Photo: Port of Seattle

East Waterway Operable Unit

Final Feasibility Study – June 2019

EXECUTIVE SUMMARY

For submittal to the U.S. Environmental Protection Agency, Region 10, Seattle, Washington

Prepared by

Port of Seattle

ANCHOR QEA

In association with Windward Environmental LLC

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List of Acronyms and Abbreviations

µg	microgram
ARAR	applicable and relevant or appropriate requirements
BMP	best management practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMA	construction management area
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
CSO	combined sewer overflow
cy	cubic yard
dw	dry weight
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
ENR-nav	enhanced natural recovery applied in the navigation channel and deep-draft berthing areas
ENR-sill	enhanced natural recovery applied in the Sill Reach
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
EW	East Waterway
EWG	East Waterway Group
FS	Feasibility Study
Hg	mercury
kg	kilogram
LDW	Lower Duwamish Waterway
mg	milligram
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
NA	not applicable
ng	nanogram
OC	organic carbon
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PQL	practical quantitation limit
PRG	preliminary remediation goal
RAL	remedial action level
RAO	remedial action objective
RBTC	risk-based threshold concentration
RMC	residuals management cover
RME	reasonable maximum exposure
ROD	Record of Decision
SCO	sediment cleanup objective
SMS	Washington State Sediment Management Standards
SQS	sediment quality standard
SRI	Supplemental Remedial Investigation
SWAC	spatially-weighted average concentration
TBT	tributyltin
TEQ	toxic equivalent
UCL95	95% upper confidence limit on the mean

Overview of the East Waterway Operable Unit Cleanup

Site Description

The East Waterway (EW) is an Operable Unit (OU) of the Harbor Island Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Superfund site located in Seattle, Washington. The EW is a 1.5-mile-long, 157-acre maintained waterway in one of Seattle's primary industrial and commercial areas. The EW is located immediately downstream and north of the Lower Duwamish Waterway (LDW) Superfund site, along the east side of Harbor Island (Figure 1). The EW was created during the construction of Harbor Island in the early 1900s to serve developing industries and commerce in Seattle.

The EW is an estuarine environment in which the Green/Duwamish River discharges freshwater to Puget Sound. The EW is open to Elliott Bay on the north, and water levels are subject to a tidal range of approximately -4 feet mean lower low water (MLLW) to +14 feet MLLW. The water column in the EW is saltwater, with a surface lens of freshwater from the riverine discharge.

Purpose of the Feasibility Study

Under the oversight of the U.S. Environmental Protection Agency (EPA), this Feasibility Study (FS) has been conducted by the East Waterway Group (EWG), consisting of the Port of Seattle, the City of Seattle, and King County. The purpose of this FS is to develop and evaluate EW-wide remedial alternatives to address the risks posed by contaminants of concern (COCs) within the EW. Specifically, this FS:

- Summarizes the results of the Supplemental Remedial Investigation (SRI; Windward and Anchor QEA 2014[1]) including EW uses, nature and extent of contamination, and human health and ecological risk assessments
- Develops remedial action objectives (RAOs) and preliminary remediation goals (PRGs) that define the goals of the cleanup
- Develops physical and chemical models to predict concentrations of key COCs in sediment over time
- Delineates remediation footprints for cleanup using remedial action levels (RALs) for key COCs
- Evaluates and screens potential remedial technologies that could be used to clean up different areas of the EW
- Develops a suite of potential remedial alternatives for cleanup of the waterway
- Compares those alternatives based on the CERCLA remedy selection criteria

Supplemental Remedial Investigation

The SRI documents the results of a series of studies completed over 8 years, including the following:

- A conceptual site model
- Physical and biological interactions of the waterway system, including physical processes that affect sediment transport into, within, and out of the EW
- The nature and extent of contamination
- The risks that contamination presents to people and animals that use the EW

Contaminants of Concern

The primary COCs in EW sediments include polychlorinated biphenyls (PCBs), arsenic, mercury, dioxins/furans, and carcinogenic polycyclic aromatic hydrocarbons (cPAHs).

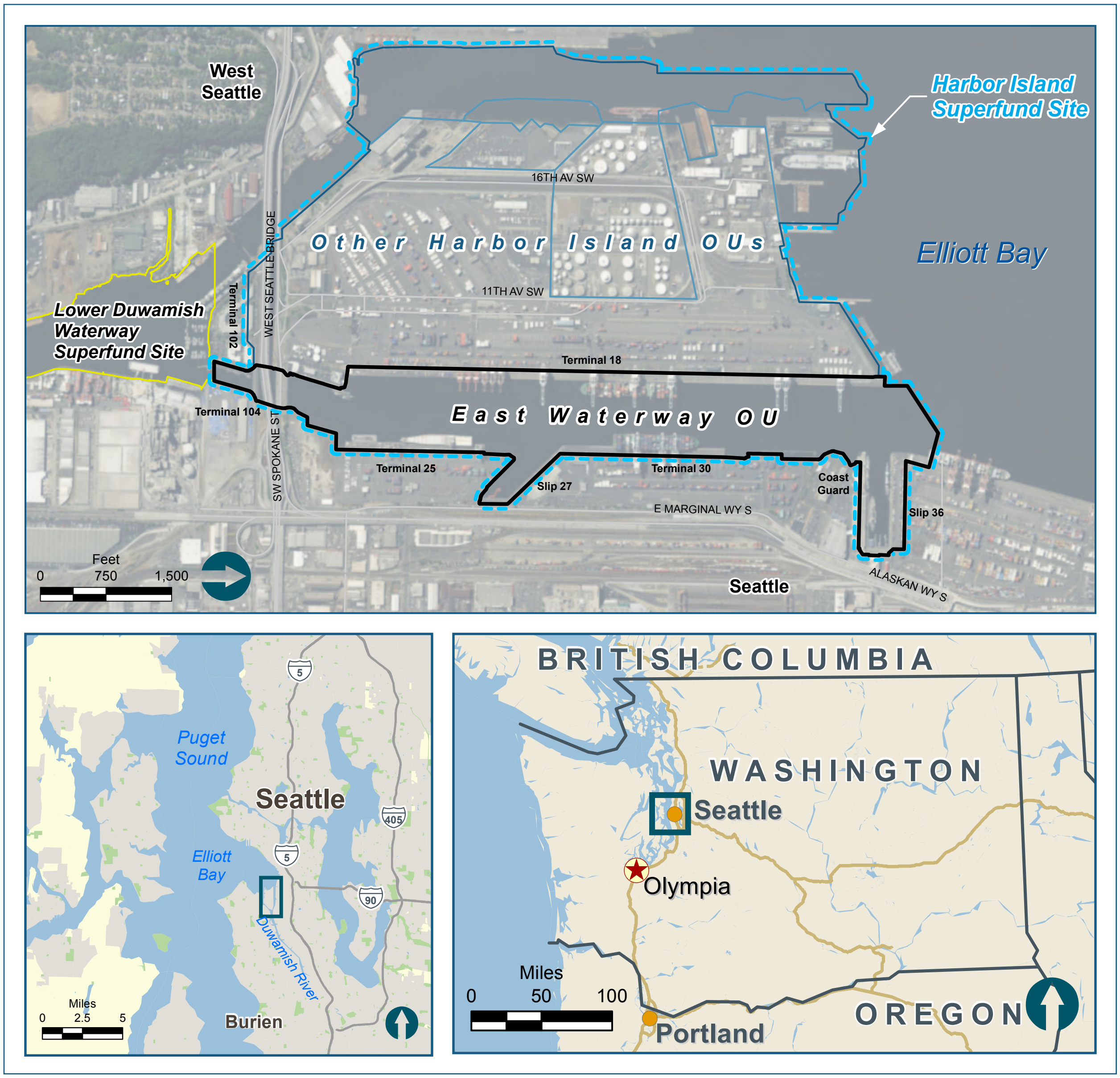
Contaminant Risks

Human health and ecological risks from contaminated sediments in the EW persist at levels that warrant action under federal and state law. Risks to people are highest from eating resident seafood that live in the waterway for most or all of their life.[2] Lower, but still significant, health risks to people come from sediment contact while clamming and netfishing. Animals that live in the sediment and some resident fish are also at risk.

1 Windward Environmental and Anchor QEA, 2014. Supplemental Remedial Investigation. East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study. Final. January 2014.

2 Salmon caught within the EW do not accumulate significant contamination or pose health risks from EW sediments because salmon spend only a small portion of their lives in the EW, and thus are not considered resident fish.

Figure 1: East Waterway Study Area



Source Control

Most of the sediment contamination in the EW is from historical releases; however, continued efforts to reduce any ongoing sources of contaminants entering the EW is a priority, to avoid recontamination after cleanup. Discharges to the EW are heavily regulated under existing state and federal programs and regulations. Sediment from upstream sources can enter the EW from the Green/Duwamish River watershed, including the LDW Superfund site. The EWG members and other entities have performed investigations and cleanups of facilities, storm drains, and combined sewer overflows (CSOs) within the EW drainage basin, and future source control activities will further reduce contaminants entering the EW.

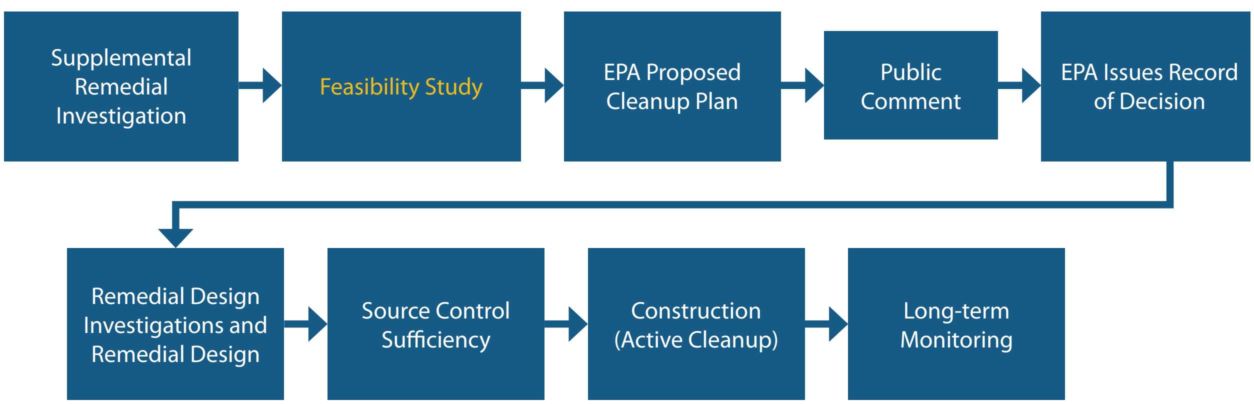
Cleanup Alternatives

The FS alternatives rely primarily on the removal (dredging) of contaminated sediment from the EW because the sediment bed elevation within most of the waterway is at the depth needed for navigation. Therefore, other cleanup options, such as capping that would raise the sediment bed elevation, are precluded in much of the EW. To varying lesser degrees, the alternatives also employ partial dredging and capping, capping (without dredging), in situ treatment, enhanced natural recovery (ENR), and monitored natural recovery (MNR). CERCLA criteria were used to develop and evaluate cleanup alternatives; this evaluation forms the basis for selecting a final cleanup plan in subsequent EPA decision documents.

CERCLA Process

Figure 2 presents the CERCLA process moving toward cleanup of the EW.

Figure 2: East Waterway Superfund Cleanup Process

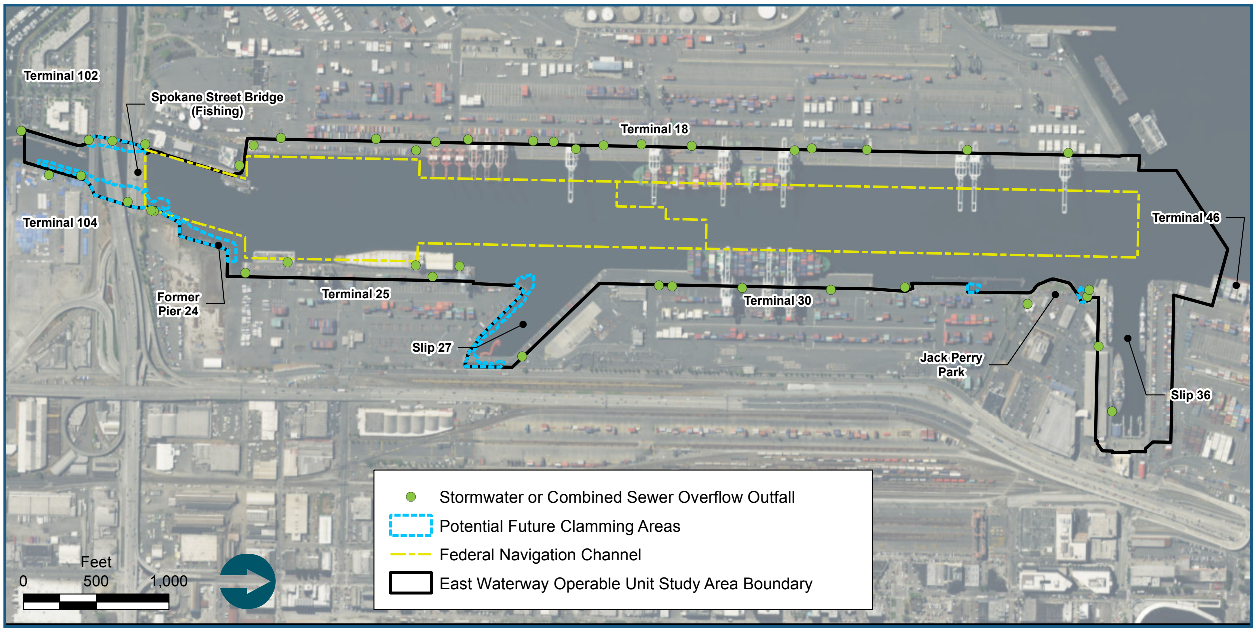


Key Definitions for the Executive Summary

- **Applicable or relevant and appropriate requirements (ARARs)** are defined as standards, criteria, or limitations under federal or state environmental or facility siting laws that are more stringent than the federal law. Remedial actions conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) must achieve them or formally waive them. For example, the Washington Model Toxics Control Act (MTCA) is an ARAR under a CERCLA cleanup action.
- The **benthic community** is made up of organisms, such as marine worms and clams, that live in and on the sediments and are an integral part of the food chain in Puget Sound ecosystems.
- **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)** are the federal requirements that regulate the site investigations and cleanup of the EW OU Superfund site.
- **Construction Management Area (CMA)** refers to an area of the EW identified in the FS that represents similar structural conditions, or similar aquatic use, habitat, or water depth conditions for the purpose of determining the applicable cleanup technologies.
- **Enhanced natural recovery (ENR)** refers to the application of thin layers of clean granular material, typically sand, to reduce chemical exposure and accelerate natural recovery processes in a sediment area targeted for remediation. Essentially, ENR reduces the time to achieve cleanup objectives over what is possible by relying solely on natural sediment deposition.
- **In situ treatment** as a technology applied at this site refers to the application of an amendment to the material used in ENR or capping or mixed directly into surface sediments. Typically, the amendment is activated carbon or organoclays used to bind contaminants and make them unavailable for biological uptake by organisms.
- **Model Toxics Control Act (MTCA)** is the Washington State requirements for environmental cleanup sites and is an ARAR for the EW OU Superfund site.
- **Monitored natural recovery (MNR)** refers to the use of natural processes such as burial by incoming sediments to reduce sediment contaminant concentrations over time. It is used where conditions support natural recovery. A monitoring program is instituted to assess if, and at what rate, risks are being reduced and whether sufficient progress is being made toward achieving the RAOs, or alternatively, whether contingency actions are warranted.
- **Natural background** represents the concentrations of hazardous substances that are consistently present in an environment that has not been influenced by localized human activities.
- **Preliminary remediation goals (PRGs)** are specific desired contaminant endpoint concentrations or risk levels for each exposure pathway that are believed to provide adequate protection of human health and the environment, based on available site information.
- **Remedial action levels (RALs)** are contaminant-specific sediment concentrations that trigger the need for remediation (e.g., dredging, capping, in situ treatment, ENR, or MNR).
- **Remedial action objectives (RAOs)** describe what the proposed remedial action is expected to accomplish. They are narrative statements of the goals for protecting human health and the environment.
- **Risk drivers** are the COCs identified in the baseline (i.e., existing condition) risk assessments that present the principal risks to people or animals.
- **Sediment Management Standards (SMS)** include the Washington State requirements for sediment cleanup sites and are an ARAR for the EW OU Superfund site. The SMS rule has a two-tier decision framework (SQS/SCO and CSL) to protect the function and integrity of the benthic community and to protect humans and upper trophic levels from bioaccumulative effects.
- **Spatially-weighted average concentrations (SWACs)** are average concentrations in an area of interest (either site-wide or in potential clamming areas for the EW) calculated by interpolating concentration data over a specified area.

East Waterway Uses

Figure 3: East Waterway Features



The EW is one of the most active commercial waterways in the Pacific Northwest, supporting a variety of shipping and water-based industries (Figure 3). In addition, the EW serves ecological and recreational functions as a deep water estuary at the mouth of the Duwamish River. It also is an area used for a tribal commercial netfishery.

Commercial and Navigation Activities

The EW provides a critical connection for cargo and other materials moving between water and land, and current land use, zoning requirements, and land ownership are consistent with the characteristics of an active commercial waterway. Most vessel traffic consists of shipping companies that move container vessels and assorted tugboats into and out of the EW. A federally authorized navigation channel runs from the Spokane Street Bridge to the northern end of the EW. Berthing areas currently maintained to various depths are present inshore of the navigation channel along much of the waterway.

Habitat

The EW shoreline is highly developed, primarily composed of over-water piling-supported piers, riprap slopes, seawalls, and bulkheads for industrial and commercial use, with a limited number of small intertidal areas. Despite the commercial use and structures, the EW contains diverse aquatic and wildlife communities, including marine mammals and birds. The EW provides habitat important to various species, including two species that are listed as threatened under the Endangered Species Act, Puget Sound Chinook salmon and bull trout.

Other Uses

While the EW is used for various recreational activities such as boating and fishing, there is limited public access. There is one public park, Jack Perry Park, and a public fishing pier in the southern portion of the waterway. The EW is part of the Muckleshoot Tribe's and Suquamish Tribe's usual and accustomed area, which provides these tribes with treaty-protected uses including a commercial fishery for salmon as well as ceremonial and subsistence uses.

The EW is also the receiving waterbody for 39 public and private storm drains and three CSOs from adjacent urban areas.

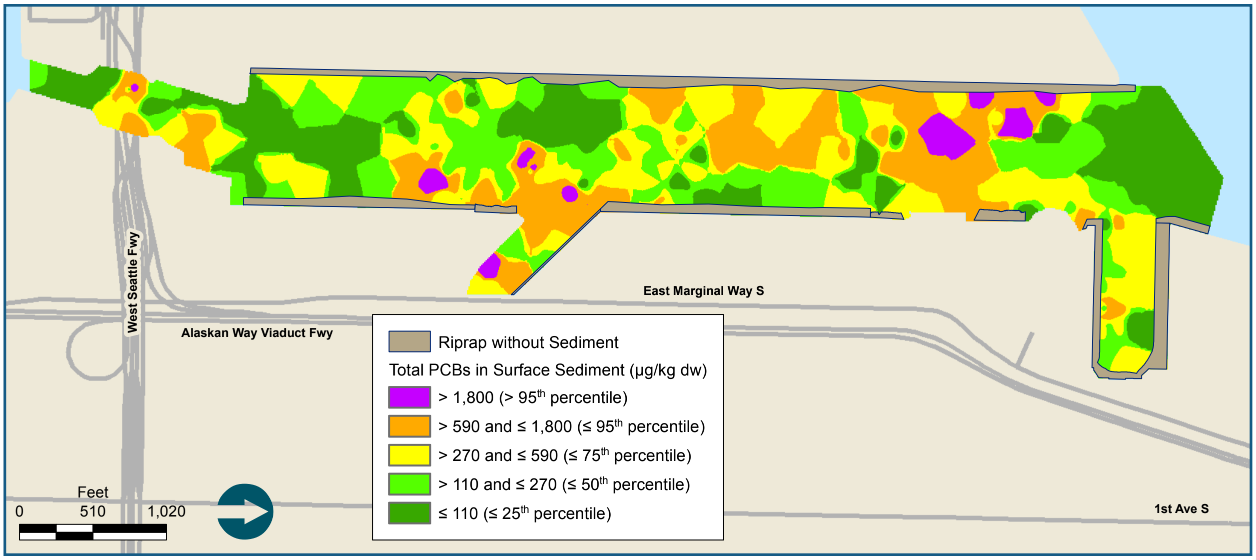
Nature and Extent of Contamination

For the SRI, scientists collected and analyzed information about the nature and extent of contamination and concluded with the following findings:

- PCBs, PAHs, dioxins/furans, phthalates, and metals were frequently detected in surface sediments.[3] Many other organic chemicals, including semivolatile organic compounds and pesticides, were less frequently or rarely detected. Contaminants are broadly distributed throughout the EW.
- Total PCBs are a key risk driver for the protection of human health and ecological health in the EW. Total PCBs surface sediment concentrations ranged from 6 to 8,400 micrograms per kilogram (µg/kg) on a dry weight (dw) basis, with a site-wide spatially-weighted average concentration (SWAC) of 460 µg/kg dw (Figure 4).
- A general depiction of the spatial extent and magnitude of contamination in surface sediment is provided by exceedance status of Washington State's Sediment Management Standards (SMS) marine benthic criteria. Figure 5 shows the spatial extent of contaminated sediment within the EW. Areas with sediment concentrations exceeding the cleanup screening level (CSL) have higher concentrations, areas with sediment exceeding sediment quality standard (SQS; but less than CSL) have moderate concentrations, and areas with sediment concentrations below the SQS have the lowest concentrations.
- The depth of sediment contamination exceeding the SQS averages approximately 5 feet.

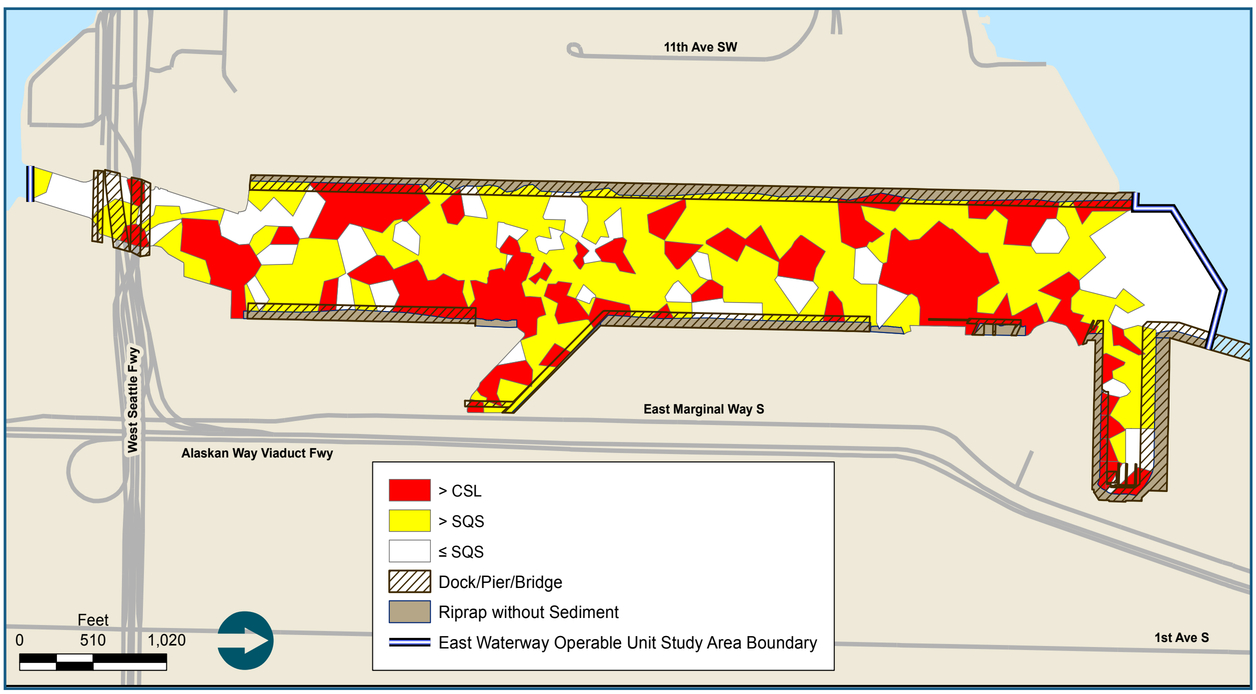
3 Surface sediment is defined as the upper 10 centimeters of sediment, also referred to as the biologically active zone, where the majority of the benthic community is generally found. Contaminants within the biologically active zone may pose risks to the benthic community and the animals that consume them.

Figure 4: Surface Sediment Total PCB Concentration



Notes: µg/kg dw – micrograms per kilogram on a dry weight basis | PCB – polychlorinated biphenyl

Figure 5: Surface Sediments Compared to Sediment Management Standards Marine Benthic Criteria



Notes: SQS – sediment quality standard | CSL – cleanup screening level


Fishing from the Spokane Street Bridge within the East Waterway. Photo: Anchor QEA

Risk Assessment

The baseline (i.e., existing condition) risk assessments conducted as part of the SRI estimated risks to people (human health) and ecological receptors (benthic community, fish, and wildlife) resulting from exposure to contaminants in the absence of any cleanup measures. The risk assessments found the risks in the EW to be high enough to warrant an evaluation of cleanup alternatives under CERCLA; these findings are summarized as follows:

Human Health Risks

- Contaminants contributing the most to human health risks are total PCBs, arsenic, cPAHs, and dioxins/furans. These are referred to as the human health risk drivers.
- The highest risks to people are associated with consumption of resident seafood, including fish, clams, and crab. The seafood consumption pathway is a significant exposure pathway and seafood can be obtained through tribal netfishing, clamming, crabbing, and hook-and-line fishing. The total excess cancer risk for all carcinogenic chemicals ranged from 4 in 10,000 (4×10^{-4}) to 1 in 1,000 (1×10^{-3}) for the reasonable maximum exposure (RME) seafood consumption scenarios. Total PCBs, dioxins/furans, and cPAHs were identified as risk drivers.

Reasonable Maximum Exposure Scenarios Developed for the EW

Seafood Consumption

- **Adult Tribal RME** = three meals per week (1/2 pound of seafood per meal) for 70 years
- **Child Tribal RME** = three meals per week (1/5 pound of seafood per meal) for 6 years
- **Adult Asian Pacific Islander RME** = one and a half meals per week (1/2 pound of seafood per meal) for 30 years

Sediment Direct Contact

- **Netfishing RME** = exposure for 119 days per year for 44 years
- **Tribal Clamming RME** = exposure for 120 days per year for 64 years

- The evaluation of non-cancer hazards (e.g., immunological or neurological effects) indicates the potential for adverse effects associated with resident seafood consumption. These non-cancer hazards have hazard quotients of up to 59 for the RME seafood consumption scenarios, with total PCBs and dioxins/furans identified as risk drivers.
- Excess cancer risks for direct sediment exposure RME scenarios for netfishing and tribal clamming were lower than those for seafood consumption RME scenarios, with total risk estimates ranging from 5 in 1,000,000 (5×10^{-6}) to 2 in 100,000 (2×10^{-5}). Arsenic was identified as a risk driver.

Benthic Risks

- The concentration of 29 contaminants in surface sediment in one or more locations exceeded the SMS marine standards, indicating at least the potential for minor adverse effects on the benthic community. Surface sediment also contains concentrations of tributyltin above the site-specific risk-based threshold concentrations (RBTCs). Approximately 38% of the EW is designated as having no adverse effects to the benthic community (all less than SQS), approximately 39% of the area has a potential for minor adverse effects to the benthic community (between SQS and CSL), and 23% of the area is expected to have at least minor adverse effects to the benthic community (greater than CSL). See Figure 5.

Ecological Risks

- Risks to crabs and fish were relatively low, with one exception. Risks associated with total PCBs were above the risk threshold for English sole and brown rockfish, and thus total PCBs were identified as an ecological risk driver. No contaminants were found to pose unacceptable risk to bird or mammal receptors.

Risk Assessment Terms

Cleanup Screening Levels (CSLs) in this Executive Summary represent the numeric marine benthic sediment chemical criteria for minor adverse effects to the benthic community. In the SMS, the CSL also represents the upper limit of the potential cleanup level considering multiple factors.

Excess Cancer Risk refers to the additional risk of developing cancer due to exposure to a toxic substance incurred over a defined exposure period, in this case lifetime exposure. Contaminant risk estimates that exceed the CERCLA threshold excess cancer risk level of 1 in 1,000,000 (1×10^{-6}) warrant further evaluation.

Hazard Quotient (HQ) is the ratio of the potential exposure to a substance and the level at which no adverse effects from that exposure are expected. Risk estimates that exceed the CERCLA threshold of HQ = 1 warrant further evaluation.

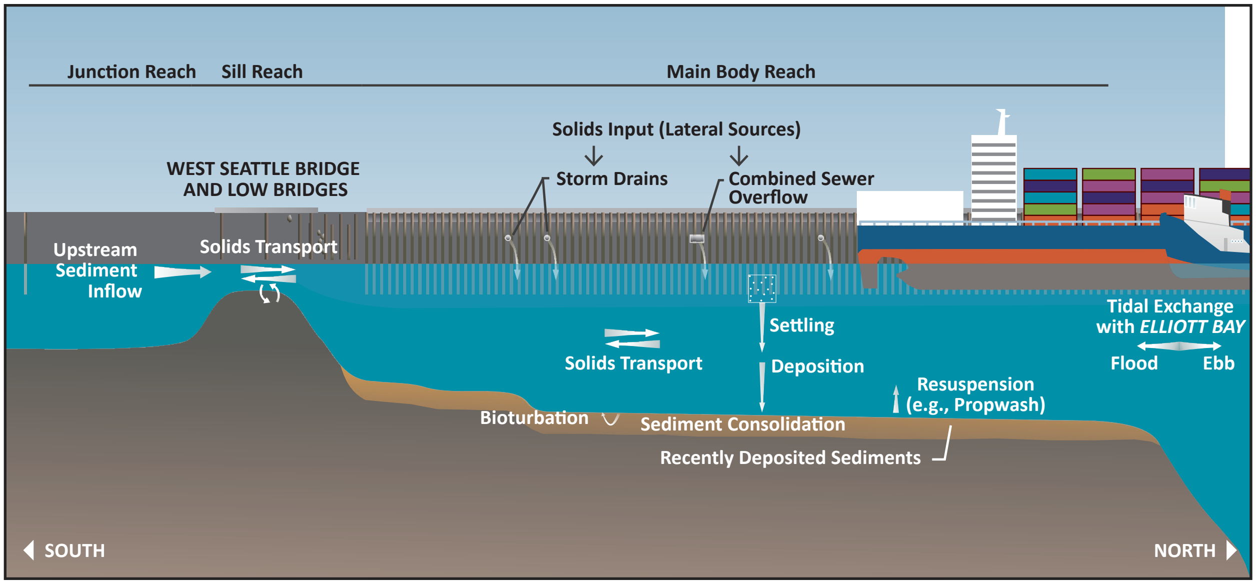
Reasonable Maximum Exposure (RME) is the maximum exposure reasonably expected to occur in a population.

Risk-based Threshold Concentration (RBTC) is the contaminant concentration in sediment that equates to a specific risk threshold. RBTCs are developed to meet specific cancer risk thresholds, HQs, or benthic criteria and are used in the development of preliminary remediation goals for the EW.

Sediment Quality Standards (SQSs) are the numeric marine sediment chemical criteria for Puget Sound, below which no adverse effects to the benthic community are expected; SQS also represents the "marine benthic sediment cleanup objective," which is the lower limit of the potential cleanup level considering multiple factors.

Physical and Chemical Modeling

Figure 6: Conceptual Site Model of Sediment Transport in the East Waterway



Hydrodynamic and sediment transport modeling and site-specific data collection were conducted to evaluate long-term sediment transport processes in the EW (the majority of contaminants are associated with sediments). The findings from these evaluations included the following:

- In most locations, sediments deposit and accumulate over time on the EW bottom. Data indicated that net sedimentation rates vary by location within the EW, from 0 to 4.2 centimeters per year.
- Newly deposited sediments are mixed with existing sediments through bioturbation and propeller wash (see Figure 6). Model-estimated vessel scour depths (i.e., the depth of sediment that could be impacted by vessel use during navigation and berthing) could range from 0.5 to 5 feet within the EW, depending on the location. The majority of the EW has potential for vessel scour of 2 feet or more from vessel use under normal to extreme operating conditions. Vessel scour is episodic and localized, with most of the scoured material re-depositing nearby.

Sedimentation in the EW

- 32,000 to 54,000 metric tons of sediment are estimated to enter the EW each year
- 40% to 75% are estimated to settle or accumulate in the EW
- Of the total sediment load entering the EW, it is estimated that:
  - » 99% originates from the Green/Duwamish River
  - » Less than1% originates from the upstream LDW Superfund site, including the LDW bed and LDW storm drains and CSOs
  - » 0.2% to 0.3% originates from EW storm drains and CSOs

- To evaluate changes in sediment contaminant concentrations over time, physical modeling results were combined with estimates of contaminant concentrations on solids that enter the EW. This analysis, conducted using hydrodynamic and particle tracking modeling, yielded the following results:
  - » 99% of solids settling in the EW originate upstream from the Green/Duwamish River watershed.
  - » Over the long term, contaminant concentrations in sediment in the EW trend toward net incoming solids concentrations, which are primarily governed by incoming sediment from the upstream Green/ Duwamish watershed.
  - » During cleanup construction activities (e.g., dredging and capping), and for 5 to 10 years following construction, contaminant concentrations are also affected by generated dredging residuals,[4] mixing with cleaner underlying sediment, and mixing of open-water and underpier sediments.
  - » Although less than 0.3% of new sediment is predicted to enter the EW from local storm drains and CSOs, these source sediments typically have higher contaminant concentrations than those associated with the upstream sediment inputs from the Green River watershed. Therefore, localized areas in the vicinity of some outfalls may have higher concentrations than surrounding areas.
  - » Modeling of environmental processes is inherently uncertain; therefore, the uncertainty in model predictions was examined with a sensitivity analysis. The sensitivity analysis shows that the predicted SWACs could vary by up to about +/-40% over the 40-year modeling period. In the long term, predicted SWACs are most sensitive to concentrations in Green River sediment inputs to the EW.

4 Generated dredging residuals are the thin layer of resuspended and redeposited sediment that result from the physical process of underwater sediment removal with large equipment.

Remedial Action Objectives and Preliminary Remediation Goals

Four remedial action objectives (RAOs) have been identified based on the risk assessments to describe what the cleanup actions aim to accomplish in the EW to address the identified risks. The RAOs are listed in the text box at right.

Preliminary remediation goals (PRGs) were developed for each RAO; they represent concentrations that are believed to provide adequate protection of human health and the environment. Depending on the RAO, PRGs for a given contaminant may be applied to individual locations (i.e., point-based), or applied as an average across the entire EW or over clamming areas. PRGs are not final cleanup levels. EPA will select cleanup levels in the Record of Decision (ROD).

The PRGs were developed for each risk driver COC, considering the following factors:

- ARARs, including Washington State SMS
- RBTCs based on the human health and ecological risk assessments
- Background concentrations if RBTCs are below background concentrations
- Analytical practical quantitation limits (PQLs) if RBTCs are below concentrations that can be quantified by chemical analysis

Both CERCLA and the SMS consider background concentrations when formulating PRGs and cleanup levels, recognizing that setting numerical cleanup goals at levels below background is impractical because such levels cannot be sustained over time. Both CERCLA and the SMS state that PRGs and cleanup levels cannot be set below natural background concentrations. Furthermore, both cleanup programs recognize that natural and human-made hazardous substance concentrations can occur at a site in excess of natural background concentrations, as a result of human activities that transport the contaminants to the site. The SMS defines the term "regional background" as concentrations that are consistently present in the environment in the vicinity of a site that are attributable to "diffuse nonpoint sources, such as atmospheric deposition or storm water, not attributable to a specific source or release." The Washington State Department of Ecology (Ecology) has not yet determined regional background for the EW; therefore, for the FS, PRGs are determined considering only RBTCs, natural background, and PQLs. The PRGs developed for this FS are presented in Table 1.

Remedial Action Objectives for the EW

RAO 1 (Human Health Seafood Consumption): Reduce risks associated with the consumption of contaminated resident EW fish and shellfish by adults and children with the highest potential exposure to protect human health.

RAO 2 (Human Health Direct Contact): Reduce risks from direct contact (skin contact and incidental ingestion) to contaminated sediments during netfishing and clamming to protect human health.

RAO 3 (Benthic Community): Reduce to protective levels risks to benthic invertebrates from exposure to contaminated sediments.

RAO 4 (Fish): Reduce to protective levels risks to crabs and fish from exposure to contaminated sediment, surface water, and prey.

Table 1: Summary of Preliminary Remediation Goals

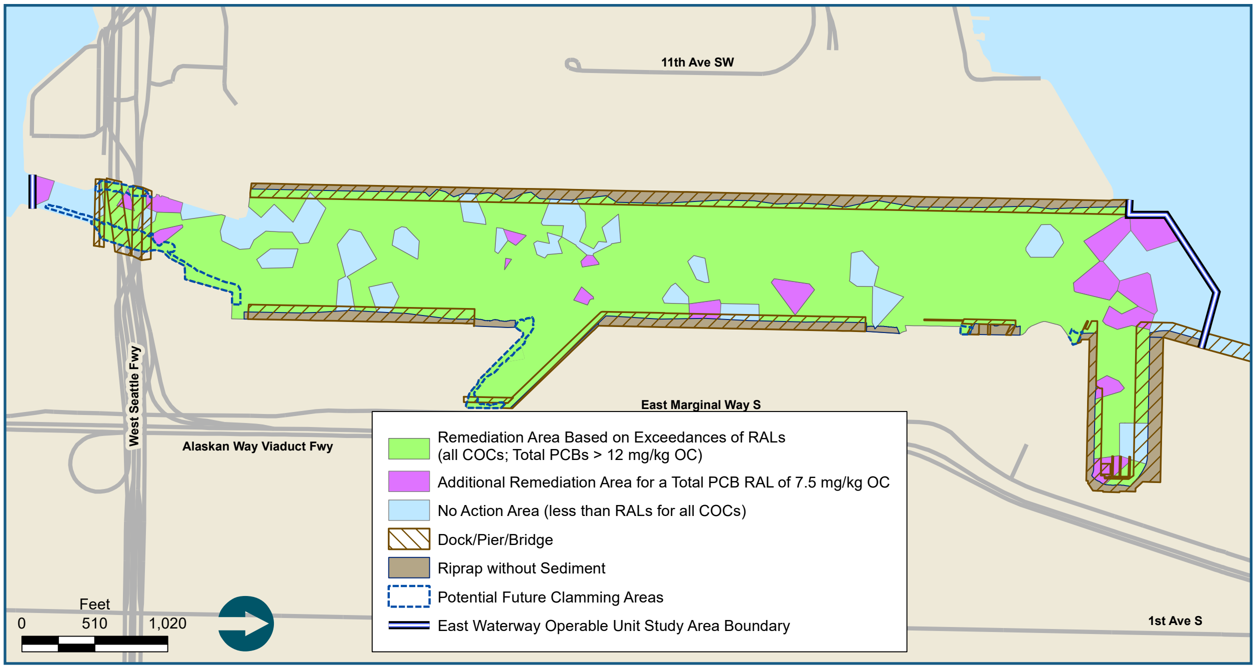
Risk Driver	PRG	Purpose	Basis	Spatial Scale
Total PCBs	2 µg/kg dw	Protection of Human Health for Seafood Consumption (RAO 1)	Natural background	Site-wide
	250, 370 µg/kg dw	Protection of Fish (RAO 4)	RBTC established based on brown rockfish (250) and English sole (370)	Site-wide
	12 mg/kg OC (SQS)	Protection of the Benthic Community (RAO 3)	RBTC	Point
Arsenic (mg/kg dw)	7	Protection of Human Health for Direct Contact (RAO 2)	Natural background	Site-wide (netfishing) and clamming areas (clamming)
	57 (SQS)	Protection of the Benthic Community (RAO 3)	RBTC	Point
Dioxins/furans (ng TEQ/kg dw)	2	Protection of Human Health for Seafood Consumption (RAO 1)	Natural background	Site-wide
TBT (mg/kg OC)	7.5	Protection of the Benthic Community (RAO 3)	RBTC	Point
Other benthic risk drivers	SQS	Protection of the Benthic Community (RAO 3)	RBTC	Point

Notes:

µg – microgram
dw – dry weight
mg – milligram
kg – kilogram
ng – nanogram
OC – organic carbon
PCBs – polychlorinated biphenyls
PRG – preliminary remediation goal
RAO – remedial action objective
RBTC – risk-based threshold concentration
SQS – sediment quality standard
TBT – tributyltin
TEQ – toxic equivalent

Remedial Action Levels and Remediation Areas

Figure 7: Remediation Areas



Notes:
COC – contaminant of concern
mg/kg – milligrams per kilogram
OC – organic carbon
PCBs – polychlorinated biphenyl
RAL – remedial action level

Remedial action levels (RALs) are contaminant-specific sediment concentrations that trigger the need for cleanup action (i.e., dredging, capping, in situ treatment, ENR, or MNR). The RALs are designed to meet the RAOs described in the previous section.

RALs were developed for four human health risk driver COCs and eight key benthic risk driver COCs (Table 2). Remediation of these risk drivers will also address the remaining risk driver COCs because they are less widely distributed, and where they are elevated, they are located in areas needing remediation for other chemicals. For total PCBs, two RALs (12 mg/kg OC and 7.5 mg/kg OC[5]) were developed for the purpose of comparing remedial alternatives. For other key risk driver COCs, a single set of RALs was used for all alternatives.

The existing surface sediment and shallow subsurface sediment chemistry data were compared to RALs to identify the areas requiring remediation for the FS alternatives.

Shallow subsurface sediment was included in developing remediation footprint in areas where vessels have the potential to disturb subsurface sediment due to propeller action. All of the alternatives remediate the majority of the waterway, with 121 of 157 acres remediated for the RALs that include 12 mg/kg OC for total PCBs, and 132 of 157 acres remediated for the RALs that include 7.5 mg/kg OC for total PCBs (Figure 7). Areas and volumes requiring remediation will be refined through additional sampling during remedial design.

5 An organic-carbon normalized RAL was selected for total PCBs to be consistent with the marine benthic standard and to acknowledge the role of organic carbon in PCB bioavailability.

Table 2: Remedial Action Levels and Objectives Achieved

Risk Driver	RAL	RAO 1 (Human Health Seafood Consumption)	RAO 2 (Human Health Direct Contact)	RAO 3 (Protection of Benthic Invertebrates)	RAO 4 (Ecological-Fish)
Total PCBs (mg/kg OC)	12 or 7.5 (site-wide)	Not expected to achieve the natural background-based PRGs. Both RALs result in significant risk reduction.		Achieves PRG of 12 mg/kg OC	Achieves PRGs of 250 and 370 µg/kg dw
Dioxins/furans (ng TEQ/kg dw)	25 (site-wide)				
Arsenic (mg/kg dw)	57 (site-wide)		Achieves PRG of 7 mg/kg dw both site-wide and in clamming areas	Achieves PRG of 57 mg/kg dw	
TBT (mg/kg OC)	7.5 (site-wide)			Achieves PRG of 7.5 µg/kg OC	
Additional SMS Benthic Key Risk Driver COCs: 1,4-dichlorobenzene, butylbenzylphthalate, acenaphthene, fluoranthene, fluorene, mercury, phenanthrene	SQS (benthic SCO; site-wide)			RALs collectively achieve the PRGs for all 29 benthic risk-drivers	

Notes:

a. RALs are developed and presented in Section 6.

b. PCB RAL of 12 mg/kg OC was selected for consistency with the marine standard (SQS), and 7.5 mg/kg OC was considered to assess the effect of a lower RAL on site-wide total PCB concentrations.

Predicted to achieve the PRG or risk threshold

Not applicable

µg – micrograms
COC – contaminant of concern
dw – dry weight
kg – kilograms
mg – milligrams
OC – organic carbon
ng – nanograms
PCB – polychlorinated biphenyl
PRG – preliminary remediation goal
RAL – remedial action level
RAO – remedial action objective
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards
SQS – sediment quality standard
TBT – tributyltin
TEQ – toxic equivalent

Evaluation and Screening of Remedial Technologies

A number of potential technologies were evaluated for remediating contaminated sediments in the EW. Of these, several technologies were retained to develop the remedial alternatives:

- **Removal** (e.g., dredging) of contaminated sediments. Dredged sediment would be disposed of in an off-site facility (e.g., in a permitted landfill). Based on site conditions, mechanical dredging would be used in open-water areas, and diver-assisted hydraulic dredging would be required in underpier areas.
- **Capping** (i.e., containment) of contaminated sediments, using engineered layers of sand, gravel, or rock. In the FS, capping is used in conjunction with partial removal to maintain appropriate water depths for navigation (partial removal and capping). Habitat quality is also a consideration in engineered cap design.
- **ENR** that uses a thin layer placement of material (e.g., sand) to accelerate natural recovery processes. In the FS, ENR in the navigation channel is referred to as ENR-nav, and ENR used in the sill reach (Figure 6) is referred to as ENR-sill.
- **In situ treatment** that adds activated carbon or other sequestering agents to sediments to reduce the bioavailability and toxicity of contaminants. In the FS, in situ treatment is used to remediate underpier sediments only.
- **MNR** that reduces surface sediment concentrations, by the natural burial and mixing of contaminated sediments with cleaner sediments over time. In the FS, MNR is used to remediate difficult to access sediments only.

These technologies have been used in the Puget Sound region and nationally at other contaminated sediment sites. Other similar technologies may be considered during remedial design.

The retained remedial technologies can be applied at different locations within the EW, depending on the site use (e.g., navigation and maintenance dredging), equipment access considerations (e.g., under piers and bridges), structural considerations (e.g., pile-supported piers, bridges, and riprap slopes), physical conditions (e.g., propwash depths and sedimentation rates), and chemical conditions (e.g., depth of contamination, magnitude of RAL exceedances, and contribution to site risk). Based on these factors, the EW was divided into construction management areas (CMAs) that represent areas with similar engineering considerations and conditions (Figure 8), and remedial technologies were retained or eliminated from consideration within each CMA.

Monitoring of sediments, biota, and water will provide the data needed to understand conditions before, during, and after remediation of the EW by any combination of the remedial technologies. Information gathered during monitoring will be used to assess the effectiveness of each of the technologies and inform the need for any adaptive management decisions. To varying degrees, institutional controls will be needed to supplement the remedial technologies (e.g., advisories to limit consumption of resident seafood from the EW or restrictions on activities such as maintenance dredging or anchoring in areas that have been capped).

Summary of Retained Remediation Technologies

Open-water Areas

- Removal (mechanical dredging)
- Partial removal and capping
- ENR

Underpier Areas

- MNR
- In situ treatment
- Diver-assisted hydraulic dredging

Remedial Alternatives

In coordination with EPA, a total of 16 remedial alternatives were initially developed by varying three components: 1) the remedial technology assignments in the open-water areas that are generally accessible to barge-mounted construction equipment; 2) the remedial technology assignments in areas with limited access to construction equipment, such as under piers; and 3) the RALs that result in variation of the remediation footprint. In consultation with EPA, alternatives were screened down to ten representative alternatives for detailed analysis. Table 3 shows the ten retained alternatives and the three components of the alternatives. The No Action Alternative is included for comparison, and the other alternatives are referred to collectively as the action alternatives.

All of the action alternatives rely primarily on removal (i.e., dredging) of contaminated sediment from the waterway because the sediment bed elevation within most of the waterway is at the depth needed for navigation. Therefore, other cleanup options, such as capping that would raise the sediment bed elevation, are precluded in much of the EW.

Remediation of difficult-to-access sediments (e.g., under piers) presents major technical challenges for cleanup of the EW; therefore, a range of technologies are evaluated. The range of technologies presented in the alternatives includes MNR, ENR, placement of in situ treatment material, and diver-assisted hydraulic dredging. Technologies were assigned to CMAs, as shown in Figure 8.

The alternatives are summarized in Table 3. The total areas, volumes, construction timeframes, and costs are shown for each alternative in Table 4 and Figure 9. The costs to implement the action alternatives range from $256 to $411 million dollars, and the estimated time to complete construction on active cleanup components ranges from 9 to 13 years.

- The **No Action Alternative** provides a basis for comparison for the other remedial alternatives and is required by CERCLA. This alternative includes no action other than long-term monitoring and provides no institutional controls beyond the existing Washington State Department of Health seafood consumption advisory.

Figure 8: Construction Management Areas Used to Develop the Alternatives

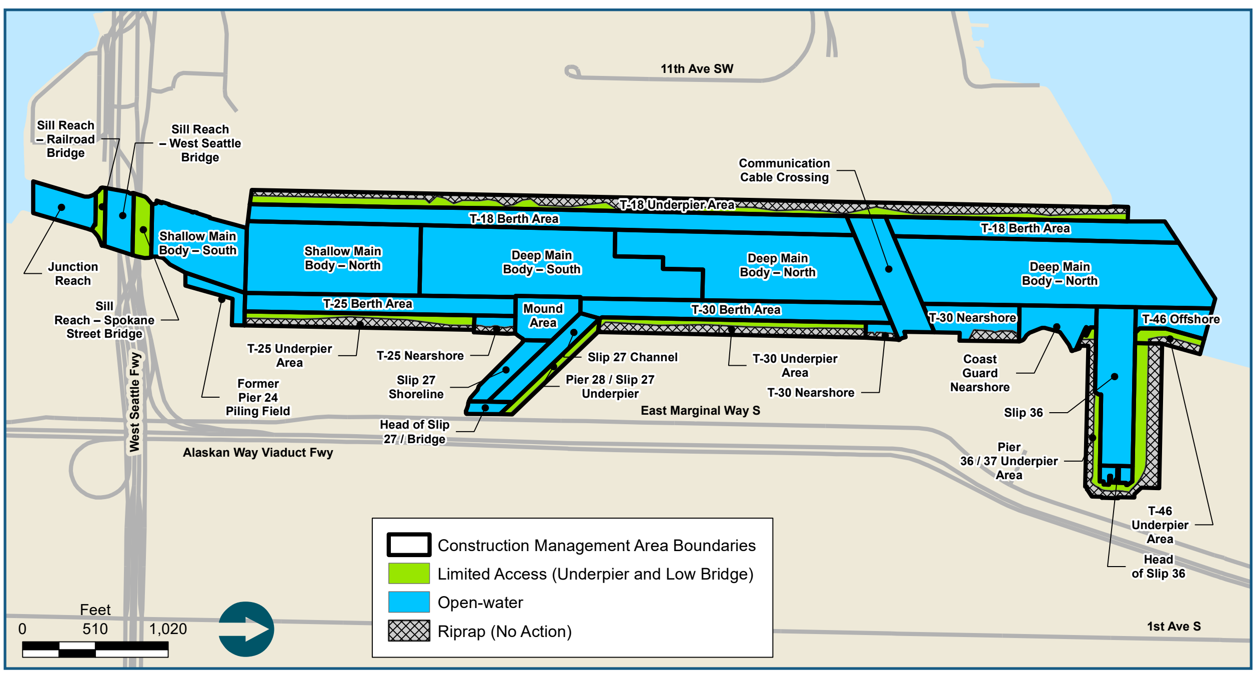


Table 3: Retained Alternatives and Alternative Key

Action Alternatives	Technologies for Open-water Areas	Technologies for Restricted Access Areas (Underpier and Low Bridges)	PCBs RAL All Areas
No Action			
1A(12)	1. Removal with capping and ENR where applicable	A MNR	(12) 12 mg/kg OC
1B(12)		B In situ treatment	
1C+(12)		C+ Diver-assisted hydraulic dredging followed by in situ treatment for PCBs or mercury > CSL; in situ treatment elsewhere	
2B(12)	2. Removal with capping where applicable	B In situ treatment	
2C+(12)		C+ Diver-assisted hydraulic dredging followed by in situ treatment for PCBs or mercury > CSL; in situ treatment elsewhere	
3B(12)	3. Maximum removal to the extent practicable	B In situ treatment	
3C+(12)		C+ Diver-assisted hydraulic dredging followed by in situ treatment for PCBs or mercury > CSL; in situ treatment elsewhere	
2C+(7.5)	2. Removal with capping where applicable		(7.5) 7.5 mg/kg OC
3E(7.5)	3. Maximum removal to the extent practicable	E Diver-assisted hydraulic dredging followed by in situ treatment	

Notes:

CSL – cleanup screening level
ENR – enhanced natural recovery
mg/kg – milligrams per kilogram
MNR – monitored natural recovery
OC – organic carbon
PCB – polychlorinated biphenyl
RAL – remedial action level

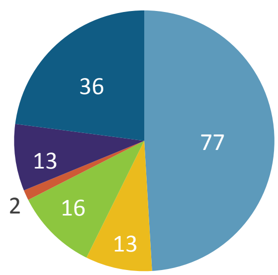
- **Alternative 1A(12)** employs open-water option 1 (removal with capping and ENR where applicable), restricted access option A (MNR in the underpier areas) and RALs that include 12 mg/kg OC for total PCBs. In sum, Alternative 1A(12) remediates 121 acres, primarily through removal (77 acres; 810,000 cy of sediment removed), followed by ENR (including partial removal and ENR-nav, ENR-nav, and ENR-sill; 18 acres), partial removal and capping (13 acres), and MNR (13 acres).
- **Alternative 1B(12)** employs open-water option 1 (removal with capping and ENR where applicable), restricted access option B (in situ treatment in the underpier areas) and RALs that include 12 mg/kg OC for total PCBs. In sum, Alternative 1B(12) remediates 121 acres of the EW, primarily through removal (77 acres; 810,000 cy of sediment removed), followed by ENR (including partial removal and ENR-nav, ENR-nav, and ENR-sill; 19 acres), partial removal and capping (13 acres), and in situ treatment (12 acres).

All Action Alternatives Rely on Removal of Contaminated Sediment

- Between 80% to 99% of the remediation area would undergo removal or partial removal
- 810,000 to 1,080,000 cy of removal

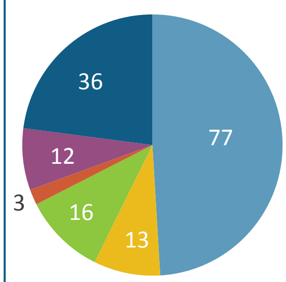
Figure 9: Comparison of Action Alternatives

Alternative 1A(12)



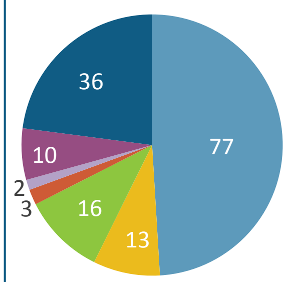
Construction Time (yr)	9
Removal Volume (cy)	810,000
Placement Volume (cy)	290,000
Costs ($)	$256M

Alternative 1B(12)



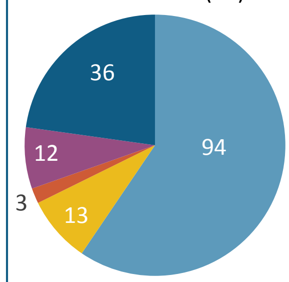
Construction Time (yr)	9
Removal Volume (cy)	810,000
Placement Volume (cy)	290,000
Costs ($)	$264M

Alternative 1C+(12)



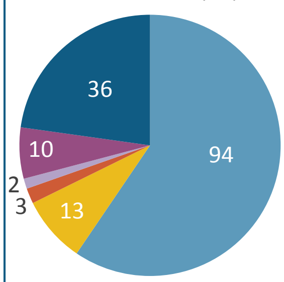
Construction Time (yr)	9
Removal Volume (cy)	820,000
Placement Volume (cy)	290,000
Costs ($)	$277M

Alternative 2B(12)



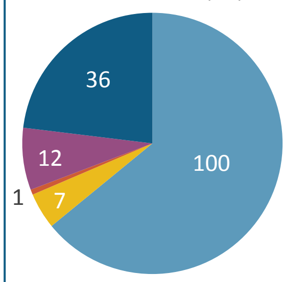
Construction Time (yr)	10
Removal Volume (cy)	900,000
Placement Volume (cy)	280,000
Costs ($)	$284M

Alternative 2C+(12)



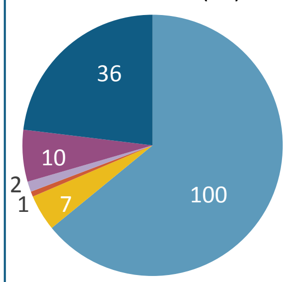
Construction Time (yr)	10
Removal Volume (cy)	910,000
Placement Volume (cy)	280,000
Costs ($)	$297M

Alternative 3B(12)



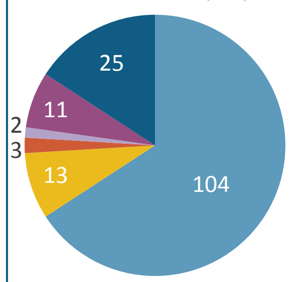
Construction Time (yr)	10
Removal Volume (cy)	960,000
Placement Volume (cy)	270,000
Costs ($)	$298M

Alternative 3C+(12)



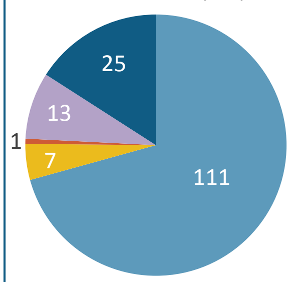
Construction Time (yr)	10
Removal Volume (cy)	960,000
Placement Volume (cy)	270,000
Costs ($)	$310M

Alternative 2C+(7.5)



Construction Time (yr)	11
Removal Volume (cy)	1,010,000
Placement Volume (cy)	290,000
Costs ($)	$326M

Alternative 3E(7.5)



Construction Time (yr)	13
Removal Volume (cy)	1,080,000
Placement Volume (cy)	270,000
Costs ($)	$411M

Legend:

- Removal – Open Water
- Partial Removal and Capping
- Partial Removal and ENR-nav or ENR-nav
- ENR-sill
- MNR
- In Situ Treatment
- Hydraulic Dredging Followed by In Situ Treatment
- No Action Area

Notes:

a. Numbers in pie chart represent acres; total sediment area is 157 acres. All values are rounded for presentation.

b. Costs are net present value and 2016 dollars.

cy – cubic yard

ENR-nav – enhanced natural recovery applied in the navigation channel

ENR-sill – enhanced natural recovery applied in the Sill Reach

MNR – monitored natural recovery

yr – year

- **Alternative 1C+(12)** employs open-water option 1 (removal with capping and ENR where applicable), restricted access ion C+ (diver-assisted hydraulic dredging followed by in situ treatment for total PCBs or mercury > CSL; in situ treatment elsewhere exceeding RALs in the underpier areas), and RALs that include 12 mg/kg OC for total PCBs. In sum, Alternative 1C+(12) remediates 121 acres of the EW, primarily through removal (77 acres; 820,000 cy of sediment removed), followed by ENR (including partial removal and ENR-nav, ENR-nav, and ENR-sill; 19 acres), partial removal and capping (13 acres), in situ treatment (10 acres), and diver-assisted hydraulic dredging followed by in situ treatment (2 acres).

- **Alternative 2B(12)** employs open-water option 2 (removal with capping where applicable), restricted access option B (in situ treatment in the underpier areas) and RALs that include 12 mg/kg OC for total PCBs. In sum, Alternative 2B(12) remediates 121 acres of the EW, primarily through removal (94 acres; 900,000 cy of sediment removed), followed by partial removal and capping (13 acres), in situ treatment (12 acres), and ENR-sill (3 acres).

- **Alternative 2C+(12)** employs open-water option 2 (removal with capping where applicable), restricted access option C+ (diver-assisted hydraulic dredging followed by in situ treatment for total PCBs or mercury > CSL; in situ treatment elsewhere exceeding RALs in the underpier areas), and RALs that include 12 mg/kg OC for total PCBs. In sum, Alternative 2C+(12) remediates 121 acres of the EW, primarily through removal (94 acres; 910,000 cy of sediment removed), followed by partial removal and capping (13 acres), in situ treatment (10 acres), ENR-sill (3 acres), and diver-assisted hydraulic dredging followed by in situ treatment (2 acres).

- **Alternative 3B(12)** employs open-water option 3 (maximum removal area with less capping, to the extent practicable), restricted access option B (in situ treatment in the underpier areas) and RALs that include 12 mg/kg OC for total PCBs. In sum, Alternative 3B(12) remediates 121 acres of the EW, primarily through removal (100 acres; 960,000 cy of sediment removed), followed by in situ treatment (12 acres), partial removal and capping (7 acres), and ENR-sill (1 acre).

- **Alternative 3C+(12)** employs open-water option 3 (maximum removal area with less capping, to the extent practicable), restricted access option C+ (diver-assisted hydraulic dredging followed by in situ treatment for total PCBs or mercury > CSL; in situ treatment elsewhere exceeding RALs in the underpier areas), and RALs that include 12 mg/kg OC for total PCBs. In sum, Alternative 3C+(12) remediates 121 acres of the EW, primarily through removal (100 acres; 960,000 cy of sediment removed), followed by in situ treatment (10 acres), partial removal and capping (7 acres), diver-assisted hydraulic dredging followed by in situ treatment (2 acres), and ENR-sill (1 acre).

- **Alternative 2C+(7.5)** employs open-water option 2 (removal with capping where applicable), restricted access option C+ (diver-assisted hydraulic dredging followed by in situ treatment for total PCBs or mercury > CSL; in situ treatment elsewhere exceeding RALs in the underpier areas), and RALs that include 7.5 mg/kg OC for total PCBs. In sum, Alternative 2C+(7.5) remediates 132 acres of the EW, primarily through removal (104 acres; 1,010,000 cy of sediment removed), followed by partial removal and capping (13 acres), in situ treatment (11 acres), ENR-sill (3 acres), and diver-assisted hydraulic dredging followed by in situ treatment (2 acres).

- **Alternative 3E(7.5)** employs open-water option 3 (maximum removal area with less capping, to the extent practicable), restricted access option E (diver-assisted hydraulic dredging followed by in situ treatment in the underpier areas), and RALs that include 7.5 mg/kg OC for total PCBs. In sum, Alternative 3E(7.5) remediates 132 acres of the EW, primarily through removal (111 acres; 1,080,000 cy of sediment removed), followed by partial removal and capping (7 acres), ENR-sill (1 acre), and diver-assisted hydraulic dredging followed by in situ treatment (13 acres).

Detailed Evaluation and Comparative Analysis of Remedial Alternatives

The retained remedial alternatives were evaluated using seven of the nine CERCLA criteria, which include two threshold criteria and five balancing criteria. The two threshold criteria, which must be met before the others can be considered, are:

- Overall protection of human health and the environment
- Compliance with ARARs of federal and state environmental laws and regulations

The five balancing criteria are:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The two modifying criteria, state/tribal and community acceptance, were not evaluated at this time. EPA will evaluate state, tribal, and community acceptance of the selected remedial action in the ROD following the public comment period on EPA's Proposed Plan.

Figure 9 and Table 4 summarize the comparison of the alternatives. The No Action Alternative does not provide adequate protection of human health and the environment, engineering controls, or institutional controls and is not expected to meet all RAOs; thus, it does not meet threshold criteria and is not discussed further in the Executive Summary. The key points of this comparative analysis are summarized in the following pages.

Overall Protection of Human Health and the Environment

Assessment of overall protection of human health and the environment primarily draws on evaluation of long-term effectiveness and short-term effectiveness. All of the action alternatives meet the threshold requirement of overall protection of human health and the environment by reducing risks to human health and the environment for each of the RAOs during and following construction of active cleanup. Although PCB concentrations in sediment can be greatly reduced, not all PRGs because of background concentrations are predicted to be achieved, and institutional controls, specifically fish consumption advisories, will be needed to limit exposures. Long-term effectiveness and short-term effectiveness are

Photo: Port of Seattle

Table 4: Summary of Alternatives Comparison

	Alternative									
	No Action	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Threshold Criteria										
Overall Protection of Human Health and the Environment										
Magnitude and Type of Residual Risk										
RAO 1 (Individual Excess Cancer Risk 40 Years After Construction; Total for PCBs and Dioxins/Furans)										
Adult Tribal RME	5×10^{-4}	3×10^{-4}	2×10^{-4}							
Child Tribal RME	9×10^{-5}	5×10^{-5}	4×10^{-5}							
Adult API RME	2×10^{-4}	1×10^{-4}	9×10^{-5}							
RAO 2 (Total Excess Cancer Risk 40 Years After Construction; Arsenic)										
Site-wide Netfishing or Clamming	$<1 \times 10^{-5}$									
RAO 3 (40 Years After Construction; 29 COCs)										
Point Locations Predicted to Meet Benthic PRGs	Not expected to achieve	99%	100%							
RAO 4 (HQ 40 Years After Construction; Total PCBs)										
English Sole and Brown Rockfish	>1 using the lowest toxicity threshold	>1[a]	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
Compliance with ARARs	**No**	**Yes**; however, one or more ARAR waivers may be required.								
Active Threshold Criteria?	**No**	**Yes**								
Balancing Criteria										
Long-term Effectiveness and Permanence										
Long-term Risk Outcomes	Does not achieve all	See the risk outcomes for Magnitude and Type of Residual Risk above. The action alternatives achieve similar risk outcomes, with Alternative 1A(12) having slightly higher risks.								
Technology Areas (acres; of 157 acres in the EW)										
Most Permanent: Removal	No controls assumed	77	77	79	94	94	100	100	104	111
Highly Permanent: Partial Dredging and Capping		13	13	13	13	13	7	7	13	7
Moderately permanent: in situ treatment		0	12	12	12	12	12	12	13	13
Less Permanent: ENR-nav, ENR-sill, and MNR		31	19	19	3	3	1	1	3	1
Ranking	★	★★★	★★★★	★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★

		Alternative									
		No Action	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Reduction of Toxicity, Mobility, or Volume Through Treatment											
	Ranking	★	★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Short-term Effectiveness											
Impacts During Construction	Construction timeframe (years)	NA	9	9	9	10	10	10	10	11	13
	Diver-assisted Dredging Timeframe (years)	NA	NA	NA	2	NA	2	NA	2	2	12
	Total Removal Volume / Consumed Landfill Capacity (cy)	NA	810,000 / 970,000	810,000 / 970,000	820,000 / 980,000	900,000 / 1,080,000	910,000 / 1,090,000	960,000 / 1,150,000	960,000 / 1,150,000	1,010,000 / 1,210,000	1,080,000 / 1,300,000
	Air Quality Impacts (CO_2/PM_{10} Emissions; metric tons)	NA	16,000 / 5.4	16,000 / 5.6	16,000 / 5.9	17,000 / 6.1	18,000 / 6.3	18,000 /6.4	18,000 / 6.6	19,000 / 7.0	23,000 / 8.3
	Carbon Footprint (acre-years)	NA	3,800	3,800	3,800	4,000	4,300	4,300	4,300	4,500	5,400
Time to Achieve RAOs (Years from Start of Construction)[b]	Human Health – Seafood Consumption (RAO 1 – Natural Background PRGs)	Does not achieve	Not predicted to achieve.								
	Human Health – Seafood Consumption (RAO 1 – Risk Ranges)[c]	Does not achieve	34	9	9	10	10	10	10	11	13
	Human Health – Direct Contact (RAO 2)	Does not achieve	9	9	9	10	10	10	10	11	13
	Ecological Health – Benthic Organisms (RAO 3)	Not expected to achieve	39	9	9	10	10	10	10	11	13
	Ecological Health – Fish (RAO 4)	25	9	9	9	10	10	10	10	11	13
	Ranking	★	★★	★★★★★	★★★★	★★★★	★★★	★★★★	★★★	★★	★
Implementability											
	Ranking	★★★★★	★★★★	★★★	★★	★★★	★★	★★★	★★	★★	★

	Alternative									
	No Action	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Costs										
Total Costs	$950K	$256MM	$264MM	$277MM	$284MM	$297MM	$298MM	$310MM	$326MM	$411MM
Ranking	★★★★★	★★★★	★★★★	★★★	★★★	★★★	★★★	★★	★★	★

Notes:

a. Alternative 1A(12) has an HQ ≤1, except for brown rockfish lowest toxicity threshold, which is >1 due to water exposure.

b. The time to achieve RAOs is at the end of construction for many alternatives and metrics. In these instances, the time to achieve could be reduced by approximately 2 years (for all action alternatives) if a longer annual construction window is feasible in the EW.

c. Time to achieve RAO 1 is based on risk-reduction milestones. Long-term modeling results predict that none of the alternatives will achieve the RAO 1 natural background-based PRGs for total PCBs and dioxins/furans.

API – Asian Pacific Islander
ARAR – applicable and relevant or appropriate requirements
CO_2 – carbon dioxide
COC – contaminant of concern
cy – cubic yards
ENR-nav – enhanced natural recovery applied in the navigation channel or berthing areas
ENR-sill – enhanced natural recovery applied in the sill reach
EW – East Waterway
HQ – hazard quotient
K – thousand
MM – million
MNR – monitored natural recovery
NA – not applicable
PM_{10} – particulate matter less than 10 microns in diameter
PRG – preliminary remediation goal
RAO – remedial action objective
RME – reasonable maximum exposure

also balancing criteria; the comparative rankings of the alternatives for these criteria are discussed in the following sections.

Compliance with ARARs

Two key ARARs for the EW cleanup are the Washington State SMS (Washington Administrative Code 173-204), which are promulgated under MTCA to define how sediment sites meet MTCA, and federal recommended and state surface water quality criteria and standards.

The SMS provide rules for developing cleanup levels considering multiple exposure pathways, background concentrations, and PQLs. The PRGs were developed to be consistent with the rules for cleanup level determination in the SMS, but without considering regional background, as it has not been defined for this area (see Appendix A for additional details[6]). All of the action alternatives achieve SMS standards for protectiveness of human health for direct contact (RAO 2), protection of the benthic community (RAO 3), and protection of higher trophic level organisms (RAO 4) by achieving the PRGs or target risk levels for these RAOs, either immediately following construction of active cleanup or following construction plus a period of natural recovery. For protection of human health for seafood consumption (RAO 1), each of the action alternatives achieves similar reductions in risk.

As shown in Table 4, some natural-background-based PRGs are not predicted to be achieved by any alternative (e.g., total PCBs for RAO 1), primarily because of the large influence of incoming Green River sediment (which exceeds EPA-derived natural background concentrations based

6 SMS allows the upward adjustment of cleanup levels to "regional background." Regional background has not been determined for the EW and, therefore, has not been considered in this FS.

on Puget Sound data).[7] However, following source control and remediation efforts, all of the action alternatives will comply with MTCA/SMS in the long term, consistent with the substantive requirements of SMS. Following remediation and long-term monitoring, a final site remedy can be achieved under CERCLA if EPA determines that no additional practicable actions can be implemented under CERCLA to meet certain MTCA/SMS or surface water ARARs such that a TI waiver would be warranted for those ARARs.

All of the alternatives must comply substantively with relevant and appropriate state water quality standards and any more stringent federal recommended surface water quality criteria upon completion of the remedial action, except to the extent that they may be formally waived by EPA. While significant water quality improvements are anticipated from sediment remediation and source control, current upstream Green River and downstream Elliott Bay water concentrations are often above federal recommended water quality criteria for some chemicals, and therefore it is not technically practicable for any alternative to meet all human health federal recommended or state ambient water quality criteria or standards based on human consumption of bioaccumulative contaminants (e.g., total PCBs and arsenic). Like MTCA/SMS requirements, if long-term monitoring data and trends indicate that water quality ARARs cannot be met, EPA will determine whether further remedial action could practicably achieve the ARAR. If EPA concludes that an ARAR cannot be practicably achieved, EPA may waive the ARAR on the basis of technical impracticability in a future decision document (ROD Amendment or ESD).

Long-term Effectiveness and Permanence

This balancing criterion compares the relative magnitude and type of residual risk (i.e., the risk that remains following cleanup) that would remain in the EW after remediation under each alternative. In addition, it assesses the extent and effectiveness of the controls that may be required to manage the residual risks from contamination remaining at the site after remediation.

The magnitude of residual risk in surface sediment was assessed by comparing the predicted outcomes of the alternatives relative to the RAOs. All of the action alternatives are predicted to achieve PRGs or risk thresholds for RAOs 2 through 4. For RAO 1, the action alternatives achieve similar risk reductions, but institutional controls will be required to address remaining seafood consumption risks. All of the action alternatives use removal for the majority of the waterway, and include monitoring, maintenance, institutional controls, periodic reviews (e.g., every 5 years), and potential contingency actions to maintain effectiveness over the long term. The subsurface contaminated sediments remaining in place in capped areas have a low potential for exposure because caps are engineered to remain structurally stable under location-specific conditions. In the context of long-term effectiveness and permanence, the differences among these alternatives are primarily related to the remedial technologies used in difficult-to-access areas (e.g., underpier areas). In the limited areas that rely on ENR, in situ treatment, and MNR, residual contaminated sediment has a greater potential for future exposure and could require more monitoring and potential maintenance or contingency actions. In situ treatment is considered more permanent than ENR and MNR because in situ treatment permanently binds and reduces the bioavailability of hydrophobic organic compounds (e.g., PCBs). Removal through diver-assisted hydraulic dredging in underpier areas is also likely to leave contaminated sediment behind due to the presence of riprap slopes and debris, which may also require further maintenance or contingency actions.

As shown in Table 4, the No Action Alternative has the lowest relative rank (★) for long-term effectiveness and permanence because it would not reduce risks sufficiently to achieve RAOs, it would leave the largest amount of subsurface contamination in place, and it would not provide reliable controls. All of the action alternatives are considered highly permanent due to achieving similar risks and relying primarily on removal. Alternative 1A(12) ranks moderate (★★★) because it is predicted to have slightly higher risks in the long term (Table 4) and would remove the least amount of contaminated sediment among the action alternatives (and would leave the largest area to be managed by MNR and ENR).

Alternatives 1B(12) and 1C+(12) rank relatively higher (★★★★) because they achieve slightly lower risks compared to Alternative 1A (12), but would remove a similar

7 Other factors that influence the long- and short-term concentrations include mixing and exchange of sediment by propwash, and dredging residuals.

amount of contaminated sediment as Alternative 1A(12) and has the largest area managed by ENR and in situ treatment. Alternatives 2B(12), 2C+(12), 3B(12), 3C+(12), 2C+(7.5), and 3E(7.5) score highest (★★★★★) because they achieve similar risks among the action alternatives, and they rely primarily on removal. These alternatives have little ENR and limited areas of engineered isolation capping, which is considered highly permanent.

Reduction in Toxicity, Mobility, or Volume through Treatment

This criterion assesses the degree to which site media are treated to permanently and significantly reduce the toxicity, mobility, or volume of site contaminants. The only treatment technology retained for the remedial alternatives is in situ treatment using activated carbon. Activated carbon lowers the mobility of contaminants, reducing the toxicity and bioavailability to biological receptors.

The No Action Alternative and Alternative 1A(12) do not use treatment technologies and rank lowest for this criterion (★). The other action alternatives rank higher for this criterion for employing in situ treatment in underpier areas (★★★★★; 12 to 13 acres).

Short-term Effectiveness

The evaluation of short-term effectiveness includes the effects of the alternatives on human health and the environment during the construction phase of the remedial action and the time until RAOs are achieved (Table 4 and Figure 10). Alternatives with larger removal volumes and longer construction timeframes (particularly for diver-assisted hydraulic dredging) present proportionately larger risks to workers, the community, and the environment.

Longer construction periods increase the time that the water column is impacted by dredging operations, equipment and vehicle emissions, carbon footprint, and consumed landfill capacity. The action alternatives vary in construction duration and associated impacts from 9 to 13 years—with Alternative 3E(7.5) having the greatest risks to workers, due to the longest overall construction timeframe and considerable underwater construction period using divers in underpier areas.

The time to achieve RAOs 2 through 4 is equal to the construction duration for all of the action alternatives except Alternative 1A(12), which meets RAO 3 in 39 years from the start of construction. The action alternatives achieve similar risk reductions for RAO 1. Alternative 1A(12) is predicted to achieve 1 x 10^{-5} order of magnitude cancer risk for Child Tribal RME in a longer timeframe than the other action alternatives (34 years from the start of construction), while the other action alternatives achieve it at the end of construction (9 to13 years, depending on the alternative).

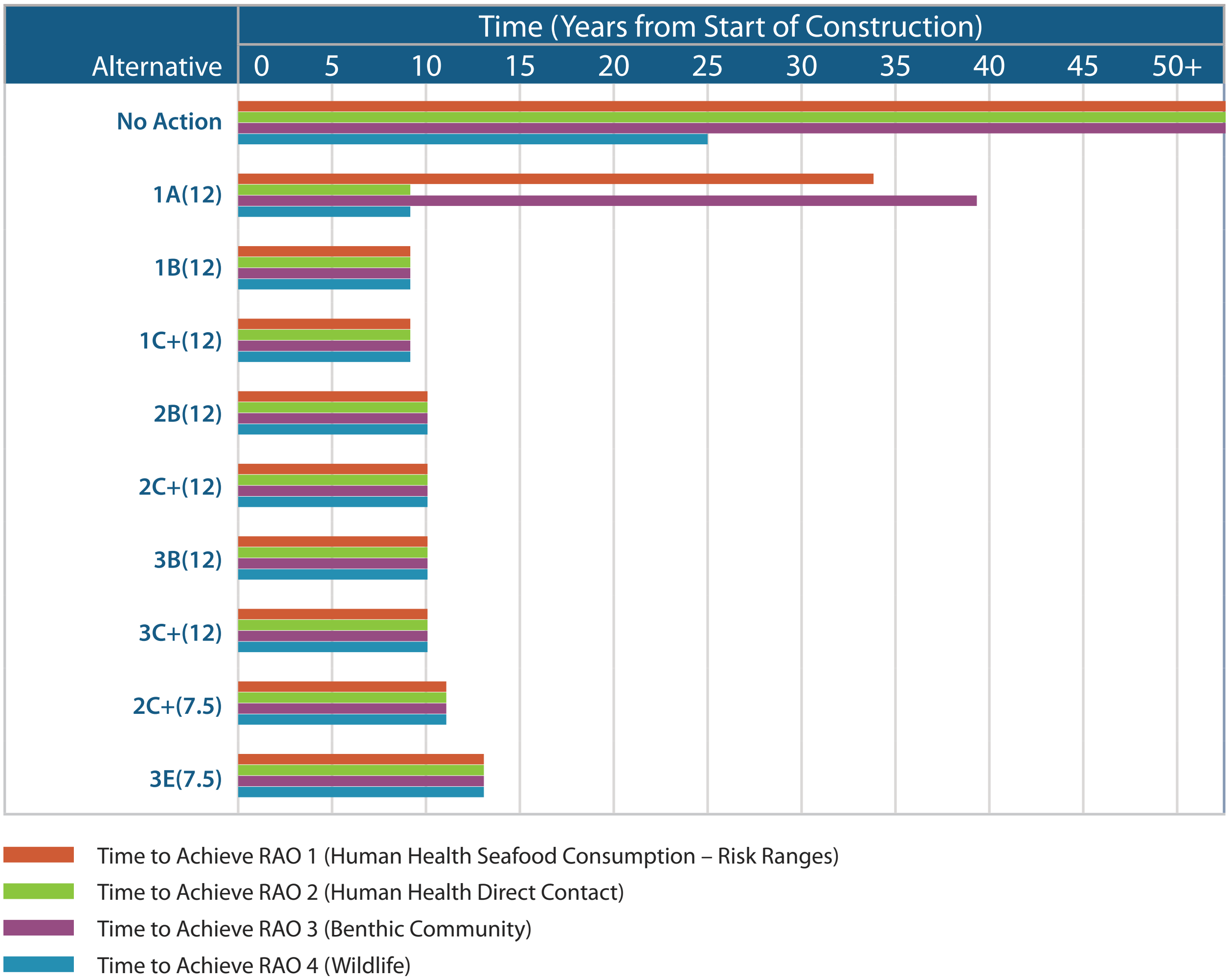
Other RAO 1 risk metrics are predicted to be achieved by the end of the construction period of the action alternatives (9 to13 years, depending on the alternative).

As shown in Table 4, the No Action Alternative has the lowest ranking (★) for short-term effectiveness because, although it has no impacts associated with construction (as no actions are included in its scope), it is not expected to achieve all of the RAOs. Alternative 3E(7.5) also ranks the lowest (★) because it has 1) the greatest short-term impacts to human health and the environment during construction, due to the amount of sediment removal and associated longer construction timeframe (13 years); 2) the highest potential for work-related accidents (due to extensive use of diver-assisted hydraulic dredging [12 years] in underpier areas), which poses substantial health and safety risks to remediation workers; and 3) has one of the longest times to achieve RAOs, among the action alternatives. Alternative 1A(12) ranks relatively low (★★) because, although it has the lowest construction-related impacts of the action alternatives, it has a longer time to achieve RAO 3 (39 years) and 1 x 10^{-5} order of magnitude cancer risk for Child Tribal RME for RAO 1 (34 years), due to reliance on some monitored natural recovery (which reduces risks less rapidly and considered to have less certainty than active remedial measures). Alternative 2C+(7.5) also ranks relatively low (★★) because of moderately more construction impacts compared to the action alternatives (11 years of construction; 2 years of diver-assisted hydraulic dredging) and moderately longer time to achieve RAOs (11 years). Alternatives 2C+(12) and 3C+(12) have a moderate ranking (★★★) due to the moderate construction impacts to human health and the environment (10 years of construction; 2 years of diver-assisted hydraulic dredging), and moderate time to achieve RAOs (10 years). Alternatives 1C+(12), 2B(12), and 3B(12) are ranked relatively higher (★★★★) due to lower construction impacts to human health and the environment (9 years of construction, with 2 years of diver-assisted hydraulic dredging for Alternative 1C+(12), and 10 years of construction with no diver-assisted hydraulic dredging for Alternatives 2B(12) and 3B(12), combined with moderately shorter time to achieve RAOs (9 to 10 years). Alternative 1B(12) ranks the highest (★★★★★) by having the least construction impacts among the alternatives (9 years of construction), no diver-assisted hydraulic dredging, and the shortest time to achieving RAOs among the alternatives (immediately following construction).

Implementability

Technical implementability and administrative implementability are factors considered under this criterion for the EW. Technical implementability encompasses the complexity and uncertainties associated with the alternative, the reliability of the technologies, the ease of undertaking potential contingency remedial actions, and monitoring requirements. Administrative feasibility includes the activities

Figure 10: Anticipated Timeframes to Achieve Remedial Action Objectives



required for coordination with other parties and agencies (e.g., consultation, or obtaining permits for construction activities). The action alternatives represent large, complex remediation projects with many technical and administrative challenges.

The technical implementability challenges are similar across action alternatives in open-water areas, but are different across these alternatives in underpier areas. Alternative 1A(12) has few technical challenges associated with MNR in underpier areas. The other action alternatives have larger technical challenges associated with placing in situ treatment material in underpier areas. In addition, Alternatives 2C+(12), 3C+(12), 2C+(7.5), and 3E(7.5) have large technical challenges associated with diver-assisted hydraulic dredging under piers. This form of dredging is more difficult to implement than other technologies, particularly in underpier areas, due to work conducted in deep water with low visibility and presence of suspended sediments; variable conditions under piers (e.g., presence of debris, cables, large wood, and broken pilings); potential prolonged impacts and delays to vessel operations (related to diving schedules); and extensive dewatering and water management operations. In addition, diver-assisted hydraulic dredging is a hazardous activity from a worker health and safety perspective.

For administrative implementability, all underpier technologies (MNR, in situ treatment, and diver-assisted hydraulic dredging) would be monitored following construction and have the possibility for future contingency actions if remediation goals are not met. In addition, Alternatives 1A(12), 1B(12), and 1C+(12) have a higher potential for future contingency actions in open-water areas because of ENR-nav in the navigation channel. Another administrative feasibility factor for the EW is that in-water construction is not allowed year-round, in order to protect juvenile salmon and bull trout migrating through the EW. Coordination will be necessary with stakeholders, waterway users, and agencies during design to define the limits of work each season.

Alternative 3E(7.5) receives the lowest rank (★) for implementability relative to the other alternatives, due to technical and safety challenges associated with 12 construction years of diver-assisted hydraulic dredging over large areas of underpier sediment, placement of in-situ treatment material under the piers, and it having the largest overall scope of the alternatives (13 years of construction).

Alternatives 1C+(12), 2C+(12), 3C+(12), and 2C+(7.5) receive a relatively low ranking (★★) because they employ some diver-assisted hydraulic dredging followed by in situ treatment under the piers and have moderate overall scope of remediation (9 to 11 years). Alternatives 1B(12), 2B(12), and 3B(12) are considered moderately implementable (★★★) because they perform in situ treatment in underpier areas (which is more implementable than diver-assisted hydraulic dredging) and have moderate overall scope of remediation (9 to 11 years). Alternative 1A(12), with MNR under the piers, scores the highest among the action alternatives (★★★★) because of the high implementability of performing MNR under the piers and a moderately lower overall scope (9 years of construction). The No Action Alternative is given the highest implementability rank (★★★★★) because it has no construction elements and no contingency actions assumed.

Cost

Figure 9 depicts the costs for the remedial alternatives plotted with the remedial technology areas. Alternative 3E(7.5) has the highest cost ($411 million), and therefore ranks lowest (★) for this criterion. Alternatives 3C+(12) and 2C+(7.5) are assigned a relatively low ranking (★★), with costs of $310 and $326 million, respectively. Alternatives 1C+(12), 2B(12), 2C+(12), and 3B(12) receive a moderate ranking (★★★), with costs ranging from approximately $277 to $298 million. Alternatives 1A(12) and 1B(12) receive a relatively high ranking (★★★★), with costs of approximately $256 to $264 million, respectively. The No Action Alternative has the lowest cost, at $950,000, and therefore has the highest ranking (★★★★★) for this criterion.

Cost-effectiveness

A statutory requirement that must be addressed in the ROD and supported by the FS is that the remedial action must be cost-effective (40 CFR § 300.430(f)(1)(ii)(D)). Cost-effectiveness is the consideration of both the costs and the benefits (or "overall effectiveness") for the remediation alternatives. The cost-effectiveness determination should carefully consider the relative incremental benefits and costs between the alternatives. In accordance with the National Contingency Plan, the cost of the selected remedy must not be greater than less costly alternatives that provide an equivalent level of protection (EPA 1999).[8] For the cost-

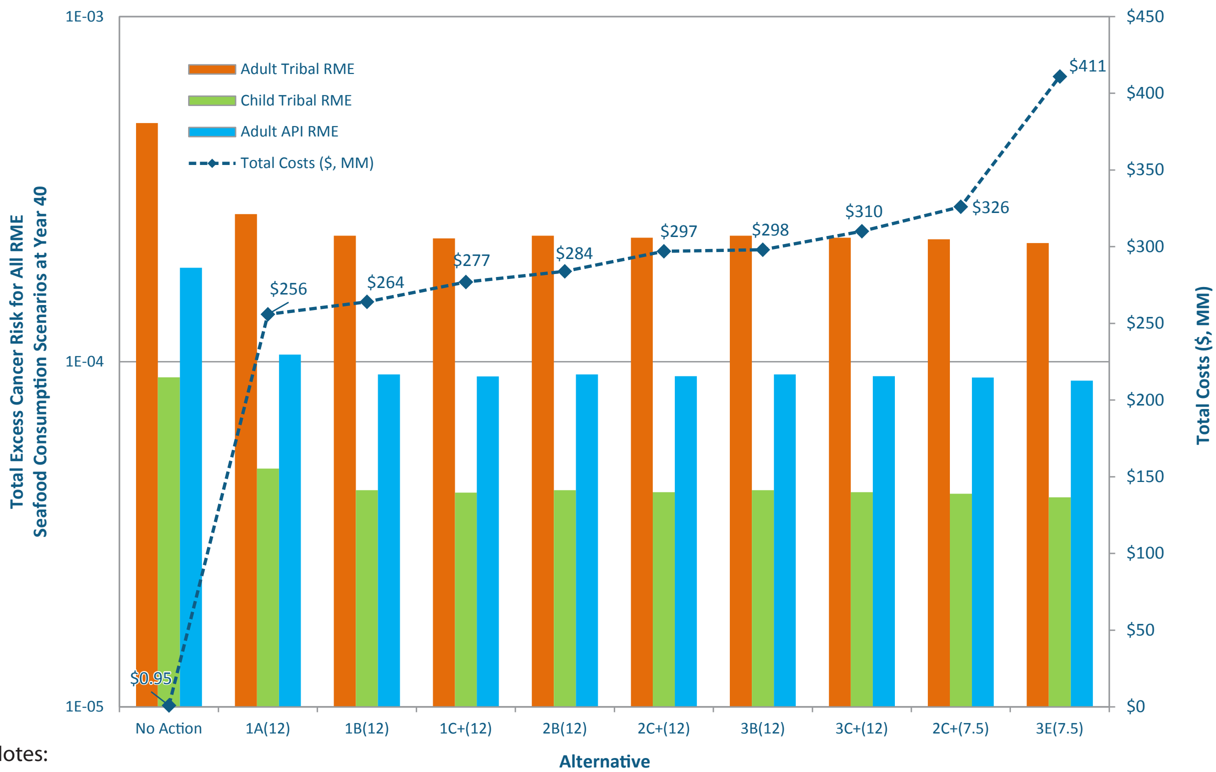
8 EPA, 1999. A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents. EPA 540-R-98-031. U.S. Environmental Protection Agency, Washington, D.C. July 1999.

effectiveness evaluation, benefits were assessed using three balancing criteria (long-term effectiveness and permanence; reduction in mobility, toxicity, or volume due to treatment; and short-term effectiveness) considered together. Figure 11 depicts long-term effectiveness and costs for the alternatives.

The least costly action alternative, Alternative 1A(12), does not rank as highly for the other balancing criteria compared to the other action alternatives, primarily due to increased time to achieve RAOs and slightly higher risks, compared to the other action alternatives. Moreover, the cost savings for this alternative are not commensurate with the decreased overall effectiveness for the alternative. While the most costly alternative, Alternative 3E(7.5), results in the largest removal volume, it does not provide a commensurate improvement in overall effectiveness relative to the other alternatives (i.e., there is no appreciable reduction in site-wide risks). Further, the incremental cost of this alternative relative to the next most costly alternative ($85 million) is disproportionate to any additional environmental benefits.

The rest of the action alternatives (Alternatives 2B(12) through 2C+(7.5)) have similar overall effectiveness, with the alternatives with only in situ treatment under the piers (Alternatives 1B(12), 2B(12), and 3B(12)) ranking slightly better than the alternatives that include diver-assisted hydraulic dredging (Alternatives 1C+(12), 2C+(12), 3C+(12), and 2C+(7.5)). The benefits among these alternatives (particularly human health risk reduction) do not increase with higher costs; therefore, lower-cost alternatives tend to be more cost-effective.

Figure 11: Long-term Risks and Costs for the Alternatives



Notes:
MM – million
RME – reasonable maximum exposure

Figure 12: CERCLA Comparative Analysis of Alternatives

	Achieve Threshold Criteria?	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-term Effectiveness	Implementability	Cost
No Action	No	Low	Low	Low	Very high	Very high
1A(12)	Yes	Moderate	Low	Low-moderate	Relatively high	Relatively high
1B(12)	Yes	Relatively high	Very high	Very high	Moderate	Relatively high
1C+(12)	Yes	Relatively high	Very high	Relatively high	Low-moderate	Moderate
2B(12)	Yes	Very high	Very high	Relatively high	Moderate	Moderate
2C+(12)	Yes	Very high	Very high	Moderate	Low-moderate	Moderate
3B(12)	Yes	Very high	Very high	Relatively high	Moderate	Moderate
3C+(12)	Yes	Very high	Very high	Moderate	Low-moderate	Low-moderate
2C+(7.5)	Yes	Very high	Very high	Low-moderate	Low-moderate	Low-moderate
3E(7.5)	Yes	Very high	Very high	Low	Low	Low

- Very high: Ranks very high compared to other alternatives
- Relatively high: Ranks relatively high compared to other alternatives
- Moderate: Ranks moderate compared to other alternatives
- Low-moderate: Ranks low-moderate compared to other alternatives
- Low: Ranks low compared to other alternatives

Notes:

Low costs are given a high rank, and high costs are given a low rank.

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

Uncertainties

Decision-making on a site of the size and complexity of the EW requires careful consideration of uncertainties in the FS data and analyses. The uncertainties associated with the EW FS are similar to other large sediment remediation sites. Uncertainty is an inherent part of sediment remediation that is acknowledged and managed through monitoring and adaptive management. Many of the uncertainties in this FS affect all alternatives to a similar degree, and therefore do not significantly affect the relative comparisons of alternatives. The following factors emerge as particularly important for managing uncertainty relative to the anticipated performance of the alternatives:

- Predictions of average surface sediment contaminant concentrations are greatly influenced by a number of factors related to incoming sediment concentrations, vessel scour, and exchange of sediment between underpier areas and open-water areas.
  - Upstream inputs, which contribute the majority of ongoing inputs to the EW, are uncertain. As a result of the large amounts of relatively clean sediments from the Green River upstream that deposit within the EW, surface sediment contaminant concentrations are predicted to converge to levels similar to the quality of incoming sediment from the Green River. (General urban inputs from EW lateral sources and the LDW will also affect long-term concentrations.) This results in similar levels of risk over time among all of the alternatives under consideration. The concentrations of these inputs are uncertain and will change over time in response to many factors, including upstream cleanups, upstream source control, and source control in the EW drainage basin.
  - Sediment concentrations following remediation will be affected by sediment mixing depths, locations, and frequency of vessel scour throughout the waterway.
  - The exchange of sediment between underpier areas and open-water areas is also predicted to affect the long-term site-wide SWACs within the EW.

These types of uncertainties were analyzed using sensitivity evaluations to understand their potential effects. Overall, predicted average surface sediment concentrations after remediation are more affected by these uncertainty factors than by expected differences associated with the remedial alternatives themselves.

- Technical challenges associated with the technologies for remediating underpier areas are a key uncertainty in this FS.
  - » The performance of MNR in underpier areas is less certain compared to the other remedial technologies due to its reliance on natural processes to reduce concentrations; however, MNR poses very few technical challenges.
  - » The performance of in situ treatment depends on many site-specific complex physical and chemical factors, and constructability of in situ treatment includes important technical challenges for placing and keeping material on steep slopes in difficult to access areas.
  - » Diver-assisted hydraulic dredging is associated with large uncertainty with both performance and technical implementability. Performance is uncertain with respect to the quantity of contaminated sediment that will be left behind due to conditions under piers (e.g., riprap interstices and debris).
  - » Technical implementability is also uncertain with respect to the construction timeframe and costs associated with removing underpier sediments in deep water. In particular, challenging working conditions, including deep dive depths, low visibility, presence of suspended sediments, presence of debris, cables, large wood, and broken pilings, all contribute to project uncertainty.
  - » Underpier work has the potential for prolonged impacts to vessel operations, and/or prolonged implementation times as diver work windows are narrowed to avoid vessel operations. Extensive dewatering and water management operations also present considerable logistical challenges and uncertainty. Finally, substantial health and safety risks are posed by this type of underwater construction, and management of those risks can slow the implementation or limit the areas that can be safely dredged by divers.
- The performance of the remedial technologies in open-water areas also have uncertainties, which are mitigated by adaptive management.
  - » Dredging results in the release of contaminants to the water column (in which fish and shellfish tissue contaminant concentrations remain elevated over the construction period) and deposition of dredge residuals to the sediment surface, which affects achievable sediment concentrations. In addition, structural offsets from existing waterway structures will limit the complete removal of sediments from the EW.
  - » Capping and ENR require ongoing monitoring and may need periodic maintenance.
  - » MNR and ENR performance may be slower or faster than predicted due to reliance on natural processes, and may require additional monitoring or potential contingency actions.

These uncertainties would be managed under the action alternatives through best management practices (BMPs) during construction, and in the long term through monitoring, contingency actions, and repairs as needed. Cost estimates in this FS include costs for both BMPs and long-term management activities. These activities would be enforceable requirements under a Consent Decree (or similar mechanism), and EPA is required to review the effectiveness of their selected remedy no less frequently than every 5 years.

- Uncertainty exists in the predictions of resident seafood tissue contaminant concentrations and associated human health risks for total PCBs and dioxins/furans following remediation.
  - » This uncertainty is driven by: 1) exposure assumptions from the human health risk assessment; assumptions used in the food web model for total PCBs such as uptake factors and future water concentrations; and 3) uncertainties in biota-sediment accumulation factors used for dioxins/furans.

The predictions of resident seafood tissue contaminant concentrations and risks are nevertheless useful for comparing the alternatives to one another because the uncertainties are the same for all alternatives, and therefore all of the alternatives should be affected similarly.

Conclusions

Many factors need to be considered in selecting a cleanup remedy for the EW. EPA will present a Proposed Plan for the EW for public comment, and then select the final remedy in the ROD based on input received from public, state, and tribal review of the Proposed Plan. Table 4 and Figure 12 highlight some of the key differences and similarities among the alternatives in the CERCLA comparative analysis. These similarities and differences are summarized below, along with key conclusions.

CERCLA Compliance: The action alternatives are predicted to achieve all RAOs. However, the action alternatives do not achieve natural background-based PRGs for total PCBs and dioxins/furans for RAO 1. The action alternatives will comply with the MTCA/SMS ARAR in the long term, consistent with the substantive requirements of SMS. Some MTCA/SMS and human health surface water ARARs may need to be waived regardless of the alternative based on long-term monitoring data and technical impracticability. Institutional controls will be required of all alternatives.

Removal of Contaminated Sediment: All alternatives emphasize the removal of contaminated sediment, and therefore, minimize contaminated subsurface sediment remaining in place after construction is complete. Total removal volumes increase with each consecutive alternative and range from 800,000 to 1,080,000 cy. The alternatives vary in the remedial approaches used in difficult-to-access underpier sediments. The alternatives include contingency actions if contaminant reduction does not occur at an acceptable pace as part of an adaptive management strategy. These long-term management requirements would be implemented through the requirements of a Consent Decree, and the associated costs are included in the form of limited contingencies in the FS cost estimates.

Monitoring Requirements: The action alternatives each require long-term monitoring to be protective. The alternatives differ in the total area that requires maintenance and certain types of monitoring.

Short-term Impacts throughout Construction: The action alternatives have short-term impacts such as disturbances to habitat, elevated contaminant concentrations in resident fish and shellfish tissue, worker safety concerns, traffic, air emissions related to off-site transport of dredged material, and consumption of landfill space that varies with the volume dredged. Contaminant exposures from resident seafood consumption are expected to remain elevated throughout the construction period and for a few years following construction. Short-term impacts are largely a function of the extent and duration of dredging and disposal activities. Alternatives with greater removal volumes have greater short-term impacts. Alternative 3E(7.5) has the largest safety risks to workers due to extensive diver-assisted hydraulic dredging.

Construction Timeframes: The action alternatives vary from 9 to 13 years for construction.

Predicted Time to Achieve RAOs: The predicted time to achieve RAOs is influenced by the length of time it takes to construct an alternative and the effectiveness of the remedial technologies used, particularly in underpier areas. All of the action alternatives, with the exception of Alternative 1A(12), achieve RAOs following construction. Alternative 1A(12) is predicted to achieve RAO 3 in 39 years from the start of construction. For RAO 1, all action alternatives achieve similar risk reductions, with Alternative 1A(12) taking longer to achieve 1×10^{-5} order of magnitude cancer risk for Child Tribal RME (34 years from the start of construction, while the other action alternatives achieve it at the end of construction).

Costs: The action alternatives range in costs from $256 to $411 million. All alternatives primarily use dredging; however, the lower-cost alternatives use more ENR (Alternatives 1A(12), 1B(12), and 1C+(12)) and partial dredging and capping (Alternatives 1A(12), 1B(12), 1C+(12), 2B(12), 2C+(12), and 2C+(7.5)). Higher-cost alternatives use more dredging (Alternatives 3B(12), 3C+(12), and 3E(7.5)). The highest cost alternative has the most removal and uses extensive diver-assisted hydraulic dredging in the underpier areas (Alternative 3E(7.5)).

Cost-effectiveness: A statutory requirement that must be addressed in the ROD and supported by the FS is that the remedial action must be cost-effective (40 CFR § 300.430(f)(1)(ii)(D)). The overall effectiveness of the least costly alternative, Alternative 1A(12), is less than the next higher cost alternative (particularly considering time to achieve RAOs), and thus is considered less cost-effective than the other alternatives. Similarly, while the most costly alternative, Alternative 3E(7.5), involves the greatest removal volume, it does not result in a commensurate improvement in overall effectiveness (particularly considering overall risk reduction), and thus is considered the least cost-effective relative to the other alternatives.

For the rest of the action alternatives (Alternatives 1B(12) through 2C+(7.5)), overall effectiveness is similar (particularly human health risk reduction) and does not increase with higher costs; therefore, lower-cost alternatives tend to be more cost-effective.

Uncertainties: Overall, predicted average surface sediment concentrations after remediation are more affected by uncertainty factors (e.g., chemistry of Green/ Duwamish River sediments and net sedimentation rates) than by expected differences associated with the remedial alternatives themselves. However, this analysis is performed using a common set of assumptions for all alternatives to demonstrate the differences among alternatives.


Photo: Port of Seattle

Next Steps

EPA will issue a Proposed Plan that identifies a preferred remedial alternative for the EW. After public, state, and tribal comments on the Proposed Plan are received and evaluated, EPA will select the final remedial alternative in the Record of Decision (ROD).

This FS has assumed that a period of 5 years would be required following the ROD and before the start of remedial construction. During this period, the following activities would occur:

- Completion of source control sufficiency evaluations to begin remedial actions.
- Negotiation and entry of consent decrees or issuance of administrative orders for remedial design and construction.
- Sampling to refine cleanup areas.
- Remedial design and demonstration of substantial compliance with construction ARARs.
- Site-wide sampling (for example, of sediments, surface water, and fish and shellfish tissue) to establish baseline conditions for comparison to post-remediation monitoring results.
- Implementation of institutional controls addressing seafood consumption risks under RAO 1.
- Selection of construction contractor(s) and preparation of detailed construction work plans.