Lower Duwamish Waterway Group

City of Seattle / King County / The Boeing Company

Intermediate (60%) Remedial Design Volume I Basis of Design Report for Lower Duwamish Waterway Middle Reach

For submittal to

U.S. Environmental Protection Agency
Seattle, WA

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ABBREVIATIONS

--	not applicable
AC	activated carbon
AIS	Automatic Identification System
AISC	American Institute of Steel Construction
AOC	Administrative Order on Consent
AOC5	fifth amendment to the AOC
ARAR	Applicable or Relevant and Appropriate Requirement
AST	area-specific technology
ASTM	ASTM International
BAZ	biological active zone
BBP	butyl benzyl phthalate
BEHP	bis(2-ethylhexyl)phthalate
BMP	best management practice
BODR	*Basis of Design Report*
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CIMP	Community Impacts Mitigation Plan
cm	centimeter
CMP	corrugated metal pipe
COC	contaminant of concern
contractor	Remedial Action Contractor
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CQAP	*Construction Quality Assurance Plan*
CSO	combined sewer overflow
CWA	Clean Water Act
cy	cubic yard
D_{50}	median particle size
DAHP	Washington State Department of Archaeology and Historic Preservation
dB(A)	A-weighted decibel
DDT	dichlorodiphenyltrichloroethane
DER	*Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Middle Reach*
DU	Decision Unit
DSAY	discounted service acre-year
EAA	early action area
Ecology	Washington State Department of Ecology

EF	exceedance factor
EFH	Essential Fish Habitat
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
ERP	Emergency Response Plan
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FNC	federal navigation channel
FS	*Final Feasibility Study, Lower Duwamish Waterway*
g	acceleration of gravity
H:V	horizontal to vertical
HDPE	high-density polyethylene
HEA	Habitat Equivalency Analysis
ICIAP	Institutional Controls Implementation and Assurance Plan
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LTMMP	Long-Term Monitoring and Maintenance Plan
mg/kg	milligram per kilogram
MHHW	mean higher high water
MIDP	monitoring and inadvertent discovery plan
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
N/A	not applicable
NAD83/91	North American Datum of 1983 through the 1991 adjustment
NAPL	nonaqueous phase liquid
NHL	National Historic Landmark
NHVM	Nearshore Habitat Values Model
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRHP	National Register of Historic Places
NTU	nephelometric turbidity unit
PAH	polycyclic aromatic hydrocarbon
PARIS	Water Quality Permitting and Reporting Information System
PCB	polychlorinated biphenyl
pcf	pound per cubic foot
PCP	pentachlorophenol

PD&C	partial dredge and cap
PDI	pre-design investigation
PDI QAPP	*Pre-Design Investigation Quality Assurance Project Plan for the Lower Duwamish Waterway – Middle Reach*
Phase III QAPP Addendum	Pre-Design Investigation Quality Assurance Project Plan for Phase III
propwash	propeller wash
PSNC	Puget Sound Nearshore Calculator
QA	quality assurance
QC	quality control
RAA	remedial action area
RAL	remedial action level
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCP	Representative Concentration Pathway
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RD	remedial design
RDWP	*Remedial Design Work Plan for the Lower Duwamish Waterway Middle Reach*
RI	*Remedial Investigation Report*
RI/FS	Remedial Investigation/Feasibility Study
RM	river mile
RMC	residuals management cover
ROD	*Record of Decision*
SCO	sediment cleanup objective
SDOT	Seattle Department of Transportation
Services	U.S. Fish and Wildlife Service and National Marine Fisheries Service
SHPO	State Historic Preservation Officer
SMA	sediment management area
SMC	Seattle Municipal Code
SSNP	Salish Sea Nearshore Programmatic
STM	sediment transport model
SVOC	semivolatile organic compound
TBD	to be determined
TCLP	toxicity characteristic leaching procedure
THPO	Tribal Historic Preservation Officer
TIN	triangulated irregular network
TMC	Tukwila Municipal Code

TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers
USC	*United States Code*
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
WCRP	Washington Coastal Resiliency Project
WDFW	Washington Department of Fish and Wildlife
WQMP	Water Quality Monitoring Plan
WSDOT	Washington State Department of Transportation

1 Introduction

This Intermediate (60%) Remedial Design (RD) *Basis of Design Report* (BODR) describes the basis of design criteria and other key elements for implementing the cleanup remedy for the middle reach of the Lower Duwamish Waterway (LDW) Superfund Site in King County, Washington. The middle reach encompasses river miles (RMs) 1.6 to 3.0 of the LDW. This BODR has been prepared consistent with the U.S. Environmental Protection Agency (EPA)-approved *Remedial Design Work Plan for the Lower Duwamish Waterway Middle Reach* (RDWP; Anchor QEA and Windward 2022a) and the EPA's November 2014 *Record of Decision* (ROD; EPA 2014) as modified by an *Explanation of Significant Differences* issued in 2021 (EPA 2021). This BODR was prepared on behalf of the City of Seattle, King County, and The Boeing Company, collectively referred to as the Lower Duwamish Waterway Group (LDWG).

1.1 Orders Governing the Work

In December 2000, LDWG[1] entered into an Administrative Order on Consent (AOC) for a remedial investigation/feasibility study with EPA and the Washington State Department of Ecology (Ecology) to conduct a remedial investigation/feasibility study for the LDW. In September 2001, the LDW was formally added to the National Priorities List as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) site; in February 2002, Ecology listed the LDW as a cleanup site under the Washington Model Toxics Control Act (MTCA). EPA and Ecology have divided lead agency responsibility for addressing the site: EPA is responsible for administering the cleanup of the sediments in the waterway, and Ecology is responsible for controlling sources of pollution to the waterway. The LDW *Remedial Investigation Report* (RI) was completed in 2010 (Windward 2010), and the *Final Feasibility Study, Lower Duwamish Waterway* (FS) was completed in 2012 (AECOM 2012). The ROD was issued by EPA in 2014.[2]

Five amendments to the AOC have been signed. The first three amendments covered activities that have been performed prior to the start of RD. The fourth amendment included development of the RD for the upper reach. The fifth amendment (AOC5) included development of the RD for the middle reach, progressing from the preliminary design phase (30%) through 60%, 90%, and final (100%) designs.

This document represents the basis of design as of the Intermediate (60%) RD and will be built upon in future design phases. It is expected that a consent decree will be executed in 2026 that will govern all future LDW response actions under CERCLA.

[1] The Port of Seattle was a member of LDWG until 2022, when it withdrew from LDWG.
[2] An Explanation of Significant Differences was issued in 2021.

1.2 Purpose and Objectives

The objective of the Intermediate (60%) RD BODR is to identify and establish design criteria for major elements of construction, present the technical evaluations of the design elements, and document how they apply to the overall remedial action for the selected remedy for the middle reach of the LDW, as set forth in the ROD and AOC5. The Intermediate (60%) RD builds upon Preliminary (30%) RD to refine footprints of remediation; update the remedial approach (e.g., dredging, capping), where needed; and provide updated estimates of quantities, durations, and costs to complete the remedial action.

This Intermediate (60%) RD BODR documents analyses conducted to select the design approach, including a summary and detailed justification of design assumptions, restrictions, and objectives used in the design of the selected remedy as defined by the list of BODR requirements in Section 6.2 of the RDWP (Anchor QEA and Windward 2022a). A complete list of RD elements of the Intermediate (60%) RD and subsequent design deliverables is provided in Table 6-1 of the RDWP.

1.3 Note on Terminology

Several different terms appear with the design documents that refer to the roles and responsibilities of different individuals or entities during the construction phase. The following terms are used in the design documents but do not replace or supersede definitions that appear in the construction Contract Documents:

- Performing Parties: The Performing Parties include the City of Seattle, King County, and The Boeing Company, which are the parties performing the response actions in the LDW. The performing parties are referred to as the LDWG.
- Owner: The Owner will be the LDWG member that holds the construction contract for the middle reach. The Owner for the middle reach remedial action will be the City of Seattle. The City of Seattle will be responsible for procurement and execution of the construction phase of the project. The Owner will be authorized to make construction decisions on behalf of LDWG. The Owner will hire the Remedial Action Contractor (contractor) and will name a Resident Engineer to oversee and administer the construction contract. The Owner will also be responsible for construction quality assurance (QA) activities as described in the *Construction Quality Assurance Plan* (CQAP). The CQAP identifies additional roles and responsibilities for management of the construction of the middle reach remedy.
- Resident Engineer: The term "Resident Engineer" refers to the City of Seattle (Owner) representative during construction who will assist the Owner with technical review and decision-making on behalf of the Owner when technical issues arise. The Resident Engineer has the contractual authority to direct the contractor.
- Designer: Anchor QEA is the remedy designer overseeing the development of the middle reach RD packages (30% to 100%). The Engineer of Record is a Washington State Professional

Engineer employed by Anchor QEA and is responsible for overseeing and stamping the Final (100%) RD. The term "Engineer of Record" generally does not appear in the design documents except where the role of the Engineer of Record relates to consultation during the construction phase to support construction QA and design changes, if needed.

1.4 Intermediate (60%) Remedial Design Organization

The Intermediate (60%) RD is organized into the following three volumes:

- Volume I (this document) contains information to document the design considerations, calculations, and evaluations. It includes this BODR and the associated appendices listed in the Table of Contents.
- Volume II includes outlines of the following plans that will be implemented during and after construction:
  - CQAP
  - Emergency Response Plan (ERP)
  - Long-Term Monitoring and Maintenance Plan (LTMMP)
  - Institutional Controls Implementation and Assurance Plan (ICIAP)
- Volume III includes the Intermediate (60%) Drawings and an outline of the Intermediate (60%) Specifications sections.

Future RD deliverables will include a Pre-Final (90%) and Final (100%) RD as required by AOC5 and include the following (as described in RDWP Table 6-1):

- Volume I:
  - New BODR elements, including engineer's construction project schedule estimate, engineer's capital, and operation and maintenance cost estimate
  - Biological Assessment
  - Clean Water Act (CWA) Section 404 and Section 10 Rivers and Harbors Act of 1899 memorandum
  - Section 408 compliance documentation
- Volume II:
  - Vessel Management Plan requirements
  - CQAP
  - Water Quality Monitoring Plan (WQMP; a component of the CQAP)
  - Archaeological Monitoring and Inadvertent Discovery Plan for construction
  - Community Outreach and Communications Plan
  - Permitting and Site Access Plan
  - Compensatory Mitigation Plan (if needed)
- Volume III:
  - Full set of Drawings and Specifications

2 Project Background, Site Conditions, and Data Sources

2.1 Project Background

2.1.1 Site Description

The Duwamish River originates at the confluence of the Green and Black rivers near Tukwila, Washington, and flows northwest for approximately 12 miles prior to discharging into Elliott Bay in Puget Sound. In the early years of the twentieth century, the lower 6 miles of the Duwamish River were straightened and channelized into a commercial corridor for ship traffic, officially designated as the LDW and the East and West Waterways (located along Harbor Island). The LDW Superfund Site extends 5 miles upstream from the southern tip of Harbor Island to just upstream of the Turning Basin, a federally authorized and maintained navigation feature consisting of an area where ship traffic can turn around. The LDW Superfund Site has been divided into three reaches (lower, middle, and upper) that are each undergoing RD on different timelines, with the middle reach being the second reach for which RD is being performed. Although each reach is being designed separately, some design overlap at the boundaries between reaches is necessary to transition remedial actions between reaches.[3] The middle reach of the LDW extends from the Duwamish Waterway Park just upstream of Slip 4 (RM 3.0) to just downstream of Slip 2 (RM 1.6) (Figures 2-1 and 2-2). The average width of the middle reach is 500 feet.

The banks of the LDW include public and private properties that support industrial and marine activities as well as public access, utility corridors, street ends, and bridge crossings. Figures 2-3a through 2-3c show the location of infrastructure and land ownership within the middle reach. Additional details are provided in Section 2.3.

2.1.2 Remedy Summary

The selected remedy for the LDW is described in Section 13 of the ROD (EPA 2014). It addresses unacceptable human health risks associated with consumption of resident fish and shellfish, and with direct contact (skin contact and incidental ingestion of sediment) from net fishing, clamming, and beach play. It also addresses ecological risks to bottom-dwelling organisms (benthic invertebrates) and wildlife.

Remedial action levels (RALs) are contaminant concentrations in sediment that apply to specific locations and depths on a point-by-point basis (EPA 2014). Per the ROD, RALs are used to delineate areas that require active remediation. These RALs are dependent on the location, elevation

[3] In addition to overlap occurring at the boundary between reaches, areas where sources are not expected to be sufficiently controlled based on Ecology's source control evaluation are deferred for design completion and construction and would occur with a different reach. For example, one area in the upper reach was deferred due to source control sufficiency findings and is being addressed as part of the middle reach design. This is discussed in detail in Section 2.2.4.

(i.e., intertidal versus subtidal), projected potential for natural recovery (i.e., recovery category), and shoaling conditions in the federal navigation channel (FNC). RAL depth intervals are as follows:

- Intertidal areas: 0 to 10 centimeters (cm; 0 to 4 inches) and 0 to 45 cm (0 to 1.5 feet)
- Subtidal areas: 0 to 10 cm (0 to 4 inches) and 0 to 60 cm (0 to 2 feet)[4]

Shoal areas[5] within the FNC also have their own set of RALs. Areas with RAL exceedances were delineated in the *Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Middle Reach* (DER; Anchor QEA and Windward 2025a), as described in Section 4 of this BODR.

The following remedial technologies were identified in the ROD (EPA 2014):

- Dredging[6]
- Placing engineered sediment caps
- Partial dredging and capping (PD&C)
- Placing a thin layer (nominal 6 to 9 inches) of clean material in areas that meet the criteria for enhanced natural recovery (ENR)
- Applying location-specific cleanup technologies to areas with structural or access restrictions (e.g., underpier areas and in the vicinity of dolphins/pilings, bulkheads, and riprapped or engineered shorelines)
- Implementing monitored natural recovery (MNR):
  - MNR above benthic sediment cleanup objectives (SCOs): Surface sediment contaminant concentrations are greater than benthic SCOs but below RALs.
  - MNR below benthic SCOs: Surface sediment contaminant concentrations are below RALs and benthic SCOs but greater than human health-based cleanup levels.[7]

The middle reach remedial technology assignments for each RAL exceedance area,[8] which are based on ROD criteria (EPA 2014), were initially presented in the DER (Anchor QEA and Windward 2025a) and have been refined in Section 5 of this BODR to reflect the Intermediate (60%) RD selected technology.

Early action areas (EAAs) comprise 7 acres (6% of the area) of the middle reach. These areas were identified for early cleanup actions to accelerate cleanup and reduce risks of exposure. Cleanup

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[4] Subtidal RALs applicable to the 0- to 60-cm depth are dependent on recovery category designation and potential vessel scour areas (see ROD Table 28).
[5] Shoal areas are locations within the FNC where the bed elevation is higher than the authorized navigation depth.
[6]The dredging technology also includes residuals management cover (RMC) placement to manage generated residuals and backfilling within defined habitat elevations or when needed to provide a stable post-construction condition.
[7] The human health-based cleanup levels are applied as 95th upper confidence limit on the mean on a site-wide basis for Remedial Action Objective (RAO) 1 and an area-specific basis for RAO 2.
[8] A RAL exceedance area is an area where the RAL is exceeded for at least one contaminant of concern (COC) based on comparison of concentrations to RALs in ROD Table 28 (EPA 2014) and the carcinogenic polycyclic aromatic hydrocarbon (cPAH) *Explanation of Significant Differences* (EPA 2021).

actions at the two EAAs in the middle reach (a portion of Boeing Plant 2 EAA and Slip 4 EAA) were conducted between 2011 and 2015. Post-remediation conditions of EAAs are factored into design of adjacent areas to maintain EAA remedy performance. Figure 2-3b shows the locations of the EAAs in the middle reach.

2.2 Upland Source Control and Adjacent Cleanup Sites

This section discusses the source control sufficiency evaluations that are in progress by Ecology and coordination needs with adjacent cleanup sites (including one site that was deferred during LDW upper reach design).

2.2.1 Upland Source Control Sufficiency

Remedial construction of the middle reach is being coordinated with upland source control sufficiency evaluations led by Ecology. Ecology works with the LDW Source Control Work Group[9] on source control efforts for the LDW sediment cleanup.[10] Ecology has identified 27 source control areas for the LDW as part of its source control strategy (Ecology 2024) for the LDW sediment remedy. Source control areas may encompass multiple upland cleanup sites. Eight of these source control areas are within the middle reach and are summarized in Table 2-1.

Sufficiency recommendations will be developed by Ecology for each of these source control areas adjacent to remedial action areas (RAAs) (although upland areas may be bundled in Ecology's documentation). Ecology will submit the source control sufficiency report(s) to EPA for final determinations. The sufficiency evaluations are scheduled to be completed by Ecology by Q3 2026 for the middle reach. Based on discussions with Ecology and EPA, it is anticipated that some areas will be determined to have sufficiently controlled sources of contamination and can proceed with in-water cleanup. Other areas may find sources are conditionally controlled and thus will require additional source controls to be implemented before in-water cleanup. Finally, if source control is determined not to be sufficient for an upland area adjacent to an RAA, the remedial action in these sediment areas may be deferred and/or delayed until the upland sources are sufficiently controlled.

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[9] The LDW Source Control Work Group currently consists of representatives from Ecology, King County, City of Seattle, City of Tukwila, and EPA.

[10] Information on the current status of upland source control efforts can be found on Ecology's website at: https://ecology.wa.gov/spills-cleanup/contamination-cleanup/cleanup-sites/lower-duwamish-waterway/source-control.

Table 2-1
Summary of LDW Middle Reach Source Control Areas and Upland Cleanup Sites

Ecology Source Control Area Designation[a]	Approximate Nearest RM	Cleanup Site ID	Adjacent Upland Cleanup Site Name	Site Listed in Ecology's 2020 LDW Source Control Status Report[b] ? (Y/N)	Site Listed in Ecology's 2024 LDW Cleanup Update[c] ? (Y/N)	EAA or Upland Cleanup Site Adjacent to Middle Reach In-Water Area with RAL Exceedances? (Y/N)
LDW Middle Reach East Shoreline						
RM 2.8E: Slip 4 EAA	3.0E	7370	Boeing Plant 2[d]	Y	N	Y; this is a completed EAA (RAL exceedance area 1)
	2.8E	2520	Crowley Marine Services 8th Ave S	Y	Y	Y (RAL exceedance areas 3, 5)
	2.85E	2732	Duwamish River Slip 4[d]	Y	N	Y; this is a completed EAA (RAL exceedance area 3)
RMs 2.3–2.8E: Seattle Boiler Works to Slip 4	2.75E	17002	Gateway Park	N	N	Y (RAL exceedance area 9)
	2.6E	9057	Puget Sound Truck Seattle	Y	N	Y (RAL exceedance area 9)
	2.4E	2819	Myrtle Street Property	Y	N	Y (RAL exceedance area 20)
	2.35E	12115	Whitehead Tyee	Y	Y	N
	2.3E	5082	Fox Ave Building	Y	Y	N
	2.25E	16678	Dawn Food Products	N	Y	Y (RAL exceedance area 23)
RMs 2.0–2.3E: Slip 3 to Seattle Boiler Works	2.05E	13121	Seattle DOT S River St	N	N	Y (RAL exceedance area 29)
RMs 1.7–2.0E: Slip 2 to Slip 3	1.9E	4146	Duwamish Marine Center	Y	Y	Y (RAL exceedance areas 31, 32, 33)
	1.7E	11205	Lone Star Concrete NW	Y	N	N
LDW Middle Reach West Shoreline						
RMs 2.2–3.4W: Riverside Drive	2.8W	17204	Eddie Bell Junk Metals	N	N	N
	2.7W	2549	640 S Riverside Dr	N	N	Y (RAL exceedance area 8)
	2.7W	9114	Hurlen Construction	N	N	Y (RAL exceedance area 8)

Ecology Source Control Area Designation[a]	Approximate Nearest RM	Cleanup Site ID	Adjacent Upland Cleanup Site Name	Site Listed in Ecology's 2020 LDW Source Control Status Report[b] ? (Y/N)	Site Listed in Ecology's 2024 LDW Cleanup Update[c] ? (Y/N)	EAA or Upland Cleanup Site Adjacent to Middle Reach In-Water Area with RAL Exceedances? (Y/N)
	2.55W	13120	SDOT S Fontanelle St	N	N	Y (RAL exceedance area 17)
	2.55W	17117	Boyer Towing, Inc.	Y	N	Y (RAL exceedance area 21)
RMs 2.1–2.2W: Trotsky Inlet EAA	2.2W–2.3W	62	Industrial Container Services WA LLC	Y	Y	Y (RAL exceedance areas 24a, 24b)
	2.1W–2.2W	6967	Douglas Management Dock	Y	Y	Y (RAL exceedance areas 24a, 24b, 27)
RM 2.1W: 1st Avenue S Storm Drain	2.1W	1324	South Park Landfill	Y	Y	N
RMs 1.6–2.1W: Terminal 115	1.6–2.1W	11307	Terminal 115 Plant 1	Y	Y	N
	1.5W	1229	North Terminal 115[e]	Y	Y	N

Notes:

a. Designation of Ecology source control area based on Ecology’s website at: https://ecology.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-sites/Lower-Duwamish-Waterway/Source-control/Source-control-areas
b. Ecology (2022)
c. Ecology (2024)
d. Boeing Plant 2 and Duwamish River Slip 4 are EPA-led upland cleanup sites.
e. North Terminal 115 is listed under middle reach in Ecology’s 2022 LDW Source Control Status Report[b] and 2024 LDW Cleanup Update;[c] however, North Terminal 115 is located at RM 1.5, which is within the lower reach of the LDW.

EAA: early action area
Ecology: Washington State Department of Ecology
LDW: Lower Duwamish Waterway
N: no
RAL: remedial action level
RM: river mile
SDOT: Department of Transportation
Y: yes

In addition to the upland cleanup sites within the eight Ecology-designated source control areas listed in Table 2-1, there are several upland sites within approximately 500 feet of the LDW middle reach top of bank that are currently under Ecology-led upland cleanups. Table A1-1 in Appendix A summarizes the known upland cleanup site conditions and cleanup status of the sites within an Ecology-designated source control area or within approximately 500 feet of the top of bank. Figures 2-3a and 2-3b show the location of the upland cleanup sites listed in Table 2-1 and their proximity to the LDW middle reach RAL exceedance areas. Table A1-1 also includes environmental permit information obtained by accessing Ecology's Water Quality Permitting and Reporting Information System (PARIS; Ecology 2026a).

2.2.2 Coordination with Upland Cleanup Sites

Of all identified upland cleanup sites, the following three are under Ecology-led upland cleanup processes, are located immediately adjacent to LDW middle reach RAL exceedance areas, and will require coordination with Ecology, EPA, and LDWG during RD to coordinate compatibility of upland and sediment remedies:

- Duwamish Marine Center: This upland cleanup site is located near RM 1.95E, within Slips 2 to 3 of the LDW. Historically, the site operated as a marine shipyard, railyard, junk dealer, various construction service companies, and a barge shipping terminal. A marine railway operated next to the southwestern shoreline from 1940 to the mid-1970s (G-Logics 2020). Currently, Samson Tug and Barge operates in the northern portion of the property, and Duwamish Metal Fabricators operates on the southern portion of the property. Due to its heavy industrial use, the Duwamish Marine Center site has been characterized by soil and groundwater contamination with a variety of contaminants of concern (COCs; total petroleum hydrocarbons [TPH], polychlorinated biphenyls [PCBs], metals [mercury], carcinogenic polycyclic aromatic hydrocarbons [cPAHs], and volatile organic compounds [VOCs]), many of which have also been identified in the adjacent sediments. According to Ecology, the Duwamish Marine Center's cleanup process is in the feasibility study development phase (as of October 2020).[11] Coordination with the upland site owner and Ecology is crucial in relation to potential building demolition that may be needed to prevent recontamination and to support the long-term effectiveness and protectiveness of the sediment remedy for the adjacent RAL exceedance areas 31, 32, and 33.
- Douglas Management Dock: This upland cleanup site is located between RMs 2.1W and 2.2W, near the 1st Avenue S Bridge. The Douglas Management Dock area was the location of Pacific Metal and Salvage Company (which specialized in dismantling, wrecking, and salvaging old boats) and Seabell Shipbuilding Company (which constructed large wooden vessels). The

[11] Ecology's website on the Duwamish Marine Center upland cleanup site can be accessed at: https://apps.ecology.wa.gov/cleanupsearch/site/4146.

current location of the Douglas Management Dock property was part of Duwamish Turning Basin No. 2, and historical aerial photographs indicate that the triangular parcel that comprises the site was filled sometime between 1960 and 1969. During the 1970s to 1990s, the site operated as a sand and gravel batch plant, a school bus parking area, and a barge terminal. It is currently used by Alaska Marine Lines for storage of equipment and shipping containers and as a general transfer facility. Investigations to date document the presence of metals, PCBs, and TPH contamination in soil and groundwater. According to Ecology, Douglas Management Dock's cleanup process is in the feasibility study development phase.[12] Coordination with the upland site owner and Ecology is required to determine timing of the upland remediation and compatibility with the design approach for the sediment remedy of the adjacent RAL exceedance areas 24a, 24b, and 27.

- Industrial Container Services: This upland cleanup site is located near RM 2.2W. Industrial activities at the site since the 1930s have included drum reconditioning and manufacturing operations. Currently, Industrial Container Services leases the property and continues to operate a drum reconditioning facility. Site investigations have found soil and groundwater contamination for a variety of COCs, including metals, TPH, cPAHs, pentachlorophenol (PCP), dichlorodiphenyltrichloroethane (DDT), PCBs, VOCs, and semivolatile organic compounds (SVOCs), many of which have also been identified in the adjacent RM 2.2W sediments. According to Ecology, a remedial investigation and a feasibility study are available for public comment as part of Industrial Container Services' cleanup process (as of May 2025);[13] the preferred cleanup alternative includes a combination of surface soil and light nonaqueous phase liquid (NAPL) excavation, containment via capping, long-term groundwater monitoring, and institutional controls. Coordination with the upland site owner and Ecology is necessary to determine the timing of the upland remediation and compatibility with the design approach for the sediment remedy of the adjacent RAL exceedance areas 24a and 24b.

LDWG also understands that the Seattle Parks & Recreation has initiated discussions with Ecology regarding potential future cleanup actions at Gateway Park at the 8th Avenue South right-of-way at RMs 2.7E and 2.8E. This area is adjacent to RAL exceedance area 9. LDWG is coordinating with the City of Seattle to remain up-to-date on potential remedial investigation plans.

2.2.3 Anticipated Coordination Schedule

Ongoing coordination between Ecology, EPA, and LDWG will be necessary so that the RD details (e.g., upland remedial actions adjacent to or on banks, areas targeted for active in-waterway sediment remediation, timelines for achieving sufficient source control) are exchanged through

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[12] Ecology's website for the Douglas Management Dock upland cleanup site can be accessed at: https://apps.ecology.wa.gov/cleanupsearch/site/6967.

[13] Ecology's website for the Industrial Container Services upland cleanup site can be accessed at: https://apps.ecology.wa.gov/cleanupsearch/site/62.

routine check-ins and at critical RD milestones. The following milestones represent anticipated coordination check-ins during RD, based on the AOC5 schedule and as specified in the RDWP (Anchor QEA and Windward 2022a):

- Following Intermediate (60%) RD, when source control sufficiency determinations are assumed to be complete in order to complete the Pre-Final (90%) RD
- Following Pre-Final (90%) RD, when remediation contracting schedules are being planned to accommodate the source control sufficiency determinations that precede remedial construction

These milestones may be modified at the direction of EPA. In addition to these milestones, the LDWG design team will coordinate as needed with upland cleanup site technical teams, especially for the four upland cleanup sites (currently under Ecology-led upland cleanup processes) requiring continued coordination with Ecology, EPA, and LDWG during RD, with the goal of optimizing design compatibility and sequencing between the LDW sediment and upland remedial actions.

Ecology is currently working on its source control sufficiency evaluation for the upland sources of RAA area COCs for the LDW middle reach and is tentatively planning to submit the evaluation to EPA in Q3 2026. The design team has requested a copy of Ecology's evaluation when it is submitted to EPA. This will assist in the design team's discussions with EPA and Ecology regarding any potential modifications to LDW sediment remedy sequencing related to upland source control sufficiency. Construction sequencing is discussed further in Section 14.

2.2.4 Sediment Management Area 10 (LDW Upper Reach Deferred Area)

During RD for the upper reach, the finalization of RD for one area, referred to as Sediment Management Area (SMA) 10, was deferred to a later stage in the overall Superfund Site cleanup due to EPA's determination that sources were not sufficiently controlled based on Ecology's source control evaluation. SMA 10 is adjacent to the Boeing Isaacson Thompson cleanup site at RM 3.75E. Integration of the upland and in-water cleanup actions is necessary within this shoreline area because the in-water portion includes unbounded contamination adjacent to an aging bulkhead. The 60% Drawings for SMA 10 are presented in Volume III Part 1B. The area has otherwise been incorporated into the middle reach design as part of this Intermediate (60%) RD. Additional figures related to SMA 10 can be found in Appendix B.

2.3 Data Sources and Evaluations

The Intermediate (60%) RD is supported by a design dataset that includes data collected during two phases of pre-design investigations (PDIs), as well as relevant data collected prior to the PDI. The design data are described and presented in the DER (Anchor QEA and Windward 2025a). The DER presents summaries of the PDIs, including the chemistry and geotechnical results of the Phase I and

Phase II PDI. The PDIs were implemented in accordance with the following plans: the *Quality Assurance Project Plan: Pre-Design Surveys of the Lower Duwamish Waterway Middle Reach* (Anchor QEA and Windward 2021), the *Pre-Design Investigation Quality Assurance Project Plan for the Lower Duwamish Waterway – Middle Reach* (PDI QAPP; Windward and Anchor QEA 2022); the *Pre-Design Investigation Quality Assurance Project Plan Addendum No. 1 for the Lower Duwamish Waterway Middle Reach – Phase II Sampling* (Anchor QEA and Windward 2024a); and the *Pre-Design Investigation Quality Assurance Project Plan Addendum No. 2 for the Lower Duwamish Waterway Middle Reach – Phase II Sampling for the Inlet at RM 2.2W* (Anchor QEA and Windward 2024b).

PDI chemistry data were collected over two phases between 2022 and 2024, as summarized in the DER (Anchor QEA and Windward 2025a). The DER provides key inputs to this BODR and include the following:

- Design dataset (combined new PDI and existing sediment chemistry data based on the data management rules presented in the DER)
- Comparisons of sediment chemistry data to the RALs based on the ROD criteria
- Adjusted recovery category areas based on ROD criteria
- Interpolated sediment chemistry data to delineate RAL exceedance areas
- Assignment of preliminary remedial technologies based on ROD criteria

The methods used to define remediation areas are presented in Sections 4 through 6 of this BODR. Consistent with the DER, Section 4 describes the horizontal and vertical extents of contamination. Section 5 builds on Section 4 and, combined with engineering considerations, develops and presents RAAs. Section 5 also presents the updated Intermediate (60%) RD assignment of remedial technologies. Section 6 describes the approach for grouping RAAs into SMAs.

The DER also summarizes the following PDI data that support the RD:

- Geotechnical investigations
- Bank inspections
- Structures inspections
- Bathymetric, topographic, and other surveys
- Other engineering design data

These data are used in Section 7 (Geotechnical Engineering Considerations), Section 8 (Structural Engineering Considerations), and Section 9 (Remedial Technology Design) and as supporting information across other sections of this document.

The DER also identified initial data gaps for the Phase III PDI, which were expanded upon in the Preliminary (30%) RD. The Phase III PDI is taking place concurrently with development of this Intermediate (60%) RD in accordance with an addendum to the PDI Quality Assurance Project Plan for Phase III, herein referred to as the Phase III QAPP Addendum. Results will be incorporated into the Pre-Final (90%) RD.

2.4 Site Conditions

The RDWP (Anchor QEA and Windward 2022a) provides a review of existing information and site conditions. In addition, comprehensive descriptions of the LDW environmental and physical site characteristics are presented in the RI (Windward 2010), FS (AECOM 2012), and the ROD (EPA 2014). Key site characteristics affecting RD are summarized in the following sections.

2.4.1 Tidal Elevations and Water Depth

The middle reach consists of 111 acres of intertidal and subtidal areas below mean higher high water (MHHW), which is at an elevation of +11.3 feet mean lower low water (MLLW) in the LDW as defined in the ROD (EPA 2014).[14] MHHW is the landward boundary that the selected remedy addresses, but remedial action occasionally extends above this elevation to provide a constructable and effective remedy. Approximately 27 acres of the middle reach are considered intertidal, with bed elevations between +11.3 feet MLLW, equivalent to MHHW, and -4 feet MLLW. Approximately 84 acres of the middle reach are considered subtidal, with bed elevations below -4 feet MLLW. Elevation data for the middle reach are presented in Figures 2-4a through 2-4e. Elevation data in the SMA 10 vicinity are presented in Figures 2-5d and 2-5e of the Final (100%) RD for the LDW upper reach (Anchor QEA and Windward 2024c), which are also included in Appendix B.

2.4.2 Federal Navigation Channel

The middle reach includes the FNC, which is maintained[15] by the U.S. Army Corps of Engineers (USACE). In this reach, the authorized FNC width varies between 150 and 200 feet, and the authorized depth varies from -15 to -30 feet MLLW depending on location (Figures 2-3a and 2-3b). The FNC covers 28 acres of the 84-acre subtidal area of the middle reach. Authorized depths are as follows:

- -30 feet MLLW from RM 1.6 to RM 2.0 (USACE Stations 113+00 to 134+00)
- -20 feet MLLW from RM 2.0 and RM 2.8 (USACE Stations 134+00 to 176+00)
- -15 feet MLLW from RM 2.8 to RM 3.0 (USACE Station 176+00 to 187+00).

[14] The Seattle tide gage, as reported by the National Oceanic and Atmospheric Administration (NOAA), has a MHHW elevation of 11.36 feet in MLLW datum (https://tidesandcurrents.noaa.gov/datums.html?id=9447130). For purposes of RD, the ROD-defined MHHW elevation is used. The minor discrepancy between ROD-defined MHHW and NOAA-reported MHHW is not considered to have a material consequence for the remedy design and will not affect the effectiveness of the remedy.

[15] Recent maintenance dredging performed by USACE has been limited to areas in the FNC south of RM 4.0. No FNC maintenance dredging activities are anticipated to occur in the LDW middle reach before construction of the remedy.

2.4.3 Infrastructure

Infrastructure within the middle reach and in the vicinity of SMA 10, shown in Figures 2-3a through 2-3c, includes waterfront facility berthing, overwater structures (e.g., piers, docks, floats, bulkheads, flow diversion structures, covered boat slips), pilings (e.g., erosion control structures, fendering, mooring piles), bridges, and utilities (e.g., underwater cables and pipe structures, overwater cables, storm drains, outfalls). Section 8 provides additional information about infrastructure that coincides with areas requiring remedial action within the middle reach.

2.4.4 Waterway Usage

Waterway uses are summarized in RDWP Section 2.5 (Anchor QEA and Windward 2022a) and include the following:

- Tribal Use and Treaty Rights: The LDW is one of the locations of the Muckleshoot Indian Tribe's commercial, ceremonial, and subsistence fishery for salmon, as part of its usual and accustomed fishing area. The Suquamish Tribe actively manages aquatic resources north of the Spokane Street Bridge, just north of the LDW study area (EPA 2014).
- Beach Play and Tribal Clamming: Beach play and Tribal clamming were considered in the Remedial Investigation/Feasibility Study (RI/FS) and ROD processes in the development of cleanup levels and RALs.
- Existing Public Shoreline Access: Public shoreline access locations (Figures 2-3a and 2-3b) are considered in the RD in order to maintain public safety and reduce the impacts of construction on the public.
- Waterway Users: Waterway users include waterfront property owners and their tenants who are supported by bank infrastructure (e.g., docks, piers, wharves, berthing areas [Figures 2-3a and 2-3b]); operators of commercial tug, barge, and cargo vessels; marinas; and recreational users.
- FNC: The FNC supports water-dependent industry along the LDW. The RD applies appropriate buffers as defined in the ROD (EPA 2014) to support USACE's ability to maintain the FNC.

2.4.5 Upland Land Use

The middle reach is adjacent to upland property in the City of Seattle. The uplands surrounding the LDW middle reach are mixed industrial, commercial, residential, and some park/open space. Tidal flats and floodplains within the middle reach were filled, throughout the past 100 years or longer, to both create the waterway as a straightened channel and create more upland areas for development. The LDW middle reach is bordered by the South Park neighborhood on the west bank (to approximately RM 2.0) and the Georgetown neighborhood on the east bank. RD considers restrictions appropriate to residential land uses (e.g., noise restrictions during construction). Upland properties are owned by a variety of landowners, as shown in Figures 2-3a through 2-3c. These figures also show the pre-1900 shoreline of the Duwamish River.

A detailed summary of historical land uses is provided in the FS Section 2.1.6 (AECOM 2012). Habitat restoration areas in the middle reach are discussed in FS Section 2.1.5 and Section 2.4.11 of this document.

2.4.6 Early Action Areas

Two EAAs are located within the middle reach (a portion of Boeing Plant 2 EAA and Slip 4 EAA). The RDWP summarizes the cleanup of each EAA (Anchor QEA and Windward 2022a). Existing conditions for the EAAs inform the cleanup approach in adjacent areas in this BODR, as described in Section 5.1.

2.4.7 Enhanced Natural Recovery/Activated Carbon Pilot Plots

In 2015 to 2020, LDWG implemented a pilot study to assess whether the performance of ENR material amended with activated carbon (AC) was more effective than ENR alone in reducing the bioavailability of PCBs in contaminated sediments in the LDW. Results of the study are available in the Year 3 monitoring report (Wood et al. 2021). None of the pilot study plots are within the middle reach. In summary, an average thickness of 10.3 inches of gravelly/sandy material was placed, with a minimum thickness of 6 inches and maximum thickness of 14 inches (Amec Foster Wheeler et al. 2018). Sections 9.4 and 9.5 discuss the results of the pilot study as they relate to the middle reach design.

2.4.8 Hydrodynamics and Sediment Transport

The middle reach is an estuarine environment, with freshwater entering from the Green/Duwamish River system and saltwater originating from Puget Sound. The location of the upstream interface between freshwater and marine layer flows, referred to as the saltwater wedge, is variable within the middle reach depending upon both river flow and tidal stage. During times of high river flow and low tide stages, the saltwater wedge is within the middle reach, whereas during low-flow conditions and high tide stages, the saltwater wedge typically extends upstream of the middle reach. The upstream-most location or “toe” of the saltwater wedge is typically located between Slip 4 (RM 2.8) in the middle reach and the Turning Basin (RM 4.7); however, the salt wedge can extend upstream as far as RM 10.2 during low flow from the Green River and high tides (WRIA 9 2021).

The Howard Hanson Dam at the head of the Green River is managed to perform flood control during storm events. As a result, the dam limits the maximum flows within the LDW. High-flow events considered in design incorporate the effects of Howard Hanson Dam management.

The hydrodynamics and sediment transport of the LDW (summarized in RI Section 2.6 and FS Section 2.1.3 [Windward 2010; AECOM 2012]) were modeled during development of the sediment transport model (STM; QEA 2008), which was prepared to support the RI/FS. Additional detail on the hydrodynamics and suspended sediment transport of the LDW is available in a recent University of Washington study (McKeon et al. 2020) and a U.S. Geological Survey (USGS) study (USGS 2018), respectively.

The primary focus of the recent modeling study by the University of Washington on the Duwamish River Estuary was on the seasonal changes in structure and dynamics in a salt wedge estuary (McKeon et al. 2020). Part of the University of Washington study included an analysis of sediment load estimates entering the estuary (not deposition or sediment transport within the waterway) using newer USGS data than were available at the time when the STM was developed. The University of Washington concluded that recent sediment loads derived from the USGS data collected between 2013 and 2020 may be 50% less than the sediment loads derived from the data that were available at the time of the STM. This is consistent with the findings from the analysis conducted by USGS (2018) that also suggested that the current upstream sediment load estimate may be up to 50% lower than previous estimates used in the STM.

Although the reasons behind this difference remain uncertain (potentially including methodological differences in estimates and true differences in loads), the implications of this change were investigated by a sediment transport modeling team composed of LDWG and EPA members. The team conducted an evaluation to determine the effects on STM calibration results if the estimated upstream sediment load was decreased by approximately 50% (Integral et al. 2019). This evaluation indicated that a 50% reduction in upstream sediment load would not affect the overall reliability of the STM (LDWG 2021). The STM was calibrated to measured deposition rates throughout the LDW, so revising upstream sediment loads and recalibrating to the same deposition rates did not significantly change deposition patterns or amounts but did change the estimated percent of upstream load retained in the LDW. The reduced estimate of sediment load resulted in STM predictions of reduced transport of fine sediments through the LDW into Elliott Bay.

The LDW is net depositional, with the majority of sediments entering the LDW originating from the upstream Green River catchment. Based on the original STM calibration, approximately 220,000 metric tons of upstream sediment and 1,100 metric tons of sediment from lateral loads enter the LDW annually. Approximately 81,000 metric tons of the sediment is deposited between RMs 4.0 and 4.9, where the water velocity is reduced due to the widening and deepening of the LDW (i.e., the Turning Basin and the FNC) compared to upstream channel dimensions. The Turning Basin within the upper reach acts as a trap for suspended solids entering the LDW. Coarser grain-sized suspended solids (i.e., sands) tend to deposit in the Turning Basin, and finer-grained sediments tend to be transported and deposited farther downstream in the LDW, as well as a portion that passes through the LDW toward East Waterway, West Waterway, and Elliott Bay.

2.4.9 Erosive Forces

Erosive forces within the LDW middle reach affect the stability of bed sediment or placed materials, such as capping materials. These erosive forces are generated from naturally occurring and human-induced forces. Natural forces that occur in the LDW include wind-generated waves and hydrodynamic flows (i.e., current velocities). Human-induced forces include propeller wash (propwash) and vessel wakes in the middle reach. Human-induced influences also include constrictions in flow due to bridge abutments. Potential effects of erosive forces and influences on capping areas are discussed in Section 9.3.2.3.

2.4.10 Presence of Debris

Debris is common in industrial waterways such as the LDW, deposited over decades of waterway use. Submerged and emergent debris are considered in the application of remedial technologies, including the type of remedial equipment used. Specifications for management of debris will be determined during Pre-Final (90%) RD. Debris identified during the PDI is shown in the 60% Drawings. Two derelict barges (one sunken [i.e., submerged below the water surface] and one beached) were identified at approximately RM 2.55W, and the sunken barge is within a RAL exceedance area footprint. Buried debris may be encountered in any dredge area, and the design specifications will require the contractor to be prepared with equipment and procedures to remove debris wherever it is encountered during the remedial action. Methods to gather additional information regarding the status of the sunken barge are discussed in the Phase III QAPP Addendum.

2.4.11 Existing Habitat Conditions

The ROD defines "habitat areas" as all areas of the waterway with elevations above -10 feet MLLW and establishes requirements for remediation within such areas (EPA 2014). Habitat for aquatic species and aquatic-dependent species exists in the LDW and extends from the riparian area above the upper elevation of the site at MHHW (+11.3 feet MLLW) down to the deep subtidal areas of the LDW. These areas are all considered habitat and are divided into the following habitat types based on elevation:

- Deep Subtidal: Deeper than -10 feet MLLW
- Shallow Subtidal: -10 feet MLLW to -4 feet MLLW
- Lower Intertidal: -4 feet MLLW to +4 feet MLLW
- Upper Intertidal: +4 feet MLLW to +11.3 feet MLLW
- Riparian: Above MHHW (+11.3 feet MLLW)

These existing habitat types, except riparian, are shown in Figure 2-5a. Figure 2-5b includes bank vegetation (trees and shrubs), which is an indicator for the riparian condition. Figure 2-5b includes potential clamming areas, existing bank conditions, bank vegetation conditions, and existing habitat restoration projects to provide context for the habitat types. Habitat types and existing conditions in the SMA 10 vicinity are presented in Figures 2-4a and 2-4b, respectively, of the Final (100%) RD for the LDW upper reach (Anchor QEA and Windward 2024c), which are also included in Appendix B.

Bank habitat data collection occurred as part of the PDI Phases I and II in 2023 and 2024. As part of this data collection effort, vegetation conditions along the riverbank in the middle reach were documented via visual inspection. Vegetation was documented along riverbank stations including vegetation type, percent cover, and plant communities. Conditions were documented for top of bank (above MHHW in riparian zone), mid-bank (below MHHW in the intertidal zone), and toe of slope (area below bank observed during the low tide inspections in the intertidal zone). The results of the vegetation observations are shown in Figure 2-5b as existing bank vegetation. Overall, where present, the bank vegetation consists of a mix of native, landscaping, and non-native trees and shrubs. Most of the banks are armored along the middle reach, removing connectivity to almost all historical floodplain. Banks were categorized as armored, unarmored, bulkheaded, or bulkheaded and armored, consistent with the LDW upstream sediment load report (Integral et al. 2019). Armored banks are defined as having an engineered surface armoring (e.g., riprap armoring, gabion armoring, bulkhead [sheet pile, concrete, wood]) to prevent bank erosion. Unarmored banks have no armoring or poorly placed or maintained armoring such that significant gaps in armoring existing (e.g., banks with intermittently exposed sediment/soil). Vegetated banks are included in the unarmored category. Bulkheaded banks most frequently occur coincident with overwater structures and are supported by armored slopes.

Based on observations during the Phase I visual inspection, the armored category was divided into two subcategories: engineered and semi-engineered. The semi-engineered bank areas included shoreline slopes that, although covered with armoring materials, clearly were not engineered or constructed of rock armoring material (e.g., riprap). The material present on most semi-engineered banks appeared to be integral to overall bank stability; these areas will require additional evaluation if they are located adjacent to or within RAL exceedance areas. As shown in Figure 2-5b, approximately 51% of the middle reach bank areas are armored, 5% are bulkheaded, 19% are bulkheaded and armored, and 25% are unarmored.

Additionally, RI Section 2.8 and FS Section 2.1.5 (Windward 2010; AECOM 2012) summarize the habitat types in the entire LDW. The habitat types in the LDW include intertidal marshes, intertidal mudflats, unarmored and armored intertidal areas, and subtidal areas. Intertidal marshes contain marsh soils (generally fine-textured and nutrient-rich) supporting grasses, sedges, rushes, and various other plants. Intertidal mudflats are generally defined as the gently sloping areas from MLLW up to the edge of intertidal marsh vegetation (Blomberg et al. 1988). They are unvegetated, with sand or mud substrate, and represent a substantial portion of the intertidal area within the middle reach.

Approximately 19 acres of the middle reach were identified in the ROD as potential clamming areas based on bathymetric elevations (i.e., shallower than -4 feet MLLW), substrate, and salinity conditions (EPA 2014). Potential clamming areas are a subset of the intertidal areas.

Existing habitat restoration projects that have been constructed within the middle reach include the following (Figure 2-5b):

- Washington State Department of Transportation (WSDOT) wetlands construction, RM 2.0W to 2.3W, which removed an abandoned barge and restored a channel that connects to an emergent vegetation area at the south landfall of the 1st Avenue S Bridge (King County 2025). This work was completed by WSDOT. It is not known if it was required for CWA 404 mitigation.
- Boeing Plant 2 Habitat Restoration, RM 2.8E to 3.0E, which removed contaminated soil and sediment, installed riparian vegetation, restored marsh and marsh vegetation, installed large woody debris and gravel, removed fill, and restored shoreline. This restoration project was a Natural Resource Damage Assessment project, completed by Boeing.
- t̓ałt̓ałucid Park and Shoreline Habitat, RM 2.7 W to 2.8W, which removed fill to restore intertidal habitat, installed riparian vegetation, and improved public shoreline access. This project was completed by the Port of Seattle. It is not known if it was required for CWA 404 mitigation.

2.5 Basemap Development

A basemap of the middle reach has been prepared as part of the design process and serves as the basis for the 60% Drawings. The basemap includes information from bathymetric and topographic surveys, structures and debris surveys, utility reviews/surveys, and other information relevant to the design and construction of the remedy. The horizontal datum for the basemap is North American Datum of 83 through the 1991 adjustment (NAD83/91), State Plane Coordinate System, Washington North Zone, measured in U.S. Survey Feet. The vertical datum for the basemap is in feet MLLW (based on the 1983 to 2001 tidal epoch).

2.5.1 Bathymetric and Topographic Surveys

Bathymetric and topographic surveys were conducted as part of the PDI. Phase I and Phase II survey collection methods and results are described in detail in the DER (Anchor QEA and Windward 2025a).

In summary, bathymetric surveying was used to collect data throughout the middle reach, and topographic surveying was used to supplement the bathymetry data on bank areas within or adjacent to RAL exceedance areas up to MHHW. The topographic survey was performed using two methods: photogrammetry and traditional land-based surveying.

Where the bathymetric and topographic survey coverage overlapped, topography data collected through traditional land-based surveying data superseded due to data accuracy. Where topography data was collected through photogrammetry, the bathymetry data generally superseded due to data density. In cases where a gap existed between the two surveys, the gap was filled in one of two ways. For data gaps ranging in size of 370 to 6,730 square feet surrounded by survey data that matched well on either side, the gap was filled through interpolation. For larger gaps or areas that were not surrounded by representative data, the Puget Sound LiDAR Consortium data from 2016 were used to fill gaps (PSLC 2016). Figures 2-4a through 2-4e show where the data were interpolated to create a composite elevation dataset for the basemap.

2.5.2 Structure and Debris Surveys

Location data and information on structures were obtained from the Waterway User Survey (Integral et al. 2018). The topographic survey team also collected survey point data for structures. Additionally, structures and debris were surveyed through a desktop review of high-resolution photographs, including ortho-aerial imagery collected as part of the topographic survey using photogrammetry and oblique photographs collected using a drone. These features have been integrated into the basemap.

2.5.3 Utilities

Location data and information on outfalls were originally obtained from the LDW RI (Windward 2010) and Ecology's 2014 outfall inventory (Leidos 2014) and further updated based on Ecology's 2020 outfall inventory updates for the LDW (Leidos 2020). In addition, outfall information has been supplemented by information available from the LDWG parties. As noted previously, outfall information was also collected during the topographic surveying activities when outfalls were encountered by the surveyor. Outfall information collected during the topographic survey was used to update or replace the information available from the outfall inventory updates. Finally, a review of available documents, such as outfall and utility as-builts from recent construction projects in or near the site, was also completed. The updated outfall information is presented in the figures in this report.

In addition to outfalls, two submarine utility corridors exist within the middle reach: one north of the 1st Avenue S Bridge and one at 8th Avenue South. Uncertainty remains as to the exact locations and elevations of these lines. Public and private utilities were located before Phase I, Phase II, and Phase III PDI sampling to confirm that no utilities were at risk of being damaged during the sampling process. The 811 public utility process was followed for the entire 1.4-mile stretch of the middle reach. This activity was followed by private utility location procedures for specific areas performed by Advanced Underground Utility Locating. Additional information ascertained as part of the design process is included in the following subsections. This information is the design team's current understanding; additional research and investigation work is ongoing.

2.5.3.1 Utility Corridor North of 1st Avenue S Bridge

The utility corridor north of the 1st Avenue S Bridge includes three separate elements, as follows:

- Active City of Seattle water line in concrete utilidor tunnel: This tunnel was installed in the 1990s in tandem with construction of the modern 1st Avenue S Bridge. Based on as-built information, it appears that the top elevation of the utilidor is at -65 to -70 feet City of Seattle datum (obsolete), which correspond to approximately -53 to -58 feet MLLW.
- Abandoned City of Seattle water line in concrete utilidor tunnel: This tunnel was installed in the 1920s and was abandoned following the construction of the new tunnel. Based on as-built information, the top of the tunnel appears to be approximately -40 feet MLLW. The datum is unknown but elevations have been translated to MLLW using other reference information (e.g., elevation of FNC). The construction drawings for the 1990s utilidor indicate that it was to be filled with quarry spalls and native material, plugged, and abandoned in place as part of a separate contract. These files also indicate a collocated gas main along the same alignment, that was also abandoned under a separate contract.
- Abandoned Lumen telecommunication line: The location of the Lumen line has not been verified, but a Lumen engineer confirmed it is inactive, was abandoned in place, and is safe to drill around. Based on discussions with City of Seattle, it is likely to be within the abandoned utilidor.

Finally, a King County outfall (i.e., the Georgetown Wet Weather Treatment outfall) was recently constructed along the east bank of the LDW south of the two utilidors. The outfall is located along the 1st Avenue S Bridge footing and runs underground from the shoreline to where it surfaces at approximately -7.0 feet MLLW (87.0 feet King County Metro datum) and runs along the existing surface to the point where it terminates at the fender line. This utility is not a crossing, but it does overlap with an area of planned remedial action. As-built linework for this structure has been incorporated into the basemap.

2.5.3.2 Utility Corridor Along 8th Ave South

The utility corridor along 8th Avenue South consists of potentially three or four telecommunication ducts/lines as follows:

- Active Lumen telecommunication ducts (formerly Pacific Northwest Bell): There are two ducts. The alignment of this line is shown on a 1980 easement recording, which utility locates have generally verified. Field locate methods show that these lines may be quite shallow (i.e., 2 to 4 feet below mudline) near the bank, but confirmed information on depth/elevation has not been found.

- Active AT&T/Comcast telecommunication duct: This duct appears to have been installed in 2002 and houses both AT&T and Comcast lines. Alignment and depth information were provided on as-built drawings by Siena Engineering Group. The alignment is to be verified. The datum is also to be verified, but depth of utility shown to be 23 feet below mudline in the channel at time of installation.
- Abandoned AT&T telecommunication line: This is an old fiber line that was damaged and replaced in the early 2000s and is likely to be encountered on or near the surface.

2.5.4 Other Basemap Data

A variety of other data have been incorporated into the basemap, including the following:

- Aerial photography
- Property boundary maps (available from King County [2006])
- Construction project as-built surveys (including EAAs and habitat projects)
- USACE centerline and stationing
- Habitat features along bank areas

Updated information collected during the Phase III PDI will be incorporated into the Pre-Final (90%) RD.

3 ARARs Compliance Evaluation

This section describes the Applicable or Relevant and Appropriate Requirements (ARARs) embodied in the federal and state laws that govern the work, as identified in the ROD (EPA 2014). Pursuant to Section 121 of CERCLA (42 *United States Code* [USC] 9621), no permits are required for on-site remedial actions. Only substantive requirements of these federal and state laws and implementing regulations apply. EPA will determine substantive compliance with ARARs in coordination with resource agencies, as EPA deems appropriate, using the supporting information presented in this section and related appendices.

ARARs fall into several categories, including cleanup and waste management standards; water quality and waterway protection; environmental protection; air quality and noise; and archaeological, cultural, and historic resources. This section describes how compliance with ARARs will be achieved and documented. In general, measures that address ARAR compliance will be documented in the project specifications. However, some ARARs will require the preparation of specific deliverables, as noted in the following sections. Appendix C contains supplemental details for each of the laws and regulations described herein.

3.1 Hazardous Substance Cleanup and Sediment Quality

Specific cleanup levels and RALs are identified in ROD Sections 8.2.1 and 13.2.1, respectively (EPA 2014, 2021). The RALs are being used to delineate areas where remedial action is necessary. Implementing remedial actions (e.g., dredging, capping, ENR) will not, by itself, address the ARARs associated with cleanup standards, including Sediment Management Standards. MTCA is Washington's environmental cleanup law (Revised Code of Washington [RCW] 70.105D; Washington Administrative Code [WAC] 173-340) and implements sediment standards under WAC 173-204. Successful implementation of the remedy will be documented in a construction completion report, and long-term monitoring is described in the LTMMP. Monitoring and maintenance will begin at the completion of the middle reach construction and will document compliance with (or progress toward) meeting cleanup levels as well as the continued effectiveness of the remedy. Although natural recovery processes are ongoing, the 10-year period for achieving cleanup levels through natural recovery will begin after sediment remedial construction is completed for the entire LDW site unless otherwise determined by EPA.

3.2 Surface Water Quality

Several federal and state programs regulate surface water quality, including the following:

- Ambient Water Quality Criteria per CWA (Section 304(a); 33 USC 1314(a))
- National Toxics Rule Standards (40 *Code of Federal Regulations* [CFR] 131.36(b)(1)) as applied to Washington (40 CFR 131.36(d)(14))

- Washington State Water Pollution Control Act (RCW 90.48)
- Washington State Water Quality Standards (WAC 173-201A)

Sediment remediation will improve surface water quality in combination with source control implementation under state-led authority. According to the ROD, surface water standards must be at least as stringent as all of the following:

- All water quality standards in WAC 173-201A
- Ambient Water Quality Criteria, unless it can be demonstrated that such criteria are not relevant and appropriate for the LDW or for a specific hazardous substance
- The National Toxics Rule Standards

Monitoring for relevant Ambient Water Quality Criteria will occur during construction. CWA Section 304(a) water quality criteria are non-binding recommendations developed by EPA.

For any construction-related discharges to the LDW, water quality monitoring will occur per an EPA-approved CWA Section 401 WQMP, which will be drafted during the Pre-Final (90%) RD. The WQMP will describe monitoring protocols, best management practices (BMPs) for the protection of water quality, and response actions to be employed, as needed, in the event of any exceedances of the compliance criteria identified in the WQMP.

The water quality standards for surface water implement portions of the federal CWA by specifying the designated uses for water in Washington. For the LDW, designated uses include aquatic life uses for rearing and migration, recreation uses for primary contact, and water supply uses for all uses except domestic water.

3.3 Waste Management

Several federal and state laws regulate the characterization, storage, and transportation for disposal of waste materials derived from remediation activities. These include the following regulations pertaining to solid waste disposal; waste treatment, storage, and disposal; and land disposal of waste:

- Solid Waste Disposal Act (42 USC 6901-6992K; 40 CFR 257-258)
- Solid Waste Management (RCW 70.95; WAC 173-350)
- Resource Conservation and Recovery Act (RCRA), Hazardous Waste (42 USC 6901-6992K; 40 CFR 260-279)
- Dangerous Waste Management (RCW 70.105; WAC 173-303)
- Toxic Substances Control Act (TSCA; 15 USC 2605; 40 CFR 761.61(c))
- RCRA, Land Disposal Restrictions (42 USC 6901-6992K; 40 CFR 268)

All material removed from the middle reach will be managed in a commercial permitted disposal site operating in conformance with their operating permits; facility compliance will be confirmed with the appropriate EPA Off-Site Rule Contact prior to shipping any waste from the site. Based on the data in the RI (Windward 2010) and DER (Anchor QEA and Windward 2025a), sediment with dry weight concentrations of PCBs greater than 50 milligrams per kilogram (mg/kg) has been identified in four RAL exceedance areas (19, 21, 24b, and 31) and is referred to as TSCA waste for the purposes of this BODR. Potential RCRA characteristic hazardous waste (D code) and potential Washington State-only dangerous waste (WT02 code) has been preliminary identified in middle reach sediments within RAL exceedance areas 8, 9, 20, 21, and 24b. Refer to Section 9.2 for information regarding transport and disposal of waste materials.

Shipments of material from the site for disposal will be documented and quantities reconciled to confirm that material removed from the site is disposed of properly. For material that is not regulated as hazardous/dangerous waste, trip tickets will be reconciled with waste receipts issued by the disposal facility. If any material is found to be regulated as hazardous/dangerous waste, manifests will be used to track the material from the point of generation to disposal. Shipments of TSCA waste and RCRA hazardous waste will require special handling, additional health and safety considerations, and adherence to disposal specifications to comply with TSCA and RCRA requirements, respectively. The contractor's transportation and disposal plan will contain additional details about the characterization, handling, and documentation of material removed from the site. Quantities of waste removed from the site will be reported by the contractor during construction and summarized in the construction completion report.

If characterization of sediment determines that any of the removed material will be regulated as TSCA or hazardous/dangerous waste, the Owner or contractor will obtain a large quantity generator identification number and manage the material characterized as hazardous/dangerous waste in a facility permitted to manage such material. The material would be treated prior to disposal to meet the requirements of applicable land disposal restrictions. The large quantity generation provisions of 40 CFR 262 and WAC 173-303 will apply to the remedial action for any sediment found to be regulated as hazardous or dangerous waste.

3.4 Dredge/Fill and Other In-Water Construction Work

Several federal and state programs regulate the discharge of dredged and fill materials and in-water construction work. These programs include the following:

- CWA Sections 401 and 404 (33 USC 1341, 1344; 40 CFR 121.2, 230, 232; 33 CFR 320, 322–323, 328–330) for the protection of water quality
- Hydraulic Code Rules (RCW 77.65; WAC 220-110) for the projection of state priority habitats and species

- Dredged Material Management Program Suitability Determination (RCW 79.105.500; WAC 332-30-166(3)) to review sediment quality and disposal
- Rivers and Harbors Act Section 10 (33 USC 403) to protect and maintain navigation
- Rivers and Harbors Act Section 14 (33 USC 408 and also known as the USACE Section 408 Program) to protect and maintain USACE civil works projects

CWA Section 401 requires that cleanup actions meet applicable water quality standards. At Pre-Final (90%) RD, evaluations to predict potential water quality impacts due to dredging will be completed. This will evaluate whether sediment resuspension during dredging or dredge return water release from haul barges is predicted to exceed water quality criteria. EPA will use this information to develop and issue a CWA Section 404 ARAR evaluation defining the requirements for CWA Section 401 compliance. Prior to construction, EPA will issue a finding that substantive requirements of the CWA Section 401 Water Quality Certification have been met, potentially with conditions determined in coordination with Ecology. The WQMP that will be developed during design as part of the CQAP will describe monitoring protocols, BMPs for the protection of water quality, and response actions to be employed, as needed, in the event of any exceedances of the compliance criteria identified in the WQMP. EPA will issue a finding that substantive requirements of the CWA Section 404 ARAR have been met. The results of water quality monitoring and any corrective actions taken will be regularly reviewed during construction to assess the need for any corrective actions and summarized in the construction completion report.

A key element of compliance with CWA Section 404 is evaluation of the placement of dredged or fill material within waters of the United States. Federal regulations (40 CFR 230) set forth specific standards to implement CWA Section 404(b)(1). No material will be placed in the water until EPA has reviewed and approved the characterization results. A separate 404(b)(1) compliance evaluation will be prepared to demonstrate compliance with CWA Section 404(b)(1) criteria.

Although a Washington Department of Fish and Wildlife (WDFW) Hydraulic Project Approval is not required for this project, substantive compliance will require the implementation of conditions to avoid or reduce potential impacts to aquatic species or habitats during construction. Examples of these conditions include the following:

- Work within established in-water work windows for the waterbody.
- Establish a staging area in a location that will prevent contaminants from entering waters of the state.
- Clearly mark boundaries establishing limits of work where practicable.
- Check equipment daily for leaks and complete repairs before using equipment in or near the water.
- During excavation, complete each pass with the dredge bucket.
- Do not stockpile dredged material waterward of the ordinary high water mark.

- Dispose of dredged bed materials in an approved disposal site.
- To reduce turbidity, hopper dredges, scows, and barges used to transport dredged materials to the disposal or transfer sites must contain the dredged material.

This Intermediate (60%) RD does not anticipate open-water disposal or beneficial reuse of sediments. Therefore, there are no specific requirements of the Dredged Material Management Program that are currently incorporated into the design.

Requirements for dredging/capping elevations have been established in the ROD (EPA 2014) and were designed to preserve navigation and commerce by maintaining elevations below the authorized depth in the FNC and associated buffers, as required by the ROD. Elevations higher than -10 feet MLLW will be maintained to preserve habitat function per the Washington State Hydraulic Code. Any existing structures that are modified as part of the project will be restored to provide the functional equivalent of existing conditions.

3.5 Fisheries, Wildlife, and Endangered Species

Several regulations relate to fisheries, wildlife, and endangered species, including the following:

- Endangered Species Act (ESA; 16 USC 1531–1544)
- Migratory Bird Treaty Act (16 USC 703–712; 50 CFR 10, 21)
- Bald and Golden Eagle Protection Act (16 USC 668; 50 CFR 22)
- Bald Eagle Protection Rules (RCW 77.12.655; WAC 232-12-292)
- Hydraulic Code (WAC 220-660)

In accordance with Section 7 of the ESA (16 USC 1536), a forthcoming Biological Assessment will be prepared for EPA to submit to the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (NMFS) (together, the Services) to initiate consultation about the potential effects of the proposed remedial action and ways to reduce those effects on species listed under the ESA. Consistent with direction received from the Services on the upper reach consultation process, a habitat evaluation for the middle reach was completed using semi-quantitative methods and the Habitat Equivalency Analysis (HEA)-based Puget Sound Nearshore Calculator (PSNC; described in the Salish Sea Nearshore Programmatic [SSNP] Biological Opinion) to determine potential impacts to habitat from implementing remedial activities. The PSNC was used to evaluate impacts associated with infrastructure removal and/or installation (e.g., piling removal and installation, debris pile removals). The semi-quantitative approach was used to evaluate impacts associated with dredging and material placement activities. The habitat evaluation compares existing habitat conditions to post-remediation conditions to determine potential impacts and benefits to habitat of implementing the proposed action. The semi-quantitative approach was used because, as described in the SSNP Biological Opinion, remedial activities that are not included in the PSNC include dredging, excavation, capping, or other methods of removing or isolating contaminated sediments from aquatic habitats. Contaminated sediment removal activities are not included in the PSNC because they are expected to result in permanent habitat improvement (NOAA 2022). Instead, a semi-quantitative comparison of existing habitat conditions to expected post-remediation conditions was performed for these activities.

The PSNC applies regional habitat models that determine habitat values for existing and proposed post-construction conditions. The values consider both adverse and beneficial impacts over time and calculate a ledger of discounted-service-acre-year (DSAY) credits or debits resulting from the project. DSAYs represent the net present value of all ecosystem services provided by one acre of habitat in 1 year and is commonly used as a unit of measurement to assess ecological value of a habitat type over time. Projects that provide environmental benefits can sometimes be self-mitigating if they generate more credits than they do debits that may be incurred from construction-related impacts. If more debits are generated, then compensatory mitigation may be required. Compensatory mitigation offsets can be generated on site through habitat restoration actions (e.g., creosote-treated timber pile removal, debris removal, or bank stabilization removal). Other options include paying into an in-lieu fee program or mitigation banking instrument capable of offsetting impacts to estuarine environments such as the LDW.

For the semi-quantitative approach for dredging and material placement remediation activities (similar to the approach used for upper reach), mapped habitat polygons were assigned an existing elevation-based habitat category (e.g., lower intertidal, shallow subtidal) relative to MLLW and based on any degraded conditions (e.g., presence of overwater structure, riprap, or debris on the substrate, adjacent to bulkhead wall). Post-remediation habitat conditions were assigned a habitat category based on engineering design details for each RAA. Spatial analysis tools were used to reassign habitat categories in each RAA based on changes to elevation, substrate type, or change in degraded condition that would occur because of remedial activities.

The impact of remedial activities on all habitat types, including the ROD-defined "habitat areas," are presented in Section 10.5. This evaluation will be used during Pre-Final (90%) RD to demonstrate compliance with CWA Section 404 of the CWA and Section 7 of the ESA. The result of the habitat evaluation indicates that the remedial activities are expected to improve habitat conditions relative to existing conditions.

NMFS and the U.S. Fish and Wildlife Service will typically issue a biological opinion that states whether EPA has ensured that its action is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat. Biological opinions provide an exemption for the "incidental take" of listed species (e.g., harassment, harm, pursuit, hunting, shooting, wounding, killing, trapping, capturing, or collecting) while specifying the extent of incidental take allowed, the reasonable and prudent measures that would reduce impacts from the federal action, and the terms and conditions with which EPA must comply.

Consideration of the effects of federal actions on Essential Fish Habitat (EFH) for covered species including salmonids is also required under the Magnuson-Stevens Fishery Conservation and Management Act (16 USC 1801) and its implementing regulations. Typically, state or federal agencies planning actions that might adversely affect an EFH-managed species must formally consult with NMFS regarding the action. An EFH evaluation will be included in the forthcoming Biological Assessment.

Based on the ROD and RDWP (EPA 2014; Anchor QEA and Windward 2022a), allowable periods of in-water work have been identified (Section 12.2 of this BODR), and specific habitat mitigation measures, including the use of habitat-compatible substrates and restoring optimal grades and elevations for biological resources, will be incorporated into the RD. The biological opinion may include additional conservation measures to further reduce impacts.

During the remedial action, steps will be taken as needed to protect habitat for migratory birds and avoid disturbing nests when possible or mitigate impacts by relocating nests. During upland construction activities with the potential to impact migratory bird nesting habitat, if construction timing overlaps with nesting periods, the construction management QA team will conduct daily observations for the presence of nesting migratory birds. Observations of nesting migratory birds will be documented in the daily and weekly QA reports, when applicable. If upland construction activities (e.g., removal of trees) have the potential to disturb nesting migratory birds, the project team will inform EPA to determine if any mitigation actions (e.g., nest removal) are needed. Impacts to trees or other habitat types containing migratory bird nests during nesting season that will be physically disturbed by construction are typically mitigated for by having a qualified biologist relocate them to another similar nearby habitat.

As a protected species, bald eagles also have specific protections. If the nearest documented bald eagle nest is within the approximately 400-foot minimum protected zone or buffer distances to the remedial construction activity, construction that is planned for within the protected zone or buffer distance must occur outside the bald eagle nesting season, which is from March through August. Construction work from September through February is typically not subject to a protected zone distance for bald eagle nests. If the nearest documented bald eagle nest is farther away from the project site than the buffer distances, the proposed action will be considered to be compliant with the Bald and Golden Eagle Protection Act. Information from the WDFW bald eagle database will be obtained prior to construction to determine whether any bald eagle habitats (e.g., nests, roosts, and forage) are present in the vicinity of the middle reach.

The WDFW promulgates the Washington State Hydraulic Code (WAC 220-660) for the protection of fish and wildlife species. Hydraulic code rules provide construction criteria and requirements and limitations, including for dredging, piers, piles, docks, bulkheads and bank protection. The code also provides specified technical provisions and special concerns to be considered to avoid or limit construction impacts. A Biological Assessment, or similar analysis evaluating impacts and avoidance and minimization measures, is typically used to help demonstrate Washington State Hydraulic Code compliance. The forthcoming Biological Assessment and supporting documentation will demonstrate that the project will meet the Hydraulic Code criteria for no net loss of ecological function and that the project achieves the protective intent and performance outcomes of the code. This includes implementing conservation measures identified by the Services. The project purpose is to cleanup contaminated sediments in the waterway, resulting in long-term benefits to species and habitats.

3.6 Floodplain Protection

In order to comply with the Floodplain Management Procedures (40 CFR 6, Appendix A, Section 6; see also Executive Order 11988), RD will avoid adversely impacting floodplains and wetlands wherever possible and consider flood hazards and floodplain management. If there is no practicable alternative to locating in or affecting floodplains or wetlands, potential impacts will be reduced to the extent practicable. In accordance with this regulation, the design will maintain the flood carrying capacity within the LDW. Section 9.9.1 describes the no-rise analysis that was considered as part of Intermediate (60%) RD.

3.7 Shoreline Management

The Shoreline Management Act (RCW 90.58; WAC 173-26) provides exceptions for cleanup actions. Per RCW 90.58.355 and WAC 173-27-044, remedial actions at a facility pursuant to a consent decree, order, or agreed order are not required to obtain shoreline permits or undergo local review. Although the project qualifies for an exception from the Shoreline Management Act, the remedial activities will be reviewed for substantive compliance. It is expected that proposed activities would all be allowed uses within the shoreline and would incorporate BMPs or conservation measures to avoid, reduce, or mitigate for potential adverse impacts to the shoreline environment, consistent with mitigation sequencing requirements.

Remedial activities include dredging, excavation, and debris removal; engineered capping; PD&C, clean material placement for backfill for habitat area restoration, residuals management cover (RMC), amended ENR, and ENR; overwater/in-water structure demolition, pile removal and re-installation, and construction access, staging, and transloading and/or containerization of contaminated materials for final off-site disposal at permitted landfill facilities. Remedial activities will occur within Shorelines of the State and upland areas within 200 feet of the ordinary high water mark. The project supports the Shoreline Management Act goal of protecting and restoring shoreline ecological functions through cleanup of contaminated sediments, and removal of contaminated debris and piles.

A habitat evaluation was completed as part of the Biological Assessment and has determined that the project will result in a net benefit to the shoreline environment, exceeding the minimum requirement of no net loss of ecological function. The modeling completed for the habitat evaluation demonstrates that the project will significantly improve ecological conditions within the shoreline environment relative to existing conditions and will result in long-term environmental benefits.

The designed remedial action is consistent with the policy objectives of the Shoreline Management Act (Chapter 90.58 RCW). The project restores ecological functions within a historically degraded shoreline while supporting the continued operation of water-dependent industrial and maritime uses within the LDW. Cleanup activities have been designed to limit temporary impacts during construction and provide long-term improvements to sediment quality, aquatic habitat, and shoreline ecological functions. Collectively, these actions advance the policy objectives of RCW 90.58.020 by protecting shoreline resources while supporting navigation, water-dependent uses, public health, and the long-term public interest as follows:

- Supporting statewide interests: The LDW includes shorelines of statewide significance and is one of Washington's principal maritime and industrial corridors. The remedial action advances statewide interests by restoring environmental quality within a major cleanup site while maintaining navigation, commerce, and other water-dependent uses that are vital to the regional and state economy. The project provides long-term public benefits through comprehensive remediation of legacy contamination while preserving the operational functions and uses of the shoreline.
- Supporting appropriate shoreline uses: The LDW includes a waterfront that support maritime commerce, navigation, terminals, and industrial operations. The remedial action addresses contaminated sediments (defined as up to MHHW), and thus, includes shoreline areas while supporting the continued long-term viability of water-dependent industrial and maritime uses and improving environmental conditions of the LDW.
- Protecting and restoring shoreline ecological functions: The remedial action will remove or isolate contaminated sediments, remove creosote-treated piles and contaminated debris within RAAs, restore impacted habitat through placement of clean material to pre-construction elevations, and implement MNR where appropriate. These actions improve aquatic habitat, sediment quality, and ecological functions consistent with the SMA restoration objectives.
- Protecting navigation and water-dependent uses: Construction activities will be coordinated to maintain safe navigation and operation within the waterway. Temporary work areas will be managed through appropriate navigation controls, and permanent remedial features are designed to be compatible with continued navigation, vessel operations, and other uses of state waters. Because sediment remediation must occur within waters of the state to achieve the remedial objectives, the project is inherently water-dependent.
- Preserving public access and recreational opportunities: The remedial action has been designed to preserve existing public access and recreational opportunities to the maximum extent practicable while accommodating construction activities and maintaining the

operational needs of the working waterfront. Temporary construction restrictions may be required for public safety; however, these will be limited in duration. By improving sediment quality, the project supports and preserves long-term recreational use of the LDW particularly where public access exists.

- Preserving public health, safety, and environmental quality: By addressing contaminated sediments, the project is reducing exposures for people and aquatic organisms, and thus, the cleanup advances the SMA objectives of protecting public health and conserving the natural resources and waters of the state for future generations.
- Supporting long-term environmental and economic benefits: The project provides remediation of sediment contamination while allowing continued operation of the working waterfront. The cleanup produces lasting environmental improvements that support aquatic resources, future economic activity, navigation, maritime commerce, and responsible shoreline use, consistent with the SMA preference for long-term benefits over short-term impacts.
- Limiting environmental impacts: Project design incorporates measures to reduce temporary construction impacts, including controls for water quality protection, noise, habitat protection, and construction timing. Where temporary impacts cannot be avoided, BMPs are incorporated to ensure no net loss of shoreline ecological functions consistent with applicable regulatory requirements.
- Providing coordinated shoreline management: The cleanup reflects coordination among EPA, Ecology, resource agencies, Tribal governments, local jurisdictions, and affected property owners. This coordinated approach promotes comprehensive shoreline management by implementing a watershed scale remedy that addresses contamination throughout the LDW.

3.8 Air Emissions and Noise

The following federal and state laws regulate the impacts of air and noise emissions:

- Clean Air Act (42 USC 7401-7671q; 40 CFR 50)
- Washington Clean Air Act (RCW 70.94; WAC 173-400)
- Noise Control Act (RCW 70.107; WAC 173-60-040, 050)

For the remedial action, reasonable precautions must be taken to: 1) prevent the release of air contaminants; 2) prevent fugitive dust from becoming airborne; and 3) maintain and operate the source to limit emissions (RCW 70.94). The design documents (i.e., the Specifications) will require that the contractor's operations limit air emissions. The project will comply with these ARARs through the development of the design Specifications and BMPs implemented during construction. The remedial action is being designed to be consistent with local air and noise ordinances.

Maximum permissible environmental noise levels for sound sources measured at or within the boundary of a receiving property, subject to exemptions, are specified in Section 10.3.1.1.2, and time-of-day considerations and construction BMPs are also included.

3.9 Historic Resources

The following federal and state laws regulate archaeological, cultural, and historic resources:

- National Historic Preservation Act Section 106 (16 USC 470; 36 CFR 800)
- Native American Graves Protection and Repatriation Act (25 USC 3001 et seq.)
- American Indian Religious Freedom Act (42 USC 1196 et seq.)
- Washington State Executive Order 21-02
- Archaeological Sites and Resources (RCW 27.53)
- Archaeological Excavation and Removal Permit (WAC 25-48)
- Abandoned and Historic Cemeteries and Historic Graves (RCW 68.60)

During RD, the potential effect of the remedial activity on any district, site, building, structure, or object included or eligible for inclusion in the National Register of Historic Places (NRHP) or of archaeological/cultural significance will be evaluated and described in correspondence with State and Tribal Historic Preservation Officers (SHPOs and THPOs) as part of EPA's Section 106 consultation process between EPA and the Washington State Department of Archaeology and Historic Preservation (DAHP). An archaeological monitoring and inadvertent discovery plan (MIDP) will be prepared and shared with SHPOs and THPOs during Pre-Final (90%) RD. The MIDP will be implemented by LDWG or the contractor during construction.

The LDW and its surrounding area have a long history of pre-colonial Tribal use, and cultural resources are known to exist in areas of land and shoreline along the waterway. It is possible that inadvertent disturbance of Native American or other cultural materials from earlier times may occur as a result of dredging or other ground disturbance. To protect Native American burials and cultural items, the regulations require that if such items are inadvertently discovered during excavation, the excavation must cease, and the affiliated Tribes and DAHP must be notified and consulted. The design documents (i.e., Specifications) will require the contractor to cease excavation should such items be observed in the materials being loaded onto the barges.

If Native American or other cultural materials may be unearthed as part of the remedial actions, the National Historic Preservation Act (16 USC 470), American Indian Religious Freedom Act (42 USC 1196 et seq.), and their implementing regulations require that federal agencies consider the possible effects on historic sites. If an agency finds a potential adverse effect on historic sites or structures, the agency must evaluate alternatives to "avoid, minimize, or mitigate" the impact, in consultation with the SHPO at DAHP.

There is one known specific historic feature located within the middle reach: the Georgetown Steam Plant and Pump Station. The Steam Plant was built in 1906 and 1907 by the Seattle Electric Company and, today, it is the last intact example of vertical Curtis turbines in the country. The Pump Station is an integral part of the Georgetown Steam Plant and was built in 1917 after the Duwamish River was straightened by USACE. The City of Seattle named the Pump Station a City of Seattle Landmark and decreed that the features of the landmark to be preserved include: the site, the waterside bulkhead, exterior and interior of Pump House, including the equipment, and the exterior of the Valve House and the equipment inside. The entire property (steam plant and pump station) has national, regional, and local significance and is officially listed on the following registers:

- NRHP
- National Historic Landmark (NHL)
- NRHP Multiple Property Submission "Hydroelectric Power Plants in Washington State, 1890-1938"
- American Society of Mechanical Engineers Historic Mechanical Engineering Landmark
- City of Seattle Landmark (Seattle Municipal Code [SMC] Chapter 25.12 [Landmarks Preservation])
- Duwamish Valley Community Resource

NRHP and NHL listings fall under Section 106 and Section 110 of the National Historic Preservation Act. Consultation must include the Advisory Council on Historic Preservation, Secretary of the Interior, DAHP, local Tribes, and public.

4 Extents of Contamination

This section describes the methods used to develop the horizontal and vertical extents of contamination for the site.

4.1 Horizontal Extents of Contamination

The horizontal extent of contamination was defined using the RALs and design dataset and applying geostatistical interpolation methods, as described in the DER (Anchor QEA and Windward 2025a). This delineates the areas with RAL exceedances in the middle reach. The horizontal extents of contamination adjacent to banks were extrapolated to the LDW Superfund Site boundary (i.e., MHHW elevation). A detailed analysis of the geostatistical interpolation methods and the RAL exceedance area maps is provided in Appendix J of the DER.

Horizontal interpolation method selection and application for the middle reach are the same as those applied for the upper reach. This was done for consistency with RD in the upper reach and because of the similarities of waterway processes and COCs across these two reaches. During RD for the upper reach, these methods were developed through a series of exploratory analyses and technical meetings with LDWG and EPA statisticians. Thus, the two selected interpolation methods are as follows:

- Indicator Kriging (PCBs): Indicator kriging was selected as the preferred method for PCB interpolation. In addition to its use for the upper reach, indicator kriging has been successfully applied to support RD and remedial action in the Lower Fox River, Green Bay, Wisconsin (Kern et al. 2008; Wolfe and Kern 2008; Anchor QEA and Tetra Tech 2016).
- Thiessen Polygons (other COCs): In localized areas, the RAL exceedance area boundary was expanded where other COCs exceeded RALs, but PCBs did not. The RAL exceedance area boundaries for COCs other than PCBs were established using Thiessen polygons, a simpler geometric and deterministic interpolation method.

Similar to the upper reach, PCBs were selected as the primary COC for geostatistical interpolation because PCBs delineate a majority[16] of the RAL exceedance areas in the middle reach. Other COCs exceeding RALs in localized areas were evaluated separately. Interpolations were performed on two sediment depth-defined datasets over which RALs are applied as follows:

- Surface Sediment: Defined as 0 to 10 cm (0 to 4 inches)

[16] Based on the results of the interpolation work described in the DER, PCBs were estimated to account for 88% of the RAL exceedance area in the middle reach. This percentage was calculated as the ratio of interpolated RAL exceedance area circumscribed by PCBs (in acres) to the total RAL exceedance area circumscribed by all COCs (see Maps J-6a and J-6b in Appendix J of the DER [Anchor QEA and Windward 2025a]).

- Subsurface Sediment: Defined as 0 to 45 cm (0 to 1.5 feet) in intertidal areas, 0 to 60 cm (0 to 2 feet) in subtidal areas, and shoaling intervals in the FNC[17]

The interpolated results for PCBs and other COCs in surface and subsurface sediments were combined in the final RAL exceedance area footprint, which served as the foundation for the RD to establish the horizontal extents of contamination.

Indicator kriging provides quantitative, probabilistic information directly in the interpolation output and is a primary line of evidence for assessing the uncertainty of the PCB RAL boundary. The indicator kriging results represent the probabilities of exceeding each of the applicable depth-specific and area-specific PCB RALs, expressed in units of percent. The indicator kriging maps presented in the DER include contours ranging from 20% to 80% probabilities of exceedance at 10% intervals (Maps J-3a through J-5b in DER Appendix J; Anchor QEA and Windward 2025a). Figures 4-1, 4-2a, and 4-2b show the 50% (median) PCB RAL exceedance boundary combined for both surface and subsurface sediments overlain with Thiessen polygons for other COCs where they extend beyond the PCB boundary in the middle reach. For SMA 10, the RAL exceedance boundary is shown in Figures 4-1a and 4-1c of Final (100%) RD for the LDW upper reach (Anchor QEA and Windward 2024c), which are also included in Appendix B. This area is labeled as RAL exceedance area 18 for the upper reach. Following the same approach used for the upper reach and as presented in the DER, the 50% probability of exceedance contour represents the median or central tendency estimate of the horizontal PCB RAL exceedance boundary (i.e., horizontal extent of contamination for PCBs). This median kriging estimate, which was also used on the Fox River and Hudson River sediment cleanup sites, was shown to provide a reasonable balance between effectively remediating contaminated sediments above the RALs and minimizing the remediation of non-target sediments below the RALs (Thornburg et al. 2005; QEA 2007; Kern et al. 2008; Wolfe and Kern 2008; Anchor QEA and Tetra Tech 2016).

Other COCs with RAL exceedances in the middle reach include dioxins/furans, metals (arsenic, cadmium, chromium, copper, lead, mercury, and zinc), polycyclic aromatic hydrocarbons (PAHs), phthalates, and other SVOCs. As done in the upper reach, the 50% (median) probability of the PCB exceedance contour plus Thiessen polygons for other COCs were used as the basis for setting RAL exceedance area boundaries in the middle reach.

In Section 5 of this BODR, RAL exceedance areas are developed into RAAs. The RAAs include engineering and constructability considerations, which typically results in RAA boundaries (i.e., the remediation footprint) extending beyond the interpolated RAL 50% probability exceedance area or

[17] The depth interval(s) for shoaling cores varies depending on the authorized depth and the amount of shoaled material at a given location. In order to define the horizontal extent of contamination, the maximum concentration in any shoaling interval or the overdredge interval (i.e., 2 feet below authorized FNC depth in the LDW) was selected for each shoaling core location.

Thiessen polygon boundaries. As a result, the design RAAs provide even greater confidence that RAL exceedances are being effectively addressed by RD.

In total, 36 distinct RAL exceedance areas were identified in the middle reach, as shown in Figure 4-3a. The RAL exceedance areas include areas with samples containing concentrations exceeding RALs and interpolation-only areas.[18] The RAL exceedance area for SMA 10 (i.e., upper reach RAA 18) is shown in Figure 4-3b.

4.2 Vertical Extents of Contamination

The vertical extent of contamination within RAL exceedance areas was defined on a point-by-point basis using sediment core sample data and engineering judgment that considered the conceptual site model and supplemental information (e.g., historical dredging depths in and adjacent to the FNC or berths, where available).

The ROD (EPA 2014) defines RALs for the applicable surface intervals (0 to 10 cm) and subsurface intervals (0 to 45 cm, 0 to 60 cm, or shoaling intervals). For defining the vertical extent of contamination, the lowest applicable RAL for a given location (which is generally the surface RAL) is used to evaluate the vertical extent (i.e., non-RAL) intervals.

Thus, contamination was considered vertically bounded if the core met one of the following criteria:

- Core with at least two clean 1-foot sampling intervals below contamination (where clean is defined as intervals with concentrations below the applicable surface RAL)
- Core where native material was encountered[19]
- Core with one clean interval above refusal

If a core does not meet any of these three criteria, the depth of contamination for that core is considered unbounded, although the determination as to whether this represents a data gap depends on the selected remedial technology. For example, in areas where PD&C is applied and greater than 1 foot of contamination remains, additional information on the depth of contamination may not be necessary. The application of these criteria to determine the depth of contamination in dredge areas is described in Appendix D. Additional vertical extent data will be collected during the

[18] Interpolation-only areas are defined as areas greater than 250 square feet that do not include a sample location with a RAL exceedance.

[19] As described in the LDW Middle Reach PDI QAPP (Windward and Anchor QEA 2022) and in the LDW Upper Reach Phase II DER (Anchor QEA and Windward 2022b), native material is defined as an alluvial unit that is composed primarily of sand with varying amounts of silt, as well as interbedded lenses of silt, clay, and poorly graded sand throughout. During the PDI for the upper reach, there were no RAL exceedances within vertical core intervals identified as native alluvium. Based on these findings, no intervals representing native alluvium were analyzed for cores in the middle reach (i.e., these intervals were assumed to represent clean material).

Phase III PDI to fill data gaps that were identified in Preliminary (30%) RD. The Pre-Final (90% RD) will reflect the Phase III PDI data and any associated adjustments to the RAAs.

5 Remedial Action Areas and Remedial Technologies

The development of RAAs is the next step after the RAL exceedance area designation in the DER (Anchor QEA and Windward 2025a). These areas were developed into RAAs based on three primary considerations: engineering considerations, review of adjacent chemistry results, and constructability of the range of applicable remedial technologies identified in the DER. Additionally, review of potential RAL exceedance area boundary uncertainties was performed as a modifying consideration. As part of Intermediate (60%) RD, RAA extents have been revised and refined to account for new information, as applicable. Once the RAA boundaries were established, remedial technology assignments were re-evaluated for each RAA.

This process is described in the following sections, with summarized information presented in Tables 5-1 and 5-2. These considerations will be refined as needed in subsequent design phases.

Figures 5-1a through 5-1f show the RAA boundaries in relationship to the RAL exceedance areas, and Figures 5-2a and 5-2b show the remedial technology selected for each RAA. Appendix D includes additional maps that illustrate the relationship between the RAA boundaries, the design dataset, and the interpolation results.

5.1 Engineering Considerations

One step in the RAA development process involved reviewing the interpolated RAL exceedance area boundaries with the overlying engineering design factors. These design factors vary slightly for each of the different remedial technologies but generally result in RAA boundaries that are more linear (e.g., straight lines) and expand the remedial action footprint to encompass a larger area compared to the RAL exceedance areas.

In some locations, engineering considerations result in an RAA boundary that is inside the interpolated RAL exceedance area boundary; for example, where construction offsets from structures or armored slopes will be required to protect structures or armored slopes. Areas where the RAA boundary may not capture the full interpolated RAL exceedance area boundary are discussed in Section 5.6.

The engineering considerations described in the following sections were used to define the Intermediate (60%) RD RAA boundaries.

5.1.1 Geometry Considerations

For RAAs where dredging or PD&C are the planned remedial technology, RAL exceedance areas were enclosed by dredging toe-of-cut boundary lines composed of straight lines and constructable angles for dredging feasibility. The toe of cut represents the boundary where the contractor will be required to conduct full vertical depth removal. The toe of cut is generally set at or outside of the RAL exceedance area boundaries (i.e., typically captures a larger area than the RAL exceedance area). For RAL exceedance areas that extend up a slope, the toe of cut was sometimes set inside the RAL exceedance area (e.g., south end of RAA 22, RAA 23A). In these cases, the dredge side slope was checked to confirm that the dredging removes the full depth of RAL interval exceedance within the full extent of the RAL exceedance area. For ENR and other material placement areas, the RAA boundaries were not squared off in straight lines because material placement over irregular shapes is less challenging than material removal. A 10-foot horizontal buffer was added around the RAL exceedance area boundary when developing ENR RAAs.

5.1.2 Site Physical Conditions

Factors including but not limited to slopes, berthing depth requirements, presence of debris, presence of armored slopes, presence of overwater structures, and presence of structures in the uplands adjacent to a bank were also considered. For example, when a RAL exceedance area is present on a sloped area, the RAA boundaries were developed using straight lines that were drawn parallel and perpendicular to existing contours to the extent possible. This was done to define action areas that are more stable for dredging and backfilling and to provide dredge prisms that are easier to measure during construction to confirm that the contractor is complying with Drawings and Specifications.

Site physical conditions specifically consider slope stability and offsets (discussed in more detail in Section 7) as follows:

- General Sediment Stability/Side-Slope Angles: Following initial definition of the toe of the dredge cut for dredge prisms, side-slope angles were established to leave a stable long-term post-dredge surface or to provide a slope angle that is stable during construction but would need to be backfilled to a flatter slope angle to achieve long-term stability. The side slope is the area over which the dredge cut slopes up from the dredge elevation/depth to meet the existing mudline. Side slopes are constructed at slope angles defined by recommendations from the geotechnical analyses (Section 7).
- Side Slopes for PD&C Areas in the FNC: For PD&C areas within the FNC, dredging depths were set to accommodate placement of cap materials to meet the requirements of the ROD (i.e., no cap shallower than 4 feet below the authorized depth). This leads to deep cuts that remove a significant portion of side-slope material outside the channel.
- Structure Offsets: For dredging and PD&C areas, horizontal offsets from structures (e.g., the 1st Avenue S Bridge, the Historic Intake Structure and associated wingwalls adjacent to Gateway Park) were included based on a review of available data compared to dredge depths. Horizontal offsets represent an area adjacent to the structure that needs protection where no

dredging or excavation will be allowed to prevent adverse impacts to the adjacent structure.[20] The offset distance includes a horizontal offset from the top of the daylight cut, which is where the dredge cut side slope intersects the existing mudline. For most ENR and area-specific technologies (ASTs) that include material placement, offsets were determined not to be necessary. One exception is that a 2-foot material placement offset has been applied from the wingwalls near the Historic Intake Structure.

- FNC Maintenance Modifications: Site geometry constraints north of the 1st Avenue S Bridge require special consideration to define the RAAs between RMs 1.8 and 2.0. The waterway in this area is very constricted and data indicate deep vertical extent of contamination and significant shoaling. Additionally, privately owned structures and critical infrastructure (i.e., overhead power line, access vaults related to utility crossings, and a confined sewer overflow [CSO] outfall) are present very close to the top of the existing bank along the east side of the waterway. A cap (following partial dredging) is required within the FNC for this area along with the eastern slope, but designing the dredge prism using the criteria in the ROD (i.e., 4-foot vertical buffer between top of cap and authorized depth) and stable side slope to be able to place cap material leads to a dredge cut that undermines the existing structures and critical infrastructure. Therefore, modifications to the horizontal and vertical extent of dredging are proposed as part of 60% RD. This is discussed in detail in Section 9.6.3.
- Utility Offsets: As discussed in Section 2.5, two submarine utility crossing corridors have been identified in the middle reach.
  - 1st Avenue South: As described in Section 2.5.3, there are various crossings along this utility corridor. The only active crossing is understood to be approximately 20 feet below the planned dredge elevation, and therefore no adjustments to the remedial action are required. The abandoned concrete utilidor is understood to be approximately 10 feet below the authorized dredging depth (i.e., elevation -40 feet MLLW) based on record drawings from installation of the utilidor in 1923. Therefore, the dredge elevation has been set at elevation -35 feet MLLW (i.e., 5-foot vertical buffer above assumed top of the abandoned utilidor). Based on proposed changes to future maintenance of the FNC described in Section 9.1.1.4, a partial dredge and cap is planned at this area.
  - 8th Avenue South: New information acquired during 60% RD indicates that there may be multiple telecommunications lines in this alignment. They are assumed to have been installed using directional drilling with the utility being deeper in the channel and shallower in the bank. As discussed in Section 2.5.3, the most recently installed line appears to be well below mudline (23 feet at time of installation), but the elevations of the older lines are unknown. Efforts to understand more about these crossings and fill

[20] Offsets are discussed further in Sections 7 and 8. A 5-foot dredge offset from structures is used in Intermediate (60%) RD.

the remaining data gaps are ongoing but for Intermediate (60%) RD, dredging has been updated to a partial dredge and cap configuration intended to avoid disturbing the utilities. This area will also require future FNC maintenance modifications, as discussed further in Section 9.6.3.

5.1.3 Adjacent Early Action Areas, Upland Site Cleanup, and Habitat Restoration Area Conditions

Another consideration used to define RAA boundaries included review of unique existing areas along the boundary of the site, including adjacent EAAs, upland cleanup sites, and habitat restoration areas. Each of these instances is described in detail, as follows:

- Adjacent EAAs: RAAs bordering EAAs were evaluated based on the horizontal and vertical extent of EAA post-dredge surfaces. In cases where buried contaminated material is interpreted to potentially remain between the RAA dredge prism and EAA post-dredge surface, RAA boundaries were expanded to create a continuous remedy. Specifically, this occurred for RAA 1A adjacent to the Boeing Plant 2 EAA. This evaluation occurred for the other middle reach EAA (i.e., Slip 4), and it was determined that no adjustments were required.
- Upland Site Cleanups: As discussed in Section 2.2, there are three Ecology-led upland cleanup sites that are adjacent to LDW middle reach RAL exceedance areas that will require coordination with Ecology, EPA, and LDWG during RD. These sites are Duwamish Marine Center, Douglas Management Dock, and Industrial Container Services. Section 2.2 and Appendix A detail the upland cleanup site conditions, cleanup status, and sufficiency assessment for these three sites and the other Ecology-led upland cleanup sites adjacent to the middle reach.
- Habitat Restoration Areas: The RAL exceedance area near one of the habitat restoration areas described in Section 2.4.11 (ṫałṫałucid Park) extends to the shoreline and appears to overlap with the habitat restoration area. The extent of potential overlap with the habitat restoration areas will be assessed during the Phase III PDI. If appropriate, design options to avoid impacting habitat will be evaluated during Pre-Final (90%) RD. Habitat areas will continue to be reviewed as design progresses to track if new habitat areas are constructed before middle reach remedial construction.

5.1.4 Review of Other Available Engineering Information that Informs the Physical Conceptual Site Model

Review of the USACE historical post-dredge and condition survey records from 1945 to 1978 indicated that maintenance dredging extended horizontally beyond the FNC in some locations during past dredge events. Additionally, there were previously large turning basins located at Myrtle Bay and north of the inlet at RM 2.2W. This information was generally considered in establishing RAA boundaries and depth of contamination. An example of how this information was applied was the transition from RAA 15A to 15B. The brown line in Figure D1-1g defines the best estimate of limits of past maintenance dredging performed by USACE and, in this area, illustrates that dredging was performed beyond the limits of the FNC boundary. This information was used in parallel to the vertical core data to establish dredge depths and the transition between remedial technologies (i.e., from dredge to partial dredge and cap).

5.2 Review of Adjacent Chemistry Results

Another step in developing RAAs involved reviewing design dataset sampling results immediately outside of the RAL exceedance areas. Sample results near RAL exceedance areas were reviewed on a point-by-point basis, and engineering best professional judgment was used to decide if and how far to extend each RAA boundary. The review included assessments of samples that were close to exceeding the RAL and samples located within beach play areas.

Samples that were close to exceeding the RAL (i.e., between a RAL exceedance factor[21] of 0.9 and 1) were reviewed with respect to proximity to RAL exceedance areas and magnitude of nearby exceedances. Data density was also considered when looking at specific areas where expansion of RAAs beyond the initial engineering considerations could be warranted. Five sample locations were identified: SS1332 (RAA 30F), SS1055 (RAA 30F), SS1591 (RAA 24H), SS1144 (RAA 22), and SC1151 (RAA 23A). Samples SS1591, SS1144, or SC1151 coincide with dredging activities and will be addressed by RMC placement. Samples SS1332 and SS1055 are more than 100 feet from the closet RAA (RAA 30F) and will not be covered by RMC placement.

5.3 Constructability

After defining RAAs based on engineering considerations and a review of adjacent chemistry data, areas were reviewed from a holistic perspective to identify potential constructability issues and reduce complexity from a contractor's constructability standpoint. Constructability refers to the ease and feasibility for a remediation contractor to construct elements of the design and is affected by the type of equipment the contractor uses, physical site conditions, and ability by the Owner to effectively monitor and measure the contractor's work. Similar to engineering considerations, constructability considerations typically expand the area covered by an RAA (compared to the RAL exceedance area). Areas where the RAA boundary may not capture the entire RAL exceedance area boundary are discussed in Table 5-2.

[21] A RAL exceedance factor is the ratio of the concentration to the RAL. An EF greater than 1 indicates a concentration greater than the RAL.

Modifications to RAAs to address constructability considerations include the following, as appropriate:

- Merging of areas near one another: Leaving small areas between RAAs will complicate construction and reduce efficiency. Remediating those small areas between RAL exceedance areas can also help address other practical considerations such as residuals management requirements.
- Incorporating small areas that are contained within a large RAL exceedance area but where the interpolation predicts there is not a RAL exceedance: Although these small interior areas with no RAL exceedances do not require action, the RD assumes that including these areas (e.g., RAA 14) will result in overall more efficient and cost-effective remediation than relying on the precision that would be necessary to exclude these areas.
- Considering equipment access limitations: Site restrictions that may limit the ability for equipment access will be evaluated to avoid specifying a remedial action that is not feasible to construct due to equipment inaccessibility. As of Intermediate (60%) Design, no RAAs have been reduced due to equipment access limitations alone.

5.4 Consideration of Interpolation Uncertainties in RAA Boundaries

This section discusses interpolation uncertainty and how such uncertainty may inform further adjustments to RAA boundaries beyond the adjustments already made for engineering considerations, review of adjacent chemistry results, and constructability.

As noted in Section 4.1, the 50% probability of exceedance contour for PCBs in combination with Thiessen polygons for other COCs (i.e., RAL exceedance areas) was used as the RAL exceedance boundary, which was the starting basis for setting RAA boundaries. During their development, RAA boundaries were compared against the RAL exceedance area probability of exceedance contour banding maps that showed probability from 20% to 80% of PCBs exceeding RALs based on data interpolation.

Figures D1-2a and D1-2b (Appendix D) show the boundaries of RAL exceedance areas, probability of exceedance bands (20% to 80%), and the Intermediate (60%) RD RAA boundaries. As the figures show, the RAA boundaries typically extend well beyond the RAL exceedance area boundaries due to design adjustments for engineering factors, adjacent sediment chemistry, and constructability. Therefore, no additional adjustments are recommended for Intermediate (60%) RD. The width of the uncertainty ranges (i.e., probability of exceedance bands) remaining outside of the RAA boundaries have been considered when evaluating additional Phase III sampling locations, and results of those analyses will be factored in during Pre-Final (90%) RD.

5.5 Remedial Technology Assignments

Remedial technology options were identified for each RAL exceedance area in the DER (Anchor QEA and Windward 2025a). Remedial technologies are assigned to each RAA using the same procedure documented in Figure 19 and Revised Figure 20 of the ROD (EPA 2014) and taking into account many factors including mudline elevation, RAL exceedance factor, depth of contamination, and recovery category designation.

Potential remedial technologies identified in the ROD (EPA 2014) for intertidal and subtidal areas include the following:

- Intertidal:
  - MNR below benthic SCO[22]
  - MNR to benthic SCO[23]
  - AST
  - ENR
  - Partial dredge and cap
  - Dredge and backfill
- Subtidal:
  - MNR below benthic SCO
  - MNR to benthic SCO
  - AST
  - ENR
  - Partial dredge and cap
  - Dredge (with backfill in habitat areas)
  - Engineered cap

The preliminary remedial technology assignments from Table K1-1 of the DER (Anchor QEA and Windward 2025a) included multiple technology options for areas with data gaps or areas that spanned boundaries with different applicable technologies (e.g., intertidal/subtidal areas, recovery categories, large areas with varied sample results). For the Intermediate (60%) RD, the technology assignments for each RAA have been updated based on site condition information and engineering considerations and are summarized in Figures 5-2a and 5-2b. Refer to Section 9.7 for further discussion on areas suitable for MNR.

[22] Per the ROD, MNR below benthic SCO will be applied where the concentration of all COCs is less than the RAL and the RAO 3 cleanup levels (benthic SCO criteria) but greater than the human health-based (RAOs 1 and 2) cleanup levels (which are measured on an LDW-wide or area-wide basis; EPA 2014).

[23] Per the ROD, MNR to benthic SCO will be applied where the concentration of any of the 39 RAO 3 COCs (i.e., excluding the human health COCs PCBs and arsenic) is less than the RAL but greater than the RAO 3 cleanup levels (benthic SCO criteria; Table 27 of the ROD [EPA 2014]) and modeling results indicate that the COC will be reduced to the benthic SCO criteria within 10 years of the completion of remedial action (EPA 2014).

In most RAAs, the selected technology can be implemented without special design considerations or need for additional data. Table 5-1 summarizes the RAAs that will require additional consideration in later design stages to finalize remedial technology assignments.

Table 5-1
RAAs with Additional Design Considerations for Final Remedial Technology Selection

RAA	Intermediate (60%) RD Technology Assignment[1]	Notable Factors Impacting Final Technology Assignment
2	Dredge	The vertical extents of contamination are not fully defined. Additional vertical sampling will occur in the Phase III PDI to confirm the appropriate technology (dredge or PD&C).
3	ENR and ENR in Berthing Area (AST)	ENR is proposed for the underpier slope and within the adjacent permitted berthing area in this RAA, the latter of which is classified as an AST. See Section 9.6.2 for further discussion on this AST.
4	Dredge	The vertical extents of contamination are not fully defined. Additional vertical sampling will occur in the Phase III PDI to confirm the appropriate technology (dredge or PD&C).
5A	Amended ENR (AST)	An AST of amended ENR will be applied to the riprap slope and underpier portion of this area. See Section 9.6.1 for further discussion on this AST.
8B	PD&C	The vertical extents of contamination are not fully defined. Additional vertical sampling will occur in the Phase III PDI to confirm the appropriate technology (dredge or PD&C).
8C, 8G	Amended ENR (AST)	These areas are under or adjacent to structures and include sample locations that exceed the ENR upper limit. Therefore, an AST (i.e., amended ENR) will be applied to these subareas. See Section 9.6.1 for further discussion on this AST.
9K	PD&C (AST)	This area has a submarine utility crossing running through the RAL exceedance area. This feature requires protection; therefore, a modified cap as an AST is being adopted. See Section 9.6.3 for further discussion on this AST.
9L, 9M	Amended ENR (AST)	These areas are adjacent to a historic structure that requires protection; therefore, an AST is being adopted. See Section 9.6.1 for further discussion on this AST.
10	None	This is an interpolation-only area that will be verified during the Phase III PDI.[2] A remedial technology will be applied to this RAA if Phase III PDI results indicate that a RAL exceedance exists.
12	Dredge	The vertical extents of contamination are not fully defined. Additional vertical sampling will occur in the Phase III PDI to confirm the appropriate technology (dredge or PD&C).
13	None	This is an interpolation-only area that will be verified during the Phase III PDI.[2] A remedial technology will be applied to this RAA if Phase III PDI results indicate that a RAL exceedance exists.
14A	PD&C	The vertical extents of contamination are not fully defined. Additional vertical sampling will occur in the Phase III PDI to confirm the appropriate technology (dredge or PD&C).

RAA	Intermediate (60%) RD Technology Assignment[1]	Notable Factors Impacting Final Technology Assignment
14B	Dredge	The vertical extents of contamination are not fully defined. Additional vertical sampling will occur in the Phase III PDI to confirm the appropriate technology (dredge or PD&C).
20A	Amended ENR (AST)	An AST has been applied to avoid impacts to the steeply armored slope. Amended ENR will be placed over the riprap. See Section 9.6.1 for further discussion on this AST.
21A	Dredge	The vertical extents of contamination are not fully defined. Additional vertical sampling will occur in the Phase III PDI to confirm the appropriate technology (dredge or PD&C).
24B–24D	Excavation Behind Cofferdam (AST)	Sediment from these areas will be removed using dry excavation methods for the following reasons: 1) tidal conditions restrict efficient access for dredge equipment; 2) significant volumes of debris are present; 3) high concentrations of contaminants are present; and 4) the area can feasibly be isolated with a cofferdam that would facilitate removal and reduce environmental impacts during construction. Selection of this technology will also facilitate removal outside of the standard environmental window because the area will be isolated from the waterway. See Section 9.6.5 for further discussion on this AST.
24E–24G	Dredge	The adjacent upland properties have active MTCA cleanup projects that have uncertain timelines in which upland remedy selection and design will be completed. The upland remedy selection could potentially affect the final technology selection, and upland timing could impede RD development.
26	Cap (AST)	An AST has been applied to the area to avoid impacts to an over-steepened slope. The approach includes capping on existing grade. See Section 9.6.4 for further discussion on this AST.
29	Dredge	The results of anticipated Phase III PDI bioassay testing may result in a change to the selected remedial technology to ENR.[3]
30C–30G	PD&C	A revised dredge and cap depth (refer to Bullet No. 4 in Section 5.1.2) and an adjustment to the maintained FNC alignment was designed to avoid undermining private structures and infrastructure along the shorelines.
31B–31D	PD&C	The adjacent upland properties have active MTCA cleanup projects that have uncertain timelines in which upland remedy selection and design will be completed. The remedy selection could potentially affect the final technology selection, and upland timing could impede RD development. There are also challenges with protecting the utilities located within this RAA.
34A	Dredge	The results of Phase III PDI sampling and analysis may result in a change to the selected remedial technology to partial dredge and cap because the vertical contamination adjacent to the structure is not defined.

RAA	Intermediate (60%) RD Technology Assignment[1]	Notable Factors Impacting Final Technology Assignment
SMA 10	Dredge; Amended ENR (AST)	The results of anticipated Phase III PDI and Boeing Isaacson Thompson Pre-Remedial Design Investigation sampling and analysis may result in a change to the selected remedial technology to PD&C depending on depth of contamination near and upland of the bulkhead. An AST (amended ENR) will be applied to the dredge offset (SMA 10H) from the southern portion of the bulkhead that will remain. See Section 9.6.1 for further discussion on this AST.

Notes:

1. The technology assignment of dredge also requires backfill to restore existing grade in habitat areas (i.e., -10 feet MLLW and above). Additionally, all dredge areas receive a placement of RMC. Refer to Section 9.1 for additional details.
2. Interpolation-only areas are artifacts from the interpolation analysis and do not include a sample location with an associated RAL exceedance.
3. Per the ROD (EPA 2014), benthic toxicity testing can be used to delineate RAL exceedance areas if there are no human health RAL exceedances. Specifically, ROD Table 20 has a footnote that states, "Benthic SCO biological criteria (WAC 173-204-562, Table IV) may be used to override benthic SCO chemical criteria where human health-based RALs are not also exceeded" (EPA 2014). For RAA 29, benthic toxicity testing is planned as part of Phase III PDI to evaluate the BBP RAL exceedance (note that the PCB exceedance cannot be overridden by toxicity testing).

AST: area-specific technology
BBP: butyl benzyl phthalate
ENR: enhanced natural recovery
MLLW: mean lower low water
MTCA: Model Toxics Control Act
PCB: polychlorinated biphenyl
PDI: pre-design investigation
PD&C: partial dredge and cap
RAA: remedial action area
RAL: remedial action level
RD: remedial design
RMC: residuals management cover
ROD: *Record of Decision*
SCO: sediment cleanup objective
SMA: sediment management area
WAC: Washington Administrative Code

5.6 Summary of Remedial Action Areas

Figures 5-2a and 5-2b provide an overview of the selected remedial technology for each RAA. Table 5-2 summarizes the unique or specific considerations for each RAA beyond the general considerations described in Section 5.1. The total surface area of the RAL exceedance areas included in the Intermediate (60%) RD, delineated as described in Section 4, is 980,000 square feet (or 22.5 acres). For comparison, the total surface area of the RAAs is 1,646,500 square feet (37.8 acres), which is a 68% increase from the RAL exceedance areas. Appendix E discusses additional RAAs for areas where the ROD (EPA 2014) cPAH RALs were considered.

Table 5-2
RAA Development Considerations

RAL Exceedance Area	Area-Specific RAA Development Considerations[1]
1	• Eastern boundary expanded slightly to overlap with Boeing Plant 2 EAA based on review of as-built survey data. • Southern boundary expanded slightly to overlap with upper reach SMA. • RAA limits expanded beyond RAL exceedance areas due to constructability considerations.
2	• None.
3	• AST C (i.e., ENR within a permitted berthing area) will be applied to the portion of the RAA within the berth.
4	• None.
5	• AST B (i.e., amended ENR) will be applied to the underpier and riprap slope portion of this area (RAA 5A). • Dredging offset from wharf applied in RAA 5B.
6	• None.
7	• None.
8	• AST B (i.e., amended ENR) will be applied to the underpier portion of this area (RAA 8C) and the slope area supporting the existing outfall structure (RAA 8G). • Dredging offset from wharf applied in RAAs 8A and 8D–8F; amended ENR from RAA 8C to be extended into offset area. • The limits of RAAs 8A and 8F are set approximately at the MHHW mark; however, slope excavation limits may extend further up slope based on survey data collected as part of the Phase III PDI and constructability evaluations performed during Pre-Final (90%) RD. Based on the results of the Phase III PDI, the limits of RAA 8A may also be adjusted to protect the adjacent habitat restoration area.
9	• Dredging offset applied in areas 9C, 9D, and 9F to protect the Historic Intake Structure and associated timber wingwalls. AST B (i.e., amended ENR) will be placed in the dredging offset (9L and 9M). • Material placement offset applied in areas 9L and 9M to protect the Historic Intake Structure and associated timber wingwalls during construction. • Transition of thickness cut into shoreline considers the location of the boundary between the upland property and Port of Seattle sliver property for area 9I. • Interpolation incorrectly extrapolates the RAL exceedance area boundary to behind a vertical wall; therefore, the eastern toe of RAA 9F was adjusted accordingly. • The limits of RAAs 9A, 9C, and 9F are set approximately at the MHHW mark; however, slope excavation limits may extend further up slope based on survey data collected as part of the Phase III PDI and constructability evaluations performed during Pre-Final (90%) RD. The design for the slope may also be adjusted as additional details regarding the adjacent upland cleanup develop. • AST D is applied to area 9K to address conditions described in Section 5.1.2.
10	• This is an interpolation-only area; to be confirmed with collection of Phase III PDI data.
11	• None.
12	• None.
13	• This is an interpolation-only area; to be confirmed with collection of Phase III PDI data.

RAL Exceedance Area	Area-Specific RAA Development Considerations[1]
14	• A sunken barge within the dredge prism will be removed (as part of this project) prior to dredging. • RAA limits expanded beyond RAL exceedance areas due to constructability considerations in the FNC.
15	• None.
16	• Dredging offset from wharf applied.
17	• None.
18	• None.
19	• None.
20	• Dredging offset from armored slope applied for RAAs 20B; an AST (i.e., amended ENR) is to be placed in offset area and on slope (RAA 20A).
21	• The limits of RAA 21A is set approximately at the MHHW mark; however, slope excavation limits may extend further up slope based on survey data collected as part of the Phase III PDI and constructability evaluations performed during Pre-Final (90%) RD.
22	• None.
23	• None.
24	• The limits of RAAs 24B–24H are set approximately at the MHHW mark; however, slope excavation limits may extend further upslope based on survey data collected as part of the Phase III PDI and constructability evaluations performed during Pre-Final (90%) RD. The limits may also be affected by the remedy selected for the adjacent MTCA upland cleanup projects. • AST F is being applied to RAAs 24B–24D to provide excavation in the dry. • A temporary cofferdam is anticipated with two possible alignments, as shown on the 60% Drawings. • A temporary shoring wall is anticipated along the northern extents of RAA 24C.
25	• None.
26	• Shoreline cap is to be placed as AST E (capping on grade) with limited debris removal.
27	• None.
28	• None.
29	• Dredging offset from boat ramp applied (RAL exceedance area includes a portion of the concrete ramp).
30	• Dredging offset from 1st Avenue S Bridge applied for areas 30B and 30C. • Restrictions on dredge depths and adjustments to the maintained FNC are being applied to protect private buildings and critical public infrastructure in and adjacent to areas 30C through 30G, as described in Section 5.1.2.
31	• The limits of RAA 31C are set with the assumption that the adjacent building and marina structures will be demolished before dredging. The limits may be further adjusted to align with the remedy selected for the adjacent MTCA upland cleanup project.
32	• None.
33	• None.
34	• Dredging offset from structure applied. Additional chemistry and geotechnical data collected as part of the Phase III PDI will result in design refinements during Pre-Final (90%) RD.

RAL Exceedance Area	Area-Specific RAA Development Considerations[1]
35	• Extent of riprap determined based on review of high-quality aerial photogrammetry; ENR applied over this area (35B). • Dredging offset from riprap applied (35A).
36	• None.
SMA 10	• Dredge offset applied in areas SMA 10B and SMA 10D to protect the bulkhead structure (to remain) during construction; AST B (i.e., amended ENR) will be applied to this area (SMA 10H). • Southern boundary of RAA limit expanded beyond RAL exceedance areas due to constructability considerations

Notes:

1. An entry of "none" indicates that no additional considerations were used in establishing the Intermediate (60%) RD RAA limits. AST designations are described in Section 9.6.

AST: area-specific technology
EAA: early action area
ENR: enhanced natural recovery
FNC: federal navigation channel
MHHW: mean higher high water
MTCA: Model Toxics Control Act
PDI: pre-design investigation
RAA: remedial action area
RAL: remedial action level
RD: remedial design
SMA: sediment management area

6 Sediment Management Areas Development

SMAs[24] will be developed as part of the Pre-Final (90%) RD to facilitate construction management by organizing the overall project into more manageable areas. SMAs do not change the RAA extents; rather, they provide a consistent nomenclature for referring to areas in design and construction management. Generally, SMAs will consist of grouped or subdivided RAAs with similar logistical considerations, such as common construction methods, adjacent locations, and similar site conditions. SMAs will be used in the Drawings to define discrete areas for construction management (e.g., construction sequencing, determining the completion of the remedial actions). SMAs may also serve as areas over which remedy construction performance can be evaluated, contingency actions can be performed as needed, and areas can be determined complete as the cleanup progresses.

SMAs will be divided into Decision Units (DUs), that will be used to review and accept work as construction progresses. Work within an SMA will be allowed to span seasons (if logistically necessary) to provide flexibility to the contractor, but work within discrete DUs must be completed within one season. SMA subdivisions are based on engineering judgment and do not take into account the means, methods, and production rates of the contractor. As such, the contractor may propose adjustments to the division of the SMAs (e.g., modifying location of boundary between contiguous SMAs to optimize production within one season) as the construction season progresses.

As a starting point for the LDW middle reach, SMA numbering will continue the numbering system developed for the upper reach, with middle reach numbering starting at SMA 19 and counting up. With this approach, each SMA in the LDW will have a unique identifier. Factors that affect SMA delineation include recontamination risk of remediation areas and adjacent areas during construction, technology types and construction methods, and administrative and site access considerations, as discussed in the following subsections.

6.1 Recontamination Risk During Construction

The development of SMAs will consider the potential for recontamination of remediated areas and adjacent areas that are not actively remediated as the construction progresses. The following considerations will be reviewed to develop SMAs that limit the risk of recontamination during construction:

- The proximity of RAAs to each other
- Potential vessel propwash from contractor operations
- Remedial technologies being used (i.e., dredging and placement activities)
- The phasing of dredging and placement activities

[24] SMAs for RD are used in a different context than described under Washington State Sediment Management Standards. Under these standards, SMAs support cleanup decision-making during the RI/FS. For the remedial design described in this BODR, SMAs are used to organize the RD for other reasons, as described in the RDWP (Anchor QEA and Windward 2022a).

- Construction activities occurring over multiple in-water work seasons

If it is determined that RAAs have the potential to pose a recontamination risk to one another, this would be a reason to combine these RAAs within one SMA such that the sequencing of the work within the individual SMA can be completed in an appropriate order to reduce the potential for recontamination.

6.2 Technology Types and Construction Methods

The type of remedial technology or equipment used to implement the remedy at a specific location will also be a factor in developing SMAs. There is a preference to consolidate and complete areas with similar technology types at the same time within the construction sequence to improve quality control and to simplify contract management and construction operations to avoid excessive equipment in the work area simultaneously. Dredging activities would generally be performed before placement activities.

6.3 Administrative and Site Access Considerations

Administrative considerations will also be considered in developing the SMAs, including site access constraints and property ownership. Combining areas with similar administrative considerations will facilitate efficiency by allowing for work with similar constraints to be completed together, limiting interruptions to waterway activities.

7 Geotechnical Engineering Considerations

This section presents the results and recommendations of the geotechnical engineering evaluations for the LDW middle reach. Appendix F presents a more detailed discussion of the geotechnical engineering evaluations completed to support RD.

7.1 Geotechnical Field Investigation Summary

Subsurface geotechnical conditions at the site were investigated by Anchor QEA as part of the Phase I and Phase II PDI efforts completed in 2022 and 2023. The DER (Anchor QEA and Windward 2025a) and Appendix F of this BODR describe the geotechnical investigation and results.

The locations of these geotechnical investigations are presented in Figures 7-1a through 7-1e for the middle reach. Locations of geotechnical investigations in the SMA 10 vicinity are presented in Figure 8-1a of the Final (100%) RD for the LDW upper reach (Anchor QEA and Windward 2024c), which is also included in Appendix B. Additional details, including boring logs, in situ testing data, and results of laboratory geotechnical testing results, are presented as attachments to Appendix F.

7.2 Subsurface Stratigraphy

This section describes the three major geologic units encountered during the geotechnical PDI. Subsurface conditions encountered during the geotechnical investigation are in general agreement with those presented in the RI/FS and consist of recent sediments overlying alluvium within the waterway. Fill material was encountered overlying the alluvium unit in upland locations, and based on the history of river realignment, it is expected to be present in shoreline bank areas to below MLLW where the historical river channel was filled and in other shoreline locations where the grade was raised to support upland development.

General descriptions of the soil and sediment layers and their geotechnical characteristics identified from the borings and investigations advanced at this site are presented in the following sections in order from the ground surface downward.

7.2.1 Fill

Fill soils were encountered at the 13 upland boring locations during the Phase II PDI and at several other upland locations investigated by others. The fill was observed to extend to depths of 5 to 30 feet below ground surface in the upland borings. Given the river history of channelization, fill is likely present along many banks of the middle reach that have not been geotechnically investigated.

Generally, the fill material had been placed to regrade the existing fluvial plain created by the Duwamish River to support shoreline development and re-channelization of the LDW. The unit weight of this material is assumed to vary, but to prepare design recommendations, the material is assumed to be conservatively represented by an overall average value of 125 pounds per cubic foot (pcf) based on laboratory direct shear test results, and as correlated to standard penetration test results in this unit (average 126 pcf, range 84 to 140 pcf). Grain-size distribution tests (sieve and hydrometer) show that this material is predominantly sands and gravels with varying amounts of silt and clay. Silt with varying amounts of sand, gravel, and clay was also observed within the fill layer. Wood fragments and cobbles were also observed. In areas where fill was more randomly placed, it would be expected to contain anthropogenic materials such as debris, which would be typical of historical shoreline development filling activities in active commercial and industrial areas. The geotechnical moisture content in the fill unit generally ranges from 5% to 174%, with an average of 33%. Direct shear testing of the fill indicates a peak friction angle average of 37 degrees. Standard penetration tests indicate a friction angle average near 33 degrees based on an average corrected blowcount $(N_1)_{60}$ of 18 (range 0 to >50).

Unified Soil Classification System (USCS) classifications of sample intervals from this unit include GM, SP, SM, and ML.

7.2.2 Recent Sediments

Recent sediments are defined as material that has deposited on top of the alluvium layer and are distinctly characterized by finer gradation and soft consistency compared to the alluvium layer beneath. Recent sediments were encountered throughout the intertidal and subtidal areas, having been naturally deposited by flows to the LDW middle reach from the Green River upstream. The thickness of this unit across the site varies widely, from less than 3 feet to more than 20 feet, and is observed to be thickest in areas of historical dredge activities in the FNC.

Based on a review of laboratory testing results, a total unit weight of 100 pcf was assumed to best represent average overall conditions. This is within the range of correlated standard penetration test results (average 104 pcf, range 84 to 119 pcf). The geotechnical moisture content ranges from 27% to 107% and an average of approximately 67%. Atterberg limits (plasticity) testing indicates that this material is typically non-plastic to very low plasticity, an indication that the finer fractions are predominantly silt rather than clay. The plasticity index ranges from 10% to 21% and liquid limit ranges from 45% to 63%. Grain-size sieve and hydrometer analyses indicate that this material is approximately 25% sand and 75% silt and clay, with silt content ranging from 47% to 72% and clay content ranging from 8% to 24%. Standard penetration test results indicate an average corrected blowcount $(N_1)_{60}$ of 4 (range 0 to 31).

USCS classifications of sample intervals from this unit include OL, OH, ML, MH, and SM.

7.2.3 Alluvium

Investigations prior to the PDI describe the alluvium by referencing an upper alluvium unit and a lower alluvium unit. Because the distinction between the upper alluvium and lower alluvium is not important in the context of the sediment cleanup, in the DER, the description of the alluvium was simplified by combining the upper alluvium and lower alluvium into a single alluvium unit, recognizing that there are some gradational changes in the alluvium with depth (Anchor QEA and Windward 2025a).

Alluvium was observed to underlie the recent sediments and consists primarily of sand with varying amounts of silt, gravel, and clay, as well as interbedded lenses and layers of silt and clay. The upper 2 to 15 feet of this unit, where disturbances have occurred, contains significant wood and sometimes anthropogenic debris. Grain-size sieve and hydrometer analyses indicate that this material is approximately 68% sand and 32% silt and clay, with silt and clay content averaging 23% and 9%, respectively. The alluvium unit has a typical specific gravity of 2.5 to 2.7, is non-plastic and has a typical total unit weight of 125 pcf (standard penetration test correlated average of 126 pcf and range of 105 to 128 pcf) and a measured peak friction angle of 43 degrees. Standard penetration tests indicate a friction angle average near 32 degrees based on an average corrected blowcount $(N_1)_{60}$ of 16 (range 0 to >50). The measured geotechnical natural moisture content within this unit ranges from 9% to 69%, with an average of approximately 32%.

USCS classifications of sample intervals from this unit include SP, SP-SM, and SM. The alluvium unit was the deepest layer encountered during the geotechnical PDI, and because the bottom of this unit was not reached, the thickness of this unit was not determined. Based on geologic information presented in the FS (AECOM 2012), it is inferred that a dense glacial or post-glacial unit of transitional silts underlies the alluvium

7.3 Geotechnical Engineering Design Recommendations

This section summarizes the results and design recommendations based on the geotechnical analyses presented in Appendix F for the following:

- Dredging geotechnical design, including dredge prism slope stability and dredging offsets from structures
- Capping geotechnical design, including bearing capacity, settlement, slope stability, and seismic performance
- Lateral earth pressures for bulkhead evaluations
- Geotechnical recommendations for pile design
- Bank and backfill slope stability

Details regarding the processes, assumptions, models, and approach used to develop the geotechnical engineering design recommendations are provided in Appendix F. The following sections describe the results of these analyses as they relate to RD.

7.3.1 Dredging Geotechnical Evaluations

This section describes geotechnical evaluations of dredging side slopes and dredging offsets from structures.

7.3.1.1 Dredge Prism Slope Stability

Dredging is required on intertidal and subtidal slopes, and dredge cuts also require side slopes to reach the design removal elevation or depth. The stability of dredge prism side slopes was evaluated using limit equilibrium methods implemented by the Rocscience SLIDE2 software (SLIDE).

Target slope stability factors of safety are 1.3 for short-term conditions (e.g., a dredge cut before backfill is placed), 1.5 for long-term conditions (e.g., a final post-backfill slope angle), and 1.3 for rapid drawdown conditions in accordance with USACE (2003).

As described in Appendix F, temporary side slopes of 2 horizontal to 1 vertical (2H:1V) and permanent unarmored side slopes of 3H:1V generally have acceptable factors of safety. Where factors of safety are below target, additional modeling evaluations will be conducted during the next phase of RD.

Where steeper permanent side slopes are required, larger angular backfill can be used as described in Appendix F.

7.3.1.2 Evaluation of Dredging Offsets from Structures

As described in Appendix F, dredging immediately adjacent to shoreline structures will reduce the lateral support provided by the sediment adjacent to the structure (i.e., the passive earth pressure). Reduction in passive earth pressure can cause structural damage if not appropriately considered in the RD. One way to limit or prevent the reduction of passive earth pressure is to offset the dredge cut a sufficient distance from the structure. This section provides a summary of the dredge offset evaluation that is described in more detail in Appendix F.

The extent to which passive earth pressure is reduced by adjacent dredging is a function of the offset distance, the depth of dredging, and the slope angle of the dredge cut. Appendix F presents the following conclusions from this evaluation:

- Without a dredge offset, resisting forces in sediment (i.e., passive earth pressures) are reduced to 38% to 75% of full passive earth pressure for dredge slope cuts ranging from 1H:1V to 2H:1V, respectively.

- A horizontal dredging offset of at least 5 feet will limit the potential for reducing passive earth pressure. The RD generally assumes a 5-foot offset from structures, which considers the geotechnical evaluation as well as additional safety measures that will limit the potential for dredging equipment to physically contact and potentially damage structures.
- Dredging will be performed adjacent to the north and south wing walls associated with the Historic Intake Structure at RAAs 9C through 9F (adjacent to Gateway Park). Due to the historic designation of the wing walls, poor structural conditions, and the nature of the soft sediment surrounding the wing walls, the offsets from the north and south wing walls should be 15 feet and 10 feet, respectively.
- Passive earth pressure reduction factors are presented in Appendix F for use during structural evaluations to consider whether any structures can tolerate a dredging offset that is closer than 5 feet.

Note that this assessment generalizes structure types and does not account for the condition of the structure. Additional data collection to support site-specific geotechnical and structural conditions will be described in the Phase III QAPP Addendum. Supplemental geotechnical analyses will be conducted during subsequent RD, as appropriate, including further consideration of the Historic Intake Structure.

7.3.2 Capping Geotechnical Evaluations

This section describes geotechnical evaluations for the following factors that govern cap design. Backfill geotechnical evaluations are described in Section 7.3.6. The following cap design geotechnical evaluations were performed:

- Bearing capacity, which evaluates the degree to which the subgrade strength is sufficient to support the weight of the cap
- Settlement, which evaluates whether the subgrade beneath the cap will compress under the weight of the cap
- Slope stability, which evaluates the degree to which the cap and the subgrade will remain stable (not move) in sloped areas

Caps were preliminarily assessed assuming a 4-foot thickness based on the cap thickness designed for the upper reach.

Caps will typically be constructed after dredging or excavation and in most cases will not raise the ground surface above the existing grade. As such, caps constructed under these conditions will balance out the subgrade loads by replacing the load imposed by the dredged sediment (unloading the subgrade) with a load imposed by the cap. For these conditions, the bearing capacity of the subgrade to support the cap was calculated and found to have an acceptable factor of safety. The settlement caused by the cap load is estimated to be on the order of 2 to 3 inches. Differential settlement of the cap or the cap subgrade is not anticipated to be significant and would not reduce the effectiveness of caps if it were to occur, as discussed in Appendix F.

In limited circumstances, caps may need to be constructed with a final surface above the existing grade, in particular for offset areas where dredging cannot be accomplished against structures. These areas will be further evaluated during subsequent RD.

In summary, the major conclusions of this evaluation presented in Appendix F are as follows:

- A 4-foot-thick cap has acceptable bearing capacity factors of safety. Thus, no consolidation periods are required between placement of cap lifts.
- Post-cap subgrade settlement in dredge areas is estimated to range from 2 to 3 inches.
- The majority of post-cap subgrade settlement is estimated to occur within 120 days after cap construction.

These subgrade settlement estimates are important to consider in the construction QA of the placed caps because surveys of the cap surface will reflect both the thickness of the cap material and the consolidation of the subgrade.

7.3.2.1 Seismic Performance of Caps

The middle reach lies in a seismically active region and is characterized by sources of strong ground shaking (earthquakes) including the Cascadia Subduction Zone and relatively shallow crustal zones such as the Seattle fault zone. Seismic performance of caps was evaluated by considering liquefaction potential and seismic stability of caps on slopes. Work included estimating liquefaction-induced settlement and estimating potential deformations (movement) of caps on slopes during an earthquake. Caps placed in flat areas would not be damaged from seismic deformation.

Two different earthquakes were evaluated. The 100-year return interval earthquake was evaluated (peak ground acceleration = 0.19 g [g = acceleration of gravity]), consistent with the 100-year modeling time frame considered for contaminant transport evaluation. In addition, the larger, 475-year earthquake (peak ground acceleration = 0.44 g) was considered. This larger earthquake has a 10% probability of exceedance in a 50-year time frame and is a commonly considered earthquake for Superfund sediment remedies.

Pseudo-static (seismic) limit equilibrium slope stability evaluations were also conducted to support the assessment of cap performance during an earthquake. For these evaluations, target slope stability factors of safety range from 1.0 to 1.15 (Duncan and Wright 2005).

The following summarizes the major conclusions of the seismic performance evaluation:

- Liquefaction is predicted under both the 100-year and 475-year earthquakes. Liquefaction results in loss of soil strength (i.e., reductions in bearing capacity) and settlement.
- Cone penetrometer test records were analyzed for liquefaction-induced settlement; predicted settlements range from 4 to 14 inches (median settlement 8 inches) under either earthquake scenario.
- Post-earthquake deformation of caps on slopes is predicted to range from 1 to 2 inches following the 100-year earthquake and 1 to 2 feet following the 475-year earthquake.

Based on the liquefaction assessment and slope displacement estimates, the RD is expected to have acceptable seismic performance. Anticipated settlement and displacement under the 100-year event is expected to be significantly less than proposed cap thicknesses. During a larger 475-year earthquake, the cap and underlying sediments may move down the slope, but the cap is not expected to be significantly damaged because the movement is predicted to be less than the overall cap thickness.

Post-earthquake assessment and mitigation measures are recommended based on this analysis and are identified in the LTMMP. Assessment typically includes visual inspections and bathymetry surveys following seismic events above a defined threshold to evaluate the condition of caps. Cap repairs, if needed, could be readily implemented by adding more cap materials to address any localized thinning associated with post-earthquake deformation or settlement.

Details of the seismic performance evaluation are presented in Appendix F.

7.3.3 ENR and Area-Specific Technology Geotechnical Considerations

In limited circumstances, cover material will be placed with a final surface above the existing grade (i.e., in ENR placement areas and offset areas where dredging cannot be accomplished against structures). ENR entails placement of approximately 1 foot of clean material on the existing mudline. As demonstrated in Appendix F, ENR has an acceptable factor of safety for bearing capacity.

ASTs as identified in Section 5 will be further evaluated during subsequent RD if the AST design materially varies from the ENR thickness already evaluated. Based on evaluations for capping described in Section 7.3.2 and ENR as described in Appendix F, it is anticipated that ASTs will have acceptable factors of safety for bearing capacity.

7.3.4 Lateral Earth Pressures for Bulkhead Evaluations

Lateral earth pressure recommendations were developed to support structural evaluations for existing bulkheads, new temporary bulkheads, and a new cofferdam structure. Structural evaluations, in turn, are used to develop recommendations regarding dredging and capping adjacent to bulkhead structures and to assess whether offsets or other measures are needed to protect bulkheads. Appendix F presents lateral earth pressure recommendations for structural design evaluations.

Two preliminary lateral pressure diagrams are provided in Appendix F for temporary retaining structures proposed at RM 2.2W within RAAs 24B through 24G. These structures include the following:

- Proposed temporary bulkhead near the Douglas Management Dock where dredging will be required adjacent an existing block wall and other structures. The bulkhead will be situated to protect the existing wall during dredging.
- Proposed temporary cofferdam near the inlet of RM 2.2W between RAA 24D and RAAs 24E and 24G (Option 1 shown on the 60% Drawings). This structure will provide a hydraulic barrier such that sediment removal in RAAs 24B through 24D can be performed "in the dry," as described in Section 5.5 as an AST.

The lateral pressure diagrams provide earth pressures, hydrostatic pressures, surcharge loads, and passive pressure reduction factors, as appropriate. It is anticipated that the final structural engineering and design of these structures will be performed by the remedial construction contractor so that the systems can appropriately accommodate the contractor's means and methods for completing the work.

Generalized equivalent lateral parameters are also provided in Appendix F for future use at other RAAs, if necessary. Additional lateral earth pressure diagrams and design recommendations for new bulkhead structures will be developed for specific cases in subsequent design phases if replacement of existing bulkheads is necessary.

7.3.5 Geotechnical Recommendations for Piling

Pilings are anticipated to be removed and replaced to facilitate access for dredging at some locations. In particular, some of the guide piles along the Boyer North Lay Berth plastic float system will need to be removed. There may be a need for isolated pile removal for derelict piles that do not have any identified current or future use but may be inhibiting access for nearby remediation. Pile removal BMPs were developed by the Washington Department of Natural Resources (WDNR 2017) by adapting protocols prepared by EPA Region 10. These protocols will be included in project specifications that govern demolition.

Replacement piles are expected to support lateral loads from river currents and boat traffic. Any piles that are removed that support Tribal net fishing will also be replaced and designed to resist forces imposed by the nets, which will be evaluated in coordination with Tribal fishers. The need for vertically loaded replacement piles has not been identified.

To support structural engineering evaluations, general geotechnical design recommendations for replacement piling are presented in Appendix F. The recommendations include modeling parameters to be used in lateral pile design analysis software (i.e., LPILE) so that pile deflection and embedment can be determined by the structural engineer. Results of these evaluations will inform the sizing (diameter, wall thickness, and length) of the replacement piles.

7.3.6 Bank and Backfill Slope Stability

The RD includes dredging near existing waterfront facilities and shorelines. Dredging removes sediments that support the toe of the slope and hence reduces the resisting force against a potential sliding mass.

7.3.6.1 General Bank Slopes

Where excavations on banks are on the order of 1 to 2 feet deep, the evaluation of bank excavation slope stability is not warranted because removal of thin cuts will not materially affect the stability of the bank itself. This assumption is reasonable for typical bank conditions but may not be applicable in sensitive areas such as those with low-strength soils or visible indications of slope instability.

Bank slope stability is a key consideration for areas where deeper cuts are required at the toe of a bank area or on the bank itself. Site-specific analyses for embankment stability adjacent to deeper cuts will be updated during the next phase of RD to develop minimum required offsets from these slopes based on updated RAA areas and dredge depths.

7.3.6.2 Backfill Slope Stability

Backfill, consisting of sand and gravel materials as described in Section 9.5, will be placed following dredging in habitat areas (i.e., elevations higher than -10 feet MLLW) to restore pre-construction grades. Backfill will also be placed to stabilize dredge cuts where appropriate where elevations are deeper than -10 feet MLLW. In these deeper dredging areas, the backfill slope will transition downward from the habitat elevation of -10 feet MLLW to meet the post-dredge surface. As described in Appendix F, backfill side slopes of 3H:1V have an acceptable slope stability factor of safety for sand and gravel habitat materials. Steeper backfill slope angles (up to 2H:1V) have acceptable factors of safety in cases where armor rock is used.

7.4 Summary of Geotechnical Engineering Design Recommendations

Table 7-1 summarizes the key geotechnical engineering recommendations presented in this section of the BODR.

Table 7-1
Summary of Key Geotechnical Engineering Design Recommendations

Remediation Element	Geotechnical Evaluation	Conclusion
Dredging	Temporary side slopes	2H:1V side slopes have an acceptable factor of safety in most cases. Additional evaluations will be performed during subsequent RD where factors of safety do not meet targets.
	Long-term side slopes	3H:1V side slopes have an acceptable factor of safety.
	Recommended structural offset (general)	Passive earth pressures should be reduced adjacent to structures unless dredge prisms are offset. Reduction factors for use in structural engineering evaluations are presented in Appendix F. Offset dredge cuts at least 5 feet from vertical structures.
	Recommended structural offset (Historic Intake Structure wing walls)	At least 15-foot offset from the north wing wall. At least 10-foot offset from the south wing wall.
Capping	Bearing capacity	Caps up to 4 feet thick have an acceptable bearing capacity factor of safety.
	Subgrade settlement	Settlement of 2 to 3 inches is predicted for caps in dredge and cap areas. Differential settlement of caps and cap subgrade will be minor and is not predicted to affect the performance of caps. Settlement is estimated to occur within 120 days after cap placement.
	Static slope stability	A 2.5H:1V-slope cap is anticipated to have an acceptable slope stability factor of safety based on previous project experience. This will be further evaluated using limit equilibrium methods during subsequent RD once dredging and capping areas have been further analyzed.
	Seismic performance	Estimated displacement of caps under 100-year earthquake = 1 to 2 inches Estimated displacement of caps under 475-year earthquake = 1 to 2 feet The LTMMP describes measures for post-earthquake inspections.
Temporary bulkheads and cofferdam	Develop recommended lateral pressures	Refer to Appendix F for detailed parameters.
Replacement of existing piles	Develop recommended LPILE parameters	Refer to Appendix F for detailed parameters.
Backfill	Long-term side slopes	For sand and gravel backfill, 3H:1V side slopes have an acceptable factor of safety. For armor rock backfill, 2H:1V side slopes have an acceptable factor of safety.

Notes:
H:V: horizontal to vertical
LTMMP: Long-Term Monitoring and Maintenance Plan
RD: remedial design

8 Structural Engineering Considerations

Within the middle reach, there are several structures and utilities that are adjacent to RAAs. Structural engineering evaluations were used to develop measures to protect or replace existing structures or utilities that may be affected during implementation of the proposed remedial actions. This section presents the results and recommendations of the structural engineering evaluations for the Intermediate (60%) RD BODR.

Visual inspections of structures were conducted during PDI activities. The following sections describe the structures identified within or adjacent to RAAs and structural engineering design considerations that were evaluated for the Intermediate (60%) RD.

8.1 Structure Types

Structure types located within or adjacent to RAAs include bridges, floating structures, boat ramps, marinas, wharves, piers, bulkheads, mooring piles, mooring dolphins, stormwater outfalls, utility crossings, and the Historic Intake Structure. Tables 8-1 and 8-2 present these structure types relative to the respective RAA, citing RAA numbers and general riverbank locations. These tables also provide a description of the structure, adjacent property owner, and RM location.

8.1.1 Overwater/In-Water Structures

Overwater structures consist of piers and wharves and the 1st Avenue S Bridge span. In-water structures include single pile fields, mooring dolphins, bulkheads, floats, and 1st Avenue S Bridge piers and fendering systems.

Along the west riverbank, structures within or adjacent to RAAs include the following:

- Pacific Pile and Marine wharf, pier, and ramp structure
- Boyer North Lay Berth plastic float system and mooring dolphins
- Structures within the inlet at RM 2.2W
- Alaska Marine Lines Yard No. 2 concrete wharf
- 1st Avenue S Bridge piers, abutment, and fender piles

Along the east riverbank, structures within or adjacent to RAAs include the following:

- 8th Avenue Terminal wharf
- Historic Intake Structure and associated wing walls
- Seattle Iron & Metals Wharves
- Mooring dolphins adjacent to the Dawn Foods and Seattle Iron & Metals properties
- Seattle Department of Transportation (SDOT) Duwamish River Boat Ramp
- Duwamish Marine Center marina, bulkhead, piers and wharves

Other structures within the RAAs include single creosote-treated timber piles, multi-timber piles and steel pile dolphins, armored shorelines, and slopes.

Table 8-1
LDW Middle Reach Overwater/In-Water Structures Within or Adjacent to RAAs

RAA	Structure Name (ID No.)[1]	Structure Type	Description	Adjacent Property	Location
3	ST09	Wharf	Segmented concrete pile-supported wharf	Crowley Marine Services/Waste Management	RM 2.8E/Slip 4
5A–5B	ST09	Wharf, timber and steel dolphins	Precast prestressed concrete deck supported by precast prestressed concrete piles, timber and steel mooring dolphins		
8A, 8C–8H	ST11	Wharf	Triangular timber pile wharf	Pacific Pile and Marine	RM 2.7W
	ST13	Wharf and pier	Timber pier		
9C, 9D, 9L, 9M	ST10	Historic Intake Structure and wing walls	Water intake structure and timber wing walls	Seattle Gateway Park/ Recology Cleanscapes	RM 2.75E
11	ST12	Mooring dolphins	Mooring dolphins and guide piles	Pacific Pile and Marine	RM 2.6W
16	ST08	Wharf	Timber wharf	Seattle Iron & Metals	RM 2.5E
17	ST19	Mooring dolphins	Steel batter pile mooring dolphins	Boyer Towing Inc.	RM 2.5W
20A, 20B	ST06	Mooring dolphins	Mooring dolphins	Hopkins Trust/ Seattle Iron & Metals	RM 2.4W/ Myrtle Bay
	ST07	Wharf	Timber wharf		
21B, 21C, 22	ST14	Float and guide piles	Plastic float system with steel decking and timber guide piles	Boyer Towing Inc.	RM 2.3W
	ST15	Mooring dolphins	Mooring dolphins		
23A–23B	ST05	Mooring dolphins	Mooring dolphins	Dawn Foods	RM 2.2E
25	ST04	Wharf	Concrete wharf with concrete aprons and finger pier	SeaTac Marine Properties LLC	RM 2.15E/Slip 3

RAA	Structure Name (ID No.)[1]	Structure Type	Description	Adjacent Property	Location
24B–24J, 27A, 27D	ST16	Mooring dolphins, timber piles, and wharf	Mooring dolphins, timber pile fields, wharf, and miscellaneous structures	Alaska Marine Yard No. 2, Industrial Container Services	Inlet at RM 2.2W
27B	ST17	Wharf and mooring dolphins	Concrete wharf with mooring dolphins	Alaska Marine Yard No. 2	RM 2.15W
29	ST03	Concrete boat ramp	Asphalt/concrete on-grade boat ramp	SDOT, Duwamish River Boat Ramp	RM 2.1E
30B–30C	ST18	Bridge	1st Avenue S Bridge—concrete and steel structure supported on concrete piers and piles	WSDOT	RM 2.0E
31B–31C	ST02	Marina	Structure consists of floats, boat houses, guide piles, gangway, timber pile field, and timber bulkhead	Duwamish Marine Center	RM 1.95E
30F, 32, 33	ST01	Pier	Two single-span piers	Samson Tug	RM 1.8E
34A	ST01	Pier	T-headpier	Samson Tug	RM 1.8E/Slip 2
SMA 10	Upper Reach ST03	Bulkhead	Steel and timber sheet-pile walls	Boeing Isaacson Thompson	RM 3.7–3.8E

Notes:

1. Structure ID No. corresponds to the structural field inspection forms presented in DER Appendix E (Anchor QEA and Windward 2025a).

RAA: remedial action area
RM: river mile
SDOT: Seattle Department of Transportation
WSDOT: Washington State Department of Transportation

Except for the 1st Avenue S Bridge, the majority of existing structures evaluated within the LDW middle reach lack as-built record drawings, and the design and current load capacities are unknown. To document their locations, the structures adjacent to RAAs will be surveyed with 3D scanning technologies during the Phase III PDI. These surveys will be used to produce a map that will provide the location and dimensions of the foundations and decking of the structures.

As-built drawings were obtained from WSDOT to determine type and depth of bridge foundations and bridge fender system. The east bridge (north-bound lanes) utilizes a 59.5-foot-by-95.5-foot foundation at each bascule pier with a bottom elevation of -41.96 feet MLLW.[25] A 64.83-foot-wide

[25] The WSDOT as-build drawings use the obsolete City of Seattle datum (City of Seattle 2026). Elevations have been converted to the project datum of MLLW by adding 12.04 feet to the elevations on the as-built drawings.

strut spans across the waterway and connects the two bascule piers. The elevation of the top of the strut is -39.96 feet MLLW. The west bridge (south-bound lanes) utilizes a 100-foot-by-68-foot pile cap at each bascule pier with an approximate 11-by-7 grid of 2-foot diameter reinforced-concrete-filled steel pipe piles extending a minimum of 155 feet below the bottom of the pile cap. The bottom of the pile cap elevation is 4.54 feet MLLW.

The bridge fender system utilizes a precast concrete guide wall and deck slab connected to two rows of reinforced-concrete steel pipe piles. The elevation of the bottom of the guide wall is 0.29 foot MLLW and the elevation of the top of the piles is 9.29 feet MLLW. At the north fender, pile tip elevations are -62.96 feet MLLW for 36-inch-diameter piles and -77.96 feet MLLW for 72-inch-diameter piles. At the south fender, pile tip elevations are -62.96 feet MLLW for 36-inch-diameter piles and -72.96 feet MLLW for 72-inch-diameter piles. Each fender pile has an epoxy coating applied to the outside of the pipe pile from the cutoff elevation to an elevation 10 feet below the mudline (elevation varies from -16.96 to -35.96 feet MLLW).

8.1.2 Outfalls

There are several public and privately owned stormwater outfalls along the middle reach east and west riverbanks consisting of cast iron, steel, or concrete pipeline material of various sizes, physical properties, and support conditions. Some of the outfalls remain active, whereas others have been abandoned or are inactive. There are also a few combined sewer overflows within the middle reach, and these are generically described as outfalls in this section and Appendix G.

Outfalls located within the RAAs on the east bank are mostly ground-supported, with some that are supported by the existing bulkhead structures. All outfalls located within the RAAs on the west bank are ground-supported. See Table 8-2 for outfall IDs adjacent to RAAs and the location along the riverbank.

Table 8-2
LDW Middle Reach Outfall Structures Within or Adjacent to RAAs

RAA	Facility ID	Outfall ID	Outfall Name	Active or Inactive	Pipe Diameter (inches)	Pipe Material	Adjacent Property	Riverbank Location
3	OF20	5008	5008	Inactive	8	PVC	Crowley Marine Services, Waste Management	RM 2.8E
	OF21	5009	5009	Inactive	8	PVC		
5A	OF19	2042	2042	Inactive	8	PVC	Crowley Marine Services, Waste Management	RM 2.8E
6	OF22	2107	8th Avenue CSO	Active	36	Concrete	Seattle Public Utilities	RM 2.83W
8F, 8G	OF23	2112	7th Avenue S SD	Active	72	Unknown	Pacific Pile and Marine	RM 2.7W
9F, 9M	OF17	CleanScapes B	CS-B	Active	Unknown	Unknown	Recology Cleanscapes	RM 2.75E
9A	OF18	DuwReload	DRLD	Active	Unknown	Unknown	Crowley Marine Services, Waste Management	RM 2.79E
16	OF13	2035	S Garden St SD	Active	30	Ductile Iron	Seattle Iron & Metals	RM 2.49E
20A, 20B	OF09	SBW-B	SBW-B	Active	Unknown	Unknown	Hopkins Trust, Seattle Iron & Metals	RM 2.4E
	OF10	2028	2028	Active	10	Unknown		
	OF11	2027	2027	Presumed Inactive	6	Clay		
	OF12	2026	S Myrtle St SD	Active	24	Ductile Iron		
21A, 21B	OF24	2115	2115	Active	8	PVC	Boyer Towing Inc.	RM 2.3W
	OF25	Boyer-2	B2	Active	Unknown	Unknown		
	OF26	Boyer-1	B1	Active	8	PVC		
23A, 23B	OF08	Dawn Foods	DWN	Active	Unknown	Unknown	Dawn Foods, Hopkins Trust	RM 2.28E
24C, 24D	OF27	2118	2nd Ave S SD	Active	24	Concrete	Industrial Container Services	RM 2.22W

RAA	Facility ID	Outfall ID	Outfall Name	Active or Inactive	Pipe Diameter (inches)	Pipe Material	Adjacent Property	Riverbank Location
24B	OF28	2120	W Seattle Reservoir Overflow	Active	36	Concrete	Alaska Marine Lines Yard No. 2	RM 2.18W
26	OF07	2025	2025	Unknown	Unknown	Unknown	SeaTac Marine Properties LLC	RM 2.15E
27B	OF29	2508	2508	Active	Swale	N/A	Alaska Marine Lines Yard No. 2	RM 2.1W
29	OF05	S River St SD	S River St SD	Active	12	Cast Iron	SDOT	RM 3.1E
30C	OF04	Georgetown WWTS	Georgetown WWTS	Inactive	54	HDPE	N/A	RM 3.0E
31C	OF01	DuwMetalFab	DuwMetalFab	Inactive	5	Unknown	Duwamish Marine Center	RM 1.9E
31D	OF02	2502	S Michigan CSO	Active	102	Steel Gate Concrete		
	OF03	2501	2501	Unknown	48	Concrete		
SMA 10	N/A	2061	2061	Active	24	Steel	Boeing Isaacson Thompson, Port of Seattle	RM 3.7-3.8E
		2062	KCIA SD#2	Active	48	CMP		
		2063	2063	Inactive	4	Steel		

Notes:
CMP: corrugated metal pipe
CSO: combined sewer overflow
N/A: not applicable
RAA: remedial action area
RM: river mile
SD: storm drain
SDOT: Seattle Department of Transportation
SMA: sediment management area

8.2 Structural Engineering Design Evaluations

Dredging and capping can affect the integrity of structures located adjacent to the work because new loading conditions are imposed on structures. The following structural engineering design considerations were evaluated to develop the engineering design recommendations presented in Section 8.3.

8.2.1 Dredging Offsets

Dredging offsets are routinely considered in engineering design to protect existing structures and slopes, including armored slopes, that could otherwise be adversely affected by dredging activities. Preliminary offsets have been defined as described in Section 7.3.1.2 based on geotechnical evaluations. Further refinement of these offset distances will be made during Pre-Final (90%) RD if applicable based on structural and geotechnical evaluations that will be revised to include the results of the Phase III PDI.

8.2.2 Load Restrictions

Load restrictions for specific structures are considered in engineering design because the design and current load-carrying capacity for the structures is not known in most cases. The assigned load restriction must consider maintaining the estimated structural capacity and minimizing potential impacts on the structure.

Structure types that could warrant load restrictions include wharves, piers, and shoreline bulkheads. A temporary restriction on loading of the top of the structure may be required during dredging activities adjacent to the structure. Areas where load restrictions are practical and necessary will be included in the Intermediate (60%) RD documents.

8.2.3 Temporary Bulkhead Shoring/Support

Shoring support is considered for a structure or excavation when the potential for collapse or an unstable condition is present. To prevent the failure of a structure, excavation, or dredge, shoring is typically used to provide support and prevent collapse. Temporary shoring design for bulkhead walls and cofferdams is described in Section 8.4.

To ensure the safety of workers, the public, and surrounding property and to facilitate the safe execution of construction, shoring will be used as a critical temporary measure to maintain stability until permanent structural elements are in place or the hazard is removed.

8.2.4 Overhead Structure Vertical Clearance

Overhead structural vertical clearance refers to the space needed for construction equipment to work or pass beneath a structure that spans the waterway. For example, when the 1st Avenue S Bridge is in its typical position to allow street traffic to cross the river, the vessel passing beneath the bridge must be shorter than the posted vertical clearance. Overhead vertical clearance considerations are applicable at the 1st Avenue S Bridge. Overhead vertical clearance in the closed position (open to traffic) is posted at 48 feet MLLW. In the open position (closed to street traffic), the 1st Avenue S Bridge overhead vertical clearance is not restricted, but the bridge is restricted from opening during weekday commute hours.

Based on LDW upper reach construction equipment used by the contractor, the bridge height (vertical distance from the waterline to the highest point of the vessel's superstructure, including deckhouses and masts) of tugs and work boats is generally 14 feet. Accordingly, tugs, work boats and material barges are expected to pass below the bridge without opening. However, equipment used for dredging and material placement activities under or near the 1st Avenue S Bridge will likely require bridge temporary closures. Coordination with WSDOT, SDOT, and other relevant agencies will occur during the Pre-Final (90%) RD to inform the contractor specifications and establish initial coordination requirements.

8.2.5 Outfall Discharge Bed Erosion Protection/Energy Dissipation

Another structural consideration for ground-supported outfalls is to incorporate engineered discharge bed erosion protection measures into the design to dissipate energy from outfall flows. Outfalls may be armored or supported on splash pads/aprons or other flow energy dissipator systems to protect the bank from erosion due to the outfall flow discharge. No outfalls requiring expansion or enhancement of armoring were identified during the 60% RD. As required, outfall bed erosion protection details will be included in the Pre-Final (90%) RD documents.

8.2.6 Temporary Relocation or Demolition and Replacement

Some in-water structures that impede or restrict access to remedial construction will be demolished permanently or temporarily removed during construction and replaced in-kind (i.e., the same footprint and function prior to remediation). Candidate structures for permanent demolition include timber piles (treated and untreated), abandoned piers, abandoned wharves, guide piles, and mooring dolphins. Pilings that serve as Tribal fishing piles will be removed and replaced with steel piles.

No outfall structures are currently identified for demolition and replacement because active outfalls within remediation footprints will be protected in place and inactive/abandoned outfalls are assumed to have already been removed or are not expected to impede remediation activities. If inactive/abandoned outfalls are encountered in the dredge prism and impact the contractor's ability to complete the remediation work, they will be removed, and the remaining pipe in the bank will be grouted. If existing unknown outfalls are encountered, the contractor will be directed to coordinate directly with the project team to assess the appropriate path forward for the outfall. See Table 8-3 for structures that are likely to be impacted by remediation efforts.

Table 8-3
Structures Potentially Impacted by Remediation Efforts

RAA	Structure Name (ID No.)	Structure Type	Description	Adjacent Property	Impacted Structure and Anticipated Mitigation
17	ST19	Mooring dolphins	Steel batter pile mooring dolphins	Boyer Towing Inc.	Dredging around exterior of piles could cause damage; damaged piles would be replaced in-kind.
20A, 20B	ST06	Mooring dolphins	Mooring dolphins	Hopkins Trust	Dredging around exterior of piles could cause damage; damaged piles would be replaced in-kind.
21B–21C, 22	ST14	Float and guide piles	Plastic float system with steel decking and timber guide piles	Boyer Towing Inc.	Dredging around exterior of piles could cause damage; damaged piles would be replaced in-kind; floating structures would be detached and moved.
21B, 22	ST15	Mooring dolphins	Mooring dolphins	Boyer Towing Inc.	Dredging around exterior of piles could cause damage; damaged piles would be replaced in-kind
23A	ST05	Mooring dolphins	Mooring dolphins	Dawn Foods/Shalmar Group LLC Seattle Iron & Metals	Dredging around exterior of piles could cause damage; damaged piles would be replaced in-kind.
24B–24D	ST16	Mooring dolphins, timber piles, and wharf	Mooring dolphins, timber pile fields, wharf, and miscellaneous structures	Boyer Towing Inc., 7100 1st Ave S Seattle LLC	Temporary bulkhead and temporary cofferdam construction; demolition of abandoned structure
31B–31C	ST02	Marina	Structure consists of floats, boat houses, guide piles, gangway, timber pile field, and timber bulkhead	Duwamish Marine Center	Dredge shoreline and channel, removal of adjacent marina structures and buildings; demolition of remaining piles and bulkhead during dredge operations
SMA 10	Upper Reach ST03	Bulkhead	Steel and timber sheet-pile walls	Boeing Isaacson Thompson	Portion of bulkhead to be demolished as part of either in-water or upland remedial action

Notes:
RAA: remedial action area
SMA: sediment management area

Table 8-4 provides a summary of the protective options that are applicable to the structure types located within an RAA. Applicable engineering design considerations and a summary of structure design recommendations are presented in Section 8.3.

Table 8-4
Structure Types and Engineering Design Considerations for LDW Middle Reach RAL Exceedance Areas

Structure Type	Structural Considerations						RAL Exceedance Areas
	Dredge Offsets[1]	Load Restrictions	Bulkhead Shoring/Support	Overhead Structure Vertical Clearance	Outfall Discharge Bed Erosion Protection	Demolition or Removal and Replacement	
Bridges	X			X			30
Wharves	X						3, 5, 8, 11, 16, 20, 24A–24B, 25, 27
Bulkheads	X	X	X				5, 24A–24B, 30, 31, SMA 10
Marinas						X	30, 31
Timber piles						X	5, 8, 21, 22, 24A–24B, 27, 30, 31
Mooring dolphins						X	9, 11, 17, 20, 21, 22, 23, 24A–24B, 27
Boat ramp	X						29
Utility crossings	X						9, 30
Outfalls	X				X		3, 5, 9, 13, 20, 21, 26, 27, 29, 31

Notes:
1. Although dredge offsets may be necessary to protect structures during remedial construction, material placement (e.g., amended ENR) is still likely feasible within the offset areas pending additional access evaluations that will be performed during Intermediate (60%) RD.

ENR: enhanced natural recovery
LDW: Lower Duwamish Waterway
RAL: remedial action level
RD: remedial design
SMA: sediment management area

8.3 Summary of Planned Actions near Structures

This section summarizes the planned remedial actions near overwater/in-water structures and outfalls located within and adjacent to RAAs. Each requirement considers the condition of the structure, future use of the structure, and construction cost efficiency.

8.3.1 *Overwater/In-Water Structures*

Overwater/in-water structures adjacent to or within RAAs have been evaluated to develop requirements for structural protection. Table 8-5 summarizes these actions.

Table 8-5
Middle Reach Overwater/In-Water Structures Planned Actions

RAA	Structure Name (ID No.)	Structure Type	Description	Adjacent Property	Planned Action Adjacent to the Structure
3	ST09	Wharf	Segmented concrete pile-supported wharf	Crowley Marine Services/Waste Management	ENR placement under structure
5A–5B	ST09	Wharf, timber and steel dolphins	Precast prestressed concrete deck supported by precast prestressed concrete piles, timber and steel mooring dolphins	Crowley Marine Services/Waste Management	5A: Amended ENR placement under structure 5B: Dredge, with offset from wharf
8C–8F	ST11	Wharf	Triangular timber pile wharf	Pacific Pile and Marine	8C: Amended ENR placement under structure 8D–8F: Dredge, with offset from wharf
8G	ST13	Wharf and pier	Timber pier and storm drain	Pacific Pile and Marine	Amended ENR placement under and adjacent to structure
9L–9M	ST10	Historic Water Intake and wing walls	Water intake structure and wingwalls	Seattle Gateway Park, Recology Cleanscapes	Amended ENR placement, with offset from intake structure and wing walls
11	ST12	Mooring dolphins	Mooring dolphins and guide piles	Pacific Pile and Marine	Dredge, with offset from mooring piles
16	ST08	Wharf	Timber wharf	Seattle Iron & Metals	Dredge, with offset from wharf
17	ST19	Mooring dolphins	Steel batter pile mooring dolphins	Boyer Towing Inc.	Dredge, with offset from piles
20A	ST07	Wharf	Timber wharf	Seattle Iron & Metals	Amended ENR placement under and adjacent to structure
20B	ST06	Mooring dolphins	Mooring dolphins	Hopkins Trust	Dredge, with offset from piles, as required

RAA	Structure Name (ID No.)	Structure Type	Description	Adjacent Property	Planned Action Adjacent to the Structure
21B, 21C, 22	ST14	Float and guide piles	Plastic float system with steel decking and timber guide piles	Boyer Towing Inc.	ENR placement adjacent to guide piles
21B, 22	ST15	Mooring dolphins	Mooring dolphins	Boyer Towing Inc.	ENR placement adjacent to guide piles
23A	ST05	Mooring dolphins	Mooring dolphins	BridgePoint/ Seattle Iron & Metals[1]	Partial dredge and cap, with offset from piles
24B–24D	ST16	Mooring dolphins, timber piles, and wharf	Mooring dolphins, timber pile fields, wharf, and miscellaneous structures	Boyer Towing Inc., 7100 1st Ave S Seattle LLC	Temporary bulkhead and temporary cofferdam construction; demolition of abandoned structure
25	ST04	Wharf	Concrete wharf with concrete aprons and finger pier	SeaTac Marine Properties LLC	ENR placement under structure
26	ST04	Wharf	Concrete wharf with concrete aprons and finger pier	SeaTac Marine Properties LLC	Cap placement near structure
27B	ST17	Wharf and mooring dolphins	Concrete wharf with mooring dolphins	Alaska Marine Yard No. 2, 7100 1st Ave S Seattle LLC	ENR placement under structure
29	ST03	Concrete boat ramp	Asphalt/Concrete on-grade boat ramp	SDOT, Duwamish River Boat Ramp	Dredge, with offset from boat ramp
30B–30C	ST18	Bridge	1st Avenue S Bridge—concrete and steel structure supported on concrete piers and piles	N/A: FNC	Dredge, with offset from bridge fendering system
31B–31C	ST02	Marina	Structure consists of floats, boat houses, guide piles, gangway, timber pile field, and timber bulkhead	Duwamish Marine Center	Dredge shoreline and channel, removal of adjacent marina structures and buildings, demolition of remaining piles and bulkhead during dredge operations
30F, 32	ST01	Pier	Two single-span piers	Samson Tug	Cap and ENR placement adjacent to structure
34A	ST01	Pier	T-head pier	Samson Tug	Dredge, with offset from pier

RAA	Structure Name (ID No.)	Structure Type	Description	Adjacent Property	Planned Action Adjacent to the Structure
SMA 10	Upper Reach ST03	Bulkhead	Steel and timber sheet-pile walls	Boeing Isaacson Thompson	Dredge, with offset from portion of bulkhead to remain

Notes:

1. The northern dolphins are maintained by Alaska Marine Lines, and the southern dolphins are maintained by Manson Construction.

ENR: enhance natural recovery
FNC: federal navigation channel
N/A: not applicable
RAA: remedial action area
SDOT: Seattle Department of Transportation
SMA: sediment management area

8.3.2 Outfalls

Outfalls located within or adjacent to RAAs have been evaluated to develop requirements for dredging setbacks/offsets and outfall energy dissipation for bank erosion protection. Table 8-6 presents planned actions as they apply to the outfall structures.

Table 8-6
LDW Middle Reach Outfall Structures Planned Actions

RAA	Outfall Name (ID No.)	Active or Inactive	Pipe Diameter (inches)	Pipe Material	Adjacent Property	Planned Action Adjacent to the Outfall
3	OF21	Inactive	8	PVC	Crowley Marine Services, Waste Management	Material placement adjacent to outfall
5B	OF19	Inactive	8	PVC	Crowley Marine Services, Waste Management	Material placement adjacent to outfall
6	OF22	Active	36	Concrete	Seattle Public Utilities	Dredging adjacent to outfall, offset to protect outfall
8F, 8G	OF23	Active	72	Unknown	Pacific Pile and Marine	Material placement adjacent to outfall, dredging offset to protect outfall
9F, 9M	OF17	Active	Unknown	Unknown	Recology Cleanscapes	Dredging adjacent to outfall, offset to protect outfall
9A	OF18	Active	Unknown	Unknown	Crowley Marine Services, Waste Management	Dredging adjacent to outfall, offset to protect outfall

RAA	Outfall Name (ID No.)	Active or Inactive	Pipe Diameter (inches)	Pipe Material	Adjacent Property	Planned Action Adjacent to the Outfall
20A, 20B	OF09	Active	Unknown	Unknown	Hopkins Trust	Material placement adjacent to outfalls
	OF10	Active	10	Unknown	Hopkins Trust	
	OF11	Presumed Inactive	6	Clay	Unknown	
	OF12	Active	24	Ductile Iron	Seattle Iron and Metals	
21A	OF26	Active	8	PVC	Boyer Towing Inc.	Dredging adjacent to outfall, offset to protect outfall
23A, 23B	OF08	Active	Unknown	Unknown	Dawn Foods, Hopkins Trust	Dredging adjacent to outfall, offset to protect outfall
24C, 24D	OF27	Active	24	Concrete	Industrial Container Services	Temporary outflow diversion while cofferdam is in place
24B	OF28	Unknown	36	Concrete	WSDOT	Temporary outflow diversion while cofferdam is in place
26	OF07	Unknown	Unknown	Unknown	SeaTac Marine Properties LLC	Material placement adjacent to outfalls
27B	OF29	Active	Swale	N/A	Alaska Marine Lines Yard No. 2	Material placement adjacent to outfalls
29	OF05	Active	12	Cast Iron	SDOT	Dredging adjacent to outfall, offset to protect outfall
30C	OF04	Active	54	HDPE	WSDOT	Outfall behind bridge fender system
31C	OF01	Inactive	5	Unknown	Duwamish Marine Center	Dredging adjacent to outfall and upland structures, offset to protect outfall
31D	OF02	Active	102	Steel Gate Concrete		
	OF03	Unknown	48	Concrete		
SMA 10	2061	Active	24	Steel	Boeing Isaacson Thompson, Port of Seattle	Dredging adjacent to outfall and upland structures, offset to protect outfall
	2062	Active	48	CMP		Dredging adjacent to outfall and upland structures, offset to protect outfall
	2063	Inactive	4	Steel		Demolish

Notes:
CMP: corrugated metal pipe
HDPE: high-density polyethylene
N/A: not applicable
RAA: remedial action area
SDOT: Seattle Department of Transportation
SMA: sediment management area
WSDOT: Washington State Department of Transportation

8.4 RM 2.2W Temporary Bulkhead Wall and Cofferdam Design

The inlet at RM 2.2W is bounded by 1st Avenue South on the west side and two separate industrial properties on the north and south sides. A temporary bulkhead wall shoring system consisting of interlocking sheet piles with tieback ground anchors is required for a section of the north shoreline where dredging is required adjacent to an existing block wall and other structures. The shoring wall is required to prevent slope failure and property damage during remediation work. The use of tieback anchors is required to limit the section size necessary for a cantilevered system, which would be a much larger wall.

In order to facilitate work in a "dry" condition within the inlet, a temporary double-walled cofferdam is recommended, which will isolate the inlet from the waterway and prevent river water from entering the remediation zone. Two potential alignment options are being considered (refer to the 60% Drawings) and will be finalized during Pre-Final (90%) RD after additional information regarding the remedy for the adjacent upland cleanup is available. The double-walled cofferdam is anticipated to be constructed using sheet piles embedded in the soil with a tie rod below the pile head. The cofferdam is expected to be in use for up to 1 year to allow work outside the fish window periods and construction duration.

To facilitate construction of both the bulkhead wall and cofferdam, it is anticipated that a contractor will require access to one of the adjacent properties for work area staging and construction. There will also be a need to store temporary dewatering equipment, water treatment systems, and materials. After construction is completed, the temporary outfall diversion structures and construction equipment and materials will be removed, including shoring walls and the cofferdam.

The approach for the Intermediate (60%) RD is to develop a conceptual temporary bulkhead shoring system and double-walled cofferdam design to a level of effort that allows for these items to be included within the cost estimate and to demonstrate the feasibility of these features. Work in the dry will also require a contractor-developed dewatering plan to remove precipitation and groundwater inflow to the inlet, and extensions of two outfalls (OF-27 and OF-28) The final engineering and design of these structures and components will be performed by a licensed PE working for the remedial construction contractor so that the systems can appropriately accommodate the contractor's means and methods for completing the work.

The sheet piles for the bulkhead shoring wall and double-walled cofferdam are anticipated to be installed and removed using a vibratory hammer. The bulkhead wall tieback anchors will be cut off and will remain in the soil.

See Sections 10.1.6 and 12.2 for discussions of dewatering and sequencing of work within RM 2.2.

8.4.1 Design Codes and Standards

Relevant codes and standards for design and analysis include the following:

- American Institute of Steel Construction (AISC) *Steel Construction Manual, Fifteenth Edition* (AISC 2017)
- Design Manual DM7.02, Foundations and Earth Structures (NAVFAC 1986)
- *Design of Sheet Pile Walls*, EM 1110-2-2504 (USACE 1994)
- Earth Retention Systems Handbook (MacNab 2002)
- *Foundation Analysis and Design*, 6th Edition (Bowles 1998)
- *Steel Sheet Piling Design Manual* (USS 1984)

8.4.2 Structural Design Concept and Performance

During the remediation work, the temporary bulkhead wall shoring system along the north side of the inlet at RM 2.2W will provide shoring for the existing shoreline embankment, the embankment behind the dilapidated timber dock, several structures in proximity to the top of the shoreline, and a gravity block retaining wall. The type and condition of these existing features need to be investigated further and is a data gap that will be addressed during Phase III PDI. The bulkhead wall shoring wall system is anticipated to be composed of interlocking sheet piles embedded in the soil with ground anchors ("tiebacks") at an interval of 8 feet or less near the pile head that will react against a waler to provide continuity.

The double-walled cofferdam located within the inlet will create separation between the remedial construction area in the inlet and the main channel of the LDW to allow for remediation work in the inlet to be done in the dry/drained condition. The remedial contractor may elect to include waterproofing material to be applied to the interlock between the sheets to limit water intrusion into the work area during high tides. The double-walled cofferdam will be constructed using sheet piles embedded in the soil and tie rods below the pile head, creating a box-like configuration. The interior of this box is anticipated to be filled with import material, which is anticipated to be reused as a backfill after the cofferdam is no longer needed. The cofferdam effective width is expected to be around 10 feet and will span across a narrow section of the inlet.

The timber dock west of the north shoring wall is to be demolished and not replaced. Consideration should be given to leaving the north shoring wall system in place after remediation work is completed to prevent slope failure or loss of embankment once the sheet piles are removed. The reason for this consideration is to prevent potential disturbance to the existing walls or bulkhead during removal of the temporary shoring wall.

8.4.3 Material Properties

Z-Steel Sheet Piles: ASTM International (ASTM) A572, Grade 50, F_y = 50 ksi.

8.4.4 Structural Loads and Load Combinations

The temporary bulkhead wall shoring system along the north side of the inlet would be designed for lateral loads consisting of earth pressure, pressure due to imposed surcharge loads on top of the bank, and hydrostatic pressure from groundwater. Seismic earth pressure on the wall will be evaluated in the Pre-Final (90%) RD documents, where it will be determined whether earthquake forces should be considered in the temporary design. The shoring wall is temporary, and the probability of a seismic event is low but not zero because the site is located within a high seismic region. Consideration may be given for an Operational Level Event, which has a 50% probability of exceedance in 50 years corresponding to a return period of 72 years.

The double-walled cofferdam wall would be designed for hydrostatic driving pressure of river tide design elevation of 12 feet on the river side and dry condition on the inlet side.

For both wall design cases, overturning moments and sliding forces resulting from the lateral loads are resisted by passive earth pressure generated by material below the proposed dredge line.

Design will be in accordance with allowable stress design and load factors for the combination of all driving and resisting earth pressures of 1.0 and a 1.25 factor of safety. The design criteria and results of these analyses are included in Appendix G.

8.5 Pile Replacement

This section summarizes the structural engineering design that is included in the Intermediate (60%) RD for replacement of removed piles located within and adjacent to RAAs. The following structural engineering design considerations have been considered to develop the pile replacement design.

8.5.1 Design Codes and Standards

Design codes and standards relevant to the replacement of removed piles include the following:

- AISC *Steel Construction Manual, Fifteenth Edition* (AISC 2017)
- American Welding Society, *D1.1 – Structural Welding Code – Steel* (AWS 2020)
- American Society of Civil Engineers, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures (7-16)* (ASCE 2017)
- International Code Council, 2021 International Building Code (ICC 2020)
- Seattle Department of Construction and Inspections, 2021 Seattle Building Code (SDCI 2020)

8.5.2 Design Concept

Piles that are removed will be replaced and in the same location. Piles will be driven to the minimum calculated design depth based on yielding of the pile, which will be included in the Pre-Final (90%) RD documents. In the event that a pile cannot be fully removed, a reasonable offset will be discussed with the owner of the structure.

8.5.3 Structural Performance

Replacement piles will be analyzed in lateral pile design analysis software (i.e., LPILE) to determine the sizing and embedment depth requirements for the replacement piles. Geotechnical design recommendations for this analysis are presented in Appendix F. Size and embedment of the replacement piles will be included in the Pre-Final (90%) RD documents.

8.5.4 Material Properties

Steel pipe piles shall be ASTM 252, Grade 3 (mod), f_y = 50 ksi.

8.5.5 Structural Loads

Replacement piles are expected to support lateral berthing and mooring loads from barges, as well as lateral loads imposed by net fishing. The limiting values assumed for these lateral loads will be governed by pile yielding and provided in the Pre-Final (90%) RD documents.

8.5.6 Load Combinations

Load combinations will be used where applicable to produce the largest lateral effect on each replacement pile. Applicable load factors will be applied as described in the design codes and standards. Load combinations and load factors will be provided in the Pre-Final (90%) RD documents. If lateral load values cannot be obtained, piles will be designed to the yield point and the maximum load will be listed.

9 Remedial Technology Design

This section describes the development of design criteria for the selected RD elements assigned to each RAA in Section 5.5. This section also describes the design analyses conducted to select the criteria, including a summary and detailed description of objectives, design assumptions, and restrictions (where appropriate) that are used in the design of the remedial actions. Specifically, details are provided for the following:

- Dredge design
- Material handling/transload
- Engineered cap design
- ENR design
- Material types and placement methods
- AST designs
- MNR
- Maintenance, monitoring, and institutional controls
- Other general design considerations:
  - Flood rise analysis
  - Climate change design considerations

Application of the criteria is demonstrated on the 60% Drawings, included in Volume III. Details of implementing these criteria will be provided in the Specifications, which are provided in an updated outline form at Intermediate (60%) RD in Volume III and will be further developed during Pre-Final (90%) RD.

9.1 Dredge Design

This section describes the dredge prism design criteria, dredging tolerances, basis for dredging equipment selection, and anticipated dredging production rates. Additionally, this section describes support activities associated with dredging, including material transloading, upland transport and disposal, post-dredge sampling, dredge residuals management, and post-dredge backfilling.

9.1.1 Dredge Prism Design

As described in Section 5, horizontal limits of the RAAs were set to encompass the RAL exceedance area and modified to account for engineering considerations, review of adjacent chemistry results, and constructability considerations. Vertical extent of dredging was defined on either an elevation or thickness basis to remove material exceeding RALs applicable to surface sediments. In limited cases, a defined slope was used as the basis for the dredge cut (e.g., RAA 23A). The dredge prism design combines these considerations to target removal of the horizontal and vertical extents of contamination.

Dredge elevations were used as the basis for the vertical extent of dredging when data suggest similar elevations of contamination over a contiguous area. The basis for the dredge elevation used in design is the field-measured mudline elevation for the relevant vertical cores.[26] In general, elevation-based cuts were used in areas within the FNC due to the typical nature of past dredging to constant dredge elevations in these areas (suggesting that contaminant releases would have been expected to settle above a similar elevation). For elevation-based dredge prisms, core data were reviewed to identify the elevation where contamination is considered to be bounded (see Section 4.2), which was then rounded to the next deepest half-foot interval for constructability purposes. For example, if the bottom of the deepest core interval exceeding surface RALs was at -18.3 feet MLLW, the required dredge elevation was set to -18.5 feet MLLW. This rounding to the next deeper interval results in a more conservative dredge cut design. Bathymetric survey measurements during construction will confirm that the required dredge elevation has been met.

Dredge thickness cuts were used as the basis for the vertical extent of dredging when vertical core data suggested similar thicknesses of contamination within an area. This approach generally occurred in areas outside the FNC and in areas that are along slopes because historically, these areas would have had natural sloping contours upon which contamination could have accumulated to consistent thicknesses instead of consistent elevations. Thickness cuts were also assigned to some areas within the FNC or berthing areas with vertically bounded contamination with only RAL exceedances in the 0- to 10-cm (0- to 4-inch) or 0- to 60-cm (0- to 2-foot) intervals (e.g., RAA 18). For these areas, the vertical extent of dredging was assigned a minimum dredge thickness because the data indicate that contamination is found only on the upper surface of the sediment bed at that location. The design thickness cut defines a 3D surface that will be the required dredge surface for use by the contractor, and the actual cut thickness to achieve the design surface will be adjusted by the contractor during construction to reflect any mudline elevation changes between the design bathymetry dataset and the pre-construction bathymetry dataset. Bathymetric survey measurements during construction will confirm that the required dredge thickness surface has been met.

Dredge thicknesses were defined by the depth of contamination, using the interface between the core interval that exceeded the surface RALs and the core interval that was below the surface RALs. For example, at a location with a 0- to 45-cm (0- to 1.5-foot) RAL exceedance where the next two 1-foot core intervals also exceed the surface RALs, but the third and fourth 1-foot core intervals do not exceed the surface RALs, the dredge thickness was set as 3.5 feet. If a thickness cut area only had an exceedance in the subsurface RAL interval (i.e., 0 to 45 cm or 0 to 60 cm), the dredge thickness was set to the subsurface RAL interval thickness (i.e., 1.5 feet or 2 feet, respectively). In contrast to elevation-based dredge depth locations, extra depth was not added to thickness cuts because the

[26] Mudline elevations in the design dataset, which are used in the design, are the field-measured mudlines (when available) or are based on the bathymetric survey when field measurements are not available.

thickness cut is already delineated to constructable 0.5-foot intervals. In addition, the core compaction correction process that was used during the PDI effectively "expands" the thickness of the RAL exceedance interval in the core, which may result in a conservative estimate of thickness. This process for accounting for the core compaction was described in the standard operating procedure for subsurface sediment collection in the PDI QAPP (Windward and Anchor QEA and 2022). Surface-only RAL exceedances (i.e., 0 to 10 cm [0 to 4 inches]) were assigned a required dredge thickness cut of 0.5 foot in intertidal areas and areas that are potentially constructable using land-based equipment and 1 foot in subtidal locations.

RAAs with multiple cores may have had different assigned vertical contamination elevations or thicknesses and were therefore broken into subareas, with each subarea having a different required dredging elevation or thickness. These subareas are notated with a letter following the RAA label (e.g., RAA 1A). RAA subareas are shown in Figures 5-1a through 5-1e. Table D-1 in Appendix D summarizes the vertical dredge prism design basis for each RAA subarea.

9.1.1.1 Dredge Cut Side Slopes

Dredge cut side slopes were evaluated as described in Section 7.3 by identifying typical side-slope angles and computing the factor of safety for the dredge cut slope under both short-term conditions (prior to backfilling) and long-term conditions (post-construction). Based on these evaluations, it was determined that dredge cut side slopes of 3H:1V should be used to maintain an adequate factor of safety for the long-term condition, whereas dredge cut side slopes of 2H:1V are allowable for the short-term condition. Where dredge cuts are thin (on the order of 1 to 2 feet thick), vertical side slopes are indicated because dredge buckets cannot practicably grade such a small slope.

Internal slopes between dredge units are assumed to be cut at 2H:1V, with the toe of the slope set at the deepest elevation or depth along the interface of the units.

9.1.1.2 Horizontal Dredge Offsets

Section 8 identifies the in-water and shoreline structures that are within or adjacent to an RAA, including structures that will be protected in place and structures that will be removed (and potentially replaced). The Intermediate (60%) RD dredge design includes horizontal offset requirements for structures based on adjacent required sediment removal elevations/thickness cuts and associated short-term and long-term structure stability. These dredging offset distances will be refined during Pre-Final (90%) RD following updates to RAAs driven by Phase III PDI data.

9.1.1.3 Dredging Tolerances

The dredge prism specification includes two components: the required dredge elevation/thickness and the allowable overdredge tolerance. The required dredge elevation/thickness information provided in Table D-1 in Appendix D represents the removal elevation grades or thicknesses that a contractor will be required to achieve throughout the RAA subarea. To achieve the required dredge elevation/thickness, an allowable overdredge tolerance, which is an additional depth of sediment below the required dredge elevation/thickness that may be removed, is necessary to account for dredging equipment accuracy, operator skill, and site conditions. The dredge prism design (including allowable overdredge tolerance) reflects the fact that it is not possible/practical for any dredge to excavate to an exactly flat surface.

The contractor will generally be provided with an allowable overdredge tolerance of 1 foot below the required dredge elevation/thickness. In defined areas, the contractor will be provided with an allowable overdredge tolerance of 0.5 foot below the required dredge thickness. Further criteria for evaluation and acceptance of dredge tolerances during construction will be defined in the CQAP, which will be developed in future design phases. The overdredge tolerance will result in a more constructable dredge surface and may also reduce dredging residuals concentrations because the overdredge layer is composed of lower concentration materials that can mix with the dredged sediment, potentially resulting in an overall lower concentration residual release.

9.1.1.4 Special Considerations for FNC North of 1st Avenue S Bridge

As described in Section 5, the segment of waterway north of the 1st Avenue S Bridge with deep contamination is very constricted. To accomplish remediation while avoiding undermining the structures and critical infrastructure along the eastern bank, LDWG has proposed shifting the navigation channel 15 feet west for this stretch of the waterway (RAAs 30C through 30G).

Additionally, the proposed future maintenance depth for a portion of the segment (RAAs 30C through 30F) is -26 feet MLLW instead of the authorized depth of -30 feet MLLW. This allows dredging depths to be shallowed to an elevation where side slopes will not undermine the western shoreline, and the eastern shoreline impacts will be limited to Port of Seattle sliver property. This provides further protection to the adjacent utilities, as well as the 1st Avenue S Bridge foundation.

These proposed modifications to alignment and elevation of future maintenance dredging, which have been discussed with USACE, are anticipated to be compatible with current and future uses of the waterway since deep draft vessels do not use this stretch based on restrictions posed by the 1st Avenue S Bridge. LDWG will continue working with USACE to coordinate on strategy for obtaining official approval of the proposal.

9.1.2 Equipment Selection

Equipment selection for sediment remediation projects must be carefully considered by contractors using their experience with the site conditions, standard and specialized equipment they have used and have access to, and the expertise of their personnel. Equipment selection is typically based on the ability of the equipment and contractor means and methods to meet specifications that set forth detailed performance requirements to be achieved by the contractor. These performance specifications include specified materials characteristics, earthwork tolerances, environmental criteria (e.g., water quality and sediment chemistry), schedule requirements, health and safety considerations, and quality-of-life considerations (e.g., air, noise, and light).

Using performance specifications allows experienced remediation contractors to develop the appropriate means and methods for using equipment that they determine is the most appropriate for the different site conditions they will encounter in the middle reach. The use of performance-based design approaches reflects key lessons learned from previous remedial actions conducted in EAAs (see Table 2-2 of the RDWP [Anchor QEA and Windward 2022a]) and the first two construction seasons of the upper reach. Performance-based specifications inform the operational characteristics and requirements of the project design and allow for contractor expertise, use of specialized equipment, and contractor flexibility to perform the work based on the constraints of the design and unique site characteristics.

The design approach to inform the contractor's equipment selection will use a combination of performance specifications with some use of method specifications, which are specifications that direct the contractor to conduct specific work in a specific manner. For example, a performance specification would set the water quality criteria that the contractor would be required to meet during in-water operations but would not determine what equipment the contractor should use to meet those criteria. An example of a method specification would be to require the contractor to dredge a side slope from the top of the cut slope to bottom of the cut slope to limit the risk of slope failure.

In general, requiring a contractor to use specific equipment or methods (e.g., method specifications) can ultimately be limiting and may prevent the contractor from applying its experience on how to best accomplish the dredging work while meeting environmental performance criteria. In this sense, using only method specifications can have the unintended consequence of causing a dredging project to be less environmentally protective than a project where the contractor can choose the equipment and bring its experience to bear. Thus, for this project, remediation equipment selection will be done by the contractor to meet performance specifications that dictate the required environmental and green remediation outcomes, the monitoring that will be conducted, and the contingency actions that will be taken to assure environmental protectiveness.

The contractor will identify proposed equipment in the Remedial Action Work Plan (RAWP), subject to review and approval by the Owner and EPA.

Based on past experience, the following sections include discussion of the specific equipment that is anticipated to be used by the contractor.

9.1.2.1 Dredging Equipment Screening

The FS included screening of removal process options, including mechanical dredging methods (e.g., mechanical cranes and barge-mounted excavators), hydraulic dredging methods, and upland excavation, and discusses the infeasibility of using hydraulic dredging as the primary dredge method due to the following (AECOM 2012):

- Impacts to waterway users
- Lack of upland space to dewater hydraulically dredged slurry
- Inability to remove debris

Hydraulic dredging entrains significant amounts of additional water (e.g., typically four to seven times the volume of dredged sediment), which requires a large area for dewatering and water treatment processes, increases the energy used, adds complexity, and generates additional waste streams (e.g., process water, expended treatment media). Hydraulic dredging also transports the dredged materials as a slurry through a hydraulic transport pipeline that extends from the hydraulic dredge to the dewatering site, sometimes located miles away; these transport pipelines are typically floating and obstruct the use of the waterway where the pipeline is located. Hydraulic dredging had been retained in the FS for location-specific circumstances where the total amount of water generated would be small and controllable. Evaluation during the Preliminary (30%) RD determined that hydraulic dredging would not be required for the LDW middle reach.

Mechanical dredging and excavation are the most commonly practiced forms of sediment removal in the Puget Sound region, with approximately 90% of projects in the region using it during project implementation. These methods are adopted in the design as the primary removal equipment for in-water work. Mechanical dredging is expected to be the optimal method in open-water areas because of the following: 1) its effective removal of consolidated sediment, debris, and other materials such as piling and riprap; and 2) its relatively compact operational footprint, thus reducing the potential impact to existing waterway operations. Dry excavation using conventional earth-moving equipment working above the water line is also retained for use in intertidal and embankment areas, and in RAAs 24 B, C, and D.

9.1.2.2 Mechanical Dredging Equipment and Bucket Selection

Mechanical dredges employ a bucket to retrieve sediment from the bed of the waterway, move the sediment up through the water column, and place it into an adjacent haul vessel (such as a barge) for transport and disposal. Two major categories of mechanical dredges are differentiated based on the method of bucket deployment. The first category uses a wire attached to a crane or derrick to lower the bucket to the bed and retrieve sediment. The second category deploys the bucket at the end of the arm of an excavator or backhoe and is sometimes referred to as an articulated fixed-arm dredge. Mechanical dredges can be further classified by the type of bucket used, such as conventional open clamshell bucket or environmental buckets (Exhibit 9-1). The *Technical Guidelines for Environmental Dredging of Contaminated Sediments* (USACE 2008a) describes the following types of mechanical dredge buckets:

- Conventional Clamshell Bucket: This conventional dredge consists of a wire-supported, open clamshell bucket. This bucket is often used from a barge-mounted derrick crane and is a heavy bucket with teeth that are suitable for digging consolidated materials, handling debris, and penetrating deeply into sediment to allow higher production rates.
- Environmental Bucket: The environmental (or closed) bucket is a near-watertight or sealed bucket (when complete bucket closure is possible) as compared to the conventional open bucket. Recent designs (e.g., Cable Arm) also incorporate a level-cut capability as compared to a circular-shaped cut for conventional buckets. The environmental bucket is typically lighter in weight than conventional clamshell bucket and can be ineffective when dredging consolidated sediment, rock, or debris.
- Articulated Bucket: Articulated buckets include both conventional buckets and environmental buckets but use a hydraulic closing mechanism to operate the bucket instead of a cable or wire pulley system. The articulated bucket is typically supported by an articulated, fixed arm (e.g., Hydraulic Profiling Grab bucket system, Young Manufacturing rehandling bucket). Articulated buckets may have tighter control on bucket location than a bucket suspended on a cable or wire pulley system. Articulated buckets used for sediment remediation dredging are typically 3 to 8 cubic yards (cy) in size and are fully closing.

Table 9-1 provides a comparison of both conventional and environmental buckets, including the benefits and constraints typically associated with each technology.

Table 9-1
Comparison of Conventional and Environmental Dredge Bucket Benefits and Constraints

Bucket Type	Benefits	Constraints
Conventional	• Limits entrained water in dredge bucket, which reduces the need for water management during offloading and disposal • Capable of removing hard sediments • More effective at removing debris	• Potential loss of sediment and increased resuspension into water column when bucket is raised • Typically result in a less even dredged surface compared to a level-cut environmental bucket
Environmental	• Reduces potential loss of sediment and resuspension when bucket is raised through the water column • Some environmental buckets have level-cut capability, which can increase precision. • Low resuspension in unconsolidated sediment deposits	• Captures more water than conventional bucket; this issue is exacerbated when precision (thin) cuts are required • May be unable to remove hard sediments or debris • Closed design can increase “bow wake” as bucket digs into sediment, causing local resuspension and residuals around digging site.

Exhibit 9-1
Different Bucket Types

Conventional clamshell bucket

Environmental bucket

Articulated bucket (horizontal profile grab)

Environmental buckets have been designed to work with mechanical dredging equipment (e.g., derrick cranes or hydraulic excavators). However, minimizing the loss of sediment out of the bucket does not necessarily mean reducing suspended solids or lowering turbidity. As discussed in Wang et al. (2002), environmental buckets have not been proven to reduce suspended sediments in all site conditions.

When used in unconsolidated sediment without significant debris, environmental buckets have been shown to be effective at reducing loss of sediment from the bucket. Unconsolidated sediments are anticipated to occur in many dredge areas in the middle reach, which supports the use of an environmental bucket as the primary technology for removal. Anticipated losses in the form of generated residuals from environmental buckets in these conditions could be on the order of 2% to 6% of the dredged mass (Patmont et al. 2018).

The selection of dredge bucket and equipment is project- and contractor-specific and can vary depending on location-specific factors even for a single dredging project. The best equipment for one task may be unsuitable for another task. Dredging soft sediments in open water with minimal debris can be effectively accomplished with a conventional derrick crane and environmental (or closed) buckets. Constrained dredging in limited access areas may be more appropriately accomplished using an articulated bucket. In site conditions with significant debris, neither environmental buckets nor conventional buckets may be able to fully close; any bucket technology tends to lose most or all of the dredged sediment from the bucket as it is raised through the water column when debris prevent complete bucket closure.

For the middle reach, the contractor will be required to use an environmental-type closing bucket as the primary dredge technology. The use of alternate buckets will be based on acceptance from the Resident Engineer if conditions are encountered that may not be suitable for an environmental bucket, such as hard substrate, debris, and/or bank areas. It is anticipated that a 6- to 8-cy-sized dredge bucket would reasonably be used for dredging in most locations given the size of the project and requirements for bank dredging. However, in areas that contain small to larger debris (e.g., heavy vegetation, rock and concrete slabs, intact and broken pilings, and fused debris piles) or harder sediment, environmental buckets are anticipated to be ineffective; therefore, a heavier bucket with conventional digging capabilities or a specialized bucket to remove debris would likely be the type of equipment selected by the contractor.

Dredging operations have well-established BMPs to limit sediment disturbance and manage potential water quality effects (USACE 2008a). Operational and engineering controls will be defined in the construction Specifications, which the contractor will be required to implement. Construction BMPs related to mechanical dredging and reducing water quality effects during dredging are discussed in Sections 10.1 and 10.2.

9.1.2.3 Land-Based Excavation

Land-based excavation using excavators, backhoes, and other conventional earth-moving equipment may be used to remove intertidal and bank area materials. Excavation in these areas may be coordinated in the dry during periods of low tidal elevations; however, depending on weather, tides, scheduling, and contractor production, it will be necessary to conduct some intertidal sediment removal (excavation or dredging) below water. Intertidal sediment and shoreline bank soil excavation in the dry reduces the potential for release of impacted intertidal sediment and shoreline bank soils to the LDW by removing the sediment accessible from the upland when the tides are low and the sediment is exposed.

Given the geometry of the bank areas and the typical reach of upland-based equipment, it is anticipated that materials removed from the bank areas may need to be placed into a temporary upland stockpile area or directly into trucks, depending on site access agreements and available upland space. Thus, any land-based work will require access, staging areas, loading operations, and ground transportation. These logistical factors tend to favor accomplishing the work with floating equipment, although that can be impractical in shallow water areas that limit hours they can be accessed or in areas such as the inlet at RM 2.2W (RAAs 24B through 24D). As stated in Section 8.4, a temporary cofferdam and outfall diversion will be constructed to facilitate excavation and material placement in the dry. The feasibility to perform dredging from a nearshore position at RAAs 6, 8F, 9C, 9I, 17, 21A, 29, 31C, 31D, and 35A will be evaluated during Pre-Final (90%) RD.

9.1.2.4 Debris Removal

As discussed in Section 2.4.10, debris is located within several dredging footprints. For the purposes of the Contract Documents, Identified Debris is generally considered to be debris that is anticipated to require specialty equipment to remove (i.e., unlikely to be removed with a dredge bucket). Debris identified during the PDI is shown in DER Map 3-1g (Anchor QEA and Windward 2025a). The contractor will be required to remove Identified Debris within an RAA prior to dredging that RAA, including the sunken barge within RAA 14A.

In addition to Identified Debris, debris may be removed with the sediment during dredging (Incidental Debris). Incidental Debris will not be separately removed prior to dredging and will be handled, transported, and disposed of with the dredged sediment.

9.1.3 Dredging Production Rates

Dredging production rates (i.e., the volume of in situ dredged material removed on an hourly or daily basis) will vary based on the contractor's selected equipment and personnel experience, sediment physical characteristics, throughput daily capacity at the transload facility and transport rate of dredged material for final landfill disposal, site constraints (such as tidally restricted access, nearby vessel traffic, presence of structures, steep slopes), and weather conditions. Production rates will be higher in some areas of the middle reach and lower in others, depending on the constraints affecting production, including sediment type (e.g., consolidated versus unconsolidated), water depths, cut thickness, type of cut (e.g., sloped cut), water quality protection, and presence of debris. Typically, production rates are lower at the start of new construction activities (e.g., beginning of a construction season[27] or start of a new activity) and then increase over time as the contractor works out efficient methods to accomplish the work. However, weather or access delays, location, adjacent marine traffic, the project's environmental controls (such as turbidity control requirements and environmental and water quality monitoring), confirmation sampling and resulting potential need to re-dredge some areas, equipment maintenance, and tangential factors (e.g., transload facility throughput capacity) are expected to periodically slow production over relatively short time spans during a typical construction season.

It is estimated that a reasonable mechanical dredging production rate in the middle reach open-water areas (such as the FNC) will be approximately 990 cy per day. Dredging production rates are anticipated to be lower for contingency re-dredging, nearshore dredging, and restricted access dredging, which are estimated to range from approximately 330 to 580 cy per day. The dredging production rate within areas that are tidally influenced is estimated to be approximately 180 cy per day because of the narrow tide window to conduct the in-water work. Excavation conducted with land-based equipment for shoreline/bank removal work assumes a production rate of 500 cy per day.

As a general example and to illustrate the calculation to determine a dredging production rate in one site condition (in open-water areas), the anticipated daily open-water dredging production rate is calculated using the following assumptions:

- The contractor uses a mechanical barge-mounted derrick crane.
- The derrick crane uses an 8-cy bucket.
- The bucket fill factor is 70% (i.e., 30% of bucket is not filled with sediment).
- Dredge cycle time (i.e., one cycle equals the time to lower the bucket to the bottom, close the bucket with dredged material, raise the bucket out of the water, place the dredged material into the barge, and make ready for the next cycle) is 1.87 minutes per cycle.
- The contractor works one 10-hour shift per day (i.e., 600 minutes per day).
- The average operational "uptime" is 55%.
    - Uptime is the proportion of time that the dredge is actually working. The remainder of the time (i.e., downtime) includes time for maintenance, dredge repositioning, debris management, shift changes, time needed to periodically switch out the barges used to

[27] A construction season is defined as the construction period in which in-water work is conducted by the contractor. The construction season designated for the LDW is based on the in-water work window, which will be determined by EPA (but is anticipated to be from approximately October 1 through February 15) to protect certain fish species for in-water work occurring below the ordinary high water elevation. See additional details in Section 12.

transport dredged material, inherent delays (i.e., including, but not limited to, commercial shipping/traffic and Tribal fishing activities within the work site and inclement weather) and other non-dredging work.

Mechanical Open-Water Dredging Daily Production Rate Equation:

*Production Rate = (bucket size * bucket fill factor) * ((total work minutes per day/cycle time in minutes) * %uptime))*

*= (8 cy * 70%) * ((600 min/1.87 min) * 55%)*

= (988 cy/day)

It is expected that this calculated open-water dredging production rate will vary significantly on a daily basis (both lower and higher) due to factors listed previously. However, from a schedule planning perspective, specific production rates for nearshore dredging, restricted access dredging, tidally influenced dredging, and shoreline/bank excavation were applied upon site-specific conditions in order to develop the Intermediate (60%) RD construction duration, resulting in an estimated 10 construction seasons. Additional options are being explored to reduce the estimated number of seasons. For example, multiple dredges working simultaneously could potentially increase these daily production rates. However, the constraint of transloading at the transload facility and shipment to a commercial landfill is anticipated to govern the maximum amount of sediment material that can be dredged per day.

9.1.4 Post-Dredge Elevation and Chemical Verification

The completeness of dredging will be verified as developed in the CQAP in future design phases. Surveys will verify that the required dredge elevations or thicknesses have been met. In locations where the required dredge elevation/thickness requirements have not been achieved, the contractor will be required to remove additional material to comply with the Drawings and Specification requirements to be developed in the CQAP.

Once post-dredge elevation requirements are achieved, post-dredge confirmation sampling (to be developed in the CQAP) will occur to characterize the post-dredge surface and to check for missed inventory. Based on the sampling results, contingency actions may be required for missed inventory or residuals management, as described in Section 9.1.5.

9.1.5 Residuals Management Approach

Dredging residuals are unavoidable and occur with all types of dredging. The quantity and quality of dredge residuals vary depending on the dredge material properties, presence of debris, and other factors. The residuals management approach differentiates generated residuals from missed inventory as follows:

- Generated residuals refer to the thin layer of disturbed contaminated sediment that are deposited on the post-dredge surface due to material loss during dredging or due to the inability of the dredge to fully remove the material disturbed during the excavation process. This material generally exhibits very high water content and very low shear strength and can be easily mobilized. Additional dredge passes are rarely effective at capturing generated residuals. Generated residuals can be deposited within the dredge prism and on nearby sediments.
- Missed inventory refers to unanticipated contaminated sediment that is below the designed dredging elevation/thickness (i.e., contaminated sediment located deeper than expected). Subject to engineering limitations (e.g., slope and structural stability), missed inventory can often be removed with additional dredge passes.

The purpose of residuals management is to provide a post-remedial action surface condition with concentrations that are all below surface RALs. Depending on the type and concentration of the residuals identified by confirmation sampling, contingency re-dredging may be required prior to placement of RMC or backfill to restore grades in areas shallower than -10 feet MLLW. The CQAP will include sampling and response protocols for generated residuals and missed inventory.

9.1.5.1 Contingency Re-Dredging

Contingency re-dredging is additional dredging that may be implemented after the required dredge surface has been achieved, based on results of the post-dredge sediment sampling. Post-dredge sediment sampling will be used to identify areas of missed inventory or high concentrations of generated residuals and to then define a re-dredge thickness or elevation over a defined area. Contingency re-dredging will be directed by the Resident Engineer. Contingency re-dredging includes an overdredge allowance of 0.5 foot. No contingency re-dredging will be performed in dredge areas that are designed as “partial dredge and cap” or “restricted” to protect infrastructure (e.g., submarine utility crossings).

9.1.5.2 Residuals Management Cover

RMC can be used to manage generated residuals and limit their movement around the site. The RMC materials are anticipated to blend with the generated residuals and provide a post-remedial action surface condition with concentrations that are below surface RALs. Placing RMC has provided greater certainty in achieving residual performance standards in the case study project sites evaluated in Desrosiers and Patmont (2009) and the USACE technical guidance *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk* (USACE 2008b). The RMC is typically a relatively thin layer (e.g., average 15 cm [6 inches]) of clean sand from local commercial aggregate suppliers.

A targeted placement thickness of 9 inches of RMC (with a 3-inch plus-or-minus vertical placement tolerance) will be placed in specified dredge areas that are not backfilled, as shown on the 60% Drawings. RMC will also be placed on dredge side slopes to a targeted placement thickness of 24 inches (with a 6-inch plus-or-minus vertical placement tolerance).

Additional RMC placement is planned for the perimeter surrounding each dredge area, consisting of one to two 20-foot-wide[28] perimeter bands. The inner perimeter is the 20-foot width from the top of dredge cut that will automatically receive RMC placement unless constraints from structures or shorelines dictate a narrower band of placement. No sampling will be conducted within the inner perimeter after completion of dredging within an SMA. The outer perimeter is an additional 20 feet outside of the inner perimeter that will be sampled to determine if placement of RMC is necessary. RMC placement on the inner perimeter and outer perimeter (if necessary) will also be placed at a targeted placement thickness of 9 inches with a 3-inch plus-or-minus vertical placement tolerance.

The dredge residuals management approach (including sampling, reporting, decision logic, and communication) will be summarized in the CQAP.

9.1.6 Post-Dredge Backfilling to Restore Grades

Backfilling dredged areas with clean material will be required in some dredged areas to restore pre-construction elevations for habitat purposes. Backfill can also serve a residuals management function. Unlike an engineered cap, this backfill layer is not armored to protect it from erosive forces; rather, it is sized, in part, to be generally stable in intertidal areas while balancing the gradation to use materials that are as fine as possible to more closely mimic the sediment that is naturally deposited. Some movement of the backfill material could occur, similar to how natural sediments in the river can move due to erosive forces. Backfill placement will target approximate existing grade above -10 feet MLLW with a 6-inch plus-or-minus vertical placement tolerance. The CQAP will include additional information on placement verification and tolerances.

In general, all dredge areas located outside of the FNC and above an elevation of -10 feet MLLW are to be backfilled and integrated with habitat material placement in intertidal areas as appropriate. One notable exception is RAAs 31B and 31C, where post-remedy elevations are controlled by the deep dredging cut in the FNC for RAAs 30D and 30E and it is not feasible to restore pre-construction elevations without significant encroachment into the FNC.

9.2 Material Handling and Transload

The details of material handling, transportation, and disposal will be determined by the construction contractor subject to approval by the Owner and EPA. A range of the most likely options is described

[28] The downstream inner and outer perimeters will be 30 feet for areas along the main flow of the river channel.

in this section with details about the facilities that may be used. A preliminary waste determination of sediment was performed using existing data, toxicity characteristic leaching procedure (TCLP) screening using the "20x rule of thumb," and Washington dangerous waste book designation, WAC 173-303-100(b)(5). The results of the preliminary determination are discussed in this section.

9.2.1 Transload Facilities

Sediment and debris removed from the middle reach will be loaded onto barges or directly into trucks during excavation activities conducted from upland access. Material loaded onto barges will be transported to a transload facility where the material will be offloaded from barges and loaded onto trucks or railcars for transportation to a permitted disposal facility. Dewatering of the dredged materials will be initially performed on barges. This on-barge dewatering will be accomplished by gravity separation of sediment solids from the water fraction, with associated filtering (or other necessary BMPs to comply with water quality criteria at the point of compliance) and return of the water to the LDW at the dredge location. After this initial dewatering, the barge scuppers or sidewalls (depending on barge configuration) will be sealed as they transit to the transload facility. When dredging in RAAs that include material characterized as TSCA waste, additional water treatment may also be required.

Once loaded to land at the transload facility, additional dewatering will be performed if determined necessary by the transloading and disposal facilities. Any effluent generated by dewatering at the transload facility will be managed (contained and, if necessary, treated) and disposed of in accordance with the facility's permit and standards for wastewater disposal.

9.2.1.1 Commercial Transload Facilities

The Duwamish Reload Facility at 7400 8th Avenue South, operated by Waste Management, is currently the only commercial transload facility located on the LDW. The facility has water access in Slip 4, at approximately RM 2.8, and has demonstrated a sufficient operational capacity to dewater and stockpile sediment and capture dewatering effluent at a rate of 1,500 tons of sediment per day (equivalent to approximately 1,035 cy per day). The facility has the capability to offload bulk material from barges and load onto trucks or railcars, and it accepts nonhazardous (Subtitle D) contaminated soil and special wastes. Any bulk material characterized as hazardous (Subtitle C), Washington dangerous waste, or TSCA waste (i.e., containing total PCB concentrations of 50 mg/kg or greater) cannot be directly managed at the Duwamish Reload Facility and must be containerized. These containers (containing dewatered sediment) can then be loaded on railcars for transportation to an acceptable landfill, as discussed in Section 9.2.

The Duwamish Reload Facility is the only commercial transload facility known to be operating at the time of this Intermediate (60%) RD. Other commercial transload facilities may become available or be identified prior to construction, and the contractor will propose the transload facility in its RAWP subject to approval by the Owner and EPA.

9.2.1.2 Contractor-Provided Transload Facility

A contractor-provided transload facility may be proposed during the contractor's work plan development phase (i.e., contractor's RAWP). The contractor would be required to obtain all necessary permits or substantive equivalence (e.g., solid waste and discharge permits), and the use of a contractor-provided transload facility would be subject to approval by the Owner and EPA. Any off-site facility would need to meet or exceed the substantive requirements associated with operating an on-site facility.

9.2.1.3 Project-Specific Transload Facility

The design team evaluated potential locations for siting a project-specific transload facility. Given the presence of an established commercial transload facility in close proximity to the LDW middle reach, a project-specific facility would need to offer significant advantages to offset the cost and time required to acquire or lease property; obtain necessary solid waste and discharge permits; and develop, equip, and staff the facility. The process for evaluating potential project-specific transload facilities began with identifying criteria for the evaluation and reviewing the local real estate market to identify any properties that met the criteria.

The property would need certain attributes, including the following, to be considered as a potential candidate as a transload facility:

- Location on the water, ideally adjacent to the LDW middle reach
- A dock with space for at least one barge
- Rail and/or road access
- Location in an industrial or commercial setting without restrictions that would limit 24-hour operations
- Sufficient size to dewater and stockpile sediment and load processed material into trucks or railcars
- Sufficient size to treat dewatered wastewater or pretreat and have sewer connection with adequate capacity to convey.

As discussed later in Section 12.2, the overall construction duration will likely be limited by the daily transloading throughput at the transloading facility. A contractor may propose to use its own waterfront facility as a transload facility, independent or in combination with a commercial facility, in order to increase the overall daily transloading throughput. This project-specific transload facility may need to obtain permits if EPA determines that the work is not on-site and subject to substantive compliance with ARARs. Such permits for off-site work (if applicable), approvals, or compliance with substantive requirements would be required for transferring nonhazardous, dangerous, or PCB remediation waste. Additional applicable requirements would include those for Spill Prevention, Control, and Countermeasures Plans and Stormwater Pollution Prevention Plans. If the facility were to include a discharge to the sanitary system, the requirements under the National Pollutant Discharge Elimination System would also apply.

9.2.2 Commercial Transfer Stations

Material removed from upland areas may be loaded directly into top-loading intermodal or similar containers and taken to a commercial transfer station to be loaded onto railcars for transportation to a landfill for disposal. Bulk material that is regulated as dangerous waste (Section 3.3) may not be managed at bulk transload facilities. Therefore, any TSCA or hazardous/dangerous waste will be direct loaded into containers (i.e., containerized) and taken to a commercial transfer station by the contractor.

Nearby commercial transfer stations that can accept containerized material and that may be used by the contractor are as follows:

- UP – Seattle Argo Yard located at 4700 Denver Avenue Seattle, Washington 98134. This facility is east of the LDW and receives containers via truck. It utilizes the Union Pacific rail line and can transport material to any of the regional facilities including the Chemical Waste Management of the Northwest landfill, operated by Waste Management.
- The Duwamish Reload Facility operated by Waste Management is located on Slip 4, within the middle reach. The facility receives containers by barge. It utilizes the Union Pacific rail line and can transport material to any of the regional facilities Waste Management operates.

9.2.3 Upland Transport and Disposal

Disposal of dredged and excavated materials will be at a permitted landfill. Waste characterization results and acceptable landfills are discussed in this section.

9.2.3.1 Waste Characterization

Material that will be removed from the site for disposal (e.g., dredged material) are characterized in design to determine how it will be managed. The standards for management are established by TSCA and RCRA. TSCA regulates PCB remediation waste, and RCRA regulates hazardous waste, which is called dangerous waste in Washington. Ecology is authorized to administer the RCRA program, and WAC has established regulations for dangerous waste, which includes wastes that may produce a leachate that exceeds regulatory levels of selected constituents and wastes that exhibit toxicity exceeding thresholds established in WAC Chapter 173-303-100. A preliminary characterization was performed using existing data and is discussed in this section.

The TSCA regulations define "PCB remediation waste" in part as waste containing PCBs as a result of a spill, release, or other unauthorized disposal, which includes affected sediment and soil. PCB remediation waste that contains less than 50 mg/kg dry weight may be managed as nonhazardous waste (i.e., at a "Subtitle D" landfill), whereas PCB remediation waste that contains greater than or equal to 50 mg/kg must be disposed of in a TSCA-authorized or hazardous waste (i.e., "Subtitle C") landfill. Material with PCBs greater than 50 mg/kg is referred to as TSCA waste in this BODR.

Wastes that are identified as nontoxic may be disposed of at a Subtitle D landfill permitted to accept waste from a cleanup site, and wastes that meet any of the definitions of hazardous waste must be disposed of at a Subtitle C landfill. Wastes that generate a toxic leachate as determined using TCLP are assigned "D" codes associated with the specific constituents that exceed regulatory levels in the leachate. In the absence of TCLP data, a conservative screening may be performed by comparing bulk concentrations of toxicity characteristic constituents in sediment to 20 times the TCLP regulatory levels. The screening is conservative because it assumes that all of the constituent present in the solid medium would leach into the aqueous phase, whereas the actual leaching would be less than 100%. In Washington, a separate category of toxic dangerous waste is determined either by calculating an "Equivalent Concentration" considering the sum of the contributions to toxicity of all the significant constituents (referred to as book designation) or by performing a specified toxicity test.

Existing sediment data were used to perform the preliminary waste characterization using total PCB concentrations, the "20 times" TCLP screening procedure, and Washington book designation. RAAs with constituent concentrations that resulted in a preliminary characterization as a regulated waste are identified in Table 9-2. Samples with concentrations of arsenic, cadmium, chromium, lead, or mercury that exceed 20 times the TCLP regulatory level are identified as D004, D006, D007, D008, or D009, respectively. Samples with an Equivalent Concentration equal to or greater than 0.001% are identified as WT02 per the book designation procedure. The locations of these samples and the associated categories of preliminary waste designation are shown in Figures 9-1a through 9-1c.

Table 9-2
Summary of RAAs with Anticipated TSCA Waste and Potentially Hazardous or Dangerous Waste

RAA	Anticipated TSCA Waste[1]	Potential RCRA Hazardous Waste (waste code)[2]	Potential Washington WT02 Dangerous Waste[3]
5A			X
8B			X
8C			X
8F		D009	X
8G			X
9A			X
9B		D004, D008	X
9C		D004, D008	X

RAA	Anticipated TSCA Waste[1]	Potential RCRA Hazardous Waste (waste code)[2]	Potential Washington WT02 Dangerous Waste[3]
9D			X
9E			X
9M			X
19	X		
20A		D008	X
21A	X		
21B		D008	
24B			X
24C	X	D006, D007, D008, D009	X
24D	X	D007, D008	X
24E		D007, D008	X
24F			X
24G		D008	X
26		D008	X
30F			X
31B	X	D008	
31C	X		
31D			X
SMA 10			X

Notes:

1. RAAs with at least one sample with a total PCB concentration of 50 mg/kg dry weight or greater, which is the threshold requiring disposal at a TSCA-authorized or hazardous waste (i.e., "Subtitle C") landfill.
2. TCLP screening is conservative based on a comparison of bulk sediment concentrations to 20 times the TCLP regulatory levels. Preliminary designations will be reassessed using TCLP testing that will be performed as part of the Phase III PDI.
3. Dangerous waste screening is conservative based on the book designation procedure in WAC 173-303-100 (5)(b). Preliminary designations will be reassessed using bioassay data per WAC 173-303-100 (5)(c) that is being conducted as part of the Phase III PDI.

mg/kg: milligram per kilogram
PCB: polychlorinated biphenyl
PDI: pre-design investigation
RAA: remedial action area
RCRA: Resource Conservation and Recovery Act
TCLP: Toxicity Characteristic Leaching Procedure
TSCA: Toxic Substances Control Act
SMA: sediment management area
WAC: Washington Administrative Code

The Phase III PDI includes bioassay and TCLP testing of sediment from the RAAs identified in Table 9-2 as potentially containing RCRA hazardous or Washington State-only dangerous waste. Those data will be reflected in Pre-Final 90% RD.

Nonhazardous waste (material that is not regulated as dangerous waste in Washington or PCB remediation waste) may be offloaded in bulk at the commercial transfer station on the LDW. Dangerous waste and PCB remediation waste will be handled separately from nonhazardous waste and placed into containers before it is transfer at the Duwamish Reload Facility or another transfer facility as stated in Section 9.2.1.1 or Section 9.2.2.

9.2.3.2 Acceptable Landfills

Several permitted landfills in the Pacific Northwest are approved to dispose of nonhazardous contaminated sediment from Superfund sites. These include the Roosevelt Regional Landfill (owned and operated by Republic Services in Roosevelt, Washington) and the Columbia Ridge Landfill (owned and operated by Waste Management in Arlington, Oregon). Other landfills are also approved for this waste stream; acceptability criteria vary by facility. The selection of a landfill will be made by the contractor in its RAWP subject to approval by the Owner and EPA. The compliance status of the landfill will be confirmed prior to removing waste from the site in conformance with the Off-Site Rule (40 CFR 300.440). The method of transportation (i.e., truck or rail) may depend on the choice of landfill. Both the Republic Services and Columbia Ridge landfills are served by rail and have dedicated rail unloading facilities. In addition, both landfills have exclusions from the requirements of the Paint Filter Test for dredged material, allowing wet material to be delivered to the landfill.

Dredged and excavated materials that classify as hazardous waste under RCRA will be disposed of in a RCRA-permitted hazardous waste landfill, and TSCA waste with total PCB concentrations equal to or greater than 50 mg/kg will be disposed of in a RCRA-permitted hazardous waste landfill or a TSCA-authorized disposal facility. The Chemical Waste Management of the Northwest landfill, operated by Waste Management in Arlington, Oregon, is the only Subtitle C landfill in the northwest region. This facility is also approved by EPA for disposal of TSCA waste.

9.3 Engineered Cap Design

Partial dredge and engineered capping was identified as the remedial technology for the following RAAs in the middle reach of the LDW: 1B, 5B, 8B, 9A, 9D, 9J, 9K, 14A, 15B, 20B, 22, 23A, 24I, 30B through 30H, and 31B through 31D. Direct placement of an engineered cap without dredging was selected for RAAs 26 (this area is also AST E, as described in Section 9.6.4) and 30A. Additionally, the caps within RAAs 5B, 8B, 9A, 9D, 20B, 24I, 26, and 31D must also include an upper layer of suitable habitat material. Appendices H and I present the evaluations performed to determine the minimum specifications for the engineered cap isolation and erosion protection layers, respectively.

9.3.1 General Cap Design Approach

Engineered caps are designed in accordance with the guidance on cap design set forth by EPA and USACE (Palermo et al. 1998) and the Interstate Technology and Regulatory Council (ITRC 2014, 2023).

These guidance documents provide a generalized approach to designing an engineered cap, including considerations of the following design components detailed in Appendices H and I:

- Chemical Isolation: Designing a cap chemical isolation layer that attenuates the transport of contaminants through processes such as advection, dispersion/diffusion, bioturbation/ bioirrigation, and surface exchange
  - Contaminant fate and transport modeling is performed to evaluate and design the chemical isolation layer component of a cap.
- Physical Isolation: Designing the cap layer thickness and/or material types to prevent direct contact of contaminants with biota and burrowing organisms (bioturbation)
  - Physical isolation also includes developing design criteria to prevent erosion of the cap.
- Geotechnical: Confirming that the bearing capacity and shear strength of underlying sediments, and of the cap itself, are sufficient to prevent excessive mixing during construction and slope failure
  - Geotechnical considerations for capping, including an evaluation of seismic risk, are discussed in Section 7.3.2.
- Cap Stability: Designing the upper layers of the cap to withstand erosive forces and prevent upward migration of fines through the overlying cap layers
  - For standard caps, the uppermost layer will include suitable erosion protection materials. For modified caps, an erosion protection layer will be placed below a layer of suitable habitat material.
- Habitat Considerations: The ROD requires that upper layers of engineered caps must meet the following location-specific criteria: 1) in intertidal clamming areas (refer to ROD Figure 6), the cap must include a minimum 45-cm habitat layer;[29] and 2) in non-clamming areas above elevation -10 feet MLLW, the uppermost cap layers must include suitable habitat materials.

9.3.2 Engineered Cap Design Components

An engineered cap includes components for chemical isolation and erosion protection. The following sections describe evaluations for both of these components.

9.3.2.1 Chemical Isolation Layers

Based on the ROD, there are a total of 42 LDW COCs: 4 COCs based on risk to human health, 40 COCs based on risk to benthic invertebrates, and 1 COC for wildlife (i.e., river otters). The chemical isolation functions of caps for specific locations are designed based on the COCs that exceeded RALs in sediments that remain beneath the proposed engineered cap at that location. A total of 19 COCs were evaluated in Appendix H for RAAs proposed for engineered capping, including PCBs, dioxins/furans, cPAHs, mercury, zinc, butyl benzyl phthalate (BBP), 1,2,4-trichlorobenzene,

[29] Refer to Section 13.2.1.1 of the ROD for requirement related to the 45-cm habitat layer for engineered caps constructed in intertidal clamming areas.

1,4-dichlorobenzene, 2,4-dimethylphenol, high-molecular-weight PAHs, and 11 individual PAHs. Total PCBs were evaluated for all RAAs except RAAs 8B and 26. Dioxins/furans were evaluated for four RAAs, and mercury, BBP, PAHs, zinc, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, and 2,4-dimethylphenol were evaluated for one RAA. Based on the pending results of the Phase III PDI, arsenic is also expected to be modeled in intertidal caps for RAAs located on the east side of the waterway between RMs 2.7 and 2.8.

Chemical Isolation Layer Design Criteria

The chemical isolation cap layer is designed to meet performance standards within the surface of the cap. Typically caps are designed to be effective at preventing the transport of contaminants to the surface of a cap, resulting in no exceedance of the performance standard within 100 years; for the LDW, this would mean designing a cap to reduce human health and ecological risks by preventing chemical concentrations at the surface (0 to 10 cm in intertidal, subtidal, and FNC areas and 0 to 45 cm in intertidal areas) from exceeding the surface RAL within 100 years. The chemical isolation analysis was performed to identify the cap thickness and composition (i.e., amendment) needed to meet applicable RALs for all COCs for 100 years.

Chemical Isolation Layer Design Approach and Results

The 1D of chemical transport within sediment caps, CapSim (version 4.2.3; Reible 2023) was used for this evaluation. The model considers the transport of contaminants under the processes of groundwater advection, diffusion/dispersion, bioturbation/bioirrigation, and exchange with the overlying surface water within the sediment cap. The modeling approach used in the middle reach is generally consistent with the EPA-approved modeling for the upper reach. As a conservative assumption, the ongoing sedimentation that will occur in most locations has not been considered in the cap design. No degradation was simulated, although some of the PAHs and SVOCs have shown to degrade in sediments.

The cap model predicts the chemical concentrations that may occur in the surface of a cap over time. This analysis was performed to identify the cap thickness and composition (i.e., amendment) needed to meet applicable RALs for all the capping RAAs and the corresponding COCs described previously. PCBs were simulated by homolog group to account for the differences in mobility among the homologs, and results were summed to calculate total PCBs in sediment for comparison with RALs. Similarly, each dioxin/furan congener and PAH compound were simulated individually for dioxin/furan toxic equivalents quotient, cPAHs, and total high-molecular-weight PAHs. The cap design was evaluated for a range of seepage rates of 400 and 800 cm per year for RAAs in the intertidal and subtidal areas and 100 and 400 cm per year for RAAs within the FNC.

Results of the cap model evaluation are described in Appendix H. That analysis demonstrated that a minimum chemical isolation layer thickness of 15 cm (6 inches) of gravelly sand without amendment would be sufficient to meet the applicable RALs for more than 100 years under the range of seepage rates evaluated for all cap design areas evaluated, except for RAAs 5B, 8B, 9D, 24I, and 26. For RAA 26, a 15-cm (6-inch) chemical isolation layer with an amendment content equivalent to 48% total organic carbon (TOC) is predicted to meet the RAL for BBP. For RAAs 5B, 9D, and 24I, a 15-cm chemical isolation layer with a 2%, 1%, and 1% TOC amendment, respectively, is predicted to meet the RAL for total PCBs. Alternatively, the same level of protection can also be achieved by a 30-cm (12-inch) chemical isolation layer with 14% TOC amendment needed for RAA 26, no amendment needed for RAAs 9D and 24I, and 1% TOC amendment needed for RAA 5B. For RAA 8B, a 75-cm (30-inch) chemical isolation layer with an amendment content equivalent to 73% TOC is predicted to meet the RAL for 1,4-dichlorobenzene. Alternately, a 60-cm (24-inch) chemical isolation layer with 100% TOC amendment is predicted to be sufficient under the lower seepage rate, although it is predicted to exceed the RAL in Year 96. The Phase III PDI includes activities to further refine the isolation layer design in these RAAs.

9.3.2.2 Bioturbation

Another consideration in the design of engineered caps is to account for the potential for surficial and deeper-burrowing benthic organisms to burrow (i.e., bioturbation) into the cap and reach the subsurface contaminants. The biological active zone (BAZ) refers to the surface sediment layer where sediments are mixed by the feeding and burrowing behaviors of benthic invertebrates. A bioturbation thickness of 10 cm (4 inches) was used in the cap design where mixing by benthic activity was simulated. Section 2.8.2 of the RI (Windward 2010) concluded that 10 cm (4 inches) can be reasonably applied for the BAZ for the LDW based on an Ecology-led study in 2006 (Ecology 2007) that included 87 sediment profile imaging stations within the LDW and 28 sediment profile imaging stations in the LDW at the Duwamish/Diagonal EAA site under a King County study (Anchor Environmental and King County DNRP 2007). The study indicated the following:

- Representativeness of the Benthic Invertebrate Community: The benthic invertebrate community primarily uses shallower sediment, based on the limited number of voids that have been observed below 10 cm (4 inches); individual benthic invertebrates have been observed at depths of 15 to 20 cm below the sediment surface.
- Relationship Between Voids and Depth in Sediment: The number of voids decreases significantly with distance from the sediment surface.
- Central Tendency of Void Depth: The mean of the maximum void depths observed in individual profile images was approximately 10 cm (4 inches) with a 95% upper confidence limit of 11 cm (4.5 inches) in subtidal and intertidal areas of the LDW, which was corroborated by the King County study (Anchor Environmental and King County DNRP 2007).
- Location: Other than an association with fine-grained sediment, there were no apparent clusters of areas with deeper voids; voids seem to be distributed throughout the RI study area and not related to presence or absence of contamination.

Caps will include an erosion protection layer that will limit the ability of organisms to reach the underlying chemical isolation layer component of the cap, as discussed in Section 9.3.2.3, due to coarser grain size (more difficult burrowing) and thickness (greater than the 10-cm [4-inch] BAZ).

9.3.2.3 Erosion Protection

Caps are designed to be stable with regard to expected erosive forces. The design of the erosion protection layer includes determining the required cap erosion protection layer grain size and thickness to prevent cap damage from erosive forces and adding an underlying layer of material to prevent the loss of the chemical isolation layer material due to winnowing into the larger-grain-sized erosion protection layer. The top layer of the cap that acts as the erosion protection layer is typically referred to as an armor layer; the material under the armor layer that helps prevent winnowing is referred to as the filter layer. The cap erosion protection design may be able to avoid a discrete filter by integrating filter material both into the armor and chemical isolation layers, which is a common design approach. The detailed cap gradation design will be specified in Pre-Final (90%) RD.

Per the RDWP (Anchor QEA and Windward 2022a), the cap has been designed to resist the following erosive forces: hydrodynamic flows, wind-generated waves, vessel propwash, and vessel wakes. The following sections summarize the erosion protection design presented in Appendix I. Climate change effects (e.g., sea level rise) on erosion protection design are discussed Section 9.9.2.

The stable particle sizes evaluated as part of this study consider a single erosive force occurring at a time. Erosive forces occurring in tandem are possible; however, they are either unlikely to occur or do not control the stable particle size. Erosive forces that are considered in the design (i.e., river currents, wake and propwash) are generally not additive forces because they act on the sediment bed in different physical ways; therefore, they are generally not superimposed when evaluating stable sediment sizes in an area subject to all of these forces. In addition, the results of this analysis (see Appendix I, Section 4) concluded that the near bed current velocities due to vessels are approximately 10 times the forces associated with a 100-year flow event, which is not significant enough to change the calculated median stable particle size (D_{50}) by more than 0.2 inch.

Hydrodynamic Flows

Hydrodynamic flows (i.e., LDW river flow velocities) are a natural cause of potential bed erosion. The FS prepared a hydrodynamic flow model for the LDW (QEA 2008) and predicted river velocities generated during a 100-year recurrence event. The 100-year flow recurrence is considered a standard design event for cap design, and predicted bed shear stress within the middle reach ranges from 1.8 to 2.2 Pascal for the 100-year flow in the LDW at peak ebb tide conditions. USGS developed a summary table of critical bed shear stress and corresponding particle (rock) size (USGS 2008). For the modeled range of bed shear stress, the corresponding stable particle (rock) size ranges from 0.1 to 0.2 inch (very fine gravel).

Additional hydrodynamic modeling was not completed as part of Intermediate 60% RD to reflect proposed dredge depths within the middle reach. This is because the middle reach is tidally dominated, and increased water depths are not expected to significantly change near bed current velocities.

Wind-Generated Waves

Wind-generated waves are formed by wind blowing over an unobstructed water surface and are formed due to continuous wind blowing in a single direction over long distances (i.e., fetch[30]). The LDW is narrow (between 250 and 450 feet wide); the water surface has obstructions that block the wind at various locations (e.g., the 1st Avenue S Bridge, bends in the waterway, high banks); and the LDW has restricted fetch distances.

A wind-wave evaluation was completed for Final (100%) RD for the LDW upper reach (Anchor QEA 2024). The controlling fetch distance for the middle reach is the same as the upper reach; therefore, the analysis for the upper reach applies to the middle reach. Based on the wind-wave analysis completed for the upper reach, calculated 100-year wave heights ranged from 0.5 to 0.6 foot. These are smaller than the maximum vessel wakes calculated for the middle reach. Thus, as expected, wind waves will not govern the stable particle size for the middle reach.

Vessel Propwash

In order to evaluate potential erosive forces from vessels transiting the middle reach, design vessels and assumed conservative operating conditions need to be identified. The design vessel selection and operating parameters are described in Appendix I.

Vessel-generated propeller-induced water velocity (i.e., propwash) was evaluated using the methods in Appendix A ("Armor Layer Design") of EPA's *Guidance for In-Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al. 1998). This model considers physical vessel characteristics (e.g., propeller diameter, depth of propeller shaft, and total engine horsepower) and operational and site conditions (e.g., applied horsepower and water depth) to estimate propeller-induced bottom velocities at various distances behind the propeller. This model was used to predict the particle size that will be stable when subjected to the steady-state propwash (i.e., the vessel is essentially stationary or maneuvering at a very low speed).

Recent vessel traffic data were obtained through the Automatic Identification System (AIS); vessel data are collected by the U.S. Coast Guard through onboard navigation safety devices that transmit and monitor vessel locations and characteristics of large vessels. These data were downloaded via

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[30] Fetch refers to the unobstructed overwater distance in the wind direction of interest. Fetch distance can be very long in large open water locations (e.g., oceans) and is very short where land masses and other wind obstructions (e.g., building, bridges) limit the ability of wind shear stress to act for sustained distance on the water surface.

MarineCadastre.gov (BOEM and NOAA 2025). Based on this AIS data evaluation, two vessels were selected due to their type, size, or frequency of travel within the middle reach:

- *Garth Foss* (tractor tug) was selected because it was the largest tug, although not the most frequent, that traveled through the middle reach in the 5-year period of record.
- *Clayton Arthur* (tug) was selected because it was the third most frequent tug that traveled through the middle reach in the 5-year period of record and was significantly larger than the first and second most frequently operated tugs in the middle reach.

During Intermediate (60%) RD, additional information regarding vessel maneuvering and berthing operations within and adjacent to specific capping areas outside the FNC was obtained to develop accurate estimates of stable sediment sizes in those areas.

Appendix I provides further details of the propwash model design scenarios and inputs. The results of the propwash evaluation for FNC areas with standard caps show that a maximum bed velocity of 3.2 feet per second requires a D_{50} of 4.9 inches. Simulations for RAA 9K, which has a reduced under-keel clearance due to utility crossing in this location, show that a maximum bed velocity of 2.6 feet per second requires a D_{50} of 3.1 inches. These are the governing particle sizes for the design of the respective erosion protection layers within and immediately adjacent to the FNC, given that vessel wake forces (discussed in the next section) are negligible at such depths.

Vessel Wakes

Estimates of vessel-induced wave heights (i.e., wakes) were completed through an evaluation of ship traffic patterns within the FNC at the cap design area and calculations of vessel wakes based on type of vessel, operational speed, and water depths. Wake characteristics were estimated using an empirical method developed by Kriebel and Seelig (2005), which improves upon the original methodology developed by Sorensen and Weggel (1984).

The speed of travel of the vessels for wake calculations was limited to the documented speed limit in the FNC within the middle reach, which is 7 knots (SMC Section 16.20.130l). The stable particle size due to vessel wake was calculated using the estimated wake parameters by applying the stability formula developed by Boeters (Boeters et. al. 1993) included in the CIRIA Rock Manual (2007). This method was specifically developed to estimate stable particle size due to vessel wakes (as opposed to wind waves or other type of wave form).

Stable sediment sizes due to vessel wake were evaluated for a range of off-channel capping conditions (i.e., distance from shore and slope steepness). These areas are shoreline and inter- and subtidal areas where the bed could be influenced by boat wake from the top of bank down to approximately -2 feet MLLW. The lowest elevation where vessel wake will influence the stable particle size is assumed to be three times the wake (wave) height per guidance in the Coastal Engineering Manual (USACE 2008c).

The resulting minimum D_{50} to resist wake forces is 3 to 2 inches, respectively for 1:1 and 1:5 slopes, with some areas potentially requiring a D_{50} of 8 inches.

Erosion Protection Summary

The armor layer material size is controlled by the largest particle size that is stable against a range of erosive forces in the middle reach, including hydrodynamic forces, wind-generated waves, and vessel-generated propwash and wakes. The D_{50} to resist these forces are shown in Table 9-3. The thickness of the erosion protection layer is generally designed as two times the D_{50} value and modified for constructability considerations. Layer thicknesses vary based on specific site conditions at each RAA and are summarized in Section 9.3.3.

Table 9-3
Cap and AST Cover Design – RAA-Specific Stable Particle Size

RAA[1]	RAA Location	D_{50} (inches)[3]	Governing Erosive Force for Intermediate (60%) RD
1B, 9J, 14A, 22, 30B–30H	FNC	4.9	Propwash
8B	Intertidal	TBD	Vessel Wake, Propwash
9A, 9B, 9C, 9D (5B)	Intertidal	TBD	Vessel Wake, Propwash
9K[2]	FNC	3	Propwash
20B, 24I, 20A	Intertidal	TBD	Propwash, Vessel Wake
23A (15B, 30A)	Subtidal	TBD	Propwash
31C, 31D	Intertidal	8	Vessel Wake

Notes:

1. Secondary RAAs listed in parentheses were not directly modeled but are assumed to be similar to the modeled RAA listed. For example, the preliminary armor sizing for RAA 5B is based on modeling for nearby RAA 9A. Each RAA will be modeled individually during Pre-Final (90%) RD.
2. RAAs 9K are AST D, not engineered caps.
3. The predicted stable particle sizes have a very wide range of possible particle sizes based on empirical calculations. If capping is the selected remedy for these RAAs based on the results of the Phase III investigation, refinement of vessel operations at these locations and more complex evaluation methods may be required to determine stable particle size in these areas.

AST: area-specific technology
D50: stable median particle size
FNC: federal navigation channel
propwash: propeller wash
RAA: remedial action area
RD: remedial design
TBD: to be determine during Pre-Final (90%) RD

Those evaluations may include different design vessels (i.e., vessel configurations in addition to the *Clayton Arthur* and *Garth Foss*) and operations from those discussed in this report. Therefore, stable sediment sizes provided for priority capping areas outside the FNC provided in this report (60% design level) should be considered preliminary and subject to change.

9.3.2.4 Habitat Substrate Considerations for Caps

The ROD (EPA 2014) requires that upper layers of engineered caps must meet the following location-specific criteria: 1) in intertidal clamming areas (refer to ROD Figure 6), the cap must include a minimum 45-cm habitat layer; and 2) in non-clamming areas above elevation -10 feet MLLW, the uppermost cap layers must include suitable habitat materials. This applies to the engineered caps planned in RAAs 5B, 8B, 9A, 9D, 20B, 24I, 26, and 31D. Habitat substrate material type and material sources are discussed further in Section 9.5; however, it is important to note that the cap erosion protection modeling performed (BODR Section 9.3.2.3 and Appendix I) indicates that gravel-sized particles are required for long-term stability. The model used to estimate stable particle size is overly conservative due to its limitations in shallow water depths (Palermo et al. 1988). Additional modeling will be required during Pre-Final (90%) RD to determine if sandy material can be placed on caps within these areas. The surface of the placed gravel materials will eventually be covered by naturally deposited sediment specific to each area placed, so in the long term (i.e., 1 to 5 years) the habitat surface will return to conditions reflecting what is naturally deposited from upstream.

9.3.3 Engineered Cap Design Summary

Total design cap thicknesses are based on the thickness of the individual chemical isolation, filter, armor, and habitat layers required for each cap. Minimum thicknesses were determined for each cap layer as described in this section. Table 9-4 summarizes the preliminary cap design thickness for each layer.

Table 9-4
Engineered Cap Design Summary – Minimum Design Thickness[1]

RAA	Cap Location	Cap Type	Chemical Isolation Layer		Minimum Filter Layer Thickness (inch)[3]	Minimum Erosion Protection Layer Thickness (inch)[4]	Minimum Habitat Layer Thickness (inch)	Total Minimum Cap Thickness (inch)[4]
			Minimum Thickness (inch)	AC Dose[2]				
1B	FNC	Standard	6	None	6	12	--	24
5B[5]	Intertidal	Modified	6	2%	--	TBD	18	30
8B	Intertidal	Modified	24	10%	--	TBD	18	48
9A–9C[6]	Intertidal	Modified	6	TBD	--	TBD	18	30
9D[7]	Intertidal	Modified	6	TBD	--	TBD	18	30
9J	FNC	Standard	6	None	6	12	--	24
14A	FNC	Standard	6	None	6	12	--	24
15B	Subtidal	Standard	6	None	6	12	--	24
20B	Intertidal	Modified	6	None	--	TBD	18	30
22	FNC	Standard	6	None	6	12	--	24
23A	Subtidal	Standard	6	None	6	12	--	24
24I	Intertidal	Modified	12	None	--	TBD	18	36
26	Intertidal	Modified	6	5%	--	TBD	18	30
30A	Subtidal	Standard	6	None	6	TBD	--	24
30B–30H	FNC	Standard	6	None	6	12	--	24
31B[6]	Sub- and Intertidal	Standard	6	None	6	18	--	30
31C[6]	Sub- and Intertidal	Standard	6	None	6	18	--	30
31D[6]	Intertidal	Modified	6	None	0	6	18	30

Notes:

1. These minimums do not include allowable overplacement tolerances for the chemical isolation, filter, armor, and habitat layers. Those allowances will be specified at Pre-Final (90%) RD.
2. It was assumed that 1% of AC would equivalent to 10% TOC. The AC dosage needed for those RAAs will be further evaluated during Pre-Final (90%) RD. For RAAs 9A through 9D, Phase III investigations are evaluating the presence of arsenic in these areas. Based on these results, a treatability study may be required to select the type and dose of an iron-based amendment.
3. Filter layer thickness is based on professional judgment. Calculations will be performed during Pre-Final (90%) RD when erosion protection layer sizing is specified.
4. Total minimum cap thickness is calculated assuming that no overplacement occurs. For RAAs that are listed with TBD as the Minimum Erosion Protection Layer Thickness, a 6-inch layer was assumed in the Total Minimum Cap Thickness summation.
5. A chemical isolation layer of 12 inches with an amendment of 1% TOC was also predicted to meet the applicable RAL.
6. RAA 9A was not evaluated in the cap chemical transport modeling (see details in Appendix H); thus, chemical isolation layer thickness and composition for RAA 9A was assumed to be the same as RAA 5B given the proximity and expected similar post-dredge sediment concentrations. Based on the results of the Phase III PDI, partial dredge with a placement of a modified cap may also be assigned to a portion or all of RAAs 9B and 9C. These areas will be modeled during Pre-Final (90%) RD.
7. A chemical isolation layer of 12 inches with no amendment was also predicted to meet the applicable RAL.

--: not applicable
AC: activated carbon
FNC: federal navigation channel
PDI: pre-design investigation
RAA: remedial actional area
RAL: remedial action level
RD: remedial design
TBD: to be determined
TOC: total organic carbon

9.4 Enhanced Natural Recovery Design

The ROD selected ENR as the sediment remedy in Recovery Category 2 or 3 areas where COC concentrations in the top 10 cm are between 1 and 3 times the surface sediment (0 to 10 cm) RALs (depending on area) or where COC concentrations in the top 45 cm are between 1 and 1.5 times the intertidal RALs for the 45-cm interval (EPA 2014). The LDW ROD did not provide an upper limit for ENR for RALs that apply to the top 60 cm and noted that ENR is not currently a designated technology for addressing areas with no ENR upper limit.

ENR includes the placement of a thin cover layer of clean sand to accelerate natural recovery processes. ENR immediately provides a new surface substrate of clean sediments. This cleaner surface material will generally mix with the underlying material through mechanisms such as bioturbation. ENR reduces contaminant concentrations in surface sediments more quickly than would happen by natural sedimentation processes alone. Findings from the ENR/AC Pilot Study Year 3 monitoring report (Wood et al. 2021) indicate that ENR alone (without AC) is effective at reducing bioavailability of PCBs (90% reduction in concentration). The ENR/AC Pilot Study also demonstrated that the ENR performed as intended under various physical conditions (e.g., wakes/waves, propwash, bridle chain dragging) over the 3-year study.

The ROD indicated that ENR may be combined with in situ treatment (i.e., the sand substrate may be amended with AC or other sequestering agents to reduce the bioavailability of organic contaminants such as PCBs; EPA 2014). The effectiveness and potential impacts of using in situ treatment or amendment technologies, as well as the areas best suited for these technologies, were evaluated in the ENR/AC Pilot Study. The ENR/AC Pilot Study concluded that adding AC to the ENR layer provided no substantial improvement in PCB bioavailability reduction when compared to ENR alone (Wood et al. 2021). The study also showed that the amount of AC used (2.7% to 4% by weight AC) did not adversely impact benthic communities. AC amendment is not included in ENR as part of the design but is considered for ASTs to provide a redundancy in protection for those areas (see Section 9.6 for more details).

Consistent with the ROD and recent Puget Sound projects, ENR will include a layer of clean sand (or other suitable habitat materials) with a targeted placement thickness of 9 inches on in situ sediments (with a 3-inch plus-or-minus vertical placement tolerance). The ENR technology is assigned to RAAs 3, 8H, 21B, 23B, 24A, 25, 27B, 27D, 28, 31A, 32, 33, and 35B.

9.5 Material Types and Placement Methods

Material placement types included in this Intermediate (60%) RD include backfill, ENR, RMC, and engineered cap materials (cap isolation, filter, habitat, and armor layers). The anticipated types of material, sources, placement methods, and production rates are discussed in this section.

9.5.1 Material Types

Table 9-5 summarizes each of the material types associated with various project technology applications. During Pre-Final (90%) RD, detailed gradations will be developed in the Specifications. Once cap material specifications and volumes have been developed, specifications will be developed to specify means and methods for cap material transport, handling, and placement.

Table 9-5
Summary of Material Characteristics by Application

Material Application	Material Description[1]
Habitat substrate	Sand and/or rounded gravel aggregate will be used in habitat areas, including clam habitat areas.
ENR	Medium- to coarse-grained sand or gravelly sand, depending on location and depth of ENR
RMC material	Medium- to coarse-grained sand or gravel, depending on location
Amended ENR	Gravelly sand with specific amendments added to target COCs present, where needed
Engineered cap armor material	Angular rock armor (cobble/quarry spalls size) in FNC and potentially larger rock along steep shoreline areas that cannot be reconfigured
Engineered cap filter material	Angular gravel
Engineered cap isolation material	Gravelly sand and gravel
Backfill material	Gravelly sand or medium- to coarse-grained sand material, depending on location

Notes:

1. Material grain size and selected gradations do not vary based on material placement within Recovery Category 1, 2, and 3 areas. A single gradation has been selected to simplify constructability and to be protective in all recovery category areas.

COC: contaminant of concern
ENR: enhanced natural recovery
RMC: residuals management cover

9.5.2 Candidate Source Material Suppliers

Materials will be obtained from established upland borrow sources. There are several regionally available commercial sources of aggregate material (i.e., sand and gravel quarries) that can supply materials for backfill, capping (e.g., sand, gravel, armor), RMC, and ENR (e.g., sand and gravel). Locally available sources of aggregate material include the following:

- Glacier Northwest commercial sources (e.g., Dupont Pioneer Aggregates, White River, Snoqualmie locations in Washington)
- Corliss Resources (Lehigh Hanson), a sand and gravel facility in Sumner, Washington
- Valley View/Dieringer Pit, a sand and gravel pit in Shelton, Washington
- Baydo, a gravel facility in Auburn, Washington
- Johns Prairie Mine, a sand and gravel pit in Shelton, Washington

- Kent-Kangley Pit, a sand and gravel pit in Ravensdale, Washington
- Miles Sand and Gravel, multiple aggregate pit locations in Puget Sound region, Washington

The contractor will ultimately select appropriate material suppliers that can meet the design quantities, delivery schedules, gradations, and chemical quality criteria established for each material type. The specific supplier(s) will be identified as part of the contractor's RAWP, and the Specifications will require test result submittals for each product.

Beneficial use of clean dredged material from off-site non-remediation projects was evaluated as a potential source of backfill, ENR, RMC, and cap attenuation layer materials. Beneficial use of clean dredged material entails significant legal, contracting, logistic, coordination, and timing complications, among other issues, and has been difficult to accomplish for recent cleanup projects. Given the anticipated schedule for cleanup in the middle reach; the uncertainty of the timing, quantity, and quality of future dredging project volumes; and the challenges encountered in past projects associated with the perceived risk of using beneficial use sources on cleanup projects, beneficial use of clean dredged material is not included as part of the Intermediate (60%) RD assumptions and will be further evaluated in Pre-Final (90%) RD.

9.5.3 Source Material Acceptance Criteria

Cap, backfill, ENR, RMC, and habitat materials must be approved for use by the Owner and by EPA; therefore, testing of the borrow source material will be required of the contractor to demonstrate that the source materials meet specifications. Chemical criteria, gradation, material properties, and testing requirements will be identified in the Specifications, to be developed in Pre-Final (90%) RD.

9.5.4 Material Placement Methods

Project specifications to be developed in Pre-Final (90%) RD will identify performance criteria that the contractor must meet and will provide flexibility for the contractor to choose the optimal means and methods that take advantage of its experience and equipment. The contractor will be required to place all materials in a manner that reduces resuspending potentially contaminated bed sediment. Additionally, material will be placed using methods that limit mixing of the placed materials with the bedded sediment. Finally, placement of material will be subject to water quality monitoring, as required.

Exhibit 9-2 depicts in-water placement of clean material using typical marine equipment.

The following methods are considered acceptable placement methods, or combinations of methods, that the contractor may use to limit disturbance of the bottom sediments during material placement operations. The contractor will be allowed to propose alternate placement methods in its RAWP for review and approval by the Owner and EPA as follows:

- Placing cap, backfill, ENR, habitat, and RMC materials with a barge-mounted, crane-operated clamshell or a spreader box ("skip box")
  - The clamshell placement method involves slightly opening the bucket and slowly releasing the sand from the bucket near or slightly below the water surface as the operator moves the bucket in a sweeping motion from side to side. Allowing sands to fall through the water column helps spread out the placed materials, which may help reduce the energy of the placed materials hitting the bed. Furthermore, allowing the operator to see movement of the bucket and rate of material distribution promotes consistent material placement for thin layer (ENR) placement and cap construction.
- Placing cap, backfill, ENR, habitat, and RMC materials from a barge with a variable-speed telebelt, which would project material over the placement area
  - This placement method has been demonstrated locally (e.g., at the Todd Shipyard remediation project on Harbor Island, completed in 2006, in underpier areas with limited access for standard marine equipment).
- Placing individual engineered cap layers by lowering the cap material close to the sediment bed surface and slowly opening the bucket to provide more accurate placement of each discrete cap layer
- Placing larger armoring layer material from near the sediment bed instead of from the surface of the water column
- On slopes, placing materials from the bottom of the slope and working up the slope to reduce the potential for slope sloughing
- Placing materials using upland earthwork equipment from the shoreline
- In intertidal areas, working at low tides in the dry to limit water quality effects and better control placement accuracy

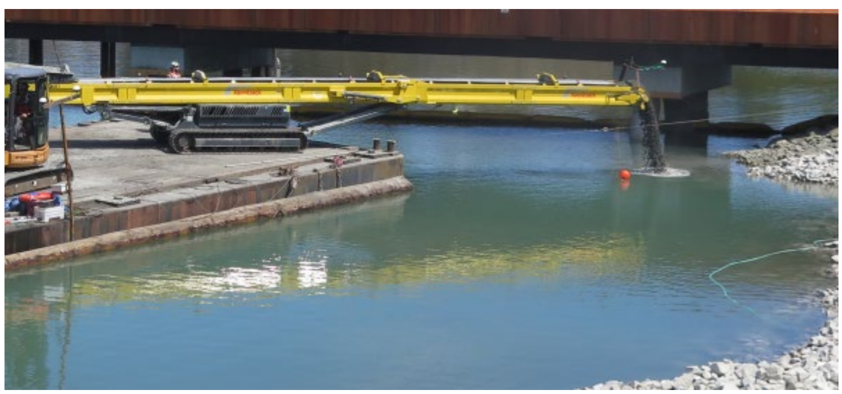
9.5.5 Placement Tolerances and Verification

In Pre-Final (90%) RD, the Drawings and Specifications will specify the required thicknesses of backfill, ENR, RMC, and engineered cap materials (cap isolation, filter, habitat, and armor layers) and overplacement allowances for material placement. Materials may be placed in single lifts for ENR and RMC, and multiple lifts may be needed in backfill and capping areas.

The Specifications will require the contractor to perform quality control (QC) during material placement activities in accordance with the Specifications and the contractor's RAWP (e.g., frequent progress surveys, pre- and post-placement acceptance surveys, bucket maps, quantity documentation, equipment inspection, sampling and analysis to verify imported materials quality). Construction QA will be performed by the Owner to review and accept specified material layer thicknesses. The draft CQAP that will be developed during Pre-Final (90%) RD will describe QA roles and responsibilities, QA activities, and the means and methods that the Owner will use to provide QA during construction to assess compliance with specifications. Contractor QA/QC is discussed further in Section 15.

Exhibit 9-2
In-Water Placement of Clean Material Using Typical Marine Equipment

Controlled bucket placement



Variable-speed telebelt placement

9.5.6 *Material Placement Production Rates*

Similar to dredge production rates presented in Section 9.1.3, material placement production rates (i.e., the volume of clean material placed on a daily basis) will vary based on the contractor's selection of equipment, water depth, material types and physical characteristics (e.g., sand, gravel, armor), site constraints (such as tidally restricted access, nearby vessel traffic, presence of structures, steep slopes), and weather conditions. It is estimated that a reasonable mechanical material placement production rate in the middle reach open-water areas (such as the FNC) will vary between approximately 730 and 960 cy per day, depending on the placement of each material type. Material production rates are anticipated to be lower for nearshore and restricted access placement, which are estimated to range from approximately 390 to 610 cy per day. Placement production rates within areas that are tidally influenced or are conducted under piers or docks are estimated to be much lower (approximately 120 to 150 cy per day) because of the narrow tide window to conduct the in-water work. Placement conducted with land-based equipment in shorelines and banks assumes a production rate of 500 cy per day.

Similar to estimating dredging production rates, other factors will affect placement production rates, may increase overall duration, and must be accounted for in the contractor's schedule. These include, for example, QA/QC and Owner acceptance of each capping layer, water quality protection, scheduled downtime, directed moves to allow safe passage of commercial vessels, inherent delays, maintenance, inclement weather, holidays, or slowdowns due to bottlenecks at other portions of the operation (e.g., material procurement and delivery).

9.6 Area-Specific Technology Design

Two ASTs were defined for the upper reach, including the ENR/AC Pilot Study (AST A)[31] and amended ENR in dredge offset areas (AST B). Four additional categories of ASTs have been defined for the middle reach: AST C, ENR placement within a permitted berthing area; AST D, restricted dredging near utility crossings; AST E, capping on grade within the intertidal; and AST F, removal in the dry.

9.6.1 Area-Specific Technology B: Amended ENR Placement Areas

AST B will be applied in localized areas where dredging, capping, or ENR cannot be applied because of structural limitations or ROD requirements (e.g., the ENR upper limit). Amended ENR (i.e., ENR with AC) will be applied to underpier or dredge offset areas in RAAs 5A, 8C, 8G, 9L, 9M, and 20A and SMA 10H where placement under structures or within dredge offsets is required and the ENR upper limit is exceeded. Additionally, amended ENR material will be placed on the riprap in RAA 20A to address interstitial sediment.

9.6.2 Area-Specific Technology C: Berthing Area ENR Placement

According to the ROD, ENR placement within permitted berthing areas is limited to 2 feet below the operating depth (EPA 2014). A portion of one area (RAA 3) is anticipated to require ENR placement within a permitted berthing area above the berthing depth. This is proposed for a number of reasons, including the following:

- Surface-only exceedance of low level (PCB exceedance factor = 1.2)
- Remedy compatibility with adjacent underpier ENR placement
- Remedy compatibility with tying into Slip 4 EAA boundary area thin layer placement

[31] AST A is not applicable to the middle reach.

- Pending plan for future maintenance dredging by property owner/tenant

Note that the underpier portion of RAA 3 is not considered an AST (i.e., it is ENR compliant with ROD requirements).

9.6.3 Area-Specific Technology D: Utility Crossing Cover

AST D will be applied at a submarine utility crossing location in RAA 9K where dredging cannot be conducted to the full vertical extent of contamination because of proximity to the buried utility corridor. As discussed in detail in Sections 2.5.3 and 5.1.2, this area includes several buried utility crossings of unknown elevation; therefore, the full depth of contamination cannot be removed without further information. For Intermediate (60%) RD, the portion of the area within the FNC will be dredged 2 feet deeper (-22 feet MLLW) than the FNC authorized depth in this area to allow for 2 feet of AST D cover. The cover material specification will be refined during Pre-Final (90%) RD and is assumed to consist of sandy gravel with a D_{50} of 3 inches (refer to Appendix I).

A restriction on future maintenance dredging may need to be placed in this area to prevent disturbance of the cover material. The effort to understand the alignment, elevation, and nature of various crossings in this area are ongoing through research, coordination with utility companies, and through field locating techniques.

9.6.4 Area-Specific Technology E: Capping On Grade

Capping on grade is not indicated as a remedy in the ROD for habitat areas (defined as -10 feet MLLW) because the post-remedy surface is to maintain pre-construction elevations. There is one area (RAA 26) where capping on grade is necessary in the middle reach due to steep existing shoreline slope configurations and nearby structures. For this 1,800 SF area, surficial debris will be removed and material will be placed directly on the existing grade to address contamination while avoiding destabilization of the slope. The top layer of the cap will consist of suitable habitat materials.

9.6.5 Area-Specific Technology F: Excavation Behind Cofferdam

Sediment from RAAs 24B through 24D will be removed using dry excavation methods. The area will be isolated from the main portion of the LDW using a double-walled cofferdam. The National Pollutant Discharge Elimination System outfall and reservoir overflow that discharge to the inlet at RM 2.2W will be temporarily rerouted to discharge on the waterside of the cofferdam. Selection of this technology will also facilitate removal outside of the in-water work window because the area will be isolated from the waterway. The 60% Drawings show two potential alignments for the cofferdam, as well as, preliminary layout for construction support facilities.

9.6.6 *Area-Specific Technology Design Summary*

Table 9-6 summarizes the preliminary AST design for each RAA.

Table 9-6
AST RAA Design Summary

RAA	Area-Specific Consideration	Constraints	AST Type and Description
3	Berthing area	Surface-only exceedance of low level (PCB EF = 1.2) and remedy compatibility with adjacent underpier ENR placement	C: Placement of ENR in permitted berthing area
5A	Inaccessible underpier	Placement under structures or within dredge offsets is required in order to protect structures and the ENR upper limit is exceeded	B: Placement of ENR with AC (amended ENR)
	Dredge offset		
8C	Inaccessible underpier	Placement under structures or within dredge offsets is required in order to protect structures and the ENR upper limit is exceeded	B: Placement of ENR with AC (amended ENR)
	Dredge offset		
8G	Dredge offset	Placement within dredge offset is required in order to protect an existing outfall structure	B: Placement of ENR with AC (amended ENR)
9K	Utility crossing	Dredging cannot be conducted to otherwise required depths/elevations because of proximity to the utility	D: Dredge to -22 feet MLLW and place 2-foot cover
9L, 9M	Dredge offset	Placement within dredge offsets is required in order to protect a historic structure and the ENR upper limit is exceeded	B: Placement of ENR with AC (amended ENR)
20A	Steeply armored slope	Protection of slope and upland property	B: Placement of ENR with AC (amended ENR) on riprap and in dredge offset
24B–24D	Low water access	Isolated removal of high debris, high concentration material	F: Excavation behind cofferdam
26	Steeply armored slope	Protection of slope and upland property	E: Capping on grade and slope
SMA 10	Dredge offset	Placement within dredge offset is required in order to protect an existing bulkhead and outfall structures	B: Placement of ENR with AC (amended ENR)

Notes:
AC: activated carbon
AST: area-specific technology
EF: exceedance factor
ENR: enhanced natural recovery
MLLW: mean lower low water
PCB: polychlorinated biphenyl
RAA: remedial action area
SMA: sediment management area

9.7 Monitored Natural Recovery

MNR is the selected remedy for sediment areas outside of the RAA and EAA boundaries that are not remediated through dredging, capping, ENR, or an AST. The compliance monitoring and decision framework regarding MNR is described in the LTMMP, a draft of which was submitted to EPA in June 2025. As stated in the ROD, MNR is split into two categories that are further described in the following subsections: MNR to benthic SCO and MNR below the benthic SCO (EPA 2014).

9.7.1 MNR to Benthic SCO

In MNR areas that exceed the benthic SCO, compliance monitoring of surface sediments (top 10 cm [4 inches]) will be implemented to evaluate whether the RAO 3 cleanup levels (benthic SCO criteria) are projected to be achieved.

Sample locations where MNR to benthic SCO may apply were originally presented in the DER (Anchor QEA and Windward 2025a). Table 9-7 and Figure 9-2 provide an updated summary for the middle reach. Sample locations in SMA 10 are presented in Figure 10-1 of the Preliminary (30%) RD for the LDW upper reach (Anchor QEA and Windward 2022c), which is also included in Appendix B. Additional samples will be proposed at some of these locations during the Phase III PDI to evaluate how surface sediment COC concentrations are changing over time as projected by natural recovery modeling (Anchor QEA and Windward 2025a).

MNR to benthic SCO areas will be defined during the Pre-Final (90%) RD. MNR to benthic SCO locations will be monitored as part of long-term monitoring. The LTMMP describes the monitoring requirements and process for addressing these areas if recovery is not achieved.

Table 9-7
Locations with Surface Sediment COC Concentrations Greater than Benthic SCO and Less than RAL that Are Not Within an RAA

Sample (year sampled)	Location	COC[1]	EF Relative to Benthic SCO[2]	EF Relative to RAL[2]
Pre-PDI Locations				
LDW-SS2122-U (2011)	RM 1.9W	BBP	1.1	0.56
SS4-PG (2016)	RM 2.0E	Mercury	1.1	0.53
LDW-SS2512-A (2011)	RM 2.1W	BBP	1.3	0.65
LDW-SS2029-D (2011)	RM 2.3E	Benzoic acid[3]	1.0	0.51
DENW6721-SSED-03-2014 (2014)	Slip 4	Benzoic acid[3]	1.4	0.69
DENW6721-SSED-05-2014 (2014)	Slip 4	Benzoic acid[3]	1.2	0.62
DENW6721-SSED-06-2014 (2014)	Slip 4	Benzoic acid[3]	1.1	0.57
DENW6721-SSED-07-2014 (2014)	Slip 4	Benzoic acid[3]	1.8	0.92

Sample (year sampled)	Location	COC[1]	EF Relative to Benthic SCO[2]	EF Relative to RAL[2]
PDI Locations (non-phenol locations)				
LDW23-SS1051 (2023)	RM 1.9W	BBP	1.9	0.97
LDW24-SS1380 (2024)	RM 2.0W	BEHP	1.7	0.87
LDW23-SS1085 (2023)	Slip 3	Zinc	1.6	0.81
LDW23-SS1812 (2023)	RM 2.4E	PAHs	1.0 to 1.6	0.51 to 0.79
LDW24-SS1496 (2024)	RM 2.6E	BBP	1.8	0.90
LDW23-SS1196 (2023)	RM 2.6E	Pyrene	1.1	0.54
LDW24-SS1587 (2024)	RM 2.6W	Indeno(1,2,3-cd)pyrene	1.1	0.54
LDW23-SS1189 (2023)	RM 2.6W	PAHs	1.0 to 1.1	0.51 to 0.56
LDW23-SS1204 (2023)	RM 2.7W	4-Methylphenol	1.1	0.54
LDW23-SS1236 (2023)	RM 2.8W	BBP	1.0	0.51
LDW21-SS599 (2021)	RM 3.8E	BEHP	1.6	0.79
PDI Locations (phenol locations)				
LDW23-SS1005 (2023)	RM 1.6W	Phenol	1.1	0.54
LDW23-SS1006 (2023)	RM 1.6	Phenol	1.3	0.63
LDW23-SS1010 (2023)	RM 1.7W	Phenol	1.1	0.56
LDW23-SS1805 (2023)	RM 1.7E	Phenol	1.2	0.61
LDW23-SS1014 (2023)	RM 1.7E	Phenol	1.8	0.90
LDW23-SS1030 (2023)	Slip 2	Phenol	1.5	0.75
LDW23-SS1052 (2023)	RM 1.9W	Phenol	1.1	0.55
LDW23-SS1094 (2023)	Slip 3	Phenol	1.6	0.82
LDW23-SS1106 (2023)	Slip 3	Phenol	1.3	0.66
LDW23-SS1112 (2023)	RM 2.1E	Phenol	1.3	0.65
LDW23-SS1117 (2023)	RM 2.2E	Phenol	1.6	0.79
LDW23-SS1162 (2023)	RM 2.4	Phenol	1.4	0.70
LDW24-SS1518 (2024)	RM 2.7	Phenol	1.0	0.52
LDW23-SS1226 (2023)	RM 2.8	Phenol	1.2	0.58
LDW23-SS1238 (2023)	RM 2.8	Phenol	1.5	0.73
LDW23-SS1245 (2022)	Slip 4	Phenol	1.3	0.65
LDW23-SS1248 (2023)	RM 2.9	Phenol	1.1	0.56

Notes:

1. As described in the DER (Anchor QEA and Windward 2025a), phenol concentrations exceeded the RAL in 31 samples in Phase I; 23 of these locations were reoccupied and analyzed for phenol in Phase II. There were no RAL exceedances in the Phase II reoccupied locations. Thus, although the locations with phenol concentrations greater than the benthic SCO and less than the RAL were not reoccupied, it is logical to assume that if these locations were reoccupied, concentrations would be similarly lower (i.e., below the benthic SCO). Based on the Phase II results and chemical properties of phenol, the phenol concentrations above the benthic SCO observed during the Phase I PDI appear to have been transient. Thus, active remediation will not occur for locations with only phenol exceedances. The approach for long-term monitoring of these chemicals that are transient in nature is described in the LTMMP.
2. The RAL is twice the benthic SCO in Recovery Category 2/3 areas, so the exceedance factor relative to the RAL is one-half that relative to the benthic SCO.

3. Benzoic acid is a benthic COC that is similar to phenol in that it appears to be transient in nature. Benzoic acid is readily biodegradable and does not have a strong affinity for particulate organic carbon. Thus, active remediation will not occur for locations with only benzoic acid exceedances.

BBP: butyl benzyl phthalate
BEHP: bis(2-ethylhexyl)phthalate
COC: contaminant of concern
DER: *Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Middle Reach*
EF: exceedance factor
LTMMP: Long-Term Monitoring and Maintenance Plan
PAH: polycyclic aromatic hydrocarbon
PDI: pre-design investigation
RAA: remedial action area
RAL: remedial action level
RM: river mile
SCO: sediment cleanup objective

9.7.2 MNR Below Benthic SCO

MNR below benthic SCO areas will be monitored as part of the sitewide monitoring program to track progress toward achieving RAOs 1 and 2. MNR below benthic SCO generally encompasses most areas of the LDW outside the RAAs, and the associated monitoring regime is presented in the LTMMP.

9.8 Maintenance, Monitoring, and Institutional Controls

Monitoring and maintenance will be implemented in accordance with the LTMMP (a draft of which was submitted to EPA in June 2025 [Anchor QEA and Windward 2025b]), and institutional controls in accordance with the Sitewide ICIAP[32] (a draft of which was submitted to EPA in January 2025 [Anchor QEA and Windward 2025c]). Per AOC5, this Intermediate (60%) RD includes outlines for the middle reach portions of the LTMMP and Sitewide ICIAP. Pre-Final (90%) RD and Final (100%) RD will include annotated outlines of the documents.

LDWG, working under a forthcoming consent decree or other enforcement mechanism, will finalize and implement the LTMMP and Sitewide ICIAP after construction is completed. It is expected that the LTMMP and Sitewide ICIAP will be subsequently amended to include site-specific requirements for each reach following construction.

The purpose of the LTMMP is to assess the following:

- Specify the actions (e.g., sampling) that will be taken to monitor long-term remedy performance in terms of ROD criteria (EPA 2014).
- Assess the integrity of the remedial actions over time.

[32] This document is simply referred to as the ICIAP in AOC5 but is referred to here as the Sitewide ICIAP as it as referred to in the *Unilateral Administrative Order for Remedial Design and Remedial Action* (EPA 2024) and to differentiate it from the Duwamish Seafood Consumption ICIAP.

- Present potential maintenance or adaptive management activities that can be conducted if performance objectives are not being met.

The LTMMP describes the plan for monitoring concentrations of COCs in affected media following completion of remedial action construction, as well as the approach for monitoring long-term remedy performance. It also provides details on how monitoring data will be used to support EPA's Five-Year Reviews. The draft LTMMP was developed in accordance with *Guidance for Management of Superfund Remedies in Post Construction* (EPA 2017a) and *Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation* (EPA 2004). The LTMMP includes both LDW-wide monitoring elements as well as elements specific to the monitoring and maintenance of the remedy in each reach (including EAAs, such as for engineered caps, ENR, and MNR to benthic SCO areas).

The purpose of the Sitewide ICIAP is to identify the institutional controls necessary to protect the physical integrity of remedial actions. The Sitewide ICIAP includes an evaluation of the most appropriate institutional, proprietary controls and location-specific use restrictions needed to support long-term effectiveness of the remedial action, consistent with Section 12.2.4 of the ROD (EPA 2014). The Sitewide ICIAP was developed in accordance with *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites* (EPA 2012a) and *Institutional Controls: A Guide to Preparing Institutional Control Implementation and Assurance Plans at Contaminated Sites* (EPA 2012b).

For the protection of risks to human health from resident seafood consumption, EPA and Public Health Seattle-King County established a community-based Duwamish Healthy Seafood Consumption Institutional Control Program for the LDW Superfund Site (Public Health Seattle and King County 2019). To avoid redundancy, the Sitewide ICIAP will refer to the Duwamish Seafood Consumption ICIAP for institutional controls related to reducing risk from consuming contaminated resident seafood from the LDW and thus will not be repeated in the Sitewide ICIAP. Per AOC5 requirements, this Intermediate (60%) RD includes an outline approach of the middle reach portions of the Sitewide ICIAP (see Volume II, Part IV). Pre-Final (90%) and Final (100%) RD will include an annotated outline of the middle reach portions of the Sitewide ICIAP. LDWG will complete and implement the Sitewide ICIAP after construction is completed, such that the Sitewide ICIAP accurately reflects the details of the constructed remedy.

9.9 Other Design Considerations

9.9.1 No-Rise Evaluation

The water surface elevations in the middle reach are tidally dominated; therefore, they are determined by the tidal elevation in Elliott Bay and are not significantly influenced by flows in the river. This is illustrated in the Federal Emergency Management Agency (FEMA) flood insurance rate map for the middle reach (No. 53033C0645G, effective date August 19, 2020), which shows that the 100-year base flood elevation is the same high tide elevation (+12 feet NAVD88) from Elliott Bay throughout the entire middle reach. Influence of river flows on 100-year base flood elevation begins just upstream of the middle reach project boundary.

Based on the remedial approach, it is expected that, below the 100-year flood elevation, the total quantity of material dredged will be greater than the total fill quantity placed for backfill, capping, RMC, ENR, amended ENR, utility crossing AST cover, and armored slope and thus will result in a net increase in flood flow capacity at lower tides within the middle reach. Because the flood elevations within the middle reach are tidally dominated (FEMA 2020), this will act not have any impact to water surface elevations in the reach. Therefore, it is expected that the RD will not result in a predicted increase to the 100-year FEMA base flood elevation. At Intermedial (60%) RD, the estimated total dredging volume (including assumed contingency re-dredging volume) is 436,800 cy; the estimated total placement volume for backfill, capping, RMC, ENR, amended ENR, and utility crossing AST cover is 238,400 cy.

The equivalent to a "no-rise" certification may need to be demonstrated for the middle reach remedial action based on hydraulic analyses to demonstrate substantive compliance with Section 60.3(d)(3) of the National Flood Insurance Program and implementing regulation King County Code Section 21A.24.240 (zero-rise flood fringe). These codes stipulate that any development or alterations to the floodplain shall not increase the base flood elevation or energy grade line elevation during the occurrence of the 100-year flood discharge.

If a zero-rise evaluation is determined to be required by EPA during ARAR substantive compliance concurrence, the existing USACE HEC-RAS hydraulic model of the Duwamish River will be used to evaluate the effect of the remedial action on the FEMA 100-year base flood elevation during Pre-Final (90%) RD. This model would be used to compare the pre-construction and post-construction 100-year water surface elevations in the middle reach. HEC-RAS is an accepted model platform for use by FEMA and others to determine base flood elevations. The existing HEC-RAS hydrodynamic model for the Duwamish River would be updated to add resolution within the middle reach (i.e., additional cross sections) and used to provide pre-construction 100-year water surface elevations within the middle reach. The model would then be modified to reflect proposed remedial work in the middle reach and used to provide post-construction 100-year water surface elevations within the middle reach. Pre- and post-construction modeling will be compared to illustrate that the proposed remediation work does not increase the 100-year base flood water surface elevation or energy gradeline within the middle reach.

9.9.2 Climate Change Design Considerations

Climate change effects in the greater Puget Sound region and, relevant to the LDW include sea level rise, changes in precipitation patterns and overall hydrological changes. Climate change adaptation generally focuses on evaluating a system's vulnerability to climate change and implementing adaptation measures, when warranted, so that the remedy continues to remain effective at meeting the ROD objectives (EPA 2014). EPA and LDWG have considered climate change design factors as they apply to the LDW since the 2014 ROD. EPA Region 10 hosted the Lower Duwamish Waterway: Climate Change Adaptation Workshop in March 2017, which focused on technical aspects of climate change impacts on sediment cleanup and upland source control at the LDW Superfund Site. Attendees included EPA, LDWG, USACE, Ecology, the Duwamish Tribe, the National Oceanic and Atmospheric Administration (NOAA), the University of Washington, and others. A full list of attendees and summaries of presentations delivered during the workshop by representatives of government agencies and supporting organizations is presented in the workshop summary (EPA 2017b).

9.9.2.1 Sea Level Rise

Based on NOAA annual prediction tide tables at the 8th Avenue South tidal gauge (Station ID: 9447029), the predicted water surface elevation for 2027 at the site ranges from -3.73 feet MLLW to +12.70 feet MLLW, with an average of +6.50 feet MLLW (Table 9-8). Predictions are limited to a future 2-year period but are useful for understanding anticipated changes in tides over time and for remedial contractors to understand anticipated ranges of water depth during the first year of construction in the middle reach. The selected contractor will ultimately sequence its work based on observed and predicted conditions during the years in which construction will occur.

Table 9-8
LDW Predicted Tidal Data for 2023 to 2027 (NOAA Station No. 9447029)

Year	Predicted Tide Elevations (feet MLLW)		
	Mean	Minimum	Maximum
2023	+6.5	-3.7	+12.7
2024	+6.5	-3.4	+12.6
2025	+6.5	-3.9	+ 12.6
2026	+6.5	-4.1	+12.6
2027	+6.5	-3.7	+12.7

Notes:
Source: https://tidesandcurrents.noaa.gov/noaatideannual.html?id=9447029
This table includes the predicted tide data available for the 8th Avenue South tide gauge, which include the past and upcoming 2 years (i.e., 2023 through 2027 at the time of this report).
LDW: Lower Duwamish Waterway
MLLW: mean lower low water
NOAA: National Oceanic and Atmospheric Administration

Climate change is expected to increase sea levels over the next few hundred years (Miller et al. 2018). An increase in mean sea level will correspond to an increase in design water levels at the middle reach due to tidal influence; however, not all components of the RD are anticipated to be affected by an increase in design water levels. For example, dredging will not be affected by the increase in long-term water depth because long-term changes in water depth do not influence dredging during the construction phase or the effectiveness of the dredging remedy in the future. Caps and ENR layers are designed assuming that the areas are currently submerged under constant or tidal immersion, and deeper water depths in the future would lower the forces on the riverbed, as described in the following paragraphs.

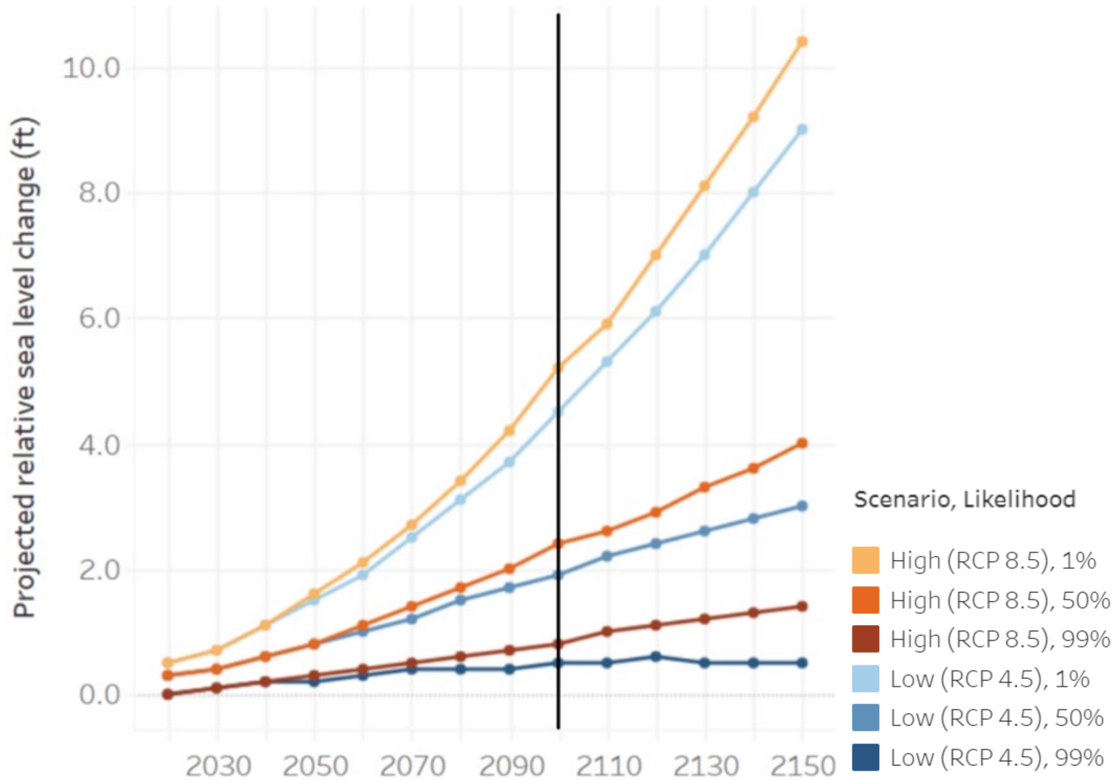
In the future, sea level rise will increase the water depths within the middle reach. The projected changes in sea level have been assessed in accordance with Ecology guidance. A report prepared for the Washington Coastal Resiliency Project (WCRP) in 2018 provided an assessment of projected sea level rise and the associated hazards for Washington State (WCRP 2018). The WCRP report provides updated projections for sea level rise that are more comprehensive than past estimates, taking into consideration recent research, land movement, and greenhouse gas emissions. Greenhouse gas emission projections depend on a variety of factors related to human behavior. Therefore, probabilistic projections for sea level rise have been made based on both low and high greenhouse gas scenarios.

Climate projections are made for two greenhouse gas emissions scenarios in the WCRP report: Representative Concentration Pathway (RCP) 4.5 and RCP 8.5. RCP 4.5 is a low estimate in which greenhouse gas estimates stabilize by mid-century and decrease thereafter. RCP 8.5 is a high scenario in which there is a continued increase in greenhouse gases until the end of the twenty-first century (Mauger et al. 2015). The Washington Coastal Network used the data presented in Miller et al. (2018) to generate visualization tools to project sea level rise applicable to various coastlines across Washington. Exhibit 9-3 shows the projected sea level rise for various potential scenarios for the middle reach. The exhibit presents the projections for RCP 4.5 and RCP 8.5 for the 1%, 50%, and 99% likelihood of occurrence. Although there is no industry standard for the application of sea level rise projections, other projects in Puget Sound have incorporated the 50% likelihood of occurrence estimate for the design of site elevations. Based on the projections and using the 50% likelihood of occurrence estimate, the relative sea level is predicted to rise between 1.9 and 2.4 feet by 2100 for RCP 4.5 and 8.5, respectively (black line, Exhibit 9-3; Miller et al. 2018).

Climate change is also expected to result in drier and warmer summers in the region, and the potential for reduced snowmelt to recharge watersheds may result in increased desiccation of caps, habitat layers, and RMC. However, because the middle reach is tidally dominated and dam-controlled, water surface elevations in the middle reach are not influenced by river flows (QEA 2008; FEMA 2020); thus, caps and ENR layers are not impacted by this aspect of climate change.

In addition, extreme events in the middle reach are associated with higher water levels. Wind waves due to extreme wind-wave events are not a significant factor (at present or in future) in the middle reach due to limited fetch distances. Therefore, increased water levels due to sea level rise or a combination of sea level rise and extreme high water events caused by storm surge (e.g., regional low pressure systems and/or sustained onshore winds) will increase water depths and decrease potential for erosion of bed sediments due to vessel operations. Increased water levels will not impact cap design in shoreline areas because those remedies will run to the top of existing slope.

Exhibit 9-3
Sea Level Rise Projections for the LDW



Source: https://wacoastalnetwork.com/research-and-tools/slr-visualization/

9.9.2.2 Hydrodynamics

As described in the RDWP, additional modeling of climate change on future hydrodynamics is not necessary as part of RD (Anchor QEA and Windward 2022a). First, propwash velocities and vessel wakes control cap design within the main channel because they are much higher than velocities due to river flows or wind-generated waves, including under future sea level rise conditions. Second, ongoing water management practices at the Howard Hanson Dam effectively control most peak river flows in the Duwamish River (USACE 2014). Finally, as stated in Section 9.9.1, water surface elevations in the middle reach are tidally dominated (FEMA 2020) and not significantly influenced by flows in the river.

Propwash forces on the riverbed are expected to be lower with sea level rise due to the larger propeller clearance as water depths increase. The deeper the water depth, the farther the propeller is from the riverbed. The farther the propeller is from the riverbed, the lower the propwash velocities are on the riverbed. As a result, there will be lower propwash forces in the future as water depths increase. Wake forces are not expected to change with sea level rise because wake heights are not expected to change; however, the wake forces will be experienced at higher elevations on the bank.

USACE evaluated how climate change could impact hydrology and water management operations on the Green River and what adaptations might be feasible at Howard Hanson Dam to accommodate those impacts (USACE 2014). The report concluded that the current water control plan at Howard Hanson Dam is somewhat resilient to climatic shifts and that flexibility inherent in the reservoir regulation could be adapted to further accommodate climate changes.

9.9.2.3 Sediment Load

Uncertainties in estimates of sediment load were evaluated as part of the RI/FS process. Climate change impacts and land use changes of upstream areas in the Green-Duwamish watershed may affect the relative and total sediment contributions to the LDW. Modeling demonstrated that the vast majority of the sediment load is delivered during higher flows (QEA 2008). Therefore, more frequent higher flows in the Green River may result in higher sediment loads in the river and therefore greater rates of net sedimentation throughout the LDW. As a result, the MNR process may be accelerated. The STM indicates that higher flows are not expected to increase overall erosion in the LDW (QEA 2008).

Climate change effects on sediment load do not affect the design of remedial action because the ROD (EPA 2014) defines what remedial technologies are applicable for the present site conditions. Qualitatively, greater net sedimentation rates will accelerate natural recovery processes. No further modeling of these effects on sediment loads is planned due to the infeasibility of predicting changes to sediment load that have many contributory factors (e.g., upland development, agricultural practices, erosion, dam operations, stormwater discharges).

10 Environmental Protection During Construction

This section describes environmental protection considerations and requirements during construction, such as any controls that will be employed to comply with ARARs and reduce environmental impacts (in accordance with Sections 12.2.5 and 12.2.8 of the ROD [EPA 2014]).

10.1 Water Quality Effects During Construction

Dredging and material placement will generate short-term turbidity caused by resuspended sediments in the water column as well as some release of COCs associated with the sediment and porewater; causes of sediment resuspension are described in this section. Compliance with water quality criteria and anticipated monitoring are also discussed.

10.1.1 Water Quality Criteria

The contractor is responsible for providing QC of its work, as well as adhering to environmental protection criteria in the Specifications. These include the performance standards for complying with applicable and relevant state water quality criteria (WAC 173-201A-210; see Section 3.2). This includes required limits measured in the water column for turbidity, dissolved oxygen, pH, and temperature and for relevant COC criteria (e.g., total PCBs). Dredging impacts on water quality are typically assessed by complying with the provisions of EPA's CWA Section 404 ARAR Memorandum (Section 3.4). The CWA Section 404 ARAR Memorandum provisions will be based on state turbidity water quality standards, which are at WAC 173-201A-210(1)(e) for waters designated as "excellent" marine quality. Of the water quality parameters, turbidity is typically the limiting factor that may affect the contractor's operations. Expected turbidity criteria of the CWA Section 404 ARAR Memorandum are that in-water construction activities do not increase the in-water turbidity more than 5 nephelometric turbidity units (NTU) above background (or 10% above background if background is 50 NTU or higher). Compliance is typically measured at the edge of the designated mixing zone (e.g., 150 feet away from the work activity at the compliance point). The CWA Section 404 ARAR Memorandum will specify the detail of any chemical monitoring required during the remedial action.

For contaminants in sediment targeted for dredging that could enter the water column due to resuspension, the acute and chronic criteria for protection of aquatic life in marine water are the applicable water quality criteria. Applicable water quality criteria are the Washington State standards (WAC 173-210A-240, Table 240) for protection of aquatic life and will be listed in the WQMP as part of the CQAP during Pre-Final (90%) RD.

The CWA Section 404 ARAR Memorandum is typically finalized following approval of the 100% design and will specify details of any chemical monitoring required during the remedial action. The WQMP will be developed in consultation with EPA to reflect the likely requirements of the CWA

Section 404 ARAR Memorandum. The WQMP will be updated by LDWG, and as required, prior to the start of construction to reflect the final CWA Section 404 ARAR Memorandum requirements.

Monitoring of water quality during construction will be conducted by the Owner, as described in Section 10.1.5.

10.1.2 Sediment Resuspension During Dredging

Dredging of contaminated sediments results in temporary water quality effects during construction. Therefore, significant effort has been made to understand, evaluate, and limit water quality effects during remediation (e.g., *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk* [USACE 2008b]). As a result, there is an established set of tools commonly used for analyzing water quality effects during sediment remediation and typical approaches employed for managing those effects.

To evaluate potential water quality impacts associated with dredging for the middle reach project, the USACE DREDGE Model (Hayes and Je 2000) was used. This model predicts the effects of dredging on contaminant concentrations within the water column and evaluate water quality compliance during dredging. Appendix J provides the detailed water quality evaluation, which included sediment cores located within RAAs where either dredging or partial dredge/cap were the identified technologies (see Section 5.5 of the BODR). For purposes of estimating LDW middle reach-wide concentrations without biasing sediment concentrations high or low, RAAs were grouped into "TSCA Waste Areas"[33] (encompassing RAAs 21A, 31B, 31C, and 31D) and "Non-TSCA Waste Areas" (encompassing the remaining RAAs with dredging or partial dredge/cap); the former grouping is representative of four RAAs with generally higher PCB sediment concentrations than the rest of the LDW middle reach.[34]

For each grouping, two sets of input parameters were developed to evaluate compliances with the marine acute and chronic water quality criteria. Acute water quality criteria were compared to potential short-term (i.e., 1-hour; 24-hour for total PCBs) effects based on an assumed maximum hourly dredging production rate of 180 cy per hour and maximum sediment concentrations in core data. Chronic water quality criteria were compared to potential longer term (i.e., 4-day; 24-hour for total PCBs) effects based on an average dredging production rate of 1,000 cy per day and average sediment concentrations in core data. Full description of the selection of the COCs subject to water

[33] For the purposes of simplifying categories for the water quality appendix evaluations only, "TSCA Waste Areas" refers to areas containing material with dry weight PCB concentrations greater than 50 mg/kg.

[34] Although RAAs 24B through 24D were identified with high PCB and metal sediment concentrations, these RAAs were not included in the Appendix J analysis because sediment removal in RAAs 24B through 24D will be conducted using dry excavation methods (excavation behind a cofferdam), as described in Sections 5.6 and 9.6.5 of the BODR.

quality criteria compliance, model inputs/assumptions, and predicted COC concentrations are provided in Appendix J.

In summary, based on LDW middle reach-specific inputs to the DREDGE model, no acute or chronic water quality exceedances were predicted in the Non-TSCA Waste Areas. In the TSCA Waste Areas, no acute water quality exceedances were predicted, while modeled total PCB concentrations exceeded marine chronic water quality criteria. Therefore, to further assess water quality effects and confirm and validate model-predicted results, Dredge Elutriate Testing was included in the LDW middle reach Phase III PDI for the RAAs 31B, 31C, and 31D, which are part of the TSCA Waste Areas.

Turbidity was also evaluated as a potential indicator of water quality compliance during dredging. In the Non-TSCA Waste Areas, the model suggested that turbidity exceedances are likely to occur before water quality exceedances, making turbidity a conservative and effective, real-time indicator of water quality effects. Therefore, turbidity can be used to trigger surface water sampling in these areas. In the TSCA Waste Areas, exceedances of water quality could occur when turbidity is within compliance, as discussed in Appendix J. This suggests that for conservativeness, additional measures—such as the implementation of BMPs, operational controls during dredging, or engineering controls—could be considered to help reduce the risk of potential water quality impacts and could be further assessed at Pre-Final (90%) RD. However, it is important to note that the evaluation incorporates conservative assumptions (i.e., high production rates, high sediment loss rate, and low settling velocity); therefore, these additional measures may not ultimately be necessary to meet the water quality criteria.

10.1.3 Dredge Return Water

Remedial activities will consist of mechanically dredging contaminated sediment, with the dredged materials placed onto a haul barge. During dredging, the bucket collects both sediment and water, especially when environmental (closed) buckets are used. A bucket fill factor of 70% was assumed, meaning that for every seven parts of sediment captured, three parts of water are also collected.

After sediments are placed onto the haul barge, collected water is typically separated from the dredged materials. The excess water is then filtered to remove solids either through active pumping or passive drainage using a filter media, such as geotextile fabric. The resulting filtered water, known as dredge return water, is then discharged back to the receiving water within the dredging work zone. The dredge return water is one of the many processes during dredging that has the potential to contribute to overall water quality effects on the surface water.

During the discharge, water quality will be monitored in accordance with the WQMP and will need to comply with appropriate quality standards at the points of compliance (Section 10.1.1). Visual observations, real-time water quality measurement results (e.g., turbidity levels) and chemistry results (when required) will be collected in accordance with the WQMP, and the contractor will be required to modify its operations as needed to comply with the requirements of the CWA 401 Water Quality Certification by enhancing the filtration or otherwise treating the return water. If discharge of dredge return water occurs at a different location than the dredging operation, separate water quality monitoring will be conducted at that different location.

For modeling purposes, potential water quality effects during dredge return water discharge were estimated following procedures described in *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual, Appendix C* (EPA and USACE 1998), with details presented in BODR Appendix J. As discussed in Section 9.2.2, sediments containing total PCB concentrations of 50 mg/kg or greater (removed from RAAs 21A and 31B through 31D) will be containerized and loaded on railcars for transportation to an acceptable landfill. As a result, discharge of dredge return water is only modeled in Non-TSCA Waste Areas.

In summary, the model predicted no exceedances of water quality criteria for COCs during dredge return water discharge in Non-TSCA Waste Areas. Therefore, no BMPs or additional monitoring measures are proposed during barge dewatering to ensure compliance with marine chronic and acute water quality criteria. Actual compliance with applicable water quality criteria will be confirmed during construction, as described in Section 10.1.5.

10.1.4 Sediment Resuspension During Material Placement

Material placement activities will result in short-term, localized sediment resuspension and, therefore, turbidity. Typically turbidity has been observed during clean material placement even when materials with very low fines content have been used. This turbidity will be transient and generated by clean aggregate material, mostly from the finer fractions of the clean aggregate material as it descends through the water. However, some resuspension of the bed sediment could occur depending upon the contractor's placement method. Sediment resuspension during material placement may also result from propwash disturbance from marine equipment and attendant vessels (e.g., tugboats).

Disturbance of the existing bed sediments during material placement is commonly managed by specifying limits on the initial lift thickness of placed materials (if needed) to avoid bearing capacity failure of the sediments (Section 7), as well as by requiring placement techniques that spread the placed material.

Experience in Puget Sound has shown that a common cause of turbidity exceedances is suspension of fines in clean materials being placed (e.g., for cap, ENR) even after BMPs are employed. Turbidity from clean fines in the placement materials will be reduced by limiting the fines content (material smaller than the U.S. No. 200 sieve) in the materials placement specification, for protection of water quality. The method for achieving compliance with the gradation specification (e.g., washing) will be determined by the material supplier, and the contractor will be required to demonstrate compliance with gradation requirements with testing results.

However, some fines are always present, and the need to evenly spread the placement material will result in the resuspension of the clean fines. Because these types of turbidity exceedances are localized and short term, and because the import material is clean (i.e., import material must comply with strict limits on COC content), it is generally recognized that the net benefit provided by placing clean material as backfill, ENR, cap, or habitat substrate outweighs the short-term effects of localized turbidity exceedances.

Many of the other resuspension mechanisms mentioned previously will be limited through BMPs (Section 10.2).

10.1.5 Water Quality Monitoring During Construction

The WQMP (to be developed during Pre-Final [90%] RD) will describe the monitoring program intended to provide QA that the contractor's operations are in compliance with water quality criteria and to identify conditions potentially requiring corrective measures in response to water quality observations. The WQMP will describe the monitoring methodology and equipment, monitoring locations (e.g., compliance and background stations), water quality criteria (listed in Section 10.1.1), monitoring frequency and schedule, and potential response and corrective actions in the event of a water quality exceedance. The WQMP will also identify communication and response protocols with EPA. Water quality monitoring results will be reported in meetings with EPA, the Owner, and the contractor regularly during construction, and any response actions will be subject to EPA approval.

10.1.6 RM 2.2W Dewatering, Treatment, and Discharge

As described in Section 9.6.5, sediment from RAAs 24B through 24D will be removed using dry excavation methods and the area will be isolated from the main portion of the LDW using a double-walled cofferdam.

It is anticipated that while the cofferdam will be constructed during the in-water work window (October 1 through February 15), the sediment excavation will occur during the dry season (May through August). Dewatering of the area will be required prior to excavation, as well as collection, storage, and treatment of water, prior to direct discharge to the local publicly owned treatment works operated by King County's Wastewater Treatment Division.

The design criteria for dewatering, storing, and treating the collected water will be defined at Pre-Final (90%) RD phase, and the contractor will be required to propose the design of a treatment system based on performance standards developed in coordination with the Wastewater Treatment Division.

10.2 Construction Best Management Practices

BMPs are management practices that are determined to be effective, practicable, and sustainable means of achieving an environmental performance objective. The Specifications will identify specific performance criteria for environmental protection (e.g., water quality criteria). BMPs will be used to meet those performance criteria during construction and to limit, to the extent practicable, potential adverse construction impacts and the magnitude of residual contamination. BMPs encompass operational and engineering controls to help reduce the environmental impacts of construction. Although operational controls include actions or modifications that can be applied by the contractor to the standard operational practices of the equipment being used for construction activities, engineering controls are equipment, barriers, and containment measures specified by the design that could be deployed based on site-specific conditions.

This section describes construction BMPs that may be implemented by the contractor during the dredging, barge dewatering, haul barge filling and in-water transportation, transloading, upland transportation, disposal, and material placement (e.g., backfill, ENR, RMC, ASTs, and engineered capping) operations or other associated construction activities. The contractor may propose additional construction BMPs in its RAWP, subject to review and approval by EPA and the Owner.

Additional BMPs specific to quality-of-life considerations are provided in Section 10.3.

10.2.1 Operational Controls to Reduce Sediment Resuspension

Operational controls are the procedures that a contractor implements to prevent or reduce potential sediment resuspension. Potential water quality effects from sediment resuspension associated with in-water work are expected to be temporary and located at or close to the point of disturbance. Water quality monitoring has been conducted during the construction of the EAAs and the two construction seasons of the LDW upper reach and many similar regional sediment remediation projects. The most common water quality issue observed has been occasional exceedances of turbidity criteria, either during dredging or placement of clean materials (e.g., ENR, ASTs, backfill, RMC, or engineered capping).

Operational controls are one approach to reduce potential sediment resuspension and include actions or modifications that can be applied by the dredging/placement operator to its standard operational practices to help reduce the potential environmental impacts of the dredging/placement operations (USACE 2008a). Operational controls to reduce sediment resuspension can include a broad array of methods; however, prescriptive requirements may not prove effective because equipment types and dredging methods will vary. Establishing performance criteria for water quality and allowing some degree of flexibility to the contractor in using operational controls allows it to customize its operations to effectively meet the performance standards.

The following standard operational control requirements to reduce sediment resuspension will be incorporated into the Specifications:

- Removal of large to medium-sized debris, if practicable, will be required prior to dredging in known debris areas (Exhibit 10-1 depicts typical debris encountered prior to dredging). Debris caught in dredging equipment can cause additional resuspension and release of contaminated sediments. Note that this operational control is not appropriate for buried debris below the mudline; debris removal itself generates turbidity. Practicability of debris removal will depend on field conditions; additional debris removal may be required based on an updated list of debris observed through pre-construction surveys.

Exhibit 10-1
Debris Removal Prior to Dredging

- Multiple bites by the dredge bucket on the sediment bed before ascending to the surface will be prohibited so that bed disturbance by the bucket is reduced.
- Closing of the dredge bucket on the bottom sediments (prior to ascension through the water column) will be required to limit resuspension.
- "Sweeping" (i.e., dragging a bucket or beam) or leveling of the sediment bed by pushing bottom sediments around with the dredge bucket to knock down high spots to achieve required dredge elevations/thicknesses will be prohibited. Instead of leveling to remove high spots, the contractor will be required to make an additional dredging pass to remove any high spots that are identified during post-construction surveys. Note that leveling may be an

appropriate step for fill placement to create habitat surfaces that are relatively leveled and within the appropriate elevation range. Leveling clean fill materials to reduce low spots can improve the performance of specific habitat types. The contractor may propose to level the placement surfaces (e.g., cap) for work conducted above the water line; such a proposal will be subject to Owner approval.

- Interim underwater stockpiling of dredged material will be prohibited (i.e., taking small dredge cuts and temporarily stockpiling material at the mudline in a mound to allow the dredge operator to grab a fuller bucket). Such action could create a pile of loose sediment that can easily be resuspended.
- Overfilling of conventional clamshell and environmental buckets will be prohibited. When the dredge bucket penetrates into soft sediment, there is the potential for the bucket to penetrate beyond the designed digging depth of the bucket. If the bucket is overfilled, a portion of the dredged material cannot be contained within the bucket and may be lost and resuspended in the water column as the bucket is raised. If bucket overloading is observed, measures will be taken to reduce this potential (e.g., decrease the thickness cut of sediment from the bucket).
- Appropriate dredge bucket/equipment will be selected by the contractor based on site-specific conditions (i.e., soft sediment versus debris or hard digging), such as using an environmental (closed) bucket where unconsolidated sediments exist and using a different (e.g., digging) bucket in areas where an environmental bucket cannot fully close or cannot penetrate the sediment.
- Specific dredging procedures (e.g., top-to-bottom cuts) will be specified to limit the potential for slope failures and slope movement that would cause sediment resuspension.
- Once out of the water, the dredge bucket should be moved reasonably quickly to the barge to reduce the amount of water that will drain out of the bucket back into the waterway.
- Dumping of sediment from partially-full or full dredge buckets back into the waterway will be prohibited.
- Dunking a dredge bucket into the waterway to clean off the bucket will be prohibited.
- All barges containing dredged materials will be required to be properly outfitted to filter dredge return water to meet the turbidity compliance criteria.
- Haul barges transporting dredged materials will be watertight,[35] will have fixed containment walls on all four sides, and will be inspected prior to barge use.
- Uneven filling and overfilling of barges beyond the required minimum freeboard will be prohibited to limit spillage from barges.
- On slopes, placing materials from the bottom of the slope and working up the slope will be required to reduce the potential for slope sloughing (see Section 9.5.4).

[35] The term "watertight" refers to only non-turbid water discharging from the barge by seeping or weeping.

The contractor is responsible for implementing additional optional operational BMPs, if needed, to reduce sediment resuspension, to manage water quality, and to meet turbidity criteria. These optional BMPs' effectiveness will depend upon the contractor's equipment and contractor's determination of feasibility and effectiveness and include, but are not limited to, the following:

- The rates of dredge bucket descent and ascent may be slowed through the water column. However, this BMP needs to be carefully implemented based on the physical characteristics of the sediments being removed (e.g., soft sediments versus hard digging, presence of debris, water depths) because limiting the velocity of the descending bucket in dredge operations may reduce the volume of sediment that is picked up by the bucket, thus requiring multiple bites to remove the project sediment and increasing the overall project duration and associated duration of short-term water quality effects.
- The dredge bucket may be paused near the bottom before raising it through the water column to allow heaped sediment (if the bucket is overloaded) within the bucket to fall out of the bucket closer to the sediment bed.
- After placing dredged sediment into the haul barge, the opened bucket may be held above the barge for a short period of time to allow residual materials from the bucket to fall into the barge.
- After placing dredged sediment into the haul barge, the bucket may be opened and closed over the haul barge to shake and remove loose residual materials from the bucket to the extent possible before lowering into the water.
- Use of the lowest safe operating power for tug operations will be recommended during barge relocation and movement through maritime traffic, as well as when changing dredge/material barges, to reduce potential sediment resuspension.

Operational controls that are overly restrictive will reduce production rates and may increase the overall project duration, which would increase the duration for potential short-term environmental impacts. Overly restrictive controls may also result in safety concerns. Thus, the advantages of applying operational controls need to be considered in light of this reduction in efficiency and impact to safety, and be appropriately balanced to support environmental protectiveness (USACE 2008a).

Implementation of operational controls during construction will be performed by the contractor. The Owner will verify that specified operational controls are adhered to, and the contractor will employ additional BMPs and/or engineering controls (Section 10.2.2) as needed to manage water quality impacts. Changes to operational or engineering controls during the project will be in coordination with EPA.

10.2.2 Engineering Controls (Specialized Equipment)

Engineering controls consist of equipment, barriers, and containment measures, either rigid or flexible, that are often specified by the design and based on site-specific conditions with the objective of mitigating potential releases during excavation/dredging to the extent practicable. Environmental (closed) buckets and silt curtains are described in the following subsections; a sheet-pile cofferdam (anticipated to facilitate work in the dry within the inlet at RM 2.2W) is described in Section 8.4.

10.2.2.1 Environmental (Closed) Buckets

For mechanical dredging, this technology consists of specially constructed dredging buckets designed to reduce the loss of dredged materials from the bucket during dredging when used properly and in the appropriate site conditions. Environmental buckets are discussed in Section 9.1.2.

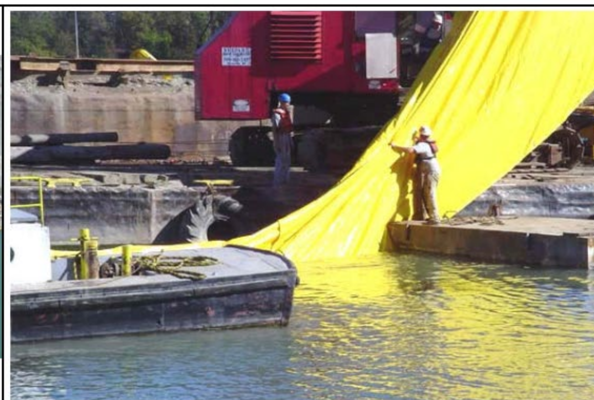
Environmental buckets are specified as the primary technology to be used for dredging to reduce sediment resuspension, but the Specifications will allow the contractor to use other buckets (e.g., digging buckets, rehandling buckets) as site conditions warrant to achieve both the required dredging elevations and thicknesses and to meet environmental protection criteria (e.g., water quality criteria).

10.2.2.2 Silt Curtains

A silt curtain is a potential engineering control that can be considered for reducing the size of turbidity plumes in the water column. A silt curtain is a constructed floating physical barrier that is positioned around the marine equipment (or the immediate area of dredging/placement) to reduce suspended sediment transport that is generated during dredging or placement operations. Silt curtains do not treat sediment resuspension or turbidity; rather, they direct and restrict the movement of the resuspended sediment to a smaller area (USACE 2008a). Exhibit 10-2 depicts a typical silt curtain installation. Silt curtains are typically constructed of flexible, reinforced geotextile material with flotation elements in the upper hem and ballast material in the lower hem.

Exhibit 10-2
Examples of Silt Curtain Installation (Black Lagoon, Detroit River, Michigan)

(a) Aerial view of Black Lagoon silt curtains, Detroit.



(b) Installation of impermeable silt curtain.

(c) Steel pipes to hold silt curtain.

(d) Semi-permeable filter curtain installed around the site.

Source: USACE 2008a

Because they are mostly impermeable, silt curtains are easily affected by tides and currents, and their effectiveness can be adversely impacted by high current velocities, moderate to large wave conditions, propwash from work tugs, or large tidal variation. Silt curtains are more effective on projects where they are not opened and closed to allow equipment access to work areas. For more complex site configurations, larger-sized dredge areas, and active vessel traffic, silt curtains need to be frequently moved, repositioned, and re-anchored, thereby reducing effectiveness and overall dredging production rates and increasing the duration of construction and overall short-term impacts from the dredging operations (EPA 2005). Typical silt curtain systems interfere with vessel navigation, so they are usually not used in active navigation channels.

Traditional silt curtain barrier controls are designed to provide either containment of the full depth or partial depth of the water column. Partial-depth curtains are more typically applied when there is a tidal range to prevent the curtain from sitting on the bottom where it could cause resuspension and/or be buried under sediment requiring constant maintenance. Full-depth curtains are either anchored directly into the mudline along a fixed alignment or affixed to installed vertical pilings or other existing in-water infrastructure. Similarly, partial-depth curtains can also be anchored or affixed to pilings or in-water infrastructure and extended from the mudline upward into the water column, or they can be deployed from the surface of the water with a series of floats and bottom weights to extend the curtain to the target depth. Partial-depth curtains can be less effective than full-length curtains because the curtain does not extend the full depth of the water column, allowing passage of water and suspended solids below the curtain extent, in effect redirecting suspended sediments near the bottom.

Another type of silt curtain configuration is "moon pools," which are mobile containment systems that move with the dredging equipment. However, unlike anchored silt curtains that remain in one location until the whole system is uninstalled and reinstalled in a new location, the moon pool system is designed to be mobile by attaching the system directly to the dredge barge so that it is always centered over the immediate dredging area. The moon pool system normally consists of a partial-depth silt curtain attached to a rigid framework of interlocking floats, enclosing a variable dimension dredging area depending on site-specific characteristics. The moon pool silt curtains can be designed to be permeable or impermeable and, in some cases, compose a curtain that is both permeable and impermeable. Depending on the size of the moon pool and hydrodynamics in the dredge area, steel spuds may be used to secure and stabilize the inner curtain.

Exhibit 10-3 depicts the moon pool deployment during the first construction season of the LDW upper reach.

Exhibit 10-3
Moon Pool Deployment During LDW Upper Reach Construction Season 1

Photograph credit: King County (top panel) and Boeing (bottom panel)

Use of a silt curtain system was evaluated for the LDW middle reach. The middle reach is a tidally influenced site with a large tide range (approximately 11 feet between MLLW and MHHW). The middle reach also experiences a variety of hydrodynamic and wave forces from river flow, wind-generated waves, and vessel propwash and wakes. Vessels routinely use the middle reach for navigation, and USACE maintains the FNC for active vessel use. Because of these factors, traditional silt curtains have typically not been used for sediment remediation projects in the LDW because they could interfere with navigation, would not be capable of being full-length due to tidal range, and would be anticipated to increase the duration of remedial construction without effectively reducing movement of resuspended sediments. However, the use of a rigid-frame silt curtain (moon pool) system, or equivalently effective flexible barrier, may be required when dredging in RAAs 21A, and 31B through 31D as a protective measure to reduce potential suspended sediment transport, as predicted in Appendix J (also see Section 10.1.2).

In general, the required use of environmental buckets and contractor operational controls is considered more effective to reduce sediment resuspension than deployment of a silt curtain. A contractor may choose to use silt curtains as a supplemental tool when localized site conditions allow them to be implemented. Therefore, silt curtains are specified in the Specifications as an engineering control for the contractor to have available on site from the beginning of construction so that they can be employed as a potential corrective measure (in response to water quality criteria exceedances during dredging and, if appropriate, during placement activities) if the contractor's primary resuspension controls are not effective for the localized site conditions. Site-specific conditions will affect whether silt curtains are feasible at any given location. The Specifications will require the contractor to meet performance requirements for water quality and will generally not identify the contractor's specific equipment, means, and methods to meet environmental protection compliance. The contractor may propose to use silt curtains in a configuration of its choice if it considers silt curtains to be an effective BMP.

10.2.3 Additional Environmental Controls

Available additional environmental controls associated with barge dewatering, haul barge filling and overwater transportation, transloading, transportation to an upland facility, spillage prevention, and decontamination of equipment are described in the following sections.

10.2.3.1 BMPs During Barge Dewatering

For dredge sediment dewatering occurring on haul barges (i.e., for nonhazardous dredged material) the dredge return water will be allowed to be discharged back into the LDW within or near the active dredging work zone. The contractor will be required to equip the barges with appropriate BMPs (e.g., filtering all water prior to discharge to remove suspended solids from the dredge return water) to maintain compliance with water quality criteria. As described in Section 10.1.3, the dredge return water modeling results did not anticipate the need for any treatment.

10.2.3.2 BMPs During Haul Barge Filling and Overwater Transportation

BMPs that will be required to reduce the potential for spillage of dredged material during haul barge filling and overwater transportation include the following:

- Haul barges will be loaded evenly (considering the physical nature of the material being loaded) to maintain barge stability.
- Haul barges will be filled with material stacked up in such a way as to prevent material from being lost from the barge during transport.
- Once the barge is loaded and stabilized, it will be inspected for sediment adhered to the outside of the barge that could fall off the barge during transport. Contractor personnel will conduct a visual inspection around the entire barge deck area to remove such sediment before moving the barge out of the dredging site.
- With the exception of dredge return water drainage ports, haul barges will be watertight[36] during all operations, and no dredge return water will be allowed to discharge into the LDW in transit to the transload facility.

10.2.3.3 BMPs During Dredged Material Transfer and Transportation to Disposal Facility

BMPs are required to reduce the potential loss of dredged material during transfer of dredged materials off the barge (at the transload facility) or from a temporary upland stockpile area (if intertidal sediment and shoreline bank soil excavation occurs, needing an onshore management area). BMPs are also required during transport of dredged/excavated material to the approved disposal facility. Such BMPs include the following:

- To prevent dredged material spillage when transloading materials between the haul barge and transload facility, spill aprons will be set up and used to direct bucket spillage back into the barges or onto the uplands and not into the LDW.
- Inside the transload facility, material captured by spill aprons will land on secondary containment areas outside the area typically traveled by trucks or railcars to avoid tracking material on tires or wheels.
- The bucket swing path from the haul barge to the upland transload facility will not be allowed to occur over open water. The contractor will need to swing the offloading bucket over either the derrick barge or a "spanning" barge that will capture any spillage from the offloading bucket.
- All haul trucks and railcars (e.g., containers or gondolas) transporting nonhazardous materials will be required to be lined, material covered by the liner or other method, and cover secured for upland transportation to reduce the chance of sediment or water release during transport. Visual monitoring will be performed by the contractor to determine whether the transport of dry dredged/excavated materials creates dust or leakage.

[36] The term "watertight" refers to non-turbid water discharging from the barge by seeping or weeping.

- Sediment characterized as RCRA hazardous waste, TSCA waste, or Washington State Dangerous waste (see Table 9-2 for applicable RAAs) will be dredged or excavated and directly transferred into containers. No transloading of sediment prior to receipt of the material at the landfill is anticipated.
- For dredged material transfer from a temporary upland stockpile area, truck loading will occur within the transfer area, and the trucks will be decontaminated and inspected within a designated contained footprint before they leave the transfer area.
- Trucks or railcars will not be overloaded to prevent loss due to spilling. Minimum freeboard height will be included in the Specifications.
- Truck loading areas will be swept frequently to reduce the probability of truck tires tracking contaminated materials outside of the loading areas.
- The trucks, truck loading area, and access route will be visually inspected to confirm that there is no loss of material from the trucks prior to releasing the trucks from the transload facility to public roads.
- Tires and truck or railcar bodies will be cleaned to remove sediment, if necessary, before leaving the site (e.g., dry brushing and tire/wheel washing).
- Containment areas will be designed so that fluids from the transloading operations can be collected separately from other site stormwater.
- The fluid collected from transloading operations will be disposed of with the other waste generated from the site (included with the sediment for disposal); sampled, treated, and discharged in accordance with approved permits of the transload facility; or disposed at a permitted commercial facility.

Exhibit 10-4 depicts examples of offloading and transloading operational controls.

Exhibit 10-4
Examples of Offloading and Transloading Operational Controls


Use of spill apron


Contained landside facility


Spanning barge


Loading of sediment into lined containers

Exhibit 10-5 depicts the use of the spill apron during transloading operations for the first construction season of the LDW upper reach.

Exhibit 10-5
Use of Spill Apron During Transloading for LDW Upper Reach Construction Season 1

Photograph credit: Geosyntec

Operations may need to be limited or suspended in the event of high river flows, storms, or high wave conditions at the transload facility that may impact the ability to moor haul barges safely and effectively, transload materials from the haul barges, or prevent potential discharge of dredged materials to the LDW. There is no specific condition (e.g., specific river velocity) that will trigger this contingency because it is impossible to predict the exact set of conditions that would impair operations. However, if conditions appear to pose a threat to meeting environmental protection goals at the transload facility, transload operations will be suspended until conditions improve.

10.2.3.4 BMPs for Oil and Other Hazardous Substance Spillage Prevention and Control

For compliance with the National Contingency Plan (40 CFR 300), the Oil Pollution Prevention Regulation, and the Oil and Hazardous Substance Spill Prevention and Response (RCW 90.56), the contractor will be required to prepare and implement a Spill Prevention, Control, and Countermeasure Plan (to be submitted as part of the RAWP), have a spill kit available during all on-water construction activities, and have a marine spill response contractor on call. BMPs to prevent and control spills of oil and other hazardous substances that will be required include the following:

- The use of environmentally sensitive hydraulic fluids (readily or inherently biodegradable) will be specified for hydraulic lines and systems of all compatible equipment associated with in-water work to limit the potential impacts of leaking hydraulic fluids on the aquatic environment.
- The contractor will contain all visible floating oils with booms, dikes, oil-absorbent pads, or other appropriate means and remove from the water prior to discharge into state waters.
- The contractor will immediately contain all visible oils on land using dikes, straw bales, or other appropriate means and remove using sand, ground clay, sawdust, or other absorbent material, and properly dispose.
- The contractor will temporarily store waste materials in drums or other leak-proof containers after cleanup and during transport to disposal.
- The contractor will dispose waste materials off property at an approved and permitted disposal facility and obtain certificates of disposal.
- Dredge vessel personnel will be trained in hazardous material handling and spill response and will be equipped with appropriate response tools, including oil-absorbent booms or pad, an oil-skimming system, oil-absorbent material, sandbags, oil dry-all gloves, and plastic bags. If a spill occurs, spill cleanup and containment efforts will begin immediately and will take precedence over normal work.
- The National Response Center (1-800-424-8802), the Washington Emergency Management Division (1-800-258-5990 OR 1-800-OILS-911), and U.S. Coast Guard (206-217-6002) will be notified immediately if a spill occurs.
- In the event of releases during transport of containerized TSCA waste and/or RCRA hazardous waste materials, the Local Emergency Planning Committee will be notified immediately.
- The contractor will inspect fuel hoses, oil or fuel transfer valves and fittings, lubrication equipment, hydraulically operated equipment, and oil drums on a regular basis for drips, leaks, or signs of damage and maintain and store properly to prevent spills into the surface water.

10.2.3.5 Sheen Management

The contractor will be required to prepare for sheen management under the Spill Prevention, Control, and Countermeasure Plan (to be submitted as part of the RAWP), in compliance with the National Contingency Plan, the Northwest Area Contingency Plan (under the Northwest Area Committee),[37] Washington State Oil Spill Contingency Plan (WAC 173-182), Oil Spill Incident Management Handbook (USCG 2025), and the Central Puget Sound Geographic Response Plan[38]

[37] Available at: https://oilspills101.wa.gov/northwest-area-contingency-plan/nw-area-contingency-plan/
[38] Available at: https://oilspills101.wa.gov/northwest-area-contingency-plan/geographic-response-plans-grps/central-puget-sound-grp/

(which pertains to the waters of the LDW). Construction QA monitoring and reporting for observed sheens will be discussed in the CQAP, to be developed at the Pre-Final (90%) RD phase.

Experience during the LDW upper reach construction demonstrated that sheens associated with dredging may move considerable distances (laterally) before expressing at the water surface, often nearshore. However, non-project-related sheens may also occur on the LDW.

A sheen can be attributed to dredging activities if observed on the dredge bucket, within the moonpool, or on materials stockpiled on the dredged material barge. If a sheen caused by those conditions are confirmed in the field, the contractor will be required to implement its Spill Prevention, Control, and Countermeasure Plan and relevant BMPs to contain and/or clean up the sheen. Notification of the sheen to the National Response Center, the construction management QA team, and EPA, is only required if the observed sheen flows beyond the work area.

Sheen collection and control measures that the contractor may implement include the use of sheen recovery equipment, such as oil-containment booms and/or oil-absorbent materials. Adaptative management on sheen response actions may be necessary based on the success of the recovery effort, such as using an oil spill recovery vessel (commonly referred to as a skimmer vessel), or operational changes (e.g., slowing down dredge production rates).

The Phase III PDI QAPP Addendum No. 3 (Anchor QEA and Barr 2026) included testing to determine if potential sheen-producing material is present in any RAAs of the LDW middle reach, and results will inform dredging design and potential required sheen management BMP decisions in the Pre-Final (90%) RD.

10.2.3.6 Decontamination of Construction Equipment

Decontamination of the dredge and haul barges will be done at the completion of the remedial activities and between construction seasons. The haul barges will be swept and pressure-washed (including all portions of the barge where sediment is visually present) such that no sediment or dredge return water is released to the LDW. The remaining sediment and water inside the barge will be managed for off-site disposal, as described in Section 9.2.

At the completion of the dredging work and prior to any material placement, the dredging buckets will be pressure-washed over the last haul barge, and the wash water will be managed for off-site disposal consistent with the barge dewatering effluents. Similarly, the dredged material haul barges will be decontaminated prior to any other use.

After all construction activities are completed, all marine and offloading equipment that handled contaminated dredged material will be required to be decontaminated.

10.3 Considerations for Quality of Life and Other Community Impacts

This section describes the activities and measures that will be taken to reduce the effects of remedial construction activities on the local community. Although much of the construction will be accomplished with water-based equipment (which is regularly employed throughout the LDW for other industrial activities), the uplands in the vicinity of the middle reach have mixed industrial, commercial, and residential uses (Section 2.4.5). Therefore, the residents in the adjacent neighborhoods, private recreational moorage areas (marinas and liveaboards), marine users on the LDW, motorists on roads shared with project truck traffic, and workers could potentially be affected.

Any quality-of-life concerns that arise from the community during construction will be identified and communicated with the mechanisms described in the Community Outreach and Communications Plan (to be developed at Pre-Final [90%] RD), which will detail the communication/response plan to the community. In addition, the Community Impacts Mitigation Plan (CIMP; Appendix K) presents the identified actions to reduce identified potential impacts on the community (e.g., residents, businesses, fishers, waterway users) from the remedy implementation through contractor requirements as described in the Specifications, environmental compliance monitoring activities, and BMPs.

Specified requirements and BMPs are discussed in the following sections. As community concerns are identified during construction, the concerns will be reviewed with EPA, LDWG, the Owner, and the contractor, and the procedures below may be modified, as practicable, to address the concern.

10.3.1 Quality-of-Life Considerations

10.3.1.1 Air, Odor, Noise, and Light Quality

As part of the Specifications, the contractor will be required to comply with performance requirements for quality-of-life criteria (i.e., air, odor, noise, and light).

Air Quality

Compliance with federal, state, and local air quality standards (Clean Air Act [42 USC 7401-7671q; 40 CFR 50], Washington Clean Air Act [RCW 70.94; WAC 173-400], and Puget Sound Clean Air Agency Regulations [Regulation I, Sections 9 and 15]) will be required during construction activities to protect the surrounding community from diminished air quality.

Air quality performance requirements to be met during construction will be defined in the Specifications, following the air emission standards defined in EPA's Tier System[39] for fossil fuel consumption, to help reduce engine emissions from construction equipment.[40]

[39] Available at: https://www.epa.gov/emission-standards-reference-guide

[40] The EPA emission standards for each tier are specific to the type of equipment (on-road vehicles, non-road equipment/engines), the year of manufacture, and the engine power. See Appendix L for more detailed information on EPA's Tier System.

Examples of BMPs that are required to limit air quality impacts include the following:

- Idling restrictions for on-road vehicles (including delivery and haul trucks) before equipment engines are shut off. Heavy marine construction equipment and nearshore excavators are excluded from this requirement.
- Changes in driving techniques (such as avoiding rapid acceleration, braking, and excessive speeds)

In addition, dust particles and odors from project activities will be required to be controlled at all times (including weekends and hours when work is not in progress). Federal and state air quality requirements also establish requirements for dust control. Dust and odor management requirements include the following measures as applicable:

- Wetting of excavation areas, unpaved traffic lanes, and soil stockpiles if needed for dust control
- Covering haul truck and railcar loads to prevent the release of dust-bearing materials during transport
- Cleaning of construction vehicles leaving the Contractor Transload Facility(ies) to remove dirt or dust from wheel treads and exterior
- Using work site controls such as ceasing above-water excavation during high winds or limiting the number and size of excavations occurring at one time
- Sweeping any paved on-site truck routes, loader paths, and loading and stockpiling areas daily during dry weather or more frequently if needed

Appendix L (Green Remediation Evaluation and Implementation Approach) presents a comprehensive list of potential BMPs that might be applicable to air pollution emission reduction in relation to the middle reach sediment remedy. The contractor's RAWP will be required to identify air quality prevention, mitigation, and control measures to be implemented during construction activities for federal, state, and local criteria compliance.

Noise

Construction noise will be generated from both in-water and upland sources (dredging and excavation of banks and shoreline) in an already industrial waterway; however, the receiving properties will be residential (including private recreational moorage areas), commercial, and industrial. The Specifications will require the contractor to comply with noise requirements for the Cities of Seattle and Tukwila[41] when working close to residential areas (upland and liveaboards) adjacent to the project site perimeter to limit the extent of potential noise impacts to the community.

[41] Noise requirements for the City of Tukwila are only applied to the remedial action in LDW upper reach SMA 10.

Local ordinances (SMC Chapter 25.08 and Tukwila Municipal Code [TMC] Chapter 8.22) establish equally stringent maximum permissible sound levels from industrial sound sources to a receiving property (residential at daytime or nighttime, commercial, or industrial), as listed in Table 10-1. For example, the contractor will be required to meet a 60-A-weighted decibel (dB[A]) limit for noise generation during daytime (between the hours of 7:00 a.m. and 10:00 p.m. on weekdays), applicable from an industrial source to a residential receiving property. In addition, the City of Seattle noise ordinances allow a 25-dB(A) addition for construction activities by heavy equipment (e.g., dredging, shoreline/bank excavation), making the maximum permissible sound level at the receiving residential property 85 dB(A) but during a shorter working period (and only between the hours of 7:00 a.m. and 7:00 p.m. on weekdays).

Table 10-1
Maximum Permissible Sound Levels from Cities of Seattle and Tukwila Noise Ordinances

District of Sound-Producing Source	Maximum Permissible Sound Levels in District of Receiving Property[1,2]			
	Residential, During Daytime	Residential, During Nighttime	Commercial	Industrial
Industrial	60 dB(A)[3]	50 dB(A)	65 dB(A)[3]	70 dB(A)[3]
At the property line or at 50-foot distance from construction equipment (whichever is further), during daytime only[4]	An additional noise allowance of 25 dB(A)	N/A	An additional noise allowance of 25 dB(A)	An additional noise allowance of 25 dB(A)

Notes:
Maximum permissible sound levels applicable to sound sources within the limits of the Cities of Seattle and Tukwila.
1. The maximum permissible noise level is applied to a minimum measurement interval of 1 minute for a constant sound source or a 1-hour measurement for a non-continuous sound source.
2. Between the hours of 10:00 p.m. and 7:00 a.m. during weekdays, and between the hours of 10:00 p.m. and 9:00 a.m. on weekends and legal holidays, the exterior sound level limits established by SMC Chapter 25.08.410 and TMC Chapter 8.22 are reduced by 10 dB(A) where the receiving property lies within a residential district of the Cities of Seattle and Tukwila.
3. Daytime is defined as the most stringent daytime period among the two city ordinances, set to be between 7:00 a.m. and 10:00 p.m. on weekdays and between 9:00 a.m. and 10:00 p.m. on weekends and legal holidays.
4. For construction equipment, daytime is reduced to be between 7:00 a.m. and 7:00 p.m. on weekdays and between 9:00 a.m. and 7:00 p.m. on weekends and legal holidays. This definition is also applicable to construction equipment used on public projects (see SMC 25.08.425).

dB(A): A-weighted decibel
N/A: not applicable
SMC: Seattle Municipal Code
TMC: Tukwila Municipal Code

Additional specific maximum permissible sound levels and working hours associated with various types of impact equipment used in construction sites and for short-duration construction activities (up to 1 hour) are described in SMC Chapter 25.08.425C and TMC Chapter 8.22.

In general, noise-generating construction activities will be limited to normal working hours (between the hours of 7:00 a.m. and 7:00 p.m. on weekdays and 9:00 a.m. and 7:00 p.m. on weekends and legal holidays) to the extent possible to reduce potential noise impacts to the community. Nighttime in-water work is anticipated to be required while working under or near the 1st Avenue S Bridge and may be required to conduct intertidal remedial actions or bank excavation activities due to the timing of low tides. SMC and TMC noise ordinances set lower sounds levels for any work conducted outside of these hours.

Noise performance requirements to be met during construction will be defined in the Specifications based on the most stringent noise ordinance for the Cities of Seattle and Tukwila. Examples of BMPs that may be used to prevent and mitigate noise impacts to the community include the following:

- Reduce vehicle speeds when transiting near residential areas (if applicable).
- Phase work with construction equipment that generates noise.
- Turn off engines when equipment is inactive for a period of time.
- Potentially limit work hours or certain construction activities in locations near residential or liveaboard occupancy.

Light

It is anticipated that artificial lighting may be required for construction work conducted during the winter season (before sunrise [with work starting at 7:00 a.m.] and after the sun sets at approximately 4:30 p.m.), to illuminate work areas and provide safe working conditions. Although work will be generally limited for overnight work, early morning and evening work accommodates for activities during low tides or to facilitate meeting the construction schedule (i.e., progress of activities within the in-water work window). The Specifications will require the contractor to comply with light requirements for the Cities of Seattle and Tukwila[42] (SMC Chapter 23.50.046 and TMC Chapter 18.044.050) when working close to residential areas (including private recreational moorage areas with liveaboards) and commercial/industrial areas adjacent to the project site perimeter to limit the extent of potential light impacts to the community. Light performance BMPs will be defined in the Specifications; for example, the contractor may be required to use light shrouds or barriers to help direct light into the work areas, re-sequence work during the day (if feasible), or reposition lighting equipment to avoid directing light outside of the immediate work area.

10.3.2 Considerations for Other Community Impacts

Additional potential community impacts derived from LDW middle reach construction may require reduction and mitigation measures to be implemented by the contractor, recommended BMPs, or monitoring to be performed to mitigate construction impacts during cleanup activities), as described below. The full list of community concerns identified during engagement and ways to reduce construction impacts during construction are described in the CIMP (Appendix K).

[42] Light requirements for the City of Tukwila are only applied to the remedial action in LDW upper reach SMA 10.

10.3.2.1 Impacts to Activities of Nearby Communities and Businesses

While construction activities will occur either on the waterway or at private, controlled properties used for staging, upland public access to parks and shorelines will not be restricted. However, temporary restrictions to public access to waterway will occur at active construction locations when public access is within 100 feet of heavy construction equipment.

In addition, businesses that depend on the waterway and are located adjacent to construction activities may be affected by middle reach construction. LDWG is directly coordinating with waterfront property owners where construction site access is needed to develop any required temporary construction easements or other agreements.

10.3.2.2 Impacts to Private Recreational Moorage Areas

Private moorage areas (including marinas and liveaboards) may be affected if weekends or nighttime work is unavoidable due to the need to work during low-tide periods or related to cleanup under the 1st Avenue S Bridge. As stated in Section 10.3.3, EPA coordination and approval will be required for any work outside the normal construction work hours. In addition, any in-water work that is conducted during these events will be subject to noise restrictions, as previously described in Section 10.3.1.1.2.

10.3.2.3 Impacts to Fishers

The LDW middle reach in-water construction schedule is established to limit impacts on certain fish species based on the established in-water work window (see Section 12.2 of this BODR). Coordination with the Muckleshoot Indian Tribe and Suquamish Tribe regarding Tribal fishing will occur to limit interactions and mitigate disruptions.

Washington Department of Health's seafood consumption advisories will remain in place during and beyond middle reach construction. LDW Superfund Seafood Consumption Institutional Control Program will also continue providing guidance to people who fish in the area about the potential risks associated with consuming resident fish and shellfish from the LDW and about safe alternatives.

Visual monitoring is anticipated to be conducted daily during construction to observe for distressed or dying fish. Mitigation actions (including stop work as needed) will be implemented if there are observed disturbances. Additional conservation measures to reduce effects on species listed under the ESA will be included as part of the forthcoming Biological Assessment.

10.3.2.4 Impacts to Maritime Traffic

To address impacts to maritime traffic within the middle reach, the contractor will be required, per the Specifications, to develop a Vessel Management Plan as part of the RAWP, which will describe the contractor's process for planning and coordinating vessel movement and safe vessel transit. This will include monitoring and adapting its operations as needed for nearby commercial vessels and to prevent unsafe transit around the contractor's equipment.

Construction operations will not be stopped for recreational users; however, a site-specific safety buffer zone will be required to be established by the contractor around in-water construction equipment to create a safe distance for recreational users. The contractor will be required to continuously monitor work areas for the presence of waterway users (e.g., commercial and recreational users); recreational users will be warned of work activities occurring nearby. The contractor will be required to temporarily adjust activities), to protect the safety of waterway users, including potentially halting all in-water work (if recreational users get within a site-specific safety buffer zone of the construction area) or moving out of the FNC (for commercial vessels, to allow for their passage).

In addition, the contractor will be required to comply with local regulations regarding navigation and waterway vessel speed limits.

10.3.2.5 Impacts to Roadway Traffic Through Residential Areas

The majority of dredged and excavated sediments will be barged and offloaded at permitted commercial and/or contractor-provided transload facilities for loading onto trucks or railcars for final disposal. Similarly, materials imported for placement (i.e., cap backfill, RMC, and ENR) are anticipated to be delivered by barge.

However, to a limited extent, truck transportation of equipment and materials may be necessary through or near residential areas, causing short-term impacts to the community and increasing construction truck traffic through local streets. Examples would be excavation of certain bank areas using land-based equipment or placement of materials from shoreline access points. The contractor may propose different access locations in its RAWP to conduct material placement, and the locations will be subject to approval by the Owner.

To the extent feasible, truck transportation will be limited to larger arterial roadways that support similar types of traffic. As described in Section 9.2, the middle reach project will rely on either established commercial transload facilities or a contractor-provided transload facility with road and/or rail connections designed to support commercial traffic. Candidate truck haul routes (if anticipated to be needed) will be provided in the Drawings. The contractor will identify any additional potential haul routes in the RAWP, and these haul routes will be subject to approval by the Owner and EPA. Haul routes will be reviewed in coordination with EPA to confirm that they are configured in a manner to reduce impacts to residential neighborhoods to the extent practicable.

In addition, construction activities under or near the 1st Avenue S Bridge will require bridge closures, causing road traffic interruptions. The contractor will prepare a plan for road closures and necessary detours in the RAWP to address extended bridge closures, which will be communicated in advance to the public. These bridge closures would not occur during peak commute hours established by WSDOT for the 1st Avenue S Bridge.

10.3.2.6 Impacts to Shoreline Access to Waterway Users

Impacts to property access from the waterway will typically be short in duration and will be communicated with property owners where remedial action occurs.

10.3.3 Construction Work Hours

The anticipated in-water work hours for the contractor will be from 7:00 a.m. to 7:00 p.m., Monday to Friday, and from 9:00 a.m. to 7:00 p.m. on Saturdays, for a 6-day-per-week work schedule. Nighttime in-water work is anticipated to be required while working under or near the 1st Avenue S Bridge (potentially requiring bridge closures, not occurring during peak commute hours). In addition, in-water work during the nighttime or on Sundays and legal holidays may be required to conduct intertidal remedial actions or bank excavation activities due to the timing of low tides, or to do occasional work proposed by the contractor to meet the construction schedule and support progress of activities within the in-water work window (see Section 12.2 for details on the in-water work window). EPA coordination and approval will be required for these events. In addition, any in-water work that is conducted during weekends or nighttime will be subject to additional restrictions, as previously described.

10.4 Green Remediation

According to the EPA Office of Solid Waste and Emergency Response *Superfund Green Remediation Strategy* (EPA 2010), "green remediation is generally recognized as a major step in maximizing the environmental outcome of a contaminated land cleanup" by incorporating specific strategies into remedial actions that reduce their environmental footprint to achieve greater net environmental benefits. A Green Remediation Evaluation and Implementation Approach (Appendix L) has been developed for the middle reach remedy to evaluate impacts of remedy construction activities, including sediment dredging and excavation, Identified Debris removal, submerged barge removal, sediment transloading at a transload facility, upland transportation and off-site disposal at a Subtitle D landfill facility, containerized sediment transfer at an intermodal facility, upland transportation and off-site disposal at a Subtitle C/TSCA-authorized landfill facility, clean import material transportation to the site and placement, and structural work (demolition and installation).

10.4.1 Green Remediation Objectives and Approach

As described in the RDWP (Anchor QEA and Windward 2022a), the purpose of the Green Remediation Evaluation and Implementation Approach is to accomplish the following:

- Establish the project's environmental footprint for the sediment remedy presented in the BODR through the five core elements identified in the framework of the *Superfund Green Remediation Strategy* (EPA 2010): air, water, materials and waste, energy, and land and ecosystems.
- Identify potential applicable greener activities, technologies, and practices that could be applied to the extent practicable during the sediment remedy implementation through any of its construction activities in an effort to reduce the project's environmental footprint (consistent with the EPA Region 10's *Clean and Green Policy* [EPA 2009]) while still achieving the ROD RAOs and protectiveness requirements in a timely manner.

The five core elements identified in the *Superfund Green Remediation Strategy* (EPA 2010) and used for the green remediation evaluation in Appendix L are summarized as follows:

- Air and Atmosphere: Reduce emissions of air pollutants, including greenhouse gases.
- Water: Reduce water use and protect water quality.
- Energy: Reduce energy use and support the use of renewable energy.
- Materials and Waste: Reduce waste generation and the use of virgin materials.
- Land and Ecosystems: Protect land resources and ecosystems near the site.

The *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012c) was used in Appendix L to develop the framework for conceptually quantifying the environmental footprint associated with remedial actions (cleanup activities), understanding the remedy components with the greatest influence, and determining key green remediation metrics for each of these green remediation core elements. Additional EPA green remediation guidance and policy documents were also reviewed and considered in the application of sustainable cleanup activities, technologies, and practices to a greener and sustainable middle reach sediment remedy to the extent practicable (Appendix L).

10.4.2 Construction Activities Required for the Sediment Remedy

Construction activities associated with the middle reach remedy are the baseline for determining the project's environmental footprint to comprehensively include the work required to be implemented, understand the sediment remedy components with the greatest influence, and appropriately represent the impacts and effects that the project may generate on the environment. It is important to note that the construction activities and the development of the environmental footprint presented in Appendix L are based on Intermediate (60%) RD criteria and assumptions. However, the quantification of the environmental footprint at this design stage is a high-level, conceptual evaluation, based on current available design information, assumed contractor equipment and schedule, and past engineering experience with similar projects.

The anticipated construction activities needed to implement the sediment remedy can be classified as primary (major construction activities) and secondary (minor construction activities). Both of these are conducted either within or outside of the project site but directly contribute to the project's environmental footprint. Additional activities, referred to as ancillary, are other activities that are indirectly required or associated with the sediment remedy implementation but are sourced elsewhere and not dependent on the remedy itself; therefore, they are not considered applicable activities to the project.

The detailed construction activities associated with the middle reach sediment remedy for the purposes of the green remediation evaluation are described in Appendix L.

10.4.3 Application of Green Remediation into Remedial Design

Consistent with the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012c), green remediation metrics are designed to accomplish the following: "1) reflect parameters that a remedy project team has a relatively direct ability to change; and 2) encourage practices that would result in favorable changes to the metric values" (EPA 2012c). The following metrics were evaluated in Appendix L for the five green remediation core elements associated with the middle reach sediment remedy:

- Core Element 1 – Air Emissions: Air emissions were calculated for eight air constituents: hydrocarbons, VOCs, carbon monoxide, nitrogen oxides, particulate matter less than 10 and 2.5 microns in diameter (PM_{10} and $PM_{2.5}$, respectively), sulfur dioxide, and carbon dioxide.[43]
- Core Element 2 – Use of Water: Consumption of water during construction activities (such as dust control, equipment decontamination, and additional uses at the transloading facility) was considered.
- Core Element 3 – Use of Materials and Waste Generation: Raw materials (imported sand, gravelly sand, gravel, quarry spalls, and granular AC for backfill, RMC, ENR, amended ENR, and engineered capping activities; steel sheet piles for temporary double-wall cofferdam and shoring wall; steel pipe piles; cement for stabilization of materials with combined TSCA waste and mercury-driven RCRA hazardous waste) and waste materials (dredge sediment, Identified Debris, removed timber and steel piles, structure demolition items, removed submerged barge) associated with the middle reach sediment remedy were quantified.

[43] Carbon dioxide is also a key greenhouse gas, along with methane and nitrous oxide, which are the largest greenhouse gas contributors. Appendix L, however, accounts for methane and nitrous oxide in the carbon dioxide equivalent total.

- Core Element 4 – Use of Energy: Total fuel-based energy consumption (diesel fuel) to power engines and equipment, facilitate transport activities, and run operations associated with the middle reach sediment remedy implementation were accounted for.
- Core Element 5 – Protection of Land and Ecosystems: A qualitative assessment on safeguarding land/ecosystems and site preparation/land restoration was conducted.[44]

These metrics establish the project's conceptual Intermediate (60%) RD environmental footprint based on the anticipated cleanup construction activities so that the most applicable greener construction activities, technologies, and practices, through BMPs, can be identified and applied to the extent practicable to reduce the impacts of the sediment remedy. Appendix L presents a comprehensive list of potential BMPs that might be applicable to the five core elements in relation to the middle reach sediment remedy and its anticipated construction activities, consistent with the BODR and the Intermediate (60%) RD.

The listed BMPs will be further assessed in Pre-Final (90%) RD for availability of more advanced technologies and materials, for feasibility and implementability of greener practices into the sediment remedy, and in consideration of procurement restrictions. To the extent that specific BMPs will be required, these BMPs will be incorporated into the project Specifications, which will be developed for submittal with the Pre-Final (90%) RD deliverable. The contractor will have inherent motivation to select other specific BMPs listed in Appendix L in cases where such BMPs will increase efficiency and reduce cost and therefore have an appropriate return on investment that justifies their use.

10.5 Habitat Considerations and Evaluation

Habitat within the LDW will be considered and evaluated during all phases of RD. As described in Section 2.4.11, existing habitat types in the LDW based on elevation ranges include the following:

- Deep Subtidal: Deeper than -10 feet MLLW
- Shallow Subtidal: -10 feet MLLW to -4 feet MLLW
- Lower Intertidal: -4 feet MLLW to +4 feet MLLW
- Upper intertidal: +4 feet MLLW to +11.3 feet MLLW
- Riparian: Above MHHW (+11.3 feet MLLW)

These different habitat types provide specific functions to aquatic species, and the value of each habitat type differs depending on the functions provided. The most valuable habitat is provided in the Upper Intertidal, Lower Intertidal, and Shallow Subtidal zones (i.e., -10 feet MLLW to +11.3 feet MLLW) as detailed in Section 10.5.3.

[44] Specific design measures to offset aquatic habitat modifications that may be incorporated into the LDW middle reach sediment remedy to the extent practicable are presented in Section 10.5, in compliance with CWA Section 404 and Section 7 of the ESA.

The ROD defines “habitat areas” as all areas with elevations between -10 feet MLLW and the MHHW elevation of +11.3 feet MLLW to provide design requirements for remedial activities that occur within those elevations. As such, this Intermediate (60%) RD considers and applies the habitat-specific ROD design requirements to remedial activities that occur within the ROD-defined “habitat areas,” to the extent possible. These design requirements will be further refined through the Pre-Final (90%) RD. Additionally, the impact of remedial activities to all habitat types, including the ROD-defined “habitat areas,” is evaluated as part of this Intermediate (60%) RD and will be modified, as needed, in the Pre-Final (90%) RD to comply with CWA Section 404 and Section 7 of the ESA. The results of the habitat evaluation are provided in the forthcoming Biological Assessment.

Additionally, a CWA Sections 404/401 and Rivers and Harbors Act Section 10 substantive compliance evaluation will be prepared as part of the Pre-Final (90%) RD that will evaluate potential impacts to other habitat types and species for substantive compliance with ARARs.

The remainder of this section includes details about the following:

- Approach for addressing potential impacts
- Design considerations for the ROD-defined “habitat areas”
- Description of the habitat evaluation that will be used to assess remedial impacts to all habitat types, including the ROD-defined “habitat areas”

10.5.1 Approach

The approach to considering and evaluating habitat during the RD is as follows:

- Identify areas where remedial activities are expected to occur in ROD-defined “habitat areas” and consider the ROD habitat design requirements during RD for these areas (Section 10.5.3).
- Determine a method for evaluating potential remedial impacts to all habitat types, including ROD-defined “habitat areas” (Section 10.5.3).
- Demonstrate that the remedial activities are consistent with the CWA Section 404(b)(1) and Section 7 of the ESA, including consistency with the USACE and EPA approach for avoiding, minimizing, or, when adverse impacts are unavoidable, mitigating for adverse impacts to the aquatic environment. This demonstration is documented in the habitat evaluation completed as part of this Intermediate (60%) RD in the forthcoming Biological Assessment. These results will be included as part of the Pre-Final (90%) RD draft CWA Sections 404/401 and Rivers and Harbors Act Section 10 substantive compliance evaluation.
- Use the results of the habitat evaluation to support the evaluation of threatened and endangered species in the draft Biological Assessment.
- Update the habitat evaluation as needed during the Pre-Final (90%) RD and include results as part of the design submittal in the final CWA Sections 404/401 and Rivers and Harbors Act Section 10 substantive compliance evaluation.

10.5.2 Design Considerations for Remedial Activities in ROD-Defined Habitat Areas

Figure 10-1a shows where remedial activities are expected to occur within ROD-defined "habitat areas" (EPA 2014). Figure 10-1b includes the following information important for understanding existing conditions and the context of the ROD-defined "habitat areas":

- Potential clamming areas as described in Section 2.4.11
- Existing restoration areas as described in Section 2.4.11
- Shoreline condition
- Existing bank vegetation

The ROD identifies the following design elements that should be considered during RD for remedial activities that occur within the ROD-defined "habitat areas" (EPA 2014):

- Restore pre-dredge elevations using suitable habitat materials. Different substrate types are naturally present throughout the middle reach in various habitat types, which are used by a variety of species.
- The RD will specify substrate that balances targeted functions (providing substrate that is as similar as possible to pre-construction conditions) and constructability/environmental protection during construction (minimizing fines content to reduce turbidity to the extent practicable). Habitat substrate is described in more detail in Section 9.5.
- Additional coordination with EPA will occur in the Pre-Final (90%) RD to evaluate proposed habitat substrate, recognizing that the post-construction surface substrate will equilibrate over time to the naturally deposited sediment grain size regardless of the selected substrate.
- Use suitable habitat material as the uppermost layer of caps and for ENR.
- Caps in intertidal clamming areas (i.e., shallower than -4 feet MLLW) must include a minimum 45-cm (1.5-foot) clam habitat layer.

EPA will determine whether the elevations and substrate materials presented in the Intermediate (60%) RD are consistent with habitat requirements. Materials used for caps, ENR, and backfill placement will be further evaluated in Pre-Final (90%) RD submittals to confirm habitat suitability in consultation with EPA. Based on the habitat material used at other sites in Puget Sound, including the LDW upper reach, suitable material is expected to be a mix of sand and gravel as described in Section 9.5.1. Selecting the appropriate habitat material type is a balance between providing substrate that is as similar as possible to pre-construction conditions and achieving constructability and environmental protection requirements during material placement. The amount of fines in the placed material is typically minimized to reduce turbidity to meet the water quality requirements during construction and to also meet the chemical concentration requirements for clean fill material. The surface of the placed materials will eventually be covered by naturally deposited sediment specific to each area placed, so in the long term (i.e., 1 to 5 years) the habitat surface will return to conditions reflecting what is naturally deposited from upstream.

Measures described above to backfill dredged habitat areas with appropriate material and place appropriate material over cap armor and as ENR material have been incorporated into the Intermediate (60%) RD to the extent practicable. Using these strategies and improving habitat conditions (e.g., through debris and derelict pile/structure removal within RAAs), the remediation is expected to avoid the need for mitigation. However, this expectation needs to be confirmed, which will be done by implementing the habitat evaluation described in Section 10.5.3.

10.5.3 Habitat Evaluation

An evaluation of potential impacts to all habitat types, including ROD-defined "habitat areas" (EPA 2014), from implementation of remedial activities has been conducted to comply with CWA Section 404 and Section 7 of the ESA. Overall, the habitat evaluation steps will include the following:

- Establish existing habitat conditions.
- Establish post-remediation habitat conditions.
- Conduct a quantitative habitat evaluation for remedial activities included in the PSNC.
- Conduct a semi-quantitative evaluation for remedial activities not included in the PSNC.

The intent of the design of the LDW middle reach is to include beneficial design features to avoid the need for mitigation. This habitat evaluation is being implemented to confirm if mitigation is still needed after considering beneficial design features. The need for mitigation will be evaluated across all reaches (upper, middle, and lower) of the LDW. The design for the middle reach seeks to maintain net habitat value and avoid the need for mitigation to the extent possible. The design for the LDW upper reach resulted in a slight habitat benefit and it is anticipated that the future design for the lower reach will also seek to avoid the need for mitigation to the extent possible, which will be confirmed by conducting the same habitat evaluation for the lower reach as the RD progresses for that reach. The intent of this approach is to use potential habitat gains generated in one reach to offset potential losses estimated in another reach, such that there is no net habitat loss for the LDW as a whole, and thus mitigation will be unnecessary. If it is determined that mitigation is needed after considering all three reaches of the LDW, a Compensatory Mitigation Plan will be included in the RD submittals for the lower reach, and temporal impacts will be accounted for if there will be delays between remediation and the restoration of habitat.

Existing habitat conditions are obtained from data collected as part of the PDIs (Phases I through III), and post-remediation habitat conditions are obtained from the RD details as described in the habitat evaluation that is part of the forthcoming Biological Assessment.

A summary of the quantitative and semi-quantitative methods that were used for the evaluation are described in the following sections. The results are provided in the forthcoming Biological Assessment.

10.5.3.1 Quantitative Evaluation: Puget Sound Nearshore Calculator

The PSNC uses HEA and the Nearshore Habitat Values Model (NHVM) to evaluate the following: 1) habitat impacts resulting from nearshore projects that decrease habitat function; and 2) habitat benefits, which are associated with projects that increase nearshore habitat function (Ehinger et al. 2023). HEA is an accounting technique for calculating the replacement of lost ecological services (defined as functions and values that a habitat provides) resulting from an impact (NOAA 1995; Ray 2009). It is a generalized method that can be used in any type of habitat, including freshwater rivers and streams, salt marshes, seagrass beds, and coral reefs. The accounting metric used in HEA is DSAYs, which is a measure of the resource service flows provided by various habitats over time.

The NHVM defines habitat values in terms of physical and biological functions of salmonid critical habitat as defined in 50 CFR 226.212 (Ehinger et al. 2023). As it will be described in the Biological Assessment, elements of salmonid critical habitat include the unobstructed migratory corridor, cover and primary production, sediment quality and quantity, and water quality. The NHVM defines habitat values for four major elevation zones including the Riparian Zone, the Upper Shore Zone, the Lower Shore Zone, and the Deep Shore Zone, which are used in the PSNC. More information on HEA and the NHVM can be found in the PSNC User Guide (Ehinger et al. 2023).

The PSNC is available at the NMFS Puget Sound Nearshore Habitat Conservation Calculator website as an Excel workbook (NOAA 2026). The PSNC is used to evaluate relevant project elements, such as riparian disturbance and replanting, debris removal, waterward repairs to bulkheads or armored shorelines (if needed), and piling removal and replacement. The results of the PSNC portion of the habitat evaluation are reported in DSAYs, where a DSAY represents the value of all the ecosystem services provided by 1 acre of habitat over 1 year, discounted by 3%. The 3% discount adds more value to past actions and discounts future actions. A negative DSAY indicates a habitat impact; a positive DSAY indicates a habitat benefit. The forthcoming Biological Assessment provides the results of the habitat evaluation.

10.5.3.2 Semi-Quantitative Habitat Evaluation

As described in the SSNP Biological Opinion (NOAA 2022), methods of removing or isolating contaminated sediments from aquatic habitats (e.g., dredging, excavation, capping) that are performed, ordered, or sponsored by government agency with established legal or regulatory authority are not included in the PSNC. Therefore, a semi-quantitative habitat evaluation was performed for this category of remedial activities by comparing the existing habitat conditions to the expected post-remediation habitat conditions. The semi-quantitative evaluation is used in the forthcoming Biological Assessment as a systematic way to determine the level of habitat benefit or habitat impact related to remedial activities not considered in the PSNC. Habitat categories in the semi-quantitative evaluation are defined by elevations referenced to MLLW based on the bathymetric and topographic data collected as part of the Phase I and II PDIs. Habitat categories used for the habitat evaluation include the following:

- Deep Subtidal: Deeper than -10 feet MLLW
- Shallow Subtidal: Between -10 and -4 feet MLLW
- Lower Intertidal: Between -4 and +4 feet MLLW
- Upper Intertidal: Between +4 and +11.3 feet MLLW
- Riparian: Above +11.3 feet MLLW

Considerations of both the PSNC calculations and the semi-quantitative evaluation of sediment remediation areas are used to determine the need for conservation offsets (i.e., mitigation) for the middle reach of the LDW. The forthcoming Biological Assessment provides the results of the habitat evaluation.

10.6 Buried Contamination Protectiveness Evaluation

EPA's 2014 ROD anticipates that subsurface buried contamination will safely remain in some areas where it would not be subject to future release, subject to the specific criteria defined in the ROD. EPA's determination was based on a variety of analyses in the FS, including the potential for exposure by scour from river flows and vessels (Appendix C of the FS; AECOM 2012). Buried contamination protectiveness evaluations were conducted to demonstrate that the sediment overlying buried contamination is sufficient to prevent the buried contamination from migrating to the surface through dissolved phase transport at some point in the future. These evaluations are summarized in the following paragraphs and are detailed in Appendix M.

Buried contamination is defined as the presence of COC concentrations greater than the surface RAL that are buried by 60 cm (2 feet) or greater of sediment with concentrations less than surface RALs in subtidal areas or by 45 cm (1.5 feet) or greater of sediment with concentrations less than the surface RALs in the intertidal zone. Therefore, these areas are primarily located outside of RAAs. A total of 13 core locations (refer to Figure M-1), not within RAAs, meet this definition of buried contamination in the middle reach. COCs that exceeded surface RALs at depth included PCBs, dioxin/furans, cPAHs, and 13 other COCs. As the dredge plans are finalized based on the Phase III PDI results, additional locations may be added to this evaluation during Pre-Final (90%) RD.

Modeling was performed to evaluate whether buried concentrations in these areas have the potential to contaminate surface sediments to a concentration greater than the respective RALs in the future (i.e., over a 100-year simulation) through dissolved phase transport driven by groundwater seepage (as well as diffusion or dispersion and bioturbation). Model results in Appendix M show that for all the 13 locations identified for buried contamination evaluation, COC concentrations within the surface of the sediment are predicted to remain less than the respective RALs for more than 100 years in all cases. Six of these cores (LDW24-SC1579, LDW24-SC1559, DENW6721-SSED-SB-12A-2014, SC-01, SC-02, and SC-032) are located within areas designated as Recovery Category 1, which have the potential to experience higher scour due to vessel activities or high flows.[45] The predicted COC concentrations in the top 50 to 200 cm of sediments of these six areas were less than the respective 0-10 cm surface RALs for more than 100 years. This suggests the exposure of buried contamination as a result of future scour is unlikely. Sedimentation was ignored in this evaluation to be conservative. The addition of new material depositing on the surface creates additional thickness over which the COCs attenuate.

[45] As described in Appendix C of the FS (AECOM 2012), the predicted high-flow-induced scour depths for the entire LDW were in the range of 0 to 10 cm. The predicted propeller-induced scour depths approximately 25 cm.

11 Property Access

Property acquisition, site access agreements, leases, or easements may be needed at properties where remedial activities will be implemented or for off-site areas that may be required for the contractor's material, equipment staging, and shore access during construction. Agreements may also be needed when remedial activities have the potential to disrupt commercial businesses. Early coordination with property owners or lessees began during Intermediate (60%) RD and will continue through Pre-Final (90%) RD to obtain information necessary to complete the Final (100%) RD where construction will occur near infrastructure and shoreline areas and where upland equipment access may be required. Depending on the owner, the nature and duration of the access, and the resulting remedy, written agreements or other legal documentation (e.g., leases, easements, deed restrictions) may be required. Section 11.1 identifies the property locations and owners where site access agreements are anticipated to be necessary. The design team will develop a draft Permitting and Site Access Plan in the Pre-Final (90%) RD, and a final Permitting and Site Access Plan in the Final (100%) RD.

11.1 Property Access Considerations

The properties adjacent to the LDW middle reach consist mostly of privately owned land. There are a few locations where portions of the aquatic lands are also privately owned (e.g., Slips 2 through 4, Myrtle Bay, the inlet at RM2.2W). Access agreements were needed for sampling during the PDI activities and will be needed for construction activities. For construction, it is anticipated that access agreements with adjacent property owners will be attainable if needed to facilitate remedial construction. Access agreements are expected to be required with all private owners of property if such areas are determined necessary to accomplish remedial construction. A summary of the anticipated site access needs by RAA is provided in Table 11-1. Site access agreements are anticipated to be required with the owners listed in the table, but only some of the properties will or potentially will (depending on construction methods) require physical access to or through the upland property.

Table 11-1
RAAs Where Site Access Agreements Are Anticipated

RAA	Non-LDWG Member Property Owner/Tenants and Adjacent Property Owner (if applicable)	Upland Site Access Anticipated?
3, 5A, 5B, 9A	Crowley Marine Services and Waste Management	No
8A, 8B, 8C, 8D, 8E, 8F, 8G, 8H	Pacific Pile and Marine and Private Entities	Yes
9C, 9D, 9L	SDOT and Seattle Parks & Recreation	Yes
9F, 9I, 9M	Recology and Private Entities	Possibly

RAA	Non-LDWG Member Property Owner/Tenants and Adjacent Property Owner (if applicable)	Upland Site Access Anticipated?
16	Seattle Iron & Metals and Shalmar Group	No
17, 21A, 21B, 21C	Boyer Towing Inc.	Possibly
20A, 20B	Private Entity and Shalmar Group LLC	No
24A–24J	Private Entity, Industrial Container Services and 7100 1st Ave S Seattle LLC	Yes
25, 26	SeaTac Marine Properties LLC	No
27A, 27B, 27D	7100 1st Ave S Seattle LLC	No
32, 33, 34A, 34B	Michigan Marine Properties LLC/Private Entities, Duwamish Marine Center, Samson Tug, Glacier Northwest Inc.	No
31B, 31C, 31D	Michigan Marine Properties LLC, Duwamish Marine Center	Yes
35A, 35B	Glacier Northwest Inc. and GFP CL SEATTLE 6335 LLC	No
36	Glacier Northwest Inc.	No
SMA 10	Boeing	Possibly

Notes:
LDWG: Lower Duwamish Waterway Group
RAA: remedial action area
SDOT: Seattle Department of Transportation
SMA: sediment management area

11.2 Permitting for Site Improvements

The Intermediate (60%) RD does not anticipate implementing any site improvement work that would require permitting. Examples would include developing new buildings not located within or adjacent to the LDW Superfund Site to support construction management or transloading operations at a LDWG-provided upland staging area.

In its review of Intermediate (60%) RD, if EPA identifies site improvement actions that fall outside of CERCLA authority and that require a permit, the draft Permitting and Site Access Plan in the Pre-Final (90%) RD will identify required permit(s) and the schedule to obtain the permit(s).

12 Preliminary Construction Sequencing and Schedule

12.1 Project Construction Sequencing

Cleanup construction activities will be sequenced to accommodate logistics and reduce the risk of contaminant release, generally beginning with contaminated debris removal (e.g., demolition and removal of creosote-treated materials) followed by intertidal excavation and subtidal dredging. Material placement, including capping, ENR, backfill, RMC, and placement associated with ASTs, will be sequenced to occur after dredging (including any potential contingency re-dredging) within each SMA (or SMA subarea for larger SMAs) is completed to limit residual contamination and reduce risk of recontamination of previously cleaned up areas. In general, work will be sequenced with consideration of potential effects on nearby completed SMAs. Construction and post-construction monitoring and institutional controls will be implemented to verify the protectiveness of the remedy.

Overall project sequencing requirements will be specified in the Specifications, such as completing all required work in a continuous manner; temporarily relocating the contractor's equipment to perform work activities in other parts of the site to limit equipment downtime (e.g., during the contingency re-dredging decision duration period); reducing impacts to LDW navigation and facility operations; Owner approval of dredge areas prior to any backfilling; and access time periods for specific properties. However, the specific sequencing of the construction will be defined in the contractor's RAWP to allow the contractor to consider its specific construction equipment, means and methods, and production rates in order to develop an effective sequence to do the work within the timing restrictions required by the Specifications (revised outline provided in Volume III; full Specifications to be developed during Pre-Final [90%] RD). Also, the contractor's sequencing will be dependent on (among other things) access agreements with property owners/users and the transloading proposed by the contractor. Assuming commercial transloading at the facility identified in Section 9.2.1, construction sequencing is anticipated to be generally as follows:

1. Development and approval of contractor's RAWP
2. Notifications to property owners, Tribes, public, and U.S. Coast Guard and any agency-required notifications, completed in accordance with ARARs and permits
3. Mobilization and setup of temporary facilities, including transloading area
4. Procurement and testing of clean placement materials
5. Pre-construction survey
6. Pre-construction conditions inspection and documentation of structures (photographs/video) and verification of utility location
7. Removal of piling and debris from dredge areas, with replacement of Tribal fishing net pilings to be replaced within the same season
8. Demolition of derelict structures within or adjacent to area of dredging and/or material placement

9. Temporary removal and disconnection of in-water structures and utilities to allow equipment access as needed
10. Dredging and excavation, including in-water transport, transload or transfer of bulk and containerized sediments, upland transport, and disposal of dredged materials at approved disposal facilities
11. Dredging acceptance surveys and re-dredging, if determined to be necessary based on post-dredge survey results
12. Post-dredge confirmation sampling and contingency re-dredging actions, if needed
13. Material placement, including backfilling, RMC placement, ENR placement, placement associated with ASTs, and capping
14. Post-placement acceptance surveys and additional placement to achieve required placement thicknesses/elevations/slopes, if needed
15. Pre-final and final inspections
16. Corrective measures (if needed)
17. Demobilization and site cleanup
18. Post-construction documentation and closeout procedures

Multiple activities may occur concurrently, such as dredging in some SMAs while material placement is occurring in other SMAs where dredging has been verified to be complete. The contractor will maintain an up-to-date detailed schedule of activities in accordance with the Specifications. Following construction of the middle reach remedy, institutional controls will be enacted, and certain components of long-term monitoring will begin.

12.2 RM 2.2W Construction Sequencing

As described in Section 9.6.5, sediment from RAAs 24B through 24D will be removed using dry excavation methods and the area will be isolated from the main portion of the LDW using a double-walled cofferdam.

The implementation of RAAs 24B through 24D with respect to other middle reach RAAs is uncertain as coordination with the upland site owner and Ecology is necessary to determine the timing of the upland remediation and compatibility with the design approach for the sediment remedy within these RAAs (see Section 2.2.2).

The following conceptual sequencing is anticipated for RAAs 24B through 24D (RM 2.2W):

- Installation of the cofferdam during the in-water work window (October 1 through February 15), with opening to allow for tidal exchange
- Overall upland site preparation, including trenching for outfall diversion and dewatering/treatment system installation (likely to occur between January and May)
- Sealing of the cofferdam and start of dewatering (likely to occur in May)

- Excavation and backfilling within RAAs 24D through 24D (likely to occur during the dry season, between May and August)
- Opening of the cofferdam to allow tidal exchange
- Extraction of the cofferdam during the in-water work window (October)

12.3 Construction Schedule

Construction of the middle reach remedy will proceed for SMAs that EPA determined to have met source control sufficiency, as described in the RDWP (Anchor QEA and Windward 2022a). In-water construction activities will occur during in-water work windows designated for the LDW (to be determined by EPA but anticipated to be from approximately October 1 through February 15) that will be set to protect certain fish species under the ESA. Construction activities will be coordinated with the Muckleshoot Indian Tribe and Suquamish Tribe to reduce impacts and fishing disruption on Tribal fishers; this may include delaying the start of in-water construction past October 1 or later season dredging in highly disruptive locations.

Remedial construction for the middle reach could potentially require six to nine construction seasons based on the Intermediate (60%) RD quantities and production rates for dredging and quantities and production rates for material placement, as defined by the in-water work windows. The overall dredging production rate is highly uncertain and dependent on the throughput capacity at the transload facility and the off-site disposal rate, and the contractor will need to coordinate with the transloading and disposal transportation provider(s) to plan transloading, truck, and rail capacities. Assumed production rates used in the design reflect similar production rates observed during past sediment remediation projects in the region and therefore likely account for the risks associated with potential off-site disposal bottlenecks, such as rail capacity.

As described in Section 9.2.1.1, the Duwamish Reload Facility, operated by Waste Management, is the only commercial transload facility currently located on the LDW or within Puget Sound. As of October 2025, Waste Management has communicated an operational throughput capacity of 1,500 tons daily (equivalent to approximately 1,035 cy per day) for offloading, dewatering, and stockpiling sediments. Therefore, although a dredging contractor could potentially dredge at a higher production rate and operate multiple sets of equipment to conduct concurrent dredging in multiple locations within the site, the dredging production rates in the Intermediate (60%) RD Opinion of Probable Cost (Appendix N) are assumed to be limited by the existing transload daily capacity for the single commercial facility and reflect the upper end of the construction duration estimate of 9 construction seasons (the most conservative assumption). The lower end of the construction duration estimate represents potential design optimizations (that could result in dredged volume reduction) and/or an increased throughput capacity (with two or more transloading facilities becoming available ahead of LDW middle reach implementation).

LDWG will continue to assess the feasibility that private parties or ports may develop a new facility, that LDWG may partner with third parties to secure additional transloading capacity, or that existing transload facilities increase their throughput. However, at this time it is unclear if an alternative facility will be available by the time the LDW middle reach remedial action starts. The LDW middle reach cost estimate and construction duration will be updated during Pre-Final (90%) and Final (100%) RD as more information as to transloading capacity is obtained. An increase in transloading capacity in the region will help reduce the overall construction duration and costs.

Table 12-1 presents the estimated timing of the various pre-construction activities leading up to the first year of middle reach implementation. The Pre-Final (90%) RD will include an engineer's estimate of the construction schedule by construction season. A detailed project sequencing schedule (by construction season) will be developed by the contractor in its RAWP and will describe anticipated start/finish dates of all construction activities associated with each SMA.

Table 12-1
LDW Middle Reach Estimated Timing of Pre-Construction Activities

Activity	Estimated Timing
Bid package preparation	November to December 2027
Contractor procurement and contract award	December 2027 to March 2028
Pre-construction submittal preparation	April to July 2028
EPA review and approval of pre-construction submittals	August to September 2028
Year 1 Mobilization	September 2028

Notes:
EPA: U.S. Environmental Protection Agency
LDW: Lower Duwamish Waterway

13 Quantity Calculations and Opinion of Probable Cost

This section provides information on quantity calculations and the Opinion of Probable Cost for the Intermediate (60%) RD.

13.1 Quantity Calculations

Quantity calculations for dredging and material placement (including backfill, RMC, ENR, amended ENR, and engineered cap materials) for the LDW middle reach are discussed in the following paragraphs and summarized in Table 13-1.

Elevation-based dredge volumes were calculated for each RAA with AutoCAD Civil3D software based on the design dredge plan (i.e., dredge prism) included on the 60% Drawings. The dredge prism volume is measured by developing a triangulated irregular network (TIN) surface of the required dredge prism and calculating the cut and fill quantities between the dredge prism TIN surface and the TIN surface of the recent bathymetric and topographic survey basemap. For RAAs with thickness-based dredging, the dredge volume was calculated by multiplying the dredge footprint area by the required cut thickness on the 60% Drawings. Side-slope dredge volumes for elevation and thickness-based dredging were calculated using 2D perimeters for each RAA, measured by AutoCAD Civil3D software; these perimeters were multiplied by the surface area of the dredge design, measured using Drawing (Volume III, Parts IA and IB) cross sections. The volume of the overdredge allowance was computed by using the area of the dredge prism boundary, including side slopes, and multiplying that area by the specified overdredge allowance (6 inches).

Following the completion of all required dredging, the RD assumed that one additional contingency re-dredging pass will be conducted over a portion of the RAA dredge footprint to remove generated residuals and missed inventory. For costing purposes only, as described in Appendix N, the RD assumes that 15% of the total required dredge area (excluding any PD&C footprints and side slopes) will be re-dredged by 1 foot (which includes 6 inches of overdredge allowance) to address generated residuals, and 20% of the total required dredge area (excluding any PD&C footprints) will be re-dredged by 2.5 feet (which includes 6 inches of overdredge allowance) to remove missed inventory.

All dredge-only RAAs will be either backfilled or covered with RMC after dredging.

Backfill placement is intended to restore habitat areas to pre-construction elevations and to flatten temporary steeper dredge cuts. All dredge areas located outside of the FNC and above elevation -10 feet MLLW are assumed to be backfilled and integrated with habitat material placement in intertidal areas as appropriate, as shown on the 60% Drawings (see also Section 9.1.6). Backfill volumes are dependent on the final dredge cut surface and may not exactly match the pre-dredge elevations due to equipment placement accuracy and geotechnical properties of the placement materials. For Intermediate (60%) RD, the backfill volume for each RAA backfilled back to grade was assumed to be equivalent to the dredge volume, based on backfill design placement elevations and grades, as well as the final dredge surface to be backfilled (starting at the overdredge allowance surface). The backfill volume also accounts for the upper end of the vertical placement tolerance (6 inches).

RMC, ENR, and amended ENR material placement quantities were developed using the Intermediate (60%) RD assumed targeted placement thicknesses plus the upper end of the vertical placement tolerances (see Sections 9.1.5.1, 9.4, and 9.6) over each respective placement area (generated via AutoCAD). Capping material quantities were developed using the Intermediate (60%) RD assumed minimum placement thicknesses, plus the maximum overplacement allowances over each respective placement area (generated via AutoCAD).

In addition, the following assumptions for RMC, ENR, amended ENR, and capping have been used for costing purposes in Appendix N:

- RMC placement:
  - RMC is to be placed over the specific dredge areas that are not backfilled or capped after dredging (as shown on the 60% Drawings).
  - The RMC placement footprint also includes dredge cut side-slope areas (top to toe of dredge cut daylight).
  - Although additional RMC placement outside of the dredge areas is not presented in the 60% Drawings, it was accounted for costing as follows:
    - Inner-perimeter RMC will be automatically placed within a perimeter surrounding the dredge area (generally 20 feet wide in the upstream, cross-channel, and downstream directions) without the need for post-dredge construction sediment sampling.
    - Outer-perimeter RMC consists of RMC placed within an assumed 25% of a perimeter (generally 20 feet wide in the upstream, cross-channel, and downstream directions) outside of and surrounding the inner RMC perimeter.[46]
- ENR is to be specifically placed in RAAs 3, 8H, 21B, 23B, 24A, 25, 27B, 27D, 28, 31A, 32, 33, and 35B (as shown on the 60% Drawings). ENR quantity assumes a placement footprint that includes a 10-foot buffer around the planned ENR placement area.
- Amended ENR (AST B) is to be specifically placed in RAAs 5A, 8C, 8G, 9L, 9M, and 20A (as shown on the 60% Drawings). Amended ENR is intended to address areas that are adjacent to existing structures or armored slopes, where dredge offsets are required, and where the ENR

[46] It is anticipated that perimeter sediment sampling within the outer perimeter will be performed to determine whether there is a need for RMC placement in the outer perimeter.

upper limit is exceeded or to address interstitial sediment (as shown on the 60% Drawings). AC is assumed to be mixed in at 2% by dry weight (see Section 9.6.1 and Appendix H).

- Standard engineered caps are to be placed in RAAs 1B, 9J, 14A, 15B, 22, 23A, 30A,[47] 30B through 30H, 31B, and 31C (as shown on the 60% Drawings) after partial dredging. The standard engineered caps will consist of three layers: a chemical isolation layer (gravelly sand material), a filter layer (gravel material), and an erosion protection layer (quarry spalls); see Section 9.3.
- Modified engineered caps (in potential habitat areas) are to be placed at -10 feet MLLW and at higher elevations in RAAs 5B, 8B, 9A, 9D, 20B, 24I, 26, and 31D (as shown on the 60% Drawings). The modified engineered caps will consist of three layers: a chemical isolation layer (gravelly sand material), an erosion protection layer (sandy gravel), and a habitat layer (sandy gravel material); see Section 9.3.
- Utility crossing cover (AST D) is to be placed in RAA 9K to avoid impacts to a buried utility crossing, as shown on the 60% Drawings. The utility crossing cover in RAA 9K is assumed to be a sandy gravel cover; see Section 9.6.3.

Table 13-1
Summary of Intermediate (60%) RD Volumes

Description	LDW Middle Reach Volumes (cy)	LDW Upper Reach – SMA 10 Volumes (cy)
Required Dredge Volume	360,100	15,700
Overdredge Allowance Volume	48,200	2,400
Contingency Re-Dredging Volume	9,100	1,300
Total Dredge Volume	**417,400**	**19,400**
Backfill Volume	48,300	16,700
Required RMC + Sloped RMC + Inner/Outer-Perimeter RMC Volume	74,600	1,500
ENR Volume	5,400	--
Amended ENR Volume	1,800[a]	100
Standard Engineered Cap Volume	83,700[b]	--
Modified Engineered Cap Volume	5,900[c]	--
Utility Crossing AST Cover Volume	400[d]	--
Total Placement Volume	**220,100**	**18,300**

Notes:
Volumes are rounded to the nearest hundred. See Appendix N for detailed dredging and material placement quantities.
a. Amended ENR (AST B) is to be placed in RAAs 5A, 8C, 8G, 9L, 9M, and 20A as shown on the 60% Drawings.
b. Standard engineered cap is to be placed in RAAs 1B, 9J, 14A, 15B, 22, 23A, 30A, 30B through 30H, 31B, and 31C. The cap at RAA 30A will be placed on existing grade. Partial dredging will occur prior to cap placement within the other RAAs listed in this note.

[47] The standard engineered cap at RAA 30A will be placed on existing grade. Partial dredging will occur prior to cap placement within the other RAAs listed in this bullet.

c. Modified engineered cap is to be placed in RAAs 5B, 8B, 9A, 9D, 20B, 24I, 26, and 31D. The cap at RAA 26 is also referred to as AST E because it is a special application of a cap on existing grade.
d. Utility crossing cover (AST D) is to be placed in RAA 9K, as shown on the 60% Drawings.

--: not applicable
AST: area-specific technology
cy: cubic yard
ENR: enhanced natural recovery
LDW: Lower Duwamish Waterway
RAA: remedial action area
RD: remedial design
RMC: residuals management cover
SMA: sediment management area

13.2 Opinion of Probable Cost

A Intermediate (60%) RD Opinion of Probable Cost (Appendix N) was prepared for the LDW middle reach implementation (based on the design information provided on the 60% Drawings). The total project cost includes costs for direct construction tasks (i.e., all construction activities anticipated to be conducted by the contractor), indirect construction tasks (i.e., project management, engineering support services, construction QA activities,[48] site access agreements/business interruption/temporary leases, and community outreach and communications) that are necessary to the project but are performed by parties other than the contractor, and additional construction oversight tasks (by EPA).

Costs were developed using both parametric and bottom-up costing approaches. Parametric costing was based on review of historical cost estimates for 11 similar sediment remediation projects completed locally (in the Seattle area) and regionally (in the Pacific Northwest). In bottom-up costing, the large project was broken down into a number of smaller components, and costs were specifically derived for each of these smaller work components based on engineering cost guidance. By comparing bottom-up costs with parametric cost information (if projects reviewed contained similar quantities and/or conditions as the middle reach), along with engineering best professional judgment, "mid-range" unit costs were then derived. In addition, a three-point estimating approach was also applied to provide a costing range around the "mid-range" or "most likely" cost scenario (lower, mid-range, and upper cost scenarios).[49]

[48] Including construction management and environmental compliance monitoring.
[49] In three-point estimating, three separate cost scenarios for the costs associated with the project were generated. The first point represents an "optimistic" or "lower" cost scenario (assumed to have a 10% decrease in unit costs relative to the "mid-range" unit costs). The second point represents the "conservative" or "upper" cost scenario (assumed to have a 20% increase in unit costs relative to the "mid-range" unit costs). The third point represents the "mid-range" (or "most likely") cost scenario (see additional detailed information in Appendix N).

Costs developed for direct and indirect construction tasks and additional construction oversight tasks include the following components:

- Direct construction costs:
  - Mobilization and demobilization of in-water/upland equipment
  - Mobilization and demobilization of specialized equipment
  - Site preparation
  - Surveys
  - Structural work (demolition and installation)
  - Required dredging and excavation and potential contingency re-dredging
  - Transloading, upland transportation, and disposal of bulk sediments at off-site Subtitle D disposal facility
  - Containerization of PCB remediation waste, RCRA hazardous waste, and Washington State dangerous waste and stabilization of the RCRA hazardous waste
  - Transfer, upland transportation, and disposal of containerized sediments at off-site Subtitle C disposal facility[50]
  - Removal and off-site disposal of Identified Debris
  - RAA-specific equipment decontamination
  - On-barge dredge return water management and treatment
  - Directed standby time
  - Material placement of backfill, required RMC, inner/outer-perimeter RMC, ENR, amended ENR, and standard and modified engineered caps
  - Environmental controls
- Indirect construction costs:
  - Project management
  - Engineering support services
  - Construction QA
    - Construction management (inspection and oversight)
    - Environmental compliance monitoring (including confirmation sediment sampling and contingency action determination, environmental monitoring during construction [water quality, air/noise/light], and inadvertent discovery monitoring)
  - Site access agreements, business interruption, and temporary leases
  - Community outreach and communications
- Additional construction oversight costs:
  - EPA oversight

[50] With the exception of containerized dangerous waste, which can be disposed at an off-site, permitted Subtitle D landfill

General and specific RD costing assumptions are detailed in Appendix N and in the cost estimate workbook (Appendix N, Attachment N.1).

The total Intermediate (60%) RD Opinion of Probable Cost for LDW middle reach and LDW upper reach SMA 10 implementations at the Intermediate (60%) RD are presented in Table 13-2.

Table 13-2
Total Project Cost for LDW Middle Reach and LDW Upper Reach SMA 10 Implementation at Intermediate (60%) RD

Description	Lower Total Cost ($)	Mid-Range Total Cost ($)	Upper Total Cost ($)
LDW Middle Reach Direct Construction Costs[1]	$250,000,000	$280,000,000	$340,000,000
LDW Upper Reach SMA 10 Direct Construction Costs[2]	$11,000,000	$12,000,000	$14,000,000
Indirect Construction Costs[3]	$69,000,000	$77,000,000	$92,000,000
Additional Construction Oversight Costs	$5,300,000	$5,900,000	$7,000,000
Total Project Costs	**$340,000,000**	**$370,000,000**	**$450,000,000**

Notes:
Costs are rounded to two significant figures. See Appendix N for detailed costs.
1. Direct construction costs for LDW middle reach include Seattle sales tax (10.55%), construction contingency (30.0%), and a separate structural contingency (50%) for specific structural work items.
2. Direct construction costs for LDW upper reach include Tukwila sales tax (10.4%) and construction contingency (30.0%).
3. Indirect construction costs include construction contingency (30.0%).

LDW: Lower Duwamish Waterway
RD: Remedial Design
SMA: sediment management area

Contingency percentages were selected to represent potential cost risks associated with the level of information available at Intermediate (60%) RD and engineering best professional judgment. All costs are presented in present-day U.S. dollars (i.e., 2026).

As discussed in Appendix N, this Opinion of Probable Cost is based on a possible nine construction season assumption, which is a probable construction duration estimate for Intermediate (60%) RD (see Section 12 for discussion of the factors leading to high uncertainty in the total construction duration estimate). Cost and schedule savings could be realized if the current transloading throughput capacity is increased to more than 1,500 tons per day (i.e., more than one transloading facility being available). With more transload capacity, the dredging production rate may not be limited to a single facility's daily throughput rate; thus, more dredging could be accomplished by the contractor on a daily basis using multiple sets of equipment, which could result in a cost reduction. However, it is important to consider that other factors (e.g., capacity limitations on rail transportation to the disposal facility, transload logistics at the disposal facility) could limit the actual benefits associated with a second transload facility.

14 Construction Contracting Strategy

Remedy construction will be implemented under a pending consent decree or other enforcement mechanism by LDWG (details to be determined).

As discussed in Section 1, LDWG has assigned the responsibility of construction contracting to one of its members, the City of Seattle (Owner). The public nature of the organization dictates the type of construction contract that will be used, the format of the Drawings and Specifications, and the specific legal arrangements between the selected remediation contractor and the Owner.

14.1 Remediation Contractor Selection

LDWG will establish contractor selection criteria and will also develop their preferred contracting approach, including number of contracts, breakdown of work between contracts, insurance and bonding requirements, and contract administration processes. Because LDWG includes two public entities, certain requirements will govern contractor selection in accordance with established public works contracting law.

14.2 Construction Quality Assurance Contract

Construction QA activities will be conducted by LDWG's construction management team. The details for field inspection and monitoring are described in Section 15.3 and in Volume II, Part I (CQAP outline).

14.3 Designer

Anchor QEA is the Designer for the LDW middle reach and will provide design support during construction to assist with implementation of the remedial action in conformance with the EPA-approved design documents, review of product approvals, request for information or clarifications, and acceptable design modifications as approved by EPA.

14.4 Multiple Construction Contracts

Due to anticipated construction duration and complex design issues that require time to work through, LDWG has determined that it will be necessary to complete the middle reach under more than one construction contract. The contracts would not be implemented in parallel but would follow one another with the goal of utilizing each available in-water construction season. Use of multiple construction contracts will allow design coordination with upland cleanup sites (refer to Section 2.2.2) that do not currently align with the design schedule to proceed without slowing down the overall construction. Additionally, it provides more time for source control sufficiency evaluations for certain RAAs by allowing areas to be deferred to later contracts, as needed. It will also allow for optimizing the scope of work through multiple contracts and contractors, which may reduce risks associated with duration and complexity of bidding a single, decade-long procurement.

For Intermediate (60%) RD, the middle reach design covers the entire middle reach. Moving forward, separate Pre-Final (90%) RD and Final (100%) RD packages will be developed for each contract. The schedule for completing the middle reach design using a phased approach aligned with multiple construction contracts will be documented separately and will need to be approved by EPA.

15 Contractor Quality Control and Construction Quality Assurance

A critical part of successful sediment remediation projects is to require that the contractor has a robust QC plan to manage their work in a manner that complies with all requirements identified in the Drawings and Specifications and with all federal, state and local regulations. This section describes how QA/QC will be implemented during remedy construction.

15.1 Pre-Construction Activities

Following the construction contract award, LDWG will direct the selected contractor to develop a RAWP as a pre-construction submittal that will describe specific means and methods the contractor will use to implement the remediation construction activities. The design specifications will identify the components of the RAWP for which the contractor is responsible.

The contractor will also be required to develop an ERP documenting the procedures to be followed in the event of an accident or emergency during remedial construction. The ERP itself will be a component of the contractor's RAWP. Key components that will be required in the contractor's RAWP include the following:

- Contractor Quality Control Plan Project Work Plan, including the following: 1) a description of construction elements, including proposed means and methods; and 2) an equipment and personnel list, including a project organization chart and reporting responsibilities
- Initial project schedule
- Site-specific Construction Health and Safety Plan, including an ERP
- Traffic Control Plan
- Environmental Pollution Control Plan, including a Water Quality Protection Plan, Spill Prevention, Control, and Countermeasure Plan
- Transportation and Disposal Plan
- Surveying Plan, including surveyor certifications (bathymetric and topographic)
- Material Placement Plan, including materials submittals per specifications (e.g., material testing results)
- Dredging and Excavation Plan, including proposed transload and disposal facility names, locations, and certification
- Erosion and Sediment Control Plan
- Water management plan
- Vessel Management Plan
- Demolition Plan
- Examples of progress reporting forms
- Change order forms and process

The RAWP will be reviewed and approved by LDWG and EPA.

15.2 Contractor Quality Control

Contractor QC refers to the procedures, actions, and documentation performed and produced by the contractor to demonstrate the contractor has met the project requirements as detailed in an approved RAWP and with the Drawings and Specifications. Construction QC (e.g., daily progress surveys, equipment inspection, sampling and analysis to verify import materials quality) will be the responsibility of the construction contractor, in accordance with the Specifications and the contractor's RAWP. The Specifications developed in Pre-Final (90%) RD will require the selected contractor to prepare a contractor Quality Control Plan as part of the RAWP.

15.3 Construction Quality Assurance

Construction QA refers to the procedures and actions implemented by LDWG to confirm that the contractor is complying with all project requirements and to provide QA related to the remedy performance. The CQAP that will be developed during Pre-Final (90%) RD will describe QA roles and responsibilities, QA activities, and the means and methods that LDWG and their consultant will use to provide QA during construction to oversee and track the contractor's work, monitor environmental compliance, and assess compliance with Specifications.

For Intermediate (60%) RD, Volume II, Part I, includes a table summarizing key elements of the CQAP as required by AOC5. The CQAP will describe QA activities conducted during pre-construction, construction, and post-construction. Construction QA for sediment remediation projects typically involves three major categories of QA, including construction inspection and engineering support, environmental controls and monitoring, and remedy performance monitoring.

15.3.1 Construction Inspection and Engineering Support

LDWG will provide construction inspection (in-field activities) and engineering support (office support activities) to oversee the contractor's activities. LDWG may use a Resident Engineer, who is a full-time qualified individual, to lead the construction management team to oversee the contractor's work and help administer the construction contract. Construction management team responsibilities likely will include construction administration, on-site inspection, review of submittals, design interpretation and development of response actions, and communication and coordination with the selected contractor and EPA.

15.3.2 Environmental Controls and Monitoring

LDWG will provide environmental monitoring and reporting to EPA for all environmental ARAR compliance requirements, such as water quality monitoring. The CQAP will include development of environmental monitoring plans and response actions (i.e., how modifications to the construction procedures will be directed, as necessary, in response to monitoring data).

15.3.3 Remedial Action Performance Monitoring

LDWG will provide remedy performance monitoring, specifically to assess the post-dredge sediment surface quality to evaluate whether the post-dredge surface concentrations are below surface RALs (0 to 10 cm [0 to 4 inches]). The CQAP will describe the post-dredge confirmatory sampling and decision framework for contingency action(s) resulting from confirmatory sampling test results.

16 Work by Others

Work by others (i.e., bank or in-water construction activities such as permitted maintenance dredging, nearshore upland cleanup activities, potential habitat enhancement projects) within the limits of the middle reach may take place during the anticipated RD duration. Middle reach construction activities could modify existing conditions. Therefore, as described in the RDWP and within this BODR, any planned or completed construction activities within the middle reach starting in 2022 (representing the middle reach RD notice to proceed) through the anticipated RD completion in 2027 are currently being tracked.

Appendix A summarizes the status of known in-water and bank construction or habitat enhancement activities occurring adjacent to the RAAs and anticipated changes in structures and in-water, riverbank, and upland areas. Construction activities have been documented by reviewing the *Lower Duwamish Waterway Source Control Status Report 2020* (Ecology 2022), the *Lower Duwamish Waterway – 2024 Cleanup Update* (Ecology 2024), the FS (AECOM 2012), the Ecology website (Ecology 2026b), and the USACE Regulatory Program website (USACE 2026). Additionally, outreach to adjacent property owners has been conducted to identify potential upcoming work. These activities are documented in Table A1-2.

Should non-remediation-related construction take place between EPA approval of the Final (100%) RD and anticipated start of remedial construction, LDWG will review the new conditions and revise the Drawings and Specifications if necessary.

17 Phase III PDI Data Collection to Address Data Gaps

During preparation of the Preliminary (30%) RD, three categories of data gaps were identified that are being addressed by the Phase III PDI for the middle reach. The following major categories of data are being collected during the Phase III PDI, as detailed in the Phase III QAPP Addendum (Anchor QEA and Barr 2026):

- Additional horizontal chemistry sampling to refine RAA boundaries
- Additional vertical chemistry sampling in areas that are vertically unbounded or where additional information is needed to refine the design
- Other engineering support data such as the following:
  - Improved understanding of the locations and elevations of submarine utility corridors in the middle reach
  - As-built information and supplemental field inspections for structures located within or adjacent to dredging or ENR locations
  - Supplemental topographic or vegetation survey data to cover gaps identified during Preliminary (30%) RD
  - Additional information for select outfalls that are within action areas, including location confirmation, invert elevation, and as-built data, if available
  - Supplemental geotechnical data to support additional engineering analyses
  - Information to support cap modeling evaluation and design (e.g., location-specific groundwater seepage rate and porewater/geochemistry information)
  - Information to complete waste profiles.

The Phase III PDI is being conducted during summer 2026, and data will be incorporated into the Pre-Final (90%) RD.

As the remedies for the upland cleanup sites identified in Section 2.2.2 are developed and approved by Ecology, there may be new data gaps within the adjacent middle reach that arise. A decision regarding additional in-water data gaps, if warranted, will be made in coordination with EPA.

18 References

AECOM, 2012. *Final Feasibility Study, Lower Duwamish Waterway*. Submitted to EPA October 2012.

AISC (American Institute of Steel Construction), 2017. *Steel Construction Manual, Fifteenth Edition*.

Amec Foster Wheeler (Amec Foster Wheeler Environment & Infrastructure, Inc.); Dalton, Olmsted & Fugelvand, Inc.; Ramboll; Floyd|Snider; and Geosyntec Consultants, 2018. *Construction Report: Enhanced Natural Recovery/Activated Carbon Pilot Study, Lower Duwamish Waterway*. Final. Approved by EPA June 2018.

Anchor Environmental and King County DNRP (Anchor Environmental, L.L.C., and King County Department of Natural Resources and Parks), 2007. *Final Data Report: Fish Tissue Sampling and Chemical Analysis in the Lower Duwamish Waterway*. July 2007.

Anchor QEA, 2024. *100% Remedial Design Basis of Design Report, LDW Upper Reach*. Appendix J, Engineered Protection Design Analysis for Engineered Caps and Area-Specific Technology. January 2024.

Anchor QEA and Barr, 2026. *Pre-Design Investigation Quality Assurance Project Plan Addendum No. 3 for the Lower Duwamish Waterway Middle Reach – Phase III Sampling.* Final. Submitted to EPA July 17, 2026.

Anchor QEA and Tetra Tech, 2016. *Localized Remodeling of Contamination in OUs 4 and 5 of the Lower Fox River.* Prepared for Boldt Oversight Team, Wisconsin Department of Natural Resources, and Kern Statistical. Document Control No. LFRR-15-0345A-R1.

Anchor QEA and Windward (Windward Environmental LLC), 2021. *Quality Assurance Project Plan: Pre-Design Surveys of the Lower Duwamish Waterway Middle Reach*. Final. Submitted to EPA October 19, 2021.

Anchor QEA and Windward, 2022a. *Remedial Design Work Plan for the Lower Duwamish Waterway Middle Reach*. Final. Submitted to EPA December 2, 2022.

Anchor QEA and Windward, 2022b. *Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Upper Reach*. Final. Submitted to EPA July 15, 2022.

Anchor QEA and Windward, 2022c. *Preliminary (30%) Remedial Design Basis of Design Report for Lower Duwamish Waterway Upper Reach*. Submitted to EPA August 29, 2022.

Anchor QEA and Windward, 2024a. *Pre-Design Investigation Quality Assurance Project Plan Addendum No. 1 for the Lower Duwamish Waterway Middle Reach – Phase II Sampling*. Final. Submitted to EPA June 12, 2024.

Anchor QEA and Windward, 2024b. *Pre-Design Investigation Quality Assurance Project Plan Addendum No. 2 for the Lower Duwamish Waterway Middle Reach – Phase II Sampling for the Inlet at RM 2.2W*. Final. Submitted to EPA June 21, 2024.

Anchor QEA and Windward, 2024c. *Final (100%) Remedial Design Basis of Design Report for Lower Duwamish Waterway Upper Reach*. Submitted to EPA January 16, 2024.

Anchor QEA and Windward, 2025a. *Pre-Design Investigation Data Evaluation Report for the Lower Duwamish Waterway – Middle Reach.* Final. Submitted to EPA September 30, 2025.

Anchor QEA and Windward, 2025b. *Institutional Controls Implementation and Assurance Plan for the Lower Duwamish Waterway*. Draft. Submitted to EPA January 13, 2025.

Anchor QEA and Windward, 2025c. *Long Term Monitoring and Maintenance Plan for the Lower Duwamish Waterway.* Draft. Submitted to EPA June 5, 2025.

ASCE (American Society of Civil Engineers), 2017. *Minimum Design Loads and Associated Criteria for Buildings and Other Structures (7-16)*.

AWS (American Welding Society), 2020. *D1.1 – Structural Welding Code – Steel*.

Blomberg, G., C. Simenstad, and P. Hickey, 1988. "Changes in Duwamish River Estuary Habitat Over the Past 125 Years." *Proceedings of the First Annual Meeting on Puget Sound Research.* Seattle, Washington.

BOEM and NOAA (Bureau of Ocean Energy Management; National Oceanic and Atmospheric Administration), 2025. Vessel Traffic. Accessed 2025. Available at: https://marinecadastre.gov/data.

Boeters, R.E.A.M, F.C.M Van der Knaap, and H.J. Verheij, 1993. "Behaviour of Armour Layers of Riprap Bank Protections Along Navigation Channels." In: Proc int riprap workshop, Fort Collins, Colorado, July. Also in: Thorne, C.R., S.R. Abt, F.B. Barends, S.T. Maynord, and R.W. Pilarczyk, editors, 1995. *River, Coastal and Shoreline Protection: Erosion Control Using Riprap and Armourstone*. New York: John Wiley & Sons.

Bowles, J.E., 1998. *Foundation Analysis and Design*, Sixth Edition. McGraw-Hill International Press.

CIRIA, CUR, and CETMEF (Construction Industry Research & Information Association; CUR; French Center for Maritime and Fluvial Technical Studies), 2007. *The Rock Manual*. The Use of Rock in Hydraulic Engineering (second edition), C683. London.

City of Seattle, 2026. *2026 Edition City of Seattle Standard Plans for Municipal Construction.* Plan No. 001a. Available at: https://www.seattle.gov/documents/Departments/SPU/Construction-Resources/standards-guidelines/specifications-plans/2026-Standard-Plans.pdf.

Desrosiers, R., and C. Patmont, 2009. *Environmental Dredging Residuals – Case Study Summaries and Analyses*. Presented at 5th International Conference on Remediation of Contaminated Sediments. February 4, 2009.

Duncan, J.M., and S.G. Wright, 2005. *Soil Strength and Slope Stability*. First edition. New Jersey: John Wiley and Sons.

Ecology (Washington State Department of Ecology), 2007. *Using Sediment Profile Imaging (SPI) to Evaluate Sediment Quality at Two Cleanup Sites in Puget Sound: Part I – Lower Duwamish Waterway.* Publication No. 07-03-025. July 2007.

Ecology, 2022. *Lower Duwamish Waterway Source Control Status Report 2020*. Publication No. 22-09-178. August 2022.

Ecology, 2024. *Lower Duwamish Waterway – 2024 Cleanup Update*. Publication No. 24-09-141. June 2024.

Ecology, 2026a. Water Quality Permitting and Reporting Information System (PARIS). Accessed June 9, 2026. Available at: https://apps.ecology.wa.gov/paris/PermitLookup.aspx.

Ecology, 2026b. Washington State Department of Ecology website. Accessed June 23, 2026. Available at: https://ecology.wa.gov/.

Ehinger, S.I., L. Abernathy, M. Bhuthimethee, L. Corum, N. Rudh, D. Price, J. Lim, M. O'Connor, S. Smith, and J. Quan, 2023. *Puget Sound Nearshore Habitat Calculator User Guide V1.5*. NOAA, editor. Available at: https://www.fisheries.noaa.gov/west-coast/habitat-conservation/puget-sound-nearshore-habitat-conservation-calculator.

EPA (U.S. Environmental Protection Agency), 2004. *Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation.* OSWER Directive No. 9355.4-28. January 2004.

EPA, 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites.* EPA 540 R 05-012, OSWER 9355.0-85. Office of Solid Waste and Emergency Response. December 2005.

EPA, 2009. *Clean and Green Policy*. Office of Environmental Cleanup; Office of Air, Waste, and Toxics; and Office of Compliance and Enforcement. August 13, 2009.

EPA, 2010. *Superfund Green Remediation Strategy*. September 2010.

EPA, 2012a. *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites*. December 2012.

EPA, 2012b. *Institutional Controls: A Guide to Preparing Institutional Control Implementation and Assurance Plans at Contaminated Sites*. December 2012.

EPA, 2012c. *Methodology for Understanding and Reducing a Project's Environmental Footprint*. EPA 542-R-12-002. Office of Solid Waste and Emergency Response and Office of Superfund Remediation and Technology Innovation. February 2012.

EPA, 2014. *Record of Decision.* Lower Duwamish Waterway Superfund Site. EPA, Region 10. November 2014.

EPA, 2017a. *Guidance for Management of Superfund Remedies in Post Construction*. February 2017.

EPA, 2017b. *Workshop Summary of the Lower Duwamish Waterway: Climate Change Adaptation*. March 2017.

EPA, 2021. *Explanation of Significant Differences*. Lower Duwamish Waterway Superfund Site. September 2021.

EPA, 2024. *Unilateral Administrative Order for Remedial Design and Remedial Action.* EPA, Region 10. CERCLA Docket No. 10-2001-1077. Seattle, Washington. July 18, 2024.

EPA and USACE (U.S. Army Corps of Engineers), 1998. *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual (Inland Testing Manual)*. February 1998.

FEMA (Federal Emergency Management Agency), 2020. *Flood Insurance Study, King County, Washington, and Incorporated Areas.* Flood Insurance Study Number 53033CV001B. December 2020.

G-Logics (G-Logics, Inc.), 2020. *Remedial Investigation Report – Duwamish Marine Center Property*. Public Review Draft. September 30, 2020.

Hayes, D.F., and C.H. Je, 2000. *DREDGE Model User's Guide*. University of Utah, Department of Civil and Environmental Engineering. July 2000.

ICC (International Code Council), 2020. 2021 International Building Code.

Integral (Integral Consulting Inc.), Moffatt & Nichol, and Windward Environmental LLC, 2018. *Waterway User Survey and Assessment of In-Water Structures – Data Report*. Prepared for EPA, Region 10. July 2, 2018.

Integral, Anchor QEA, and Windward Environmental LLC, 2019. *Effects of Changes in Estimated Upstream Sediment Load on Lower Duwamish Waterway Sediment Transport Modeling*. Appendix A of *Recovery Category Recommendations Report*. Final. Prepared for EPA, Region 10. February 2019.

ITRC (Interstate Technology and Regulatory Council), 2014. *Contaminated Sediments Remediation: Remedy Selection for Contaminated Sediments (CS-2)*. Washington, DC: Interstate Technology and Regulatory Council, Contaminated Sediments Team. Available at: https://clu-in.org/download/contaminantfocus/sediments/Sediment-ITRC-CS-2.pdf.

ITRC, 2023. *Sediment Cap Chemical Isolation Guidance (SD-1)*. Accessed September 20, 2023. Available at: https://sd-1.itrcweb.org/.

Kern, J., J. Wolfe, and N. Barabas, 2008. Evaluation of Increased Sampling Density for Refinement of 30% Dredge Prism Design in Upper OU3 in Attachment C to Appendix D. *Lower Fox River Remedial Design 100 Percent Design Report*. Construction Quality Assurance Project Plan for 2009 Remedial Actions. For submittal to Wisconsin Department of Natural Resources and EPA. Kern Statistical Service and LimnoTech.

King County, 2006. King County Parcels. Available at: https://gis-kingcounty.opendata.arcgis.com/datasets.

King County, 2025. *Habitat Restoration Along the Lower Duwamish Waterway*. Available at: https://cdn.kingcounty.gov/-/media/king-county/depts/dnrp/waste-services/wastewater-treatment/program/lower-duwamish/docs/1208_restoration_map_handout_v8_final.pdf?rev=aaf06247ed864f7c9604d7764e2a2c9c&hash=3DBBE8814DD022852B20E11949D633E5.

Kriebel, D. L. and W.N. Seelig, 2005. "An Empirical Model for Ship-Generated Waves." *Proceedings of the 5th International Symposium on Ocean Wave Measurement and Analysis*.

LDWG (Lower Duwamish Waterway Group), 2021. Memorandum to: Elly Hale, EPA. Regarding: Evaluation of Sedimentation Rates and Sediment Load Assumptions for Lower Duwamish Waterway Sediment Transport Model. August 3, 2021.

Leidos, 2014. *Lower Duwamish Waterway Outfall Inventory Update, January 2012 – February 2014*. Prepared for Washington State Department of Ecology. SC_00035548.

Leidos, 2020. *Lower Duwamish Waterway Outfall Inventory Update, August 2020*. Prepared for Washington State Department of Ecology.

MacNab, A., 2002. *Earth Retention Systems Handbook*. McGraw-Hill.

Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. *State of Knowledge: Climate Change in Puget Sound*. Prepared for the Puget Sound Partnership and National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington.

McKeon, M.A., A.R. Horner-Devine, and S.N. Giddings, 2020. "Seasonal Changes in Structure and Dynamics in an Urbanized Salt Wedge Estuary." *Estuaries and Coasts* 44:589–607. https://doi.org/10.1007/s12237-020-00788-z.

Miller, I.M., H. Morgan, G. Mauger, T. Newton, R. Weldon, D. Schmidt, M. Welch, and E. Grossman, 2018. *Projected Sea Level Rise for Washington State – A 2018 Assessment*. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, University of Oregon, University of Washington, and U.S. Geological Survey. Prepared for the Washington Coastal Resilience Project.

NAVFAC (Naval Facilities Engineering Systems Command), 1986. *Design Manual 7.02 Foundations and Earth Structures*. September 1986.

NOAA (National Oceanic and Atmospheric Administration), 1995. *Habitat Equivalency Analysis: An Overview*. NOAA Damage Assessment and Restoration Program, Department of Commerce. Washington, DC. March 21, 1995.

NOAA, 2022. *Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Salish Sea Nearshore Programmatic Consultation (SSNP)*. NMFS consultation number WCRO-2019-04086. June 29, 2022.

NOAA, 2026. Puget Sound Nearshore Habitat Conservation Calculator. Available at: https://www.fisheries.noaa.gov/west-coast/habitat-conservation/puget-sound-nearshore-habitat-conservation-calculator.

Palermo, M., S. Maynord, J. Miller, and D. Reible, 1998. *Guidance for In-Situ Subaqueous Capping of Contaminated Sediments*. EPA 905-B96-004. Great Lakes National Program Office, Chicago, Illinois.

Patmont, C., P. LaRosa, R. Narayanan, and C. Forrest, 2018. "Environmental Dredging Residual Generation and Management." *Integrated Environmental Assessment and Management* 14(3):335–343.

PSLC (Puget Sound LiDAR Consortium), 2016. LiDAR data. Available at: https://pugetsoundlidar.ess.washington.edu/.

Public Health Seattle and King County, 2019. *US EPA's Institutional Control Implementation and Assurance Plan (ICIAP) for Seafood Consumption at the Lower Duwamish Waterway (LDW) Superfund Site*. Final. August 2019.

QEA (Quantitative Environmental Analysis, LLC), 2007. *Hudson River PCBs Site Phase 2 Dredge Area Delineation Report.* Prepared for General Electric Company.

QEA, 2008. *Lower Duwamish Waterway Sediment Transport Model Report*. Final. Prepared for EPA, Region 10, and Washington State Department of Ecology, Northwest Regional Office. October 2008.

Ray, G.L., 2009. *Application of Habitat Equivalency Analysis to USACE Projects*. Ecosystem Management and Restoration Research Program. ERDC TN-EMRRP-EI-04. April 2009.

Reible, D., 2023. *CapSIM 4.2 Basic Users Manual.* Available at: https://www.depts.ttu.edu/ceweb/research/reiblesgroup/CapSim_4.2_Basic_User_Manual.pdf.

SDCI (Seattle Department of Construction and Inspections), 2020. 2021 Seattle Building Code.

Sorensen, R., and R. Weggel, 1984. "Development of Ship Wave Design Information." Conference Proceedings, Coastal Engineering, January 1984.

Thornburg T., J. Wolfe, and N. Barabas, 2005. *Comparative Evaluation of Geostatistical Methods for Delineating PCB Remediation Areas and Volumes, Lower Fox River*. Society of Environmental Toxicologists and Chemists, 26th Annual North American Meeting (Baltimore, Maryland); November 2005.

USACE (U.S. Army Corps of Engineers), 1994. *Design of Sheet Pile Walls*. Engineering and Design. EM 1110-2-2504. March 31, 1994.

USACE, 2003. *Slope Stability*. Engineering Manual EM 1110-2-1902.

USACE, 2008a. *Technical Guidelines for Environmental Dredging of Contaminated Sediments.* Engineer Research and Development Center. ERDC/EL TR-08-29. September 2008.

USACE, 2008b. *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk.* Engineer Research and Development Center. ERDC/EL TR-08-4. January 2008.

USACE, 2008c. *Coastal Engineering Manual*. EM 1110-2-1100. April 2022; revised 2008.

USACE, 2014. *Howard Hanson Dam, Green River, Washington, Climate Change Impacts and Adaptation Study.* April 2014.

USACE, 2026. "USACE Regulatory and Section 408 Publicly Available Data." Accessed June 9, 2026. Available at: https://permits.ops.usace.army.mil/orm-public.

USCG (U.S. Coast Guard), 2025. *Incident Management Handbook*. U.S. Coast Guard COMDTPUB P3120.17C - U.S. Department of Homeland Security. June 2025.

USGS (U.S. Geological Survey), 2008. S*imulation of Flow, Sediment Transport, and Sediment Mobility of the Lower Coeur d'Alene River, Idaho*. Scientific Investigations Report 2008–5093. 2008.

USGS, 2018. *Suspended-Sediment Transport from the Green-Duwamish River to the Lower Duwamish Waterway, Seattle, Washington, 2013-17*. Open-File Report 2018-1029.

USS (United States Steel), 1984. *Steel Sheet Piling Design Manual*. July 1984.

Wang, T.S., K. Larm, and D. Hotchkiss, 2002. "Evaluation of Closed Buckets for Remedial Dredging and Case Histories." *Proceedings – Third Specialty Conference on Dredging and Dredged Material Disposal, ASCE Dredging 2002*. Orlando, Florida. May 2002.

WCRP (Washington Coastal Resilience Project), 2018. *Projected Sea Level Rise for Washington State: A 2018 Assessment.* Available at: https://cig.uw.edu/wp-content/uploads/sites/2/2019/07/SLR-Report-Miller-et-al-2018-updated-07_2019.pdf.

WDNR (Washington State Department of Natural Resources), 2017. *Washington Department of Natural Resources Derelict Creosote Piling Removal Best Management Practices For Pile Removal & Disposal*. Updated January 25, 2017.

Windward (Windward Environmental LLC), 2010. *Remedial Investigation Report*. Lower Duwamish Waterway Remedial Investigation. Final. Submitted to EPA July 2010.

Windward and Anchor QEA, 2022. *Pre-Design Investigation Quality Assurance Project Plan for the Lower Duwamish Waterway – Middle Reach*. Final. Submitted to EPA October 21, 2022.

Wolfe, J., and J. Kern, 2008. Ground Rules for Evaluating Extent of Vertical and Horizontal Remedial Coverage. Attachment A-8 to Appendix A. *Dredging and Materials Handling Design Support Documentation in the Lower Fox River Remedial Design 100 Percent Design Report for 2009 Remedial Actions.* For submittal to Wisconsin Department of Natural Resources and EPA. Kern Statistical Services and LimnoTech.

Wood (Wood Environmental & Infrastructure Solutions, Inc.); Ramboll; Floyd|Snider; Geosyntec Consultants; and Integral Consulting, Inc., 2021. *Year 3 Monitoring Report, Enhanced Natural Recovery/Activated Carbon Pilot Study, Lower Duwamish Waterway*. Final. Approved by EPA October 2021.

WRIA 9 (Water Resource Inventory Area 9), 2021. *Water Resource Inventory Area 9 Green/Duwamish and Central Puget Sound Watershed Salmon Habitat Plan 2021 Update. Making Our Watershed Fit for a King*. Approved by the Watershed Ecosystem Forum February 11, 2021.