundwater results shown are the average concentrations from all 2013 and 2015 sampling events.

· All monitoring wells are screened in the shallow aquifer at depths ranging from 4 to 19 feet bgs.
· This figure does not show three locations along the southern boundary of the Site. Metals results at locations MW-05 and MW-03 are near or below natural background concentrations, whereas metals results at TP-6 are above the proposed CUL for arsenic, copper, and zinc. These results are presented in Table 5.13 and Figure 5.12.
· Sample locations and data collected in 2015 within the Interim Action area are not shown unless significant to the nature and extent of contamination; however, they are shown in the Basis of Design Report (Floyd|Snider 2017).
· Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank
bgs = Below ground surface
GW = Groundwater
SMS = Sediment Management Standard
SW = Surface water

Qualifiers:
U = Analyte is not detected at the associated reporting limit.

N

0 20 40 80

Scale in Feet

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Harris Avenue Shipyard
Bellingham, Washington

Figure 5.9
Groundwater and Soil Comparison—Zinc

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.9 Groundwater and Soil Comparison - Zinc.mxd
6/7/2019

Legend

🟥 Greater Than Proposed CUL

🟩 Less Than Proposed CUL

🟪 Not Detected

⊕ Monitoring Well

1998 Bathymetry Data

Fence Line

Harbor Line

0-feet Mean Lower Low Water Level

Riprap

Analyte	Proposed CUL (µg/L)[1]
1-Methylnaphthalene (1MN)	1.5
2-Methylnaphthalene (2MN)	32
Acenaphthene (Ace)	10
cPAH TEQ (cPAH)	0.01
Fluorene (Fluo)	5

Notes:

1. The proposed CUL is based on protection of surface water quality.

- Results shown are the average concentrations from all 2013 and 2015 sampling events.
- All results are reported in µg/L.
- Aerial image provided by City of Bellingham, 2013.

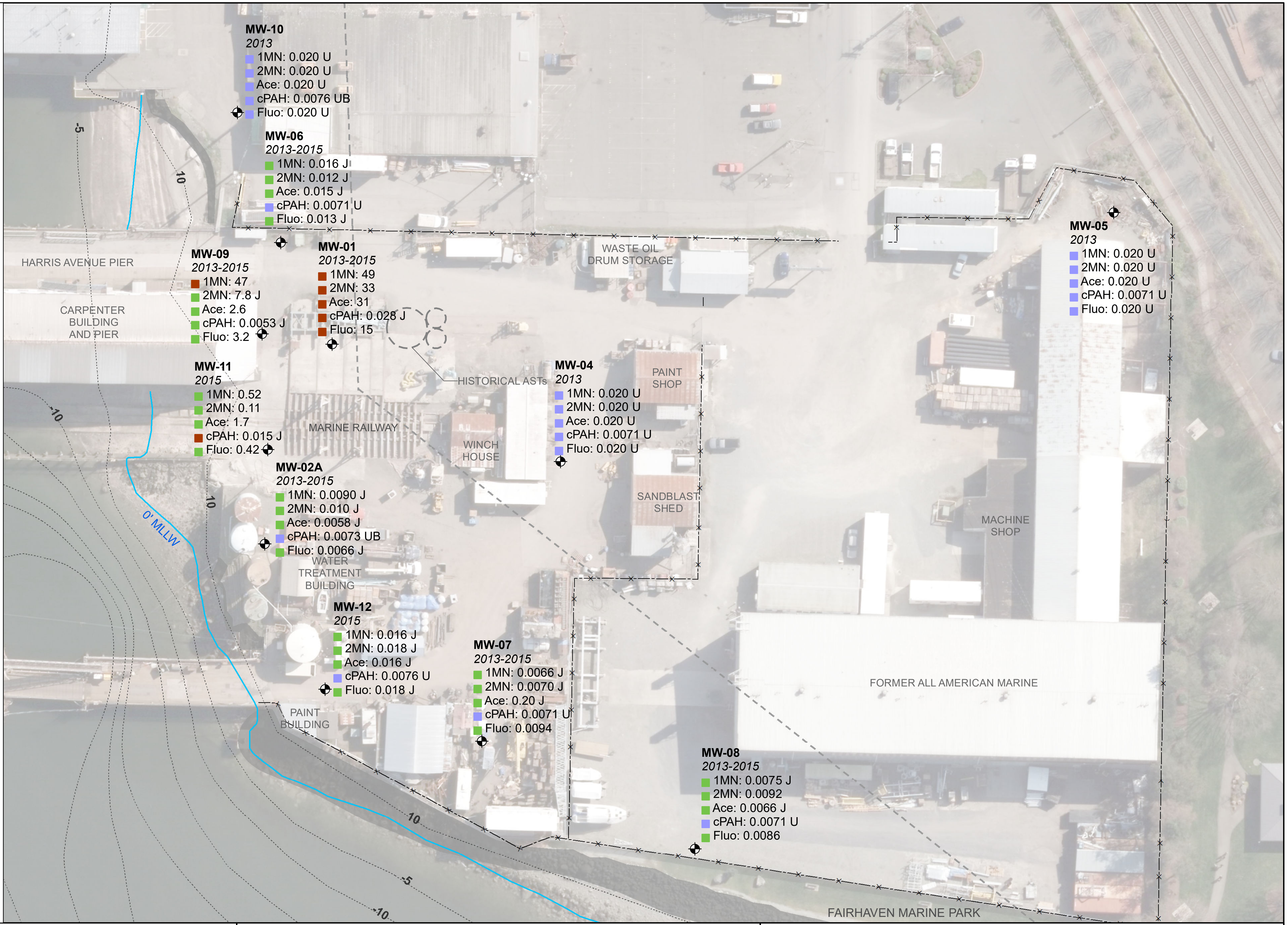
Abbreviations:

AST = Aboveground storage tank.
cPAH = Carcinogenic polycyclic aromatic hydrocarbon.
µg/L = Micrograms per liter.
MLLW = Mean Lower Low Water.
NA = Not analyzed.
TEQ = Toxic equivalent

Qualifiers:

J = The analyte was detected and the result should be considered an estimate.
U = Analyte was not detected at given reporting limit.

0 30 60 120
Scale in Feet



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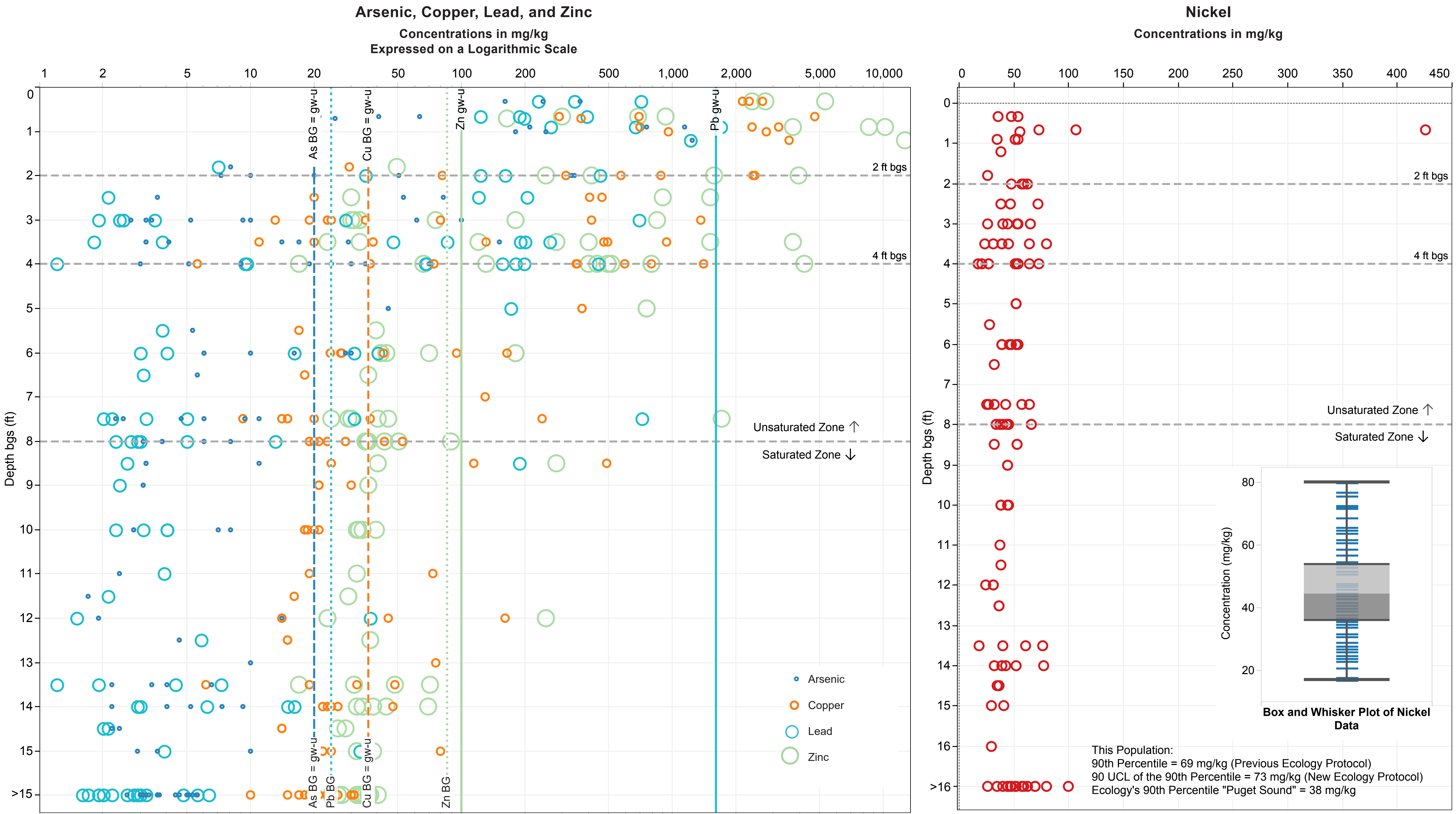
Bellingham, Washington

Figure 5.10
Average cPAH and Key LPAH Concentrations in Groundwater

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.10 cPAHs, and Key LPAHs in Groundwater.mxd
6/7/2019



This Population:
90th Percentile = 69 mg/kg (Previous Ecology Protocol)
90 UCL of the 90th Percentile = 73 mg/kg (New Ecology Protocol)
Ecology's 90th Percentile "Puget Sound" = 38 mg/kg

Dashed lines indicate natural background concentrations; solid lines indicate concentrations protective of groundwater in the unsaturated zone.

Abbreviations: As = Arsenic; BG = Background; bgs = Below ground surface; Cu = Copper; ft = Feet; gw-u = unsaturated soil to protect groundwater criteria; mg/kg = Milligrams per kilogram; UCL = Upper Confidence Limit; Zn = Zinc

Nickel displayed separately; concentrations do not indicate a release. Below 12 ft bgs many samples are in native soil representing the original glacial ridge. The box and whisker plot shows the data are normally distributed, characteristic of naturally occurring deposits. Each area of the plot represents a quartile of the data. Shaded regions show the middle half of the data; the whiskers show variability in the dataset. Three outliers are not shown in the box and whisker plot, but are shown on the chart of concentration vs. depth. Data shown represent site conditions prior to completion of the Interim Action.

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Harris Avenue Shipyard
Bellingham, Washington

Figure 5.11
Metal Concentrations by Depth in Soil

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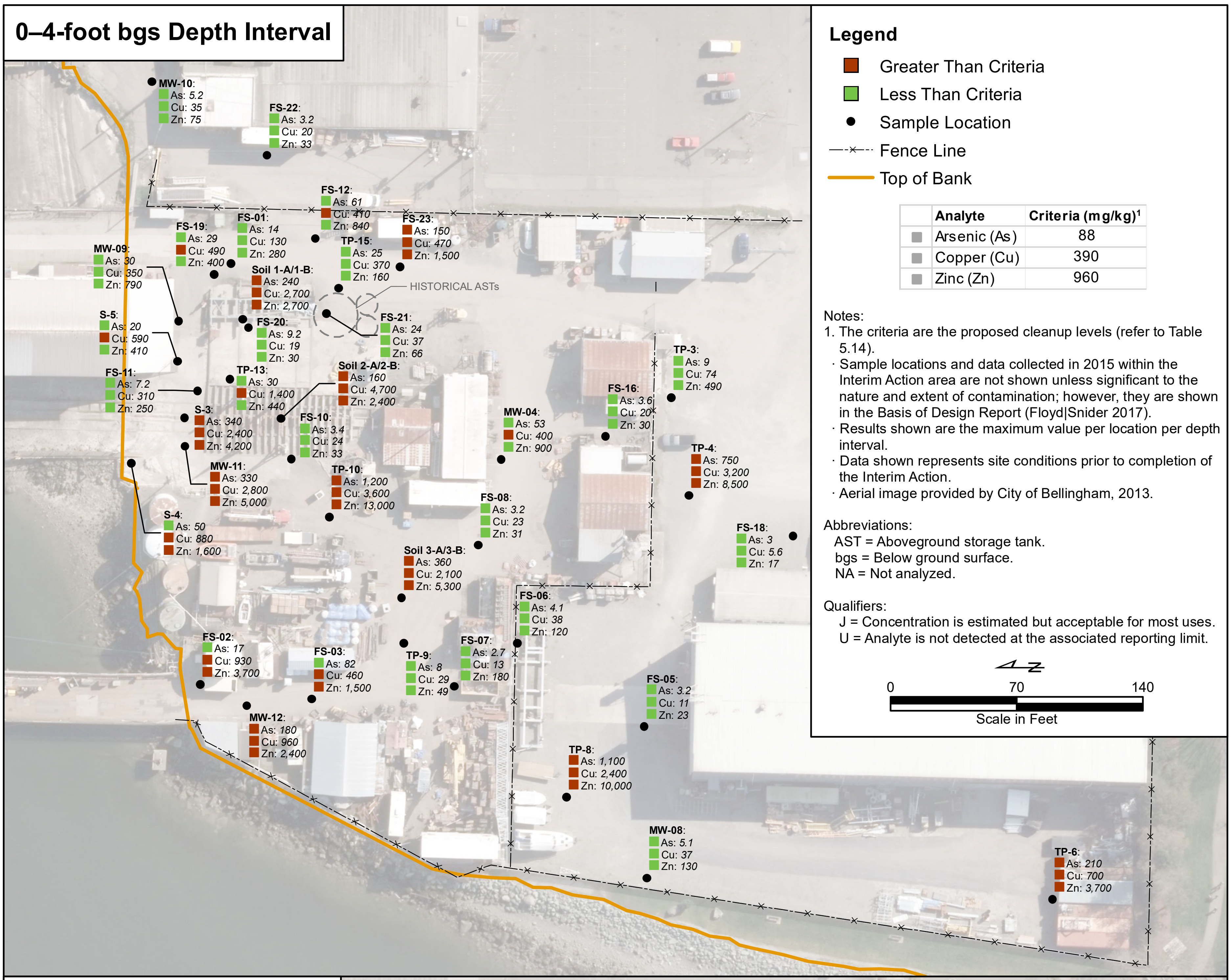
08/28/2018



0–4-foot bgs Depth Interval

Legend

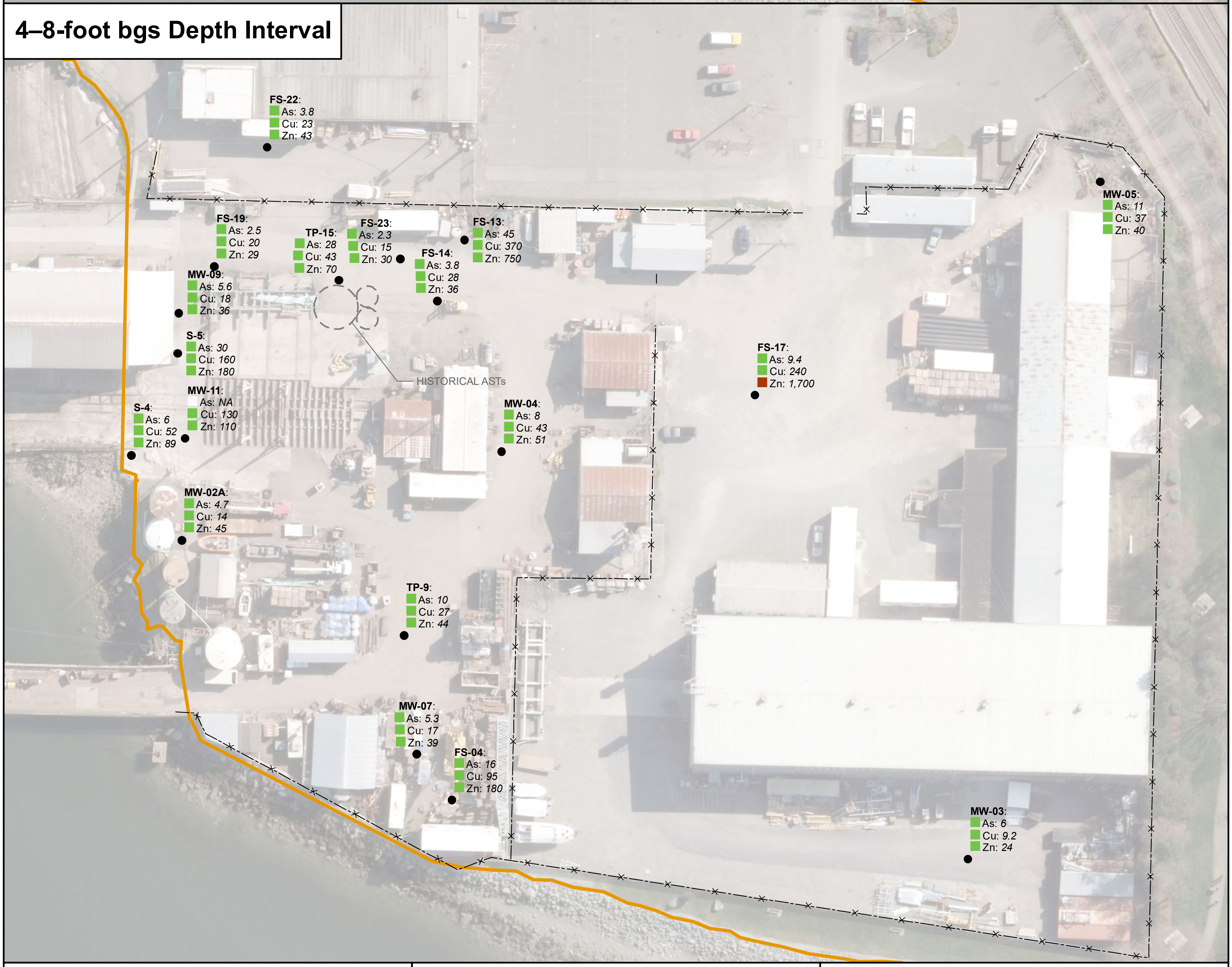
🟥 Greater Than Criteria
🟩 Less Than Criteria
● Sample Location
—·×·— Fence Line
— Top of Bank

	Analyte	Criteria (mg/kg)[1]
■	Arsenic (As)	88
■	Copper (Cu)	390
■	Zinc (Zn)	960

Notes:
1. The criteria are the proposed cleanup levels (refer to Table 5.14).
- Sample locations and data collected in 2015 within the Interim Action area are not shown unless significant to the nature and extent of contamination; however, they are shown in the Basis of Design Report (Floyd|Snider 2017).
- Results shown are the maximum value per location per depth interval.
- Data shown represents site conditions prior to completion of the Interim Action.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
bgs = Below ground surface.
NA = Not analyzed.

Qualifiers:
J = Concentration is estimated but acceptable for most uses.
U = Analyte is not detected at the associated reporting limit.



4–8-foot bgs Depth Interval

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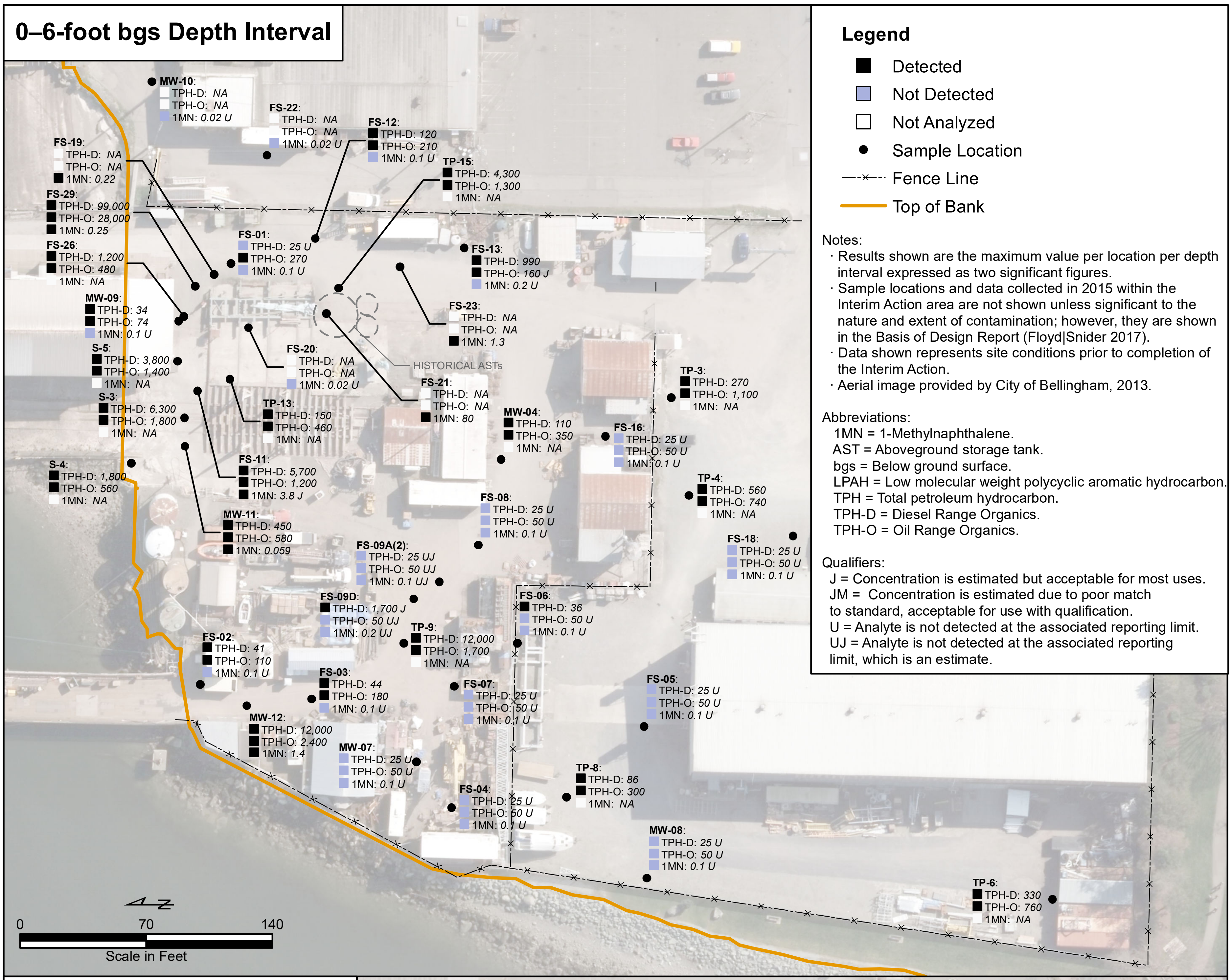
Figure 5.12
Arsenic, Copper, and Zinc
in Unsaturated Soils

0–6-foot bgs Depth Interval



Legend

■ Detected
▨ Not Detected
☐ Not Analyzed
● Sample Location
—x— Fence Line
— Top of Bank

Notes:

- Results shown are the maximum value per location per depth interval expressed as two significant figures.
- Sample locations and data collected in 2015 within the Interim Action area are not shown unless significant to the nature and extent of contamination; however, they are shown in the Basis of Design Report (Floyd|Snider 2017).
- Data shown represents site conditions prior to completion of the Interim Action.
- Aerial image provided by City of Bellingham, 2013.

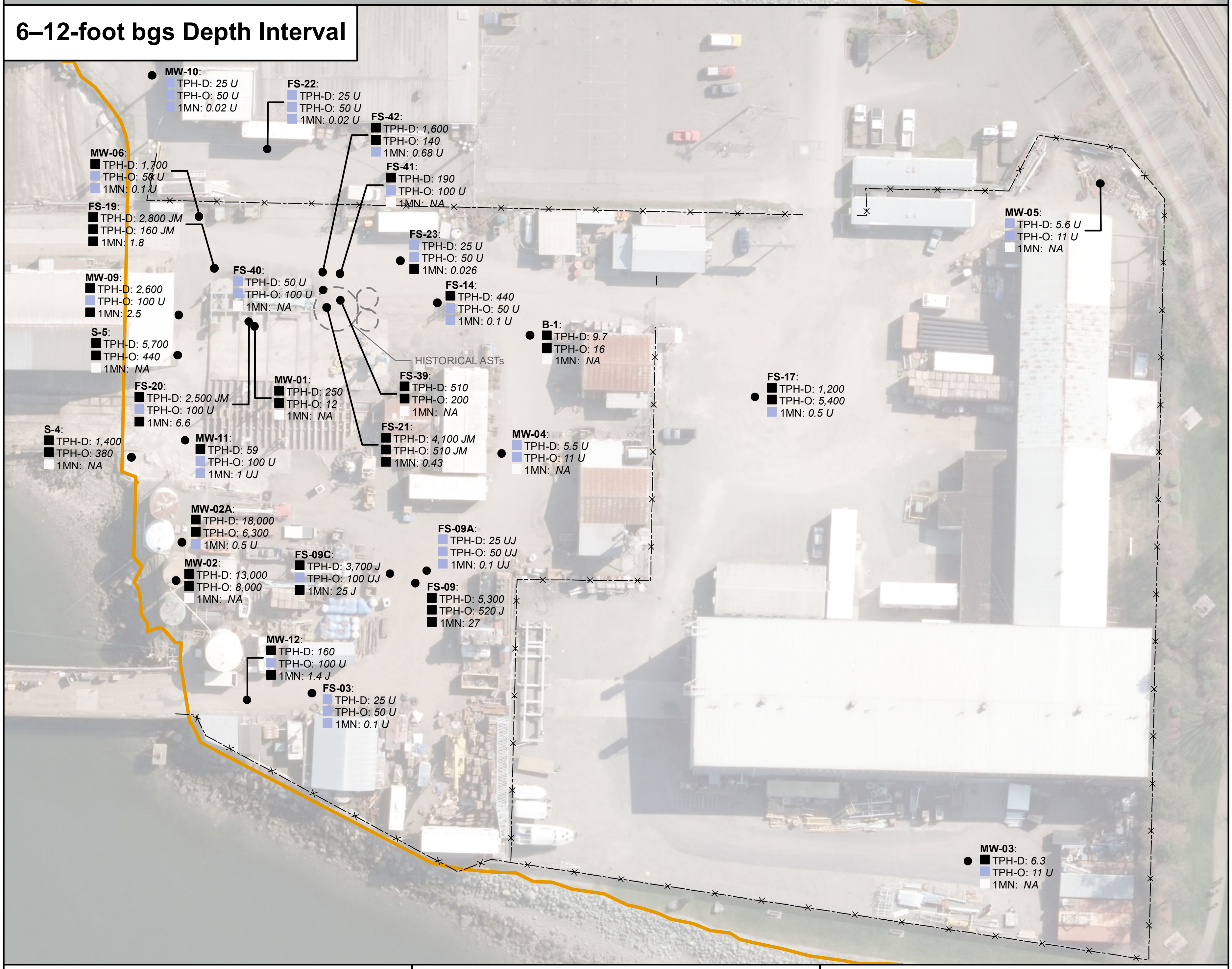
Abbreviations:

1MN = 1-Methylnaphthalene.
AST = Aboveground storage tank.
bgs = Below ground surface.
LPAH = Low molecular weight polycyclic aromatic hydrocarbon.
TPH = Total petroleum hydrocarbon.
TPH-D = Diesel Range Organics.
TPH-O = Oil Range Organics.

Qualifiers:

J = Concentration is estimated but acceptable for most uses.
JM = Concentration is estimated due to poor match to standard, acceptable for use with qualification.
U = Analyte is not detected at the associated reporting limit.
UJ = Analyte is not detected at the associated reporting limit, which is an estimate.

6–12-foot bgs Depth Interval



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Harris Avenue Shipyard
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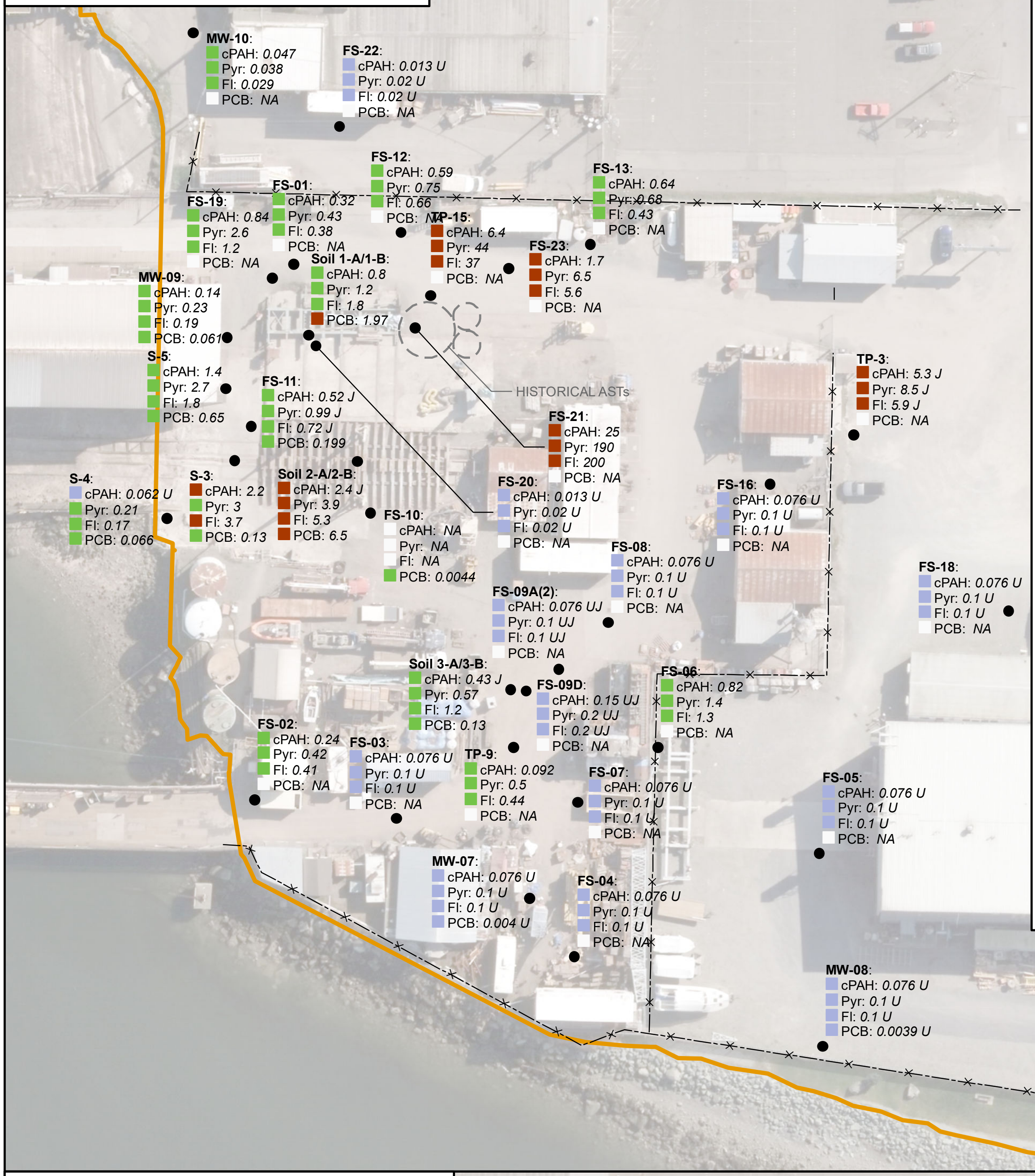
Figure 5.13
TPH and Key LPAH Concentrations in Unsaturated and Water Table Zone Soils

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.13 TPH and Key LPAH Concentrations in Unsaturated and Water Table Zone Soils.mxd
6/7/2019

0–6-foot bgs Depth Interval



Legend

- 🟥 Greater Than Criteria
- 🟩 Less Than Criteria
- 🟦 Not Detected
- ☐ Not Analyzed
- —·×·— Fence Line
- ━ Top of Bank

	Analyte	Criteria[1] (mg/kg)
■	cPAH TEQ 1/2 ND (cPAH)	1.4
■	Pyrene (Pyr)	3.3
■	Fluoranthene (Fluo)	2.5
■	Total PCBs (PCB)	1

Notes:
1. The criteria are the proposed cleanup levels (see Table 5.14).
 · Sample locations and data collected in 2015 within the Interim Action area are not shown unless significant to the nature and extent of contamination; however, they are shown in the Basis of Design Report (Floyd|Snider 2017).
 · Data shown represents site conditions prior to completion of the Interim Action.
 · Results shown are the maximum value per location per depth interval.
 · Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
bgs = below ground surface.

Qualifiers:
J = Concentration is estimated but acceptable for most uses.
U = Analyte is not detected at the associated reporting limit.

0 70 140
Scale in Feet

6–12-foot bgs Depth Interval

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Harris Avenue Shipyard
Bellingham, Washington

Figure 5.14
cPAH, HPAHs, and Total PCB Concentrations in Unsaturated and Water Table Zone Soils

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.14 cPAH, HPAHs, and Total PCB Concentrations in Unsaturated and Water Table Zone Soils.mxd
6/7/2019

Legend

- ●/🟥 Greater Than Criteria
- ●/🟩 Less Than Criteria
- ▭ Area of Concern[2,3]
- 1998 Bathymetry Data
- Fence Line
- Harbor Line
- 0-feet Mean Lower Low Water Level
- Marine Park Boundary
- Riprap

	Soil CUL	
	Chemical	**Criteria[1] (mg/kg)**
▨	Arsenic (As)	88
▨	Copper (Cu)	360
▨	Zinc (Zn)	960

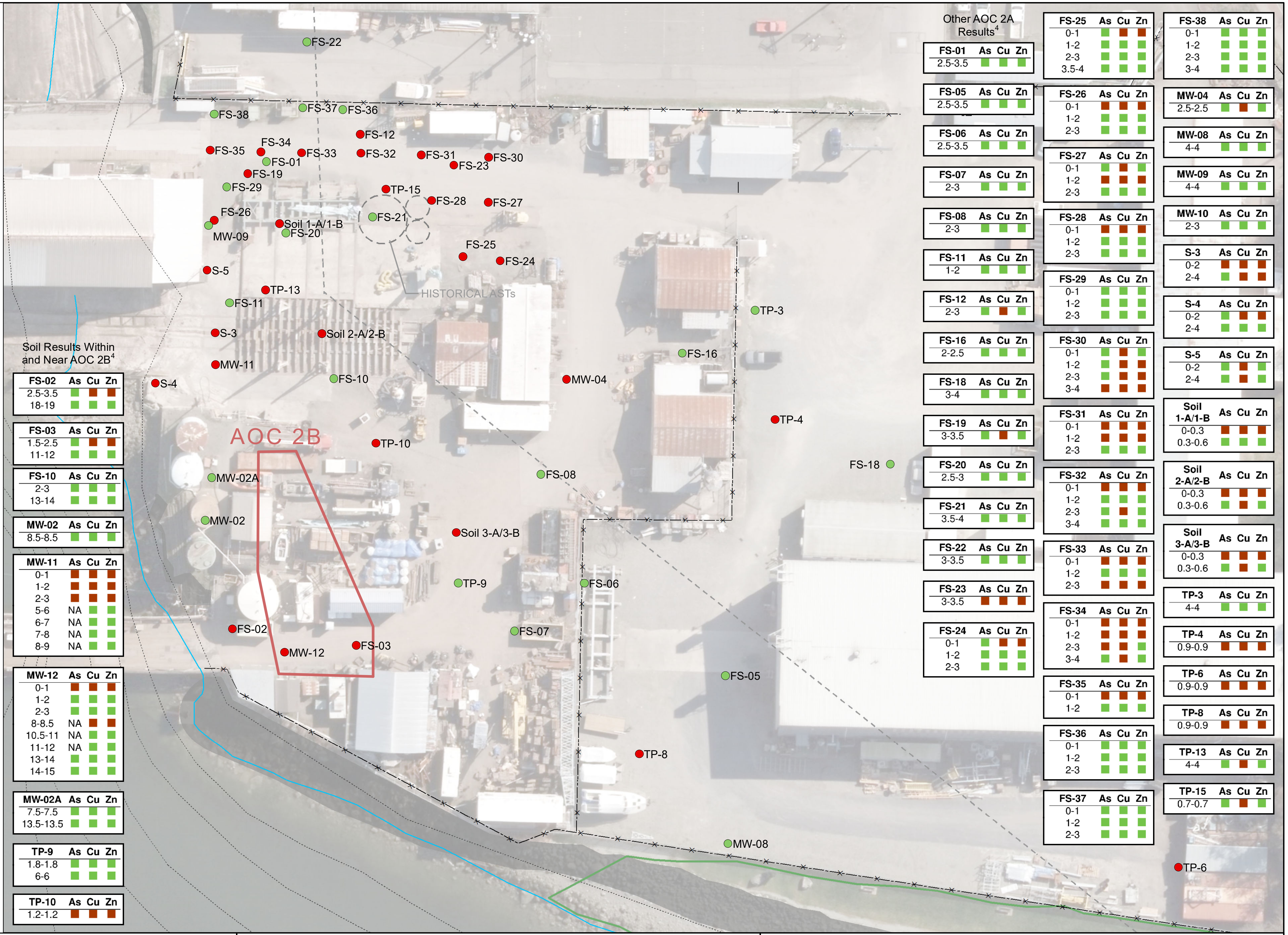
Notes:

1. Criteria are the proposed CULs. Proposed CUL for arsenic is based on the direct contact criterion protective of industrial workers for all pathways. Proposed CULs for copper and zinc are based on the SMS CSL. Refer to Section 5.4.1 for details.
2. AOC 2A addresses the direct contact pathway and the soil to protect groundwater pathway for arsenic in surface soils (i.e., soils from 0—4 feet bgs). A boundary for AOC 2A is not shown on this figure because AOC 2A is diffuse across the Site.
3. AOC 2B addresses the soil to protect groundwater pathway for metals (copper and zinc) that may be negatively impacting groundwater quality at MW-02A and MW-12. AOB 2B due to being in AOC 2A also addresses the direct contact pathway for arsenic in surface soils (i.e., soils from 0—4 feet bgs).
4. Results are expressed to two significant figures. In the vicinity of AOC 2B (i.e., within the boundaries of AOC 2B and within a 50 foot buffer surrounding AOC 2B), metals results at all depths are shown. Soil deeper than 4 feet bgs elsewhere at the site are either in compliance with proposed CULs, or do not negatively impact groundwater at the groundwater point of compliance. Within AOC 2A, only arsenic data collected within the top 4 feet of soil are shown.

- · Basemap and locations of previous investigations provided by the RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- · Data shown represents site conditions prior to completion of the Interim Action.
- · All sample depths are in feet bgs unless otherwise noted.
- · Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
bgs = Below ground surface.
CUL = Cleanup Level.
mg/kg = Milligrams per kilogram.

0 25 50 100
Scale in Feet



Soil Results Within and Near AOC 2B[4]

FS-02	As	Cu	Zn
2.5-3.5	🟩	🟥	🟥
18-19	🟩	🟩	🟩

FS-03	As	Cu	Zn
1.5-2.5	🟩	🟥	🟥
11-12	🟩	🟩	🟩

FS-10	As	Cu	Zn
2-3	🟩	🟩	🟩
13-14	🟩	🟩	🟩

MW-02	As	Cu	Zn
8.5-8.5	🟩	🟩	🟩

MW-11	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟥	🟥	🟥
2-3	🟥	🟥	🟥
5-6	NA	🟩	🟩
6-7	NA	🟩	🟩
7-8	NA	🟩	🟩
8-9	NA	🟩	🟩

MW-12	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩
8-8.5	NA	🟥	🟥
10.5-11	NA	🟩	🟩
11-12	NA	🟩	🟩
13-14	🟩	🟩	🟩
14-15	🟩	🟩	🟩

MW-02A	As	Cu	Zn
7.5-7.5	🟩	🟩	🟩
13.5-13.5	🟩	🟩	🟩

TP-9	As	Cu	Zn
1.8-1.8	🟩	🟩	🟩
6-6	🟩	🟩	🟩

TP-10	As	Cu	Zn
1.2-1.2	🟥	🟥	🟥

Other AOC 2A Results[4]

FS-01	As	Cu	Zn
2.5-3.5	🟩	🟩	🟩

FS-05	As	Cu	Zn
2.5-3.5	🟩	🟩	🟩

FS-06	As	Cu	Zn
2.5-3.5	🟩	🟩	🟩

FS-07	As	Cu	Zn
2-3	🟩	🟩	🟩

FS-08	As	Cu	Zn
2-3	🟩	🟩	🟩

FS-11	As	Cu	Zn
1-2	🟩	🟩	🟩

FS-12	As	Cu	Zn
2-3	🟩	🟥	🟩

FS-16	As	Cu	Zn
2-2.5	🟩	🟩	🟩

FS-18	As	Cu	Zn
3-4	🟩	🟩	🟩

FS-19	As	Cu	Zn
3-3.5	🟩	🟥	🟩

FS-20	As	Cu	Zn
2.5-3	🟩	🟩	🟩

FS-21	As	Cu	Zn
3.5-4	🟩	🟩	🟩

FS-22	As	Cu	Zn
3-3.5	🟩	🟩	🟩

FS-23	As	Cu	Zn
3-3.5	🟥	🟥	🟥

FS-24	As	Cu	Zn
0-1	🟩	🟥	🟥
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩

FS-25	As	Cu	Zn
0-1	🟩	🟥	🟥
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩
3.5-4	🟩	🟩	🟩

FS-26	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩

FS-27	As	Cu	Zn
0-1	🟩	🟥	🟩
1-2	🟥	🟥	🟥
2-3	🟩	🟩	🟩

FS-28	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩

FS-29	As	Cu	Zn
0-1	🟩	🟩	🟩
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩

FS-30	As	Cu	Zn
0-1	🟩	🟥	🟩
1-2	🟩	🟥	🟥
2-3	🟩	🟥	🟥
3-4	🟥	🟥	🟥

FS-31	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟥	🟥	🟥
2-3	🟩	🟩	🟩

FS-32	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟩	🟩	🟩
2-3	🟩	🟥	🟩
3-4	🟩	🟩	🟩

FS-33	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟩	🟩	🟩
2-3	🟥	🟥	🟥

FS-34	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟥	🟥	🟥
2-3	🟥	🟥	🟩
3-4	🟩	🟥	🟩

FS-35	As	Cu	Zn
0-1	🟥	🟥	🟥
1-2	🟩	🟩	🟩

FS-36	As	Cu	Zn
0-1	🟩	🟩	🟩
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩

FS-37	As	Cu	Zn
0-1	🟩	🟩	🟩
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩

FS-38	As	Cu	Zn
0-1	🟩	🟩	🟩
1-2	🟩	🟩	🟩
2-3	🟩	🟩	🟩
3-4	🟩	🟩	🟩

MW-04	As	Cu	Zn
2.5-2.5	🟩	🟥	🟩

MW-08	As	Cu	Zn
4-4	🟩	🟩	🟩

MW-09	As	Cu	Zn
4-4	🟩	🟩	🟩

MW-10	As	Cu	Zn
2-3	🟩	🟩	🟩

S-3	As	Cu	Zn
0-2	🟥	🟥	🟥
2-4	🟩	🟥	🟥

S-4	As	Cu	Zn
0-2	🟩	🟥	🟥
2-4	🟩	🟩	🟩

S-5	As	Cu	Zn
0-2	🟩	🟥	🟩
2-4	🟩	🟥	🟩

Soil 1-A/1-B	As	Cu	Zn
0-0.3	🟥	🟥	🟥
0.3-0.6	🟩	🟩	🟩

Soil 2-A/2-B	As	Cu	Zn
0-0.3	🟥	🟥	🟥
0.3-0.6	🟩	🟥	🟩

Soil 3-A/3-B	As	Cu	Zn
0-0.3	🟥	🟥	🟥
0.3-0.6	🟩	🟥	🟩

TP-3	As	Cu	Zn
4-4	🟩	🟩	🟩

TP-4	As	Cu	Zn
0.9-0.9	🟥	🟥	🟥

TP-6	As	Cu	Zn
0.9-0.9	🟥	🟥	🟥

TP-8	As	Cu	Zn
0.9-0.9	🟥	🟥	🟥

TP-13	As	Cu	Zn
4-4	🟩	🟥	🟩

TP-15	As	Cu	Zn
0.7-0.7	🟩	🟥	🟩

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Harris Avenue Shipyard
Bellingham, Washington

Figure 5.15
Proposed Soil Area of Concern for Metals – AOC 2A and AOC 2B

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.15 Proposed Soil Area of Concern for Metals - AOC 2A and AOC 2B.mxd
6/7/2019

Legend

🟥 TPH Soil Concentration Exceeds CUL[1,2]

🟩 TPH Soil Concentration does Not Exceed CUL[1,2]

🟦 TPH Soil Concentrations were Not Detected.

▭ Area of Concern

1998 Bathymetry Data

—×— Fence Line

- - - Harbor Line

〜 0-feet Mean Lower Low Water Level

▭ Marine Park Boundary

Riprap

Soil CUL	
Area	**Criteria[1] (mg/kg)**
Inside AOC 3 and 20' Buffer	8,000
Outside AOC3 and 20' Buffer	24,000

Notes:
1. Proposed CUL for TPH is 8,000 mg/kg within AOC 3 (with a 20-foot buffer), and 24,000 mg/kg outside AOC 3.
2. Results are expressed to two significant figures.
- The TPH criteria when diesel is present is based on site-specific protection of groundwater quality (refer to text for details).
- AOC 2 addresses arsenic for the direct contact pathway. It is not shown on this figure because it is diffuse across the Site.
- In areas where TPH is a heavy oil, the soil CUL is 24,000 mg/kg to protect workers from direct contact and the POC is 0 to 15 ft bgs.
- TPH is the sum of diesel-range and oil-range concentrations. Gasoline-range concentrations are not a concern at the Site and any gasoline-range concentrations detected are low boiling fraction of diesel No. 2 and/or kerosene.
- Basemap and locations of previous investigations provided by the RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- All results reported as mg/kg.
- All sample depths are in feet bgs.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
bgs = Below ground surface.
CUL = Cleanup Level.
mg/kg = Milligrams per kilogram.
TPH = Total petroleum hydrocarbons.

Qualifiers:
J = Concentration is estimated but acceptable for most uses.
JM = Concentration is estimated due to poor match to standard, acceptable for use with qualification.
U = Analyte was not detected at given reporting limit.

Results From Inside 20' AOC 3 Buffer[2]

FS-01		**TPH**	
2.5-3.5	🟩	270	
14-15	🟩	190	
24-24.8	🟩	230	
24.8-25	🟩	78	

FS-11		**TPH**	
1-2	🟩	6,900	
12.5-13.5	🟦	25	U

FS-12		**TPH**	
2-3	🟩	330	
17-18	🟦	25	U

FS-19		**TPH**	
7-7.5	🟩	3,000	JM
11.5-12	🟦	25	U
27-27.5	🟦	25	U

FS-20		**TPH**	
10.5-11	🟩	2,500	JM
15.5-16	🟦	25	U

FS-21		**TPH**	
8-9	🟩	4,600	JM
13.5-14	🟩	5,600	JM
22-22.5	🟦	25	U

FS-26		**TPH**	
2-3	🟩	250	
3-4	🟩	1,700	

FS-29		**TPH**	
3-4	🟥	130,000	

FS-39		**TPH**	
9-10	🟦	50	U
10-10.5	🟦	50	U
10.5-11	🟩	710	
11-12	🟦	50	U

FS-40		**TPH**	
9-10	🟦	50	U
10-10.5	🟦	50	U
10.5-11	🟩	44	
11-12	🟦	50	U

FS-41		**TPH**	
9-10	🟦	50	U
10-10.5	🟦	50	U
10.5-11	🟦	50	U
11-12	🟩	210	

FS-42		**TPH**	
9-10	🟩	1,700	
10-10.5	🟩	420	
11-12	🟩	22	

MW-01		**TPH**	
10	🟩	260	

MW-06		**TPH**	
10	🟩	1,700	
14.5	🟦	25	U

MW-09		**TPH**	
4	🟩	110	
6-6.5	🟩	2,600	
10	🟦	25	U

S-5		**TPH**	
0-2	🟩	340	
2-4	🟩	5,200	
4-6	🟩	3,300	
6-8	🟩	6,100	

TP-13		**TPH**	
4	🟩	610	

TP-15		**TPH**	
0.7	🟩	5,600	
6	🟩	4,300	

Results From Outside 20' AOC 3 Buffer[2]

FS-02		**TPH**	
2.5-3.5	🟩	150	
18-19	🟦	25	U

FS-03		**TPH**	
1.5-2.5	🟩	220	
11-12	🟦	25	U

FS-04		**TPH**	
5-6	🟦	25	U
11.5-12.5	🟦	25	U

FS-06		**TPH**	
2.5-3.5	🟩	36	
19-20	🟦	25	U

FS-07		**TPH**	
2-3	🟦	25	U
12.5-13.5	🟦	25	U

S-3		**TPH**	
0-2	🟩	3,700	
2-4	🟩	8,100	

FS-08		**TPH**	
2-3	🟦	25	U
21-22	🟦	25	U

FS-09		**TPH**	
8-8.5	🟩	5,800	J
18.5-20	🟦	25	U

FS-09A(2)		**TPH**	
5-6	🟦	25	U
14-15	🟦	25	U

FS-09A		**TPH**	
6-7	🟦	25	U

FS-09B		**TPH**	
14-15	🟦	25	U

FS-09C		**TPH**	
8.5-9.5	🟩	3,700	J

FS-09D		**TPH**	
5-6	🟩	1,700	J

FS-10		**TPH**	
13-14	🟦	25	U

FS-13		**TPH**	
4-5	🟩	1,200	J
16-17	🟦	25	U

FS-14		**TPH**	
7-8	🟩	440	
17-19	🟦	25	U

FS-15		**TPH**	
13-14	🟩	950	
23-24	🟦	25	U

FS-22		**TPH**	
7-8	🟦	25	U

FS-23		**TPH**	
7-7.5	🟦	25	U

MW-02		**TPH**	
8.5	🟩	21,000	

MW-02A		**TPH**	
7.5	🟩	24,000	
13.5	🟩	25	U

MW-04		**TPH**	
2.5	🟩	460	
8	🟦	5.5	U

MW-07		**TPH**	
5.5	🟦	25	U
14	🟦	25	U

MW-11		**TPH**	
1-2	🟩	1,000	
5-6	🟦	50	U
6-7	🟩	130	
7-8	🟦	50	U
8-9	🟦	50	U

MW-12		**TPH**	
1-2	🟩	57	
4-5	🟩	14,000	
8-8.5	🟦	50	U
10.5-11	🟩	220	
11-12	🟩	97	
13-14	🟩	49	

S-4		**TPH**	
0-2	🟩	1,100	
2-4	🟩	2,400	
4-6	🟩	17	
6-8	🟩	1,800	

TP-9		**TPH**	
1.8	🟩	14,000	
6	🟩	2,600	

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Figure 5.16
Proposed Soil Area of Concern for TPH – AOC 3

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 5.16 Proposed Soil Area of Concern for Protection of Groundwater from TPH Impacts - AOC 3.mxd
6/7/2019

Legend
Soil and Groundwater Alternative 1

▨	**Interim Action** · AOC 2A · AOC 3	*Completed in 2018. Excavation to CULs with upland landfill disposal of excavated materials. Overlain by gravel surface.*
🟦	**6-Inch Excavation** · AOC 2A · AOC 2B	*Excavation of 6 inches of surface material in unpaved areas with placement of geotextile and gravel cap.*
▨	**Protect Existing Structures** · AOC 2A · AOC 2B · AOC 3	*Existing buildings and pavement to remain.*

● Compliance Monitoring Well

□ Area of Concern

-x- Fence Line

- - - - Harbor Line

Notes:
- Institutional controls will require industrial land use and an Operations, Maintenance, and Monitoring Plan.
- Implementation of the remedy may be phased to minimize interruptions to shipyard operations.
- Basemap and locations of previous investigation provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
CUL = Cleanup level.

0 30 60 120
Scale in Feet

N

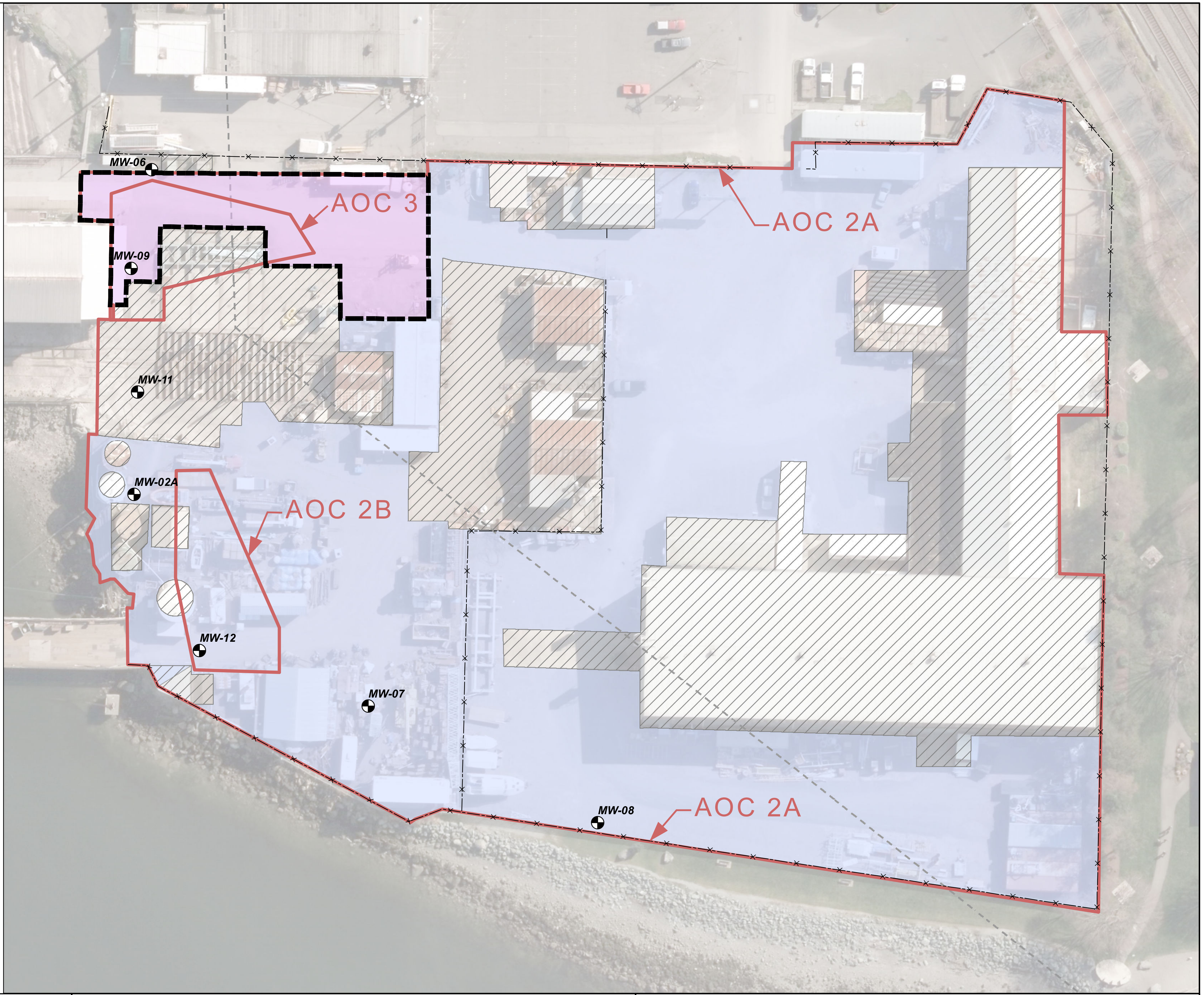

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Figure 9.1
Soil and Groundwater Alternative 1 – Remedy Components

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 9.1 Soil and Groundwater Alternative 1 - Remedy Components.mxd
6/7/2019

Legend
Soil and Groundwater Alternative 2

▨	**Interim Action** · AOC 2A · AOC 3	*Completed in 2018. Excavation to CULs with upland landfill disposal of excavated materials. Overlain by gravel surface.*
🟫	**Excavate and Place Gravel or Asphalt Cap** · AOC 2A · AOC 2B	*Excavate 2 feet bgs and place gravel cap or excavate 1 foot bgs and place asphalt cap. Installation of stormwater conveyance system where necessary.*
🟩	**Contingency Bioremediation** · AOC 3	*Apply contingency bioremediation amendment based on results of compliance groundwater monitoring.*
▩	**Deeper Soil Excavation** · AOC 2B	*Excavate deeper contaminated soil based on results of remedial design sampling. Soil solidification amendment at base of excavation may be required.*
▨	**Protect Existing Structures** · AOC 2A · AOC 2B · AOC 3	*Existing buildings and pavement to remain.*

●	Compliance Monitoring Well	-·-×--	Fence Line
🟥	Area of Concern	- - - -	Harbor Line

Notes:
- Institutional controls will require industrial land use and an Operations, Maintenance, and Monitoring Plan.
- Implementation of the remedy may be phased to minimize interruptions to shipyard operations.
- Basemap and locations of previous investigation provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
bgs = below ground surface.
CUL = Cleanup level.

0 30 60 120
Scale in Feet

N

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Bellingham, Washington

Figure 9.2
Soil and Groundwater Alternative 2 – Remedy Components

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6/7/2019

Legend

Soil and Groundwater Alternative 3

▨	**Interim Action** · AOC 2A · AOC 3	*Completed in 2018. Excavation to CULs with upland landfill disposal of excavated materials. Backfilled with clean fill overlain by gravel surface.*
🟦	**Full Excavation to CULs** · AOC 2A · AOC 2B · AOC 3	*Full excavation to CULs and backfill with clean fill overlain by gravel surface.*
▨	**Protect Existing Structures** · AOC 2A	*Existing buildings on the south side of the Site will remain.*
▩	**Demolish and Rebuild Existing Structures** · AOC 2A · AOC 2B · AOC 3	*Demolish existing structures as necessary to excavate subsurface soil to CULs. Backfill with clean fill and rebuild the structures to their original conditions.*

◉	Compliance Monitoring Well	—x—	Fence Line
☐	Area of Concern	- - - -	Harbor Line

Notes:
- Institutional controls will require industrial land use and an Operations, Maintenance, and Monitoring Plan.
- Implementation of the remedy may be phased to minimize interruptions to shipyard operations.
- Basemap and locations of previous investigation provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
CUL = Cleanup level.
Site = Harris Avenue Shipyard Site.

0 30 60 120
Scale in Feet

N

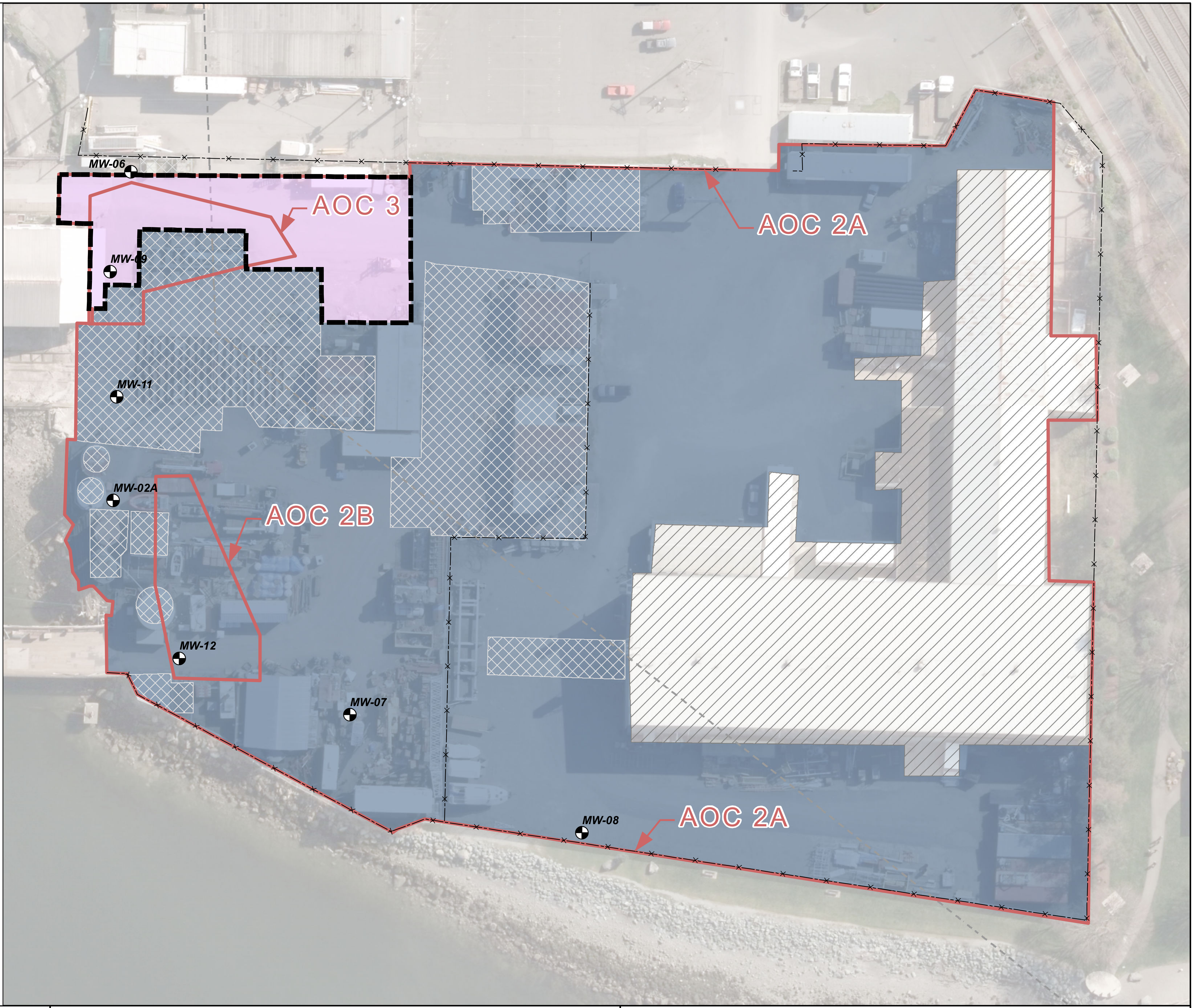

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Figure 9.3
Soil and Groundwater Alternative 3 – Remedy Components

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 9.3 Soil and Groundwater Alternative 3 - Remedy Components.mxd
6/7/2019

Legend

Sediment Alternative 1

▨	**Interim Action** · SMU 1 · SMU 3	*Completed in 2018. Removal of over-water structures. Dredging to CULs or RALs, with upland landfill disposal of dredged materials. Construction of new Harris Avenue Pier.*
▤	**Interim Action** · SMU 2 · SMU 4	*Completed in 2018. Removal of over-water structures. Excavation of 3 feet of contaminated intertidal sediments, with upland landfill disposal of excavated materials. Capping with clean fill to match pre-construction grades. Construction of new Harris Avenue Pier.*
🟩	**Dredge to CULs/RALs** · SMU 1[1]	*Dredge, 2- to 4-foot average depth, to meet CULs/RALs. Upland disposal or reuse of dredged sediment.*
🟦	**Open Water Granular Cap** · SMU 6 · SMU 9	*Place granular cap, 3-foot minimum thickness.*
🟩	**Under-Pier Granular Cap**[2] · SMU 5 · SMU 11	*Place granular cap, 1-foot minimum thickness.*
🟪	**Marine Railway Subtidal Sediment Granular Cap** · SMU 7	*Place granular cap, 1 to 3 feet thick, given clearance between existing mudline and marine railway girders.*
🟪	**Marine Railway Intertidal Sediment Excavation and Granular Cap** · SMU 8	*Targeted excavation and placement of 1-foot minimum thickness granular cap at marine railway to top of girders.*
🟩	**Intertidal Sediment Excavation and Granular Cap** · SMU 10	*Excavate to an average 3-foot depth and backfill with appropriate habitat substrate to meet existing elevations.*
	Enhanced Natural Recovery · All SMUs	*In alternatives for which dredging to CULs/RALs is selected, if those target concentrations are unable to be achieved (e.g., due to subsurface obstructions), a 6-inch-thick layer of sand will be placed as ENR.*

🟥 AOC 1

⋰⋱ 2011 Bathymetry Data[3]

┼─┼ Marine Railway

Notes:
1. Area not addressed during the Interim Action. Additional sampling during remedial design will determine if action is necessary in this area.
2. For SMUs where under-pier capping is proposed, the remedy includes institutional controls that require evaluation of a more permanent remedy (dredging or capping) if the overwater structures are removed in the future.
3. Bathymetric survey west of the dry dock from a topographic survey performed in June 2011 (Berger ABAM 2011). Bathymetry data east of the dry dock were interpolated from bathymetric contour data created in 1998. Vertical Datum: MLLW (1986–2001 Epoch).

- Implementation of the remedy may be phased to minimize interruptions to shipyard operations.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
CUL = Cleanup level.
ENR = Enhanced Natural Recovery.
MLLW = Mean lower low water.
RAL = Remedial Action Level.
SMU = Sediment Management Unit.

0 35 70 140
Scale in Feet

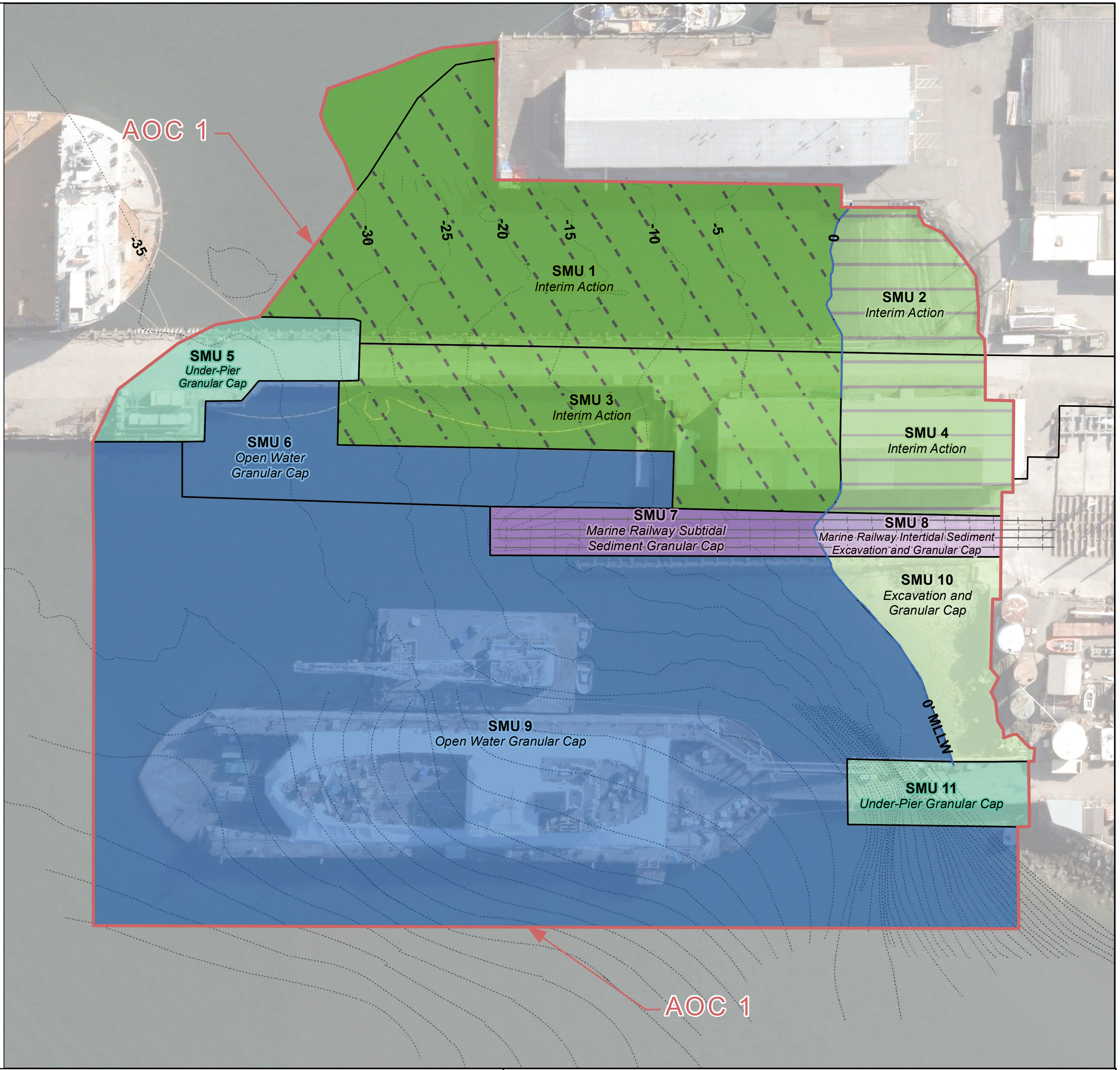

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Figure 12.1
Sediment Cleanup Alternative 1 – Remedy Components

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 12.1 Sediment Alternative 1 - Remedy Components.mxd
6/7/2019

Legend

Sediment Alternative 2

▨	**Interim Action** · SMU 1 · SMU 3	*Completed in 2018. Removal of over-water structures. Dredging to CULs or RALs, with upland landfill disposal of dredged materials. Construction of new Harris Avenue Pier.*
▤	**Interim Action** · SMU 2 · SMU 4	*Completed in 2018. Removal of over-water structures. Excavation of 3 feet of contaminated intertidal sediments, with upland landfill disposal of excavated materials. Capping with clean fill to match pre-construction grades. Construction of new Harris Avenue Pier.*
🟩	**Dredge to CULs/RALs** · SMU 1[1] · SMU 6 · SMU 9	*Dredge, 2- to 4-foot average depth, to meet CULs/RALs. Upland disposal or reuse of dredged sediment.*
🟩	**Under-Pier Granular Cap[2]** · SMU 5 · SMU 11	*Place granular cap, 1-foot minimum thickness.*
🟪	**Marine Railway Subtidal Sediment Granular Cap** · SMU 7	*Place granular cap, 1 to 3 feet thick, given clearance between existing mudline and marine railway girders.*
🟪	**Marine Railway Intertidal Sediment Excavation and Granular Cap** · SMU 8	*Targeted excavation and placement of 1-foot minimum thickness granular cap at marine railway to top of girders.*
🟦	**Intertidal Sediment Excavation and Backfill** · SMU 10	*Excavate to an average 3-foot depth, and backfill with appropriate habitat substrate to meet existing elevations.*
	Enhanced Natural Recovery · All SMUs	*In alternatives for which dredging to CULs/RALs is selected, if those target concentrations are unable to be achieved (e.g., due to subsurface obstructions), a 6-inch-thick layer of sand will be placed as ENR.*

▭	AOC 1
⋰	2011 Bathymetry Data[3]
—+—	Marine Railway

Notes:
1. Area not addressed during the Interim Action. Additional sampling during remedial design will determine if action is necessary in this area.
2. For SMUs where under-pier capping is proposed, the remedy includes institutional controls that require evaluation of a more permanent remedy (dredging or capping) if the overwater structures are removed in the future.
3. Bathymetric survey west of the dry dock from a topographic survey performed in June 2011 (Berger ABAM 2011). Bathymetry data east of the dry dock were interpolated from bathymetric contour data created in 1998. Vertical Datum: MLLW (1986–2001 Epoch).

- Implementation of the remedy may be phased to minimize interruptions to shipyard operations.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
CUL = Cleanup level.
ENR = Enhanced Natural Recovery.
MLLW = Mean lower low water.
RAL = Remedial Action Level.
SMU = Sediment Management Unit.

0 35 70 140
Scale in Feet

N

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Figure 12.2
Sediment Cleanup Alternative 2 – Remedy Components

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6/7/2019

Legend

Sediment Alternative 3

●	**Demolition of Existing Structures and Rebuild Following Dredging** · SMU 5 · SMU 7 · SMU 8 · SMU 11	*Removal of existing structures to allow access for dredging to CULs/RALs.*
▨	**Interim Action** · SMU 1 · SMU 3	*Completed in 2018. Removal of over-water structures. Dredging to CULs or RALs, with upland landfill disposal of dredged materials. Construction of new Harris Avenue Pier.*
▤	**Interim Action and Excavation and Backfill if Sampling Confirms Necessary** · SMU 2 · SMU 4	*Interim Action completed in 2018 as described in Alternatives 1 and 2. Remove 3-feet of cap materials. Excavate 2- to 3-foot average depth, to meet CULs/RALs in areas where remediation is necessary to meet CULs/RALs. Upland disposal or reuse of dredged sediment. Backfill with appropriate habitat substrate to meet existing elevations.*
🟩	**Dredge to CULs/RALs** · SMU 1[1] · SMU 6 · SMU 9	*Dredge, 2- to 4-foot average depth, to meet CULs/RALs. Upland disposal or reuse of dredged sediment.*
🟦	**Intertidal Sediment Excavation and Backfill** · SMU 10	*Excavate to an average 3-foot depth, and backfill with appropriate habitat substrate to meet existing elevations.*
	Enhanced Natural Recovery · All SMUs	*In alternatives for which dredging to CULs/RALs is selected, if those target concentrations are unable to be achieved (e.g., due to subsurface obstructions), a 6-inch-thick layer of sand will be placed as ENR.*

🟥 AOC 1

2011 Bathymetry Data[2]

Marine Railway

Notes:
1. Area not addressed during the Interim Action. Additional sampling during remedial design will determine if action is necessary in this area.
2. Bathymetric survey west of the dry dock from a topographic survey performed in June 2011 (Berger ABAM 2011). Bathymetry data east of the dry dock were interpolated from bathymetric contour data created in 1998. Vertical Datum: MLLW (1986–2001 Epoch).

- Implementation of the remedy may be phased to minimize interruptions to shipyard operations.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
CUL = Cleanup level.
ENR = Enhanced Natural Recovery.
MLLW = Mean lower low water.
RAL = Remedial Action Level.
SMU = Sediment Management Unit.

0 35 70 140
Scale in Feet

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Figure 12.3
Sediment Cleanup Alternative 3 – Remedy Components

I:\GIS\Projects\POB-HARRIS\MXD\RIFS_Figures\RIFS 2018 Figures\Figure 12.3 Sediment Alternative 3 - Remedy Components.mxd
6/7/2019

Legend

● Subsurface Sediment Location (>12 cm depth bottom)
🟥 Greater Than Criterion
🟩 Less Than Criterion
🟪 Not Detected
☐ Not Analyzed
▭ AOC 1
2011 Bathymetry Data
Fence Line
Harbor Line
0-feet Mean Lower Low Water Level
Riprap

Location ID	
Analyte	**Criteria (mg/kg)**
Arsenic (As)	13
Copper (Cu)	390
Zinc (Zn)	410
cPAHs	4.2
Fluoranthene (Fl)	1.7
PCBs	0.13
Pyrene (Pyr)	2.6

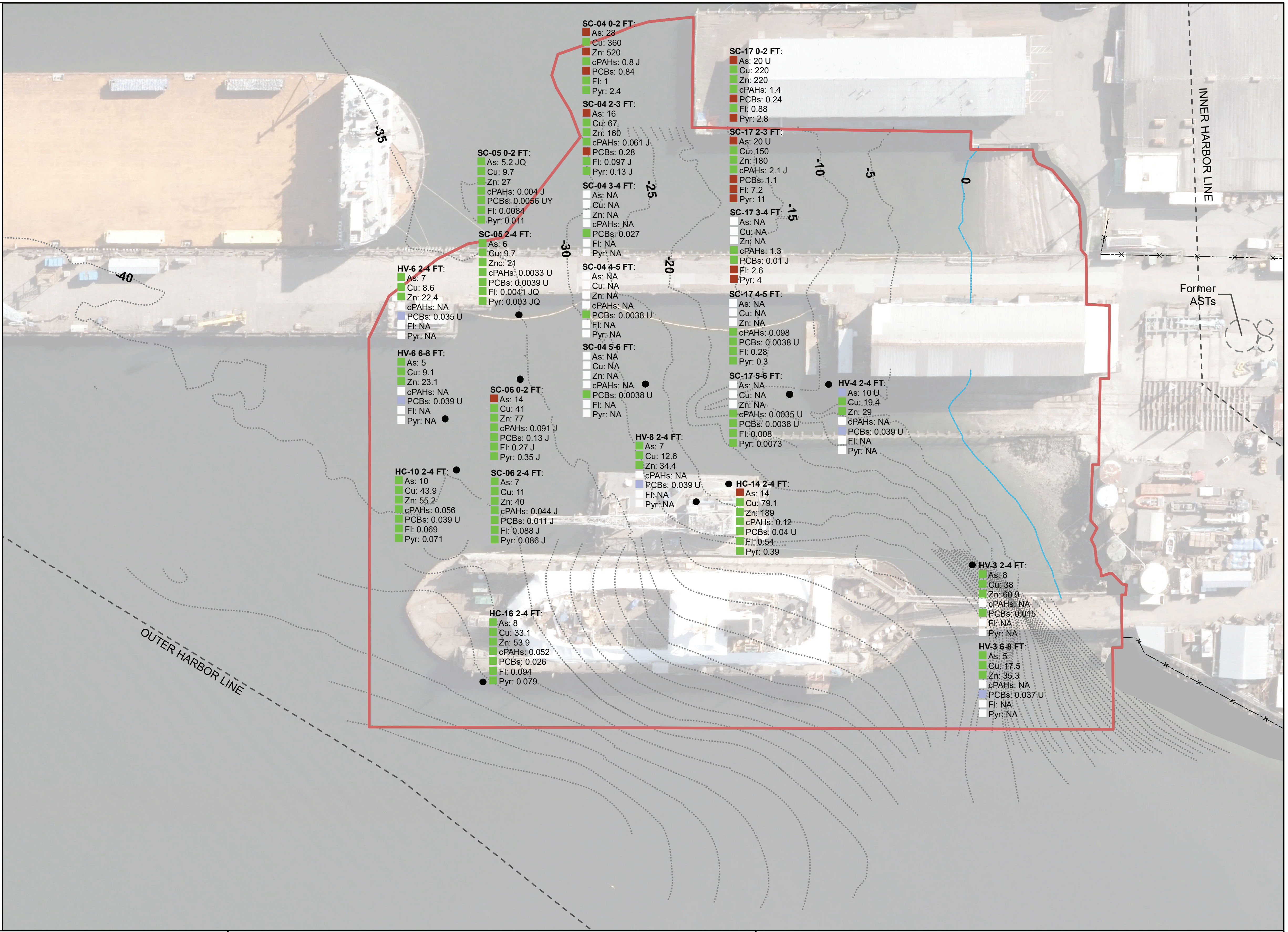
Notes:
- Criteria are screening levels protective of benthic species and human health during net fishing (subtidal), beach play (intertidal), or shipyard activites (intertidal).
- Sample results are from subtidal locations outside the Interim Action area with bottom depths that are deeper than 12cm.
- Data shown represents site conditions prior to completion of the Interim Action.
- Basemap and locations of previous investigations provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
- All results are reported in mg/kg dry weight.
- Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AST = Aboveground storage tank.
cm = Centimeters.
cPAH = Carcinogenic polycyclic aromatic hydrocarbon.
mg/kg = Milligrams per kilogram.
MLLW = Mean Lower Low Water.
NA = Not analyzed.
PCB = Polychlorinated biphenyl.

Qualifiers:
J = The associated value is an estimate due to QA concerns.
JQ = Concentration is an estimated value reported below the associated quantitation limit but above the MDL, acceptable for use with qualification.
U = The analyte was not detected at the given reporting limit.
UJ = The material was analyzed for, but was not detected. The associated value is an estimate due to QA concerns.
UY = Analyte is not detected at the associated reporting limit. The reporting limit is elevated due to chromatographic overlap with the detected compound(s).

N

0 50 100 200
Scale in Feet



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Remedial Investigation/Feasibility Study
Harris Avenue Shipyard
Bellingham, Washington

Figure 12.4
Subtidal Sediment Core Data with Bottom Depths Greater than 12 cm

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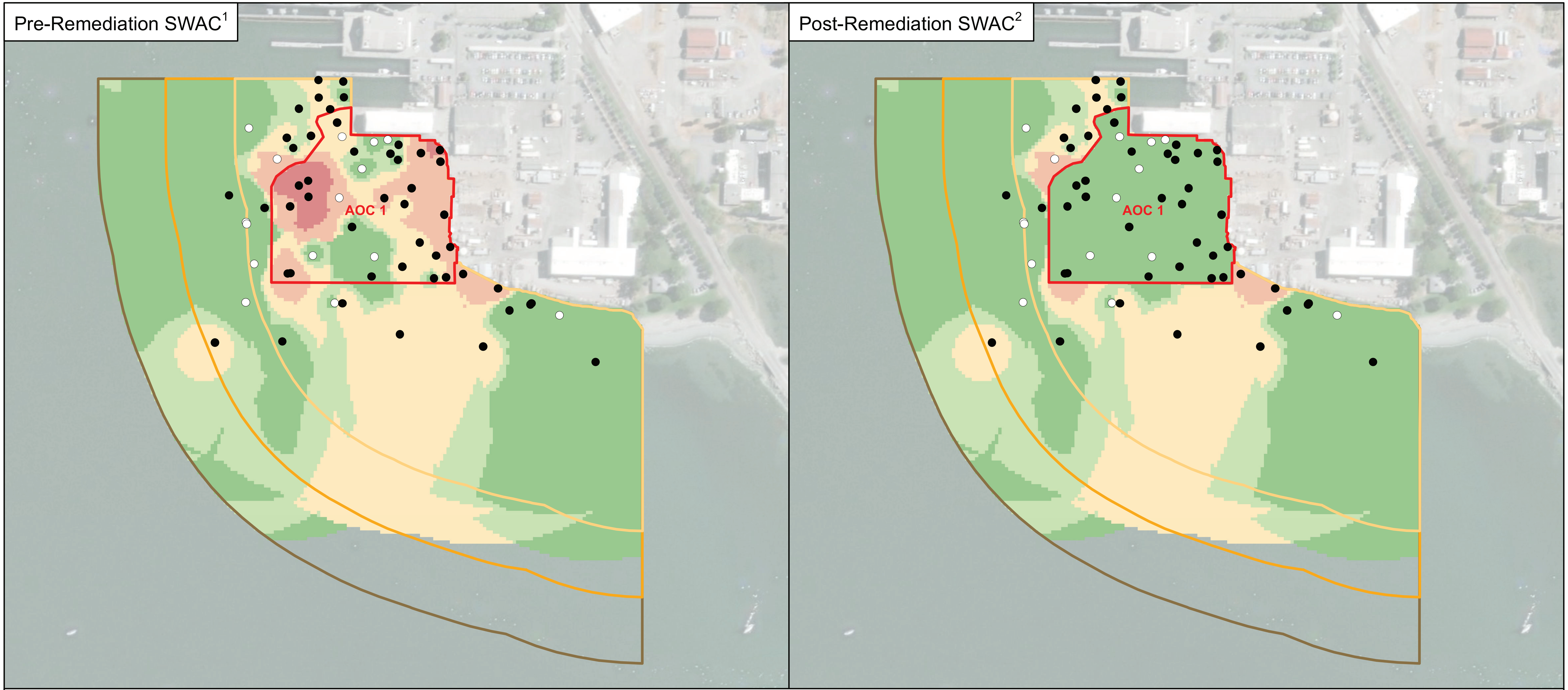
6/7/2019



Legend

Arsenic Concentration Ranges

- 🟩 ≤ 11 mg/kg (Natural Background)
- 🟩 > 11–13 mg/kg (Site-Specific Regional Background)
- 🟨 > 13–20 mg/kg (Natural Soil Background)
- 🟧 > 20–57 mg/kg (Benthic SQS)
- 🟥 > 57 mg/kg

Arsenic Sample Locations

- ● Detect
- ○ Non-Detect
- ◯ 600-foot
- ◯ 800-foot
- ◯ 1,000-foot
- 🟥 AOC 1

Notes:

1 Data shown represents site conditions prior to completion of the Interim Action.

2 Expected SWAC following active remediation of AOC 1.

3 The CUL for arsenic is 13 mg/kg, based on site-specific regional background.

4 This value would be assigned to the active remediation area (AOC 1) following remediation and is based on the data in subsurface sediments indicating the concentrations that will be left in place following remediation.

· Where arsenic is not detected, one-half of the detection limit is used to calculate the SWAC.

· IDW developed with the following parameters:
  - 600-foot/4 minimum 8 maximum-point variable search radius
  - Power = 2

· Shoreline buffer is the distance from the shore in the amount specified by the feature name.

· Aerial imagery provided by Esri, 2015.

Abbreviations:

AOC = Area of Concern.
CUL = Cleanup level.
ft = Foot.
IDW = Inverse distance weighted.
mg/kg = Milligrams per kilogram.
SQS = Sediment Quality Standards.
SWAC = Surface-weighted average concentration.

N

0 100 200 400

Scale in Feet

SWAC Results for Arsenic

CUL[3]	AOC 1 Post-Remediation Concentration[4]	Area Used For SWAC Calculation	Pre-Remediation SWAC (mg/kg)	Post-Remediation SWAC (mg/kg)
13	8.4	AOC 1	30	8.4
		Shoreline Buffer 600-ft	16	11
		Shoreline Buffer 800-ft	15	11
		Shoreline Buffer 1,000-ft	14	11

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Bellingham, Washington

Figure 13.1
Arsenic SWAC

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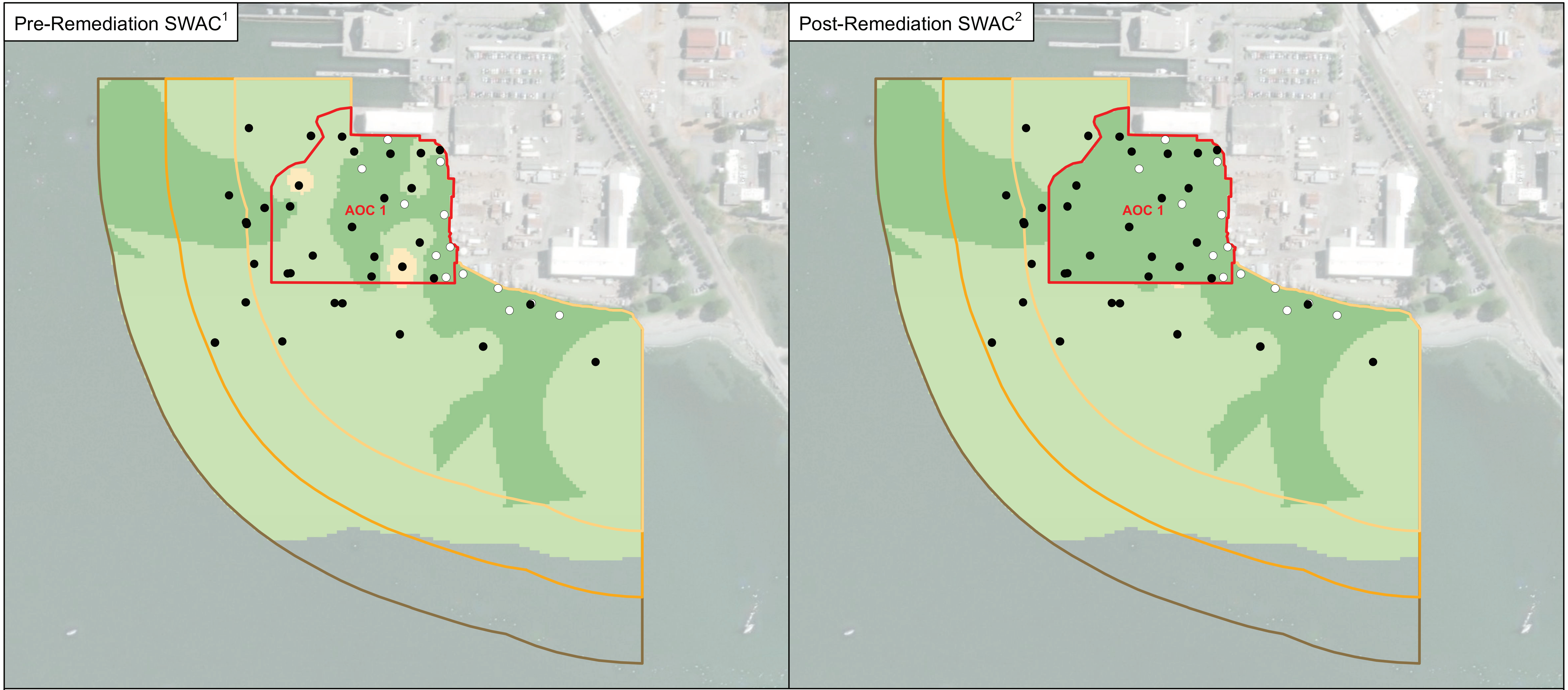
6/7/2019



Legend

Cadmium Concentration Ranges

🟩	≤ 0.8 mg/kg (Natural Background)
🟩	> 0.8–2.1 mg/kg (Higher Trophic Level Species Risk)
🟨	> 2.1–5.1 mg/kg (Benthic SQS)
🟥	> 5.1 mg/kg

Cadmium Sample Locations

●	Detect
○	Non-Detect
⬭	600-foot
⬭	800-foot
⬭	1,000-foot
▢	AOC 1

Notes:
1 Data shown represents site conditions prior to completion of the Interim Action.
2 Expected SWAC following active remediation of AOC 1.
3 The CUL for cadmium is 0.8 mg/kg, based on natural background.
4 This value would be assigned to the active remediation area (AOC 1) following remediation and is based on the data in subsurface sediments indicating the concentrations that will be left in place following remediation.
· Where cadmium is not detected, one-half of the detection limit is used to calculate the SWAC.
· IDW developed with the following parameters:
  - 600-foot/4 minimum 8 maximum-point variable search radius
  - Power = 2
· Shoreline buffer is the distance from the shore in the amount specified by the feature name.
· Aerial imagery provided by Esri, 2015.

Abbreviations:
AOC = Area of Concern.
CUL = Cleanup level.
ft = Foot.
IDW = Inverse distance weighted.
mg/kg = Milligrams per kilogram.
SQS = Sediment Quality Standards.
SWAC = Surface-weighted average concentration.

N

0 100 200 400
Scale in Feet

SWAC Results for Cadmium

CUL[3]	AOC 1 Post-Remediation Concentration[4]	Area Used For SWAC Calculation	Pre-Remediation SWAC (mg/kg)	Post-Remediation SWAC (mg/kg)
0.8	0.58	AOC 1	0.97	0.58
		Shoreline Buffer 600-ft	0.93	0.83
		Shoreline Buffer 800-ft	0.94	0.87
		Shoreline Buffer 1,000-ft	0.93	0.87

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Figure 13.2
Cadmium SWAC

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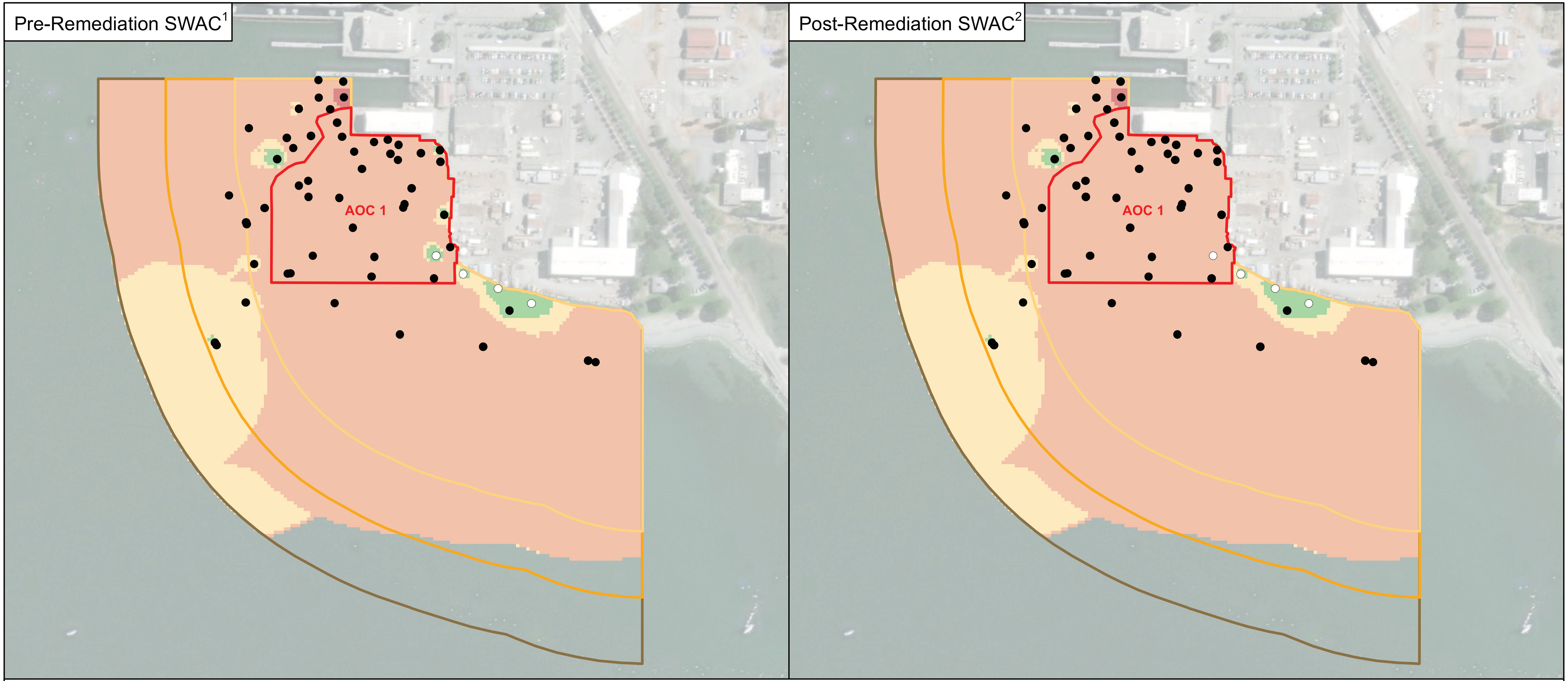
6/7/2019



Legend

cPAH TEQ Concentration Ranges

- 🟩 ≤ 0.021 mg/kg (Natural Background)
- 🟩 > 0.021–0.086 mg/kg (Regional Background)
- 🟨 > 0.086–0.14 mg/kg (Seafood Consumption Risk)
- 🟧 > 0.14–4.2 mg/kg (Netfishing Direct Contact Risk)
- 🟥 > 4.2 mg/kg

cPAH Sample Locations

- ● Detect
- ○ Non-Detect

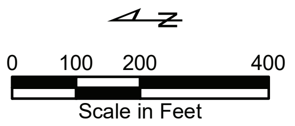
Notes:

1 Data shown represents site conditions prior to completion of the Interim Action.
2 Expected SWAC following active remediation of AOC 1.
3 The CUL for cPAH TEQ is 0.14 mg/kg, based on protection of seafood consumption.
4 This value would be assigned to the active remediation area (AOC 1) following remediation and is based on the data in subsurface sediments indicating the concentrations that will be left in place following remediation.

- IDW developed with the following parameters:
  - 600-foot/4 minimum 8 maximum-point variable search radius
  - Power = 2
- Shoreline buffer is the distance from the shore in the amount specified in the feature.
- Aerial imagery provided by Esri, 2015.

Abbreviations:

AOC = Area of Concern.
cPAH = Carcinogenic polycyclic aromatic hydrocarbon.
CUL = Cleanup level.
ft = Foot.
IDW = Inverse distance weighted.
mg/kg = Milligrams per kilogram.
SWAC = Surface-weighted average concentration.
TEQ = Toxicity Equivalent.



SWAC Results for cPAH TEQ

CUL[3]	AOC 1 Post-Remediation Concentration[4]	Area Used For SWAC Calculation	Pre-Remediation SWAC (mg/kg)	Post-Remediation SWAC (mg/kg)
0.14	0.26	AOC 1	0.64	0.26
		Shoreline Buffer 600-ft	0.42	0.32
		Shoreline Buffer 800-ft	0.37	0.30
		Shoreline Buffer 1,000-ft	0.33	0.28

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Bellingham, Washington

Figure 13.3
cPAH TEQ SWAC

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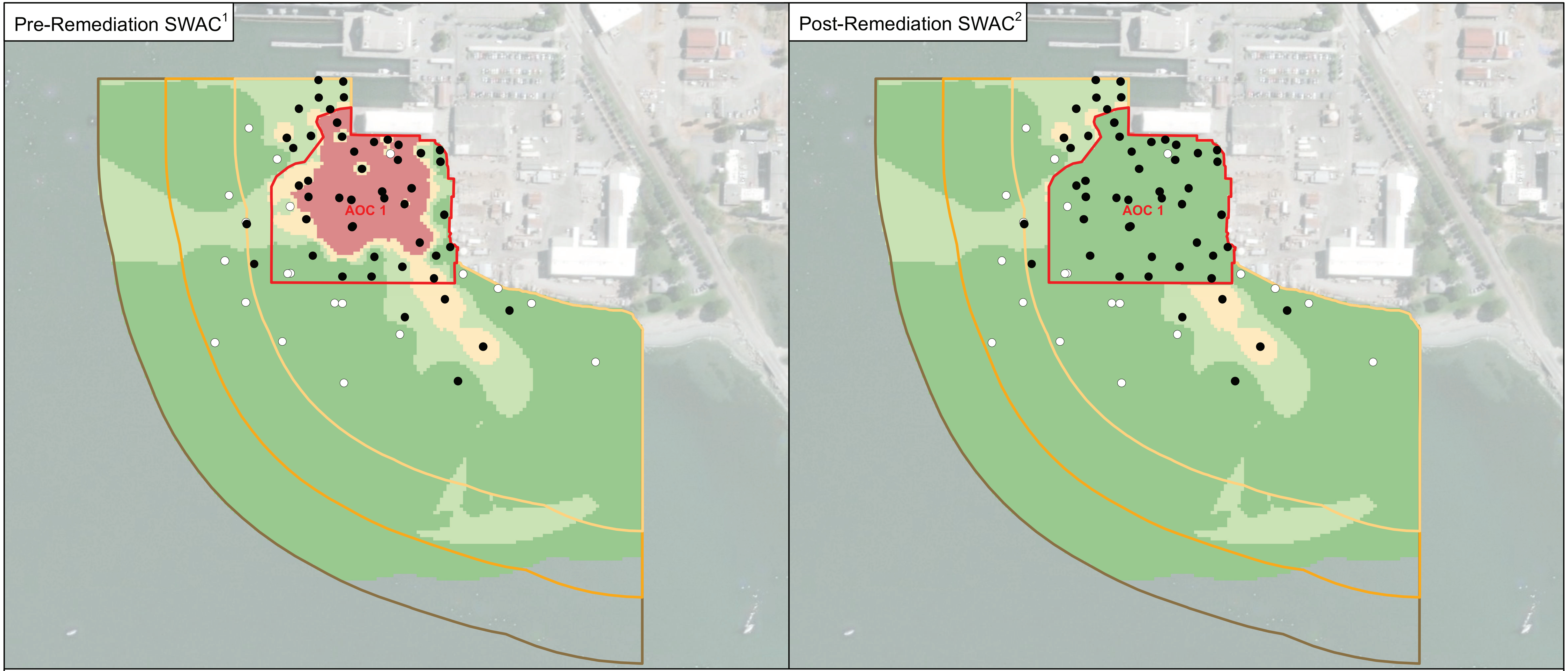
6/7/2019



Legend

PCB Concentration Ranges

- 🟩 ≤ 0.033 mg/kg (PQL)
- 🟩 > 0.033–0.067 mg/kg (2x PQL)
- 🟨 > 0.067–0.13 mg/kg (Benthic SQS)
- 🟥 > 0.13 mg/kg

PCB Sample Locations

- ● Detect
- ○ Non-Detect

Notes:
1 Data shown represents site conditions prior to completion of the Interim Action.
2 Expected SWAC following active remediation of AOC 1.
3 The CUL for Total PCBs is 0.033 mg/kg, based on the PQL.
4 This value would be assigned to the active remediation area (AOC 1) following remediation and is based on the data in subsurface sediments indicating the concentrations that will be left in place following remediation.

- IDW developed with the following parameters:
  - 600-foot/4 minimum 8 maximum-point variable search radius
  - Power = 2
- Shoreline buffer is the distance from the shore in the amount specified by the feature name.
- Aerial imagery provided by Esri, 2015.

0 100 200 400
Scale in Feet

Abbreviations:
AOC = Area of Concern.
CUL = Cleanup level.
ft = Foot.
IDW = Inverse distance weighted.
mg/kg = Milligrams per kilogram.
PCB = Polychlorinated biphenyl.
PQL = Practical Quantitation Limit.
SQS = Sediment Quality Standards.
SWAC = Surface-weighted average concentration.

SWAC Results for Total PCB Aroclors

CUL[3]	AOC 1 Post-Remediation Concentration[4]	Area Used For SWAC Calculation	Pre-Remediation SWAC (mg/kg)	Post-Remediation SWAC (mg/kg)
0.033	0.031	AOC 1	0.27	0.031
		Shoreline Buffer 600-ft	0.089	0.030
		Shoreline Buffer 800-ft	0.070	0.029
		Shoreline Buffer 1,000-ft	0.060	0.028

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Figure 13.4
Total PCBs SWAC

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Legend

Sediment Components

▨ **Interim Action** (SMUs: 1, 3)
Completed in 2018. Removal of over-water structures. Dredging to CULs or RALs, with upland landfill disposal of dredged materials. Construction of new Harris Avenue Pier.

▤ **Interim Action** (SMUs: 2, 4)
Completed in 2018. Removal of over-water structures. Excavation of 3 feet of contaminated intertidal sediments, with upland landfill disposal of excavated materials. Capping with clean fill to match pre-construction grades. Construction of new Harris Avenue Pier.

🟩 **Dredge to CULs/RALs** (SMUs: 1^1, 6, 9)
Dredge, 2- to 4-foot average depth, to meet CULs/RALs. Upland disposal or reuse of dredged sediment.

🟩 **Under-Pier Granular Cap**^{2} (SMUs: 5, 11)
Place granular cap, 1-foot minimum thickness.

🟪 **Marine Railway Subtidal Sediment Granular Cap** (SMU: 7)
Place granular cap, 1 to 3 feet thick, given clearance between existing mudline and marine railway girders.

🟪 **Marine Railway Intertidal Sediment Excavation and Granular Cap** (SMU: 8)
Targeted excavation and placement of 1-foot minimum thickness granular cap at marine railway to top of girders.

🟦 **Intertidal Sediment Excavation and Backfill** (SMU: 10)
Excavate to an average 3-foot depth, and backfill with appropriate habitat substrate to meet existing elevations.

Enhanced Natural Recovery (SMUs: all)
In portions of SMUs for which dredging to CULs/RALs is selected, if those target concentrations are unable to be achieved, (e.g. due to subsurface obstructions), a 6-inch-thick layer of sand will be placed as ENR.

Upland Components

▭ **Interim Action** (AOCs: 2A, 3)
Completed in 2018. Excavation to CULs with upland landfill disposal of excavated materials. Overlain by gravel surface.

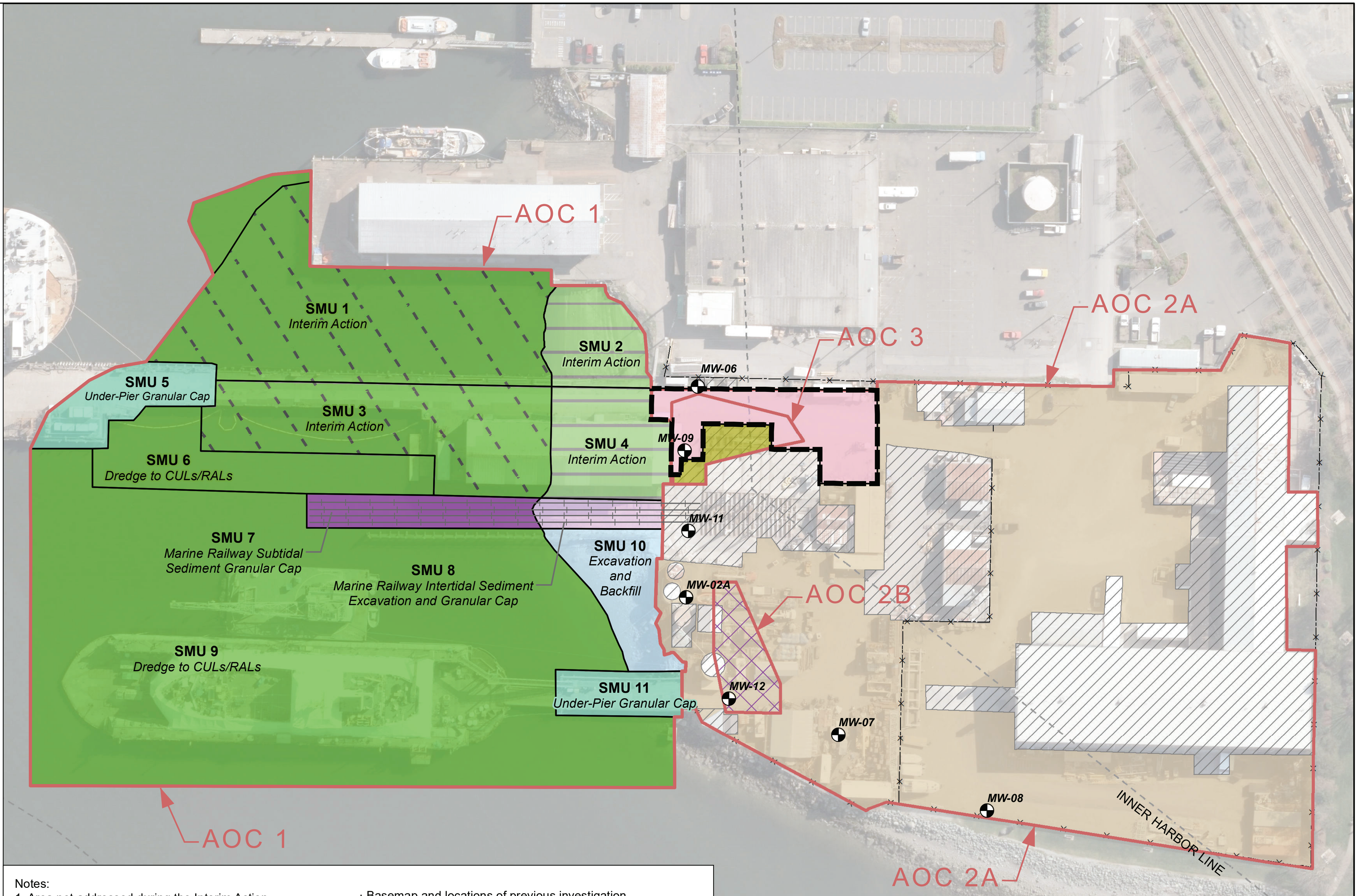
▭ **Excavate and Place Gravel or Asphalt Cap** (AOCs: 2A, 2B)
Excavate 2 feet bgs and place gravel cap or excavate 1 foot bgs and place asphalt cap. Installation of stormwater conveyance system where necessary.

🟨 **Contingency Bioremediation** (AOC: 3)
Apply contingency bioremediation amendment based on results of compliance groundwater monitoring.

▩ **Deeper Soil Excavation** (AOC: 2B)
Excavate deeper contaminated soil to CULs based on results of remedial design sampling. Soil solidification/stabilization at base of excavation may be required..

▧ **Protect Existing Structures** (AOCs: 2A, 2B, 3)
Existing buildings and pavement to remain.

◐ Compliance Monitoring Well
--×-- Fence Line
▭ Area of Concern
- - - - Harbor Line
—+— Marine Railway



Notes:
1. Area not addressed during the Interim Action. Additional sampling during remedial design will determine if action is necessary in this area.
2. For alternatives in which capping under existing structures is evaluated. Institutional controls requiring evaluation of a more permanent remedy if overwater structures are removed in the future are part of the alternative.
· Institutional controls will require industrial land use and an Operations, Maintenance, and Monitoring Plan.
· Implementation of the remedy may be phased to minimize interruptions to shipyard operations.
· Basemap and locations of previous investigation provided by The RETEC Group (1998 Phase 2 Sampling of Soil and Groundwater at the Harris Avenue Shipyard).
· Aerial image provided by City of Bellingham, 2013.

Abbreviations:
AOC = Area of Concern.
bgs = Below ground surface.
CUL = Cleanup level.
MLLW = Mean lower low water.
RAL = Remedial Action Level.
SMU = Sediment Management Unit.

N

0 25 50 100
Scale in Feet

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Figure 14.1
Site-Wide Preferred Remedial Alternative

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