FINAL

Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

PRE-DESIGN INVESTIGATION DATA EVALUATION REPORT FOR THE LOWER DUWAMISH WATERWAY - UPPER REACH

FINAL

For submittal to

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ABBREVIATIONS

AC	activated carbon
ARI	Analytical Resources, Inc.
ASTM	American Society for Testing and Materials
BBP	butyl benzyl phthalate
BEHP	bis(2-ethylhexyl) phthalate
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPT	cone penetrometer testing
CSL	cleanup screening level
DCP	dynamic cone penetrometer
DER	Data Evaluation Report
DQO	data quality objective
DRET	dredge elutriate testing
Ecology	Washington State Department of Ecology
EF	exceedance factor
ENR	enhanced natural recovery
EPA	US Environmental Protection Agency
ESD	explanation of significant differences
FFP	full flow penetrometer
FNC	federal navigation channel
FS	Feasibility Study
GPS	global positioning system
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
ID	identification
IDW	inverse distance weighting
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LPAH	low-molecular-weight polycyclic aromatic hydrocarbons
MHHW	mean higher high water
MLLW	mean lower low water
MNR	monitored natural recovery
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PDI	Pre-Design Investigation
QAPP	Quality Assurance Project Plan

QC	quality control
RAA	remedial action area
RAL	remedial action level
RAO	remedial action objective
RD	remedial design
RDWP	Remedial Design Work Plan
RI	Remedial Investigation
RM	river mile
RTK	real time kinematic
ROD	Record of Decision
SCO	sediment cleanup objective
SEF	*Sediment Evaluation Framework for the Pacific Northwest*
SMS	Washington State Sediment Management Standards
SPT	standard penetration test
SVOC	semivolatile organic compound
TEQ	toxic equivalent
TOC	total organic carbon
USACE	US Army Corps of Engineers
VST	vane shear testing
WUS	Waterway User Survey

1 Introduction

This document is the Data Evaluation Report (DER) created per the fourth amendment to the Administrative Order on Consent in support of remedial design (RD) for the upper reach (river mile [RM] 3.0 to RM 5.0) of the Lower Duwamish Waterway (LDW) Superfund site in King County, Washington. The DER presents the combined results of the Phase I and Phase II Pre-Design Investigation (PDI),[1] which was implemented in accordance with the US Environmental Protection Agency (EPA)-approved PDI QAPP (Windward and Anchor QEA 2020) and Addendum to the PDI QAPP for Phase II (Phase II QAPP Addendum) (Anchor QEA and Windward 2021a).

This DER also defines areas in the upper reach with exceedances of the RALs,[2] lists preliminary technology assignment options for these areas, and identifies initial data gaps for the Phase III PDI. The Phase III data gaps will be further defined at 30% design and addressed through an Addendum to the PDI QAPP for Phase III, herein referred to as the Phase III QAPP Addendum. This DER has been prepared on behalf of the City of Seattle, King County, the Port of Seattle, and The Boeing Company, collectively referred to as the Lower Duwamish Waterway Group (LDWG) under the oversight of EPA.

Additional Phase I and Phase II information and results are included in the Phase I and Phase II PDI data packages provided separately to EPA and posted on https://ldwg.org. These packages include maps and coordinates of sediment sampling locations, field notes and forms, chain of custody forms, laboratory and validation reports, photographs, and validated analytical results for all tiers of Phase I and Phase II chemical analysis.

1.1 Data Evaluation Report Objectives

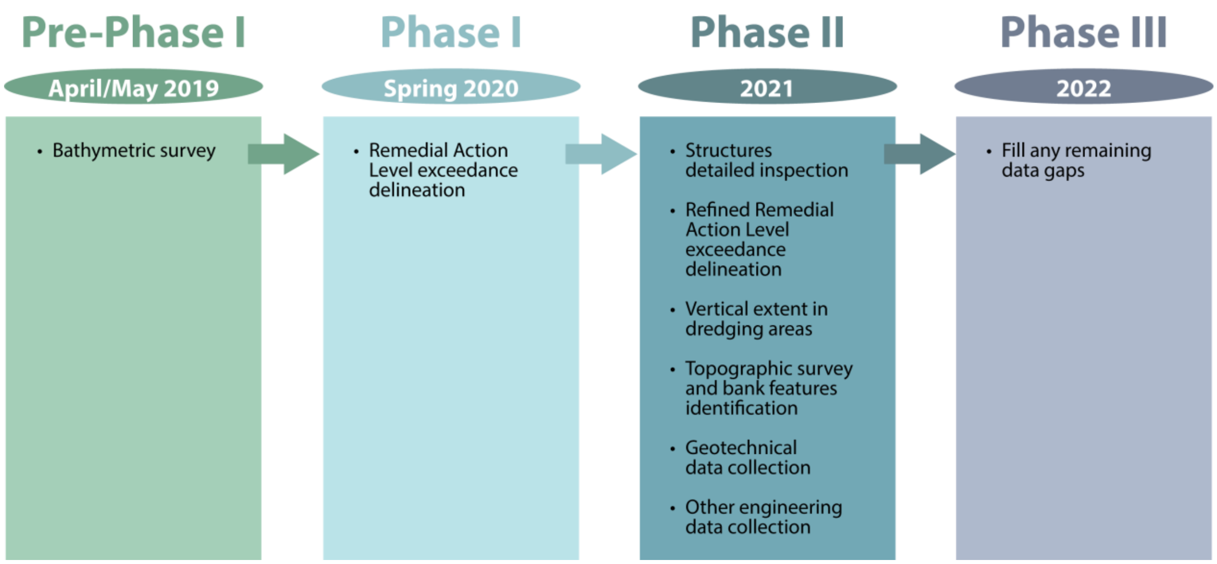
Per the Remedial Design Work Plan (RDWP) (Anchor QEA and Windward 2019), design sampling is being done in phases (Figure 1-1). Phase I focused on defining the horizontal extent of RAL exceedance areas and considered technology assignment options to identify Phase II PDI data gaps. Phase II involved the collection of data to further delineate the areas with RAL exceedances in surface sediment (0–10 cm), subsurface sediment (0–45 cm in the intertidal and 0–60 cm in the subtidal), and shoaling areas, and to assess the vertical extent of contamination (i.e., the overall depth of contamination) in dredge or partial dredge and cap areas. Phase II also

[1] All elements from the Phase I DER are included in this DER except for the following items: 1) field notes, photos, forms, laboratory and validation reports, and data files, which were included in the Phase I data package posted to https://ldwg.org; and 2) bathymetry surveys, data rules, and recovery category assessments, as well as dry weight concentration and non-remedial action level (RAL) interval data and maps, which were included in the Quality Assurance Project Plan (QAPP) Addendum for Phase II) (Anchor QEA and Windward 2021a).

[2] RALs are defined in Table 28, titled *Remedial Action Levels, ENR Upper Limits, and Areas and Depths of Application*, of EPA's November 2014 Record of Decision (ROD) (EPA 2014) and in the explanation of significant differences (ESD) for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) (EPA 2021). As stated in the ROD, a RAL is a contaminant concentration above which remedial action is required.

involved collection of characterization data in bank areas within areas with RAL exceedances, geotechnical data, and area-specific engineering data needed for RD. Phase III PDI will be conducted to address data gaps that remain following Phase II and any additional data gaps identified at 30% RD.

Figure 1-1
Design Sampling Phases



Per the RDWP and PDI Work Plans (Windward and Anchor QEA 2019; Anchor QEA and Windward 2019), this DER meets the following objectives in the overall design process:

- Summarize the results of the Phase I PDI, including results from the sediment chemistry analyses (Tiers 1, 2, and 3), bank visual inspection, and structures visual inspection.
- Summarize the results of the Phase II PDI, including results from the sediment chemistry analyses (Tiers 1 and 2), geotechnical investigation, structures detailed inspection, topographic surveying, sediment thickness over armored banks, and other engineering data.
- Refine areas with RAL exceedances using the interpolation method developed for the PDI in coordination with EPA and the updated design dataset.
- Identify technology assignment options for each area with RAL exceedances, consistent with the decision trees in the ROD (Figure 19 and updated Figure 20 of the ROD).
- Finalize the recovery category areas in the upper reach based on additional Phase II contaminant trend data.
- Identify Phase III data gaps to set the stage for the Phase III QAPP Addendum.

Based on the RAL exceedance areas presented in this DER and other engineering considerations, remedial action areas (RAAs) will be defined at 30% design and refined and grouped into sediment management areas at 60% design, as discussed in the RDWP (Anchor QEA and Windward 2019) (Table 1-1).

Table 1-1
Areas to be Defined During the RD Process

Area	Definition	Where Defined
RAL exceedance area	Area where RAL is exceeded by at least one contaminant based on comparison of interpolated concentrations to RALs in 2014 ROD Table 28 and Table 3 in the 2021 cPAH ESD	See Section 3.4.1, Map 3-3, Maps 3-4a-j, and Appendix K of this document
RAA	Area developed by considering how the selected remedial technologies are constructed and overlaying engineering considerations; RAA boundaries are set at or beyond the final interpolated boundaries of the RAL exceedance areas	30% RD
Sediment management area	Area organized by grouping or dividing RAAs by remedial technology, site physical conditions, or operational restrictions	60% RD

Notes:
cPAH: carcinogenic polycyclic aromatic hydrocarbon
DER: Data Evaluation Report
ESD: explanation of significant differences
PDI: Pre-Design Investigation
RAA: remedial action area
RAL: remedial action level
RD: remedial design
ROD: Record of Decision

The areas with RAL exceedances delineated in this document will differ to varying degrees from the RAAs to be identified in 30% design, because the RAAs will include engineering considerations, such as geotechnical, slope and structural stability, sediment stability, and constructability considerations.

The main text of this DER identifies the RAL exceedance areas based on the RALs in the 2014 ROD and the RAL for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in EPA's 2021 explanation of significant differences (ESD). Additionally, Appendix B of this DER identifies the incremental areas where the original ROD cPAH RALs are exceeded.

1.2 Data Quality Objectives

The Phase II QAPP Addendum (Anchor QEA and Windward 2021a) presented data quality objectives (DQOs) for Phase I and Phase II. Phase I DQOs are summarized in Table 1-2. DQOs 1 through 7 were met through the collection and chemical analysis of sediment from 212 Phase I locations in June 2020. These data, combined with pre-PDI sediment data from the Remedial Investigation (RI)/Feasibility Study (FS) and post-FS data, provided a preliminary horizontal footprint of RAL exceedance areas that was used to identify Phase II data gaps. DQO 8 was met through visual surveys conducted during a series of low tides in June through August 2020.

Table 1-2
DQOs for Phase I PDI in the Upper Reach

DQO	DQO Description	Activities Conducted to Address DQO[1]
DQO1	Delineate 0–10-cm RAL exceedances in Recovery Category 2/3.	DQO was met through the collection and chemical analysis of 178 surface sediment (0–10-cm) samples in June 2020 (see Section 2.1.1.3).
DQO2	Delineate 0–10-cm RAL exceedances in Recovery Category 1.	
DQO3	Delineate 0–45-cm intertidal RAL exceedances in Recovery Category 2/3.	DQO was met through the collection and chemical analysis of 92 subsurface intertidal sediment (0–45-cm) samples in June 2020 (see Section 2.1.1.3).
DQO4	Delineate 0–45-cm intertidal RAL exceedances in Recovery Category 1.	
DQO5	Delineate 0–60-cm PCB RAL exceedances in potential vessel scour areas in Recovery Category 2/3.	DQO was met through the collection and chemical analysis of 71 subsurface subtidal sediment (0–60-cm) samples in June 2020 (see Section 2.1.1.3).
DQO6	Delineate 0–60-cm RAL exceedances in Recovery Category 1.	
DQO7	Delineate RAL exceedances in shoaling areas.	DQO was met through the collection and chemical analysis of 52 shoaling interval samples from 29 locations in June 2020 (see Section 2.1.1.3).
DQO8	Conduct a visual inspection of the banks in the upper reach to identify features relevant to design, such as the presence/absence of bank armoring, and to plan how to access banks and areas under structures for sampling purposes.	DQO was met through the visual bank inspection conducted throughout the upper reach in June 2020 (see Section 2.3).

Notes:
1. All DQOs were sufficiently addressed to support 30% design; additional data collected may be recommended in Phase III for further refinement (see Section 4).
DQO: data quality objective
PCB: polychlorinated biphenyl
PDI: Pre-Design Investigation
RAL: remedial action level

Phase II DQOs are summarized in Table 1-3. DQOs 9 through 12 were met through the collection and chemical analysis of sediment from 202 Phase II locations in June and July 2021. These data, combined with Phase I and pre-PDI sediment data, provided a refined horizontal footprint of RAL exceedances. Vertical extent cores collected and chemically analyzed from 78 locations during Phase II will inform the remedial approach for areas where dredge and partial dredge and cap remedial technologies will be used. DQOs 13 and 14 were met by performing geotechnical investigations at 64 sample locations and collecting applicable engineering data (e.g., structures inspection, utility location verification, thickness of sediment on top of riprap layers) within and near the preliminary footprint of RAL exceedances defined by Phase I and pre-PDI data.

Table 1-3
DQOs for Phase II PDI in the Upper Reach

DQO	DQO Description	Activities Conducted to Address DQO[1]
DQO9	If feasible, delineate RAL exceedances in areas under overwater structures.	DQO was met through Phase I and Phase II sampling, confirming that contamination does not extend under any overwater structures in the upper reach (see Section 4.1), with the exception of the South Park Bridge.
DQO10	Further delineate RAL exceedances,[2] as needed for unbounded areas.	An additional 80 0–10-, 59 0–45-, 63 0–60-cm and 26 shoaling interval samples from 13 locations were analyzed in Phase II to partially meet this DQO; most of which were collected in July 2021 (see Section 2.1.1.3). Additional data will be collected as part of Phase III to fully meet this DQO.
DQO11	Assess chemical and physical characteristics of banks (including topographic survey), as needed, depending on remedial technology selected for adjacent sediment and whether bank is erosional.	DQO was partially met through sampling and surveying of banks during Phase II within Phase I RAL exceedance areas (see Section 2.1 and 2.5.2). Additional data will be collected as part of Phase III to fully meet this DQO.
DQO12	Delineate vertical elevation of RAL exceedances in dredge (and partial dredge and cap) areas and collect subsurface sediment chemistry data in cap areas where contamination under caps will remain.[3]	DQO was partially met through analysis of a total of 293 vertical extent samples from 78 locations (see Section 2.1.1.3). Additional data will be collected as part of Phase III to fully meet this DQO.
DQO13	Collect geotechnical data as needed depending on technology proposed and/or physical characteristics of RAL exceedance areas.	DQO was met through geotechnical investigations at 64 sample locations (see Section 2.2).
DQO14	Collect other engineering-applicable data as needed (e.g., structures inspection, utility location verification, thickness of sediment on top of riprap layers, groundwater velocities[4]).	DQO was met through the following efforts during Phase I and Phase II PDI: • Inspecting structures and outfalls near Phase I RAL exceedance areas (see Section 2.4) • Measuring the thickness of sediment on top of armored banks to estimate the volume of sediment over armoring and identified the toe of armored slopes (where applicable) at 9 locations (see Section 2.6). • Assessing extent of vegetation along banks to inform engineering design (see Section 2.7.1) • Archiving samples for waste characterization to inform disposal options for engineering design (see Section 2.7.2 of this document and Section 5.3.3 of the Phase II QAPP Addendum)

Notes:
1. All DQOs were sufficiently addressed to support 30% design; additional data collected may be recommended in Phase III for further refinement (see Section 4).
2. Benthic toxicity testing may be used to override chemical data in RAL delineation (DQO 10), per the ROD (EPA 2014).
3. Vertical delineation includes an assessment of whether an additional 1 ft of dredging in partial dredge and cap areas would be sufficient to achieve complete removal, as shown in ROD Figure 20.

4. Groundwater velocity data were not collected during the Phase II PDI. Existing information will be evaluated in 30% design. Data collection will be recommended for Phase III PDI if groundwater velocity data are identified as a data gap during 30% design.
DQO: data quality objective
PDI: Pre-Design Investigation
RAL: remedial action level
ROD: Record of Decision

In addition to the Phase I and Phase II DQOs defined in the QAPP and Phase II QAPP Addendum, DQOs specific to surveying activities were included in the Survey QAPP (Anchor and Windward 2019) and Survey QAPP Addendum (Anchor QEA and Windward 2021b). The nomenclature for these DQOs has been modified for clarity in this DER by adding "Survey" to the DQO to differentiate them from the Phase I and Phase II PDI DQOs (Table 1-4). A summary of how these survey DQOs were met is provided in Section 2.5.

Table 1-4
Survey DQOs for the Upper Reach

DQO	DQO Description	Activities Conducted to Address DQO
Survey DQO1[1]	Provide the bathymetric data to generate new sun illumination maps that identify areas with scour from propellers and other vessel interactions with the sediment; this information will be used to potentially modify recovery category area designations.	DQO was met by conducting the 2019 and 2020 bathymetric surveys for the upper reach and generating sun illumination maps (see Section 2.5.1 and Phase II QAPP Addendum).
Survey DQO2[1]	Define the current bathymetry of the LDW upper reach with sufficient confidence (as presented in the accuracy discussion in this section) to inform selection of sampling locations for PDI data collection to support the RD.	DQO was met by conducting the 2019 and 2020 bathymetric surveys within the entire upper reach to inform study design.
Survey DQO3 (revised)[2]	Complete the base map for RD by providing topographic data of sufficient quality and sufficient areal extent to tie into the bathymetric three-dimensional surface created from prior surveys and extend the surface up the bank to support RD in areas where RAL exceedances indicate the need for remedial action on bank areas.	DQO was met by conducting the 2021 topographic survey, extending the coverage of the three-dimensional surface beyond the limits provided by the bathymetric survey (see Section 2.5.2).
Survey DQO4[2]	Define the extent of features (including structures, bank armoring, woody vegetation, utilities, and debris) that may have a bearing on RD and construction of potential remedial actions.	DQO was met during Phase II PDI through identification of critical features at the beginning of the field work for the topographic survey (see Section 2.5.3). Surveyors collected location information to delineate the spatial limits of the features identified by the engineers.

Notes:
1. Survey DQO1 and Survey DQO2 are presented in the Survey QAPP (Anchor QEA and Windward 2021b).
2. Survey DQO3 (revised) and Survey DQO4 are presented in the Survey QAPP Addendum (Anchor QEA and Windward 2021b).
DQO: data quality objective
LDW: Lower Duwamish Waterway
PDI: Pre-Design Investigation
QAPP: Quality Assurance Project Plan
RAL: remedial action level
RD: remedial design

1.3 Report Organization

The remainder of this DER is organized into the following sections:

- Section 2: PDI Summary
- Section 3: Data Evaluations
- Section 4: Phase III Data Gaps
- Section 5: Next Steps
- Section 6: References

The following appendices are attached to this document:

- Appendix A: PDI Dry Weight Concentration Maps, Mudline Elevations, Coordinates, and Data Replacement
- Appendix B: cPAH Data and RAL Exceedance Areas Relative to 2014 ROD RALs
- Appendix C: Relationship Between Surface and Subsurface COC Concentrations
- Appendix D: Geotechnical Testing Results
- Appendix E: Bank Inspection Results
- Appendix F: Structures Inspection Results
- Appendix G: Topographic Survey Data Report and Bank Features
- Appendix H: Sediment Thickness Probing Data
- Appendix I: Vegetation Observations
- Appendix J: Inadvertent Discovery Plan Results
- Appendix K: Interpolation Methods for Delineating Areas with RAL Exceedances
- Appendix L: Updated Remedial Technology Assignment Options for Areas with RAL Exceedances

2 Pre-Design Investigation Summary

This section presents the results from the LDW upper reach (Map 2-1) Phase I and Phase II PDI. In combination with pre-PDI chemistry data, the PDI sediment sampling results presented in this section are evaluated in Section 3 to identify areas with RAL exceedances. In addition, this section presents results from the geotechnical investigation, bank inspection, structures inspection, bathymetry and topography surveys, sediment thickness survey, and discusses other engineering data. These data will support the RD. The implementation of the inadvertent discovery plan is also discussed.

2.1 Sediment Sampling

2.1.1 Field Sampling Overview

The sediment sampling and analysis activities described in this section were performed to address Phase I DQOs 1 through 7 in Table 1-2 and Phase II DQOs 9 through 12 in Table 1-3. During the Phase I sampling in June 2020, sediment samples were collected from 266 locations. Specifically, surface sediment grab samples were collected at 249 locations from June 5 through 30, 2020, and subsurface sediment cores (including shoaling cores) were collected at 247 locations from June 1 through 26, 2020 (Maps 2-2a, 2-2b, and 2-3); surface and subsurface samples were often collected at the same locations.

During the Phase II sampling from late June 2021 through early August 2021, sediment samples were collected from 208 additional locations throughout the upper reach of the LDW. Specifically, surface sediment grab samples were collected from 82 locations from June 28 through July 22, 2021, and subsurface sediment cores (including shoaling cores and deeper vertical extent cores) were collected from 180 locations from June 28 through August 3, 2021 (Maps 2-2a, 2-2b, and 2-3); some surface and subsurface samples were collected at the same locations.

Target and actual sampling coordinates and mudline elevations for the sampling locations (both surface and subsurface) are provided in Appendix A. Maps of the target vs. actual sampling locations are available in the Phase I and Phase II data packages provided to EPA and posted to https://ldwg.org. The data packages also include validated data, field forms and logbooks, chain of custody forms, and photographs and videos.

2.1.1.1 Field Methods

Surface grab samples and subsurface sediment cores were collected and processed following the standard operating procedures described in Appendix F of the QAPP and Appendix J of the Phase II QAPP Addendum (Windward and Anchor QEA 2020; Anchor QEA and Windward 2021a). Generally, sediment samples were collected from the target depths using a pneumatic grab sampler (for surface sediment) or a vibracorer (for subsurface cores and deeper vertical cores). The rotary sonic drill rig was also used to collect deep vertical extent cores at two locations within Slip 6.

Mudline elevations were recorded for all locations. For surface sediment samples, mudline elevations were estimated using the GPS coordinates and bathymetry survey data. For subsurface sediment samples, because of the need to know the mudline elevation for sample processing, mudline elevations were calculated in the field using field-measured tidal stage and water depth information (referred to as the real time kinematic [RTK] tide elevation). For the subsurface sediment sampling locations, a table comparing RTK and bathymetry mudline elevations is presented in Appendix A. A review of this comparison indicates that while the RTK-estimated mudline elevation is more often deeper than the elevation estimated from the bathymetry survey, the RTK elevation is sometimes higher and sometimes lower than the bathymetry elevation. Given that there is uncertainty in both of these measurements, there does not appear to be a systematic error in either method for estimating mudline elevation.

2.1.1.2 Field Deviations

Deviations from the QAPP and Phase II QAPP Addendum involved modifications to sediment core acceptance criteria at some locations. EPA was notified of all modifications when the samples were collected. These field deviations did not affect the data quality. The core acceptance criteria deviations for Phase I were as follows:

- The intertidal core from location 127 was accepted with 52.5% (64.0 cm) recovery after hitting refusal during five attempts. EPA approved retaining and processing the core with the best recovery.
- The subtidal core from location 214 was accepted with 74.1% (101.6 cm) recovery after three attempts. EPA approved retaining and processing the core with the best recovery.
- The subtidal core from location 380 was accepted with 100% (49.5 cm) recovery after hitting refusal at that depth during 12 attempts. The target depth for this location was 60 cm. EPA was consulted and authorized retaining the best core sample while remaining within the targeted Recovery Category 1 boundary.
- Coring was not successful at location 417. The target depth for this location was 45 cm. A reconnaissance of the area during sampling revealed riprap armoring throughout the targeted area. EPA was consulted and authorized manual sample collection (e.g., with a spoon and bowl) to obtain the sample. The sample for this location was collected from the 0–29-cm depth interval.
- Z-layer samples (-17 ft to -18 ft mean lower low water [MLLW]) were not collected at subtidal (shoaling) core locations[3] 148 and 201. The cores were driven to refusal at -17 ft

[3] Sample depths to be collected at shoaling locations were defined in Figure 4-1 in the PDI QAPP (Windward and Anchor QEA 2020).

MLLW during three attempts at location 148 and seven attempts at location 201 and Z-layer samples could not be collected.

The core acceptance criteria deviations for Phase II were as follows:

- The subtidal core from location 550 was accepted with 72.5% (88.4 cm) recovery after eight attempts. EPA was notified of this deviation in the weekly updates.
- In consultation with EPA, the sampling approach for core collection along the eastern shoreline around RM 4.9 was changed to allow the collection of up to three cores at each location (designated as X, Y and Z) due to sampling conditions (i.e., difficulty achieving the desired penetration and recovery).[4]
  - The intertidal core from location 698X was accepted with 74.4% (204.2 cm) recovery.
  - Intertidal cores from archived Tier 2 locations 703X and 703Y were accepted with 65.0% (79.2 cm) and 53.1% (129.5 cm) recoveries.

2.1.1.3 Counts of Samples Collected and Analyzed

The numbers of sampling locations for the Phase I and Phase II PDI sampling efforts are presented in Table 2-1. Sediment was collected from a total of 474 locations during these two sampling efforts (Maps 2-2a and 2-2b). The sediment depth intervals collected at each location were specified in the QAPP and in the Phase II QAPP Addendum, based on the bathymetry of the sample location (intertidal, subtidal, or shoaling area) and the recovery category, consistent with ROD Table 28 (Windward and Anchor QEA 2020; Anchor QEA and Windward 2021a). Targeted depth intervals in the federal navigation channel (FNC) shoaling areas are shown in Figure 2-1; Map 2-3 shows the intervals sampled at each shoaling location during the PDI.

Table 2-1
Summary of Upper Reach Locations Sampled for Chemical Analysis During the Phase I and II PDI

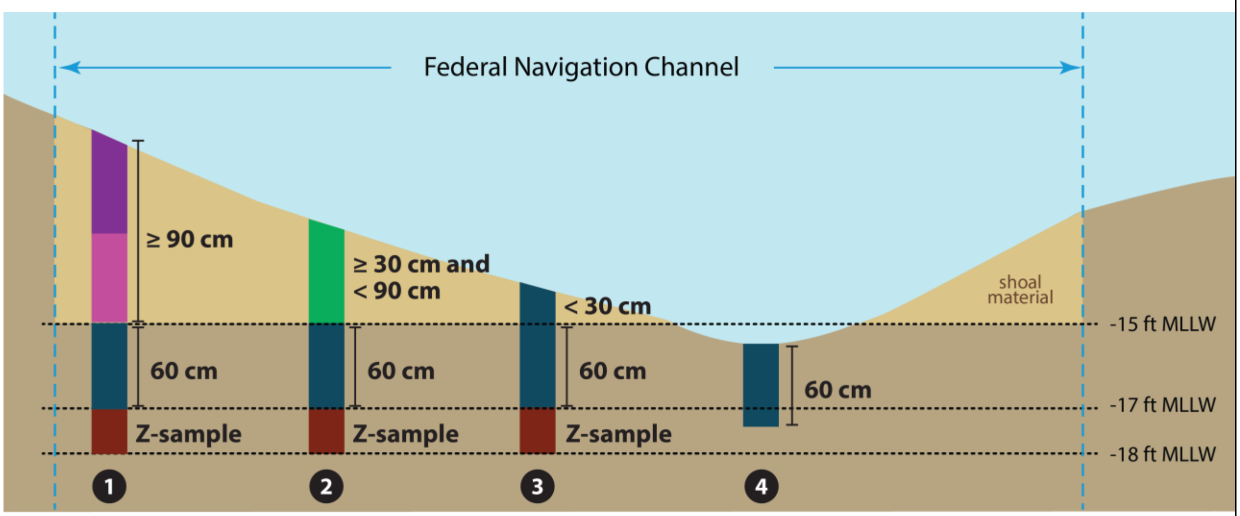
Phase	Total Locations[1]	No. of Surface Sediment Locations (0–10 cm)	No. of Subsurface Sediment Locations		No. of Shoal Core Locations	Vertical Extent Core Locations
			Intertidal (0–45 cm)	Subtidal[2] (0–60 cm)		
Phase I (Summer 2020)	266	249	120	88[3]	39[3]	0
Phase II[4] (Summer 2021)	208	82	87	83[5]	10[5]	86
Total	**474**	**331**	**207**	**171**	**49**	**86**

Notes:

[4] A total of 11 cores were collected at the 5 vertical extent sampling locations in the area near RM 4.9 (2 cores at location 698, 3 cores at location 699, 1 core at location 701, 2 cores at location 702, and 3 cores at location 703).

1. The total locations count is lower than the sum of the counts by location type because many locations have results for multiple intervals.
2. The number of 0–60-cm locations does not include shoal core locations.
3. No shoaling material was present at one Phase I location (217) proposed for the collection of shoaling intervals. Instead, this location is counted as a 0–60-cm subtidal subsurface location (i.e., rather than a shoaling location, as proposed in the QAPP).
4. Phase II counts do not include the nine Phase I archive locations included as Tier 1 or Tier 2 samples in Phase II; these locations are included in the Phase I counts.
5. No shoaling material was present at two Phase II locations (548 and 549) proposed for the collection of shoaling intervals. Instead, these locations are counted as 0–60-cm subtidal subsurface locations (i.e., rather than a shoaling location, as proposed in the QAPP Addendum) (Anchor QEA and Windward 2021a).
QAPP: Quality Assurance Project Plan
PDI: Pre-Design Investigation

Figure 2-1
Federal Navigation Channel Design Sampling



1. When thickness of shoal material is greater than or equal to 90 cm, then the core will be taken to -18 ft MLLW and three samples will be collected. Two samples will represent the shoal material and will be archived (Tier 2) and one sample will represent material between -15 ft and -17 ft MLLW and will be analyzed (Tier 1). A 1 ft Z-sample (-17 ft to -18 ft MLLW) will be collected and archived. A 0-10 cm sample will also be collected (not shown).

2. When thickness of shoal material is greater than or equal to 30 cm and less than 90 cm, then the core will be taken to -18 ft MLLW and two samples will be collected. One sample will represent the shoal material and will be Tier 2 and the other sample will represent material between -15 ft and -17 ft MLLW and will be Tier 1. A 1 ft Z-sample (-17 ft to -18 ft MLLW) will be collected and archived. A 0-10 cm sample will also be collected (not shown).

3. When thickness of shoal material is less than 30 cm, then the core will be taken to -18 ft MLLW and one sample will represent both the shoal material and the material between -15 ft and -17 ft MLLW. A 1 ft Z-sample (-17 ft to -18 ft MLLW) will be collected and archived. A 0-10 cm sample will also be collected (not shown).

4. In the portions of the FNC that are not shoaled (deeper than -15 ft MLLW) a 0-60 cm sample will be collected. A 0-10 cm sample will also be collected (not shown).

Note: The shoal thickness will be measured in the field based on field bathymetry at each location. The shoal thickness values provided here are approximate.

The numbers of samples collected and analyzed for Phases I and II are presented in Table 2-2. Field duplicates are not included in the sample counts. For many locations, multiple samples were collected, and thus the location counts and sample counts do not match. For example, in Phase I, in the intertidal areas, a surface sediment (0–10-cm) sample and/or a subsurface intertidal sediment (0–

45-cm) sample were collected at each location, and in the subtidal areas, a surface sediment (0–10-cm) sample and/or a subsurface sediment (0–60-cm) sample was collected at each location. In the shoaling areas within the FNC, cores were collected to characterize the shoal material above the authorized navigation depth at -15 ft MLLW in this reach of the LDW, as well as the 60-cm interval below the authorized depth (the allowable overdredge interval between -15 and -17 ft MLLW) and Z-samples below the overdredge interval (Map 2-3). In addition, vertical extent cores (which included the appropriate subsurface RAL interval) were collected in Phase II where vertical delineation information was needed.

Table 2-2
Summary of Upper Reach Samples Collected and Analyzed for at Least One Analyte During the Phase I and II PDI

Phase	Category	No. of Samples[1]				
		RAL Interval Samples				Samples Below RAL Interval (Z-Layer and Vertical Extent)
		Surface Sediment (0–10 cm)	Subsurface Sediment		Shoal Intervals[3]	
			Intertidal (0–45 cm)	Subtidal (0–60 cm)[2]		
Phase I	Total collected	249	120	88	78	38
	Total analyzed (Phase I)	178[4]	92	71[4]	52	0
	Total analyzed (Phase II)[5]	3	2	1	8	21
	Total archived	68	26	16	18	17
Phase II[6, 7]	Total collected	82	87[9]	83	23	589
	Total analyzed	77[8]	52[9]	62	18	303
	Total archived	5	35	21	5	286
PDI Dataset Total	Total collected	331	207	171	101	627
	Total analyzed	258	146	134	78	324
	Total archived	73	61	37	23	303

Notes:
1. Sample counts include all samples submitted for analysis through January 24, 2022. Field duplicates are not included in sample counts.
2. The number of 0–60-cm samples does not include shoal core samples.
3. Sample depths and number of samples collected per location for subsurface samples in shoaling areas varied depending on the depth of the shoal at each location (see QAPP Figure 4-1) (Windward and Anchor QEA 2020). Shoal interval samples counted herein include shoaled material (i.e., sediment above -15 ft MLLW) and sediment from the -15 to -17-ft interval. Details for each shoaling location are presented on Map 2-3.
4. At one Phase I location, samples (SS164 and SC164) were analyzed only for TOC to supplement PCB data collected by another party. These samples are not included in the counts presented here.
5. Counts in this row enumerate Phase I samples that were analyzed as part of Phase II.
6. The Phase II counts do not include seven surface (0–10 cm), three intertidal subsurface (0–45 cm), and four subtidal subsurface (0–60 cm) field duplicates that were analyzed as part of Phase I.
7. Counts in these rows only include samples collected during Phase II.
8. At one Phase II location, the surface sediment sample (SS682) was analyzed only for TOC/total solids and toxicity conventionals (i.e., ammonia, sulfides, and grain size). This sample is not included in the counts presented here.
9. At five locations in the ENR/AC Pilot Study intertidal plot (locations 615, 617, 618, 624, 626), samples were either collected or available to characterize the 0–45-cm interval from the mudline as well as the 0–45 cm interval below the ENR layer (see Figure 4-1 in the Phase II QAPP Addendum) (Anchor QEA and Windward 2021a). These locations are counted as one sample in this table.

AC: activated carbon
ENR: enhanced natural recovery
MLLW: mean lower low water
PCB: polychlorinated biphenyl
PDI: Pre-Design Investigation
QAPP: Quality Assurance Project Plan
RAL: remedial action level
TOC: total organic carbon

In addition to chemical analysis, samples from two locations were sampled in Phase II for toxicity testing per the Phase II QAPP Addendum (Anchor QEA and Windward 2021a). At location 682, 0–10-cm and 0–45-cm samples were collected, and at location 688, a 0–10-cm sample was collected for toxicity testing. Both of the location 682 samples were tested for toxicity. The sample from location 688 was not tested for toxicity because it was inadvertently analyzed for chemistry and did not have any exceedances of Washington State Sediment Management Standards (SMS) criteria. The samples from 682 were not analyzed for chemistry, per the Phase II QAPP Addendum (Anchor QEA and Windward 2021a).

In addition to the above analyses conducted per the QAPP and Phase II QAPP Addendum, cPAHs were analyzed in samples from six locations (677, 678, 681, 683, 684, and 703X). These analyses were conducted because cPAH toxic equivalents (TEQs) at or near these locations in pre-PDI or PDI samples were less than RALs in the cPAH ESD but greater than the RALs in the 2014 ROD. These data are presented in Appendix B and are included in the sample counts in the DER tables in this section.

2.1.2 Laboratory Testing Overview

2.1.2.1 Chemical Analysis Methods

The methods and procedures used to chemically analyze the sediment samples are described briefly in this section and in detail in the QAPP (Windward and Anchor QEA 2020). This section also discusses laboratory deviations from the QAPP. Laboratory and validation reports and the full chemistry results for Phase I and Phase II are provided in the data packages provided to EPA and posted on https://ldwg.org.

Analytical Resources, Inc. (ARI) performed polychlorinated biphenyl (PCB) Aroclor, cPAH, semivolatile organic compound (SVOC), dioxin/furan, arsenic and other metals including mercury, total organic carbon (TOC), and total solids analyses. Sediment samples were analyzed according to the methods presented in Table 2-3.

Table 2-3
Analytical Methods for Sediment Analyses

Analyte	Method	Reference	Extraction Solvent	Laboratory
PCB Aroclors	Gas chromatography/ electron capture detector	EPA 3546/EPA 8082A	Hexane/acetone	ARI

Analyte	Method	Reference	Extraction Solvent	Laboratory
PAHs/SVOCs[1]	Gas chromatography/mass spectrometry	EPA 3546/EPA 8270E	Dichloromethane/ acetone	ARI
cPAHs/SVOCs	Gas chromatography/mass spectrometry	EPA 3546/EPA 8270E-select ion monitoring	Dichloromethane/ acetone	ARI
Hexachlorobenzene	Gas chromatography/ electron capture detector	EPA 3546/EPA 8081B	Hexane/acetone	ARI
Dioxins/furans	High-resolution gas chromatography/high-resolution mass spectrometry	EPA 1613B	80:20 toluene: acetone extraction	ARI
Metals	Inductively coupled plasma-mass spectrometry	EPA 3050B EPA 6020A universal cell technology-kinetic energy discrimination	Not applicable	ARI
Mercury	Cold vapor-atomic fluorescence spectrometry	EPA 7471B	Not applicable	ARI
TOC	High-temperature combustion	EPA 9060A	Not applicable	ARI
Total solids	Drying oven	Standard Method 2540G	Not applicable	ARI
Ammonia[2]	Flow injection	SM 4500-NH3 H-97	Not applicable	ARI
Total sulfides[2]	Colorimetric	SM 4500-S2 D-0 PSEP prep	Not applicable	ARI

Notes:

1. The SVOC analysis of a subset of PDI sediment samples included the analysis of benzyl alcohol, which is an aromatic organic alcohol found in a wide variety of plants and other materials, as discussed in Appendix A to the PDI work plan (Windward and Anchor QEA 2019), The benzyl alcohol data obtained through routine SVOC analysis of PDI samples were provided to EPA per its request. These data are not part of the DER because benzyl alcohol is not a CERCLA hazardous substance, and thus benzyl alcohol was not included in defining the remedial design footprint (Windward and Anchor QEA 2020).
2. Ammonia and total sulfide analyses conducted only on the sediment locations targeted for possible toxicity testing.

ARI: Analytical Resources, Inc.
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
cPAH: carcinogenic polycyclic aromatic hydrocarbon
DER: data evaluation report
EPA: US Environmental Protection Agency
PAH: polycyclic aromatic hydrocarbon
PDI: Pre-Design Investigation
PCB: polychlorinated biphenyl
SVOC: semivolatile organic compound
TOC: total organic carbon

For both Phase I and Phase II, samples were chemically analyzed in tiers. In Phase I, samples were analyzed in three tiers (Tiers 1, 2, and 3). Tier 1 samples (263 samples) were analyzed for all applicable analytes, with a subset of samples analyzed for dioxins/furans (62 samples). Following a review of the unvalidated Tier 1 data and in consultation with EPA, Tier 2 analyses were conducted for 141 samples, 22 of which were analyzed in Tier 1 for at least one other analyte. The Tier 2 analyses included selected analytes that exceeded the RALs in nearby Tier 1 samples or were analyzed for additional spatial coverage. The unvalidated Tier 2 data were then reviewed in consultation with EPA to determine the Tier 3 samples to be analyzed. Using the same rationale for Tier 2 sample analysis selection, 13 samples were selected and analyzed for PCBs in Tier 3.

In Phase II, samples were analyzed in two tiers (Tier 1 and 2). Tier 1 samples (418 samples) were analyzed for selected analytes, as described in the Phase II QAPP Addendum (Anchor QEA and Windward 2021a). As in Phase I, following a review of the unvalidated Tier 1 data and in consultation with EPA, Tier 2 analyses were conducted for 135 samples (1 of which was analyzed in Tier 1 for at least one other analyte). The Tier 2 analyses included selected analytes that exceeded the RALs, had exceedance factors (EFs) of > 0.9 in adjacent samples, or were analyzed in response to other PDI questions, as described in Section 4.1.4 of the Phase II QAPP Addendum (Anchor QEA and Windward 2021a).

A summary of the total number of samples analyzed for each contaminant of concern (COC) in Phase I and II is presented in Table 2-4. Field duplicate samples are not included in the sample counts. Key takeaways from this table include the following:

- For Phase I Tier 1, samples were analyzed for all COCs (with the exception of dioxins/furans) for which there was an applicable RAL. Samples analyzed as part of Phase I Tiers 2 and 3 and as part of Phase II (all tiers) were analyzed for a subset of chemicals that exceeded the RALs in nearby samples or as requested to address other PDI questions.
- Over 95% of the Phase I and II PDI samples were analyzed for PCBs.
- For the other human health risk drivers, arsenic was analyzed in 50% of PDI samples, cPAHs were analyzed in 44% of PDI samples, and dioxins/furans were analyzed in 20% of PDI samples.
- About a third of the Phase I and II PDI samples were analyzed for one or more of the other benthic risk drivers.
- All samples analyzed in any tier (with the exception of a few Phase II Tier 2 samples analyzed for cPAHs) were also analyzed for TOC and total solids.

Table 2-4
Total Number of Chemical Analyses by RAL Interval in Phases I and II

Sediment Type	Depth Interval	Total Samples Analyzed	No. of RAL Interval Samples Analyzed[1]									
			Human Health Risk Drivers				Other Benthic Risk Drivers[2,3]					
			PCB Aroclors	Dioxins/ Furans	Arsenic	cPAHs	Other Metals	PAHs	Phthalates	Other SVOCs	TOC/ Total Solids	Grain Size
Phase I PDI												
Surface	0–10 cm	178	175	43	133	135	138	135	134	135	178	129
Subsurface	Intertidal (0–45 cm)	92	92	38	76	54	9	9	9	9	92	66
	Subtidal (0–60 cm)	71	70	7	25	27	27	27	25	25	71	47
Shoal intervals (depth varies)[4]		52	52	4	22	21	23	21	20	20	52	20
Phase II PDI[5]												
Surface	0–10 cm	77	71	12	19	18	19	18	22	9	77	7
Subsurface	Intertidal (0–45 cm)	52[6]	48[6]	12	18[6]	7	0	1	0	1	52	0
	Subtidal (0–60 cm)	63	61	1	8	5	8	5	11	1	62	0
Shoal intervals (depth varies)[4]		26	26	3	2	0	2	0	0	0	26	0
Total PDI Samples[7]												
Surface	0–10 cm	255	246	55	152	153	157	153	156	144	257	136
Subsurface	Intertidal (0–45 cm)	144	140	50	94	61	9	10	9	10	144	66
	Subtidal (0–60 cm)	134	131	8	33	32	35	32	36	26	133	47
Shoal intervals (depth varies)[4]		78	78	7	24	21	25	21	20	20	78	20

Notes:
1. Field duplicates are not included in the counts presented in this table.
2. Other benthic risk drivers include RAO 3 COCs; PCBs and arsenic are counted separately. Other metals (cadmium, chromium, copper, lead, mercury, silver, and zinc), phthalates (bis[2-ethylhexyl]phthalate, BBP, and dimethyl phthalate), PAHs (2-methylnaphthalene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene, total benzofluoranthenes, total HPAHs, total LPAHs), and SVOCs (1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2,4-dimethylphenol, 4-methylphenol, benzoic acid, hexachlorobenzene, n-nitrosodiphenylamine, pentachlorophenol, and phenol) are counted if at least one of the analytes in this group was analyzed.
3. Most Phase I Tier 2 and Phase II samples were analyzed for a specific subset of benthic risk drivers, as determined by Tier 1 RAL exceedances or to address spatial coverage.
4. Shoal interval samples consisted of shoaled material in the FNC (i.e., sediment above -15 ft MLLW in this reach of the LDW) and sediment from the -15 to -17-ft interval (see Map 2-3).
5. Counts for Phase II include Phase I samples analyzed as part of Phase II. Sample counts include all samples submitted for analysis through January 24, 2022.

6. At five locations in the ENR/AC Pilot Study intertidal plot (locations 615, 617, 618, 624, 626), two samples at each location were compared with the 0-45 cm RAL for PCBs and arsenic. These included the 0–45-cm interval from the mudline and that interval below the ENR or ENR/AC layer. These locations are each counted as one sample in this table.
7. This table presents only the PDI dataset; the full design dataset is summarized in Section 3.

AC: activated carbon
BBP: butyl benzyl phthalate
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
ENR: enhanced natural recovery
FNC: Federal Navigation Channel
HPAH: high-molecular-weight polycyclic aromatic hydrocarbons
LDW: Lower Duwamish Waterway
LPAH: low-molecular-weight polycyclic aromatic hydrocarbons
MLLW: mean lower low water
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
PDI: Pre-Design Investigation
RAL: remedial action level
RAO: remedial action objective
SVOC: semivolatile organic compound
TOC: total organic carbon

2.1.2.2 Analytical Laboratory Deviations from the QAPP

Deviations from the methods and procedures described in the QAPP (Windward and Anchor QEA 2020) that occurred in the analytical laboratory are described below. Data were determined to be acceptable for use as qualified.

Phase I deviations included the following:

- A different PCB standard reference material (CRM911-50g) than the standard reference material listed in the QAPP (Puget Sound reference material) was analyzed for sample delivery group (SDG) 20F0288. The recovery was within quality control (QC) limits.
- Hexachlorobenzene was missing from the EPA 8081 initial calibration verification standard in SDG 20F0109. The continuing calibration recoveries were within QC limits.
- The grain size sample jar for location LDW20-SS113 was inadvertently disposed of by the laboratory. There is no grain size result for this location.

Phase II deviations included the following:

- Phase I samples analyzed during Phase II were analyzed outside of hold time for SDGs 21G0430 and 21H0263. Sample results were qualified as estimated for metals, SVOCs, TOC, and total solids. PCB results were not qualified by the validator based on professional judgment.
- Phase II samples for ammonia and sulfide were analyzed outside of hold time, with the exception of ammonia in SDG 21G0269. Sample results were qualified as estimated.
- PCB samples for SDG 21G0321 were extracted outside of hold time. The results were not qualified by the validator based on professional judgment.

2.1.2.3 Data Validation Results

Independent data validation was performed on all analytical chemistry results by Laboratory Data Consultants. Stage 4 validation was performed on a minimum of 10% of the data or a single SDG, as specified in the QAPP (Windward and Anchor QEA 2020). Stage 2B validation review was conducted on the remaining datasets.

The data validation reports, which are included in the data packages provided to EPA and posted to https://ldwg.org/https://ldwg.org, include detailed information regarding all data qualifiers. No data were rejected. The issues that resulted in the greatest number of J-qualified (estimated concentration) results are summarized as follows for Phase I and Phase II.

- Phase I data validation:
  - Calibration verification percent differences >20% for individual EPA 8082A PCB Aroclors (37 of 39 SDGs) and EPA 8270E SIM SVOC compounds (32 of 34 SDGs).

  - Laboratory control sample (or certified reference material) percent recoveries outside of QC limits for EPA 8270 SVOC compounds (20 of 32 SDGs) and EPA 8270E SIM SVOC compounds (15 of 34 SDGs).
- Phase II data validation:
  - Calibration verification percent differences > 20% for individual EPA 8082A PCB Aroclors (10 of 46 SDGs) and EPA 8270E SIM SVOC compounds (10 of 12 SDGs).
  - Matrix spike percent recoveries outside of QC limits for individual EPA 6020 metals (6 of 23 SDGs), EPA 8270E SVOC compounds (5 of 22 SDGs), and EPA 8270E SIM SVOC compounds (5 of 12 SDGs).

All data presented in this report were determined to be acceptable for use as qualified.

2.1.2.4 Sediment Chemistry Results

Sediment data in the PDI dataset were compared with RALs presented in ROD Table 28 (EPA 2014), and cPAH results were compared with RALs presented in the cPAH ESD (EPA 2021), in order to delineate RAL exceedance areas. A summary of RAL exceedances in the PDI dataset is presented in Table 2-5, and these exceedances are shown by location on Maps 2-4a through 2-4j. A discussion of the full design dataset is presented in Section 3.2. Concentrations of the human health COCs in co-located surface and subsurface samples are compared in Appendix C.

Table 2-5
Summary of RAL Exceedances in the PDI Dataset

COC	Counts by Interval in the PDI Dataset[1]							
	Surface (0–10 cm)		Subsurface (0–45 cm)		Subsurface (0–60 cm)		Shoal intervals (depth varies)[2]	
	No. > RAL/ Total	%	No. > RAL/ Total	%	No. > RAL/ Total	%	No. > RAL/ Total	%
Human Health COCs								
PCBs	27/246	11	19/140	14	36/131	27	0/78	0
Dioxin/furan TEQ	3/55	5	5/50	10	0/8	0	0/7	0
Arsenic	0/152	0	1/94	1	0/33	0	0/24	0
cPAHs[3]	0/153	0	0/61	0	0/32	0	0/21	0
Benthic COCs (with RAL Exceedances)[4]								
Mercury	1/155	0.6	0/9	0	0/32	0	1/25	4
PAHs	2/153	1	1/10	10	0/32	0	1/21	5
Benzoic acid	1/142	0.7	0/9	0	0/25	0	0/20	0
Phenol	1/140	0.7	0/9	0	0/25	0	0/20	0
BBP	3/154	2	0/9	0	1/36	3	0/20	0

Notes:

1. Counts are up to date as of April 2022 and do not include field duplicates. Sample counts include PDI samples submitted for analysis through January 24, 2022.
2. Shoal interval samples consisted of shoaled material from the FNC (i.e., sediment above -15 ft MLLW in this reach of the LDW) and sediment from the -15 to -17-ft interval (see Map 2-3).
3. cPAH results are compared with the RALs presented in the cPAH ESD (EPA 2021).
4. PCBs and arsenic are also benthic COCs but are counted separately under human health COCs. Benthic COCs shown here are those with RAL exceedances in the design dataset.
BBP: butyl benzyl phthalate
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
EPA: US Environmental Protection Agency
ESD: explanation of significant differences
FNC: Federal Navigation Channel
LDW: Lower Duwamish Waterway
MLLW: mean lower low water
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
PDI: Pre-Design Investigation
RAL: remedial action level
TEQ: toxic equivalent

2.1.2.5 Toxicity Testing Methods and Deviations

The methods to toxicity test sediment samples were outlined in the QAPP (Windward and Anchor QEA 2020). The following three standard Puget Sound Estuary Program (PSEP) sediment toxicity tests were conducted by EcoAnalysts, Inc., on the 0–10-cm and 0–45-cm samples from location 682:

- Acute 10-day amphipod mortality test (*Eohaustorius estuarius*)
- Acute 48-hour bivalve larvae combined mortality and abnormality test (*Mytilus galloprovincialis*)
- Chronic 20-day juvenile polychaete survival and growth test (*Neanthes arenaceodentata*)

Toxicity testing was conducted according to *Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments* (PSEP 1995), consistent with the updated protocols in (Ecology 2017). The laboratory standard operating procedures for the sediment toxicity tests were provided in Appendix F of the QAPP.

No deviations were reported for the toxicity testing. The toxicity testing laboratory report is included in the Phase II data package at http://ldwg.org.

The results of the toxicity testing at location 682 are presented in Table 2-6. In summary, the 0–10-cm interval failed the acute 48-hour bivalve larvae test based on the SCO biological criteria, and the 0–45-cm interval passed all biological criteria for toxicity tests. This location will be included in a RAL exceedance area based on the toxicity test failure in the surface sediment.

Table 2-6
Toxicity Test Results Compared with Marine Biological Criteria of Sediment Management Standards

Sample	COC	10-day Amphipod Mortality Test			Chronic 20-day Juvenile Polychaete Survival and Growth Test			Acute 48-hour Bivalve Larvae Combined Mortality and Abnormality Test		
		M_T-M_R [1] (%)	SCO (>25%)	CSL (>30%)	MIG_T/ MIG_R [2]	SCO (<0.70)	CSL (<0.50)	N_T/N_R [3]	SCO (<0.85)	CSL (<0.70)
SS682	PAHs[4]	3	Pass	Pass	0.81	Pass	Pass	0.78	Fail[5]	Pass
IT682	PAHs[4]	4	Pass	Pass	0.77	Pass	Pass	1.00	Pass	Pass

Notes:

1. Test mean mortality (M_T) comparison to reference mean mortality (M_R).
2. Test mean individual growth (MIG_T) relative to reference individual growth (MIG_R).
3. Test normal survival (N_T) relative to reference normal survival (N_R).
4. Concentrations of acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, total LPAHs, and total HPAHs exceeded the RALs.
5. Ammonia and sulfide levels were below trigger values throughout the test and would not be expected to have contributed to the adverse biological effects.

COC: chemical of concern
CSL: cleanup screening level
HPAH: high-molecular-weight polycyclic aromatic hydrocarbons
LPAH: low-molecular-weight polycyclic aromatic hydrocarbons
PAH: polycyclic aromatic hydrocarbon
RAL: remedial action level
SCO: sediment cleanup objective

2.2 Geotechnical Investigations

This section provides an overview of the geotechnical investigations, including grain size determinations, conducted during Phase I and Phase II of the PDI. Phase I was completed in June 2020, and Phase II was completed in July and August 2021. The sampling activities described in this section were performed to address DQO 13 (Table 1-3). The Phase I geotechnical investigation was completed in accordance with the QAPP, and the Phase II geotechnical investigation was completed in accordance with the Phase II QAPP Addendum (Anchor QEA and Windward 2021a). Deviations and adjustments are described in Section 2.2.2.1.

2.2.1 Phase I Field Sampling Overview and Geotechnical Data Results

This section provides a summary of the findings associated with grain size testing results from Phase I PDI sediment samples throughout the upper reach. Phase I geotechnical investigations included grain size determinations only; no other geotechnical investigations or geotechnical laboratory analyses were performed as part of the Phase I investigation program. Grain size data and observations inform basic geotechnical characteristics of the materials tested, such as overall soil classification as described in American Society for Testing and Materials (ASTM) D2487 *Standard*

Practice for Classification of Soils for Engineering Purposes (Unified Classification System) (ASTM 2018). Phase I geotechnical grain size sample locations are shown on Maps 2-2a and 2-2b.

Field observations of the surface samples and subsurface sediment cores collected during Phase I are provided in the Phase I data package available on http://ldwg.org. Visually distinct layers of silt and sand were observed in 27 of 120 (23%) intertidal subsurface samples (0–45 cm) and in 15 of 87 (17%) subtidal subsurface samples (0–60 cm). In general, the cores were homogenous. In the FNC, deeper cores with more sample intervals were collected to characterize the shoaled material above the authorized FNC depth of -15 ft MLLW (in this reach of the LDW), as well as the 2-ft interval below this depth. The depositional material in the shoal cores was also generally homogeneous; visually distinct layers of silt and sand were observed in 7 of the 40 (18%) shoal cores.

Grain size testing was completed by Harold L. Benny & Associates on 262 Phase I surface and subsurface sediment samples, as well as on 14 field duplicates using the 1986 grain size method from the Puget Sound Estuary Program (PSEP).

In general, grain size data indicated that surface (0–10-cm) and subsurface (0–45-cm and 0–60-cm) samples are predominantly sand and silt, with varying gravel and clay compositions. Specific percentage ranges of gravel, sand, silt, and clay detected in Phase I samples analyzed for grain size were as follows:

- Gravel: 0–38%
- Sand: 4–99%
- Silt: 4–80%
- Clay: 1–26%

Appendix D presents the Phase I grain size results.

2.2.2 Phase II Field Sampling Overview

This section provides a summary of the findings associated with geotechnical sampling and testing results from the Phase II PDI geotechnical investigation locations throughout the upper reach. Phase II geotechnical investigation locations are shown on Maps 2-5c and 2-5d. Per the Phase II QAPP Addendum, surface and subsurface geotechnical sampling and data collection were conducted using several methods (Anchor QEA and Windward 2021a). Geotechnical samples were collected with split spoon samplers and thin-walled samplers (Shelby tubes). *In situ* geotechnical testing was performed using standard penetration testing (SPT), cone penetrometer testing (CPT), full flow penetrometer (FFP) testing, and downhole vane shear testing (VST). Geotechnical borings were advanced using rotary sonic drilling methods from a barge-mounted drill rig and upland truck-mounted drill rig.

Land-based, hand-operated investigations were also conducted to collect geotechnical data, including dynamic cone penetrometer (DCP) testing and hand auger sampling. Two small hand-operated devices were used during core processing: a torvane and a pocket penetrometer to further classify soil strength parameters. Torvane and pocket penetrometer testing was completed on subsamples from each geotechnical boring.

Table 2-7 displays the number of locations investigated using each method. Actual sampling coordinates and mudline elevations for the locations are provided in Appendix D-1 summary tables.

Table 2-7
Geotechnical Sampling Program Summary

Investigation Method	Total Locations	Count of Locations by Area Type[1]			
		FNC	Between FNC and Toe of Bank	Within Bank	Upland
Rotosonic Borings	29	9	18	-	2
CPTs	20	-	20	-	-
VSTs	5	-	5	-	-
FFPs	7	4	3	-	-
Hand augers	2	-	-	2	-
DCPs	2	-	2	-	-

Notes:
1. Banks are defined as the transition area from the LDW subtidal or intertidal bed to the upland areas above MHHW. Upland is defined as landward of MHHW.
CPT: cone penetrometer testing
DCP: dynamic cone penetrometer
FFP: full flow penetrometer
FNC: federal navigation channel
MHHW: mean higher high water
VST: vane shear testing

The primary goal of the geotechnical boring and hand auger program was to identify subsurface lithology and collect samples for laboratory testing including index parameters, consolidation, and strength properties. The geotechnical drilling subcontractor (Holocene Drilling) used a rotary sonic drill rig to complete the geotechnical borings. SPTs were performed at 5-ft depth intervals to assess material density until the boring termination elevation was achieved, and material samples were collected for laboratory testing using a split spoon sampler. Shelby tube (undisturbed) samples were also collected at the discretion of the Anchor QEA field engineer for laboratory testing. Collection methods and boring logs from the geotechnical boring program are provided in Appendix D, with a summary of data collection information provided in Table D-1.

In situ penetration testing (CPTs and FFPs) was conducted to measure penetration resistance, sleeve friction, and pore pressure in order to collect subsurface data that will be used in development of geotechnical design parameters (e.g., sediment strength, permeability, and consolidation properties). Results of *in-situ* penetration testing are provided in Appendix D.

DCP tests were conducted at two locations within the intertidal portion of the upper reach to provide subsurface density information for development of geotechnical engineering design parameters. Logs for DCP tests are presented in Appendix D.

2.2.2.1 Field Deviations and Adjustments

Two deviations from the approved QAPP and Phase II QAPP Addendum occurred during implementation of the Phase II geotechnical investigation, as follows:

- Sample location coordinates were not successfully transferred from the global positioning system (GPS) device to the export log at the following four locations: LDW21-GT3-GB, LDW21-GT20-GC, LDW21-GT26-FFP/-GV, and LDW21-GT32/34-FFP. Field notes indicate that these locations were collected using the GPS system at the target location per the standard operating procedure; however, an unknown data transfer error occurred, resulting in the loss of these coordinates at the time of download. The approximate locations were developed using field notes and are shown on Maps 2-5c and 2-5d. The accuracy of these locations is considered acceptable because geotechnical data are intended to be extrapolated over distance from a location to represent surface and subsurface geotechnical conditions.
- CPT investigations at the following three locations were terminated prior to reaching the target elevation of -20 ft MLLW: LDW21-GT46-GC, LDW21-GT50-GC, and LDW21-GT51-GC. Practical refusal of the testing equipment was realized at each of these locations when the probe no longer penetrated the subsurface and observations of the barge lifting were noted in the field logs. Equipment refusal is considered an acceptable reason to discontinue advancement of a geotechnical investigation and can be attributed to presence of debris or dense subsurface conditions.

In addition to the two deviations listed above, three field adjustments from the approved QAPP and Phase II QAPP Addendum occurred during implementation of the Phase II geotechnical investigation, as follows:

- FFP testing was implemented at seven locations to characterize strength properties of low-strength near-surface silt material because the SPT approach was not able to measure sediment strength. These additional tests were completed to improve data resolution and to generate strength data for the low-strength surface silt material.
- CPTs were implemented at locations LDW21-GT20 and LDW21-GT27 to determine if near-surface sediments were cohesive (i.e., fine-grained silt or clay) or non-cohesive (i.e., sand or gravel) prior to conducting VST, which is only applicable for testing within cohesive materials. Non-cohesive sediment was encountered at location LDW21-GT27; therefore, the planned VST at this location was not conducted. Cohesive sediment was encountered at location LDW21-GT20 and a VST was completed at multiple depth intervals at that location.

- Geotechnical investigation approaches were adjusted at the following locations: LDW21-GT8 and LDW21-GT40. LDW21-GT8 was completed using a DCP instead of a CPT due to equipment access limitations within the South Park Marina. LDW21-GT40 was completed using a CPT due to shallow water conditions that prevented sonic drill rig and barge access.

The field deviations and adjustments described above did not result in adverse effect to data quality or generate additional geotechnical data gaps. The geotechnical data collected as part of the Phase II investigation effort is suitable for fulfilling DQO 13.

2.2.3 Phase II Geotechnical Laboratory Testing Overview

Geotechnical laboratory testing was completed on 222 field-collected samples from 29 locations to measure sediment and upland soil index parameters, strength, and consolidation properties. Testing was conducted by Materials Testing and Consulting, Inc. (MTC) on select samples to generate a sufficient dataset that would capture the range of subsurface geotechnical conditions observed and support development geotechnical engineering design recommendations.

Specific geotechnical laboratory testing included the following:

- Moisture content (ASTM D2216): 222 tests
- Specific gravity of soils (ASTM D854): 48 tests
- Atterberg limits (ASTM D4318): 47 tests
- Grain size analysis (ASTM D6913): 64 tests
- Grain size and hydrometer analysis (ASTM D6913 and D7928): 29 tests
- One-dimensional consolidation (ASTM D2435): 3 tests
- Consolidated-undrained triaxial shear strength (ASTM D4767): 3 tests
- Direct shear strength (ASTM D3080): 27 tests

Results of the geotechnical laboratory testing are presented in Appendix D including all laboratory data reports. Additionally, per the Phase II QAPP Addendum, geotechnical engineers considered the need for additional grain size testing from composite samples collected from the environmental cores and determined no additional grain size testing was necessary (Anchor QEA and Windward 2021a).

2.2.4 Phase II Geotechnical Data Results

Specific geotechnical engineering data collected during the Phase II investigation program include SPT and DCP blow counts, *in situ* CPT, FFP, and VST data (all collected in the field), and the laboratory testing data summarized previously. Key points about these types of data are as follows:

- The SPT and DCP blow count data are used to measure the relative density of the soil and sediment units in the subsurface. These data are presented on the geotechnical boring logs (Appendix D) and in the subsurface descriptions presented in Section 2.2.5.

- CPT and FFP *in situ* penetration test results are presented as plots of corrected cone tip resistance, sleeve friction, undrained shear strength, and pore pressure versus depth. These plots are included in reports provided by the *in situ* testing contractor (ConeTec) and presented in Appendix D.
- VST data provide a field measurement of the undrained shear strength of the cohesive sediments. Both undisturbed (peak) and remolded (residual) VST readings were collected in the field to evaluate the sediment strength sensitivity (degradation with disturbance). Data are presented in tables included in Appendix D.
- Samples designated for laboratory testing (as summarized in Section 2.2.3) are identified on the geotechnical boring logs. Associated data are presented in the laboratory data reports included in Appendix D.

Geotechnical industry standard relationships have been developed to correlate SPT-, CPT-, FFP-, DCP-collected data and laboratory testing data with geotechnical design parameters such as material type, unit weight, undrained shear strength, and frictional strength. These correlations will be used to evaluate the geotechnical data as part of the engineering design phase of the project, and results of the evaluations will be presented in the Basis of Design Report.

2.2.5 Phase II Subsurface Conditions

This section provides a description of the four major geologic units encountered during the Phase II geotechnical investigation and sampling at locations within the upper reach. The descriptions include initial interpretations and references to geotechnical laboratory testing data to describe each sediment or soil unit. Subsurface conditions encountered during the Phase II geotechnical investigation program are in general agreement with those presented in the RI/FS, consisting of recent sediments overlying alluvium within the waterway. Fill material is also noted to be present, and overlying the alluvium unit, at the upland locations, and based on the history of river realignment, is expected to be present in some bank areas.

Fill: Fill material was encountered at the two upland locations, LDW21-GT24-GB and LDW21-GT36-GB (located on CenterPoint Properties and Boeing 9725 E Marginal Way S [i.e., Slip 6 upland], respectively). Fill material was observed to a depth of 9.5 to 13.6 ft below the ground surface, and is described as consisting of relatively dry, dense to very dense, brown silty sand with varying amounts of gravel, organics, and debris. From laboratory tests, this material generally had moisture contents ranging from 6% to 28%.

Recent Sediments: Recent sediments include very soft silt deposits located within the intertidal and subtidal environments, and soft silt deposits with varying amounts of sand located within the navigation channel. This material is described as non-plastic, wet, dark brown to black silt, with varying amounts of fine-grained sand, clay, shell hash, and organics. Atterberg Limits testing indicates this material is non-plastic with moisture contents ranging from 34% to 97%.

Alluvium Underlying the recent sediments is an alluvial unit which has been historically referred as having an upper and lower layer. For the purposes of this report and analysis to follow, these two units have been combined into one singular reference unit. The Alluvium at the Site consists of primarily sand with varying amounts of silt, as well as silt, clay, and poorly graded sand interbedded lenses and layers throughout. The upper 2 to 17 ft of this unit, where disturbed, contain significant wood and sometimes anthropogenic debris as well as laminations of shell hash. Moisture content ranges from 14% to 78% within this unit.

2.3 Bank Visual Inspection

2.3.1 Methods

The Phase I bank visual inspection was conducted to address DQO 8 (Table 1-2), building upon the existing LDW Waterway User Survey (Integral et al. 2018) by collecting additional detail to support engineering design.

Based on visual observations, banks along the entire upper reach were broadly classified as armored, unarmored, or bulkheaded, consistent with the Waterway User Survey (Integral et al. 2018). Maps 2-6a through 2-6f show updated bank type classifications based on Phase I visual observations. Consistent with Section 2.1.7 of the RDWP (Anchor QEA and Windward 2019), "armored banks" are banks that have engineered surface armoring, while banks that have no armoring, discontinuous armoring, or poorly placed/maintained armoring are considered "unarmored." Vegetated banks are also classified as "unarmored."

Because what constitutes the toe of a bank can be subjective, for this DER, the toe of an armored bank is defined as the start of the armor material; for bulkheads, the toe is defined as the point at which the vertical bulkhead meets the adjacent sediment or soil surface below the bulkhead. The toe of an unarmored bank was previously defined as "where the relatively flat waterway bed (which will vary in elevation) begins to steeply slope to the top of bank." Although the Waterway User Survey also defined "dock faces" as a fourth type of bank (Integral et al. 2018), the dock faces classification is not being carried forward to characterize banks for RD. "Dock faces" herein refer to docks, which are covered in Section 2.4.

In addition to the broad bank type classifications, detailed observations were collected to note the presence of the following features (as applicable[5]), per the QAPP (Windward and Anchor QEA 2020):

- Type of armor material
- Estimated slope/grade
- Presence of sediment accumulated on armored slopes
- Observed bank erosion
- Observed utility crossings
- Observed outfalls/pipes
- Observed discharge flowing from outfalls
- Navigational obstructions
- Access points
- Vegetation

One field deviation from the QAPP (Windward and Anchor QEA 2020) occurred during the bank visual inspection. The method of documenting visual observations (Appendix D-3 of the QAPP) included a shoreline visual inspection form that proved to be too rigid to adequately allow documenting detailed observations of shoreline features, which vary significantly along the upper reach. The alternative method of field data collection included the use of a tablet and ArcGIS Collector, supplemented by field notes handwritten directly on figures to better tie observations to locations. The field data entered into the ArcGIS Collector were continually uploaded to a project database. This field deviation did not affect the data quality and allowed the field team to more accurately and efficiently collect field data.

A shoreline stationing system was developed as a reference for the bank and structures visual inspections to provide reference points for visual observations. The stationing system for the upper reach follows the Waterway User Survey (Integral et al. 2018) shoreline structure boundary, which applies to the entire upper reach. As such, the stationing begins on the LDW eastern bank at RM 0.0 (south of Harbor Island) and follows the top-of-bank line running upstream along the east bank to RM 5.0; it then continues downstream along the western shoreline top-of-bank line back to RM 0.0 (i.e., clockwise; see Maps 2-6a through 2-6f for reference) at 100-ft intervals. The first interval shown on Map 2-6a is location 247.

[5] While the visual bank inspection was conducted at low tide to maximize observations, this timing also limited the ability of the inspection vessel to get close to the shoreline, and some features were difficult to document during Phase I. These features were further investigated in areas with RAL exceedances during Phase II PDI, as presented in Section 2.5.2.

The bank type classifications were not updated during Phase II of the PDI, although bank features within each RAL exceedance area were documented as part of the topographic survey activities, as discussed in Section 2.5.2.

2.3.2 Results

The Phase I bank inspection was conducted primarily by boat around daytime low tides (2 hours before and 2 hours after) on June 11, 16, 18, 23, and 26 and August 4, 2020. At the time of the Phase I PDI, approximately 41% of the upper reach bank areas were observed to be armored, 46% were observed to be unarmored, and 13% were observed to be bulkheaded.

Subsequent to the Phase I bank visual inspection, habitat restoration work was conducted by the Port of Seattle at the Duwamish River People's Park and Shoreline Habitat site (located adjacent to The Boeing Company's South Park property) along the western shoreline from approximately RM 3.68 to RM 3.9, above a toe elevation ranging from +4 to +8 ft MLLW. Other shoreline work has also been completed along the west shoreline between RM 4.8 and 5.0. The Phase I bank classifications in these areas have been removed from the maps, since the Phase I data are no longer representative of current bank conditions. Despite these recent changes (as well as any future changes that may occur), the information collected during the Phase I bank inspection is judged to be useful for RD. As-built drawings and survey data will be obtained for recently constructed areas adjacent to areas requiring remedial action. For example, data from the Duwamish River People's Park and Shoreline Habitat site as-built survey, which is scheduled for completion in June 2022, will be incorporated into 30% RD.

Detailed observations are documented for each discrete shoreline segment in Attachments E-1a and E-1b in Appendix E. Shoreline segments are shown on Maps 2-6a through 2-6f. Photographs and videos from the bank visual inspection are included in the Phase I data package on http://ldwg.org.

2.4 Structures Inspection

2.4.1 Phase I Visual Inspection

The Phase I structures visual inspection was conducted to support DQO 8 (as described in Section 5.2 of the QAPP; (Windward and Anchor QEA 2020)) and to confirm and supplement the identified structures and observations in the existing Waterway User Survey (Integral et al. 2018) along the upper reach. The inspection also provided additional information to support engineering design, including changed conditions that may have occurred between the time when the Waterway User Survey was completed and the field work for the Phase I structures visual inspection occurred.

The inspected structures consisted of overwater structures (wharfs, piers, docks, etc.), in-water structures (piles, pile groups, dolphins, etc.), and shoreline structures and utilities (outfalls, bulkheads, wing walls, etc.).

For the Phase I structures inspection, each unique structure was classified as a Structure, noted on Maps 2-6a through 2-6f and Appendix F as "ST-##" (i.e., shoreline, overwater, and in-water structures) or an Outfall (i.e., shoreline utility). Structures were numbered sequentially clockwise, starting at RM 3.0E, based on the shoreline stationing system described in Section 2.3.1. For uniformity and correlation with previous studies, references to existing nomenclature were used where applicable. On the DER maps, reference to the Waterway User Survey (WUS) (Integral et al. 2018) identification (ID) is shown in addition to the Phase I PDI label. However, several structures identified during the Phase I PDI were not included in the Waterway User Survey and do not have a corresponding WUS ID label. Therefore, the Phase I PDI classification is shown as the primary structure designation on Maps 2-6a through 2-6f.

Outfalls have been substantially documented in previous studies, including the *Lower Duwamish Waterway Outfall Inventory Update: January 2012 – February 2014*[6] (Leidos 2014) and Appendix H of the LDW RI report (Windward 2010), and all outfalls observed during the Phase I PDI have been previously documented. Therefore, the outfall nomenclature from the existing studies has been adopted as the sole designation for outfalls identified during this investigation on Maps 2-6a through 2-6f.

Structural visual inspection was conducted by boat during low tides the morning of June 15, 2020, and the afternoon of July 17, 2020. The inspection was limited to boat-accessible areas. Information collected during the structural visual inspection included the following:

- General observations of structure condition, visible physical damage, and surface deterioration or defects of structure component materials
- Information to supplement existing data in the Waterway User Survey (Integral et al. 2018), including structure identification numbers, physical descriptions of the structures observed, and notations of any discrepancies or changed conditions
- Visual assessments of access or safety concerns that may be important considerations for chemistry or geotechnical sampling in the vicinity of or beneath the structure during Phase II PDI.

Details of the general observations, information to supplement existing data in the Waterway User Survey (Integral et al. 2018), and accessibility/safety concerns are included in Appendix F.[7]

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[6] The Washington State Department of Ecology (Ecology) completed an updated outfall inventory in 2020 (Leidos 2020), the information from which will be incorporated into the Basis of Design Report maps, following agreement with EPA and Ecology that the information in the outfall base layer is up-to-date.

[7]The Phase I PDI visual bank and structures inspections documented observations for outfalls that were visible from the inspection vessel and did not locate every known outfall previously identified in the upper reach. The Phase II PDI inspection was focused on

2.4.2 Phase II Detailed Inspection

The Phase II inspection included a more detailed investigation of the structures and outfalls located in the areas with RAL exceedances, based on Phase I PDI data, and their immediate vicinity. The inspections were conducted during low and high tides the mornings of July 12, July 14, and July 29, 2021, from the boat and/or on the riverbank where it was possible and safe to disembark. Information collected included the following:

- Close observation of condition, visible damage, or defects
- Impact or sounding of relevant concrete/rigid member components to verify soundness and lack of cavity
- Spike/nail penetration of wood, rubber, or soft materials to verify soundness and/or depth of decay or deterioration
- Vertical/horizontal measurement of clearances around the structures for accessibility
- Diameter measurements of outfall, invert elevation (where available), and support condition, including aprons and/or pipe protection

Information from the observations and survey notes supplement the Phase I reports and is included on Maps 2-7a and 2-7b and Appendix F for the structures and outfalls. Some outfalls could not be closely observed or located due to heavy vegetated embankment and unfavorable tide conditions. The contents of the facility condition assessment reports for these outfalls are based on alternative photographs or data collected by the team during Phases I and II. These outfalls include 2076, 2097, BDC-2, and BDC-5.

2.5 Surveying

2.5.1 Phase I Bathymetric Surveying

To complete bathymetric survey coverage of the upper reach, a 2020 bathymetric survey was performed to fill data gaps remaining from the Phase I 2019 bathymetric survey. No bathymetry coverage data gaps remain for the upper reach. The 2019 bathymetric survey results were presented in the QAPP (Windward and Anchor QEA 2020). Northwest Hydro's report for the supplemental 2020 bathymetric survey was provided in Attachment B of the Phase II QAPP Addendum (Anchor QEA and Windward 2021a).

The 2020 bathymetric survey was performed on June 15 and 16, 2020, by Northwest Hydro, which also performed the 2019 bathymetric survey. The equipment and methods used to perform the 2020 survey were the same as those used for the 2019 bathymetric survey, per the approved Survey QAPP

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outfalls near areas with RAL exceedances. Information for outfalls not included in Appendix F is available in the *Lower Duwamish Waterway Outfall Inventory Update: January 2012 – February 2014* (Leidos 2014).

(Anchor and Windward 2019). The precision and accuracy of the two surveys are the same and yielded compatible data. There were no deviations from the Survey QAPP. The key targets and related data for the 2019 and 2020 surveys are summarized in Table 2-8.

Table 2-8
Key Targets and Related Datums for Bathymetric Surveying

Description	Quantity or Datum
Horizontal positioning accuracy	1.6 ft minimum
Horizontal survey accuracy	3 ft at a 95% confidence interval
Horizontal datum	North American Datum of 1983/1991 Washington North Zone
Vertical survey accuracy	+/- 0.5 ft at a 95% confidence interval
Vertical datum	MLLW

Notes:
Source: Table 3 of the Survey QAPP (Anchor and Windward 2019).
MLLW: mean lower low water

An updated three-dimensional bathymetric surface for the upper reach was created by combining the 2019 and 2020 Northwest Hydro bathymetric surveys and part of the January 2020 US Army Corps of Engineers (USACE) FNC survey. USACE conducted maintenance dredging within the FNC from approximately RM 4.05 to RM 4.71 from December 2019 to January 2020. The January 2020 survey results reflect the post-dredge condition within the dredged portion of the FNC. The combined bathymetric survey limits of each of the three surveys are presented in Map 2-8. The results of the 2022 USACE bathymetric survey of the FNC will be included in 30% RD.

The three-dimensional bathymetric surface and elevation contours were presented in the Phase II QAPP Addendum prior to performing the topographic survey as part of the Phase II PDI (Anchor QEA and Windward 2021a). One survey anomaly was noted in the 2020 Northwest Hydro survey at the head of Slip 6, where the surveyor interpreted an underwater log with a root ball to be floating above the sediment bed. The bathymetric survey data from 2019 did not show this underwater feature; therefore, the 2019 survey data were retained in this Slip 6 area instead of being replaced by the 2020 data, as the presence of an underwater tree and root ball is judged to represent a transient condition.

2.5.2 Phase II Topographic Surveying

Topographic surveying was performed to complete data gathering to address Survey DQO 3 (revised) and Survey DQO 4 (Table 1-4) following the methods in Survey QAPP Addendum (Anchor QEA and Windward 2021b). The specific areas where topographic surveying was performed are shown on Map 2-9. The topographic survey began on June 30, 2021, and was completed on August 10, 2021. The equipment and methods used to perform this survey were selected to obtain data with precision and accuracy at least comparable to that of the data from the bathymetric surveys. The key targets and related data for the topographic surveys are summarized in Table 2-9.

Table 2-9
Key Targets and Related Datums for Topographic Surveying

Description	Quantity or Datum
GPS horizontal positioning accuracy	+/- 0.3 ft minimum
Total location horizontal survey accuracy	+/- 0.1 ft minimum
Horizontal datum	North American Datum of 1983/1991 Washington North Zone
GPS vertical survey accuracy	+/- 0.2 ft minimum
Total location vertical survey accuracy	+/- 0.02 ft minimum
Vertical datum	MLLW

Notes:
Source: Table 2 of the Survey QAPP Addendum (Anchor QEA and Windward 2021b).
MLLW: mean lower low water

The report for True North Land Surveying's 2021 topographic survey is provided in Appendix G.

2.5.2.1 Field Deviations and Adjustments

In accordance with the Survey QAPP Addendum, the topographic survey generally extended approximately 50 ft landward of the mean higher high water (MHHW) elevation (Anchor QEA and Windward 2021b). The landward limit of the survey was reduced in two areas (near RM 4.7W and RM 4.9E) to minimize disturbance of restored habitat and due to the presence of a walkway structure that impeded access further upland. One other location where data coverage did not extend to the planned coverage extent included a point near RM 4.1E where the field surveyor was unable to determine their location in dense blackberry bushes. The field deviations and adjustments described above did not result in adverse effect to data quality or generate additional survey data gaps.

2.5.3 Phase II Bank Features Identification

The project engineers performed site visits on June 30 and July 13, 2021, to address Survey DQO 4 by documenting bank features of interest that will be relevant during 30% RD. The engineers spent the first visit working closely with the surveyors to communicate the features that needed to be documented during the surveying activity. The topographic surveyors noted locations and extents of bank features that were encountered during surveying activities. Features documented included horizontal extents of vegetation and armoring, locations of aboveground utilities (e.g., outfalls, storm drains), large surface debris, and structures (e.g., corner points of structures, fence lines, paved surface).

Bank features are presented in Attachment G-2 in Appendix G.

2.6 Sediment Thickness Over Armored Banks

Some areas with RAL exceedances were classified as armored banks during the Phase I PDI. In these areas, as noted in the Phase II QAPP Addendum, confirming the presence of armor, measuring the thickness of sediment over the armor layer, and determining the location of the buried toe of the armored bank are necessary to support RD (Anchor QEA and Windward 2021a). These measurements were part of addressing DQO 14 (Table 1-3). Sediment thickness over armored banks was measured from July 19 through July 23, 2021, in areas with RAL exceedances based on Phase I PDI results. The areas where sediment thickness was measured are referenced per river mile and survey location number in this report.

2.6.1 Methods

In most areas, the toe of bank armoring location was accessible by foot at low tide. The method to collect sediment thickness measurements involved hand probing the sediment in coordination with recording measurements and locations using differential GPS equipment. For this method, a rod marked with measurement ticks was used to determine the thickness of sediment over the armor layer.

In areas where the toe of bank armoring was located below the waterline during low tide, or was not accessible by foot, a sediment jet probe was deployed from a vessel during a moderate or high tide to measure sediment thickness and attempt to locate the toe of bank armoring. The sediment jet probe consisted of a push rod with a pneumatic jet nozzle and a penetrometer depth sensor.

Sediment probing occurred along transects extending perpendicular to the shoreline and spaced between 50 and 100 ft apart. Data were collected approximately every 5 ft along the transect from the top of the armored bank (if accessible) to the toe of the armored bank. Prior to probing at each location along the transect, descriptions were recorded to include the following (as applicable):

- Location identification
- Water depth measurement in feet and time of measurement (if applicable)
- Coordinates of each probe point
- Observed surface substrate type (e.g., rock, sand, silt, shell) and color
- Other observations of note (e.g., description of visible surface debris)

After documenting the surface conditions at the location, probing commenced. The field crew performing probing documented the following:

- Sediment thickness, depth of layers penetrated, refusal depth
- Subsurface debris or obstructions encountered during probing
- Any other relevant observations noted during probing

When obstructions were encountered during probing, the field crew considered surface debris in the surrounding area, the firmness of the obstruction, and the sound produced when the probe made contact with the obstruction. For example, there was a significantly different sound when the probe contacted a piece of wood than when it contacted riprap or armoring. Additionally, a compacted sand or gravel layer made a different sound than a solid object and could typically be penetrated with additional force.

No deviations from the proposed procedures in the Phase II QAPP Addendum (Anchor QEA and Windward 2021a) were required during this portion of the investigation.

2.6.2 Results

Hand probing was completed along transects in nine bank areas in the upper reach based on Phase I RAL exceedance areas, as shown on Map 2-10. Observations were noted from the top of the transect, typically at the top of the armored bank where accessible, and continuing downslope toward the water. The initial sediment thickness measurement at each transect was collected at the waterward extent of visible armoring or the vegetation line when no surface armoring was present. The depth to refusal and suspected reason for refusal were noted in the field forms, included in Appendix H. Typical reasons for refusal generally included the presence of buried dense material such as riprap, gravel, concrete debris, or wood. In some cases, it was suspected that consolidated layers of sand may have caused refusal, and such instances were noted in the field forms. At each transect, the first probe location where no refusal was encountered was noted as the toe of armoring. The toe of armor material was identified at all locations where armoring was present. Sediment over armoring and distance down the slope to the edge of armoring varied significantly.

Jet probing was completed at the transects within Slip 6. Two transects were completed within the area, both of which met refusal on a dense layer interpreted to be gravel and riprap. Within Slip 6, refusal was met at thicknesses ranging from 7.1 to 7.8 ft deep and more than 20 ft downgradient on the transect line.

Detailed results and field forms for the bank areas where sediment and jet probing was conducted are included as Appendix H.

2.7 Other Engineering Design Data

This section describes other data that were collected during the PDI to support engineering design, including vegetation and waste characterization data.

2.7.1 Vegetation

As part of the bank visual inspection conducted during Phase I (Section 2.3), information was collected regarding the presence of vegetation along the shoreline. During Phase II, additional information was documented for the banks of Phase I RAL exceedance areas using the same methodology as that used during Phase I. Vegetation species composition data in the areas inspected were similar to the information collected during Phase I. Several areas within the Phase I RAL exceedance areas lacked vegetation or had very sparse vegetation. Detailed information from the visual inspection of vegetation is documented in Appendix I.

2.7.2 Waste Characterization for Disposal

Commercial landfills typically require waste characterization testing to confirm that the material proposed for disposal meets any facility-specific design or permit limitations. Waste characterization testing will be performed after 30% RD using archived samples collected during the Phase II vertical extent delineation. Waste characterization for disposal will be conducted as follows:

- A minimum of two regional commercial landfills will be contacted by the design team to confirm their facility-specific testing requirements.
- Representative samples from within an RAA dredge prism will be selected to produce an average concentration for the RAA; samples will be selected based on spatial and concentration results. Not every RAA will be analyzed for waste characterization, but representative RAAs will be selected based on bulk chemistry results from the design dataset.
- The representative samples from a representative RAA will be composited into a single test sample, which will be tested for the suite of analytes identified by the landfill. The results of the testing will be documented in the Basis of Design Report.

The results of the testing will be evaluated to confirm compatibility with commercial landfill requirements. This information will be incorporated into the RD specifications as reference material to be used by the construction contractor.

2.8 Inadvertent Discovery Plan Implementation

An archaeological monitoring and inadvertent discovery plan was developed for Phase II PDI to address the potential for unanticipated discovery of cultural resources, artifacts, or other archaeological features during sampling activities. The plan, included as Attachment G of the Phase II QAPP Addendum (Anchor QEA and Windward 2021a), described the locations where archaeological monitoring was required and provided direction, contact information, and procedures to follow should an inadvertent discovery occur.

Prior to implementation of the field program, Stell Environmental Enterprises conducted a literature review of the Washington Information System for Architectural and Archaeological Records Data, as well as other cultural and environmental documents. During this review, 11 cultural resource surveys, 7 archaeological sites, 5 cemeteries, 6 registered historic properties, and 3,083 structures were identified within 1 mile of the upper reach.

During the Phase II PDI, archaeological monitoring was performed by Stell Environmental Enterprises from June 28 to August 3, 2021. No significant cultural resources were encountered during monitoring. Detailed information on the monitoring program and documentation of field oversight are included in Appendix J.

3 Data Evaluation

This section presents the data management rules used to derive the design dataset, a count of RAL exceedances in the design dataset, the final recovery category assessment, and the RAL exceedance areas based on the design dataset.

3.1 Data Management Rules for the Design Dataset

The LDW database includes all sediment data that have been collected for the LDW. The subset of the sediment chemistry data used in geostatistical models to delineate areas with RAL exceedances in the upper reach (see Section 3.3) is referred to as the design dataset. This dataset will be expanded throughout the design process as additional data become available (e.g., Phase III data).

The design dataset has been constructed in accordance with the data management rules provided in Appendix D of the Phase II QAPP Addendum (Anchor QEA and Windward 2021a). This dataset includes pre-PDI data (RI/FS data, post-FS data)[8] and the Phase I and II PDI data; it has been posted to https://ldwg.org. The steps followed in creating the design dataset are as follows:

1. Identify all samples that have been analyzed for chemicals with RALs.
2. Exclude any samples that are:
    - Located within early action areas[9]
    - Located within an area that has been dredged since the sample was collected
    - Collected as part of a monitoring program and superseded by newer data (e.g., data from monitoring year 1 are superseded by those from monitoring year 2)
    - Collected from a depth interval shallower than 5 cm (e.g., 0–2 cm)
3. For subtidal locations with multiple sample depths within the 0–60-cm RAL interval, average the results to create a single concentration per contaminant that represents the 0–60-cm interval (i.e., results from a 0–30-cm sample and a 30–60-cm sample are averaged to represent the 0–60-cm interval).
4. Exclude composite samples, as they do not provide location-specific information.

[8] The data management rules that were used to construct the RI/FS database are described in Appendix E of the LDW RI (Windward 2003). These rules have also been applied to the post-FS data.

[9] Monitoring data for early action areas were summarized in the PDI work plan (Windward and Anchor QEA 2019); an updated dataset has been provided to EPA and Ecology. Monitoring data from within early action areas were not included in developing RAL exceedance areas.

5. Where sampling locations have been re-occupied, select more recent data (if collected within 10 ft[10]) to represent current conditions. If an older sample includes data for contaminants not analyzed in the newer sample, retain the older chemistry in the dataset. This rule has remained consistent since the establishment of the RI dataset (LDW RI Appendix E (Windward 2003)). The purpose of this rule is to include the most current result available for the 0–10-cm interval for comparison to RALs, since surface sediments can change over time as new sediment is deposited. In rare instances, subsurface sample locations have also been re-occupied to address specific questions. These data have been included on a case-by-case basis in consultation with EPA.

The only data rules that are new for the design dataset since the RI/FS involve field duplicates and PCBs. With respect to field duplicates, parent sample results are selected when both parent and field duplicate results are reported, except when a RAL exceedance occurs only in the field duplicate and not in the parent. In such a case, the field duplicate results are selected for all analytes. For PCBs, both PCB Aroclor and congener sums are compared to the PCB RAL. When a sample is analyzed for both, the greater of the two sums is selected for the design dataset.

Table 3-1 shows how many sampling locations were contributed by the RI/FS, post-FS, and Phase I and II PDI to the design dataset for each of the RAL sediment depth intervals.

Table 3-1
Number of Upper Reach Design Dataset Locations with RAL Intervals by Data Source

Dataset	Date Range	No. of Surface Sediment Locations (0–10 cm)	Subsurface Sediment Locations		No. of Shoal Core Locations
			No. of Intertidal (0–45 cm)	No. of Subtidal (0–60 cm)	
RI/FS	1990–2010	354	0	15	0
Post-FS	2010–2019	230	0	0	7[1]
PDI (Phase I)[2]	2020	178	92	71	29[3]
PDI (Phase II)[2]	2021	80	54	63	13[4]
Total		**842**	**146**	**149**	**49**

Notes:
1. The 7 post-FS shoal locations include a total of 18 discrete depth interval samples. Six of these cores were collected in 2012 as part of the USACE sampling effort and one core was collected in 2016 as part of sampling done at South Park Marina.
2. PDI location counts presented here are not intended to match those in Section 2. This table presents counts of locations where various RAL intervals were analyzed; Table 2-1 presents counts of locations where samples were collected (i.e., not necessarily analyzed) and Table 2-2 presents sample counts, which may be higher than the values presented here because, in some cases, there are multiple samples per location.

[10] The 10-ft rule is consistent with inherent measurement inaccuracies in the differential global positioning systems (GPSs) used in sampling surveys for the Phase I PDI and past sampling efforts. The differential GPS used for Phase I surface sediment sampling has a measurement accuracy of approximately 3–6 ft. Given the inherent measurement accuracy, it is not possible to definitively distinguish different sampling locations within 10 ft of one another for samples collected after 2001. Prior to 2001, GPS technology was less accurate, so measurement inaccuracies may have been greater. If a re-occupied location was more than 10 ft away from the old location, it was considered a separate sample location and the older data were retained.

3. PDI Phase I shoal locations have a total of 52 discreet depth interval samples.
4. PDI Phase II shoal locations have a total of 26 discreet depth interval samples.
PDI: Pre-Design Investigation
RAL: remedial action level
RI/FS: Remedial Investigation/Feasibility Study
USACE: US Army Corps of Engineers

3.2 Comparison of Design Dataset with RALs

Sediment data in the design dataset were compared with RALs presented in ROD Table 28 (EPA 2014), and cPAH results were compared with RALs presented in the cPAH ESD (EPA 2021), in order to delineate RAL exceedance areas. A summary of RAL exceedances in the design dataset is presented in Table 3-2. RAL exceedances are shown by location on Maps 2-4a through 2-4j. The design dataset includes the Phase I and Phase II PDI data as well as the pre-PDI data from the RI/FS and post-FS sampling events.

Table 3-2
Summary of RAL Exceedances in the Design Dataset

COC	Counts by Interval[1]								Total Counts	
	Surface (0–10 cm)		Subsurface (0–45 cm)		Subsurface (0–60 cm)		Shoal Intervals (depth varies)[2]			
	No. > RAL/ Total	%	No. > RAL/ Total	%	No. > RAL/ Total	%	No. > RAL/ Total	%	No. > RAL/ Total	%
Human Health COCs										
PCBs	67/767	9	18/139	13	39/145	27	4/96	4	128/1147	11
Dioxin/furan TEQ	3/137	2	5/50	10	0/9	0	0/22	0	8/218	4
Arsenic	8/569	1	1/94	1	0/38	0	0/39	0	9/740	1
cPAHs[3]	1/507	0.2	0/61	0	0/36	0	0/36	0	1/640	0.2
Benthic COCs (with RAL Exceedances)[4]										
Lead	1/562	0.2	0/9	0	0/32	0	0/39	0	1/642	0.2
Mercury	3/567	0.5	0/9	0	0/37	0	1/40	3	4/653	0.6
Zinc	1/531	0.2	0/9	0	0/35	0	0/39	0	1/614	0.2
PAHs	3/513	0.6	1/10	10	0/37	0	1/36	3	5/596	0.8
4-Methylphenol	1/463	0.2	0/9	0	0/30	0	0/35	0	1/537	0.2
Benzoic acid	2/465	0.4	0/9	0	0/30	0	0/35	0	2/539	0.4
Phenol	1/471	0.2	0/9	0	0/30	0	0/35	0	1/545	0.2
BBP	8/474	2	0/9	0	1/41	2	0/35	0	9/559	2

Notes:
1. The design dataset includes samples from the pre-PDI and PDI datasets; counts are updated as of April 2022. Sample counts include PDI samples submitted for analysis through January 24, 2022.
2. Shoal interval samples consisted of shoaled material from the FNC (i.e., sediment above -15 ft MLLW in this reach of the LDW) and sediment from the -15 to -17-ft interval (see Map 2-3).
3. cPAH results are compared with the RALs presented in the cPAH ESD (EPA 2021). See Appendix B for a comparison of cPAH results with the 2014 ROD RALs.

4. PCBs and arsenic are also benthic COCs but are counted separately under human health COCs. Benthic COCs shown here are those with RAL exceedances in the design dataset.
BBP: butyl benzyl phthalate
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
EPA: US Environmental Protection Agency
ESD: explanation of significant differences
LDW: Lower Duwamish Waterway
MLLW: mean lower low water
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
PDI: Pre-Design Investigation
RAL: remedial action level
RAO: remedial action objective
ROD: Record of Decision
TEQ: toxic equivalent

Key takeaways from Table 3-2 include the following:

- **PCBs** – PCBs were the primary COC in the upper reach with the most RAL exceedances. Concentrations of PCBs were greater than the RAL in 11% of samples in the design dataset across all sample types.
- **Other COCs** – Additional COCs with at least one RAL exceedance in the design dataset include dioxins/furans, arsenic, cPAHs, lead, mercury, zinc, polycyclic aromatic hydrocarbons (PAHs), 4-methylphenol, benzoic acid, phenol, and butyl benzyl phthalate (BBP). These COCs exceeded the RAL in 0.2% to 4% of the design dataset samples. No PDI locations had cPAH TEQs greater than the RALs in the EPA ESD (EPA 2021); one pre-PDI surface sediment sample had a concentration exceeding the ESD RAL at a location where other PAHs and BBP also exceeded their respective RALs.
- **Surface samples** – The majority of surface RAL exceedances were for PCBs; there were PCB RAL exceedances in 9% of surface sediment samples in the design dataset. Other COCs exceeded the RAL in surface sediment in 0% to 2% of the design dataset.
- **Subsurface samples** – The majority of subsurface RAL exceedances were for PCBs; there were PCB RAL exceedances in 20% of the subsurface samples (both intertidal and subtidal areas, not including shoaling cores). Dioxins/furans exceeded the RAL in 9% of subsurface samples (all exceedances in intertidal areas). Other COCs exceeded the subsurface RALs in 0% to 2% of the design dataset. Other COCs with concentrations greater than subsurface RALs were arsenic (one intertidal subsurface sample), PAHs (one intertidal subsurface sample), and BBP (one subtidal subsurface sample).
- **Shoaling samples** – There were no RAL exceedances in the majority of the shoaling samples. The exceptions were for PCBs (four samples from three locations), mercury (one sample), and PAHs (one sample).

In addition, there were some Z-sample results from shoaling locations in the FNC at depth intervals below where ROD RALs apply (i.e., -17 to -18 ft MLLW in this reach of LDW). Locations with

Z-samples (or deeper intervals) with concentrations greater than shoaling RALs are shown in purple on Map 2-3. These data provide vertical extent of contamination information to be used in 30% RD within RAL exceedance areas. Outside of RAL exceedance areas, remedial action is not required for contamination buried deeper than the subsurface RAL intervals, according to the ROD (EPA 2014). The ROD requirements are based on analyses presented in a supplemental technical memorandum to the LDW FS (AECOM 2012) that determined that buried contamination at these depths is stable and will not be exposed. As discussed in the LDW FS (Section 5 and Appendix G), the maximum depth of scour from high-flow events in the LDW is 22 cm (approximately 9 in.) at a single location and up to 36 cm (approximately 14 in.) in isolated spots from propeller wash from vessels. Maintenance dredging in the navigation channel, if performed, may expose the Z-layer (-17 to -18 ft MLLW in the upper reach) in portions of the FNC where the contractor removes the full allowable overdredge depth of 2 ft. Post-construction monitoring will be conducted throughout the LDW following the remedy, as will be described in the Long-Term Maintenance and Monitoring Plan, with contingency actions if needed.

3.3 Recovery Category Assessment

This section presents the final recovery category assessment using the design dataset. Recovery categories are used as one of the conditions for the spatial application of RALs and remedial technologies (EPA 2014). Recovery category areas were developed in the FS (AECOM 2012) and subsequently re-assessed and revised, as new information became available, in the *Recovery Category Recommendations Report* (Integral et al. 2019), in Appendix B of the PDI QAPP (Anchor and Windward 2019), and most recently in Attachment C of the Phase II QAPP Addendum (Anchor QEA and Windward 2021a). The most recent recovery category assessment recommended a re-occupation of three locations between RM 3.9 to RM 4.0 on the east side of the LDW. This sampling was conducted as part of Phase II PDI sampling to further evaluate the recovery category designation for this area. This section presents the results of re-occupied locations in this area (two re-occupied in the Phase I PDI and three re-occupied in the Phase II PDI) and reassesses the recovery category designations in this area.

3.3.1 Methodology

The LDW ROD (EPA 2014) describes the recovery category definitions and how areas are delineated. Recovery categories are defined as follows:

- Category 1: Recovery presumed to be limited
- Category 2: Recovery less certain
- Category 3: Predicted to recover

Recovery category areas were delineated in the ROD based on the following physical and chemical criteria:

1. Identification of vessel-induced scour areas based on a visual review of sun-illuminated bathymetric survey maps
2. Identification of berthing areas based on berthing area information and documentation
3. Identification of sediment transport model-predicted 100-year high-flow event high-scour areas and net-scour areas
4. Empirical contaminant trends over time, used on a case-by-case basis to adjust recovery categories based on physical criteria (1 through 3)

The purpose of the analysis presented herein is to assess whether any recovery category modifications from RM 3.9 to RM 4.0 on the east side of the LDW are warranted based on a comparison of Phase I and II PDI chemistry data to pre-PDI data (i.e., criterion 4). Surface sediment (0–10 cm) data from the PDI are compared with pre-PDI surface sediment data at re-occupied locations (i.e., locations within 10 ft of each other) using the methodology previously employed in the *Recovery Category Recommendations Report* (Integral et al. 2019) and Attachment C of the Phase II QAPP Addendum (Anchor QEA and Windward 2021a).

Concentration changes for PCBs, cPAHs, arsenic, and bis(2-ethylhexyl)phthalate (BEHP) in each location were mapped in one of four color categories:

- **Red**: Contaminant concentration **increased** more than 50% over previous concentration.
- **Gray**: **No concentration trend** (defined as less than a 50% change relative to previous concentration).
- **Blue**: Contaminant concentration **decreased** more than 50% from previous concentration.
- **Green**: Concentrations in both samples in the pair **were less than** the SMS benthic SCO or lowest ESD RAL for cPAHs and were considered too low to assess any trend.[11]

Next, the data for the re-occupied locations were interpreted in the context of potential recovery category modifications consistent with the ROD:

- Areas with increasing concentrations of PCBs or increasing concentrations of other detected COCs (red) are considered for adjustment to Recovery Category 1.

[11] Assessing trends at re-occupied locations was discussed in Section F.4.1.1 of Appendix F of the FS (AECOM 2012).

- Areas with mixed results by COC or concentration changes less than 50% are considered for adjustment to Recovery Category 2.
- Areas with more than 50% decreases or a mix of 50% decreases and changes of less than 50% are considered for adjustment to Recovery Category 3.
- Areas with concentrations less than the benthic SCO or RAL (green) are considered for adjustment to Recovery Category 3, because these areas have historically recovered or have not been historically impacted by concentrations exceeding the benthic SCO or RAL.

The final recovery category designations are made considering all lines of evidence, including surrounding sediment concentration data and physical site conditions. Additionally, point sample comparisons are interpreted in light of potential sources of variability, such as spatial heterogeneity; different sampling and analytical events; and analytical variance, which can be up to 25% in a concentration measurement (an acceptability criterion in data validation).

3.3.2 Recovery Category Evaluation RM 3.9 to RM 4.0 (East)

Five locations were re-occupied between RM 3.9 and RM 4.0 on the east side of the waterway in recovery category 2. For PCBs, two locations showed increasing concentrations (SS257 and SS266, coded red), two locations showed decreasing concentrations (SS631 and SS633, coded blue), and one location was in equilibrium (SS645, coded gray) (Table 3-3 and Map 3-1). For arsenic, cPAHs and BEHP, all samples were less than RALs (coded green).

Table 3-3
Re-occupied Surface Sediment Locations RM 3.9 to RM 4.0

Current Location	Location Identification	Year	PCBs (µg/kg)	Arsenic (mg/kg)	cPAHs TEQ (µg/kg)	BEHP (µg/kg)
SS257	AN-019	2006	770	8.6	67	86 U
	SS257	**2020**	**3,380 J**	**10.5**	**46.8 J**	**84.3**
SS631	LDW-B9b	2004	210	8.85 J	94	69 J
	SS631	**2021**	**93.2**	**8.12**	**65.7**	**121**
SS633	AN-018	2006	350 J	8.1	310	210
	SS633	**2021**	**146**	**7.34**	**125**	**11.9 J**
SS266	EST145	1997	170	na	na	na
	SS266	**2020**	**271**	**8.26**	**177**	**247**
SS645	AN-011	2006	250	8.3	120 J	120 U
	SS645	**2021**	**151**	**13**	**54.1**	**67.4**

Notes:
Bold: Resampled location
For context, surface sediment RALs are as follows: 12 mg/kg OC PCBs (or 130 µg/kg if TOC is < 0.5 or > 3.5%), 57 mg/kg arsenic, 5,500 µg/kg cPAH TEQ, and 47 and 94 mg/kg OC BEHP in Recovery Category 1 and 2 areas, respectively (or 1,300 and 3,100 µg/kg if TOC is < 0.5 or > 3.5%).
Red: Contaminant concentration increased more than 50% over previous concentration.

Gray: No trend occurred in concentration (defined as less than a 50% change relative to previous concentration).
Blue: Contaminant concentration decreased more than 50% from previous concentration.
Green: Both samples in the pair were less than the SMS benthic SCO or lowest ESD RAL for cPAHs.
BEHP: bis(2-ethylhexyl)phthalate
cPAH: carcinogenic polycyclic aromatic hydrocarbon
ESD: Explanation of significant differences
J: estimated concentration
na: not analyzed
OC: organic carbon
PCB: polychlorinated biphenyl
RAL: remedial action level
RM: river mile
ROD: Record of Decision
SCO: sediment cleanup objective
SMS: Washington State Sediment Management Standards
TOC: total organic carbon
U: non-detected

The broad area shows mixed trends, consistent with the current Recovery Category 2 designation. Location 257 had the greatest increase in surface sediment PCB concentrations and coincided with a localized area of deepening bathymetry (>6 in. over 16 years; Appendix B of the Phase I QAPP, Map B-3 (Anchor QEA and Windward 2021a)). In this localized area, the recovery category designation has been changed to Recovery Category 1. Outside of this localized area, no recovery category modifications are recommended. The recovery category designations are shown on Map 3-2.

3.4 Areas with RAL Exceedances and Preliminary Technology Assignments

This section presents a summary of the updated data interpolation process used to identify areas with RAL exceedances in the upper reach. It also presents the preliminary technology assignment options for each area that will be considered in 30% RD. Details of the data interpolation and the technology assignment options are presented in Appendices K and L, respectively.

3.4.1 Defining Areas with RAL Exceedances

Spatial data interpolation methods were used to delineate areas with RAL exceedances to serve as the foundation for 30% design to establish the initial horizontal extent of the RD footprint. RAL interval data in the design dataset were used in the data interpolations. Interpolation uses a local neighborhood of surrounding data points to estimate the values at all unsampled points in the map domain. Interpolation is a standard method used in RD to define areas requiring remedial action (e.g., Anchor QEA 2014; Anchor QEA and Tetra Tech 2016; City of Tacoma 2002; Thornburg et al. 2005). Interpolation method selection and application were developed through a series of technical meetings with LDWG and EPA statisticians. This section provides a summary of the interpolation analyses and results.

Appendix K provides a detailed presentation of statistical data characteristics, spatial correlation structures, interpolation method evaluation and selection, RAL exceedance area maps, and uncertainty analysis using multiple lines-of-evidence to assess the uncertainty in the RAL exceedance area boundaries. Section 4.3.2 in Appendix K also discusses why the interpolation was not extrapolated into the intertidal ENR/activated carbon (AC) pilot plot, where approximately 25 cm of clean ENR material was placed in 2017. In brief, the pilot study PCB monitoring data (Wood et al. 2021) and PDI Phase II data indicated that COC concentrations in surface (0–10-cm) and subsurface (0–45-cm) sediment are less than RALs in the areas with ENR material, and three years of chemical and physical monitoring have demonstrated that ENR has been effective during that time. This area, like other areas where ENR technology is applied, will be monitored as will be described in the Long-Term Maintenance and Monitoring Plan.

This rest of this section provides a summary of the analyses and results detailed in Appendix K.

3.4.1.1 Interpolation Methods

PCBs were selected as the primary COC for detailed numerical data interpolation because PCBs delineate a large majority[12] of the RAL exceedance areas in the upper reach. Other COCs exceeding RALs in localized areas were evaluated separately, and the results for all COCs were combined with the PCB results in the final RAL exceedance area footprint.

Interpolations were performed on two sediment depth-defined datasets applicable to RALs: surface sediment, defined as 0 to 10 cm; and subsurface sediment, defined as 0 to 45 cm in intertidal areas, 0 to 60 cm in subtidal areas, and shoaling intervals in the FNC.[13] Using a GIS raster computation, the interpolations of surface and subsurface sediment were merged into a single map showing the combined exceedance footprint of both surface and subsurface layers.

Several interpolation methods were evaluated for use in the upper reach using exploratory spatial data analysis, including ordinary kriging, indicator kriging, inverse distance weighting (IDW), and Thiessen polygons. Based on these evaluations, two interpolation methods were selected by the EPA/LDWG technical team to define areas of RAL exceedances for use in RD:

- Indicator Kriging (PCBs)
- Thiessen Polygons (Other COCs)

[12] Based on the results of the interpolation work described in this section, PCBs were estimated to account for 88% of the RAL exceedance area in the upper reach. This percentage was calculated as the ratio of interpolated RAL exceedance area circumscribed by PCBs (in acres or square ft) to the total RAL exceedance area circumscribed by all COCs (see Map K-4a).

[13] The maximum concentration in any shoaling interval or the -15 to -17 ft MLLW interval (i.e., 2 ft below authorized FNC depth in this reach of LDW) was selected for each shoaling core location.

Ordinary kriging, like other kriging methods, provides useful information regarding underlying data correlation structure and estimation uncertainty, and it provides a direct assessment of concentration distributions. However, ordinary kriging is complicated by: a) high skewness of concentration data, which must be log-transformed and back-transformed to control the effects of extreme values; and b) mixture of OC-normalized and dry weight measurement units.

IDW is another viable method to assess concentration distributions. However, IDW is subject to many of the same limitations as ordinary kriging. In addition, a laborious cross-validation analysis is generally required to calibrate an optimal IDW weighting parameter.

Indicator Kriging. Indicator kriging was selected as the preferred method for PCB interpolation for several reasons: a) indicator kriging provides quantitative estimates of the uncertainty of the RAL exceedance area boundaries; b) indicator kriging is a nonparametric method that does not require the data to conform to a normal distribution; c) indicator kriging can readily accommodate mixed units, specifically, mixed OC-normalized and dry weight concentrations and RALs; and d) indicator kriging has been successfully applied to support RD and remedial action on other large sediment sites (Anchor QEA and Tetra Tech 2016; Thornburg et al. 2005).

Thiessen Polygons. Although PCB exceedances delineate the majority of contamination in the upper reach, in localized areas the PCB RAL exceedance area boundaries were expanded where other COCs exceeded RALs but PCBs did not. Because these areas are small and more localized, the RAL exceedance area boundaries for COCs other than PCBs were established using Thiessen polygons, a simpler geometric and deterministic interpolation method. Other COCs that locally determine the RAL exceedance area boundary include metals, polycyclic aromatic hydrocarbons (PAHs), other semivolatile organic compounds (BBP, benzoic acid, 4-methylphenol, phenol), and dioxins/furans, depending on the area.

3.4.1.2 Interpolation Results and Uncertainty Analysis

RAL exceedance area maps based on indicator kriging for PCBs and Thiessen polygons for other COCs are presented on Map 3-3, Maps 3-4a through 3-4j, and Appendix K. In Appendix K, Maps K-3a through K-3c show the surface sediment, subsurface sediment, and combined surface and subsurface sediment PCB RAL exceedance areas. The indicator kriging contours represent the probabilities of exceeding the applicable RALs, expressed in units of percent. The 50% probability of exceedance contour represents the median or central tendency estimate of the horizontal RAL exceedance boundary. Other contours are provided for comparison, including the 20%, 30%, 40%, 50% (median), 60%, 70%, and 80% probabilities of exceedance. Maps K4-a through K-4d show the median (50%) PCB RAL exceedance boundary overlain with Thiessen polygons for other COCs that extend beyond the median PCB boundary.

Indicator kriging provides quantitative, probabilistic information directly in the interpolation output, and it is the primary line of evidence for assessing the uncertainty of the PCB RAL boundary. In addition, the uncertainty of the PCB RAL exceedance area boundary is being assessed using three independent lines of evidence, which include, in order of priority: (1) indicator kriging probability contours, (2) cross-validation prediction errors, and (3) kriging standard errors. These lines of evidence, which are further discussed in Appendix K, show that the interpolations are unbiased and more precise in areas of more dense sample coverage, and that spatial correlations among neighboring samples help to control variance and uncertainty in the interpolated values.

The median indicator kriging boundary, corresponding to the 50% probability of exceedance, is recommended as the beginning basis for RD. On the Fox River and Hudson River sediment cleanup sites (Anchor QEA and Tetra Tech 2016; Kern et al. 2008; Wolfe and Kern 2008; QEA 2007), the median kriging estimate was used to define the remediation boundary for RD and was shown to provide a reasonable balance between effectively removing contaminated sediment with concentrations above the RALs and excluding sediment with concentrations below the RALs. During the design process, the remediation footprint can be expanded beyond the median boundary to address engineering and constructability considerations. Thus, a greater level of confidence will be achieved after design.

Locations with greater uncertainty may be addressed through the application of best professional engineering judgment to adjust RAA boundaries during RD and/or by identifying the need for Phase III data to reduce uncertainties in particular areas. Additional spatial analysis of cross-validation errors will be performed and summarized in a technical memorandum. This analysis will be used in the Phase III QAPP Addendum to help identify particular areas of greater uncertainty, where additional sampling may be warranted to help refine the delineation of the remediation boundary. Additional sampling may be conducted in areas where significant overprediction, underprediction, or classification errors (i.e., false negative or false positive errors) tend to occur. Specifically, the following maps and tables will be prepared as part of the technical memorandum to support the Phase III QAPP Addendum in determining Phase III sampling locations to reduce the uncertainty of the RAL exceedance area boundary:

- **Summary tables of cross-validation errors**. Cross-validation errors—including root mean squared errors, mean absolute deviations, prediction biases, and classification errors—will be calculated in surface and subsurface sediment in RAL=12 mg/kg OC and RAL=65 mg/kg OC areas. False negative (i.e., sensitivity) and false positive (i.e., efficiency) error rates, as well as other reliability metrics, will be calculated for various probability thresholds (p=0.5, 0.4, 0.3, and 0.2). A balanced RD will strive to control both types of errors and maximize the percentage of correct predictions.

- **Maps of cross-validation errors**. The cross-validation errors at each sample location will be mapped, including positive or negative errors representing a tendency toward overprediction or underprediction, respectively.

- **Maps of classification errors**. Cross-validation output files will be processed to flag the locations of false positive and false negative errors at the 50%, 40%, 30%, and 20% probability of exceedance boundaries. False positive and false negative errors will be mapped to their corresponding sampling locations to identify particular areas that may be more susceptible to misclassification.

In total, as a result of interpolation, 35 RAL exceedance areas were identified (Map 3-3); these areas are shown relative to the design dataset in Maps 3-4a through 3-4j. These areas include areas with RAL exceedances and interpolation-only areas.[14]

3.4.2 Preliminary Remedial Technology Assignments

Figures 19 and 20[15] in the ROD describe the process by which remedial technologies are to be assigned during the design process. A variety of factors govern the preliminary selection of applicable remedial technologies, including mudline elevation, RAL EF, depth of contamination, and recovery category designation.

As described in Appendix L, more than one remedial technology may be applicable in an area with RAL exceedances, and these may conflict with each other from a constructability standpoint. Therefore, the final remedial technology assignment within each area without data gaps will be determined during 30% and 60% RD by factoring in engineering and constructability considerations, in order to develop a constructable, stable, and protective design. There are other areas that have not yet been vertically bounded, so a final technology cannot be selected at this time. For these seven areas (Areas 1, 3, 11, 16, 18, 22, and 31; see Table L-1), the final remedial technology assignment will be determined during 90% RD based on Phase III data. Additional vertical data will help determine if the remedy will be dredging or partial dredge and cap. For 30% RD, a single technology will be assumed for each area (or subarea) based on available data, site condition information, and engineering considerations.

Potential remedial technologies identified in the ROD for intertidal and subtidal areas include the following:

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[14] Included interpolation-only areas are defined as areas greater than 250 sq ft that do not include a sample location with a RAL exceedance.

[15] Figure 20 was corrected after the ROD had been published. Reference to Figure 20 herein refers to the corrected version, which was published in a memorandum from EPA dated August 26, 2015.

- Intertidal:
  - Monitored natural recovery (MNR) to benthic SCO
  - Area-specific technology[16]
  - ENR
  - Partial dredge and cap
  - Dredge and backfill
- Subtidal:
  - MNR
  - Area-specific technology
  - ENR
  - Dredge (with backfill in habitat areas)[17]
  - Cap or armored cap

Preliminary technology assignments for each area with RAL exceedances are shown on Maps 3-5a and 3-5b. Technology assignments for the majority of RAL exceedance areas are well defined, although some areas still have more than one technology option that may be applied (dredging vs. partial dredge and cap). In addition, some areas may have subareas with different technology assignments. Details are presented in Appendix L.

Section 4 discusses the data gaps that have been identified for all applicable remedial technologies in each RAL exceedance area. Engineering considerations evaluated during 30% and 60% RD and additional data collected during the Phase III PDI will be used to select final remedial technologies.

[16] In areas with structural or access restrictions, location-specific cleanup technologies will be applied in accordance with ROD Section 13.2.1.3 (EPA 2014).

[17] Habitat areas were defined in the FS as all areas above -10 ft MLLW.

4 Initial Identification of Phase III Data Gaps

This section identifies initial types of data gaps to be filled by Phase III PDI to address data needed for RD. Additional data gaps will be identified during 30% design, as some data gaps are expected to be encountered while making design decisions and during design review. The approach for data gaps identification in this document is discussed generally for each type of data needed. Three types of data have been identified to support the DQOs presented in Table 1-3.

- Further horizontal delineation (DQOs 9 and 10)
- Further vertical delineation (DQO 12)
- Other engineering data (DQO 14)

Detailed information regarding sediment sampling locations, depth intervals, and analytes to support DQOs 10 and 12 will be provided in a Phase III QAPP Addendum, which will combine the data gaps identified in this DER with any data gaps identified during the preparation and review of 30% design. The Phase III QAPP Addendum will also include any updates to the inadvertent discovery plan to describe actions that will be performed during the Phase III investigations related to cultural resources. The Phase III sampling event will occur in late 2022 following receipt of EPA comments on the 30% design and EPA approval of the Phase III QAPP Addendum.

4.1 Further horizontal delineation (DQOs 9 and 10)

The results of the Phase I and II PDI, in combination with pre-PDI data, delineate where a remedy will be needed. Following 30% RD, to further refine some remediation areas, focused data gaps will be identified in the Phase III QAPP Addendum. The data gaps fall into the following general categories:

- In select areas, bound RAL exceedances identified in Phase II sampling (e.g., west of locations 705 and 706 at RM 4.9 W [Map 3-4j]).
- Investigate areas that are > 250 sq ft where RAL exceedances are defined using only the PCB data interpolation (e.g., RM 3.19 W of the FNC [Map 3-4a]).
- Investigate areas with greater uncertainty in the data interpolation (see Appendix K for a description of the uncertainty analysis).
- Investigate "MNR to benthic SCO" areas as needed (i.e., areas with chemical concentrations greater than the benthic SCO but less than the RAL for Recovery Category 2/3).

With respect to "MNR to benthic SCO" areas, Map 4-1 shows the 33 locations where benthic risk driver concentrations are > SCO and < RAL. Of these locations, 24 are either within RAL exceedance areas or immediately adjacent to such areas. Locations within RAL exceedance areas will be remediated; MNR to benthic SCO locations immediately adjacent to exceedance areas may also be remediated depending on the RAA boundaries to be identified in 30% RD. The remaining nine surface sediment locations are not within or immediately adjacent to a RAL exceedance area; they are summarized in Table 4-1. As stated in the ROD, “Areas with MNR would require the most monitoring to determine if surface sediment COC concentrations are reducing over time as projected by the natural recovery model…should MNR not achieve RAO 3 cleanup levels or progress sufficiently toward achieving them in 10 years, additional actions (dredging, capping, or ENR) will be implemented” (EPA 2014).

Table 4-1
Locations with surface sediment COC concentrations > Benthic SCO and < RAL that are not within or immediately adjacent to RAL exceedance areas

Sample (Year Sampled)	Location	COC	EF Relative to Benthic SCO	EF Relative to RAL[1]
DR203 (1998)	RM 3.28 W	Phenol	1.7	0.85
LDW20-SS156 (2020)	RM 3.4 in FNC	Mercury	1.1	0.56
DR209 (1998)	RM 3.71 W	Phenol	1.0	0.51
04-intsed-3 (1996)	Slip 6 N	Mercury	1.6	0.8
LDWSS383 (2020)	West side of Turning Basin	Dibenzofuran	1.3	0.67
LDWSS384 (2020)	West side of Turning Basin	Individual PAHs	1.2–1.3	0.58–0.63
R79 (1997)	East side of Turning Basin	Individual PAH	1.3	0.63
DR254 (1998)	East side of Turning Basin	Lead	1.4	0.69
NFK005 (1994)	RM 4.94 E	BEHP	1.4	0.71

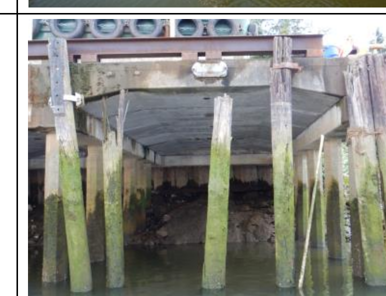
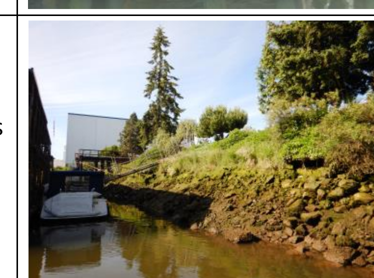
Notes:
1. The RAL is twice the benthic SCO in Recovery Category 2/3 areas, so the exceedance factor relative to the RAL is one-half that relative to the benthic SCO.
BEHP: bis(2-ethylhexyl) phthalate
COC: chemical of concern
EF: exceedance factor
FNC: federal navigation channel
PAH: polycyclic aromatic hydrocarbon
RAL: remedial action level
RM: river mile
SCO: sediment cleanup objective

In the Phase III QAPP Addendum, an analysis will be presented to determine if data are needed in the vicinity of or at the locations listed in Table 4-1 (and any others not included in RAAs in 30% design). The weight-of-evidence analysis will consider the density and years of data in these areas, temporal trends based on these data, and information related to sedimentation rates (e.g., bathymetry comparisons, sediment transport model-predicted rates) and potential sources. Additional data at these locations will be used to determine if surface sediment COC concentrations are reducing over time as projected by natural recovery models.

With respect to DQO 9 (sampling under overwater structures), the QAPP Addendum identified two upper reach overwater structures as having RAL exceedance areas (based on Phase I data) extending into the footprint of the structure: the South Park Bridge and one of the piers in Slip 6. The decision was made to collect samples under the South Park Bridge and reassess the need for additional sampling under overwater structures following the Phase II PDI. The Phase II PDI data collected in Slip 6 and the RAL exceedance area interpolation indicated that the contamination of adjacent sediments does not extend to the edge of the structure.

In addition to reviewing COC concentrations in adjacent sediment, LDWG has previously evaluated the types of structures in the upper reach, their uses, and the potential presence of outfalls under existing overwater structures. Based on this review, none of the overwater structures in the upper reach have a pathway (e.g., open hatches in the decking, older creosote piling, outfalls or storm drains located under the overwater structure) to a potential discrete contaminant source; more information on each upper reach overwater structure is presented in Table 4-2. Because upper reach overwater structures do not have a discrete contaminant source pathway, the results from sediment sampling locations close to the overwater structure are considered representative of the under-structure sediment condition. Thus, no additional sampling under an overwater structure is needed. Photographs associated with overwater structures are included in Table 4-2.

Table 4-2
Over-water Structures in the Upper Reach

WUS Information[1]						Other Information	Phase I/Phase II PDI							
Over-water Structure	**River Mile**	**WUS ID**	**Phase I ID**	**Over-Water Structure Description**	**Operational History**	**Overwater Coverage (sf)**	**Accessibility**	**Structure Condition Assessment**	**Armoring Under structure?**	**Reference Photographs for Visual Bank/ Under-pier Observation[2]**	**Debris or Waste Identified Based on Visual Observations**	**RAL Exceedance Area that Extends to Over-water structure Footprint?**	**Are Samples Near Under-structure Sediments?**	**Under-structure Sample(s) Collected**
South Park Bridge	3.3–3.4	57	ST02	Bascule bridge	Current bridge built in 2014, just north of the former bridge alignment	44,565	Elements around the bascule piers are accessible but may be limited outside the navigable channel.	Good	No		None (naturally occurring logs)	Yes	Yes, see Map 3-4b	Yes, additional samples were collected as part of Phase II PDI
South Park Marina floats	3.4	39	ST20	Marina with timber floating docks and timber guide piles	Moorage of commercial and recreational vessels	17,404	Floating docks are accessible on all sides. Access to under-float areas is only by diver.	Fair	No		None observable	No, but adjacent	Yes, see Maps 3-4b and 3-4c	No, considered similar to surrounding sediments
National Industrial Holdings pier	4.0	40	ST16	Concrete pile, concrete-decked finger pier	Dock used to load and berth barges	3,634	Accessible on south and north sides (but limited depth); access to east side is obstructed by fender piles.	Fair	Yes		Mound of debris (Photo 150)	No	Yes, see Map 3-4e	No, considered similar to surrounding sediments
Duwamish Yacht Club floats	4.1	42	ST15	Marina with covered moorage, timber guide piles, and concrete floats	Moorage of recreational vessels	68,354	Limited space between floats, clearance width limited, and overhead covers on floats. Access to under-float areas is only by diver.	Fair	Discontinuous /non-engineered		None observable	No	Yes, see Map 3-4f	No, considered similar to surrounding sediments

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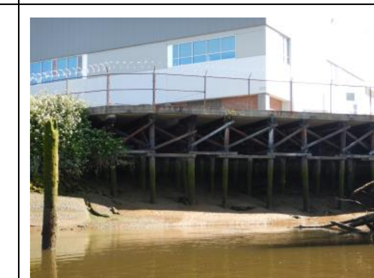
WUS Information[1]						Other Information	Phase I/Phase II PDI							
Over-water Structure	River Mile	WUS ID	Phase I ID	Over-Water Structure Description	Operational History	Overwater Coverage (sf)	Accessibility	Structure Condition Assessment	Armoring Under structure?	Reference Photographs for Visual Bank/ Under-pier Observation[2]	Debris or Waste Identified Based on Visual Observations	RAL Exceedance Area that Extends to Over-water structure Footprint?	Are Samples Near Under-structure Sediments?	Under-structure Sample(s) Collected
Delta Marine Industries floats	4.2	43	ST12	Floating dock with steel guide piles	Mooring vessels for outfitting and repair, fiberglass vessels manufactured on site	4,901	Floating docks are generally accessible from all sides except when large vessels are present. Access to under-float areas is only by diver.	Good	No		None observable	No	Yes, see Map 3-4f	No, considered similar to surrounding sediments
The Boeing Company Seattle Wharf (Slip 6)	4.3	44	ST05	Six concrete pile, concrete-decked, asphalt surfaced loading piers	Barge moorage	11,089	Each of the piers are accessible along the east and west sides; access to the north sides is obstructed by fender piles.	Fair to poor	Yes		None (naturally occurring sticks and logs, rope in use)	No	Yes, see Map 3-4g	No, considered similar to surrounding sediments
Boeing Platform	4.7	66	ST07	Timber pile-supported concrete wharf	Unknown	794	There is limited access to areas under the wharf.	Poor	No		Concrete slabs, naturally occurring logs	No, but adjacent	Yes, see Map 3-4i	No, considered similar to surrounding sediments; access and safety concerns exist
S 98th Street Bridge	4.8	na	ST08	Bridge	Unknown	14,222	There is limited accessibility between piers and abutments.	Good	Yes		Concrete slabs	No	Yes, see Map 3-4j	No, considered similar to surrounding sediments

Notes:
1. Information from Table 3 of the WUS (Integral et al. 2018); information confirmed during Phase I and Phase II PDI for the LDW upper reach.
2. Photographs were also submitted as part of the Phase I data package and posted on https://ldwg.org.
ID: identification
LDW: Lower Duwamish Waterway
na: not applicable
PDI: Pre-Design Investigation

RAL: remedial action level
WUS: Waterway User Survey

4.2 Further vertical delineation (DQO 12)

Information from the Phase II PDI on the vertical extent of contamination, presented in vertical core diagrams in Maps 3-4a through 3-4i, provides most of the data needed to design the remedy where dredging is needed. However, some focused data gaps remain that will be addressed in the Phase III PDI. Specifically, additional vertical data may need to be collected in RAL exceedance areas that will likely require dredging if the data interpolation expanded the preliminary RAL exceedance area footprint, resulting in portions of the interpolated RAL exceedance areas with insufficient vertical data coverage (e.g., west side of RAL exceedance area at RM 3.12 as shown on Map 3-4a). Additional vertical data will also be collected in the vicinity of shoaling cores collected by USACE in 2012 (LDW13, LDW14, LDW17)[18] and near shoaling location 148 within RAL exceedance area 11,[19] where data could not be collected previously to define the vertical extent of contamination. Additional vertical data needs may be identified during 30% RD in unarmored bank areas within interpolated RAL exceedance areas.

4.3 Other engineering data (DQO 14)

Data for the RAL exceedance areas shown on Map 3-3 were reviewed to determine if there are any new data gaps for geotechnical data, topography, sediment thickness, or detailed structural inspection since Phase I RAL exceedance area boundaries were delineated. No data gaps were identified. However, engineering data gaps may potentially be identified during 30% design. Examples of engineering data gaps that could be identified during 30% design review include:

- Supplemental topographic bank data
- Supplemental utility location information
- Supplemental habitat and vegetation information, particularly in areas where bank construction may have occurred following Phase I and II PDI and where remedial actions include removal on or near such banks
- Supplemental design criteria data for cap design
- Supplemental data to support quantification and/or limits of debris
- Supplemental geotechnical and/or structural condition data to support structural stability and/or demolition evaluations

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[18] See Map 3-4b for the location of LDW13 and SC558, Map 3-4c for the location of LDW14 and SC564, and Map 3-4d for the location of LDW17 and SC629.

[19] This location is the only shoaling location in the FNC where contaminant concentrations exceeded RALs only at depths below the top 2 ft (60 cm). At these locations, cleanup may be deferred if USACE determines it is not currently an impediment to navigation, but must be dredged in the future if USACE determines that the area has become an impediment to navigation, per the ROD (EPA 2014).

In addition, the RDWP (Anchor QEA and Windward 2019) stated that if specific dredged material treatment studies were determined to be necessary, a QAPP addendum for treatment studies would be developed for the Phase III PDI and summarized in the Phase III PDI Data Evaluation Report to be appended to the 90% design document. Based on the chemistry results in the design dataset, dredged material treatment studies are not anticipated to be necessary, and thus, this element is not considered to be a data gap. The chemistry results in the design dataset are consistent with the range of concentrations and analytes that have been disposed of at commercial landfills during other regional dredging projects without requiring treatment.

4.3.1 Elutriate Testing

Dredge elutriate testing (DRET) is a laboratory-scale simulation of the release of chemicals into the water column that occurs during dredging of contaminated sediments. In some cases, DRET can inform the specific needs of the water quality monitoring program during construction. The potential need for DRET (DiGiano et al. 1995) was also evaluated as a potential data gap.

In place of DRET, contaminant partitioning calculations will be used during 30% design to calculate dissolved phase concentrations, similar to the calculation procedures outlined in the *Sediment Evaluation Framework for the Pacific Northwest* (RSET 2016) (SEF). The SEF developed elutriate test triggers based on general partitioning assumptions; these triggers can be used to approximate water quality impacts at the point of dredging and identify the potential need for elutriate testing (SEF Table 9-2). Additional transport and mixing calculations can be used to estimate concentrations at the water quality point of compliance.

Recent projects have favored partitioning calculations over DRET (e.g., LDW early action areas) because partitioning calculations have provided reasonable estimates of dissolved concentrations. There is also a great deal of project experience of monitoring the actual water quality effects of dredging in Puget Sound, and that experience will directly inform the water quality monitoring approach. Therefore, elutriate testing is not considered a data gap.

4.3.2 Debris

In areas with RAL exceedances, large surface debris may need to be removed and disposed of during remedial construction. The photographs collected during the Phase I bank visual inspection provide useful information regarding the general locations of shoreline debris above the water line at the time the photographs were taken. During the Phase II PDI topographic survey, location data for large debris (e.g., concrete rubble) observed during low tides in the intertidal areas were collected. The general description of observed debris is presented on Maps 2-6a through 2-6f. The topographic surveyor provided general location and extent information for observed debris in the surveyor's notes; this information has been translated into approximate locations and is shown on the Maps 2-6. However, individual locations were only identified for large debris that may require special construction methods to remove. 60% RD will include a drawing indicating the locations of large debris within or adjacent to RAAs that require specific call out.

Multibeam bathymetric data collected during the Phase I PDI (Section 2.4) are of sufficient resolution to allow for the identification and location of large surface debris for 30% RD in areas where remedial action will occur below MLLW. The bathymetric survey did not indicate any large surface debris below MLLW. Therefore, identification of large surface debris below the MLLW elevation is not considered a data gap. Buried debris may be encountered in any dredge area, and the design specifications will require the contractor be prepared with equipment and procedures to handle debris wherever it is encountered during the remedial action.

5 Next Steps

Per the schedule outlined in the RDWP (Anchor QEA and Windward 2019), 30% RD has begun and is expected to be submitted to EPA in August 2022. The 30% RD will include preliminary designs for remediation technologies to be used in each RAL exceedance area. The 30% RD will also delineate RAA boundaries, including those adjacent to early action areas, restoration areas, and upland cleanup areas, and those within, overlapping, or adjacent to the FNC and its 10-ft buffer. Cross sections will be prepared as needed for design and will also depict the interface between remedial actions and adjacent areas.

The DER identified general data gaps to be addressed in the Phase III PDI. During 30% design, additional data gaps may be identified that will also be addressed in the Phase III PDI and incorporated into the Phase III QAPP Addendum. Specific details regarding this data collection, including chemistry and other engineering information, will be described in the Phase III QAPP Addendum following EPA comments on the 30% design.

After the Phase III QAPP Addendum is approved by EPA, LDWG will conduct the Phase III PDI. Phase III PDI data collection is planned for November 2022. Following the Phase III PDI, the design dataset will be supplemented with the Phase III data and used in RD. The Phase III data will be incorporated into 90% design and presented in an appendix to the 90% design document.[20]

[20] The PDI work plan (Windward and Anchor QEA 2019) stated that if Phase III design sampling is conducted, a Phase III DER will be submitted to EPA 45 days after submittal of all Phase III data. Because the validated Phase III data will not be available until mid-March 2023 at the earliest, they will not be available for 60% design, which will be submitted in February 2023, and comments on a Phase III DER (if one were prepared) would not be available prior to 90% design, which will be submitted in June 2023. Therefore, the Phase III DER elements describing the results of and deviations from the Phase III PDI will be appended to the 90% design, and a separate Phase III DER will not be submitted. In addition, when validated Phase III chemistry data are submitted to EPA, preliminary maps will also be included to facilitate the review and a meeting will be scheduled to discuss how the results may affect design.

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