Report

Proposed Plan
Lockheed West Seattle Superfund Site

Prepared for

U.S. Environmental Protection Agency, Region 10
Seattle, Washington

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Prepared by

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Abbreviations and Acronyms

2LAET	second lowest apparent effects threshold
3-D	three-dimensional
AOPA	area of potential action
ARAR	applicable or relevant and appropriate requirement
ASAOC	Administrative Settlement Agreement and Order on Consent
AWQC	ambient water quality criteria
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	*Code of Federal Regulations*
cm	Centimeters
COC	contaminant of concern
COPC	contaminant of potential concern
cPAHs	carcinogenic polycyclic aromatic hydrocarbons
CSL	cleanup screening level
DDT	dichlorodiphenyltrichloroethane
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
ELCR	excess lifetime cancer risk
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FS	feasibility study
ft	foot or feet
GSR	green and sustainable remediation
HHRA	human health risk assessment
HI	hazard index
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IC	institutional control
LAET	lowest apparent effects threshold
LDW	Lower Duwamish Waterway
LOAEL	lowest observed adverse effects level
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon

LSSOU	Lockheed Shipyard No. 1 Sediment Operable Unit
LTM	long-term monitoring
MDL	method detection limit
mg/kg	milligram(s) per kilogram
mg/kg dw	milligram(s) per kilogram dry weight
mg/kg OC	milligram(s) per kilogram organic carbon
mhhw	mean higher high water
ML	maximum level
mllw	mean lower low water
MTCA	Washington State Model Toxics Control Act
NCP	National Contingency Plan
ng TEQ/kg dw	nanograms toxicity equivalents per kilogram dry weight
NOAEL	no observed adverse effects level
NPL	National Priorities List
NPV	net present value
OC	organic carbon
OU	operable unit
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PM_{10}	particulate matter less than 10 micrometers in aerodynamic diameter
PMA	Port Management Area
Port	Port of Seattle
ppm	parts per million
ppt	parts per trillion
PQL	practical quantitation limit
PRG	preliminary remediation goal
PRP	potentially responsible party
PSR	Pacific Sound Resources
RAL	remedial action level
RAO	remedial action objective
RBTC	risk-based threshold concentration
RCRA	Resource Conservation and Recovery Act of 1976
RCW	*Revised Code of Washington*
RG	remediation goal
RI	remedial investigation

RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROC	receptor of concern
ROD	Record of Decision
SL	screening level
SMS	Washington State Sediment Management Standards
SQS	Sediment Quality Standards
SVOC	semivolatile organic compound
TBT	tributyltin
TCDD	tetrachlorodibenzodioxin
TEQ	toxicity equivalent
TI	technical impracticability
TSCA	Toxic Substances Control Act
TSSOU	Todd Shipyard Sediment Operable Unit
U&A	Usual and Accustomed
UECA	Uniform Environmental Covenant Act
WAC	*Washington Administrative Code*
WQA	water quality assessment
WRDA	Waterway Resource District Act
WWOU	West Waterway Operable Unit
µg /kg-dw	micrograms per kilogram – dry weight
µg TEQ/ kg dw	micrograms toxicity equivalents per kilogram dry weight
µg/kg	micrograms per kilogram
yd^3	cubic yard(s)

1.0 Introduction

This Proposed Plan describes the potential cleanup alternatives, including the Preferred Alternative, for the Lockheed West Seattle Superfund Site (Site). The Site is located in Elliott Bay near the mouth of the West Waterway in Seattle, Washington (Figure 1-1) and is the location of a former industrial shipyard. Ship construction, dry dock ship repairs, vessel sandblasting, and painting resulted in contamination of underlying sediments in Elliott Bay. The primary contaminants found and studied in sediments at the Site are metals, polychlorinated biphenyls (PCBs), dioxins/furans, and carcinogenic polycyclic aromatic hydrocarbons (cPAHs). The contamination in the sediments poses a risk to humans through consumption of seafood, direct exposure during beach play, and Tribal clamming and netfishing. Sediment contamination also poses an ecological risk to benthic invertebrates (including clams), crab, and fish through direct contact and ingestion, and to the spotted sandpiper from ingesting prey and sediments.

This Proposed Plan is issued by the U.S. Environmental Protection Agency (EPA) Region 10 to fulfill public comment requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Section 117(a) and the National Contingency Plan (NCP) Section 300.430(f)(2). As the lead agency for the cleanup, EPA has identified Alternative 3C Plus as the Preferred Alternative to address risks at the Site (Figure 1-2). This action is considered necessary to protect public health and the environment from actual and threatened releases of hazardous substances. EPA, with input from the Washington State Department of Ecology (Ecology) and consultation with the Muckleshoot and Suquamish Indian Tribes, will make a final remedy selection after considering public comments.

This is the final and only remedial action proposed for the Site. No early actions were taken at this Site.

1.1 Summary of the Proposed Action

EPA's Preferred Alternative for the Site is based on site investigations conducted between 1980 and 2010, including the *Final Remedial Investigation/Feasibility Study, Lockheed West Seattle Superfund Site* (RI/FS) (Tetra Tech, 2012a), *EPA Requested Feasibility Study Alternative Variations Technical Memorandum, Lockheed West Seattle Superfund Site* (Tetra Tech, 2012b), and associated ecological and human health risk evaluations (Tetra Tech and Pascoe, 2009a,b). The feasibility study (FS) describes 19 options for addressing contamination at the Site. After consideration of the FS and in consultation with the State of Washington and Tribes, EPA proposes Alternative 3C Plus as the Preferred Alternative for cleanup of contaminated sediments at the Site.

The Preferred Alternative includes the following elements:

- Dredge the northeastern and eastern shoreline bank to mean higher high water (mhhw) and all intertidal sediment to remove sediments with contaminants of concern (COCs) at levels in excess of Washington State Sediment Management Standards (SMS) (*Washington Administrative Code* [WAC] Chapter 173-204) Sediment Quality Standards (SQS) and backfill to grade with a layer of habitat restoration "fish mix" material.
- Place habitat substrate and fish mix on the northern shoreline bank, where large riprap currently supports the Terminal 5 bank, to provide a more habitat-friendly environment.
- Dredge the former shipway area (westernmost portion of the Site) to remove sediments with COC concentrations in excess of the SQS levels and place a thin layer (6 to 9 inches) of clean material to cover dredge residuals.
- Dredge the former Dry Docks 1 through 3 area and other localized areas throughout the Site to remove sediments with COC concentrations that exceed SMS cleanup screening levels (CSL), and place a thin layer (6 to 9 inches) of clean material over dredge residuals.
- Dredge the Navigation Channel in the West Waterway to remove sediments with COC concentrations that exceed SQS, and place a thin layer (6 to 9 inches) of clean material to cover dredge residuals.

- Dispose of dredged sediments and other related remediation materials by truck or rail transport to an appropriate offsite upland facility permitted to accept these materials.
- Remove debris, riprap, failing wooden bulkheads, and pilings as necessary or directed by EPA, and dispose of them offsite.
- Place a thin layer (6 to 9 inches) of clean sand and gravel material to promote enhanced natural recovery (ENR) over the remainder of the Site where concentrations of most risk-driver COCs are between the SQS and CSL and concentrations of other COCs are no greater than two times the SQS.
- Place institutional controls (ICs) in the form of a proprietary control that runs with the land and that requires coordination with EPA and management of any residual contamination that is disturbed or encountered in the event of future excavation or dredging within the boundaries of the Site. It is EPA's expectation that the state Uniform Environmental Covenant Act (UECA) will be used. The ICs will not affect or restrict Tribal fishing rights in this area nor will they restrict pile installation, anchoring, or water-based commerce. The Lockheed Martin Corporation will secure appropriate restrictive covenants from the Port of Seattle (Port) and the Washington State Department of Natural Resources (DNR). In addition, Elliott Bay fish consumption advisories, established by the Washington State Department of Health, to reduce human exposure from ingestion of contaminated seafood will be posted at the Site.
- Conduct post-remedial confirmation sampling.
- Conduct long-term monitoring at the Site in the event of a major storm (with high winds from the north at 30 miles per hour or greater, that persist for more than 4 hours), or an earthquake of significance. If those events occur, bathymetric monitoring will be implemented to determine whether one or more components of the selected remedy are affected.
- Conduct 5-year reviews (with scopes limited to bathymetric surveys to ensure that the ENR areas remain in place), file reviews, and interviews with the landowner pertaining to any development that has occurred at the Site since remediation was completed.

The overall size of the Site is approximately 40 acres. Implementation of the Preferred Alternative will encompass the entire site and involve removal and/or addition of the following quantities of materials:

- Dredging—13.6 acres total (167,450 cubic yards [yd^3]) derived from the following areas:
  - Shoreline/intertidal area – 1.2 acres (9,300 yd^3)
  - Former shipway area – 0.8 acre (6,500 yd^3)
  - Area below -10 feet (ft) mean lower low water (mllw) – 11.6 acres (151,650 yd^3)
- Backfill/capping of dredged areas—2.2 acres total in the following areas:
  - Shoreline/intertidal area – 1.2 acres (13,100 yd^3 of habitat mix, 1,900 yd^3 of riprap)
  - Former shipway area – 1 acre (9,850 yd^3 of habitat mix)
- ENR—28.6 acres total over the remaining (nondredged) area below -10 ft mllw to the limits of the Site boundary (45,900 yd^3)

1.2 Purpose and Scope of Proposed Plan

The purpose of this Proposed Plan is to facilitate public involvement and seek input from the public in the remedy selection process. This Plan summarizes information that can be found in greater detail in the RI/FS (Tetra Tech, 2012a) and other documents contained in the Information Repositories at http://yosemite.epa.gov/r10/cleanup.nsf/sites/LockheedWest and at the EPA Records Center, EPA Region 10, Seattle, Washington. Also available in these Information Repositories will be an Administrative Record, which is a formal collection of documents that supports the selected remedy. The public is encouraged to review these documents to gain a more comprehensive understanding of the Site and EPA's recommended cleanup plan and to provide comments on all of the alternatives presented in this Proposed Plan.

1.3 Public Participation

Community involvement has played an essential part in developing the cleanup plan for the Lockheed West Seattle Superfund Site. Some of EPA's community involvement efforts are as follows:

- Representatives of the Tribes, Natural Resource Trustees, and People for Puget Sound, a regional environmental group, reviewed early drafts of the RI/FS and provided feedback that EPA has taken into consideration.
- EPA will host an open house and public meeting to inform community members about the Preferred Alternative.
- EPA will provide public notice of the availability of the Proposed Plan and the public comment period in *The Seattle Times*, as well as in neighborhood papers, blogs, and list serves.
- A 30-day public comment period will be provided.
- A fact sheet explaining the Proposed Plan and public comment opportunity will be distributed to neighbors in West Seattle who can see this Site from their homes.
- The Port of Seattle has agreed to install a box containing fact sheets on the Jack Block Park tower that overlooks the Site. When the cleanup starts, EPA will work with Lockheed Martin and the Port to develop signs explaining the work.
- EPA and Lockheed Martin staff will provide information either in person or through written updates to neighborhood associations, local newspapers, Chambers of Commerce, and other relevant organizations.

Following the comment period, EPA will consider all comments. EPA will provide a written Responsiveness Summary when it issues the Record of Decision (ROD). The ROD will describe the final cleanup plan for the Site.

Once the ROD is issued, a Consent Decree will be negotiated with Lockheed Martin to implement the selected remedy. When the Consent Decree is finalized, an approved remedial design for the selected remedy will be prepared and implemented. Collaboration among the agencies, Tribes, local governments, and community members will continue to be critical throughout this next phase of the cleanup effort.

Legend

	Approximate Site Boundary: Site boundaries will be finalized in the Record of Decision.		Creek
	Highway		Railroad
	Major Road		Greenbelt
	Local Road	LSSOU	Lockheed Shipyard Sediment Operable Unit
	RA5 - Former Shipyard Uplands	TSSOU	Todd Shipyard Sediment Operable Unit
		OU	Operable Unit

Figure 1-1 Lockheed West Site Location and Vicinity Map

0 500 1,000
Feet

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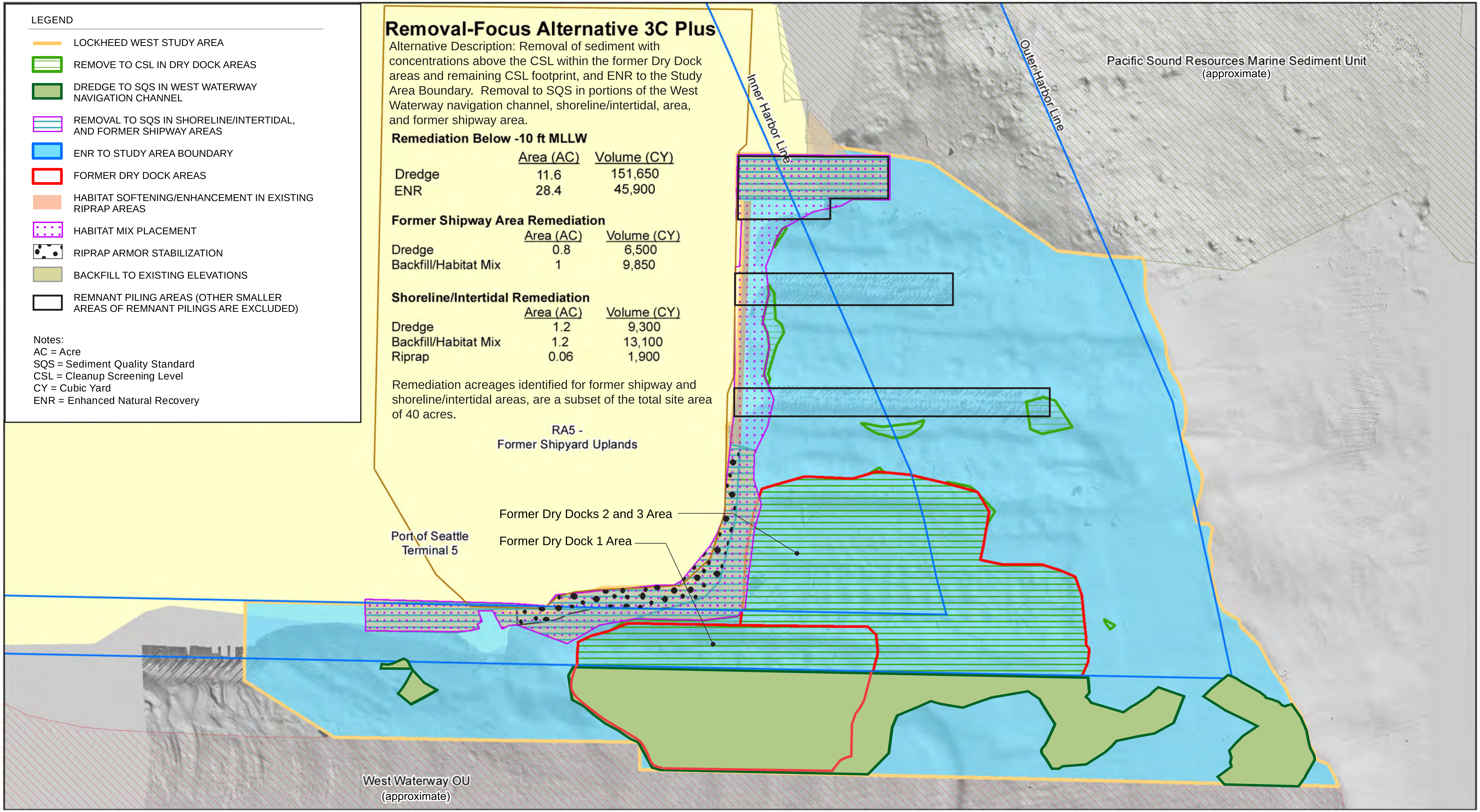


Feet
0 125 250 500

Source: Adapted from Tetra Tech, May 2012, Final RI/FS.

Figure 1-2
Removal-Focus Alternative 3C Plus
Lockheed West Superfund Site
Seattle, WA

ES061212084335SEA

2.0 Site Description, History, and Background Conditions

The Lockheed West Seattle Superfund Site includes the aquatic portions of what formerly was known as Lockheed Shipyard No. 2, located near where the West Waterway enters Elliott Bay, west of the city of Seattle, Washington (Figure 1-1). The Site is located next to the upland areas of the Port Terminal 5, including the former upland shipyard support operations area (designated as Remediation Area 5). Remediation Area 5 was previously remediated under a Washington State Model Toxics Control Act (MTCA) cleanup order and is not part of the Lockheed West Seattle Superfund Site.

2.1 Site History

Prior to industrial development, the Site and surrounding area consisted of an intertidal delta at the mouth of the Duwamish River. Most of the original wetlands and mudflats were lost during construction of the Lower Duwamish Waterway and Harbor Island, and as a result of the dredging of intertidal areas on the northern terminus of the current Port Terminal 5. At the start of World War II, the Puget Sound Bridge and Dredge Company owned the Site and operated a shipyard there. This company provided ship repair, maintenance, and vessel construction from five major piers (of which only Piers 23 and 24 remain today), three dry docks, and a shipway. Figure 2-1 presents all of these features in a 1980 aerial photograph of the Site. Industrial activities from the dry docks and shipway generated considerable sandblast grit that accumulated on and contaminated underlying sediments. The Lockheed Shipbuilding and Construction Company purchased Site assets in 1959 and continued operating the shipyard until 1987, when it ceased operations. In 1988, the Port purchased the adjacent upland property and the harbor leases from Lockheed Martin. In 1996, the Port discontinued the harbor leases, causing them to be returned to DNR management. Figure 2-2 indicates the current ownership areas of the Site today.

The Lockheed West Seattle Superfund Site was placed on the National Priorities List (NPL) on March 7, 2007. Before its transfer to the Superfund program, the Site (then referred to as Lockheed Shipyard No. 2) was listed as a sediment cleanup priority project under State of Washington authority through the requirements of MTCA.

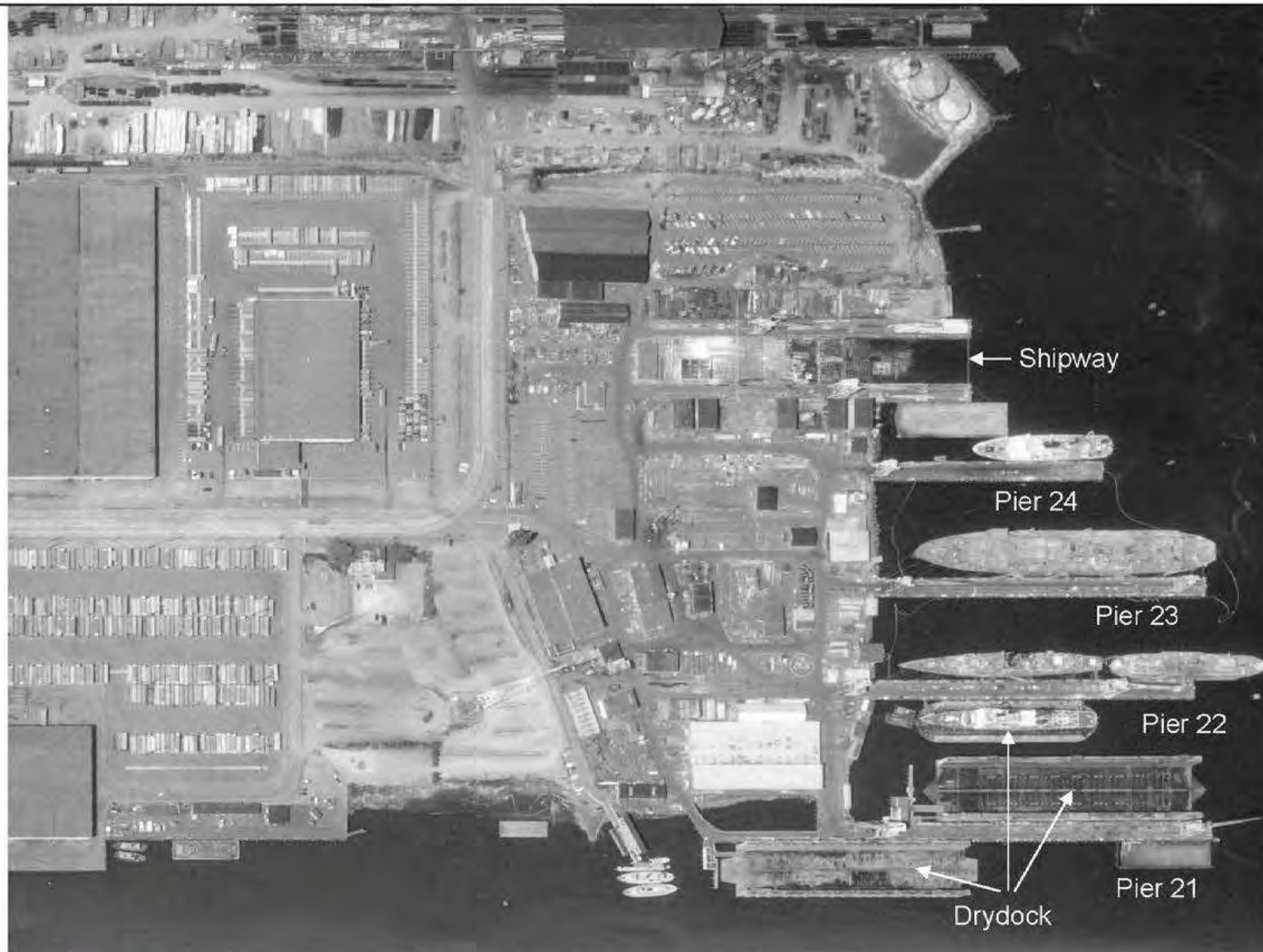
2.2 Background Conditions

Key background conditions that led to development of the Preferred Alternative are as follows:

- **Contaminated Media**—Sediment.
- **Cause of Current Site Contamination**—The primary source of Site sediment contamination is historical shipyard operations/activities and related discharges from historical shipyard operations. Contaminants (for example, PCBs, cPAHs, metals, tributyltin [TBT]) were released into the surface receiving waters during Site operations and accumulated in sediments. The Pacific Sound Resources (PSR) site adjacent to the Site was a potential source of dioxins/furans. These contaminants are commonly found at wood treatment sites and were included as a COC in EPA's 1999 ROD for the PSR site. Dioxins/furans were also found in much of the Lower Duwamish Waterway. Therefore, dioxins/furans were included as a risk driver at this Site.
- **Summary of Previous Investigations**—Since 1984, Lockheed Martin and the Port have independently conducted an extensive series of studies in an effort to determine the nature and extent of sediment contamination at the Site (Tetra Tech, 2008). Much of this information was compiled by Parametrix (1994a,b) and by Enviros, Inc. (1990) to support characterization of the Site, when it was known as Lockheed Shipyard No. 2, as part of harbor development planning by the Port. Available historical sediment quality information in the vicinity of the Site includes samples collected before 1998 and in 2003 as part of a due diligence investigation (Hart Crowser, 2003). Previous work also supported studies for the

Harbor Island RI/FS (Weston, 1993), evaluation of sediments in the West Waterway, and other sediment quality evaluations.

- **Summary of Previous Remedial Response Actions**—No response actions have been implemented at this Site. Remediation activities conducted at adjacent sites include both upland and aquatic sediment cleanup. Additional information concerning these activities is summarized in Section 3 and evaluated in the Final Existing Information and Data Gap Summary Report (Tetra Tech, 2009a) and the Final Source Control Evaluation Report (Tetra Tech, 2009b).
- **Responsible Parties**—During the 28 years that Lockheed operated the shipyard, hazardous substances from these operations were released to sediments. Lockheed implemented the RI/FS per a 2006 Administrative Settlement Agreement and Order on Consent (ASAOC).



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Lockheed West Seattle
Superfund Site
Seattle, WA

Figure 2-1
1980 Aerial Photograph

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Lockheed West Seattle Superfund Site, Seattle, WA

Figure 10-1
Current Management and Ownership

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3.0 Site Characteristics

The Site includes in-water marine sediments where the former Lockheed Shipyard No. 2 was located. It is affected by tides with additional influence from the Lower Duwamish Waterway that flows into the West Waterway. The Site includes a narrow shoreline bank and intertidal sediments along the northern and eastern shorelines, and subtidal sediments that extend to -40 to -50 ft mllw in historically dredged areas. Numerous pilings remain within the footprints of the former shipway and pier structures in the northwestern portion of the Site.

Several Superfund sites resulting from separate operations are located near the Site:

- Pacific Sound Resources (PSR) Superfund Site borders the Site on the west
- Harbor Island Superfund Site, including the following:
  - Todd Shipyard Sediment Operable Unit (TSSOU) on the east side of the West Waterway and northwest side of Harbor Island
  - Lockheed Shipyard No. 1 Sediment Operable Unit (LSSOU) on the west side of Harbor Island along the West Waterway
  - West Waterway Operable Unit (WWOU)
- Lower Duwamish Waterway (LDW Superfund Site) flows into the West and East Waterways of Harbor Island and into Elliott Bay

In addition to these Superfund sites, Ecology issued state cleanup orders for the cleanup of five MTCA remediation areas located in the Terminal 5 uplands area adjacent to the Lockheed West Seattle and PSR Superfund Sites. The predominant cleanup action applied to these upland remediation areas was capping to keep soil contamination in place and to prevent surface water infiltration into the underlying groundwater. Remediation Area 5 is located in the upland areas immediately south of the Lockheed West Seattle Site and was the site of former shipbuilding activities.

3.1 Land Use

The 40-acre Site includes approximately 7 acres of aquatic tidelands owned by the Port and 33 acres of state-owned aquatic lands administered by DNR (Figure 2-2). The Port also maintains management authority for harbor leases in the Port Management Area (PMA) located along the eastern portion of the Site near the mouth of the West Waterway and into Elliott Bay. An additional PMA is located at the southwest corner of the Site. The current DNR-managed harbor area on the north side of the Site is available as a potential future PMA. DNR also manages the state-platted West Waterway to the east of the Site that includes the shipping navigation channel. The U.S. Army Corps of Engineers has jurisdiction for maintaining the navigational channel to -34 ft mllw. The adjacent upland operations are the Port's Terminal 5 facility, which includes container transfer and handling associated with marine terminal activities.

The Site is not currently used for port-related or other commercial activities, but the Port envisions expanding the Terminal 5 facility, including pier structures, as a multi-modal container terminal along the West Waterway. Container ships use the navigational channel and offload in the West Waterway at Terminal 5. In 2010 and 2011, the Port requested Waterway Resource District Act (WRDA) authorization to dredge the navigation channel to -50 ft mllw. The Port described potential future development in letters to EPA in November 2010, May 2011, and September 2011.

The Site and adjacent aquatic areas are designated as Tribal Usual and Accustomed (U&A) Fishing Areas. The Site is not a major recreational resource compared with other water bodies in the area because it is fenced off due to its Homeland Security designation in association with the Port's Terminal 5 activities. Jack Block Park to the west of the Site was created for public viewing and water access at the PSR site.

3.2 Shoreline Characteristics

The Duwamish Estuary and Elliott Bay were extensively developed during the 20th century. Tidal flats and marshes that once dominated the mouth of the Duwamish River were dredged and filled to form Harbor Island and the upland areas of the Site. The shoreline is densely armored with riprap, wooden and steel retaining walls, or bulkheads. Since closure of the shipyard, the Port has demolished Piers 21 and 22 and removed the decking from Piers 23 and 24. Pilings for these piers and the former shipway area were left in place, and the Port is required to remove some of them per an agreement with DNR in DNR leased areas (between the inner and outer harbor lines). A narrow intertidal zone extends along the landward edge of the Site, wrapping around the eastern and northern shoreline between the West Waterway and the PSR site.

3.3 Sediments

Sediments at the Site consist of soft organic silt with varying amounts of clay and gravel extending from the surface to depths of about 3 to 7 feet below the mudline. The uppermost sediments are underlain by interbedded sands and silts of alluvial origin from the deltaic environment of the Duwamish River or from fill derived from these materials. Alluvial sands and gravels extend to depths of 100 ft or more below the mudline.

The shoreline area is composed of medium sand, shell hash, small- to medium-size cobbles, medium to large riprap, concrete keel blocks, cut-off and broken-off wood pilings, and debris (including trash, wire rope, concrete and ductile iron piping, and portions of deteriorated wooden bulkheads). Numerous debris piles and multiple pilings are present in the intertidal and subtidal areas of the former dry docks and shipway.

3.4 Bathymetry

The Site is situated on a relatively flat bathymetric bench located in an intertidal zone (Figure 3-1). The bathymetric profile is composed of an upper layer of 3 ft of very loose sandy silt, followed by a 10- to 20-ft layer of interbedded soft sandy silt and loose silty sand, underlain by medium dense to dense silty sand to a depth of 75 to 100 ft, below which the material becomes very dense. This pattern is consistent with deltaic deposits. These deposits transition to glacial till at a depth of about 150 ft; below 300 feet, the glacial till behaves as bedrock. The bedrock at the Site is at a range of 650 to 1,000 ft (Hart Crowser, 2003).

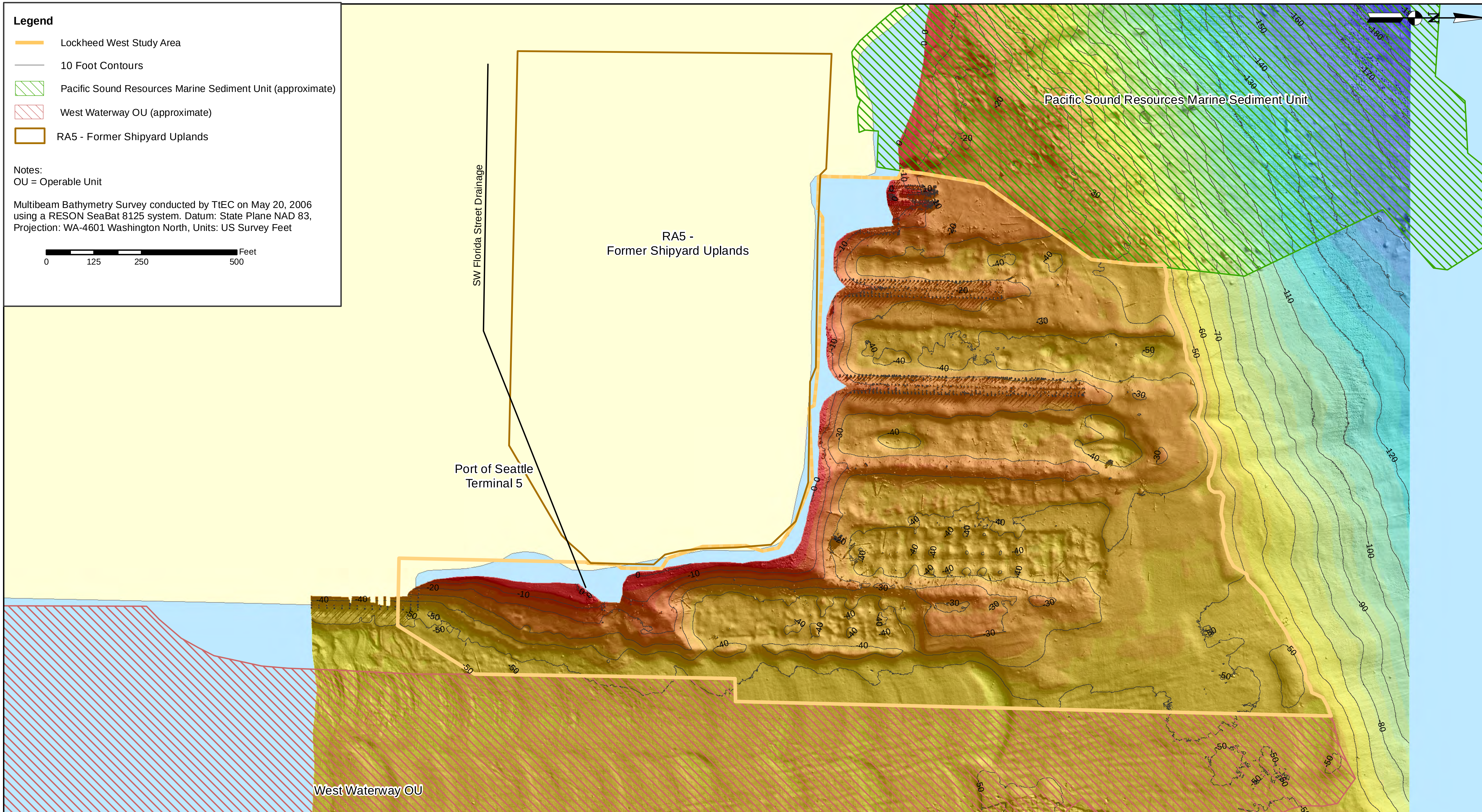
3.5 Seismic Conditions

An engineering evaluation of seismic stability and liquefaction potential that evaluated several representative remedial alternatives was completed for the Site (see Appendix H in Tetra Tech, 2012a). This evaluation assessed the outcome for nominal 100-, 500-, and 2,500-year earthquake events in terms of ground movement, sediment disturbance, and predicted impacts to Site remedial actions. This seismic evaluation confirmed that extensive liquefaction and ground failure of sediments within the Site boundary and vicinity are likely to occur during moderate to large earthquakes. These areas are also susceptible to lateral spreading, post-liquefaction settlement, and earthquake-induced displacement during seismic events.

3.6 Ecology

Sediment and the bottom water column on the eastern portion of the Site that lies in the West Waterway are estuarine in nature. The shoreline habitat is typical of the industrial shoreline in much of the Duwamish Waterway, with armoring and sheet pile bulkheads along with broken pilings, deteriorating wooden bulkheads, and debris. There is a single, small intertidal beach area located along the West Waterway between the Terminal 5 pier and the South Florida Street Outfall. Current shoreline conditions within the remainder of the Site boundary indicate a highly modified and affected industrial shoreline with little to no natural intertidal habitat.

Flora and fauna of the aquatic area and shoreline include bivalves, crustaceans, and worms in the fine sediments. Crustaceans and mollusks are typically found in coarser sediments. The Site environment also supports birds, crabs, and resident fish (such as perch, sculpin, rockfish), as well as anadromous fish (such as salmon).



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Lockheed West Seattle Superfund Site, Seattle, WA

Figure 3-1
Lockheed West Site Bathymetry

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4.0 Nature and Extent of Contamination

Lockheed Martin submitted the Final RI/FS for the Lockheed West Seattle Superfund Site to EPA Region 10 in May 2012 (Tetra Tech, 2012a). The Site RI fieldwork was conducted from 2006 through 2008. RI field activities and collected data include the following:

- Performance of a high-resolution multibeam bathymetry survey, shoreline conditions survey, and topographic survey
- Collection of surface sediment samples from the intertidal and subtidal areas
- Collection of subsurface sediment samples from the subtidal area
- Collection of pore water and surface water samples
- Performance of clam reconnaissance surveys and collection of clam tissue samples

Analytical data from the surface and subsurface sediment samples (Table 4-1) show that metals, PCBs, TBT, and polycyclic aromatic hydrocarbons (PAHs) are the most frequently detected compounds in the study area.

In addition to Site sediment conditions, the RI investigated the potential for contamination from known or suspected adjacent sources to affect the Site. These sources included groundwater and surface water contamination, spills and unauthorized releases, permitted wastewater discharges, and combined sewer outfall bypasses. The RI concluded that there are no indications that these sources represent a significant source of contamination to the Site nor are they likely to affect post-remediation sediment quality at the Site.

There are four major media and associated fate and transport processes at the Site: (1) physical sediment transport, (2) surface-mixed sediment layer and associated pore water, (3) surface water, and (4) biota.

Available information from sediment transport and surface water circulation studies for Elliott Bay, the Harbor Island area, and the PSR site suggests that the Lockheed West Seattle Superfund Site is a net depositional area characterized by a low sedimentation rate. Comparison of Site bathymetric data from 2006 with historical bathymetric data supports the conclusion that the Site sediments are stable, with little (if any) noticeable change in bottom surface elevations following historical dredging events. The potential for contaminant migration offsite through the resuspension of sediment particles is, therefore, low. Conversely, the Site may receive sediment transported from adjacent in-water sources such as the adjacent West Waterway and Elliott Bay as a result of wave and current action. After cleanup, sediments containing contaminant concentrations higher than background could be brought onto the Site.

Most of the risk-driver contaminants in the sediments at the Site adhere strongly to sediment particles. Therefore, pore water and surface water transport processes are expected to have only a small influence on contaminant fate and transport at the Site.

Analytical data from surface and subsurface sediment samples indicate that metals, PCBs, TBT, and PAHs are the most frequently detected compounds in the study area. Typical shipyard-related metals (including arsenic, chromium, copper, lead, mercury, and zinc) exceeded Washington SMS SQS and CSL criteria in both surface and subsurface samples. Table 4-1 summarizes carbon-normalized results for total PAHs, PCBs, and several miscellaneous semivolatile organic compounds (SVOCs) in comparison with SMS screening criteria. PCBs were the most common contaminant detected above SQS and CSL screening criteria in both surface and subsurface samples. PAHs were the next most common contaminant detected with exceedances of SMS criteria. Dioxins and furans were also identified as COCs based on concentrations found in sediments during the clam reconnaissance survey.

4.1 Extent of Contamination

Sediment quality data from the RI were evaluated to estimate the extent of Site-related contamination. This evaluation included use of three-dimensional (3-D) modeling and a 3-D visualization software program known as C-Tech MVS. The RI results show that the highest contaminant concentrations, including exceedances of the CSL screening criteria, were detected primarily in surface sediments located in the former dry dock areas and in the area of the former shipway. Similarly, locations of the deepest areas with concentrations above the SQS were also located in the former dry dock areas. For the majority of the sediment cores collected, the deepest sample interval analyzed showed concentrations of risk-driver contaminants that were less than the SQS concentrations. The vertical extent of contamination in these cores ranged from 2 to 12 ft below the top of the sediment surface, depending on location and contaminant. At sediment core locations where the deepest sample interval had contaminant concentrations above the SQS, data from nearby cores indicate that the likely vertical extent of contamination is not substantially deeper. Contaminant concentrations in surface sediments (upper 10 centimeters [cm]) tend to decrease outward toward the Site boundaries. Beyond the former dry dock areas, sediment concentrations generally are not greater than twice the SQS.

In addition, surface sediment quality data for dioxins and furans were collected from one intertidal and three subtidal locations. Dioxins/furans were assumed to be prevalent at this Site due to the proximity of the PSR site (a wood treatment facility where dioxins/furans were listed as COCs in the 1999 ROD for that site) and because they are also present throughout much of the Lower Duwamish Waterway. Detected concentrations of dioxins/furans at the Lockheed West Seattle Superfund Site were 0.69 parts per trillion (ppt) for the intertidal sample and 2.0 to 13.8 ppt for the subtidal samples. These concentrations represent dioxin levels expressed as the tetrachlorodibenzodioxin (TCDD) toxicity equivalent (TEQ) for each sample. There are no MTCA SMS SQS or CSL criteria for dioxin/furans in sediments. The calculated risk levels for dioxins/furans are provided in Section 6.

4.2 Comparison of Detected Contaminant Concentrations with Puget Sound Background Levels

Under CERCLA, it is EPA's policy (EPA, 2002) not to clean up contamination below background concentrations. Under MTCA, natural background is used to establish cleanup goals if such concentrations are higher than risk-based cleanup levels. Sediment samples from all areas throughout the Site contain PCBs, PAHs, and several metals at concentrations that exceed natural background levels established for the Puget Sound region (see natural background concentrations in Table 4-2). Background concentrations were established in the EPA "Bold Study" (EPA, 2009a).

4.3 Pacific Sound Resources Superfund Site Surface Sediment Quality Data

In 2006 and 2007, the U.S. Army Corps of Engineers coordinated surface sediment sampling and chemical testing to evaluate the performance of remedial caps placed at the PSR Superfund site in 2005 (Science Applications International Corporation [SAIC], 2008). The PSR site is located immediately west of the Lockheed West Seattle Superfund Site (Figure 1-1). Post-cap sediment sampling and chemical testing were conducted as part of the site monitoring program supporting EPA's Five-Year Review Report for PSR (EPA, 2009b). The PSR sediment sample testing results also provide general information regarding equilibration of sediment COCs to Elliott Bay background conditions following placement of the PSR capping materials. A number of the sediment samples collected from the PSR capping areas contained concentrations of metals above natural background levels established for Puget Sound by the Bold Study . For example, 11 of the 12 sediment samples collected in 2006 had concentrations of mercury in excess of the natural background concentration of 0.101 mg/kg- dw, and 9 of the samples had lead concentrations in excess of the background concentration of 11 mg/kg-dw. Concentrations of certain metals also exceeded the Elliott Bay urban background levels. For example, arsenic concentrations in 5 of the 7 seven samples with natural background exceedances also exceeded the urban background concentration. In addition, concentrations of cPAHs and PCBs in the 2007 PSR surface sediment data set also exceeded natural background levels. For example, detected concentrations of cPAHs in the 25 samples ranged from 10.48 to 242 ug/kg-dw TEQ and all 25 results exceeded the natural background concentration for cPAHs at 9 ug/kg TEQ dw. However, none of the cPAH results exceeded the urban background level of 757 ug/kg dw TEQ. Detected concentrations of total PCBs ranged from 2 to 317 ug/kg dw, in comparison to a natural background concentration of 2 ug/kg dw (24 of 25 samples exceeded the value, 1 equaled it). Concentrations of total PCBs in 2 of the samples also exceed the urban background concentration of 119 ug/ kg dw. With regard to projected post-remediation surface sediment quality at the Lockheed West site, the PSR results indicate that COC concentrations may equilibrate to concentrations above background over time.

TABLE 4-1
Comparison of Surface and Subsurface Sample Results with the Sediment Management Standard Criteria

Parameter	SQS	CSL	Unit Basis	LAET (µg/kg-dw)	2LAET (µg/kg-dw)	Number Samples Exceeding SQS/LAET[2]	Percent Exceeding SQS/LAET[2]	Number Samples Exceeding CSL/2LAET[2]	Percent Exceeding CSL/2LAET[2]
Surface Sediment									
PAHs									
Acenaphthylene	66	66	mg/kg-OC	1,300	1300	6	8.2	2	2.7
Benzo(a)anthracene	110	270	mg/kg-OC	1,300	1,600	9	12.3	1	1.4
Benzo(a)pyrene	99	210	mg/kg-OC	1,600	3,000	9	12.3	1	1.4
Benzofluoranthenes (total)	230	450	mg/kg-OC	3,200	3,600	5	6.8	1	1.4
Benzo(g,h,i)perylene	31	78	mg/kg-OC	6,760	720	21	28.8	2	2.7
Chrysene	110	460	mg/kg-OC	1,400	2,800	15	20.5	1	1.4
Dibenzo(a,h)anthracene	12	33	mg/kg-OC	230	540	14	19.2	2	2.7
Fluoranthene	160	1200	mg/kg-OC	1,700	2,500	19	26	0	0
Indeno(1,2,3-cd)pyrene	34	88	mg/kg-OC	600	690	15	20.5	2	2.7
Phenanthrene	100	480	mg/kg-OC	1,500	5,400	11	15.1	0	0
Pyrene	1000	1400	mg/kg-OC	2,600	3,300	0	0	0	0
Acenaphthene	16	57	mg/kg-OC	500	730	6	8.2	2	2.7
Anthracene	220	1200	mg/kg-OC	960	440	0	0	0	0
Fluorene	23	79	mg/kg-OC	1,700	2,500	5	6.8	0	0
Naphthalene	99	170	mg/kg-OC	2,100	2,400	1	1.4	0	0
2-Methylnaphthalene	38	68	mg/kg-OC	670	1,400	0	0	0	0
Total LPAH	370	780	mg/kg-OC	5,200	13,000	2	2.7	1	1.4
Total HPAH	960	5300	mg/kg-OC	12,000	17,000	15	20.5	0	0
Other SVOCs									
1,2-Dichlorobenzene	2.3	2.3	mg/kg-OC	35	50	0	0	0	0
1,4-Dichlorobenzene	3.1	9	mg/kg-OC	110	120	0	0	0	0
1,2,4-Trichlorobenzene	0.81	1.8	mg/kg-OC	31	51	0	0	0	0
2-Methylphenol	63	63	µg/kg-dw	63	63	0	0	0	0
4-Methylphenol	670	670	µg/kg-dw	670	670	0	0	0	0
2,4-Dimethylphenol	29	29	µg/kg-dw	29	29	0	0	0	0
Benzyl alcohol	57	73	µg/kg-dw	57	73	0	0	0	0
Benzoic Acid	650	650	µg/kg-dw	650	650	0	0	0	0
Butyl benzyl phthalate	4.9	64	mg/kg-OC	63	900	0	0	0	0
Dibenzofuran	15	58	mg/kg-OC	540	700	2	2.7	0	0
Bis(2-ethylhexyl)phthalate	47	78	mg/kg-OC	1,300	1,900	8	11.0	3	4.1
Diethylphthalate	61	110	mg/kg-OC	200	200	0	0	0	0
Dimethyl phthalate	53	53	mg/kg-OC	71	160	0	0	0	0
Di-n-butyl phthalate	220	1700	mg/kg-OC	1,400	1,400	0	0	0	0
Di-n-Octyl phthalate	58	4500	mg/kg-OC	6,200	6,200	0	0	0	0
Hexachlorobenzene	0.38	2.3	mg/kg-OC	22	70	2	2.7	0	0

TABLE 4-1

Comparison of Surface and Subsurface Sample Results with the Sediment Management Standard Criteria

Parameter	SQS	CSL	Unit Basis	LAET (µg/kg-dw)	2LAET (µg/kg-dw)	Number Samples Exceeding SQS/LAET[2]	Percent Exceeding SQS/LAET[2]	Number Samples Exceeding CSL/2LAET[2]	Percent Exceeding CSL/2LAET[2]
Hexachlorobutadiene	3.9	6.2	mg/kg-OC	11	120	0	0	0	0
Pentachlorophenol	360	650	µg/kg-dw	360	650	4	5.4	0	0
Phenol	420	1200	µg/kg-dw	420	1,200	0	0	0	0
PCBs									
PCBs (total)	12	65	mg/kg-OC	130	1,000	59	81	11	15.1
Metals									
Arsenic	57	93	mg/kg-dw	57[1/]	93[1/]	12	16.4	10	13.7
Cadmium	5.1	6.7	mg/kg-dw	5.1[1/]	6.7[1/]	0	0	0	0
Chromium	260	270	mg/kg-dw	260[1/]	270[1/]	3	4.1	3	4.1
Copper	390	390	mg/kg-dw	390[1/]	390[1/]	16	21.9	16	21.9
Lead	450	530	mg/kg-dw	450[1/]	530[1/]	3	4.1	2	2.7
Mercury	0.41	0.59	mg/kg-dw	0.41[1/]	0.59[1/]	32	44	24	33
Silver	6.1	6.1	mg/kg-dw	6.1[1/]	6.1[1/]	0	0	0	0
Zinc	410	960	mg/kg-dw	410[1/]	960[1/]	17	23.3	3	4.1
Subsurface Sediment									
PAHs									
Acenaphthylene	66	66	mg/kg-OC	1,300	1300	9	5.6	9	5.6
Benzo(a)anthracene	110	270	mg/kg-OC	1,300	1,600	45	28	29	16
Benzo(a)pyrene	99	210	mg/kg-OC	1,600	3,000	38	24	24	15
Benzofluoranthenes (total)	230	450	mg/kg-OC	3,200	3,600	34	21	23	14
Benzo(g,h,i)perylene	31	78	mg/kg-OC	6,760	720	49	31	30	19
Chrysene	110	460	mg/kg-OC	1,400	2,800	46	29	21	12
Dibenzo(a,h)anthracene	12	33	mg/kg-OC	230	540	53	33	26	16
Fluoranthene	160	1,200	mg/kg-OC	1,700	2,500	55	34	26	16
Indeno(1,2,3-cd)pyrene	34	88	mg/kg-OC	600	690	26	16	7	4.4
Phenanthrene	100	480	mg/kg-OC	1,500	5,400	52	33	32	20
Pyrene	1,000	1,400	mg/kg-OC	2,600	3,300	26	16	16	10
Acenaphthene	16	57	mg/kg-OC	500	730	56	35	36	23
Anthracene	220	1,200	mg/kg-OC	960	440	28	18	3	1.9
Fluorene	23	79	mg/kg-OC	1,700	2,500	49	31	32	20
Naphthalene	99	170	mg/kg-OC	2,100	2,400	23	14	18	6.3
2-Methylnaphthalene	38	68	mg/kg-OC	670	1,400	16	10	12	7.5
Total LPAH	370	780	mg/kg-OC	5,200	13,000	47	29	36	23
Total HPAH	960	5,300	mg/kg-OC	12,000	17,000	53	33	19	12
Other SVOCs									
1,2-Dichlorobenzene	2.3	2.3	mg/kg-OC	35	50	0	0	0	0
1,4-Dichlorobenzene	3.1	9	mg/kg-OC	110	120	0	0	0	0

TABLE 4-1

Comparison of Surface and Subsurface Sample Results with the Sediment Management Standard Criteria

Parameter	SQS	CSL	Unit Basis	LAET (µg/kg-dw)	2LAET (µg/kg-dw)	Number Samples Exceeding SQS/LAET[2]	Percent Exceeding SQS/LAET[2]	Number Samples Exceeding CSL/2LAET[2]	Percent Exceeding CSL/2LAET[2]
1,2,4-Trichlorobenzene	0.81	1.8	mg/kg-OC	31	51	0	0	0	0
2-Methylphenol	63	63	µg/kg-dw	63	63	0	0	0	0
4-Methylphenol	670	670	µg/kg-dw	670	670	0	0	0	0
2,4-Dimethylphenol	29	29	µg/kg-dw	29	29	0	0	0	0
Benzyl alcohol	57	73	µg/kg-dw	57	73	0	0	0	0
Benzoic Acid	650	650	µg/kg-dw	650	650	0	0	0	0
Butyl benzyl phthalate	4.9	64	mg/kg-OC	63	900	0	0	0	0
Dibenzofuran	15	58	mg/kg-OC	540	700	48	30	28	18
Bis(2-ethylhexyl)phthalate	47	78	mg/kg-OC	1,300	1,900	38	24	29	16
Diethylphthalate	61	110	mg/kg-OC	200	200	0	0	0	0
Dimethyl phthalate	53	53	mg/kg-OC	71	160	0	0	0	0
Di-n-butyl phthalate	220	1,700	mg/kg-OC	1,400	1,400	0	0	0	0
Di-n-Octyl phthalate	58	4500	mg/kg-OC	6,200	6,200	2	1.3	0	0
Pentachlorophenol	360	690	µg/kg-dw	22	70	4	2.6	0	0
Phenol	420	1,200	µg/kg-dw	11	120	0	0	0	0
PCBs									
PCBs (total)	12	65	mg/kg-OC	130	1,000	74	46	36	23
Metals									
Arsenic	57	93	mg/kg-dw	57 [1/]	93 [1/]	27	17	15	9.4
Cadmium	5.1	6.7	mg/kg-dw	5.1 [1/]	6.7 [1/]	0	0	0	0
Chromium	260	270	mg/kg-dw	260 [1/]	270 [1/]	7	4.4	7	4.4
Copper	390	390	mg/kg-dw	390 [1/]	390 [1/]	29	18	29	18
Lead	450	530	mg/kg-dw	450 [1/]	530 [1/]	14	8.8	11	6.9
Mercury	0.41	0.59	mg/kg-dw	0.41[1/]	0.59 [1/]	52	33	43	27
Silver	6.1	6.1	mg/kg-dw	6.1 [1/]	6.1 [1/]	0	0	0	0
Zinc	410	960	mg/kg-dw	410 [1/]	960 [1/]	33	21	17	11

Notes:

[1/] Criteria are in mg/kg-dw.

[2/] For OC normalized SQS and CSL criteria where the percent OC in the sample is less than 0.5 percent the sample concentrations are compared to the LAET or 2LAET for SQS and CSL, respectively.

2LAET = Second Lowest Apparent Effects Threshold

CSL = Cleanup Screening Level

HPAH = heavy weight polycyclic aromatic hydrocarbon

LAET = Lowest Apparent Effects Threshold

LPAH = light weight polycyclic aromatic hydrocarbon

mg/kg-dw = milligram per kilogram dry weight

mg/kg-OC = milligram per kilogram organic carbon

µg/kg-dw = microgram per kilogram dry weight

PCB = polychlorinated biphenyl

SQS = Sediment Quality Standard

SVOC = semivolatile organic compound

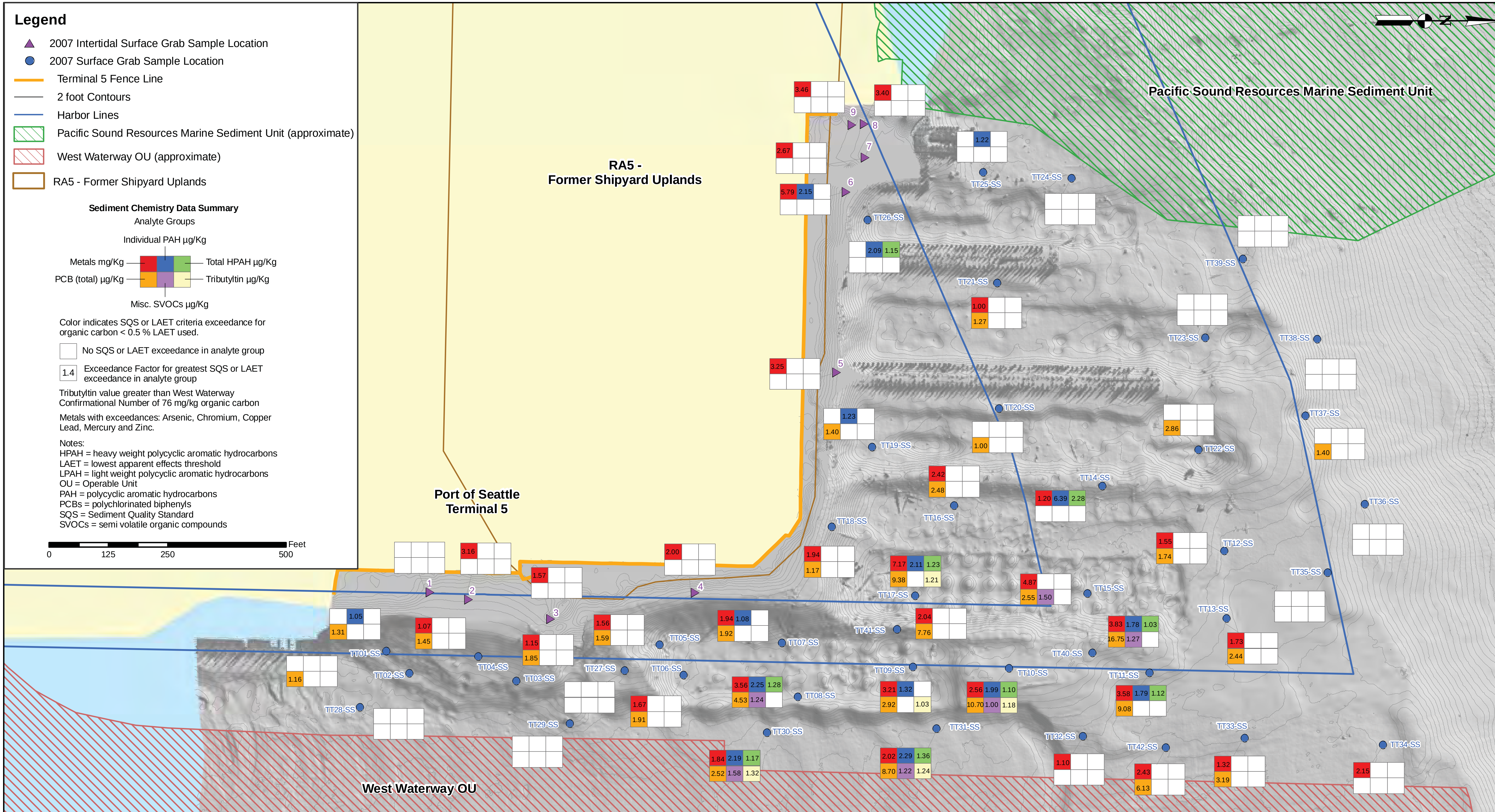
TABLE 4-2
Sediment Background Concentration Information

Parameter	Bold Study (Puget Sound Natural Background Level)	Elliott Bay Area Sediment		
		Basin [1/]	Urban	Harbor
Metals				
Arsenic	7.3	9.13	8.44	73.4
Copper	24.9	41.1	48.9	112
Lead	10.9	26.9	47	66.9
Mercury	0.101	0.175	0.438	0.335
Organics				
cPAHs	0.00797	0.125	0.757	1.21
Total PCBs	0.0014[2/]	0.048	0.119	0.355
Tributyltin	NA	NA	NA	NA

Notes:
All concentrations in mg/kg dry weight.
[1/] Value is the maximum detected result for the two samples in the defined region.
[2/]Total PCB result is for the sum of congeners as all Aroclor data was ND for Aroclors 1221 – 1260.
cPAH = carcinogenic polycyclic aromatic hydrocarbon
NA = analyte not analyzed
PCB = polychlorinated biphenyl

Sources:
Bold Study (EPA, 2009a) – Dredged material management program agencies collected 70 surface sediment samples at locations throughout Puget Sound. Samples were analyzed for dioxins/furans, PCBs and DMMP contaminants including PAHs and trace metals. The 95 UCL was determined for the 6 risk-driver chemicals with reported data.

Elliott Bay Sediment (Ecology, 2009) – Under the Urban Waters Initiative, the Washington State Department of Ecology collected data on sediment contaminant concentrations in three anthropogenic-use/geomorphological areas of Elliott Bay: deep basin (2 samples), urban/mid-bay (13 samples), and harbor/inner bay (15 samples).



Lockheed West Seattle Superfund Site Seattle, WA

Figure 4-1 Exceedances of Sediment Quality Standards in Surface Sediment Samples from 2007 (Remedial Investigation Data)

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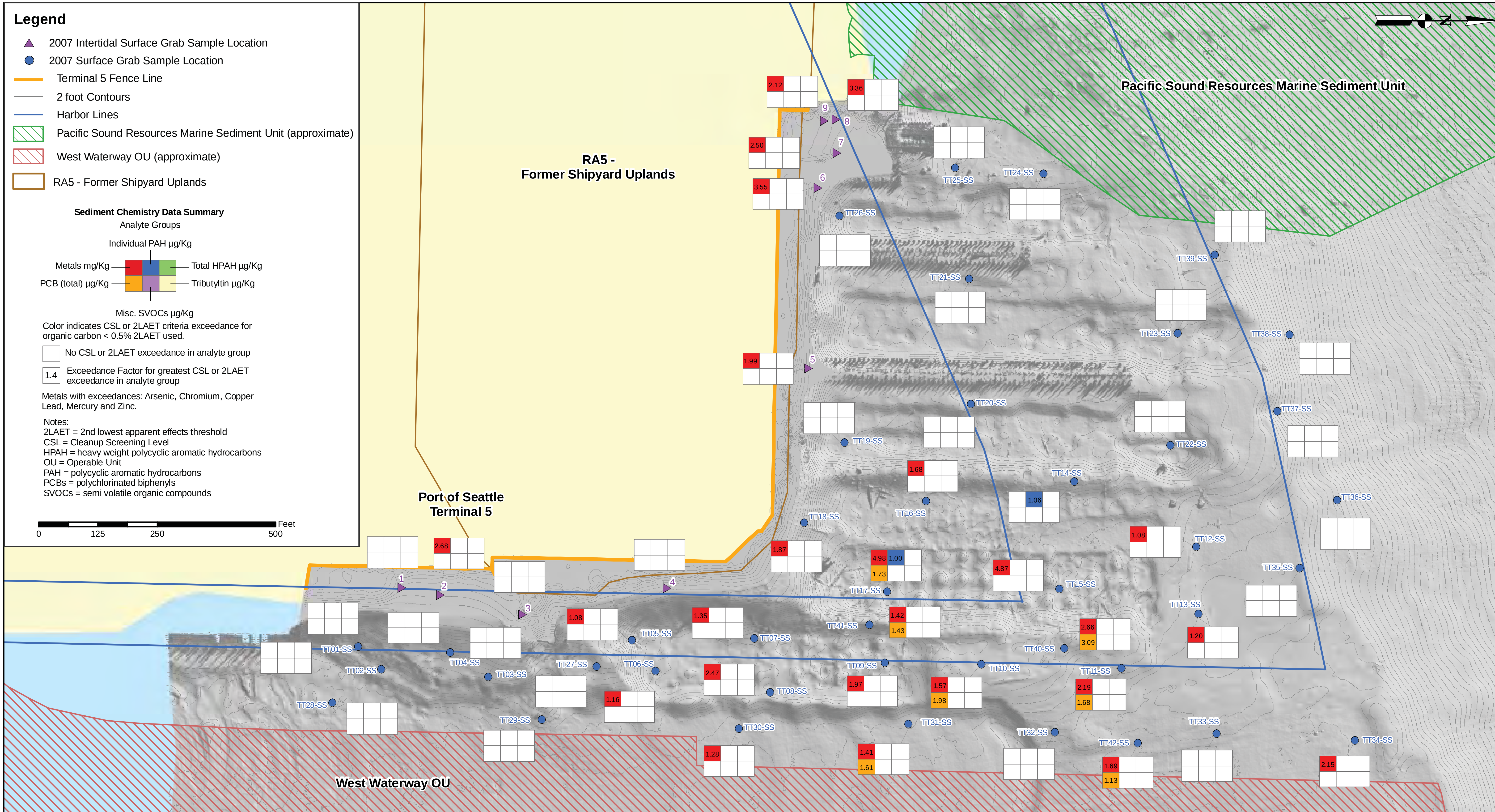
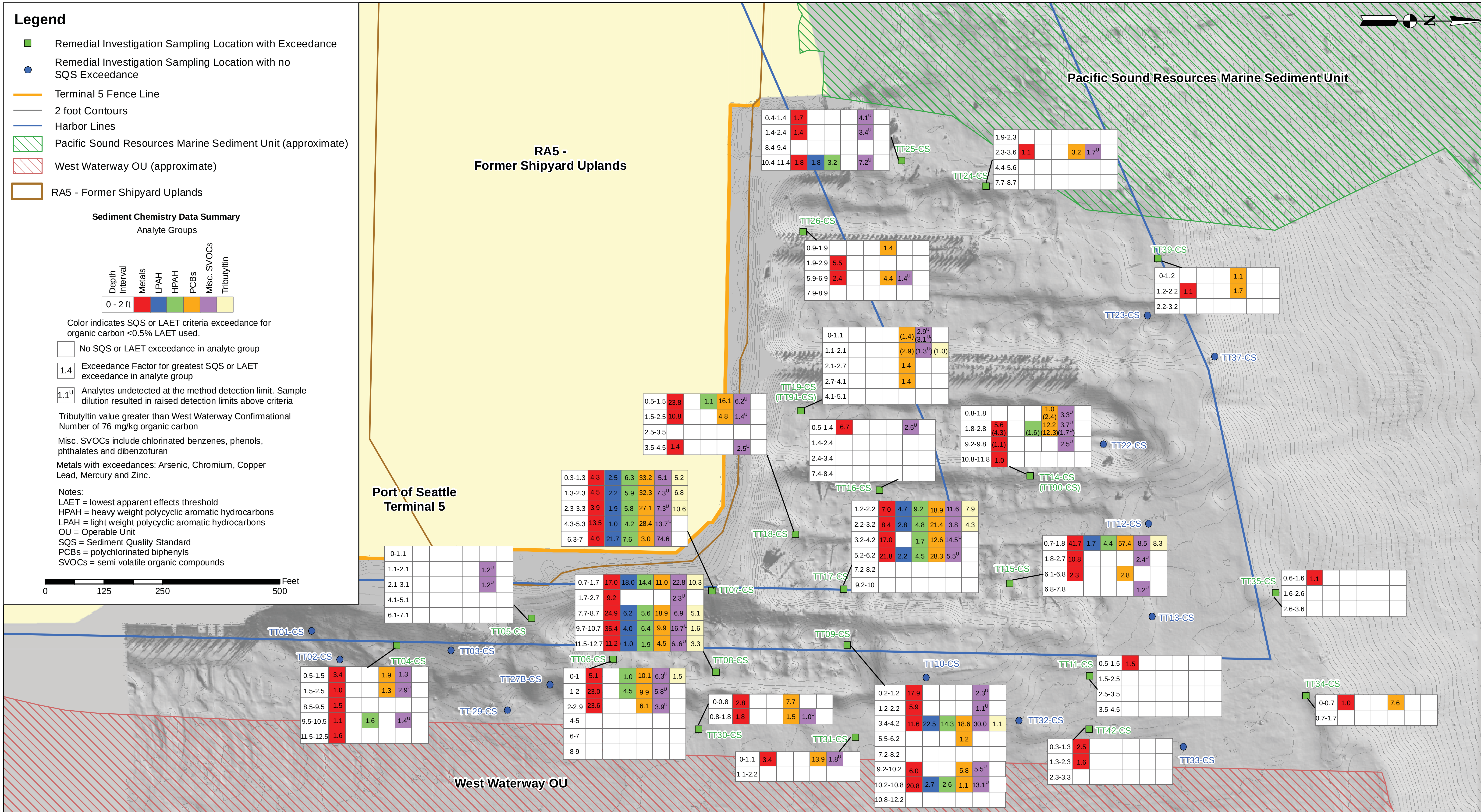


Lockheed West Seattle Superfund Site
Seattle, WA

Figure 4-2
Exceedances of Cleanup Screening Levels in Surface Sediment Samples from 2007 (Remedial Investigation Data)



TETRA TECH

Lockheed West Seattle Superfund Site Seattle, WA

Figure 4-3 Exceedances of Sediment Quality Standards in Subsurface Sediment Samples from 2007 (Remedial Investigation Data)

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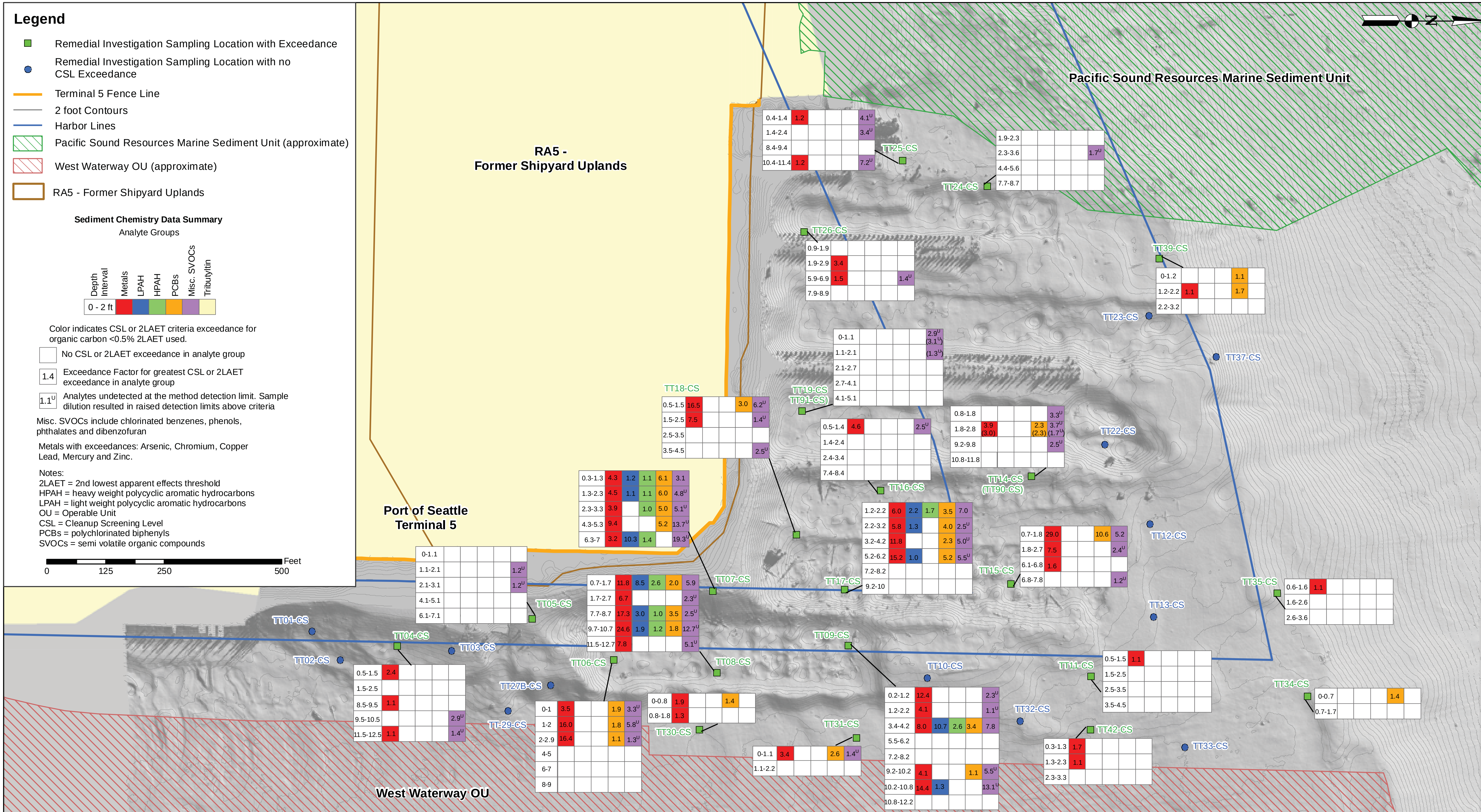

TETRA TECH

Lockheed West Seattle Superfund Site
Seattle, WA

Figure 4-4
Exceedances of Cleanup Screening Levels in Subsurface Sediment Samples from 2007 (Remedial Investigation Data)

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5.0 Scope and Role of Operable Unit

This is the final and only remedial action proposed for the Site. There are no other operable units. No early actions were taken at this Site.

The scope of the problem addressed by this Proposed Plan focuses on the shoreline bank and intertidal and subtidal sediments within the defined study area where there are unaddressed contamination issues. In particular, this action will address contaminated sediments posing risk, prevent further detrimental impacts to the water quality of Elliott Bay, and minimize contaminants available to fish from this Site.

6.0 Summary of Site Risks

EPA conducted human health and ecological risk assessments and looked at potential pathways that might expose humans or wildlife to contamination from the Site. The exposure scenarios evaluated for people are summarized in Figure 6-1 and those for ecological receptors are summarized in Figure 6-2. The major findings of the risk assessments are presented in the following subsections.

6.1 Human Health Risks

As part of the risk assessment, EPA identified contaminants of potential concern (COPCs) that were detected at the Site and subjected to the risk-based screening process. From this list of COPCs, EPA identified COCs that pose an unacceptable risk to human health and that the remedial action should address.

COCs are defined by the level of risk estimated for reasonable maximum exposure scenarios in the human health risk assessment. Human health COCs are identified as contaminants having an excess lifetime cancer risk (ELCR) greater than 1×10^{-6} for carcinogenic chemicals, or having a hazard quotient greater than 1 for noncarcinogens. The hazard quotient is the ratio of the exposure concentration or dose to the lowest observed adverse effect level of a given contaminant. Table 6-1 provides a summary of the risk levels associated with each COPC and exposure scenario. Human health COCs identified at the Site include the following:

- Metals (arsenic, cadmium, chromium, copper, lead, mercury, zinc, and TBT)
- Pentachlorophenol
- cPAHs
- Total PCBs
- Dioxins/furans

In addition, total chlordane and total dichlorodiphenyltrichloroethane (DDT) are tentatively identified contaminants retained as COCs.

From this list, EPA identified risk-driver contaminants that are predicted to have the highest relative contribution to estimated human health risks based on the assumed exposure scenarios, as summarized below:

- **Tribal adult seafood consumption**—arsenic, cPAHs, total PCBs, dioxins/furans, and TBT (total ELCR = 9×10^{-3} and total noncancer hazard index [HI] = 173)
- **Tribal child seafood consumption**—arsenic, lead, cPAHs, total PCBs, dioxins/furans, and TBT (total ELCR = 4×10^{-3} and total noncancer HI = 372)
- **Clamming**—arsenic, dioxins/furans (total ELCR = 1×10^{-4} and total noncancer HI = 0.5)
- **Beach play**—arsenic, cPAHs, dioxins/furans (total ELCR = 7×10^{-5} and total noncancer HI = 2.6)
- **Netfishing**—arsenic, cPAHs, dioxins/furan (total ELCR = 3×10^{-5} and total noncancer HI = 0.1)

Because of their tentative identification and overall low relative contributions to risk, total chlordane and total DDT were not retained as risk-driver contaminants.

6.2 Ecological Risks

Ecological COPCs were identified based on the potential exposure of ecological receptors of concern (ROCs) to contaminants present at the Site. For the benthic community, COPCs were identified by comparing sediment contaminant concentrations with sediment quality criteria listed in the Washington SMS. COPCs for fish and crab receptors were identified as contaminants exceeding risk-based bioaccumulation criteria. Fish ROCs for the Site ecological risk assessment (ERA) are grouped into two broad categories based on potential sediment exposure at the Site:

- **Benthivorous fish**—represented by English sole *(Parophrys vetulus)*, and including rock sole and starry flounder. This category is also considered to be protective of fish that prey on pelagic and encrusting organisms, such as Pacific herring and pile perch.
- **Upper-trophic-level fish**—represented by Pacific staghorn sculpin *(Leptocottus armatus)*, and including bull trout and sand sole. Pacific staghorn sculpin is used to represent piscivorous and omnivorous species that prey on other fish.

Avian receptors are represented by the spotted sandpiper (*Actitis macularia)* that had associated COPCs exceeding risk-based contaminant concentrations in sediment. Other potential receptors—such as mammals like river otters and harbor seals, or piscivorous birds like bald eagles, ospreys, or great blue herons—were not selected as ROCs. This is because of their limited exposure to contaminants at the Site, as well as the relatively low risks calculated for these receptors at the LDW site when compared with shorebirds.

Tables 6-2 through 6-4 provide summaries of the risk levels associated with each ROC.

Ecological COCs were identified as contaminants with a hazard quotient (HQ) greater than 1 for the applicable exposure pathways for ecological receptors and those contaminants exceeding Washington SMS criteria. The ecological COCs, by ROC,[1] are as follows:

- **Benthic invertebrates** (includes clams)—metals (arsenic, antimony, chromium, cobalt, copper, lead, mercury, nickel, selenium, vanadium, zinc), TBT (pore water), pentachlorophenol, total PCBs, bis(2-Ethylhexyl)phthalate, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and total high-molecular-weight PAHs (HPAHs)
- **Crab** —TBT
- **Fish** (as represented by English sole and Pacific staghorn sculpin)—copper, TBT, total PCBs
- **Birds** (as represented by the spotted sandpiper)—copper and lead

Total DDT is an additional tentatively identified contaminant retained as a COC.

Of the COCs identified, risk-driver contaminants with the greatest contributions to ecological risk are as follows:

- **Benthic invertebrates (includes clams)**—arsenic, copper, mercury, and total PCBs
- **Crab**—TBT
- **Fish**—copper, TBT, and total PCBs
- **Birds**—copper and lead

Because of tentative identification and overall low relative contribution to risk, total DDT was not retained as a risk-driver contaminant.

6.3 Risks from Surface Water Exposure

The 2009 human health risk assessment for the Site (Tetra Tech and Pascoe, 2009b) summarized direct- contact exposure risks to surface water based on a previous quantitative evaluation by King County for Elliott Bay and the lower Duwamish River. The King County Water Quality Assessment (WQA) evaluated risks to aquatic users using contaminant exposure point concentrations estimated from a water and sediment quality model. The King County model was further modified and calibrated during the human health risk assessment completed for the LDW site. Modeling results were applied to the Lockheed West Site to support the RI/FS. For noncarcinogenic risks, no risk HQs exceeding 1 were predicted by the King County model for direct-contact exposure scenarios for adults or children at any exposure levels at locations in the Duwamish River (Duwamish Park) and Elliott Bay (Duwamish Head). Negligible noncarcinogenic health effects to swimmers, scuba divers, or windsurfers were indicated from direct exposure. Estimated cancer risks were less than 1×10^{-6} for individual chemicals and for total incremental

[1] More information about the selection of ROCs for the Site is provided in the RI/FS (Tetra Tech, 2012a).

carcinogenic risks across all COPCs. Excess cancer risks for swimmers exceeding 1 x 10^{-6} were estimated by the King County model only at relatively high exposure levels (that is, 24 days per year at 2.6 hours per day). The latter estimate also accounted for exposure to sediments while swimming.

Assessments of surface water exposure risks for biota were included in the 2009 ecological risk assessment for the Site (Tetra Tech and Pascoe, 2009a). The ecological risk assessment considered ingestion and direct-contact exposure pathways for sandpipers, and exposure of benthic invertebrates (including clams) to groundwater discharging to surface water from adjacent upland areas. Results of the ecological risk assessment completed for the LDW site were evaluated and applied to the Lockheed West Site for the sandpiper exposure scenarios. The LDW site ecological risk assessment determined that surface water ingestion was an insignificant proportion of the exposure risk to sandpipers. Direct contact was also assumed to be insignificant because of the presence of feathers that limit exposure over much of the body area. The sandpiper ingestion and direct-contact exposure pathways were likewise determined to be insignificant for the Lockheed West Site.

The 2009 ecological risk assessment also evaluated exposure of benthic infaunal organisms to surface water based on available historical groundwater data from the adjacent uplands as a “worst case” comparison (Tetra Tech and Pascoe, 2009a). Results of this evaluation suggest that this exposure pathway does not present significant risks to benthic infaunal organisms relative to ambient water quality criteria, although the representativeness of the historical groundwater data is uncertain. Other mobile aquatic ROCs such as English sole and crabs have large foraging ranges, and their exposure to potential contaminants in surface water would extend far beyond the Site. For the latter species, there is no indication that the Site is contributing a disproportionate portion of potential contaminant exposure from surface water.

6.4 Basis for Taking Action

On the basis of the potential risk from contaminant exposure to human health and ecological receptors in sediment at the Site, it is EPA’s current judgment that the Preferred Alternative identified in this Proposed Plan is necessary to protect public health and welfare and the environment from actual or threatened releases of hazardous substances into the environment.

TABLE 6-1
Cancer Risks and Non-Cancer Hazard Estimates for Human Health Risk Assessment Scenarios

RME Scenario	Medium	COPC	Cancer Risk	Hazard Quotient	COC?
Adult Tribal Seafood Consumption – Tulalip Survey	Subtidal and Intertidal Sediment	Arsenic[1/]	**3×10^{-3}**	**5.8**	**YES**
		Cadmium	Not COPC	0.89	No
		Chromium	Not COPC	0.09	No
		Copper	Not COPC	**1.2**	**YES**
		Mercury	Not COPC	0.40	No
		Zinc	Not COPC	**1.2**	**YES**
		Fluoranthene	Not COPC	0.06	No
		Pyrene	Not COPC	0.05	No
		TBT (as ion)	Not COPC	**89**	**YES**
		Pentachlorophenol	**3×10^{-6}**	0.001	**YES**
		cPAHs[2/]	**3×10^{-3}**	Not COPC	**YES**
		Total PCBs	**3×10^{-3}**	**72**	**YES**
		Total chlordane[3/]	**2×10^{-5}**	0.1	**YES**
		Total DDTs[3/]	**3×10^{-4}**	**1.5**	**YES**
		Dioxins/Furans	Not quantified		**YES**
		Total Excess Cancer Risk and Non-Cancer Hazard Index[4/]	9×10^{-3}	173	--
Child Tribal Seafood Consumption – Tulalip Survey	Subtidal and Intertidal Sediment	Arsenic[1/]	**5×10^{-4}**	**12**	**YES**
		Cadmium	Not COPC	**1.9**	**YES**
		Chromium	Not COPC	0.20	No
		Copper	Not COPC	**2.6**	**YES**
		Mercury	Not COPC	0.85	No
		Zinc	Not COPC	**2.6**	**YES**
		Fluoranthene	Not COPC	0.12	No
		Pyrene	Not COPC	0.11	No
		TBT (as ion)	Not COPC	**193**	**YES**
		Pentachlorophenol	6×10^{-7}	0.002	No
		cPAHs[2/]	**3×10^{-3}**	Not COPC	**YES**
		Total PCBs	**5×10^{-4}**	**154**	**YES**
		Total chlordane[3/]	**3×10^{-6}**	0.22	**YES**
		Total DDTs[3/]	**5×10^{-5}**	**3.2**	**YES**
		Dioxins/Furans	Not quantified		**YES**
		Total Excess Cancer Risk andNon-Cancer Hazard Index[4/]	4×10^{-3}	372	--
Netfishing	Subtidal and Intertidal Sediment	Antimony	Not COPC	0.02	No
		Arsenic[1/]	**3×10^{-5}**	0.1	**YES**
		Chromium	Not COPC	0.006	No
		cPAHs[2/]	**3×10^{-6}**	Not COPC	**YES**
		Total PCBs	4×10^{-7}	0.02	No
		Dioxins/Furans	Not quantified		**YES**
		Total Excess Cancer Risk and Non-Cancer Hazard Index[4/]	3×10^{-5}	0.1	--
Beach Play	Intertidal Sediment	Antimony	Not COPC	0.5	No
		Arsenic[1/]	**7×10^{-5}**	**1.8**	**YES**
		Chromium	Not COPC	0.2	No
		Copper	Not COPC	0.1	No
		Vanadium	Not COPC	0.03	No
		cPAHs[2/]	**2×10^{-6}**	Not COPC	**YES**
		Dioxins/Furans	Not quantified		**YES**
		Total Excess Cancer Risk and Non-Cancer Hazard Index[4/]	7×10^{-5}	2.6	--

TABLE 6-1
Cancer Risks and Non-Cancer Hazard Estimates for Human Health Risk Assessment Scenarios

RME Scenario	Medium	COPC	Cancer Risk	Hazard Quotient	COC?
Clamming – 120 day/year	Intertidal Sediment	Antimony	Not COPC	0.08	No
		Arsenic[1/]	**1×10^{-4}**	0.35	**YES**
		Chromium	Not COPC	0.03	No
		Copper	Not COPC	0.01	No
		Vanadium	Not COPC	0.004	No
		cPAHs[2/]	1×10^{-6}	Not COPC	No
		Dioxins/Furans	Not quantified		**YES**
		Total Excess Cancer Risk and Non-Cancer Hazard Index[4/]	1×10^{-4}	0.5	--

Notes:

1/ Arsenic EPCs and risk estimates are based on inorganic arsenic.

2/ cPAHs are presented as benzo(a)pyrene equivalents.

3/ Tentatively identified chemical (JN-qualified).

4/ Total across all chemicals. This total is not directly interpretable for risk assessment, but a value greater than 1 suggests that an HQ may exceed 1 for individual endpoints.

Not COPC = not a chemical of potential concern for that scenario, or the toxicity endpoint is not relevant, and hence cancer risk or hazard quotient not calculated.

COC = chemical of concern, based on excess cancer risks > 1×10^{-6} or HQ > 1.

cPAH = carcinogenic polycyclic aromatic hydrocarbon

EPC = exposure point concentration

PCB = polychlorinated biphenyl

TBT = tributyltin

TABLE 6-2

Intertidal Sediments Benthic Invertebrate Community Risk Potential

COPC	Detection Frequency (Percent) (n=9)	Percent of Stations > Low Criteria[1/]		Percent of Stations > High Criteria[2/]	
		No. of Stations	Percent	No. of Stations	Percent
Metals					
Antimony	100	0	0	0	0
Arsenic	100	5	56	5	56
Chromium	100	1	11	1	11
Cobalt	100	5	56	0	0
Copper	100	4	44	4	44
Lead	100	1	11	1	11
Mercury	100	1	11	0	0
Nickel	100	2	22	0	0
Selenium	100	0	0	0	0
Vanadium	100	2	22	0	0
Zinc	100	7	78	2	22
PAHs					
Acenaphthene	67	1	11	0	0
Benzo(a)anthracene	100	0	0	0	0
Benzo(a)pyrene	100	0	0	0	0
Benzo(b)fluoranthene	100	0	0	0	0
Benzo(g,h,i)perylene	100	0	0	0	0
Chrysene	100	0	0	0	0
Dibenzo(a,h)anthracene	78	0	0	0	0
Fluoranthene	100	0	0	0	0
Indeno(1,2,3-cd)pyrene	100	0	0	0	0
Phenanthrene	89	0	0	0	0
Total HPAH	100	0	0	0	0
PCBs					
PCBs (total)	100	0	0	0	0
Other SVOCs					
bis(2-ethylhexyl)phthalate	33	0	0	0	0
Pentachlorophenol	0	0	0	0	0

Notes:

[1/] Low criteria = SQS, SL, NOAEL, or LAET.

[2/] High criteria = CSL, ML, LOAEL, or 2LAET.

COPC = chemical of potential concern
CSL = cleanup screening level (SMS)
HPAH = high-molecular-weight polycyclic aromatic hydrocarbon
LAET = lowest apparent effects threshold
2LAET = second lowest apparent effects threshold
LOAEL = lowest observed adverse effect level
ML = maximum level (DMMP)
NOAEL = no observed apparent effects level
OC = organic carbon
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
SL = screening level (DMMP)
SQS = sediment quality standards (SMS)
SVOC = semivolatile organic compound

TABLE 6-3
Subtidal Sediment Benthic Invertebrate Community Risk Potential

COPC	Detection Frequency (Percent) (n=42)	Percent of Stations > Low Criteria[1/]		Percent of Stations > High Criteria[2/]	
		No. of Stations	Percent	No. of Stations	Percent
Metals					
Antimony	100	1	2.4	0	0
Arsenic	100	6	14	4	9.5
Chromium	100	1	2.4	1	2.4
Cobalt	100	6	14	0	0
Copper	100	8	19	8	19
Lead	100	1	2.4	0	0
Mercury	100	21	50	17	41
Nickel	100	0	0	0	0
Selenium	38	8	19	0	0
Vanadium	100	10	24	0	0
Zinc	100	6	14	1	2.4
PAHs					
Acenaphthene	100	2	4.8	0	0
Benzo(a)anthracene	100	3	7.1	0	0
Benzo(a)pyrene	100	4	9.5	0	0
Benzo(b)fluoranthene	100	7	17	2	4.8
Benzo(g,h,i)perylene	100	9	21	0	0
Chrysene	100	8	19	0	0
Dibenzo(a,h)anthracene	100	6	14	0	0
Fluoranthene	100	10	24	0	0
Indeno(1,2,3-cd)pyrene	100	10	24	0	0
Phenanthrene	100	6	14	0	0
Total HPAH	100	9	21	0	0
PCBs					
PCBs (total)	100	27	64	7	17
Other SVOCs					
bis(2-ethylhexyl)phthalate	95	3	7.1	0	0
Pentachlorophenol	48	3	7.1	0	0

Notes:
[1/] Low criteria = SQS, SL, NOAEL, or LAET.
[2/] High criteria = CSL, ML, LOAEL, or 2LAET

LAET = lowest apparent effects threshold
2LAET = second lowest apparent effects threshold
LOAEL = lowest observed apparent effects level
NOAEL = no observed apparent effects level
ML = maximum level
SL = screening level
SQS = sediment quality standards

COC = chemical of concern
COPC = chemical of potential concern
CSL = cleanup screening level (SMS)
HPAH = high-molecular-weight polycyclic aromatic hydrocarbon
OC = organic carbon
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
SVOC = semivolatile organic compound

TABLE 6-4
Summary of Risks for Crabs and Fish

COPC	Crab		Fish – Tissue Residue		Fish – Dietary		COC?
	HQ NOAEL	HQ LOAEL	HQ NOAEL	HQ LOAEL	HQ NOAEL	HQ LOAEL	
Metals							
Chromium	0.1	0.02	--	--	0.1 – 0.3	--	No
Copper	0.3	--	--	--	**28 – 36**	**14 – 18**	YES
Lead	--	--	--	--	0.02 – 0.07	--	No
Mercury	0.01	0.01	0.3	0.2	--	--	No
Selenium	--	--	--	--	--	--	--
PAHs							
Acenaphthene	--	--	--	--	--	--	--
Acenaphthylene	--	--	--	--	--	--	--
Anthracene	--	--	--	--	--	--	--
Benzo(a)anthracene	--	--	--	--	--	--	--
Benzo(a)pyrene	--	--	--	--	0.009 – 0.01	0.007 – 0.009	No
Benzo(b)fluoranthene	--	--	--	--	--	--	--
Benzo(g,h,i)perylene	--	--	--	--	--	--	--
Benzo(k)fluoranthene	--	--	--	--	--	--	--
Benzofluoranthenes (total)	--	--	--	--	--	--	--
Chrysene	--	--	--	--	--	--	--
Dibenzo(a,h)anthracene	--	--	--	--	--	--	--
Fluoranthene	--	--	--	--	--	--	--
Fluorene	--	--	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	--	--	--	--	--	--	--
Phenanthrene	--	--	--	--	--	--	--
Pyrene	--	--	--	--	--	--	--
Total PAHs	--	--	--	--	0.09 – 0.5	0.03 – 0.2	No
Organometals							
Tri-n-butyltin	**202**	--	**158**	**18**	--	--	YES
Other SVOCs							
Pentachlorophenol	--	--	0.005	0.003	--	--	No
PCBs							
Aroclor 1254	--	--	--	--	--	--	--
Aroclor 1260	--	--	--	--	--	--	--
Aroclor 1268	--	--	--	--	--	--	--
Total PCBs	**9**	**0.9**	**6 – 31**	**1 – 6**	--	--	YES
Organochlorine Pesticides							
Total DDT	**10**	**7**	**1**	**1**	--	--	YES
Methoxychlor	**3**	0.33	**2**	0.4	--	--	No
Mirex	--	--	0.01	0.002	--	--	No
Chlordane (total, gamma)	0.05	0.02	0.2	0.11	--	--	No

Notes:
Bold identifies HQs greater than 1.
-- = Not a COPC for that receptor or pathway, or lack of toxicity data or modeling parameter for tissue concentration.

COC = chemical of concern
COPC = chemical of potential concern
DDT = dichlorodiphenyltrichloroethane
HQ = hazard quotient SVOC = semivolatile organic compound
LOAEL = lowest-observed-adverse-effect level
NOAEL = no-observed-adverse-effect level
PAHs = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl

TABLE 6-5

Summary of Risks for Spotted Sandpiper

COPC	NOAEL HQ	LOAEL HQ	COC?
Chromium	**6**	1	No
Copper	**4**	**3**	YES
Lead	**48**	**14**	YES
Vanadium	**1**	0.6	No
Total PCBs	0.1	0.05	No

Notes:
Bold identifies HQs greater than 1.
COC = chemical of concern
COPC = chemical of potential concern
HQ = hazard quotient
LOAEL = lowest-observed-adverse-effect level
NOAEL = no-observed-adverse-effect level
PCB = polychlorinated biphenyl

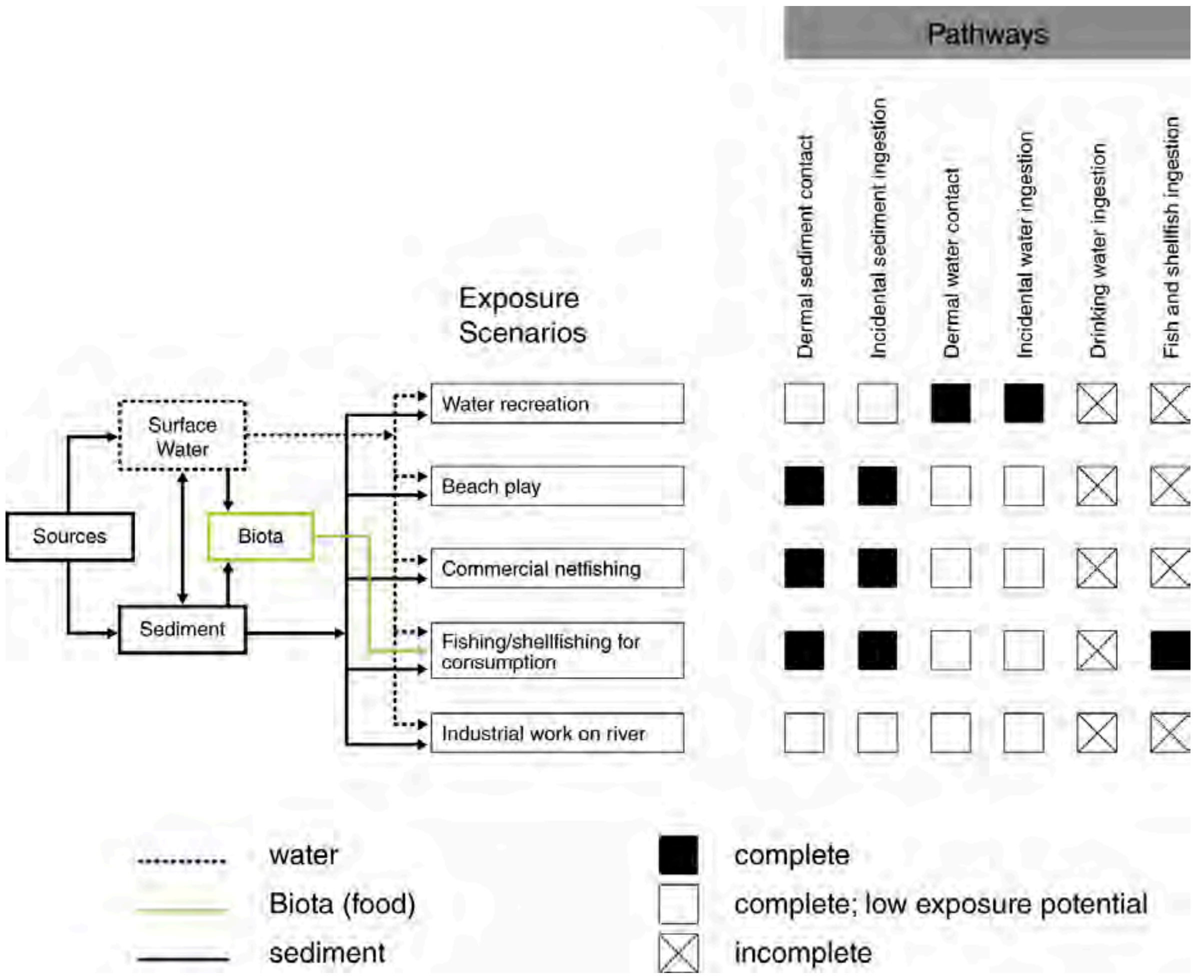


Figure 6-1. Conceptual Site Model for Human Health Risk Assessment at the Lockheed West Site

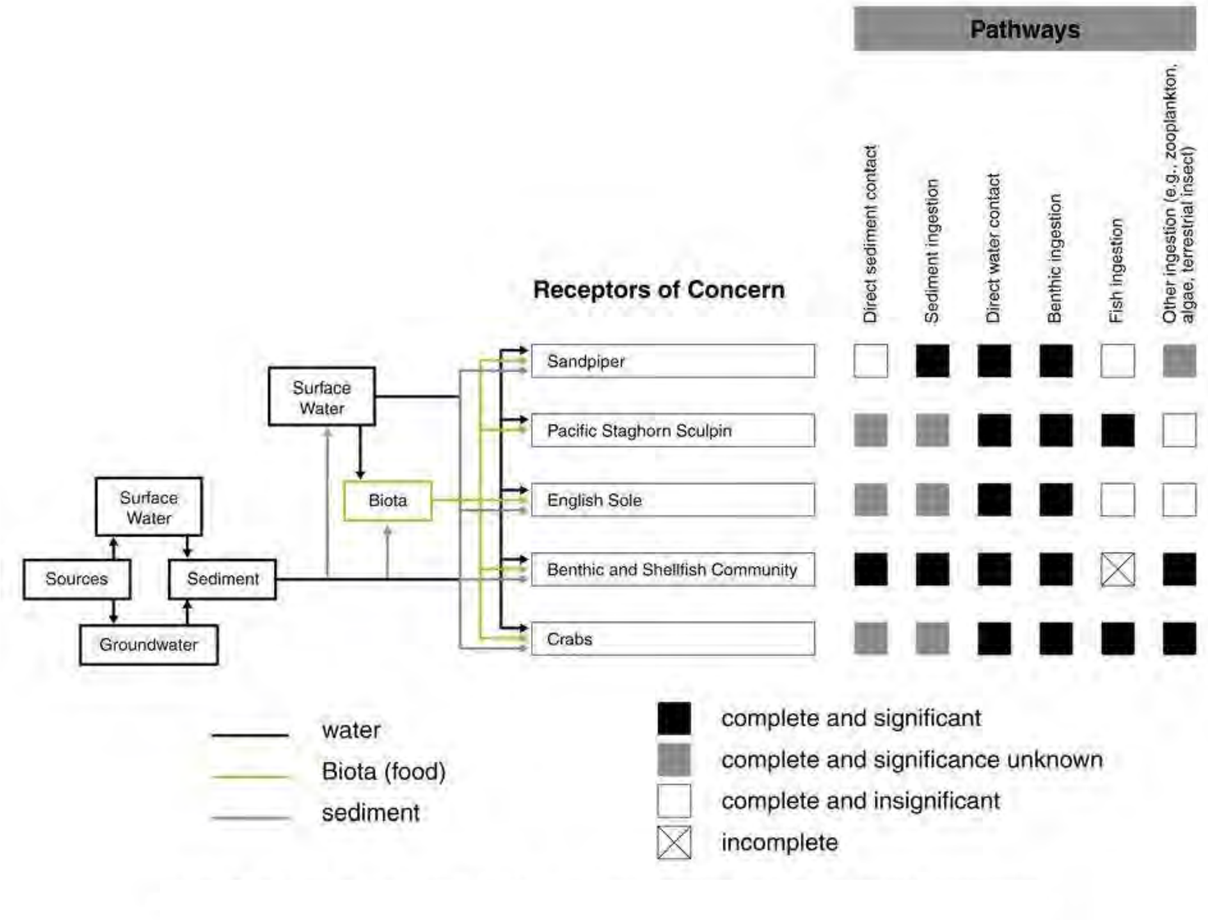


Figure 6-2. Conceptual Site Model for Benthic Invertebrates, Fish, and Wildlife at the Lockheed West Site

7.0 Remedial Action Objectives and Preliminary Remediation Goals

Remedial action objectives (RAOs) provide a general description of what the cleanup is expected to accomplish. These goals typically serve as the design basis for the remedial alternatives. RAOs are environmental, medium-specific goals selected to protect human health and the environment. The proposed RAOs for the Site are as follows:

- Human
  - **RAO 1** – Reduce human exposure from ingestion of onsite seafood contaminated with COCs from Site sediments to levels that are protective of recreational or subsistence fishing.
  - **RAO 2** – Prevent human exposure to COCs in the sediment through incidental ingestion of sediments to levels protective of netfishing, Tribal clamming, and beach play uses.
- Ecological
  - **RAO 3** – Prevent exposure to benthic invertebrate organisms from COCs in surface sediments to protective levels.
  - **RAO 4** – Reduce exposure to crabs, fish (English sole and Pacific staghorn sculpin), and birds (spotted sandpiper) from COCs in sediments to protective levels.

7.1 Applicable or Relevant and Appropriate Requirements

In addition to ensuring that human and ecological receptors are protected, remedial actions to clean up a site must take into account applicable or relevant and appropriate requirements (ARARs), which are derived from promulgated federal, state, and Tribal standards and requirements. The identification of ARARs is an iterative process, which began during preparation of the RI/FS Work Plan for the Site (Tetra Tech, 2008) and will continue until final ARAR determinations are made by EPA during preparation of the ROD. The current ARARs for the Site are listed in Table 7-1.

7.2 Surface Water Technical Impracticability Waiver

No active remediation of surface water will be conducted. The ambient water quality criteria (AWQC) that are applicable to site COCs may not be attained through Site cleanup. As such, a surface water technical impracticability (TI) waiver is necessary and is being proposed for the Site.

Although improvements to surface water quality from implementation of the selected remedy are anticipated, achievement of AWQC levels is unlikely because cleanup of the 40-acre Site would not measurably improve Elliott Bay water quality. Contaminated sediments from the Site are one of many sources of contamination to surface water in this urban bay. Other potential surface water contaminant sources are being addressed by EPA and Ecology through different authorities, and additional sources remain (such as municipal and industrial discharges and nonpoint source runoff).

7.3 Preliminary Remediation Goals

Preliminary remediation goals (PRGs) are developed during the RI/FS and are based on ARARs and other available information, such as risk threshold criteria identified from human health and ecological risk assessments. PRGs are contaminant-specific concentration goals for affected media (such as sediment) that serve as target cleanup goals during the initial development, analysis, and selection of cleanup alternatives. PRGs are intended to provide adequate protection of human health and the environment, and, if met, achieve the risk reductions associated with each RAO. PRGs may be further modified based on risk, exposure, uncertainty, and technical feasibility considerations. As data are gathered during the RI/FS, PRGs are refined into final contaminant-specific cleanup levels identified in the ROD and are called remediation goals (RGs). Based on the consideration of many factors during evaluation of the nine CERCLA and NCP criteria and using the PRG as a point of departure, it is possible that final RGs may differ from the PRGs. The final RGs will be established in the ROD.

PRGs for the Site are based on current and reasonable maximum exposure, anticipated future land use, the exposure pathways, COPCs and COCs identified in the human health and ecological risk assessments, and ARARs. PRGs were developed for the Site that are protective contaminant endpoints or risk levels. The proposed PRGs developed for sediment at the Site are based on the following:

- Risk-based threshold concentrations (RBTCs) for human health exposure and SMS criteria for ecological receptors (that is, SQS)
- Natural background concentrations for COCs with RBTCs or other ARAR values less than natural background
- Practical quantitation limits (PQLs) for COCs that have risk or background levels too low to detect with available analytical technology

The PRGs for risk-driver and non-risk-driver COCs in sediment are summarized in Table 7-2.

While remediation of sediment at the Site will remove a source of surface water contamination in Elliott Bay, the small size of the cleanup will not affect overall surface water contaminant levels in a body of water as large as Elliot Bay. Consequently, EPA is not proposing PRGs for surface water.

The same is true with respect to fish tissue. Sediment remediation will address Site-related contributions to elevated contaminant levels in Elliott Bay seafood. However, there is no way to predict the exact reduction in contaminant levels that can be expected. Therefore, EPA is not proposing PRGs for fish tissue.

7.4 Principal Threat Waste

The NCP establishes the expectation that treatment will be used to address the principal threats posed by a site whenever practicable, in accordance with federal regulations (40 *Code of Federal Regulations* [CFR] 300.430[a] [1] [iii] [A]). In general, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner. Contaminants identified at the Site are considered low-level threats and are not highly mobile or highly toxic. For example, the maximum PCB sediment concentration at the Site is 3 parts per million (ppm), with an average of 0.42 ppm. These values are well below the 50-ppm threshold for designation as a Toxic Substances Control Act (TSCA) waste. Similarly, the maximum dioxins/furans TEQ concentration is 13.8 ppt TEQ, which is only slightly above the background concentration of 2 ppt. Metals concentrations also do not trigger principal threat waste issues, and no Resource Conservation and Recovery Act of 1976 (RCRA)-listed hazardous wastes will be generated during Site remediation.

7.5 Integration of Remedial Action Objectives and Preliminary Remediation Goals

The PRGs are linked to the RAOs to address risk in the following ways:

- RAO 1 is met when site-wide average concentrations of COCs in the upper 45 cm of intertidal sediment and in the upper 10 cm of subtidal sediment do not exceed PRGs that are based on human consumption of seafood caught or gathered at the Site.
- RAO 2 is met when site-wide average concentrations of COCs in the upper 45 cm of intertidal sediment and in the upper 10 cm of subtidal sediment do not exceed the most stringent PRGs that are based on direct contact with sediment during netfishing, Tribal clamming, or beach play.
- RAO 3 is met when point-by-point concentrations of COCs in the upper 10 cm of intertidal and subtidal sediments do not exceed PRGs that are based on protection of benthic invertebrates (that is, SQS values).

- RAO 4 is met when site-wide average concentrations of COCs in the upper 10 cm of intertidal and subtidal sediments do not exceed PRGs that are based on protection of crabs, fish, and birds.

At the end of the cleanup, post-construction sediment verification sampling will be conducted to confirm that the RAOs have been met.

Note that surface water and sediment conditions at the Site are influenced by the natural counter-clockwise flow of water and tidal influences in Elliott Bay. Elliott Bay is affected by nearby urbanization, and overall concentrations of certain COCs in bay sediments are not at the natural background concentrations identified as being protective of human consumption of seafood. Therefore, it is likely that concentrations of these COCs will increase in Site sediments after remediation as a result of the movement of sediment and surface water from Elliott Bay. If this occurs, sediment concentrations at the Site may no longer meet RGs that are based on natural background concentrations (see Section 4-3, which summarizes sediment concentrations at the PSR site after cap placement). This would not constitute a failure of the selected remedy. This is because the RAOs for this remedial action will be met despite any post-remedial action recontamination from other non-Site-specific sources. The intent of this remedial action is to address the sediment contamination attributable to operations at the Site and any commingled contamination. Reducing contaminant loads incrementally through individual site cleanups improves the overall health of the larger Elliott Bay.

TABLE 7-1
Applicable or Relevant and Appropriate Requirements

Topic	Standard or Requirement	Regulatory Citation: Federal	Regulatory Citation: State or Local	ARAR Category C (Chemical-specific), A (Action-specific), and/or L (Location-specific)	Project-Specific Comments
Hazardous Waste Cleanup	Washington State cleanup standards	NA	Washington State Model Toxics Control Act (RCW 70.105D; WAC 173-340)	C, A. L	MTCA is an ARAR where the substantive requirements are more stringent than CERCLA and the NCP.
Sediment Quality	Sediment quality standards, cleanup screening levels	NA	Sediment Management Standards (WAC 173-204)	C	The SMS is a statutory requirement under MTCA and an ARAR under CERCLA. Numerical standards for the protection of benthic marine invertebrates. SMS is used in the development, analysis and selection of remedial action alternatives. Final remedy will meet requirements of the SMS.
Surface Water Quality Standards	Surface water quality standards	Ambient Water Quality Criteria established under Sections 303 and 304(a) of the Clean Water Act (33 U.S.C. 1251-1376; 40 CFR 100–149, 40 CFR 131) http://www.epa.gov/ost/criteria/wqctable/	Washington Water Pollution Control Act - State Water Quality Standards for Surface Water (RCW 90.48; WAC 173-201A)	A, L, C	State surface water quality standards apply where the State has adopted, and EPA has approved, Water Quality Standards. Federal recommended Water Quality Criteria established under Section 304(a) of the Clean Water Act that are more stringent than State criteria and that are relevant and appropriate also apply. Both chronic and acute standards, and marine and freshwater are used as appropriate. Expected improvements to surface water quality will be achieved through remediation of site sediments; no active remediation of surface water will be conducted. We do not expect improvements to surface water quality post remedial action to be measurable because the Site is influenced by the surface water of Elliott Bay. Remedial action plans will define measures to be taken to comply with applicable surface water standards during remedial action implementation. CWA Section 304 includes federal criteria that are advisory only for CWA purposes, but nevertheless represent a cleanup standard/ARAR per Section 121(d)(2)(A)(ii) of CERCLA.
Fish Tissue Quality	Concentrations of contaminants in fish tissues	Food and Drug Administration Maximum Concentrations of Contaminants in Fish Tissue (49 CFR 10372-10442)	NA	C	The Washington State Department of Health assesses the need for fish consumption advisories.
Waste Treatment, Storage, and Disposal	Hazardous Waste Management	Resource Conservation and Recovery Act (42 U.S.C. 7401-7642, 40 CFR 264, 265)	Washington State Dangerous Waste Regulations (RCW70.105; WAC 173-303)	C, A	Portions of RCRA and Washington State Dangerous Waste Regulations related to hazardous waste determination and analytical testing; onsite storage, treatment, and disposal are applicable to this project. State criteria for dangerous waste are broader than federal criteria.
Land Disposal of Waste	Management and disposal of materials containing PCBs	Toxic Substance Control Act (15 U.S.C. 2605; 40 CFR761	Washington State Dangerous Waste Regulations (RCW70.105; WAC 173-303, -140, -141)	C, A,L	None
	Hazardous waste	Resource Conservation and Recovery Act Land Disposal Restrictions (42 U.S.C. 7401-7642; 40 CFR 268)			None
Solid Waste Disposal	Requirements for solid waste handling management and disposal	Solid Waste Disposal Act (42 U.S.C. 215103259-6901-6991; 40 CFR 257, -258)	Solid Waste Handling Standards (RCW 70.95; WAC 173-350)	C, A	Covers non-hazardous waste generated during remedial activities unless wastes meet recycling exemptions.
Dredge/Fill and Other In-water Construction Work	Discharge of dredged/fill material into navigable waters or wetlands	Clean Water Act (33 U.S.C. 401 et seq; 33 U.S.C. 141; 33 U.S.C. 1251-1316; 40 CFR 230, 231, 404; 33 CFR 320-330) Rivers and Harbor Appropriations Act (33 U.S.C. 401 et seq)	Hydraulic Code Rules (RCW 75.20; WAC 220-110)	C, A, L	Requirements for in-water dredging, filling, or other construction
	Open-water disposal of dredged sediments	Marine Protection, Research and Sanctuaries Act (33 U.S.C. 1401-1445; 40 CFR 227)	Dredged Materials Management Program (RCW 79.90; WAC 332-30-166)	C, A, L	Regulates dumping of dredged material in open water.
Discharge to Surface Water	Point source standards for new discharges to surface water	National Pollutant Discharge Elimination System (40 CFR 122, 125)	Discharge Permit Program (RCW 90.48; WAC 173-216, -222)	C, A, L	Remediation discharges must comply with substantive requirements of NPDES rules. If upland handling of sediment is planned, construction stormwater requirements will be addressed including development of a stormwater pollution prevention plan and implementation of best management practices. NPDES program requirements will be reviewed as part of project final design.
Shoreline	Construction and development	Coastal Zone Management Act (16 U.S.C. 1451 et seq.)	Shoreline Management Act (WAC 173-16); King County and City of Seattle Shoreline Master Plans (KCC Title 25; SMC 23.60)	A, L	For construction within 200 feet of the shoreline.

TABLE 7-1
Applicable or Relevant and Appropriate Requirements

Topic	Standard or Requirement	Regulatory Citation		ARAR Category C (Chemical-specific), A (Action-specific), and/or L (Location-specific)	Project-Specific Comments
		Federal	State or Local		
Habitat for Fish, Plants, or Birds	Conserve endangered or threatened species, consult with species listing agencies, evaluate and mitigate habitat impacts	Clean Water Act (Section 404 (b)(1)) Endangered Species Act of 1973 (16 USC 1531 et seq; 50 CFR 200, -402); Magnuson-Stevens Fishery Conservation and Management Act (16 USC 1801-1884) U.S. Fish and Wildlife Mitigation Policy (44 FR 7644) U.S. Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq) Migratory Bird Treaty Act (16 U.S.C. 703-712)	Washington Department of Fisheries Habitat Management Policy (POL-410) Endangered, threatened, and sensitive wildlife species classification (WAC 232-12-297)	A, L	Habitat mitigation needs will be assessed and addressed in the remedial design if necessary. Mitigation requirements will be defined in project permitting and vary with the type of work conducted if necessary.
Critical (or Sensitive) Area	Regulates construction in environmentally critical or sensitive areas	NA	Growth Management Act (RCW 37.70a); King County Critical Area Ordinance (KCC Title 21A.24); City of Seattle (SMC 25.09)	A, L	The site is within an industrially zoned area and not within a critical or sensitive area.
Floodplain Protection	Avoid adverse impacts, minimize potential harm	Executive Order 11988, Protection of flood plains (40 CFR 6, Appendix A) ; FEMA National Flood Insurance Program Regulations (44 CFR 60.3Ld) (3).	Local ordinances: KCC Title 9 and SMC 25.09.	A, L	For in-water construction activities, including any dredge or fill operations.

Notes:

ARAR = Applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFR = Code of Federal Regulations
CWA = Clean Water Act
DMMP = Dredged Materials Management Program
FEMA = Federal Emergency Management Agency
KCC = King County Code
Lockheed Martin = Lockheed Martin Corporation
MCL = Maximum Contaminant Level
MCLG = Maximum Contaminant Level Goal
MTCA =Model Toxics Control Act
NPDES = National Pollutant Discharge Elimination System
NA = Not applicable
NEPA = National Environmental Policy Act
PCBs = Polychlorinated biphenyls
POTW = Publicly Owned Treatment Works
PSDDA = Puget Sound Dredge Disposal Analysis
RCRA = Resource Conservation and Recovery Act
RCW =Revised Code of Washington
SEPA =State Environmental Policy Act
SMC = Seattle Municipal Code
TSCA = Toxic Substances Control Act
SMS = Washington Sediment Management Standards
U.S.C. = United States Code
WAC = *Washington Administrative Code*

TABLE 7-2
Summary of Preliminary Remediation Goals for Sediment

COC	Risk Driver	Units	Spatial Scale of Exposure[1/]	RAO 1 Human Seafood Consumption[2/]	RAO 2 Human Direct Contact[2/]	RAO 3 Benthic Organisms[3/]	RAO 4 Ecological (Fish, Crab, Sandpiper)[4/]
Total PCBs	Yes	µg/kg dw	Sitewide	**2**	n/a	n/a	100
			Intertidal	**2**	n/a	n/a	n/a
			Point	n/a	n/a	**12 (OC)/130 (dw)**	n/a
cPAHs	Yes	µg TEQ/kg dw	Sitewide	**9**	**550**[6/]	n/a	n/a
			Intertidal	**9**	**150**[7/]	n/a	n/a
			Point	n/a	n/a	n/a[8/]	n/a
Arsenic	Yes	mg/kg dw	Sitewide	**7**	**7**	n/a	n/a
			Intertidal	**7**	**7**	n/a	n/a
			Point	n/a	n/a	**57**	n/a
Lead	Yes	mg/kg dw	Sitewide	**11**	n/a	n/a	n/a
			Intertidal	**11**[9/]	n/a	n/a	**50**
			Point	n/a	n/a	n/a	n/a
Tributyltin	Yes	µg/kg dw	Sitewide	**430**	n/a	n/a	**150**
			Intertidal	**2,000**[9/]	n/a	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Copper	Yes	mg/kg dw	Sitewide	**400**	n/a	n/a	**114**
			Intertidal	**400**[9/]	n/a	n/a	**420**
			Point	n/a	n/a	**390**	n/a
Mercury	Yes	mg/kg dw	Sitewide	**0.41**	n/a	n/a	n/a
			Intertidal	**0.17**	n/a	n/a	n/a
			Point	n/a	n/a	**0.41**	n/a
Dioxins/ Furans	e	ng TEQ/kg dw	Sitewide	**2**	**37**[10/]	n/a	n/a
			Intertidal	**2**	**13**[10/]	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Antimony	No	mg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**150**	n/a
Cadmium	No	mg/kg dw	Sitewide	**0.398**	n/a	n/a	n/a
			Intertidal	**0.398**	n/a	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Chromium	No	mg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**260**	n/a
Cobalt	No	mg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**10**	n/a

TABLE 7-2
Summary of Preliminary Remediation Goals for Sediment

COC	Risk Driver	Units	Spatial Scale of Exposure[1/]	RAO 1 Human Seafood Consumption[2/]	RAO 2 Human Direct Contact[2/]	RAO 3 Benthic Organisms[3/]	RAO 4 Ecological (Fish, Crab, Sandpiper)[4/]
Nickel	No	mg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**140**	n/a
Selenium	No	mg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**1**	n/a
Vanadium	No	mg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**57**	n/a
Zinc	No	mg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**410**	n/a
Pentachloro-phenol	No	µg/kg dw	Sitewide	**58**	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**360**	n/a
Total Chlordanes	No	µg/kg dw	Sitewide	**0.96**[5/]	n/a	n/a	n/a
			Intertidal	**1.1**	n/a	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Total DDTs	No	µg/kg dw	Sitewide	**1.1**[5/]	n/a	n/a	**14**
			Intertidal	**1.1**[5/]	n/a	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Bis(2-ethylhexyl)-phthalate	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**47 (OC)/710(dw)**	n/a
Acenaphthene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**16 (OC)/240 (dw)**	n/a
Benzo(a)-anthracene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**110 (OC)/1,700 (dw)**	n/a
Benzo(a)-pyrene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**99 (OC)/1,500 (dw)**	n/a
Benzo(g,h,i)-perylene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**31 (OC)/470 (dw)**	n/a

TABLE 7-2
Summary of Preliminary Remediation Goals for Sediment

COC	Risk Driver	Units	Spatial Scale of Exposure[1/]	RAO 1 Human Seafood Consumption[2/]	RAO 2 Human Direct Contact[2/]	RAO 3 Benthic Organisms[3/]	RAO 4 Ecological (Fish, Crab, Sandpiper)[4/]
Total Benzofluor-anthenes	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**1,800**	n/a
Chrysene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**110 (OC)/1,700 (dw)**	n/a
Dibenz(a,h)-anthracene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**12 (OC)/180 (dw)**	n/a
Fluoranthene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**160 (OC)/2,400 (dw)**	n/a
Indeno(1,2,3-cd)pyrene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**34 (OC)/510 (dw)**	n/a
Phenanthrene	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**100 (OC)/ 1,500 (dw)**	n/a
Total HPAH	No	µg/kg dw	Sitewide	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	**960 (OC)/ 14,400 (dw)**	n/a

[1/] The spatial scale of exposure is measured as sitewide (i.e., all subtidal and intertidal sediments), intertidal sediments only, and point measurements at single locations throughout the site (i.e., all subtidal and intertidal sediment locations) or at single locations in intertidal sediment only. The spatial scale is RAO-specific, with sitewide exposures applicable to human seafood consumption, human direct contact, and exposures of fish and crab. Intertidal-only exposures are applicable to human consumption of clams from intertidal areas and exposures of sandpiper. Point exposures are applicable to benthic organisms, which are evaluated at single station locations. The statistical metric for sitewide and intertidal evaluation of alternatives and compliance monitoring is the upper confidence limit on the mean, whereas point exposures are evaluated with concentration data at single locations.

[2/] PRGs are based on 10^{-6} cancer risk for carcinogens (e.g., PCBs, cPAHs, arsenic) or on a child exposure hazard quotient of 1 for noncarcinogens (lead, tributyltin, copper). Where PRGs based on carcinogenic risks are below background, the background concentration is selected; where no background values are available (chlordanes and DDT), the method detection limit (MDL) is selected.

[3/] Applicable on a point exposure only. Values for PCBs and PAHs (except total benzofluoranthenes) are the organic carbon-normalized SQS and the dry weight equivalent based on an average sediment TOC content of 1.5%; for all other compounds values are dry weight. Under the SMS, sediment cleanup standards are established on a site-specific basis within an allowable range. The SQS and CSL define this range. For chemicals without SMS, LAET and 2LAET values or the SL and ML of the DMMP define this range. The PRG has been set at the lowest end of the ranges. However, the final cleanup standard will be set in consideration of risk, exposure, uncertainty, and technical feasibility considerations. [4/] PRGs for sitewide exposure are the lowest for either fish or crab; PRGs for intertidal exposure are for sandpiper

[5/] The PRG is the MDL

[6/] The PRG for sitewide direct contact is based on netfishing.

[7/] The PRG for intertidal direct contact is based on the lowest for either Tribal clamming or child beach play exposures.

[9/] The PRG for intertidal seafood consumption is based on consumption of clams from the intertidal sediment.

[10/] PRGs based on values presented in the Draft Final FS for the Lower Duwamish Waterway (AECOM, 2010) site-wide and Tribal clamming (intertidal)

n/a = compounds do not present a risk for the RAO scenario.
mg/kg dw = milligrams per kilogram dry weight
µg/kg dw = micrograms per kilogram dry weigh
ng TEQ/kg dw = nanograms toxicity equivalents per kilogram dry weight
µg TEQ/kg dw = micrograms Toxicity Equivalents per kilogram dry weight
OC = Organic Carbon

8.0 Summary of Remedial Alternatives

Remedial alternatives for the Site were developed to meet the requirements of the NCP (40 CFR 300.430). The NCP requires a range of remedial alternatives be considered in which treatment that reduces the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants is a principal element. As appropriate, this range shall include an alternative that removes or destroys hazardous substances, pollutants, or contaminants to the maximum extent feasible, eliminating or reducing, to the degree possible, the need for long-term management. Remedial alternatives must provide protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants. The development and screening of remedial alternatives and the detailed analysis of the alternatives form the basis for the Preferred Alternative for the Site and are discussed below.

8.1 Areas of Potential Action

In developing remedial alternatives, three areas of potential action (AOPAs) were defined by comparing concentrations of risk-driver COCs in the upper 1 foot of sediment with three major threshold levels, with modifications to account for physical constraints and boundaries. The threshold levels used to develop the AOPA footprints for the risk-driver COCs are as follows:

- **SQS AOPA** —The SQS footprint is the extent of surface sediment in the subtidal area where the concentrations for the risk-driver chemicals are above the SQS levels. The SQS AOPA is about 18 acres.
- **Urban Background AOPA**—The Urban Background AOPA is the extent of surface sediment in the subtidal area where the concentrations for the risk-driver COCs are above the Urban Background concentrations for Elliott Bay listed in Table 4-2. The Urban Background AOPA is about 30 acres.
- **Study Area AOPA—The** Study Area AOPA is defined by the administrative boundaries that exist for the Site, the West Waterway operable unit (OU) to the east of the Site, and the PSR marine sediment unit to the west of the Site, as well as to the north where sediment concentrations are above the natural background concentrations for those risk-driver COC where an extent from the area of historical activities can be defined. The Study Area AOPA is about 40 acres.

The AOPAs are depicted in Figure 8-1.

8.2 Remedial Action Alternatives

Four general approaches—no action, containment, removal, and complete removal—were used to develop remedial action alternatives for the Site. A total of 19 remedial action alternatives were developed using different combinations of remedial technologies, AOPAs, and remedial action levels (RALs).

8.2.1 Remedial Action Levels

RALs are concentration-specific values that take into consideration the magnitude of human health and ecological risk reductions achieved by the different remedial technologies. RALs are typically used at CERCLA sites to make engineering decisions regarding the application of various remediation technologies, and to determine when the application of such technologies is complete. RALs are used to define where active remediation is to occur for a given cleanup alternative and to verify that active remediation for an alternative is complete or successful before construction equipment is demobilized. These determinations are made on a point-by-point basis. The long-term cleanup goals for the Site are not tied to a particular technology or alternative. When RALs for active remediation are selected, the RGs identified in the ROD (currently represented by the PRGs) will remain the cleanup goals for the Site. The effectiveness of a remedy relative to the PRGs is an important aspect of alternatives development and evaluation, in part because ICs must be incorporated into any remedy that leaves behind contaminant concentrations in excess of the identified PRGs.

The following sediment criteria were incorporated into RAL groups for use in alternatives development addressing specific AOPAs, or portions of AOPAs, for the Site:

- PRGs, consisting of human and ecological RBTCs and Puget Sound natural background levels (if higher than the lowest RBTC)
- Elliott Bay Urban Background[2] concentrations
- SQS criteria for protection of benthic ROCs
- CSL criteria for protection of benthic ROCs

The selected RALs are designed to address the project-specific RAOs and have been used to determine the type and extent of remedial actions (that is, dredge, isolation cap, or ENR) taken in each alternative. RALs were developed for each risk-driver COC based on the understanding that remediation to address these chemicals will also address the other COCs. Concentrations of risk-driver COCs for each RAL group are listed in Table 8-1.

8.2.2 No Action Alternative

As required under CERCLA, a no action alternative (Alternative 1) is evaluated in order to compare cleanup alternatives with baseline site conditions.

8.2.3 Containment Focus Alternatives

The emphasis of the Containment Focus approach is conventional capping and placing a thin layer of sand (6 to 9 inches) to enhance natural recovery of the sediments. Figure 8-2 provides a general overview of the components of the Containment Focus alternatives. The nine alternatives developed using the Containment Focus approach are listed in Table 8-2.

8.2.4 Removal Focus Alternatives

The emphasis of the Removal Focus approach is a combination of removing contaminated sediments above SQS or CSL by dredging, then placing a thin layer of clean sediments (6 to 9 inches) for ENR above urban contaminant concentrations found in Elliott Bay. Figure 8-3 provides a general overview of the components of the Removal Focus alternatives. The six alternatives developed using the Removal Focus approach are listed in Table 8-3.

8.2.5 Complete Removal Focus Alternatives

The emphasis of the Complete Removal Focus approach evaluates dredging to achieve SQS, Urban Background concentrations, and PRGs, respectively. Figure 8-4 provides a general overview of the components of the Complete Removal Focus alternatives. The three alternatives developed using the Complete Removal Focus approach are listed in Table 8-4.

8.2.6 Common Elements of All Alternatives

The common elements of all the alternatives evaluated, except for Alternative 1 (no action) and Alternative 3C Plus, are as follows:

- **Former Shipway Area Remediation**—Remove sandblast grit and CSL-contaminated sediments to the extent possible, place 3-foot cap of habitat mix, blend cap with PSR beach next to former shipway.
- **Shoreline/Intertidal Remediation and Habitat Improvements**—To mhhw, remove existing shoreline structures (such as debris piles, remaining derelict bulkhead, and some pilings), dredge and backfill shoreline

[2] Although the Urban Background data are affected by point and nonpoint pollutant sources in Elliott Bay and are not representative of natural background (or CERCLA area background), the data demonstrate the general concentrations of sediments in Elliott Bay during Ecology's sampling in 2006 (Ecology, 2007). The Urban Background concentrations are typically below the SQS concentrations but above the PRG concentrations. The use of the term "background" in this context does not connote (as "natural background" does) that these concentrations are acceptable to regulatory agencies and these sediments might also require cleanup in the future.

slopes from edge of existing intertidal habitat to landward edge of cleanup boundary with the goal of no net loss of intertidal habitat.

- **Institutional Controls**:
  - Proprietary Controls (for alternatives that leave bank areas or sediment concentrations greater than PRGs), including deed restrictions and restrictive covenants to ensure the integrity of the remedy and guide management of any residual contamination that is disturbed or encountered in the event of future dredging or construction at the Site.
  - Informational Devices – Fish consumption advisories to reduce human exposure from ingestion of contaminated seafood, Elliott Bay fish consumption advisories posted at the Site.
- **Disposal**—Transport dredged sediment via truck or rail for disposal at permitted upland landfill facility. Dispose of debris and pilings at an appropriate permitted facility.
- **Surface Water**—Surface water will be monitored during the remediation activities in order to ensure that short-term water impacts are not caused by cleanup actions addressing contaminated sediments (dredging, dredge water treatment and return). EPA would waive the surface water ARAR, the federal AWQC through a TI waiver based on the fact that cleaning up contaminated sediments at this small, 40-acre Site would not likely improve the water quality to a measurable extent within Elliott Bay even though the source of contaminated sediments at this Site would be removed or covered.
- **Long-term Monitoring**—Activities to cover post-construction monitoring and maintenance activities that are required to ensure the long-term performance of the remedy and outline performance expectations and potential courses of action that should be taken based on sampling results, passage of time, influence of marine activities or occurrence of natural phenomenon such as earthquakes or significant weather events.

8.3 Cleanup Timeframes

Most of the cleanup alternatives are expected to take 1 year to complete. However, the alternatives with more dredging are expected to take longer. Alternatives 3C and 3C Plus may take 1 to 2 years, 4A may take 3 years, 4B may take 6 years, and 4C may take 9 years to remove all the contaminated sediments.

8.4 Satisfying RAOs

Cleanup alternatives that achieve PRGs throughout the site (that is, 2A3, 2A4c, 2B, 3C Plus, and 4C) will meet RAOs 1, 2, 3, and 4. The remaining FS alternatives leave some exposed contamination at the surface of the Site with concentrations above PRGs; therefore, these remedies are not as protective. However, the remaining alternatives do provide significant reduction in site risks.

The RALs and how they relate to the RAOs are summarized as follows:

- **RAO 1**— Achievement of RAO 1 is based on achieving risk-based PRGs for human consumption of seafood, or by achieving natural background concentrations for some COCs. Achievement of RAO 1 PRGs is determined by the sitewide reduction in the average residual concentrations for the risk-driver COCs: total PCBs, arsenic, copper, lead, TBT, and cPAHs. Applying RALs would result in a range of protective COC concentrations in surface sediments based on the resulting sitewide averages. Because the PRGs for several of the risk-driver chemicals (for example, PCBs) are set to the natural background levels from the Puget Sound “Bold Study” (EPA, 2009a), the complete achievement of RAO 1 would not be feasible without ICs. Since at the natural background level the estimated risk for some chemicals exceeds 1×10^{-4}, even the complete achievement of the PRGs for RAO 1 does not result in a reduction of the estimated risk for the consumption of seafood at Tribal or subsistence consumption rates to acceptable levels (see Section 8.5). Therefore a fish advisory limiting the amount of fish that can be consumed is required as an IC.
- **RAO 2**— Achievement of RAO 2 is based on achieving risk-based PRGs for direct contact exposure scenarios (netfishing, Tribal clamming, and beach play) associated with arsenic and cPAHs as risk-driver COCs. For

arsenic, the PRG for RAO 2 is set to the natural background level, as it is for RAO 1. For cPAHs, the risk-based PRG for RAO 2 is calculated to be 550 µg/kg-dw. Achievement of RAO 2 PRGs is determined by calculating sitewide average for COCs following application of RALs during remediation. No ICs or other site use limitations are expected to be needed.

- **RAO 3**— Achievement of RAO 3 is based on achieving PRGs associated with SQS criteria for protection of benthic organisms. Achievement of RAO 3 PRGs is determined on a point by point basis across the site following application of RALs for COCs during remediation. RALs applicable to RAO 3 are the CSL and SQS. No ICs or other site use limitations are expected to be needed.
- **RAO 4**—Achievement of RAO 4 is based on achieving risk-based PRGs for protection of crabs, fish, birds, and mammals. Achievement of RAO 4 PRGs is determined by the sitewide reduction of average residual concentrations of the risk-driver COCs: total PCBs, copper, and TBT. Combinations of the previously described RALs are expected to achieve RAO 4 on completion of the remediation. No ICs or other site use limitations are expected to be needed.

8.5 Residual Risks Following Remediation

The remedial alternatives evaluated for the Lockheed West site will achieve PRGs associated with each of the project RAOs. By achieving these PRGs, risks to receptors will be reduced to the following levels:

RAO	Risk Threshold Achieved
RAO 1 – Human Seafood Consumption	2×10^{-4} to 2.8×10^{-4} (Based on sitewide average surface PCB concentrations)
RAO 2 – Human Direct Contact	Cumulative less than or equal to 1×10^{-5}
RAO 3 – Benthic Organisms	SQS
RAO 4 – Ecological	Hazard Quotient (HQ) less than 1

These residual risk levels do not apply to the No Action Alternative, where risks would remain the same as for current conditions. Alternative 2A1 (capping over CSL footprint and ENR over remaining SQS footprint) and Alternative 2A4a (cap over SQS footprint) achieve cumulative direct contact risks of 1×10^{-5} for RAO 2, but the PRG for arsenic is not achieved. The PRG for total PCBs is also not achieved for RAO 4 in the latter alternatives.

8.6 Reasonably Anticipated Future Land Use

This Site is located within a Usual and Accustomed (U&A) Fishing Area for the Suquamish and Muckleshoot Indian Tribes, who have Tribal treaty rights in this area. The Tribes have a strong preference for unimpeded and unrestricted fishing, clamming, and access to this area (i.e., no ICs) and prefer more contamination removal versus capping and ENR. DNR and the Port, as landowners, also have concerns about the use of conventionally capped areas with regard to potential restrictions this may cause with respect to “water dependent purposes” or for future development of Port activities, respectively.

8.7 Distinguishing Features of the Remedies

The alternatives with more mass removal, conventional capping and active remediation (dredge/cap/ENR) to the Site boundaries generally result in more material handling, greater protectiveness and permanence and higher short-term risks and costs (Table 8-5 provides a comparative summary of alternative components including quantities and costs). These alternatives are more protective because they remove more, isolate, and contain more contaminated sediments than other alternatives considered in the FS. None of the alternatives evaluated rely on active treatment, which would not be technically practicable or cost effective due to the relatively low concentrations and different types of contamination (metals, PCBs, dioxin/furans, and cPAHs). A multi-step treatment train would be necessary and would also result in residuals that would still require offsite upland disposal in an appropriate facility. Consequently, treatment was eliminated as a possible component of remedial action alternatives in the technology screening portion of the FS (Tetra Tech, 2012a).

Alternatives that do not include capping will allow for unrestricted fishing, clamming and boat anchorage, which meets the Tribal Treaty requirements for the Suquamish and Muckleshoot Indian Tribes.

In addition, any of the alternatives that include dredging contaminated sediments in the dry dock areas and/or dredging in the navigational channel in the West Waterway meet the reasonably anticipated future land use requirements of the Port. Alternatives that minimize, or eliminate, conventional capping, and contaminated sediments remaining on the Site comport with the DNR mandate to maintain state-owned aquatic lands for water-dependent uses only and prevent or minimize encroachment on these lands.

TABLE 8-1
Remedial Action Levels for the Risk-Driver Chemicals of Concern in Sediment

Risk Driver	Basis	Remedial Action Level Group			
		PRG	**Urban Background**	**SQS**	**CSL**
cPAHs	µg/kg dw	9 [2/]	757	1,100*	3,000*
Arsenic	mg/kg dw	7.3 [2/]	8.44	57	93
Lead	mg/kg dw	10.9 [2/]	47	450	530
Copper	mg/kg dw	114 [3/]	49	390	390
Mercury	mg/kg dw	0.41 [4/]	0.44	0.41	0.59
TBT	µg/kg dw	150 [3/]	n/a	1,335**	1,335**
	mg/kg OC#	n/a	n/a	78**	78**
Total PCBs	µg/kg dw	2 [1/]	119	130	1,000
	mg/kg OC#	n/a	n/a	12	65

Notes:
PRG = lowest of the human and ecological RBTCs or natural background if higher than the lowest RBTC. Sources as shown below
[1] RBTC - seafood consumption
[2] natural background
[3] RBTC – ecological exposure(fish)
[4] RBTC – benthic invertebrate exposure
*PRG is based on benzo(a)pyrene TEQ value
** West Waterway confirmation value
# assumes 1.5 µg/kg dw total organic carbon

RBTC = Risk Based Threshold Concentration
SQS = Sediment Quality Standard
CSL = Cleanup Screening Level
cPAHs = carcinogenic polycyclic aromatic hydrocarbons
TBT = tributyltin
PCBs = polychlorinated biphenyls
mg/kg-OC = milligram per kilogram organic carbon
mg/kg-dw = milligram per kilogram dry weight
µg/kg-dw = microgram per kilogram dry weight

TABLE 8-2
Summary of Containment Focus Alternatives

#	Alternative Description	Capping Extent				ENR Extent			Additional Components			Common Elements
		SQS	CSL	Urban Bkgd	Study Area	SQS	Urban Bkgd	Study Area	Dredging to SQS	Dredging to CSL	Cap Replacement	
2A1	Conventional capping over the area defined by the CSL footprint and ENR over the remaining area to the SQS footprint		X			X						X
2A2a	Conventional capping over the areas defined by the CSL footprint, ENR over the remaining area to the Urban Background footprint, and potential cap replacement in the event of seismic damage.		X				X					X
2A2a Plus	Variant of Alternative 2A2a, adds dredging sediment with concentrations above the SQS in the navigational channel in the West Waterway, application of ENR to the Study Area boundary, and potential cap replacement in the event of seismic damage.		X					X	X		X	X
2A2b	Conventional capping over the areas defined by the risk-drivers to the SQS footprints and ENR over the remaining area to the Urban Background footprint.	X					X					X
2A3	Conventional capping over the area defined by the CSL footprint and ENR over the remaining area to the Study Area boundary		X					X				X
2A4a	Conventional capping to the SQS footprint	X										X
2A4b	Conventional capping to the Urban Background footprint			X								
2A4c	Conventional capping to the Study Area boundary footprint				X							X
2B	Capping surface sediments in areas above the CSL footprint and removal of sediments within the capping footprint to maintain bathymetry. ENR applied in remaining areas to the Study Area boundary		X					X		X		X

Common Elements:

- **Former Shipway Area Remediation** – remove sandblast grit and contaminated sediments to the extent possible, place three foot cap with habitat mix, blend cap with PSR beach next to former shipway.
- **Shoreline/Intertidal Remediation and Habitat Improvements** –remove existing shoreline structures (e.g., debris piles, remaining derelict bulkhead, and some pilings), dredge and backfill shoreline slopes from edge of existing intertidal habitat to landward edge of cleanup boundary with the goal of no net loss of intertidal habitat.
- **Disposal:**
  - Transport sediment via truck or rail for disposal at permitted upland landfill facility.
  - Dispose of debris and pilings at an appropriate permitted facility
- **Institutional Controls**:
  - Proprietary Controls (for alternatives that leave sediment concentrations greater than PRGs), including deed restrictions and restrictive covenants.
  - Informational Devices – Elliott Bay fish consumption advisories posted at the Site.
- **Surface Water** – Surface water will be monitored during the remediation activities in order to ensure that short-term water impacts are not caused by cleanup actions addressing contaminated sediments (dredging, dredge water treatment and return). EPA would waive the surface water ARAR, the federal ambient water quality criteria through a technical impracticability waiver based on the fact that cleaning up contaminated sediments at this small 40 acre Site would not likely improve the water quality to a measurable extent with Elliott Bay even though the source of contaminated sediments at this Site would be removed or covered.
- **Long-term Monitoring** – Identification of activities to cover post-construction monitoring and maintenance activities that are required to ensure the long-term performance of the remedy and outline performance expectations and potential courses of action that should be taken based on construction confirmation sampling results, passage of time, influence of marine activities or occurrence of natural phenomenon such as earthquakes or significant weather events.

TABLE 8-3

Summary of Removal Focus Alternatives

#	Alternative Description	Dredging Extent		Capping Extent		ENR Extent		Remove Pilings in Former Shipway	Common Elements
		SQS	CSL	CSL	>SQS and <CSL	Urban Bkgd	Study Area		
3A1	Remove 3 feet of sediment over the CSL footprint, conventional cap where exposed residual concentrations are between the SQS and CSL, and ENR to Urban Background concentrations in Elliott Bay		X		X	X			X
3A2	Remove 3 feet of sediment over the SQS footprint, conventional cap where exposed residual surface concentrations are between the SQS and CSL, and ENR to Urban Background concentrations in Elliott Bay	X			X	X			X
3A2 Plus	Variant of 3A2 - includes all of the 3A2 elements, plus dredging all sediment with concentrations above the SQS in the navigational channel in West Waterway, extending ENR area to the Study Area boundary, and potential cap replacement in the event of seismic damage.	X			X		X		X
3B	Remove sediments over CSL within the former Dry Dock 1 (entire depth), conventional capping over the remaining CSL footprint, and ENR to the Urban Background concentrations in Elliott Bay		X	X		X			X
3C	Removes sediments over CSL within all of the former Dry Dock areas (entire depth), conventional capping over the remaining CSL footprint, and ENR to the Urban Background concentrations identified in Elliott Bay		X	X		X			X
3C Plus*	Variant of 3C - includes all of the 3C elements, plus dredging all sediment with concentrations above the SQS in the navigational channel in West Waterway and the former shipway area, removing pilings from former shipway area, and extending ENR area to the Study Area boundary	X	X	X			X	X	X

Common Elements:

- **Former Shipway Area Remediation** – remove sandblast grit and contaminated sediments to the extent possible, place three foot cap with habitat mix, blend cap with PSR beach next to former shipway. [*Note: Alternative 3C Plus removes all sediments with concentrations above SQS.]
- **Shoreline/Intertidal Remediation and Habitat Improvements** –remove existing shoreline structures (e.g., debris piles, remaining derelict bulkhead, and some pilings), dredge and backfill shoreline slopes from edge of existing intertidal habitat to landward edge of cleanup boundary with the goal of no net loss of intertidal habitat.
- **Disposal:**
  - Transport sediment via truck or rail for disposal at permitted upland landfill facility.
  - Dispose of debris and pilings at an appropriate permitted facility
- **Institutional Controls**:
  - Proprietary Controls (for alternatives that leave sediment concentrations greater than PRGs), including deed restrictions and restrictive covenants.
  - Informational Devices – Elliott Bay fish consumption advisories posted at the Site.
- **Surface Water** – Surface water will be monitored during the remediation activities in order to ensure that short-term water impacts are not caused by cleanup actions addressing contaminated sediments – dredging, dredge water treatment and return. EPA would waive the surface water ARAR, the federal ambient water quality criteria through a technical impracticability waiver based on the fact that cleaning up contaminated sediments at this small 40 acre Site would not likely improve the water quality to a measurable extent with Elliott Bay even though the source of contaminated sediments at this Site would be removed or covered.
- **Long-term Monitoring** – Identification of activities to cover post-construction monitoring and maintenance activities that are required to ensure the long-term performance of the remedy and outline performance expectations and potential courses of action that should be taken based on construction confirmation sampling results, passage of time, influence of marine activities or occurrence of natural phenomenon such as earthquakes or significant weather events.

TABLE 8-4
Summary of Complete Removal Focus Alternatives

#	Alternative Description	Dredging Extent			Common Elements
		PRGs	SQS	Urban Bkgd	
4A	Complete removal to SQS surface sediment footprint		X		X
4B	Complete removal to Urban Background surface sediment footprint			X	X
4C	Complete removal to PRGs (within Site boundary)	X			X*

*Proprietary Controls excluded for alternative 4C

Common Elements:

- **Former Shipway Area Remediation** – remove sandblast grit and contaminated sediments to the extent possible, place three foot cap with habitat mix, blend cap with PSR beach next to former shipway.
- **Shoreline/Intertidal Remediation and Habitat Improvements** –remove existing shoreline structures (e.g., debris piles, remaining derelict bulkhead, and some pilings), dredge and backfill shoreline slopes from edge of existing intertidal habitat to landward edge of cleanup boundary with the goal of no net loss of intertidal habitat.
- **Disposal:**
  - Transport sediment via truck or rail for disposal at permitted upland landfill facility.
  - Dispose of debris and pilings at an appropriate permitted facility
- **Institutional Controls**:
  - Proprietary Controls (for alternatives that leave sediment concentrations greater than PRGs), including deed restrictions and restrictive covenants.
  - Informational Devices – Elliott Bay fish consumption advisories posted at the Site.
- **Surface Water** – Surface water will be monitored during the remediation activities in order to ensure that short-term water impacts are not caused by cleanup actions addressing contaminated sediments – dredging, dredge water treatment and return. EPA would waive the surface water ARAR, the federal ambient water quality criteria through a technical impracticability waiver based on the fact that cleaning up contaminated sediments at this small 40 acre Site would not likely improve the water quality to a measurable extent with Elliott Bay even though the source of contaminated sediments at this Site would be removed or covered.
- **Long-term Monitoring** – Identification of activities to cover post-construction monitoring and maintenance activities that are required to ensure the long-term performance of the remedy and outline performance expectations and potential courses of action that should be taken based on construction confirmation sampling results, passage of tie, influence of marine activities or occurrence of natural phenomenon such as earthquakes or significant weather events.

TABLE 8-5
Summary of Alternative Quantities and Costs

#	Alternative Description*	Cap Area (acres)	ENR Area (acres)	Dredging Area (acres)	Estimated Cost		
					Capital (MM)	ICs and LTM (MM)	NPV Total Cost (MM)
1	No action	0	0	0	$0	$0	$0
2A1	Conventional capping over the area defined by the CSL footprint and ENR over the remaining area to the SQS footprint	10.3	7.7	0	$11.0	$6.0	$17.0
2A2a	Conventional capping over the areas defined by the CSL footprint, ENR over the remaining area to the Urban Background footprint, and potential cap replacement in the event of seismic damage.	10.3	19.7	0	$12.7	$6.1	$18.7
2A2a Plus	Variant of Alternative 2A2a, adds dredging sediment with concentrations above the SQS in the navigational channel in the West Waterway, application of ENR to the Study Area boundary, and potential cap replacement in the event of seismic damage.	7	27.6	5.4	$31.1	$4.7	$35.8
2A2b	Conventional capping over the areas defined by the risk-drivers to the SQS footprints and ENR over the remaining area to the Urban Background footprint.	18	12	0	$15.8	$9.2	$25.0
2A3	Conventional capping over the area defined by the CSL footprint and ENR over the remaining area to the Study Area boundary	10.3	29.7	0	$14.1	$6.1	$20.2
2A4a	Conventional capping to the SQS footprint	18	0	0	$14.0	$8.4	$22.4
2A4b	Conventional capping to the Urban Background footprint	30	0	0	$20.3	$13.7	$34.1
2A4c	Conventional capping to the Study Area boundary footprint	40	0	0	$25.7	$18.1	$43.8
2B	Capping surface sediments in areas above the CSL footprint and removal of sediments within the capping footprint to maintain bathymetry. ENR applied in remaining areas to the Study Area boundary	10.3	29.7	0	$27.4	$5.8	$33.3
3A1	Remove 3 feet of sediment over the CSL footprint, conventional cap where exposed residual concentrations are between the SQS and CSL, and ENR to Urban Background concentrations in Elliott Bay	5.4	30	10.3	$24.8	$4.1	$28.9
3A2	Remove 3 feet of sediment over the SQS footprint, conventional cap where exposed residual surface concentrations are between the SQS and CSL, and ENR to Urban Background concentrations in Elliott Bay	5.4	30	18	$43.4	$4.0	$47.5
3A2 Plus	Variant of 3A2 - includes all of the 3A2 elements, plus dredging all sediment with concentrations above the SQS in the navigational channel in West Waterway, extending ENR area to the Study Area boundary, and potential cap replacement in the event of seismic damage..	4.4	17.6	18	$52.7	$3.1	$55.8
3B	Remove sediments over CSL within the former Dry Dock 1 (entire depth), conventional capping over the remaining CSL footprint, and ENR to the Urban Background concentrations in Elliott Bay	6.3	23.7	4 (Dry Dock 1)	$33.0	$4.4	$37.5
3C	Removes sediments over CSL within all of the former Dry Dock areas (entire depth), conventional capping over the remaining CSL footprint, and ENR to the Urban Background concentrations identified in Elliott Bay	1.3	23.7	10.3 (Dry Docks 1, 2, 3)	$44.5	$2.4	$47

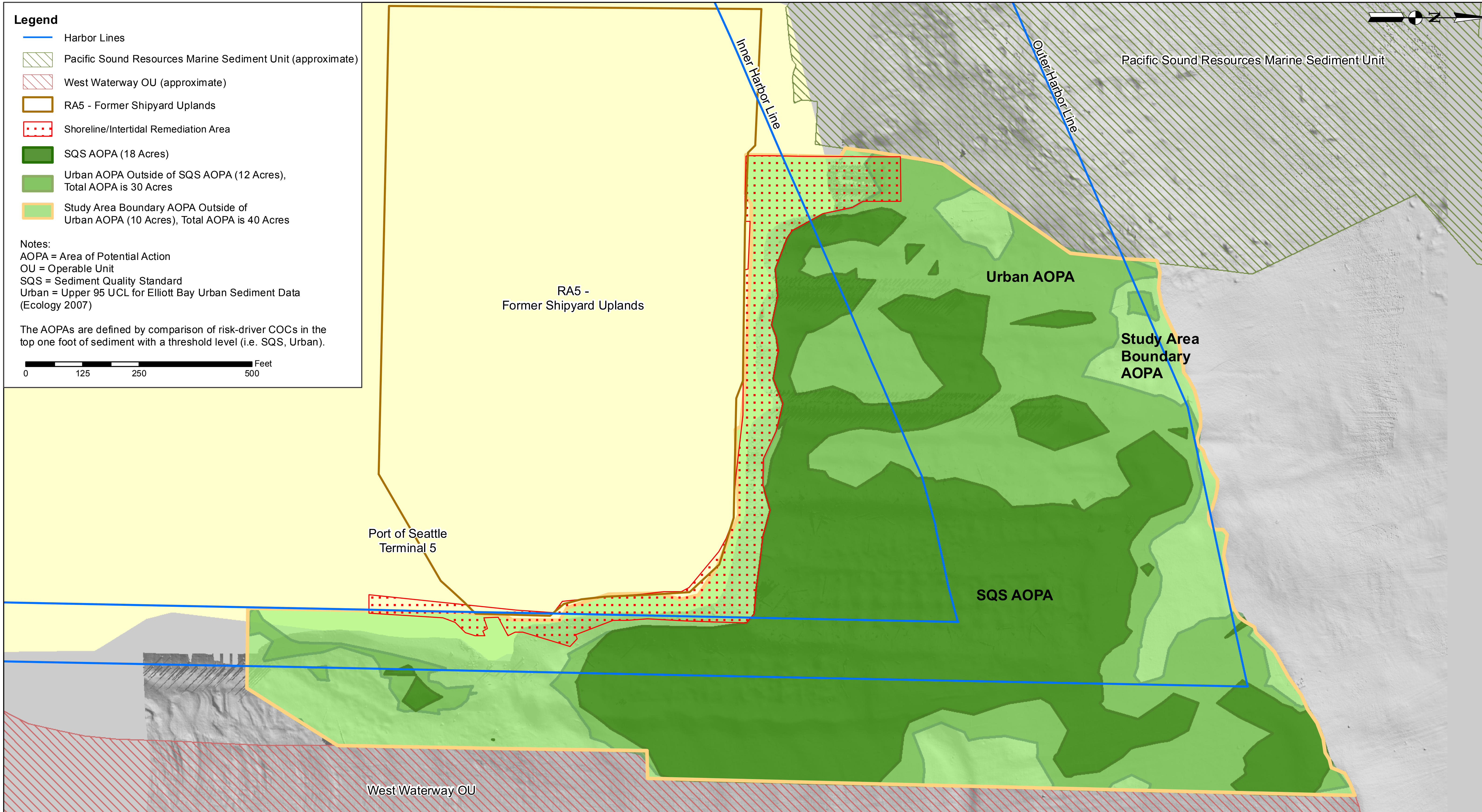
TABLE 8-5
Summary of Alternative Quantities and Costs

#	Alternative Description*	Cap Area (acres)	ENR Area (acres)	Dredging Area (acres)	Estimated Cost		
					Capital (MM)	ICs and LTM (MM)	NPV Total Cost (MM)
3C Plus*	Variant of 3C - includes all of the 3C elements, plus dredging all sediment with concentrations above the SQS in the navigational channel in West Waterway and the former shipway area, removing pilings from former shipway area, and extending ENR area to the Study Area boundary	0	28.4	11.6	$47.7	$0.5	$48.1
4A	Complete removal to SQS surface sediment footprint	0	0	23	$92.0	$0.3	$92.3
4B	Complete removal to Urban Background surface sediment footprint	0	0	34	$203.8	$0.3	$204.0
4C	Complete removal to PRGs (within Site boundary)	0	0	40	$302.8	$0	$302.8

***Alternatives 2A1 through 4C include the following common elements (exceptions noted):**

- **Former Shipway Area Remediation** – remove sandblast grit and CSL-contaminated sediments (approximately 700 cy) to the extent possible, place three foot cap with habitat mix, blend cap with PSR beach next to former shipway. Note: Alternative 3C Plus removes all sediments with concentrations above SQS.
- **Shoreline/Intertidal Remediation and Habitat Improvements** –remove existing shoreline structures (e.g., debris piles, remaining derelict bulkhead, and some pilings), dredge (approximately 9,300 cy) and backfill shoreline slopes from edge of existing intertidal habitat to landward edge of cleanup boundary with the goal of no net loss of intertidal habitat.
- **Disposal:**
  - Transport sediment via truck or rail for disposal at permitted upland landfill facility.
  - Dispose of debris and pilings at an appropriate permitted facility
- **Institutional Controls (excluded for Alternative 4c)**:
  - Proprietary Controls, including deed restrictions and restrictive covenants.
  - Informational Devices – Elliott Bay fish consumption advisories posted at the Site.
- **Surface Water** – Surface water will be monitored during the remediation activities in order to ensure that short-term water impacts are not caused by cleanup actions addressing contaminated sediments (dredging, dredge water treatment and return). EPA would waive the surface water ARAR, the federal ambient water quality criteria through a technical impracticability waiver based on the fact that cleaning up contaminated sediments at this small 40 acre Site would not likely improve the water quality to a measurable extent with Elliott Bay even though the source of contaminated sediments at this Site would be removed or covered.
- **Long-term Operations and Maintenance** – Identification of activities to cover post-construction monitoring and maintenance activities that are required to ensure the long-term performance of the remedy and outline performance expectations and potential courses of action that should be taken based on sampling results, passage of time, influence of marine activities or occurrence of natural phenomenon such as earthquakes or significant weather events.

NPV = net present value (3% discount rate applied)
LTM = long-term monitoring



TETRA TECH

Lockheed West Seattle Superfund Site, Seattle, WA

Figure 8-1
Areas of Potential Action

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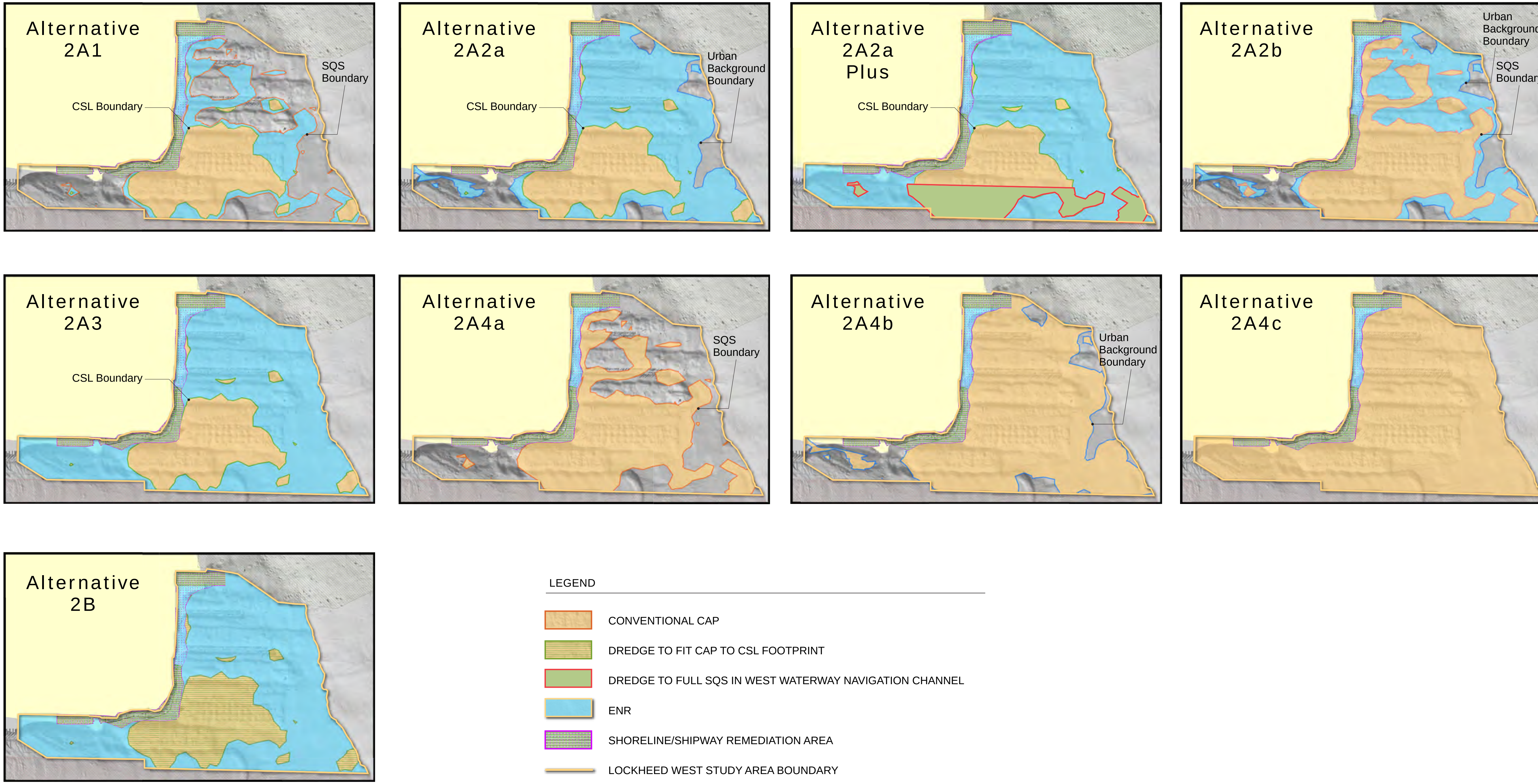

Feet
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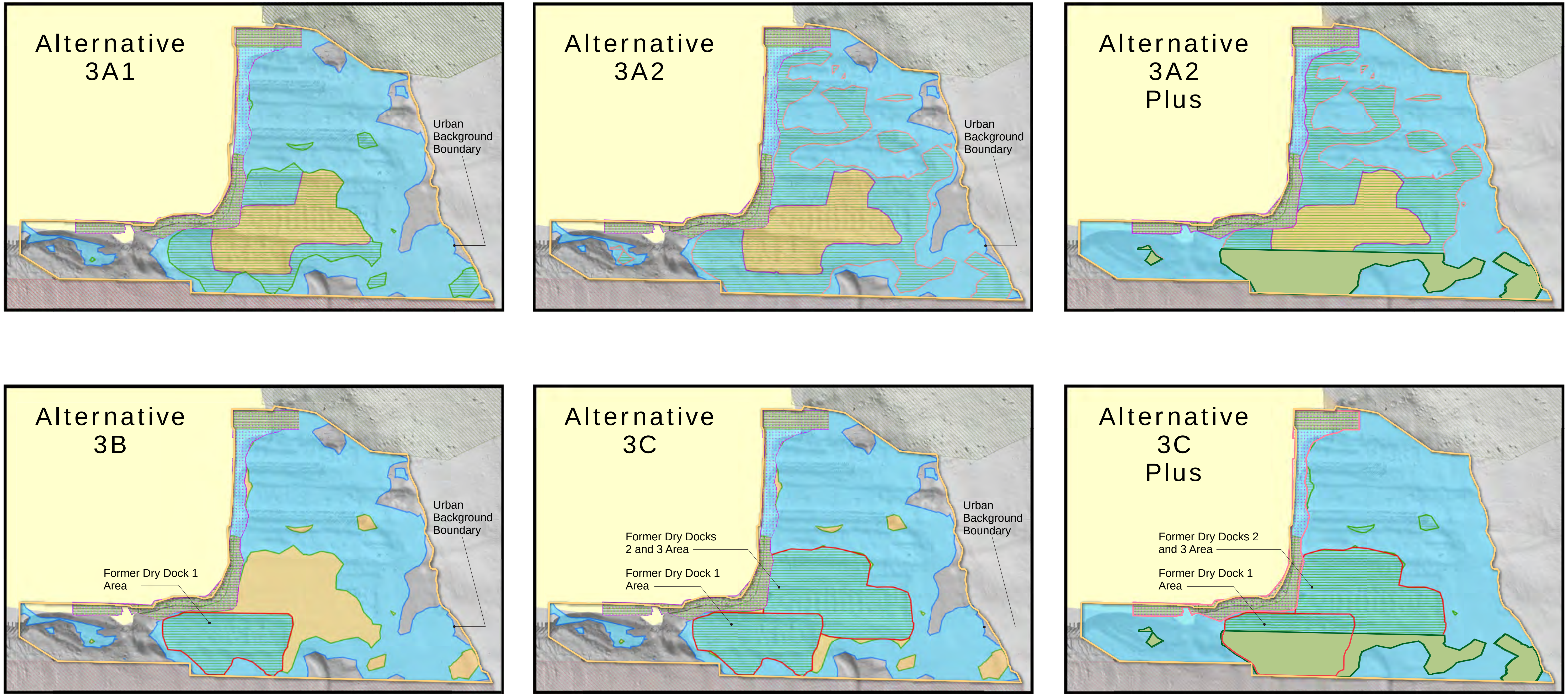
Source: Adapted from Tetra Tech, May 2012, Final RI/FS.

Figure 8-2
Containment-Focus Alternatives
Lockheed West Superfund Site
Seattle, WA

ES061212084335SEA



LEGEND

- DREDGE TO 3-FOOT DEPTH IN CSL FOOTPRINT
- DREDGE TO 3-FOOT DEPTH IN SQS FOOTPRINT
- PLACE 3-FOOT CAP IN POST-DREDGE AREAS WITH RESIDUAL CONTAMINANT CONCENTRATIONS BETWEEN THE SQS AND CSL (RISK-DRIVER COCs) AND NO GREATER THAN 2 TIMES THE SQS (REMAINING COCs)
- CAP REMAINING CSL FOOTPRINT
- DREDGE TO SQS IN WEST WATERWAY NAVIGATION CHANNEL
- ENR
- SHORELINE/SHIPWAY REMEDIATION AREA
- LOCKHEED WEST STUDY AREA BOUNDARY

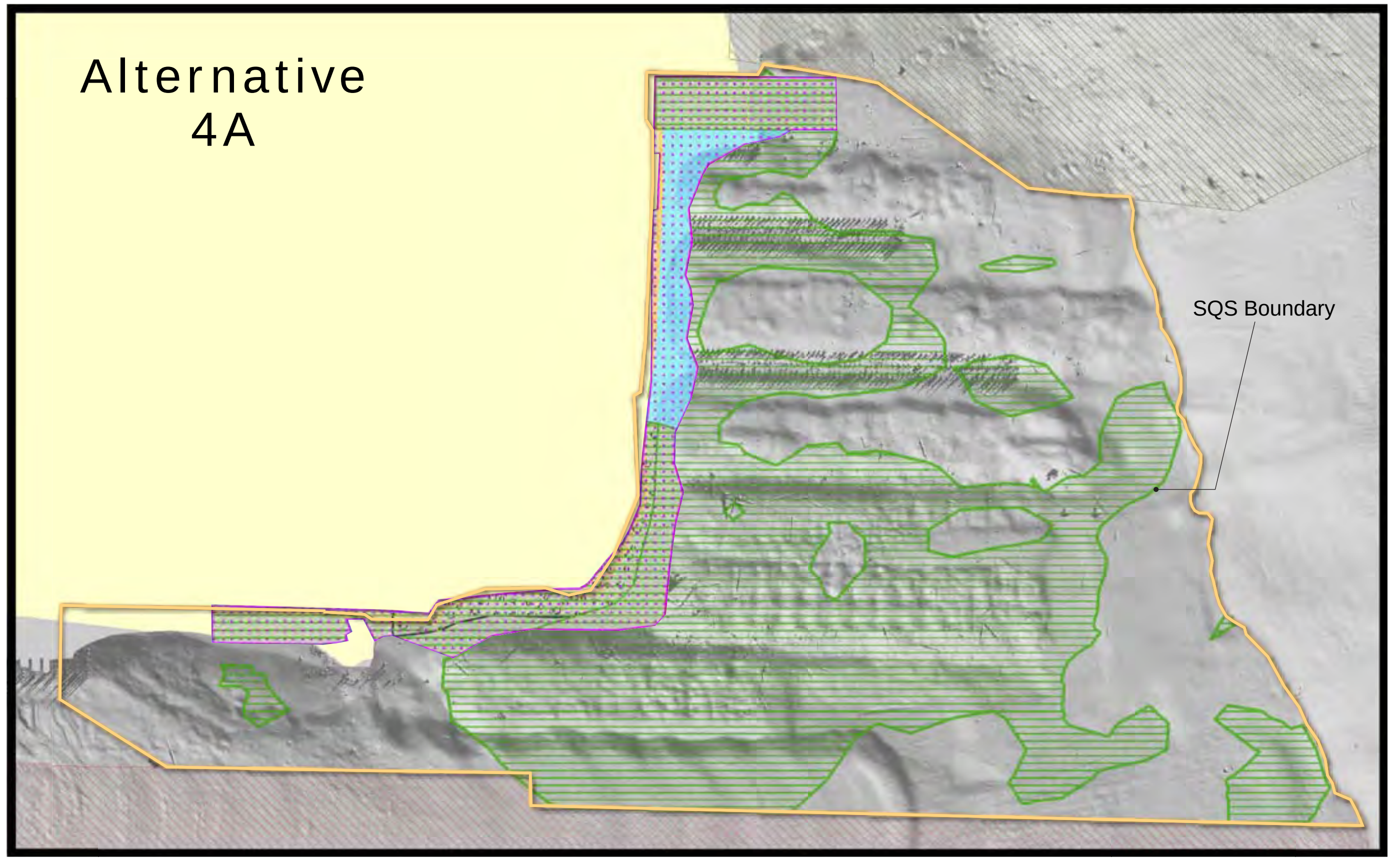
Feet
0 125 250 500

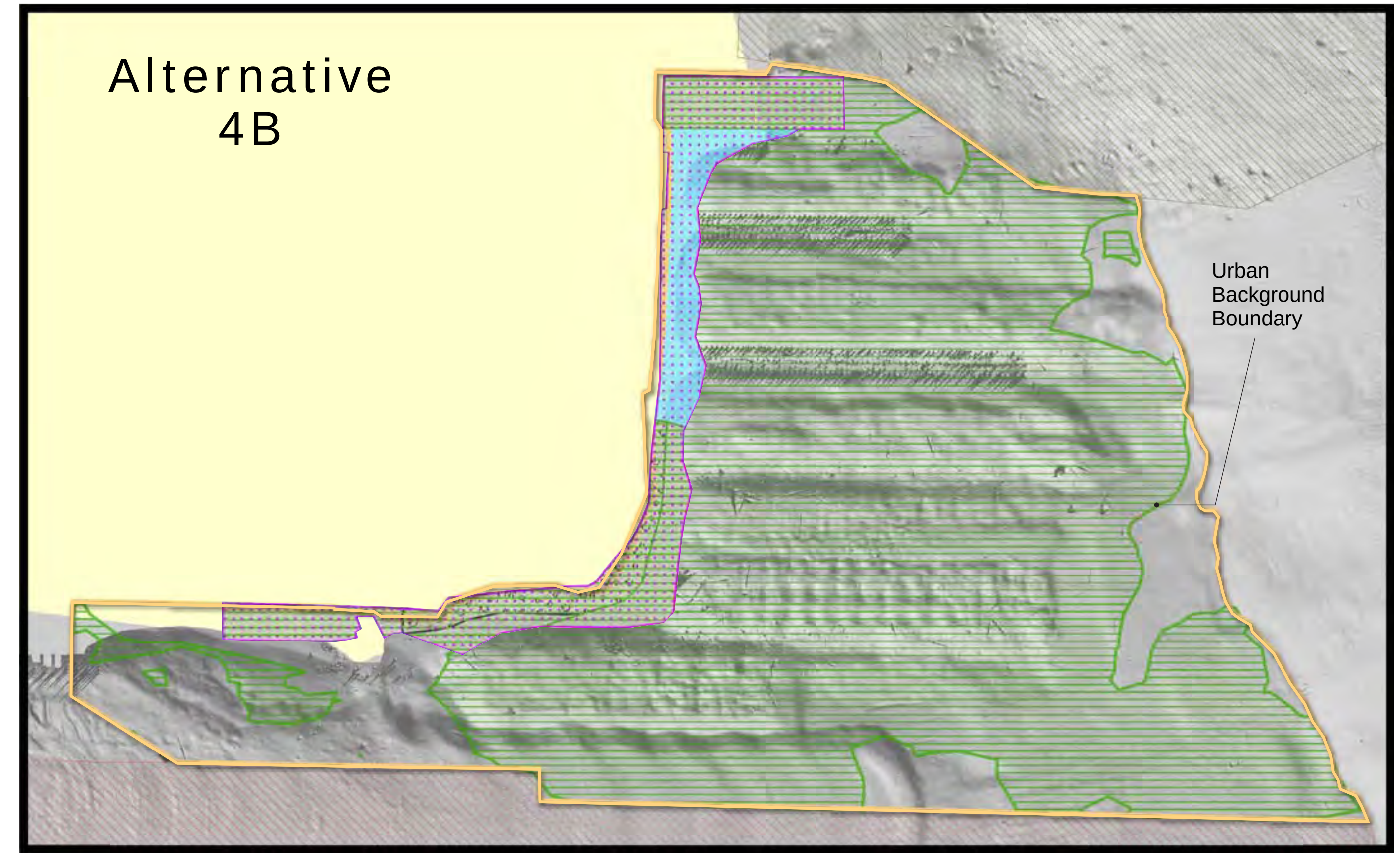
N

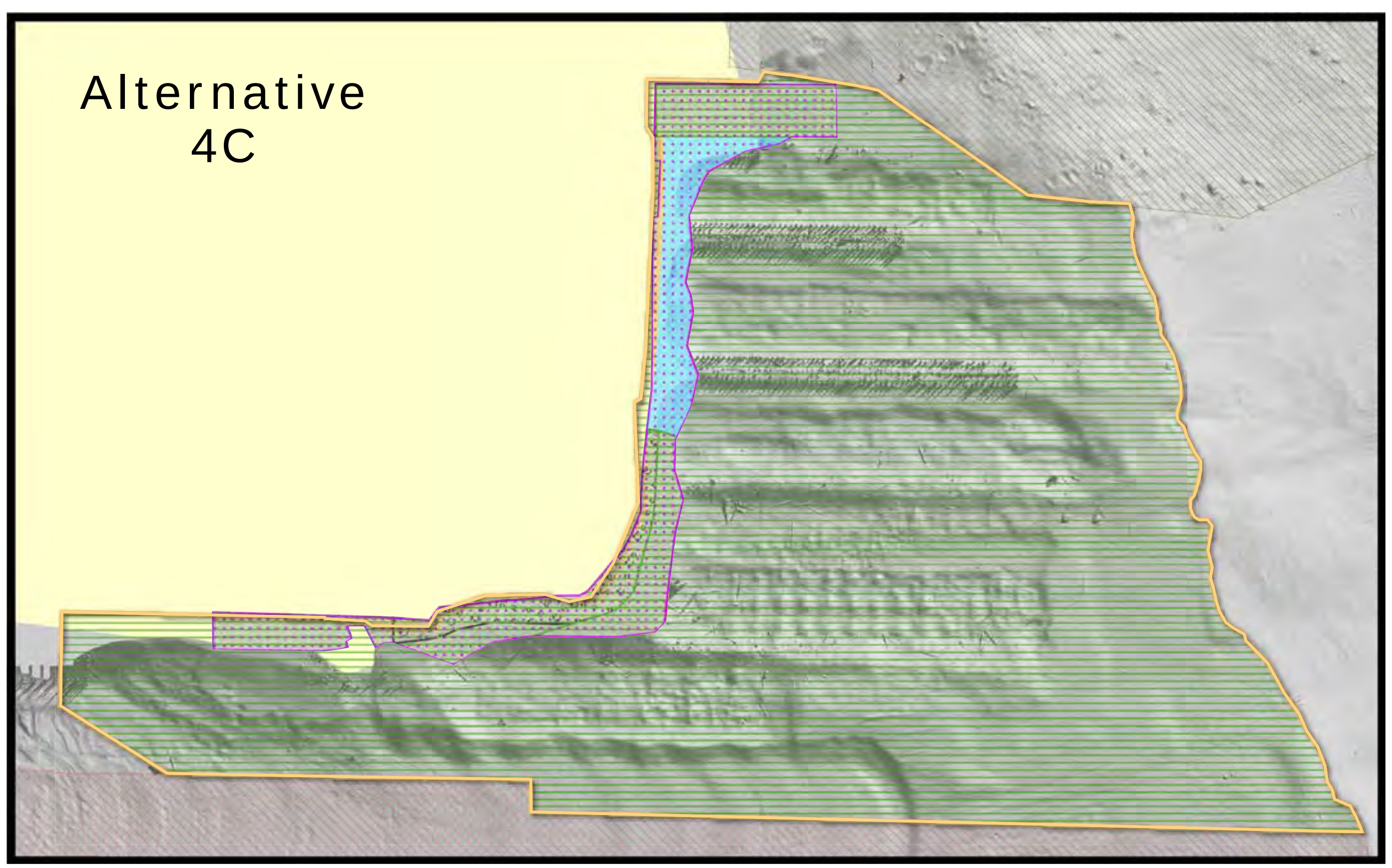
Source: Adapted from Tetra Tech, May 2012, Final RI/FS.

Figure 8-3
Removal-Focus Alternatives
Lockheed West Superfund Site
Seattle, WA

ES061212084335SEA







LEGEND

- DREDGING/REMOVAL AREA
- ENR
- SHORELINE/SHIPWAY REMEDIATION AREA
- LOCKHEED WEST STUDY AREA BOUNDARY

N

Feet
0 125 250 500

Source: Adapted from Tetra Tech, May 2012, Final RI/FS.

Figure 8-4
Complete Removal Alternatives
Lockheed West Superfund Site
Seattle, WA

9.0 Evaluation of Alternatives

In accordance with the NCP, the alternatives for the Site were evaluated using seven of the nine[3] criteria described in Section 121(b) of CERCLA and NCP §300.430(f)(5)(i). The seven criteria are the components of the Threshold Criteria and Balancing Criteria. The Modifying Criteria involve public input and community acceptance and are assessed at the end of the public review and comment period.

This section describes the relative performance of each alternative against the CERCLA criteria, noting how they compare to the other options under consideration. A more detailed analysis can be found in the FS.

9.1 Threshold Criteria

Threshold criteria are standards that an alternative must meet to be eligible for selection as a remedial action.

9.1.1 Overall Protection of Human Health and the Environment Evaluation

Determines whether a remedial action eliminates, reduces, or controls threats to public health and the environment through institutional controls, engineering controls or treatment.

All of the alternatives (except no action) would provide protection of human health and the environment by eliminating, minimizing or controlling risk through engineering controls and/or ICs. All of the alternatives would require ICs.

Alternatives that include active remediation to the Site boundary will meet the PRGs for RAO 1 at the surface (10 to 45 cm) at the completion of remediation. RAO 2 is met by removing contaminated sediments in the intertidal area and placing clean backfill to eliminate direct contact and incidental ingestion of impacted sediments. Ecological RAOs (RAOs 3 and 4) are met by all alternatives that use PRGs or SQS-based RALs as the basis for removal or capping surficial sediments. RAO 4 is also met by eliminating or reducing the crab, fish, and sandpiper exposure to Site contaminants in the top 10 to 45 cm of sediment.

Removal focus and complete removal focus alternatives result in less subsurface contamination after remediation and therefore achieve greater long-term effectiveness and permanence because the reduction in subsurface contamination results in less risk of recontamination from disruption and redistribution of subsurface sediments to the surface. Containment-focus alternatives leave higher concentrations of subsurface contamination behind, which may result in recontamination of the surface sediments. All of the alternatives requiring capping include long-term maintenance and monitoring in order to ensure the cap stays in place. Alternatives 2a2a Plus and 3A2 Plus includes provisions to replace the cap in the event is damaged during the long term monitoring period.

9.1.2 Compliance with ARARs

Evaluates how each alternative complies with state and federal environmental laws and regulations that pertain to the site or whether a waiver is justified.

The sediment quality ARARs will be met by alternatives in which contaminated sediments are completely removed or sequestered by conventional cap/ENR combinations that extend to the site boundary, thereby removing the exposure pathways.

It is anticipated that all of the alternatives can be designed and implemented in a manner that will allow conditions at the site to meet sediment quality and other location- and action-specific ARARs (see Table 7-1). However, the overlying surface water quality of the Site is not expected to meet the Clean Water Act, federal ambient water quality criteria (AWQC) for all of the Site COCs. This is because the Site consists of 40 acres within the larger Elliott Bay. Elliott Bay sediments and surface water are not the subject of this cleanup. Implementation

[3] The last two, or "Modifying Criteria," are evaluated until after public comment on the Proposed Plan is received. However, EPA has coordinated with the State and it concurs with the Preferred Alternative.

of the remedy at the Site will not prevent any existing sediment and surface water contamination from impacting our Site post remedial action. Therefore a surface water TI waiver will be necessary.

Final ARARs will be identified in the ROD.

9.2 Balancing Criteria

Balancing criteria weigh the tradeoffs between alternatives.

9.2.1 Long-term Effectiveness and Permanence

Considers the ability of a remedial alternative to maintain protection of human health and the environment over time and the reliability of such protection.

Removal-based alternatives are more effective and permanent than alternatives that rely only on containment because the contaminants are physically removed from the Site. Of the removal based alternatives, Alternative 4C achieves the most long-term effectiveness and permanence because all of the sediment contamination greater than the PRGs would be removed from the Site. Alternative 3B, which removes to CSL RAL only in Dry Dock 1 and has conventional capping and ENR elsewhere, has the least amount of dredging. Alternatives 3A2, 3A2 Plus, 3C Plus, 4A and 4B also remove contamination to at least the SQS RAL in all or portions of the Site, and would result in a more permanent remedy than containment focus and combination removal and containment alternatives. Any dredging alternatives that leave sediment concentrations in excess of the PRGs would also require proprietary ICs that run with the land and require coordination with EPA for any future disturbance (for example, excavation or dredging) in the cleanup area.

The next most effective and permanent alternatives include combinations of dredging and containment (at least 3 feet of cap material to contain remaining contaminated sediments). Containment is proven to be effective and permanent with the implementation of ICs that prohibit specific activities that may damage or compromise the cap (for example, anchor drag, scour). In addition, Alternatives 2A2a Plus and 3A2 Plus include provisions for cap replacement following seismic or other erosive events that disturb the cap. Of the combination alternatives, Alternative 3A2 has the largest area/volume of dredging (3 feet of dredging in all areas exceeding the SQS RAL) and capping of the remaining areas with concentrations between the SQS and CSL Alternative 3B has the smallest volume/area of dredging (3 feet of dredging in Dry Dock 1 only) and capping to the CSL RAL.

Cleanup alternatives that rely on containment alone can also be effective and permanent in the long term. The most effective and permanent alternative that relies solely on containment is 2A4c, which caps the entire Site to its boundary. Alternative 2A4b is the next most protective alternative that relies solely on containment. It requires capping to the Urban Background RAL. Containment alternatives that isolate contaminants in excess of the CSL RAL are less effective because sediment concentrations between the SQS and CSL are not sequestered by a conventional cap. Consequently, sediment concentrations in excess of the SQS (measured on a point by point basis) are left on site. Such concentrations are known to have potential adverse effects to benthic invertebrates (including clams).

Most of the containment and removal focus alternatives also include placing a thin-layer of sand (6 to 9 inches) over contaminated sediments in order to enhance the natural recovery process. ENR represents an active remedy addressing areas with relatively low concentrations of contaminants (i.e., areas with concentrations exceeding SQS but below CSLs). Placing ENR in such areas and extending it to the Site boundary is the most protective remedial approach. Alternatives that extend ENR to the Urban Background boundary are also protective, but less so since contaminant concentrations between the PRG and Urban Background concentrations are still exposed.

Any alternative that leaves sediment concentrations greater than PRGs at depth (only Alternative 4C does not) allows for the possibility of redistribution of subsurface contaminants into surface sediment. Alternatives that dredge more contamination leave less contaminated sediments on the Site. However, caps can be designed to sequester subsurface contamination. In the case of a large seismic event, alternatives that rely on capping have the likelihood of dispersing underlying contaminated sediments throughout the seismically-affected area. To address this concern, all capping alternatives include long term monitoring and Alternatives 2a2a Plus and 3A2 Plus include provisions for cap replacement following seismic or other erosive events that disturb the cap.

Contaminants left in place beneath ENR areas have a greater potential for re-exposure because this remedial approach is not engineered to ensure isolation and containment of buried contaminated sediments, but rather anticipates that the clean material will mix into the underlying sediments by natural processes (bioturbation, natural movement of sediments, human activities such as anchors). Therefore, the potential for contaminated sediment to be exposed by scour or future uncontrolled human disturbance is greater in ENR areas than in capped areas. For this reason, ENR is only employed in portions of the Site with lower sediment concentrations so in the event of thorough mixing, only concentrations less than or equal to SQS would be on the sediment surface. Because this Site is in a slightly depositional environment and it is unlikely that all of the ENR material will thoroughly mix in across the Site. In addition, there are few SQS exceedences outside of the areas identified for dredging. Consequently, the possibility of sediment mixing resulting in contaminant concentrations at the surface of ENR areas to reach SQS levels on a site-wide averaging basis is not considered likely.

All the alternatives include maintenance of fish advisories, specifically posting of the Elliott Bay fish advisory along the shore of the Site.

9.2.2 Reduction of Toxicity, Mobility, and Volume through Treatment

Evaluates use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount or residual contamination remaining.

Reduction of toxicity, mobility, and volume (TMV) through treatment will not occur with any of the alternatives because treatment is not utilized. None of the alternatives evaluated rely on treatment due to the complexities of treating multiple types of contamination (metals, PCBs, dioxin/furans, and cPAHs) at relatively low concentrations. A multi-step treatment train would be necessary and would also result in residuals that would require off-Site upland disposal in an appropriate facility. Consequently, treatment was eliminated as a possible component of remedial action alternatives in the technology screening portion of the FS (Tetra Tech, 2012a). Reduction of toxicity, mobility, and volume solely comes from dredging the most contaminated sediments and disposing them in an upland landfill facility and covering the remaining Site with clean sediments for ENR.

9.2.3 Short-term Effectiveness

Considers the length of time needed to implement a remedial alternative poses to workers, residents, and the environment during implementation.

Dredging alternatives require longer construction times and create larger amounts of contaminated materials that need to be handled through dredging and disposal. As a result, these remedies pose proportionately larger risks to workers, the community, and the environment. Dredging may also redistribute contaminated dredge material to nearby sediments and to the water column in the form of dredge residuals. The longer construction periods for these alternatives also increase impacts from equipment and vehicle emissions, noise, and resource disruption and consumption, even when implementing green and sustainable remediation (GSR) policies.

Larger active remediation areas (measured in acres capped or dredged or depth of sediments dredged) increase the short-term disturbance of the existing benthic community and other resident aquatic life and can potentially cause releases of bioavailable contaminants over a longer period of time. Alternatives 4A, 4B and 4C dredge the most contaminated sediments and would result in the highest short-term risks to workers and benthos and greater potential for dredge residuals. These alternatives also create the most greenhouse gas emissions, particulate matter less than 10 micrometers in aerodynamic diameter (PM_{10}), consume the most fuel and need the most landfill capacity, even when implementing GSR policies. These alternatives take 3 to 9 years to implement. Containment-only alternatives have low to moderate short-term risks and cause fewer greenhouse gas emissions and PM_{10}, use less fuel, do not use any landfill capacity, and pose fewer risks to workers because the cleanup time is shorter. However, they do use more capping material than the dredging-only alternatives and require more material to be delivered, handled, and placed on the Site. Combination removal and containment alternatives have moderate short-term risks based on the amount of fuel needed for cleanup, carbon footprint and PM_{10} emissions, and landfill space.

9.2.4 Implementability

Considers the technical and administrative feasibility of implementing a remedial alternative, such as relative availability of goods and services. This criterion also considers whether the technology has been used successfully at other similar sites.

All of the alternatives evaluated are implementable. In general, the potential for technical problems and schedule delays increases in direct proportion to duration and complexity of the cleanup alternative. Alternatives with dredge components have more complex technical and administrative implementability issues (e.g., coordination with agencies, availability of dredge equipment, etc.) due to the complexity of dredging and ancillary technologies (i.e., water management, transporting, transloading, truck or rail transport, disposal, dredge monitoring, and residuals management). Alternatives with larger remediation areas that are designed to remove large volumes of material and require longer construction periods have a comparatively higher potential for problems and delays than the alternatives with smaller active footprints, smaller volumes of material, shorter construction times.

In this context, containment focus alternatives have a low potential for technical and administrative difficulties and schedule delays. From the operational reliability perspective, the alternatives with dredging components are more challenging than the containment-focus alternatives. This is mainly due to residuals management, which poses a concern for reliability insofar as additional passes or expansions of the limits of dredge footprints may be required.

Containment focus alternatives are easier to implement technically and administratively than the removal-focus and complete removal alternatives. Consistent with this discussion, Alternative 2A1 is most implementable followed by Alternatives 2A4a and 2A2a, while complete removal-focus alternatives are harder to implement due to the scope of the remedies.

For any alternatives with a conventional cap, measures will be taken to monitor, and if necessary, maintain the cap. Activities such as anchoring, that create scour or other disturbances to the cap would be restricted. In any areas with contaminants left in place at concentrations higher than PRGs, a propriety control that runs with the land that requires coordination with EPA for any excavation or dredging in the cleanup area will be necessary. This is expected to be implemented in accordance with the Washington State UECA.

9.2.5 Cost

Includes estimated capital and operation and maintenance costs. Costs are expected to be accurate within a range of +50 to -30 percent.

The costs summarized in Table 8-5 range between $17 million and $302.8 million. Alternative 2A1 is the least expensive with conventional capping to the CSL RAL and ENR to the SQS RAL. The most expensive remedy, Alternative 4C, calls for dredging sediment to the PRGs which removes all of the contaminated sediments from the Site. All of the complete removal alternatives are the most expensive and would take the most amount of time to implement.

9.3 Modifying Criteria

Modifying criteria are described in the following subsections.

9.3.1 State/support Agency Acceptance

Considers whether the State supports EPA's analyses and recommendations of the RI/FS and the Proposed Plan.

Ecology was briefed on the Proposed Plan in March 2012. Ecology concurs with the preferred cleanup alternative selected by EPA. Ecology will submit a concurrence letter prior to EPA finalizing the ROD.

9.3.2 Community Acceptance

Considers whether the local community agrees with the EPA's analysis and recommendations of the RI/FS and the Proposed Plan.

Community acceptance of the Preferred Alternative will be evaluated after the public comment period ends. Comments received during that time will be included and responded to in a Responsiveness Summary section of the ROD.

10.0 EPA Preferred Alternative

This section presents EPA's Preferred Alternative and describes additional details of the remedy components. The Preferred Alternative, Alternative 3C, is a removal focus alternative involving dredging in the former dry dock areas, West Waterway navigation channel, and former shipway (see Figure 1-2). The portions of the Lockheed West Site peripheral to the dredging areas would be remediated using ENR extending to Study Area boundary.

The Preferred Alternative can change in response to public comments or if new information becomes available that would influence this selection. Any changes will be identified in the ROD and discussed further in the ROD Responsiveness Summary.

10.1 Preferred Alternative

EPA has identified Alternative 3C Plus as the Preferred Alternative for cleanup of sediments at the Site. The Preferred Alternative includes the following elements:

- Dredge the northeastern and eastern shoreline bank to mhhw and all intertidal sediment to remove sediments with COCs at levels in excess of SQS and backfill to grade with a layer of habitat restoration "fish mix" material.
- Place habitat substrate and fish mix on the northern shoreline bank where large riprap currently supports the Terminal 5 bank to provide a more habitat friendly environment.
- Dredge the former shipway area (westernmost portion of the Site) to remove sediments with COC concentrations in excess of the SQS and place a thin layer (6 to 9 inches) of clean material to cover dredge residuals.
- Dredge the former Dry Docks 1 through 3 area and other localized areas throughout the Site to remove sediments with COC concentrations that exceed SMS CSLs, and place a thin layer (6 to 9 inches) of clean material to cover dredge residuals.
- Dredge the Navigation Channel in West Waterway to remove sediments with COC concentrations that exceed SQS, and place a thin layer (6 to 9 inches) of clean material to cover dredge residuals.
- Dispose of dredged sediments and other related remediation materials by truck or rail transport to an appropriate offsite upland facility permitted to accept these materials.
- Remove debris, riprap, failing wooden bulkheads, and pilings throughout the Site, as necessary or as required by EPA, and dispose of them offsite.
- Place a thin layer (6 to 9 inches) of clean sand and gravel material to promote ENR over the remainder of the Site where concentrations of risk driver COCs are between the SQS and CSL and concentrations of other COCs are no greater than two times the SQS.
- Place ICs in the form of a proprietary control that runs with the land and that requires coordination with EPA and management of any residual contamination that is disturbed or encountered in the event of future excavation or dredging within the boundaries of the Site. It is EPA's expectation that the state UECA will be used. The ICs will not affect or restrict Tribal fishing rights in this area nor will they restrict pile installation, anchoring, or water-based commerce. The Lockheed Martin Corporation will secure appropriate restrictive covenants from the Port and DNR. In addition, Elliott Bay fish consumption advisories, established by the Washington State Department of Health, to reduce human exposure from ingestion of contaminated seafood will be posted at the Site.
- Conduct post-remedial confirmation sampling.
- Conduct long-term monitoring at the Site in the event of a major storm (with high winds from the north at 30 miles per hour or greater, that persist for more than 4 hours), or an earthquake of significance. If those events

occur, bathymetric monitoring will be implemented to determine whether one or more components of the selected remedy are affected.

- Conduct 5-year reviews (with scopes limited to bathymetric surveys to ensure that the ENR areas remain in place), file reviews, and interviews with the landowner pertaining to any development that has occurred at the Site since remediation was completed.

The overall size of the site is approximately 40 acres. Implementation of the Preferred Alternative will encompass the entire site and involve removal and/or addition of the following quantities of materials:

- Dredging—13.6 acres total (167,450 yd^3) derived from the following areas:
  - Shoreline/intertidal area – 1.2 acres (9,300 yd^3)
  - Former shipway area – 0.8 acre (6,500 yd^3)
  - Area below -10 ft mllw – 11.6 acres (151,650 yd^3)
- Backfill/capping of dredged areas—2.2 acres total in the following areas:
  - Shoreline/intertidal area – 1.2 acres (13,100 yd^3 of habitat mix, 1,900 yd^3 of riprap)
  - Former shipway area – 1 acre (9,850 yd^3 of habitat mix)
- ENR —28.6 acres total over the remaining (nondredged) area below -10 ft mllw to the limits of the Site boundary (45,900 yd^3)

The total capital cost to construct the preferred alternatives is estimated to be $48.1 million. The present value of the total cost of construction plus operations and maintenance is $47.7 million since IC costs are minimal, there are no cap replacement costs and no long-term monitoring costs will be incurred because the remedy will meet the RAOs at the end of construction.

Construction is expected to take one to two construction seasons. A detailed schedule for construction and implementation of the remedy will be determined during design.

10.2 Rationale for Selection of 3C Plus

The Preferred Alternative was selected based on the protection of human health and the environment, the ability of the remedy to meet ARARs, including natural background, long-term protectiveness (including limiting seismic concerns since no engineered caps are required), considerations regarding reasonably anticipated future land use, and minimizing the use of ICs. This alternative maintains and upholds the Tribal Treaty rights in this area. The Preferred Alternative does not result in any obstructions or impedances for future land use by the DNR or the Port, but does require coordination with EPA. In addition, after post-construction sampling verification to determine that the RAOs and cleanup criteria have been achieved, no additional long-term monitoring will be required. Five-Year Reviews will include bathymetric surveys, record reviews and interviews with the landowner regarding development that has occurred at the Site in the intervening time before the review.

The 2012 Final RI/FS (Tetra Tech 2012a) identified Containment-Focused Alternative 2A2a (conventional capping over the areas defined by the CSL footprint, ENR over the remaining area to the Urban Background footprint, potential cap replacement in the event of seismic damage, and common elements) as the “best-supported” alternative. This determination was made primarily on the basis of weighted scoring of CERCLA evaluation criteria for the RI/FS base alternatives, although the resulting scores varied over a relatively narrow range. This scoring comparison did not include the three EPA-requested “Plus” alternatives. Alternative 3C Plus represents a more suitable remedy than Alternative 2A2a for the following reasons:

- The actively remediated site surface area is greater for Alternative 3C Plus because it extends to Study Area boundary rather than the Urban Background boundary.
- Alternative 3C Plus does not involve capping, negating the need for more restrictive ICs and long-term monitoring.

- Potential for re-exposure of subsurface contaminated sediments and seismic damage is less for Alternative 3C Plus because the areas of highest-contaminant concentrations are removed via dredging and the remaining contaminant concentrations on the Site are low (generally less than SQS).
- Future site use restrictions required by capping that could affect Port development plans, and that are inconsistent with the DNR mandate for "water dependent uses" of state-owned lands would be eliminated by Alternative 3C Plus. Alternative 2A2a encumbers the Site with a cap and additional ICs, but does not preclude reasonably anticipated future land uses envisioned by the Port and DNR.

Alternative 3C Plus is more expensive ($48.1 million versus $18.6 million) and has more short-term impacts during implementation than 2A2a, and may require a longer construction duration; however these disadvantages are offset by the benefits listed above.

10.3 Summary

Removal focus Alternative 3C Plus is the Preferred Alternative. This alternative is recommended because it will achieve substantial risk reduction by dredging the most highly contaminated sediments, and placing ENR in Site areas where sediments contain lower concentrations of contaminants. This combination of technologies reduces risk more effectively and provides greater benefits to human health and the environment than the other alternatives evaluated.

Based on the information currently available, EPA believes the Preferred Alternative meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the balancing criteria. EPA expects the Preferred Alternative to satisfy the following statutory requirements of CERCLA §121(b): 1) be protective of human health and the environment; 2) comply with ARARs; 3) be cost-effective; 4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and 5) satisfies the preference for treatment as a principal element.

11.0 References

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