Lower Duwamish Waterway Group

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

LOWER DUWAMISH WATERWAY BASELINE SURFACE SEDIMENT COLLECTION AND CHEMICAL ANALYSES - QUALITY ASSURANCE PROJECT PLAN

FINAL

Prepared for

Lower Duwamish Waterway Group

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SURFACE SEDIMENT COLLECTION AND CHEMICAL ANALYSES
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Acronyms

%RSD	percent relative standard deviation
95UCL	95% upper confidence limit for the mean
ac	acre
ALS	ALS Environmental-Kelso
AOC	Administrative Order on Consent
ARI	Analytical Resources, Inc.
Axys	Axys Analytical Services Ltd.
CFR	Code of Federal Regulations
City	City of Seattle
CLT	Central Limit Theorem
COC	contaminant of concern
COPC	contaminant of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CRM	certified reference material
CTO	chemothermal oxidation
CV-AFS	cold vapor-atomic fluorescence spectrometry
DCM	dichloromethane
DGPS	differential global positioning system
DL	detection limit
DQI	data quality indicator
DQO	data quality objective
dw	dry weight
Ecology	Washington State Department of Ecology
EDL	estimated detection limit
EIM	Environmental Information Management
ENR	enhanced natural recovery
EPA	US Environmental Protection Agency

FC	field coordinator
GC/ECD	gas chromatography/electron capture detection
GC/MS	gas chromatography/mass spectrometry
GPC	gel permeation chromatography
GPS	global positioning system
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HpCDD	heptachlorodibenzo-*p*-dioxin
HpCDF	heptachlorodibenzofuran
HRGC/HRMS	high-resolution gas chromatography/high-resolution mass spectrometry
HSP	health and safety plan
HxCDD	hexachlorodibenzo-*p*-dioxin
HxCDF	hexachlorodibenzofuran
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IR	infrared spectroscopy
ISO	International Organization for Standardization
LCS	laboratory control sample
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LLOQ	lower limit of quantitation
LMCL	lower method calibration limit
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MDL	method detection limit
MHHW	mean higher high water
MLLW	mean lower low water
MNR	monitored natural recovery
MS	matrix spike
MSD	matrix spike duplicate

NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
OCDD	octachlorodibenzo-*p*-dioxin
OCDF	octachlorodibenzofuran
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PARCCS	precision, accuracy, representativeness, completeness, comparability, and sensitivity
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
PE	polyethylene
PeCDD	pentachlorodibenzo-*p*-dioxin
PeCDF	pentachlorodibenzofuran
PM	project manager
PPE	personal protective equipment
PRC	performance reference compound
PSEP	Puget Sound Estuary Program
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RAL	remedial action objective
RAO	remedial action objective
RI/FS	remedial investigation/feasibility study
RL	reporting limit
RM	river mile
RME	relative margin of error
ROD	Record of Decision
RPD	relative percent difference
SCO	sediment cleanup objective

SD	storm drain
SDG	sample delivery group
SIM	selected ion monitoring
SM	Standard Methods
SMS	Washington State Sediment Management Standards
SOP	standard operating procedure
SoundEarth	SoundEarth Strategies, Inc.
SPU	Seattle Public Utilities
SRM	standard reference material
SVOC	semivolatile organic compound
SWAC	spatially weighted average concentration
SWPPP	stormwater pollution prevention plan
T-107	Terminal 107
TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
TEF	toxic equivalency factor
TEQ	toxic equivalent
TM	task manager
TOC	total organic carbon
UCT-KED	universal cell technology-kinetic energy discrimination
WAC	Washington Administrative Code
Windward	Windward Environmental LLC
ww	wet weight

Acknowledgements

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1 Introduction

This quality assurance project plan (QAPP) describes the quality assurance (QA) objectives, methods, and procedures for collecting surface sediment[1] from the Lower Duwamish Waterway (LDW) for chemical analyses, with a subset of the samples also being used for an *ex situ* porewater investigation for polychlorinated biphenyls (PCBs). As described in the *Pre-Design Studies Work Plan* (Windward and Integral 2017b), hereafter referred to as the Work Plan, these data are being collected and analyzed to address the third amendment to the Administrative Order on Consent (AOC) (EPA 2016c).

The Work Plan presents the data quality objectives (DQOs) and conceptual study design for the surface sediment collection and associated analyses (Windward and Integral 2017b). This QAPP includes these DQOs and presents the detailed study design, including specifics on project organization, field data collection, laboratory analyses, and data management.

US Environmental Protection Agency (EPA) guidance for QAPPs was followed in preparing this document (EPA 2002). The remainder of this QAPP is organized into the following sections:

- Section 2 – Project Objectives and Description
- Section 3 – Project Organization and Responsibilities
- Section 4 – Data Generation and Acquisition
- Section 5 – Assessment and Oversight
- Section 6 – Data Validation and Usability
- Section 7 – References

Appendix A to this QAPP is a health and safety plan (HSP) designed to protect on-site personnel from physical, chemical, and other hazards posed by the field sampling effort. Field collection and analysis forms are included as Appendix B. Laboratory methods and the associated reporting limits (RLs) are provided in Appendix C. Appendix D presents standard operating procedures (SOPs) for the *ex situ* porewater investigation and subsampling sediment. Appendix E contains reconnaissance survey notes.

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[1] Bank samples are also being collected; they are included in the general discussion of surface sediment except where specifically noted otherwise.

2 Project Objectives and Description

EPA issued a Record of Decision (ROD) for the LDW Superfund site on November 21, 2014 (EPA 2014b). The ROD describes the selected sediment remedy for the LDW, and identifies monitoring activities, including baseline sampling of LDW media for comparison to post-remedial data. This QAPP addresses baseline sampling of surface sediment as well as an *ex situ* assessment of PCBs in porewater.

2.1 DATA QUALITY OBJECTIVES

Per the third amendment to the AOC (EPA 2016c), the collection of surface sediment data is required to characterize baseline conditions prior to implementation of the sediment remedy, and to support source control efforts. As described in the Work Plan (Windward and Integral 2017b), which includes the porewater addendum (Windward and Integral 2017a), 10 DQOs have been identified for the collection and analysis of baseline surface sediment samples, including an *ex situ* porewater investigation for PCBs as well as source-related samples. These DQOs are presented in Sections 2.1.1 through 2.1.3.

2.1.1 Surface sediment (0–10-cm) samples

Surface sediment samples (0–10-cm) will be collected to establish site-wide baseline concentrations, to determine location-specific concentrations in monitored natural recovery (MNR) areas, to collect additional PCBs porewater data through an *ex situ* investigation, and to collect source-related data near outfalls and from banks. Six DQOs have been identified for 0–10-cm sediments; these DQOs are summarized in Table 2-1.

Table 2-1. DQOs for surface sediment samples (0–10 cm)

DQO Step	DQO 1	DQO 2	DQO 3	DQO 4	DQO 5	DQO 6
STEP 1: State the problem.	A synoptic site-wide sediment dataset is needed to assess the baseline condition prior to implementation of the sediment remedy.		Because surface sediment concentrations are likely to change over time, additional sediment concentration data from MNR areas[a] are needed for a qualitative check on natural recovery[b] prior to the sediment remedy to compare to RAO 3 sediment (benthic invertebrate) cleanup levels.		Additional co-located bulk sediment-porewater data are needed over the range of PCB concentrations in MNR/ENR areas to assess the potential effects of sediment concentrations on biota exposure and tissue concentrations. If the relationship is predictive, porewater data may not be needed to predict whether reductions in sediment concentrations will reduce tissue concentrations in biota.	Additional bank and near-outfall sediment data are needed to fill data gaps from earlier source control sampling efforts.
STEP 2: Identify the goals of the study.	Establish baseline, site-wide 95UCL concentrations of RAOs 1, 2, and 4 risk drivers.	Establish a baseline, site-wide SWAC to serve as the foundation for assessing temporal trends for RAOs 1, 2, and 4 risk drivers.	Compare (on a point-by-point basis) concentrations in baseline samples collected from within MNR areas to RAO 3 (benthic) cleanup levels.[b]	Collect site-specific sediment data to support future trend assessment and comparison to predicted concentrations in MNR areas.[b]	Investigate baseline porewater PCB concentrations in MNR/ENR areas to assess the predictability of the relationship between porewater and sediment PCB congener concentrations.	Collect bank and near-outfall sediment data to assist Ecology in source control efforts.
STEP 3: Identify the information inputs.	Existing sediment data from the LDW were used to determine the appropriate sample size needed to achieve desirable statistical precision for the site-wide mean.[c]		Existing sediment data were used to identify locations of SMS exceedances in preliminary MNR areas in ROD Figure 18 (EPA 2014b).		Existing sediment data and ROD Figure 18 (EPA 2014b) were used to estimate the range of PCB concentrations in preliminary MNR/ENR areas.	Existing source data were reviewed in consultation with EPA and Ecology to determine where additional data are needed.

DQO Step	DQO 1	DQO 2	DQO 3	DQO 4	DQO 5	DQO 6
STEP 4: Define the boundaries of the study.	The boundary of the study has been defined by the ROD. Preliminary MNR and ENR areas were established in Figure 18 of the ROD (EPA 2014b).					The boundary of the study has been defined by the ROD.
STEP 5: Develop the analytical approach.	The 95UCL will be calculated using the best-fit statistical distribution for the data.	The site-wide SWAC will be estimated from the arithmetic mean of the composite samples. Each composite sample represents approximately the same-sized spatial area, allowing for a simplified estimate of the SWAC.	Individual sample results from 20 locations will be compared to RAO 3 cleanup levels on a point-by-point basis.	Data from 10 reoccupied RI locations will be used on a point-by-point basis over time to assess changes in surface sediment quality.	Paired sediment-porewater data will be combined with existing paired sediment-porewater data from the LDW to evaluate the regression relationships.	Data from 24 near-outfall sediment locations, as well as from 6 banks, will be collected and submitted to Ecology to assist in source control efforts.
STEP 6: Specify performance or acceptance criteria.	Performance or acceptance criteria are described in Section 4.6, including field QC samples and laboratory QC samples. DQIs for laboratory analyses (i.e., PARCCS) will be met, as described in Section 4.6.					

<table>
<tr><th>DQO Step</th><th>DQO 1</th><th>DQO 2</th><th>DQO 3</th><th>DQO 4</th><th>DQO 5</th><th>DQO 6</th></tr>
<tr><td>STEP 7: Develop the detailed plan for obtaining data.</td><td colspan="2">A spatially balanced random sampling design has been developed to collect 168 samples distributed throughout the study boundary. One random sampling location will be selected within each of 168 sampling grid cells of approximately equal area. A total of 24 composite samples will be constructed, each composed of the grab samples from 7 neighboring grid cells. This design will avoid spatially clustered samples, which will improve statistical efficiency. The random sampling will allow for the calculation of unbiased estimates of the site-wide mean and standard error. The arithmetic mean of the observations will also be a SWAC, because equal spatial weighting is intrinsic to the sample design.</td><td>Ten reoccupied RI locations in preliminary MNR areas with sediment concentrations > benthic SCO were selected, plus 10 random locations from the 168 samples for DQOs 1 and 2 that fall within MNR areas.</td><td>Data from the 10 reoccupied RI locations that were selected from MNR areas with sediment concentrations > benthic SCO will be compared to past and potentially to future data to assess changes over time.</td><td>Twenty candidate locations were selected, including the 10 reoccupied RI locations used in DQO 3, plus an additional 10 reoccupied locations targeted to capture a wider range of PCB concentrations. All 20 bulk sediment samples will be analyzed for PCBs and organic carbon. Among the samples with the desired range of PCB concentrations in sediment, 10 will be selected for *ex situ* porewater testing and PCB congener analysis.</td><td>The 24 near-outfall sediment samples were selected to fill data gaps near outfalls without existing data nearby. At the 6 bank areas, a total of 11 locations will be sampled. One sample will be collected from each bank location unless conditions suggest the need for a vertical transect sample(s).</td></tr>
</table>

[a] It is acknowledged that the remedial boundaries and technology assignments portrayed in ROD Figure 18, titled *Selected remedy*, are likely to change following design. Thus, any reference to MNR areas refers to preliminary area designations.

[b] Concentrations are not expected to meet natural recovery predictions during baseline sampling because the projections are for 10 years post-remedy. In addition, additional data will be collected during remedial design to support design decisions, such as where remedial technologies apply, and to better establish baseline relative to RAO 3 cleanup levels.

[c] Assumptions for the composite sample dataset (i.e., normally distributed data and a coefficient of variation of 0.7 or less) result in an RME of 25% or better for the post-remedy mean.

95UCL – 95% upper confidence limit for the mean
DQI – data quality indicator
DQO – data quality objective
Ecology – Washington State Department of Ecology
ENR – enhanced natural recovery
LDW – Lower Duwamish Waterway
MNR – monitored natural recovery
PARCCS – precision, accuracy, representativeness, completeness, comparability, and sensitivity
PCB – polychlorinated biphenyl
QC – quality control
RAO – remedial action objective
RI – remedial investigation
ROD – Record of Decision
RME – relative margin of error
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards
SWAC – spatially weighted average concentration

2.1.1.1 Baseline surface (composite samples 0–10-cm) sediment for site-wide RAOs

The DQOs for the establishment of site-wide baseline conditions in 0–10-cm LDW surface sediment samples are as follows:

1. Establish baseline, site-wide 95% upper confidence limit for the mean (95UCL) concentrations of remedial action objectives (RAOs) 1, 2, and 4 risk drivers.[2]
2. Establish baseline, site-wide spatially weighted average concentration (SWAC) to serve as the foundation for assessing trends from before to after sediment remediation for RAOs 1, 2, and 4 risk drivers.

The baseline surface sediment sample design is tailored to the DQOs above. Specifically, a spatially balanced sampling design has been developed to collect 168 samples distributed throughout the study boundary. The 168 samples will be collected at one random location within each sampling grid cell, all of which are of approximately equal area. Once collected, the surface sediment samples from these 168 cells will be combined into 24 composite samples for analysis. Each composite sample will contain seven grab samples.

Baseline concentrations will be established based on the composite sample data collected from a single site-wide sampling event. This sediment sampling approach can then be repeated over time to generate comparable datasets to assess progress toward cleanup goals, and to assess the effectiveness of the remedy in attaining the site-wide RAOs.

Baseline site-wide concentrations will reflect the combined effects of 1) cleanup actions at approximately 29 acres (ac) of early action areas, 2) ongoing source control, and 3) ongoing natural recovery throughout the LDW. Site-wide SWAC comparisons over time will establish trends in sediment concentrations, while the 95UCL is the ROD compliance metric for surface sediment area-wide cleanup levels (EPA 2014b).

The surface sediment composite samples will be analyzed for the contaminants of concern (COCs) for RAOs 1, 2, and 4 (PCBs, total arsenic, cPAHs, and dioxins/furans) (ROD Table 19) (EPA 2014b) and conventional parameters, including total organic carbon (TOC), black carbon, grain size, and total solids.

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[2] Risk drivers are PCBs, dioxins/furans, carcinogenic polycyclic aromatic hydrocarbons [cPAHs], and arsenic (ROD Table 19, titled *Cleanup levels for PCBs, arsenic, cPAHs, and dioxins/furans in sediment for human health and ecological COCs [RAOs 1, 2, and 4]*). PCBs are the only risk drivers for RAO 4.

2.1.1.2 Individual 0–10-cm sediment samples

Twenty individual samples will be collected within the preliminary MNR areas shown in ROD Figure 18 (EPA 2014b)[3] and individually analyzed for RAO 3 COCs to address DQOs 3 and 4:

3. Compare (on a point-by-point basis) concentrations in baseline samples collected from within MNR areas to the (benthic) cleanup levels presented in ROD Table 20[4] (EPA 2014b).
4. Support the evaluation of site-wide trends and comparison of concentrations to predicted natural recovery in MNR areas.[5]

Ten of the 20 locations were identified to reoccupy LDW remedial investigation (RI) surface sediment locations in MNR areas with sediment cleanup objective (SCO)[6] exceedances (MNR > SCO) based on existing data. The other 10 locations were randomly selected from locations within MNR areas. During long-term monitoring, repeated measurements over time using a fixed or rotating panel design will support the evaluation of trends and comparisons with predicted natural recovery in MNR areas. Note that these data are not being collected to delineate MNR areas, nor to assess MNR area compliance; data to address those needs will be collected during design and compliance monitoring.

These 20 samples will be analyzed for the target analytes in Table 20 of the ROD (EPA 2014b), and archives will be retained.

2.1.1.3 **Ex situ** *porewater samples*

The DQO for the collection of PCB porewater data[7] is as follows:

5. Estimate baseline porewater concentrations in MNR/ENR areas for PCBs. This DQO is primarily intended to help assess the effect of reduced sediment concentrations on biota exposure and tissue concentrations.

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[3] It is acknowledged that the remedial boundaries and technology assignments portrayed in ROD Figure 18, titled *Selected remedy*, are likely to change following design. Thus, any reference to MNR, enhanced natural recovery (ENR), cap, or dredge areas in this QAPP refers to preliminary area designations.

[4] ROD Table 20 is titled *Sediment cleanup levels for ecological (benthic invertebrate) COCs for RAO 3*. MNR areas are preliminary because remedial boundaries and technology assignments portrayed in ROD Figure 18 (EPA 2014b), titled *Selected remedy*, are likely to change during remedial design.

[5] Concentrations are not expected to meet natural recovery predictions during baseline sampling because the projections are for 10 years post-remedy.

[6] SCO is the term used in this sediment QAPP to refer to the benthic numeric cleanup criteria in Washington State Sediment Management Standards (SMS) Chapter 173-204-562. The benthic SCOs are also the cleanup levels for RAO 3 in the ROD.

[7] Porewater data for cPAHs are discussed in the clam QAPP.

In the LDW, PCB porewater data currently are available for 31 locations (Windward and Integral 2017a). In addition to these field data, porewater concentrations can be predicted from sediment concentrations using the two-carbon equilibrium partitioning modelling that has been conducted for the LDW. To address DQO 5, PCB concentrations in sediment and porewater from 10 additional locations will be analyzed to potentially improve the ability to predict PCB concentrations in porewater.

Twenty sampling locations have been identified with surface sediment PCB concentrations that represent the range of PCB concentrations in the MNR/ENR areas. These 20 targeted locations include the 10 reoccupied RI locations in MNR areas selected to address DQO 3 (Section 2.1.1.2), and an additional 10 reoccupied RI locations to maximize the likelihood of sampling locations with the targeted range of total PCB concentrations, including six locations with concentrations above 720 µg/kg.[8]

Sediment from the 20 sampling locations will be exposed to passive samplers for 28 days as part of an *ex situ* porewater investigation. Passive samplers will be used to characterize the freely dissolved PCB congener concentrations in porewater.

All 20 sediment samples will be analyzed for PCB Aroclors and TOC; based on these data (in consultation with EPA), 10 samples will be selected for analysis of the passive sampler extracts for PCB congeners. The goal is to have 10 samples with total PCB concentrations (Aroclor sums) distributed across the range of concentrations detected in the 20 samples (potentially up to approximately 2,000 µg/kg dry weight [dw]). The 10 corresponding sediment samples will be analyzed for PCB congeners and black carbon.[9] The remaining 10 porewater extracts and sediment samples will be archived.

Details regarding the methodology for conducting this *ex situ* investigation (e.g., type of passive sampler) are presented in Section 4.5 of this QAPP.

2.1.1.4 Evaluation of relationship between total PCBs as sum of Aroclors and total PCBs as sum of congeners

The relationship between total PCBs based on the sum of detected congeners versus the sum of detected Aroclors in LDW sediment was also assessed as part of this QAPP, per the Work Plan (Windward and Integral 2017b).

The existing RI/feasibility study (FS) and post-2010 (Task 2) data were reviewed to identify sediment samples with results for both PCB Aroclors and PCB congeners. These data were evaluated to determine whether total PCBs calculated using an

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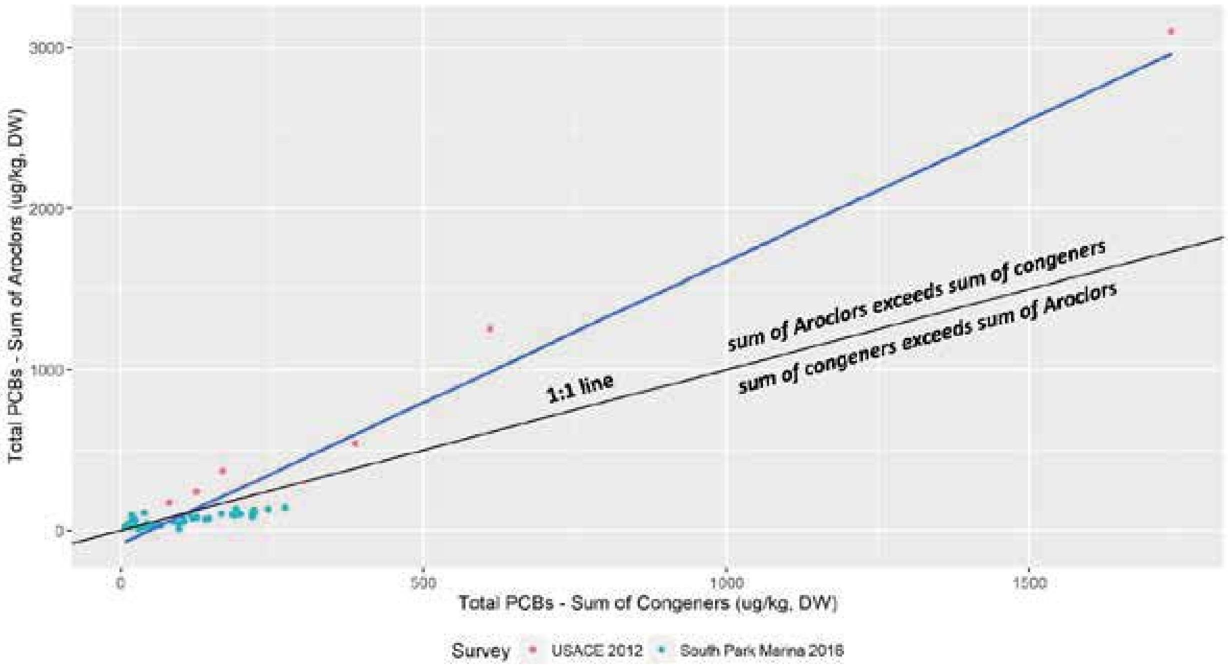
[8] The additional 10 reoccupied RI locations had concentrations as high as 2,154 µg/kg, while the upper limit of the MNR/ENR range is 720 µg/kg (based on the ENR upper limit and assuming 2% TOC). The larger range will increase the likelihood that the actual range of PCB concentrations in samples will be up to 720 µg/kg, and may also be helpful in assessing the relationship between current PCB concentrations in sediment and porewater in MNR/ENR areas.

[9] These 10 sediment samples, along with paired Aroclor-congener results, will be used as described in Section 2.1.1.4.

Aroclor sum and total PCBs calculated using a PCB congener sum appear to be reliably correlated, or whether detectable systematic bias exists for one method to over- or under-estimate the total.

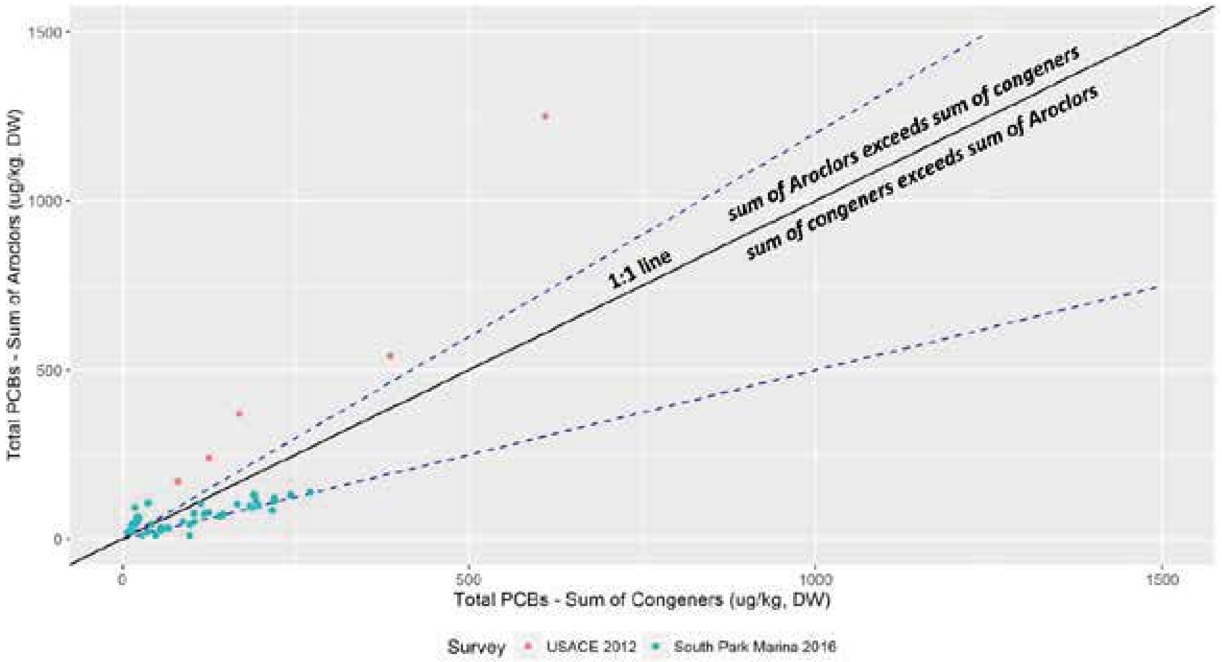
A total of 51 existing sediment samples from 21 unique locations are available from within the LDW with detected PCB Aroclors and congeners. These data are from two sampling events: an LDW-wide sediment characterization conducted for the US Army Corps of Engineers (USACE) in 2012 (HDR et al. 2013), and a focused investigation of the South Park Marina conducted by the Intelligence Group in 2016 (TIG 2016). The USACE characterization included the collection of sediment cores from six locations in the LDW. Samples were analyzed from the 0–2-ft depth at four locations and the 6.5–, 8.5–, and 8–10-ft depths at one location each. The South Park Marina samples were collected from 16 locations in the vicinity of the marina. Three depth intervals were analyzed at each location: a surface sediment sample (0–10 cm) and two subsurface sediment samples (0.3–3.3 and 3.3–6.6 ft). Data from these two studies were evaluated to assess the relationship between the two PCB sums. When the relationship was viewed on a linear scale (Figure 2-1), the correlation coefficient was large (Pearson's $r = 0.97$, $p < 0.001$), indicating a strong correlation between the two sums. However, visual inspection of the graphic suggests that two different trends may be present or that influential data points are present. The correlation is strongly influenced by two samples with PCB concentrations greater than 600 µg/kg dw. Most of the available PCB data were less than 300 µg/kg dw.



The black line is the 1:1 line, indicating perfect agreement between the two sums; the blue line is the best-fit regression line fit to all the data on the linear scale.

Figure 2-1. Relationship between total PCBs as sum of Aroclors and as sum of congeners, linear-scaled axes

To assess how well results from the two methods match one another, the paired sediment data were plotted relative to the 1:1 line (indicating perfect agreement), the analytical variance around the 1:1 line was estimated based on the accuracy limits for the PCB Aroclor analysis of 50 to 120% (Figure 2-2). All of the data points above the 1:1 line, for which the Aroclor sums over-estimate the congener sums, were outside of the analytical variance. Most (82%) of the data points below the 1:1 line, for which the Aroclor sums under-estimate the congener sums, were within the analytical variance.



The black line is the 1:1 line, indicating perfect agreement between the two sums; the dashed lines represent the acceptable analytical variance around the 1:1 line. One sample with PCB concentration greater than 1,500 µg/kg dw is not shown on this plot.

Figure 2-2.Relationship between total PCBs as sum of Aroclors and as sum of congeners, relative to analytical variance

Sediment data from the 10 locations selected for the *ex situ* porewater investigation (Section 2.1.1.3) will be added to the Aroclor/congener sediment dataset when these data are available, and the relationship will be re-evaluated with and without the existing data. Additional data may be collected to better define this relationship in the future. These data will be collected over time for a variety of purposes (including those associated with remediation efforts), and the relationship will be re-evaluated with respect to the questions posed at that time.

2.1.2 Targeted source-related sampling

In addition to the baseline sediment sampling, targeted source-related sampling will be conducted to address the following DQO:

6. Help Ecology assess the sufficiency of contaminant source control through additional near-outfall sediment sampling and bank sampling (EPA 2016c).

2.1.2.1 Near-outfall surface sediment sampling

To assist Ecology in its source evaluation for the LDW, surface sediment (0–10 cm)[10] will be collected near the outfalls recommended by Leidos (2014a)[11] that also meet the screening criteria developed in the Work Plan (Windward and Integral 2017b). Specifically, an attempt will be made to sample sediment near outfalls that fit the following conditions:

- Do not have sufficient data within approximately 50 ft (outfalls with diameters less than or equal to 24 in.) or approximately 100 ft (outfalls with diameters greater than 24 in.)
- Are not near a cleanup site under an Agreed Order or expected to be
- Are expected to be sampleable based on information from Leidos (SAIC 2011; Leidos 2014a) and information gathered during a field reconnaissance effort performed on September 1 and 25, 2017 (see Appendix E)

As discussed in Section 4.1.2.1 of this QAPP, as a result of this screen, a total of 24 source-related surface sediment samples will be collected near 22 outfalls. Near outfalls with no additional nearby sediment data, two samples will be collected. Near outfalls with some existing nearby sediment data, one sample will be collected. Where feasible, samples will be collected within 50 ft of outfalls with diameters less than or equal to 24 in., and within 100 ft of outfalls with diameters greater than 24 in.

Sediment samples will be analyzed for the analytes listed in ROD Table 20 (EPA 2014b). A subset of samples will also be analyzed for dioxins/furans based on existing sediment data (see Section 4.1.2.1). In addition, an archive jar will be filled for samples collected near all other outfalls.

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[10] During its 2011 outfall surface sediment sampling, SAIC collected samples from a depth of 0–10 cm where possible (sample depths ranged from 0–3 to 0–10 cm) (SAIC 2011). Samples from a depth of 0–10 cm are consistent with the SAIC 2011 sampling effort and with other surface sediment samples described in this QAPP. If a 0–10-cm sample cannot be collected from a given location, samples from a depth of less than 10 cm will be retained for analysis (see Section 4.2.2.2).

[11] Leidos (2014a) recommended sediment sampling near outfalls that met the following criteria: 1) the outfall was active or presumed active, 2) it was not adjacent to a cleanup site, and 3) existing post-1999 surface sediment data were not sufficient (i.e., two sediment samples collected within 50 to 100 ft from 2000 to present).

2.1.2.2 Bank soil sampling

Uncharacterized bank soils (0–10 cm)[12] between +4 and +12 ft mean lower low water (MLLW)[13] will also be sampled to assist Ecology in its source evaluation for the LDW, if the bank meets all of the following criteria:

- Bank soils are exposed and potentially erodible (i.e., constructed armoring is absent or of poor integrity).
- The bank is not adjacent to an upland cleanup site under or expected to be under an Agreed Order or an early action.
- Insufficient bank soil data exist.
- The bank soil can be sampled.

Overwater structures prevent characterization in some bank areas. Such areas will be addressed in remedial design.

- After eliminating the bank areas that did not meet these criteria, the remaining uncharacterized exposed bank areas were assessed in a field reconnaissance survey on August 31 and September 1, 2017. The goal of this survey was to determine whether the locations appear to be sampleable based on the presence and condition of overwater structures (which can create unsafe sampling conditions) and the presence and integrity of armoring. Based on this field reconnaissance (see Appendix E), six banks appear to be sampleable; see Section 4.1.2.2 for details.

For each of the six banks, discrete samples will be collected. The number of discrete samples per bank will range from one to three, depending on the length of the bank. Samples will be analyzed for the analytes listed in ROD Table 20 (EPA 2014b). Samples from Bank Area 2 will also be analyzed for dioxins/furans, and an archive jar will be filled for all bank sample locations (see Section 4.1.2.2).

2.1.3 Intertidal surface sediment (0–45 cm) samples

Four DQOs have been identified for the 0-45 cm sediment samples to be collected in potential clamming and beach play areas to establish baseline concentrations and provide a foundation for assessing trends. These DQOs are summarized in Table 2-2.

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[12] In 2011, Hart Crowser collected bank samples for Ecology from a depth of 1–10 cm at 7 of the 8 bank sampling locations (Hart Crowser 2012). To be generally consistent with the Hart Crowser samples, bank samples for this effort will be collected from a depth of 0–10 cm.

[13] This elevation is approximately equal to mean higher high water (MHHW). The National Oceanic and Atmospheric Administration (NOAA) reports MHHW at the Seattle station (Elliott Bay) as +11.36 ft MLLW (NOAA 2013).

Table 2-2. DQOs for intertidal surface sediment samples (0–45 cm)

Step	DQO 7	DQO 8	DQO 9	DQO 10
STEP 1: State the problem.	A synoptic site-wide sediment dataset is needed to assess the baseline condition in potential clamming areas prior to implementation of the sediment remedy.		Sediment concentration data from beach play areas are needed prior to implementation of the sediment remedy.	
STEP 2: Identify the goals of the study.	Establish a baseline, site-wide 95UCL concentration of RAO 2 risk drivers across all potential clamming areas within the LDW.	Establish a baseline, site-wide mean concentration in potential clamming areas to serve as the foundation for assessing temporal trends for RAO 2 risk drivers.	Establish baseline 95UCL concentrations of human health risk drivers for RAO 2 within each of the 8 beach play areas of the LDW.	Establish baseline mean concentrations to serve as a foundation for assessing temporal trends in the 8 beach play areas for RAO 2 risk drivers.
STEP 3: Identify the information inputs.	Spatial area estimates for the potential clamming areas identified in the ROD were used to determine the appropriate number of sampling locations across the entire potential clamming area to achieve approximately spatially proportional sampling.		Spatial area estimates for the beach play areas identified in the ROD were used to determine the appropriate number of locations within each beach play area to achieve approximately proportional sampling by beach.	
STEP 4: Define the boundaries of the study.	The boundaries of the potential clamming areas were defined in the ROD.		The boundaries for each of the 8 beach play areas were defined in the ROD.	
STEP 5: Develop the analytical approach.	The baseline 95UCL will be calculated using a *t*-interval, and will be justified by invoking the CLT due the large number of field samples (n = 72) per analytical sample.	The baseline mean will be estimated as the arithmetic mean of the 3 potential clamming area-wide composites.	The baseline 95UCL will be calculated using the Chebyshev Inequality.	The baseline mean for each beach play area will be estimated as the arithmetic mean of the 3 composites from each beach.
STEP 6: Specify performance or acceptance criteria.	Performance or acceptance criteria are described in Section 4.6, including field QC samples and laboratory QC samples. DQIs for laboratory analyses (i.e., PARCCS) will be met, as described in Section 4.6.			
STEP 7: Develop the detailed plan for obtaining data.	Three site-wide composite samples (each consisting of sediment from up to 72 intertidal locations) will be prepared from samples collected from spatially balanced random locations throughout the potential clamming areas in the LDW. Exact sampling locations will be determined in the field using a transect approach. After the completion of the sampling event, samples will be assigned to 1 of the 3 spatially balanced site-wide composite samples, each composite representing the LDW-wide potential clamming area.		Three composite samples will be assembled for each of the 8 beach play areas (each consisting of sediment from 3 to 9 locations) for a total of 24 composite beach play area samples. Spatially balanced random samples will be collected from each beach play area using a transect approach. The number of sampling locations per beach will be approximately proportional to the size of the beach play area, and will range from 9 samples (i.e., 3 per composite) to 27 samples (i.e., 9 per composite). After the completion of the sampling event, samples from a given beach play area will be assigned to 1 of the 3 spatially balanced beach-specific composites.	

95UCL – 95% upper confidence limit for the mean
CLT – Central Limit Theorem
DQI – data quality indicator
DQO – data quality objective
LDW – Lower Duwamish Waterway
PARCC – precision, accuracy, representativeness, completeness, comparability, and sensitivity
QC – quality control
RAO – remedial action objective
ROD – Record of Decision

2.1.3.1 Intertidal baseline sediment for direct contact RAO 2 – potential clamming areas

The DQOs for the collection and analysis of surface sediment samples (0–45 cm) for RAO 2 in potential clamming areas are as follows:

7. Establish baseline 95UCL concentrations of human health risk drivers for RAO 2 across all potential clamming areas identified in the ROD.
8. Establish baseline site-wide potential clamming area mean concentrations to assess trends following sediment remediation for RAO 2 (direct contact – clamming) risk drivers.

Potential clamming areas will be sampled to assess baseline conditions in these intertidal areas throughout the LDW. Three site-wide composite samples will be prepared from samples collected from up to 216 spatially balanced[14] locations throughout the potential clamming areas in the LDW. As described in Section 4.1.3.1, samples from each potential clamming subarea will be assigned to one of three site-wide composite samples, each consisting of sediment from up to 72 locations. Samples will be assigned to achieve spatial balance. Within each potential clamming subarea, the first location along a transect will be randomly assigned to one of the three composites, and the second location will be randomly assigned to one of the remaining two composites. Thereafter, the locations will follow the same systematic pattern, achieving a similar spatial distribution within each composite. The samples to be included in each composite sample will be documented in a compositing memorandum submitted for EPA approval.

Concentrations in each composite sample represent the site-wide mean concentration; the three composites are independent estimates of the mean. The variance among the composite sample concentrations will be used to calculate the site-wide potential clamming area 95UCL.

The composite samples will be analyzed for human health direct contact COCs (PCBs, total arsenic, cPAHs, and dioxins/furans) identified in ROD Table 19. The samples will also be analyzed for toxaphene, which is identified in ROD Table 14 as a direct contact contaminant of potential concern (COPC) (EPA 2014b).[15]

2.1.3.2 Intertidal baseline sediment for direct contact RAO 2 – beach play areas

The DQOs for the collection and analysis of surface sediment samples (0–45 cm) for RAO 2 in beach play areas are as follows:

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[14] The total number of locations within each potential clamming area is roughly proportional to the size of the area.

[15] ROD Table 14 is titled *Summary of COPCs and Rationale for Selection as COCs for Human Health Exposure Scenarios*.

9. Establish baseline 95UCL concentrations for risk drivers to achieve RAO 2 in each of the eight beach play areas.
10. Establish baseline beach play area-specific mean concentrations to assess trends following sediment remediation for RAO 2 (direct contact – beach play) risk drivers.

Baseline conditions within each of the eight beach play areas will be characterized with three composite samples from each beach play area. The number of locations per composite within each beach play area composite sample will be roughly proportional to the size of each beach play area, varying from 9 samples (3 per composite) to 27 samples (9 per composite) in each of the beach play areas. Concentrations in each composite sample will represent the mean concentration at each beach; thus, the three composites will be independent estimates of the beach-wide mean, capturing small-scale spatial variability as well as sampling and analytical error. The variance among the composite sample concentrations will be used to calculate the 95UCL by beach.

These composite samples will be analyzed for human health direct contact COCs (PCBs, total arsenic, cPAHs, and dioxins/furans) identified in ROD Table 19 (EPA 2014b). The samples will also be analyzed for toxaphene, which is identified in ROD Table 14 as a direct contact COPC.

2.2 PROJECT APPROACH AND SCHEDULE

Two separate sampling events will be conducted to address the 10 surface sediment DQOs described in Section 2.1. Figure 2-3 presents the schedule for the surface sediment sampling events and the porewater investigation.

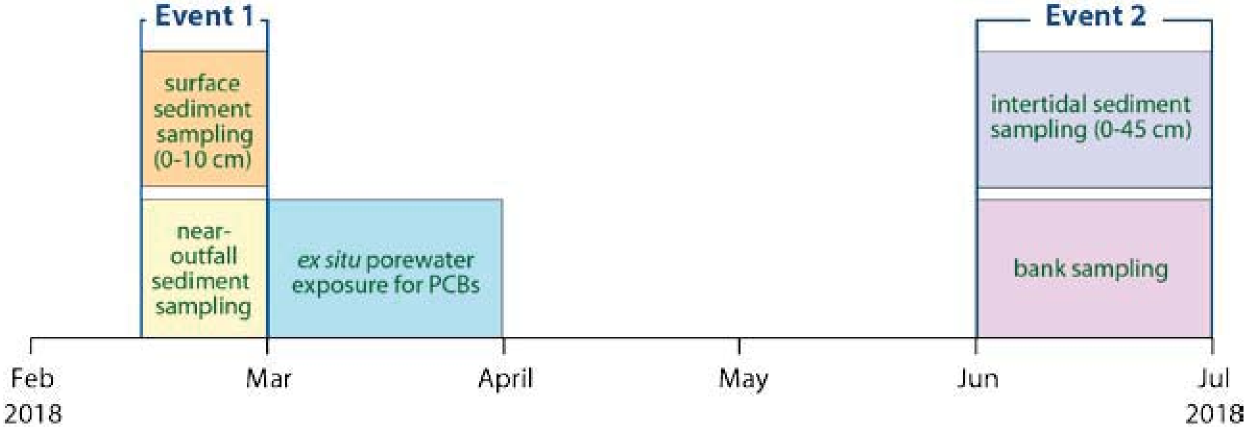

Figure 2-3. Timeline showing target schedule for the two surface sediment sampling events and the *ex situ* porewater laboratory exposure period

Sampling of the 0–10-cm sediment samples (including near-outfall sampling) began in mid-February 2018; the chemical analysis and 28-day *ex situ* porewater laboratory exposures began when the 0–10-cm sediment sampling and compositing was complete. The 0–45-cm and bank soil sampling will be conducted in June 2018 during the period of daytime low tides; targeted sampling days will have low tides of -1.3 ft MLLW or lower.[16] Chemical analysis of the samples will begin when the sampling and the compositing of the 0–45-cm samples is complete. Field conditions or logistics may require deviations from these target timeframes; such deviations will be communicated to EPA as they are realized and noted in the data reports (described below).

Chemical analysis of the samples from each sampling event will require approximately four weeks. Data validation will be completed approximately three weeks after receipt of the chemistry data. EPA will be notified when the final data validation report has been received for each event.

Draft sampling data reports for each event (Work Plan Task 5 (Windward and Integral 2017b)) will be submitted to EPA 21 days after receipt of the final validated analytical results. The first data report will contain the results of Sampling Event 1 in February. The second of the two data reports will contain the results of Sampling Event 2 in June and the *ex situ* porewater investigation results. Draft final data reports will be submitted to EPA 30 days after receipt of EPA's comments on the draft data reports. Final validated data will be submitted to Ecology's Environmental Information Management (EIM) system and EPA's Scribe database within 30 days of the approval of the final data report. Surface sediment and porewater data will be evaluated in the data evaluation report (Work Plan Task 6).

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[16] Near-outfall sediment sampling locations that are not accessible by boat may be sampled from shore at low tide during Sampling Event 2.

3 Project Organization and Responsibilities

The overall project organization and the individuals responsible for the various tasks required for surface sediment sample collection and analysis are shown in Figure 3-1. Responsibilities of project team members, as well as laboratory project managers (PMs), are described in the following sections.

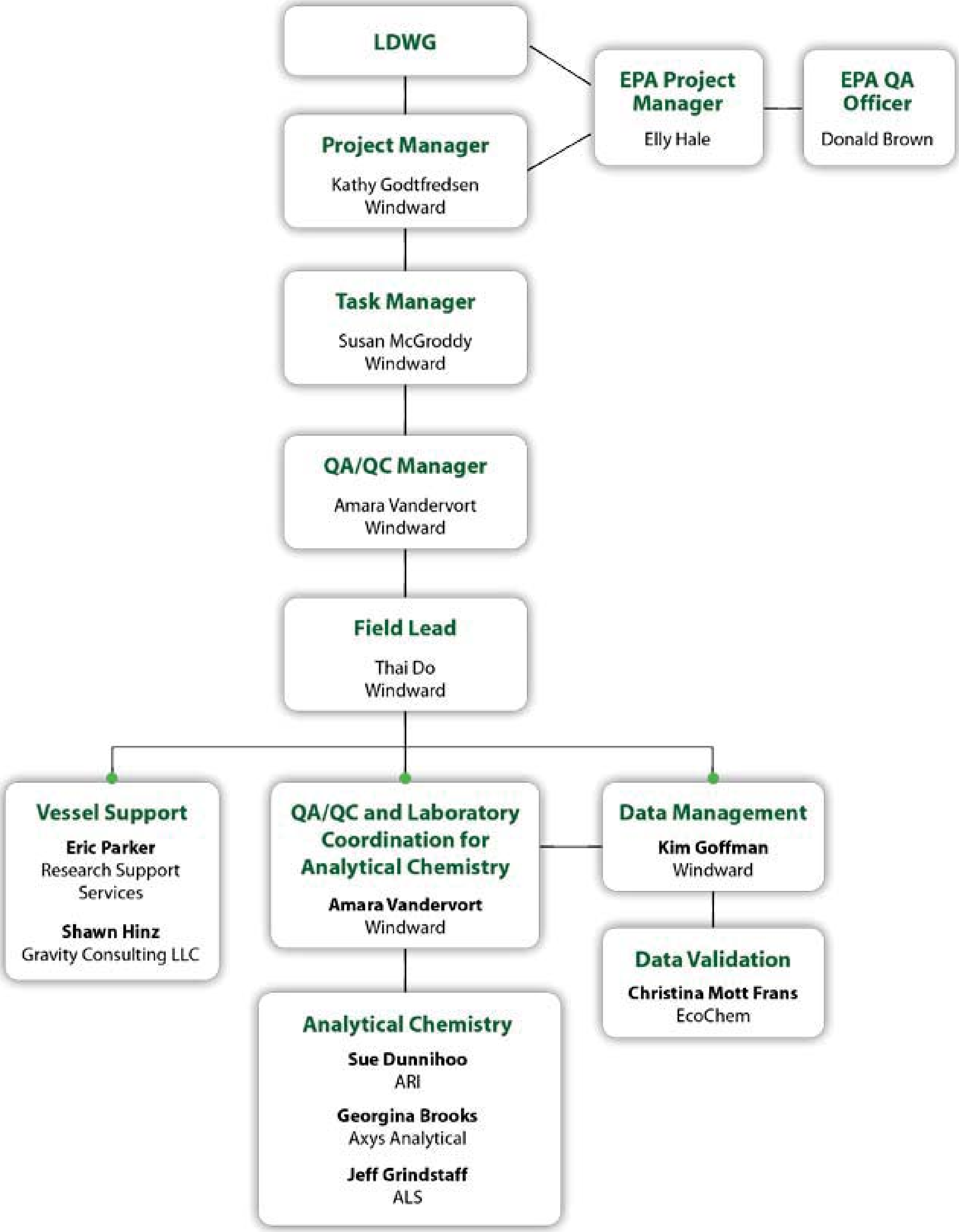

Figure 3-1.Project organization and team responsibilities

3.1 PROJECT MANAGEMENT

Both the Lower Duwamish Waterway Group (LDWG) and EPA are involved in all aspects of this project, including discussion, review, and approval of this QAPP, and interpretation of the results of the investigation. Elly Hale is the EPA PM for the pre-design studies (EPA 2016c).

Kathy Godtfredsen is the Windward Environmental LLC (Windward) PM. In this capacity, she will be responsible for overall project coordination, and for providing oversight for planning and coordination, work plans, all project deliverables, and performance of the administrative tasks needed to ensure timely and successful completion of the project. She will also be responsible for coordinating with LDWG and EPA on schedule, deliverables, and other administrative details. Dr. Godtfredsen can be reached as follows:

Dr. Kathy Godtfredsen
Windward Environmental LLC
200 West Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.577.1283
E-mail: kathyg@windwardenv.com

Susan McGroddy is the Windward monitoring task manager (TM). As TM, she will be responsible for communicating with the Windward PM on the progress of project tasks, conducting detailed planning and coordination, and monitoring and communicating any deviations from the QAPP. Significant deviations from the QAPP will be further reported to representatives of LDWG and EPA. Dr. McGroddy can be reached as follows:

Dr. Susan McGroddy
Windward Environmental LLC
200 West Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5421
E-mail: susanm@windwardenv.com

3.2 FIELD COORDINATION

Thai Do is the Windward field coordinator (FC). As FC, he will be responsible for managing field sampling activities and general field and QA/quality control (QC) oversight. He will ensure that appropriate protocols are observed for sample collection, preservation, and holding times, and will oversee delivery of environmental samples to the designated laboratories for chemical analyses. The FC will report deviations from this QAPP to the TM and PM for consultation. Significant deviations from the QAPP will be further reported to representatives of LDWG and EPA. Mr. Do can be reached as follows:

Mr. Thai Do
Windward Environmental LLC
200 West Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5407[17]
Email: thaid@windwardenv.com

Eric Parker is one of two boat captains. He will be responsible for operating the boat, and will coordinate closely with the FC to ensure that samples are collected in keeping with the methods and procedures presented in this QAPP. Mr. Parker can be reached as follows:

Mr. Eric Parker
Research Support Services
321 High School Road NE D3/563
Bainbridge Island, WA 98110
Mobile: 260.550.5202
Email: eparker@rssincorporated.com

Shawn Hinz is the other boat captain. He will be responsible for operating the boat and will coordinate closely with the FC to ensure that samples are collected in keeping with the methods and procedures presented in this QAPP. Mr. Hinz can be reached as follows:

Mr. Shawn Hinz
Gravity Consulting LLC
32617 Southeast 44th Street
Fall City, WA 98024
Mobile: 425.281.1471
Email: shawn@gravity.com

3.3 QUALITY ASSURANCE/QUALITY CONTROL

Amara Vandervort is the Windward QA/QC coordinator. In this capacity, she will oversee coordination of the field sampling and laboratory programs, and will supervise data validation and project QA coordination, including coordination with the analytical laboratories and the EPA QA officer, Donald Brown. Ms. Vandervort will also maintain the official approved QAPP and ensure that the appropriate parties receive any updated versions of the QAPP. Ms. Vandervort can be reached as follows:

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[17] This is Mr. Do's office phone number. A mobile phone number will be provided prior to field sampling.

Ms. Amara Vandervort
Windward Environmental LLC
200 West Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5415
Email: amarav@windwardenv.com

Mr. Brown can be reached as follows:

Mr. Donald Brown
US Environmental Protection Agency, Region 10
1200 6th Avenue
Seattle, WA 98101
Telephone: 206.553.0717
Email: brown.donaldm@epa.gov

Independent third-party chemical data review and validation will be provided by EcoChem. The PM at EcoChem can be reached as follows:

Ms. Christina Mott Frans
EcoChem
1011 Western Avenue, Suite 1006
Seattle, WA 98104
Telephone: 206.508.2110
Email: cmfrans@ecochem.net

3.4 LABORATORY RESPONSIBILITIES

Amara Vandervort of Windward is the laboratory coordinator for the analytical chemistry laboratories. Analytical Resources, Inc. (ARI) will perform all chemical analyses on the surface sediment samples, with the exception of analyses for dioxins/furans, PCB congeners, and black carbon. Axys Analytical Services Ltd. (Axys) will prepare the porewater passive samplers and perform analyses for PCB congeners and dioxins/furans. ALS Environmental-Kelso (ALS) will perform analyses for black carbon.

The laboratory PM at ARI can be reached as follows:

Ms. Susan Dunnihoo
Analytical Resources, Inc.
4611 South 134th Place
Tukwila, WA 98168-3240
Telephone: 206.695.6207
Email: limsadm@arilabs.com

The laboratory PM at Axys can be reached as follows:

Ms. Georgina Brooks
Axys Analytical Services Ltd.
2045 West Mills Road
Sidney, British Columbia V8L 5X2
Canada
Telephone: 250.655.5801
Email: Georgina.Brooks@sgs.com

The laboratory PM at ALS can be reached as follows:

Mr. Jeff Grindstaff
ALS Environmental-Kelso
1317 13th Avenue South
Kelso, WA 98626
Telephone: 360.577.7222
Email: Jeff.Grindstaff@alsglobal.com

ARI, ALS, and Axys will meet the following requirements:

- Adhere to the methods outlined in this QAPP, including those methods referenced for each procedure.
- Adhere to documentation, custody, and sample logbook procedures.
- Implement QA/QC procedures defined in this QAPP.
- Meet all reporting requirements.
- Deliver electronic data files as specified in this QAPP.
- Meet turnaround times for deliverables as described in this QAPP.
- Allow EPA and the QA/QC manager, or a representative, to perform laboratory and data audits.

3.5 DATA MANAGEMENT

Kim Goffman of Windward will oversee data management, and will ensure that analytical data are incorporated into the LDW database with appropriate qualifiers following acceptance of the data validation. QA/QC of the database entries will ensure accuracy for use in the pre-design studies. Ms. Goffman can be reached as follows:

Ms. Kim Goffman
Windward Environmental LLC
200 West Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5414
Email: kimg@windwardenv.com

3.6 SPECIAL TRAINING/CERTIFICATION

The Superfund Amendments and Reauthorization Act of 1986 required the Secretary of Labor to issue regulations through the Occupational Safety and Health Administration (OSHA) providing health and safety standards and guidelines for workers engaged in hazardous waste operations. Accordingly, 29 Code of Federal Regulations (CFR) 1910.120 requires that employees be given the training necessary to provide them with the knowledge and skills to enable them to perform their jobs safely and with minimum risk to their personal health. All sampling personnel will have completed the 40-hour HAZWOPER training and 8-hour refresher courses, as necessary, to meet OSHA regulations.

Also, ARI and Axys have current environmental laboratory accreditation from Ecology for methods to be performed. Ecology does not offer accreditation for the black carbon method. However, ALS is International Organization for Standardization (ISO) accredited for the instrumental portion of black carbon analysis, which is the only accreditation available for this method.

3.7 DOCUMENTATION AND RECORDS

All field activities and laboratory analyses will be documented following the protocols described in this section. In addition, data reduction rules and data report formats are provided herein.

3.7.1 Field observations

All field activities will be recorded in a field logbook maintained by the FC or designee. The field logbook will provide a description of all sampling activities, conferences between the FC and EPA oversight personnel associated with field sampling activities, sampling personnel, and weather conditions, as well as a record of all modifications to the procedures and plans identified in this QAPP and the HSP (Appendix A). The field logbook will consist of bound, numbered pages, and all entries will be made in indelible ink. Photographs, taken with a digital camera, will provide additional documentation of the surface sediment collection activities and all bank sampling areas. The field logbook is intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the sampling period.

The following field data collection sheets, included as Appendix B, will also be used to record pertinent information after sample collection:

- Surface sediment collection form
- Bank collection form
- Percent moisture benchsheet for *ex situ* porewater investigation
- Exposure setup benchsheet for *ex situ* porewater investigation

- Daily conditions benchsheet for *ex situ* porewater investigation
- Protocol modification form

Information regarding equipment calibration and other sampling activities will be documented in the field logbook.

3.7.2 Laboratory records

ARI, ALS, and Axys will be responsible for internal checks on sample handling and analytical data reporting and will correct errors identified during the QA review. The laboratory data packages will be submitted electronically and will include the following, as applicable:

- **Project narrative**: This summary, in the form of a cover letter, will present any problems encountered during any aspect of sample analyses. The summary will include, but not be limited to, discussion of QC, sample shipment, sample storage, and analytical difficulties. Any problems encountered by the laboratory will be documented, as will their resolutions. In addition, operating conditions for instruments used for the analysis of each suite of analytes and definitions of laboratory qualifiers will be provided.
- **Records**: Legible copies of the chain of custody forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented.
- **Sample results**: The data package will summarize the results for each sample analyzed. The summary will include the following information, as applicable:
    - Field sample identification (ID) code and the corresponding laboratory ID code
    - Sample matrix
    - Date of sample extraction/digestion
    - Date and time of analysis
    - Weight used for analysis
    - Final dilution volumes or concentration factor for the sample
    - Percent solids in the samples
    - Identification of the instruments used for analysis

  - Method detection limits (MDLs)[18] and RLs[19]
  - All data qualifiers and their definitions
- **QA/QC summaries:** These summaries will contain the results of all QA/QC procedures. Each QA/QC sample analysis will be documented with the same information required for the sample results (see above). The laboratory will make no recovery or blank corrections, except for isotope dilution method correction prescribed in EPA methods 1613b and 1668c. The required summaries will include the following information, as applicable:
  - The calibration data summary will contain the concentrations of the initial calibration and daily calibration standards and the date and time of analysis. The response factor, percent relative standard deviation (%RSD), relative percent difference (RPD), and retention time for each analyte will be listed, as appropriate. Results for standards analyzed to indicate instrument sensitivity will be reported.
  - The internal standard area summary will report the internal standard areas, as appropriate.
  - The method blank analysis summary will report the method blank analysis associated with each sample and the concentrations of all compounds of interest identified in these blanks.
  - The surrogate spike recovery summary will report all surrogate spike recovery data for organic analyses. The names and concentrations of all compounds added, percent recoveries, and QC limits will be listed.
  - The labeled compound recovery summary will report all labeled compound recovery data for EPA methods 1613b and 1668c. The names and concentrations of all compounds added, percent recovery, and QC limits will be listed.
  - The matrix spike (MS) recovery summary will report the MS or MS/matrix spike duplicate (MSD) recovery data for analyses, as appropriate. The names and concentrations of all compounds added, percent recoveries, and QC limits will be included. The RPD for all MS and MSD analyses will be reported.
  - The matrix duplicate summary will report the RPD for all matrix duplicate analyses. The QC limits for each compound or analyte will be listed.

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[18] The term MDL includes other types of detection limits (DLs), such as estimated detection limit (EDL) values calculated for PCB congeners and dioxin/furan congeners.

[19] RL values are consistent with the lower limit of quantitation (LLOQ) values required under EPA-846.

  - The standard reference material (SRM) analysis[20] summary will report the results of the SRM analyses and compare these results with published concentration ranges for the SRMs.
  - The LCS analysis summary will report the results of the analyses of LCSs. The QC limits for each compound or analyte will be included.
  - The relative retention time summary will report the relative retention times for the primary and confirmational columns of each analyte detected in the samples and the percent difference between the columns, as appropriate.
  - The ion abundance ratio summary for samples analyzed by EPA methods 1613b and 1668c will report computed ion abundance ratios compared to theoretical ratios listed in the applicable method.
- **Original data**: Legible copies of the original data generated by the laboratory will be provided, including the following:
  - Sample extraction/digestion, preparation, and cleanup logs
  - Instrument specifications and analysis logs for all instruments used on days of calibration and analysis
  - Reconstructed ion chromatograms for all samples, standards, blanks, calibrations, spikes, replicates, LCSs, and SRMs
  - Enhanced and unenhanced spectra of target compounds detected in field samples and method blanks, with associated best-match spectra and background-subtracted spectra, for all gas chromatography/mass spectrometry (GC/MS) analyses
  - Enhanced and unenhanced spectra of target performance reference compounds (PRCs) detected in field samples, day-zero blank, field blank, and method blanks, with associated best-match spectra and background-subtracted spectra, for all GC/MS analyses
  - Quantitation reports for each instrument used, including reports for all samples, blanks, calibrations, MSs/MSDs, laboratory replicates, LCSs, and SRMs

ARI, ALS, and Axys will submit data electronically, in EarthSoft EQuIS® standard four-file or EZ_EDD format. Guidelines for electronic data deliverables for chemical data are provided on the EarthSoft website, http://www.earthsoft.com/en/index.html, and additional information will be communicated to ARI, ALS, and Axys by the project QA/QC coordinator or data

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[20] SRMs will be analyzed for polycyclic aromatic hydrocarbons (PAHs), PCB Aroclors, dioxins/furans, and PCB congeners. All other analyses will include a laboratory control sample (LCS). Specific information is listed in Section 4.7.

manager. All electronic data submittals must be tab-delimited text files with all results, MDLs (as applicable), and RLs reported to the appropriate number of significant figures. If laboratory replicate analyses are conducted on a single submitted field sample, the laboratory sample identifier must distinguish among the replicate analyses.

3.7.3 Data reduction

Data reduction is the process by which original data (analytical measurements) are converted or reduced to a specified format or unit to facilitate analysis of the data. Data reduction requires that all aspects of sample preparation that could affect the test result, such as sample volume analyzed or dilutions required, be taken into account in the final result. It is the laboratory analyst's responsibility to reduce the data, which are subjected to further review and reduction by the laboratory PM, the Windward TM, the QA/QC coordinator, and independent reviewers. The data will be generated in a format amenable to review and evaluation. Data reduction may be performed manually or electronically. If performed electronically, all software used must be demonstrated to be true and free from unacceptable error.

3.7.4 Data report

Two data reports will be prepared documenting all activities associated with the collection, handling, and analysis of samples, as specified in Task 5 of the third amendment to the AOC (EPA 2016c). The first data report will document Sampling Event 1 and present the analytical results for the 0–10-cm sediment samples. The second data report will document the Sampling Event 2 and present the analytical results for any near-outfall samples that were collected during low tide, bank samples, and 0–45-cm sediment samples, as well as the analytical results of the *ex situ* porewater investigation.

The following information will be included in each data report:

- Summary of all field activities, including descriptions of any deviations from the approved QAPP
- Sampling locations reported in latitude and longitude to the nearest one-tenth of a second and in northing and easting to the nearest foot
- Summary of the chemical data QA/QC review
- Results from the analyses of field samples and *ex situ* analyses, included as summary tables in the main body of the report, data forms submitted by ARI, ALS, and Axys, and cross-tab tables produced from Windward's database
- Copies of field logs and photographs (appendix)
- Copies of chain of custody forms (appendix)
- Data validation report (appendix)

Once each data report has been approved by EPA, a database export will be created from Windward's database. The data will be exported in two formats: one that is compatible with Ecology's EIM system, and one that is compatible with EPA's Scribe database.

3.7.5 Data storage and backup

All electronic files related to the project will be stored on a secure server on Windward's network. The server contents are backed up on an hourly basis, and a copy of the backup is uploaded nightly to a secure off-site facility.

4 Data Generation and Acquisition

Surface sediment samples will be collected, processed, and analyzed according to the procedures described in this section. In addition, methods for the *ex situ* porewater investigation are described herein. QA/QC, instrument maintenance and calibration, non-direct measurement, and data management requirements are also provided.

4.1 SAMPLING DESIGN

Sampling design components for sediment collections are detailed in the following sections. The study designs for the collection of the 0–10-cm surface sediment grab samples, related composites, and sediment samples for the *ex situ* porewater investigation are described in Section 4.1.1. The analyses to determine the locations for targeted source-related sampling of sediments near outfalls and banks are presented in Section 4.1.2. The study designs for the intertidal 0–45-cm surface sediment composite samples from potential clamming areas and the eight beach play areas are detailed in Section 4.1.3.

4.1.1 Surface sediment samples (0–10 cm)

This section presents the sampling design for the 0–10-cm surface sediment samples that will be collected to evaluate DQOs 1 through 5 (Table 2-1). The sampling design used to characterize surface sediment concentrations was statistically based to ensure unbiased coverage of the LDW to generate the data needed for the DQOs.

Random sampling was used to satisfy DQOs 1 and 2. A subset of these samples was augmented with non-random sampling (i.e., reoccupation of RI locations) to provide data for DQOs 3 through 5. An overview of the design is presented in Table 4-1, and details about the sample sizes and how the sampling locations were selected for each DQO are presented below.

Table 4-1. Overview of 0–10-cm surface sediment sampling approach

Design Component	Approach			
	DQOs 1 and 2 – Site-wide 95UCL and SWAC	**DQO 3 – Point-by-Point Evaluation**	**DQO 4 – Trend Support**	**DQO 5 – *Ex Situ* Porewater Evaluation**
Sediment sample type	composites of grab samples	individual grab samples	individual grab samples	individual grab samples
Sample size	24 composite samples (7 grab samples each)	20 grab samples	10 grab samples	20 grab samples
Sampling locations	168 random locations spatially balanced across the LDW	20 locations (10 reoccupied RI locations and 10 random) within MNR areas.	10 reoccupied RI locations within MNR areas	20 candidate locations with targeted PCB concentrations based on RI/FS data

95UCL – 95% upper confidence limit for the mean
DQO – data quality objective
LDW – Lower Duwamish Waterway
MNR – monitored natural recovery
PCB – polychlorinated biphenyl
RI/FS - remedial investigation/feasibility study
SWAC - spatially weighted average concentration

The sampling design for collecting the baseline surface sediment samples that will be used to estimate the site-wide 95UCL and the SWAC (DQOs 1 and 2) is based on a spatially balanced random sampling design with composite samples.

Locations

A spatially balanced random sampling design was used because it provided an efficient way to ensure that the dataset had an equal chance of capturing all areas within the waterway while avoiding randomly clustered sampling locations that could overly influence mean and variance. Spatial balance was achieved using a stratified design, which placed one sample per grid cell in each approximately equally sized grid cell.

Sample Size

The total number of grid cells selected to characterize the site-wide average (as SWAC and 95UCL) was based on simulated variance estimates and EPA direction (Section 2 of Appendix A to the Work Plan (Windward and Integral 2017b)). The sampling design included 24 composite samples of 7 samples each (for a total of 168 field samples), and used an irregular grid of 168 cells of approximately equal area. This approach is expected to result in a relative margin of error (RME)[21] for the mean of 25% or less,[22] which is less than analytical variability.[23]

Once collected, the surface sediment samples from these 168 cells will be combined into 24 composite samples for analysis (Map 4-1), and individual samples will be archived. Each composite sample will contain seven samples from neighboring grid cells (Map 4-1). The composite areas and the remedy technology assignments (as preliminarily mapped in the ROD Figure 18 (EPA 2014b)) are provided in Map 4-2.

In future years of monitoring, the number of samples per composite should remain consistent to maintain year-to-year comparability of the datasets. However, the numbers of field samples and composite samples may change in response to updated information about site variance, and to achieve a desired RME for the site-wide mean. In this way, a robust site-wide SWAC and 95UCL can be calculated for each sampling event.

A total of 188 0–10-cm surface sediment samples will be collected. The 168 random locations (sample locations 1 through 168 on Map 4-3) will contribute to the site-wide composites to address DQOs 1 and 2. Ten of the random locations that are located in MNR areas will also be analyzed for SMS analytes as individual samples to address DQOs 3 and 4 (Table 4-2). In addition, 10 reoccupied RI locations will also be analyzed for SMS analytes to address DQOs 3 and 4. To address DQO 5, splits from the 10 reoccupied RI locations and samples from 10 additional locations will be analyzed for PCBs (Table 4-2).

Table 4-2. Location and rationale for 0–10-cm grab samples to be analyzed individually

Sample Location	RM	Reoccupied RI Location	PCB Conc. (µg/kg)	DQO 3	DQO 4	DQO 5
Random locations within MNR areas (sample splits)						
8	0.1	na	na	X	X	
23	0.5	na	na	X	X	
40	0.7	na	na	X	X	
52	0.9	na	na	X	X	
69	1.4	na	na	X	X	
91	2.1	na	na	X	X	
101	2.4	na	na	X	X	

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[21] RME is measured as the width of the 95UCL as a percent of the mean.

[22] The expectation of 25% RME or better for the mean was based on a normal distribution and a coefficient of variation of 0.7, or less, for the composite sample dataset.

[23] The analytical precision required by EPA functional guidelines for the analytical methods typically used in sediment characterization ranges from 20 to 50%, comparable to a range of 16 to 42% for RME as defined for this project.

Sample Location	RM	Reoccupied RI Location	PCB Conc. (µg/kg)	DQO 3	DQO 4	DQO 5
130	3.5	na	na	X	X	
143	4.1	na	na	X	X	
161	4.7	na	na	X	X	
Reoccupied RI locations						
169	0.3	DR005	168	X	X	X
170	0.6	DR010	74	X	X	X
171	0.6	DUD040	620			X
172	0.6	LDW-SS312	1,010			X
173	0.7	DR083	567			X
174	0.7	WIT288	340	X	X	X
175	0.8	LDW-Pilot 4B-SS4	1,640			X
176	1.0	LDW-SS321	450			X
177	1.5	LDW-SS57	750			X
178	1.6	DR092	64	X	X	X
179	2.1	DR111	311 (1998), 176 (2004)	X	X	X
180	2.2	2154-DSS-21	1,520			X
181	2.2	DR139	2,830			X
182	2.2	B5a-2	1,730			X
183	2.5	WRC-SS-B3	18	X	X	X
184	3.0	WIT270	100	X	X	X
185	3.7	SD-336-S	250			X
186	3.9	DR258	62	X	X	X
187	4.5	DR290	170	X	X	X
188	5.0	DR276	32	X	X	X

DQO – data quality objective
PCB – polychlorinated biphenyl
MNR – monitored natural recovery
na – not applicable or available
RI – remedial investigation
RM – river mile
SCO – sediment cleanup objective

4.1.2 Targeted source-related sampling

In addition to the baseline sediment samples discussed in Sections 4.1.1 and 4.1.3, targeted source-related sediment sampling will be conducted to address DQO 6 to "help Ecology assess the sufficiency of contaminant source control through additional near-outfall sediment sampling and bank sampling" (EPA 2016c).

4.1.2.1 Near-outfall sediment sampling

Near-outfall sediment samples (0–10-cm) will be collected as part of targeted source-related sampling. In 2014, Leidos conducted an assessment to identify sediment data gaps near outfalls, evaluate the feasibility of filling those gaps, and provide information needed to conduct additional outfall sediment sampling (Leidos 2014a). The list that Leidos developed was then screened against additional criteria presented in the Work Plan and in Figure 4-1 herein (Windward and Integral 2017b).

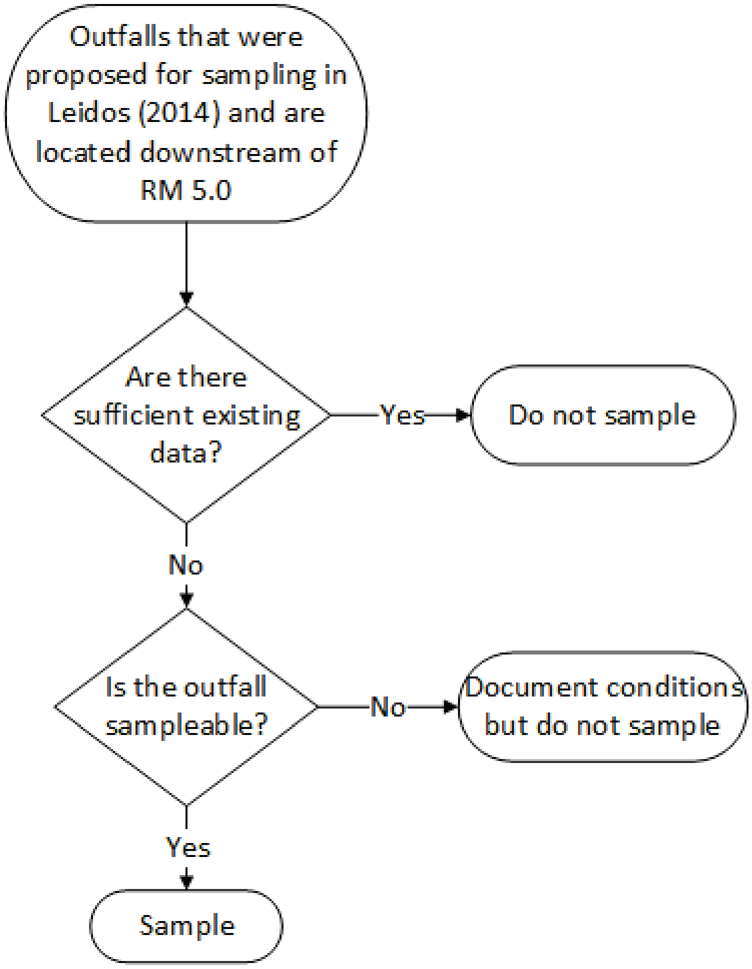

Figure 4-1.Selection criteria for sampling sediment near active outfalls

Leidos (2014a) recommended 68 outfalls for additional sediment sampling. Eight of these outfalls are located outside of the site boundaries or have not been located: five (Outfalls E&E-2, E&E-3, E&E-4, 3842, and 3921) are located south of river mile (RM) 5.0, two (Outfalls 8132 and 8133) are located north of RM 0.0, and the location of Outfall 2167 is unknown. All of these outfalls were therefore excluded. The remaining 60 outfalls are circled on Map 4-4.

To determine whether sufficient surface sediment data exist in the vicinity of these 60 outfalls, all available surface sediment data[24] within approximately 50 ft of outfalls with diameters of 24 in. or less, and within approximately 100 ft of outfalls with diameters greater than 24 in., were considered (Map 4-4). Of the 60 outfalls, 26 had sufficient surface sediment sample locations within approximately 50 or 100 ft (Table 4-3). These 26 outfalls will not be sampled.

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[24] All data from the RI/FS dataset were considered, as well as those compiled as part of Task 2 of the Work Plan (Windward and Integral 2017b).

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
2156	0	18	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate			0
2151	0	12	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate			0
HRE-1	0	18	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate			0
2154	0	6	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate			0
S Nevada St SD	0.3 E	18	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate		"never been found," per Ecology	0
2225	0.6 E	18	screen out (sufficient data)	1		1 sample within 50-ft buffer zone and 4 additional samples within 135 ft		0
2003	0.7 E	12	try to sample during low tide	0	did not sample during Phase I because of riprap/rocky substrate (but noted that sampling may be possible by foot during low tide)	existing sediment sample within 61 ft; outfall is within potential Clamming Subarea 3; will collect a sample during Sampling Event 2		1
2006	0.7 E	12	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate		outfall plugged, per King County	0
FedCtrS	0.8 E	unknown	sample	0		two existing sediment samples within 100 ft; outfall in potential Clamming Subarea 3; will collect a sample during Sampling Event 2		1

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
2005	0.9 E	8	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate			0
2004	0.9 E	8	screen out (not sampleable due to dock)	0	did not sample during Phase I because of obstructions (dock)			0
2014	1.6 E	24	screen out (not sampleable due to riprap/rocky substrate)	0	did not sample during Phase I because of riprap/rocky substrate			0
GlacierNW- CBP	1.7 E	unknown	sample	0		located in Slip 2, numerous other samples in slip		1
GenBiodiesel	1.7 E	not reported	sample	0		located in Slip 2, numerous other samples in slip		1
2503 (1st Ave. S Bridge SD)	2.0 E	36	screen out (sufficient data)	0	collected 1 sample near mouth of 100-ft drainage ditch where outfall is located	not sampleable due to riprap and other armoring		0
SCS Refd Services	2.1 E	unknown	screen out (not sampleable due to overwater structures and armoring)	0		located in Slip 3; not sampleable due to structures and armoring (wooden piles and riprap) along the shoreline		0
Seattle Dist Ctr	2.1 E	10	sample	0		near Outfall 2025 at head of Slip 3, numerous other samples in vicinity at head of Slip 3		1
2025	2.1 E	unknown	screen out (sufficient data)	1		1 sample within 50 ft and 3 additional samples within 135 ft at the head of Slip 3; located near Seattle Dist Ctr; unclear if 2025 is an outfall or seep		0

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
Dawn Foods	2.3 E	unknown	sample	1		1 sample within 50-ft buffer	Per the City of Seattle, this outfall drains stormwater from 6 catch basins on the Dawn Foods property. Dawn Foods has identified a pipe that enters its collection system from off-site to the south (Seattle Boiler Works), but no additional information is available. A riprap bank exists.	1
Clean-Scapes B	2.7 E	unknown	sample	0		9 samples within 235 ft; two of these samples just outside 50 ft but are older; outfall is within potential Clamming Subarea 10; will collect a sample during Sampling Event 2		1
2052	2.9 E	30	screen out (sufficient data)	6				0
2088	4.4 E	36	screen out (sufficient data)	3				0
BDC-1	4.4 E	unknown	screen out (sufficient data)	1		1 sample within 50 ft and 2 additional samples within 75 ft; located within 34 ft of Outfall 2088		0
2087	4.4 E	36	screen out (sufficient data)	8				0
2085	4.5 E	36	screen out (sufficient data)	5				0
BDC-3	4.7 E	unknown	screen out (sufficient data)	1		1 sample within 50 ft and 11 samples within 165 ft		0

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
E&E-1	5.0 E	unknown	screen out (sufficient data)	1		1 sample within 50 ft and 5 samples within 110 ft		0
8134	0.0 W	na	sample	0		outfall reportedly located in a ditch; will attempt to collect 1 sample in the ditch if ditch can be located		1
2232	0.2 W	18	screen out (sufficient data)	0		3 samples within 80 ft		0
2157	0.4 W	24	screen out (not sampleable due to dock)	1	did not sample during Phase I because of obstructions (dock extending over and beyond outfall)	could not see outfall during recon because of the large over-water structure and barges		0
2226 (Herring's House Park)	0.5 W	na	sample if accessible	0	did not sample during Phase I because property access was unavailable	outfall is a creek; access may be difficult by land, and there is riprap in and near the creek; shoreline area north of creek covered by a wooden pier; access limited		1
Evergreen Trails	0.5 W	unknown	screen out (sufficient data)	2		2 samples within 50 ft and 2 additional samples within 100 ft		0

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
T107 Park	0.6 W	unknown	sample	0		area is shallow, contains riprap, and is in potential Clamming Subarea 2; will try to collect a sample during Sampling Event 2	Per the City of Seattle, SoundEarth (2011) refers to a pipe outlet that was observed near the ravine on the northern portion of the T-107 park property during a site reconnaissance; no flow was observed, and the location of the pipe inlet is unknown. In addition, a stormwater pipe with input from a catch basin located near the public parking lot transmits water to a grass swale. Area is largely undeveloped. There are no known historical sources.	1
5005	1.2 W	48	screen out (sufficient data)	2		2 within 100 ft and 3 within 125 ft; approximately co-located with Outfall 2137		0
2137	1.2 W	24	screen out (sufficient data)	0	did not sample during Phase I because location overlaps with Outfall 5005 (only planned for adjacent sample)	outfall is located adjacent to Outfall 5005		0
AML-DP2	1.3 W	unknown	screen out (sufficient data)	1		1 sample within 50 ft and an additional 4 samples located within 130 ft; almost co-located with Outfall AML-DP3		0

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
AML-DP3	1.3 W	unknown	screen out (sufficient data)	0		5 samples located within 135 ft; almost co-located with Outfall AML-DP2		0
2220	1.8 W	20	screen out (sufficient data, over-water structure, and riprap/rocky substrate)	1	did not sample during Phase I because of obstructions (bulkhead) and riprap/rocky substrate	1 sample within 50-ft buffer; outfall located at edge of over-water structure; likely riprap/rocky substrate in vicinity based on Leidos notes		0
2123	1.9 W	12	screen out (sufficient data)	1		1 sample within 50 ft and 4 additional samples within 115 ft; located within 45 ft of Outfall 2124		0
2124	1.9 W	18	screen out (sufficient data)	1		1 sample within 50 ft and 4 additional samples within 115 ft; located within 45 ft of Outfall 2123		0
2505	2.0 W	12	screen out (sufficient data)	1	did not sample during Phase I because of lack of DGPS while collecting on foot	1 sample within 50 ft and 5 additional samples within 135 ft		0
2507	2.1 W	8	sample	0		outfall is under the 1st Ave. Bridge and is in potential Clamming Subarea 7; will collect a sample during Sampling Event 2	Per the City of Seattle, these outfalls are believed to be bridge drains. The outfalls, both of them small, are located in the channel downstream of a large wetland by SR99. There is likely scour in this channel.	1-2 as possible
2510	2.1 W	8	sample	0		outfall is under the 1st Ave. Bridge and is in potential Clamming Subarea 7; will collect a sample during Sampling Event 2		

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
2509	2.1 W	12	sample	0		outfall is under the 1st Ave. Bridge and is in potential Clamming Subarea 7; will collect a sample during Sampling Event 2	Per the City of Seattle, this outfall is believed to be a bridge drain, but it appears to be at the same location as Outfall 2121. It is not clear whether this is a separate outfall. This location needs to be verified. There are 3 outfalls in this area.	1
2116	2.3 W	6	screen out (sufficient data at similar outfalls)	1	did not sample during Phase I because of riprap/rocky substrate (but noted that sampling may be possible by foot during low tide)	1 sample within 50-ft buffer; Outfall 2116 appears to drain the same property and operations as Outfalls Boyer-1, Boyer-2, and 2115, for which there are 10 additional samples within 115 ft		0
2114	2.4 W	6	sample if accessible	0	did not sample during Phase I because of obstructions (barges continuously docked in front of outfall)	could not see outfall during recon because of boats and barges in front of outfall		1 (if possible)

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
5th Ave S	2.5 W	unknown	sample	1		1 sample within 50-ft buffer zone but was only analyzed for grain size and PCBs; access could be an issue; outfall is located in potential Clamming Subarea 9; to collect a sample during Sampling Event 2	Per the City of Seattle, surface discharge is at the end of 5th Avenue South. According to the United Iron Works SWPPP, surface runoff from this and several other facilities discharges to the LDW at this location. Neighbors occasionally cut an opening through the bank at this location to discharge stormwater that backs up on 5th Avenue South/South Fontanelle Street. This is an area where the river overtops the bank during king tides.	1 (if possible)
2113 (S Webster St SD)	2.6 W	6	screen out (sufficient data and potential obstructions)	0	did not sample during Phase I because of obstructions (dock and catwalk on either side)	5 samples within 120 ft and uncertainty related to over-water structures		0
2110	2.9 W	15	screen out (sufficient data)	0	did not sample during Phase I because of obstructions (outfall located behind dock, crane, and catwalk)	1 sample located within 55 ft; adjacent to Outfall 2109		0

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
2109	2.9 W	11	sample if accessible	0	did not sample during Phase I because of obstructions (barges continuously docked in front of outfall)	appears sampleable now (no barges in front of outfall during recon); sample will be collected in vicinity of Outfall 2109 and Outfall 2110	Per the City of Seattle, outfall is near the end of South Chicago Street. Independent Metals currently operates on this parcel. There are multiple outfalls and sources along the shoreline opposite the former Independent Metals Plant 2 site. Stormwater from the on-site treatment system (Metals Rx) was discharged via Outfall L2106, but the entire shoreline was stacked with materials.	2
2215 (16 Ave S Bridge [west])	3.4 W	12	sample	0		numerous existing samples nearby; outfall is located in potential Clamming Subarea 13; will collect a sample during Sampling Event 2	Per King County, the County built a bioretention system to treat runoff from South Park Bridge.	1
South Park Marina	3.4 W	unknown	screen out (cleanup site)	0		South Park Marina is a cleanup site		0
2101	4.0 W	18	sample	0		numerous existing samples nearby		1
2100A (North Fork Hamm Creek)	4.2 W	72	sample	0				2
Delta Marine	4.2 W	unknown	sample	0		existing sample nearby		1

Table 4-3. Summary of screen to determine which areas to sample for sediment near outfalls

Outfall[a]	Location (approx. RM)	Outfall Diameter (in.)	Preliminary Assessment	No. of Sample Locations Within 50 or 100 ft[b]	Note from Leidos Documents on Sampleability	Notes from Windward: Sampleability Recon and Data Assessment	Additional Notes	Proposed No. of Samples
2205 (South Fork Hamm Creek)	4.3 W	na	screen out (sufficient data)	1		1 sample within 50 ft analyzed for TOC, grain size, and PCBs only; outfall is a creek; source tracing data indicate source control sufficiency (Leidos 2015; King County [in prep]).		0
DuwSD#3	4.4 W	8	sample	0		existing sample nearby; outfall in potential Clamming Subarea 15; will collect a sample during Sampling Event 2		1
2201	4.6 W	36	screen out (sufficient data)	1	did not sample during Phase I because property access was unavailable (property owned by Muckleshoot Tribe)	1 sample within 100-ft buffer zone and 3 additional samples within 130 ft		0
Ditch #1	4.7 W	na	screen out (sufficient data)	0		outfall is a ditch with 3 existing samples; existing data do not show exceedances except for 1 PCB exceedance that could not be replicated		0
Ditch #2	4.9 W	na	sample	0		outfall is a ditch, which will be sampled if possible		1 (in ditch)

Note: Leidos documents include Phase 1 data report (including field forms) and Phase 2 scoping document.

[a] Source: Leidos (2014b)

[b] This column lists the numbers of sample locations within 50 ft (outfall diameter ≤ 24 in.) or 100 ft (outfall diameter > 24 in.) from all RI/FS and Task 2 data.

City – City of Seattle
Ecology – Washington State Department of Ecology
DGPS – differential global positioning system
LDW – Lower Duwamish Waterway
LDWG – Lower Duwamish Waterway Group
PCB – polychlorinated biphenyl
RAL – remedial action level
RI/FS – remedial investigation/feasibility study
RM – river mile
SD – storm drain
SoundEarth – SoundEarth Strategies, Inc.
SWPPP – stormwater pollution prevention plan
T-107 – Terminal 107
Windward – Windward Environmental LLC

Sampleability of sediment near the remaining 34 outfalls was assessed based on information provided by Leidos (2014a) and SAIC (2011) and a limited-scope field reconnaissance performed by boat on September 1 and September 25, 2017 (see Appendix E for field notes). Sediment near 2 of these 34 outfalls (Outfalls 2004 and 2157) was determined to not be sampleable based on their locations (under large docks). Sediment near 9 of these 34 outfalls was determined not likely to be sampleable because of riprap/rocky substrate (Leidos 2014a), although sediment near 1 of these outfalls may be sampleable by foot at a lower tide (SAIC 2011). Sediment at the SCS Refd Services outfall was determined not to be sampleable due to both overwater structures and riprap. Therefore, sediment near 11 of the 34 remaining outfalls is not considered sampleable. The area near a South Park Marina outfall was eliminated because it is adjacent to a cleanup site.

The remaining 22 outfalls are targeted for sampling (Map 4-5). Either one or two samples will be collected from the vicinity (50 or 100 ft, depending on outfall diameter) of each outfall. The number of samples specified per outfall is dependent on the number of existing surface sediment locations within, or close to, the 50- or 100-ft radius. Based on these criteria, a total of 24 surface sediment samples are targeted (Table 4-3). This sampling design will not generally result in adjacent, upstream, and downstream samples within the 50- or 100-ft radius at each outfall (the original Ecology goal). However, because sampling near these outfalls is difficult (as noted based on earlier sampling attempts[25]), Ecology has deemed this design sufficient to fill remaining data gaps. Section 4.2.2.2 provides information on field contingencies.

Per the Work Plan (Windward and Integral 2017b), all near-outfall sediment samples will be analyzed for the analytes listed in ROD Table 20. Dioxins/furans will also be analyzed in samples collected near Outfalls 2226, T107 Park, 2507, Seattle Dist Ctr, 5th Ave South, CleanScapes B, and 2100A, based on existing surface sediment data (Map 4-6). Archives will be kept of all near-outfall samples. Archived samples will be analyzed for dioxins/furans, unless existing information indicates or suggests dioxins/furans data are not needed at a given location.[26] Data considered in these decisions will include all existing data and surface sediment data collected pursuant to this QAPP. EPA and Ecology will be consulted prior to finalizing which additional near-outfall sediment samples will be analyzed for dioxins/furans.

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[25] Ecology has previously attempted to collect three samples near each outfall: adjacent to, upstream, and downstream of the direction of flow from the outfall (Leidos 2014a).

[26] Pursuant to Ecology's source control strategy, use of the remedial action level (RAL) is sufficient for source control for constituents without SMS (e.g., dioxins/furans) (Ecology 2016).

4.1.2.2 Bank soil sampling

Uncharacterized exposed bank areas between +4 and +12 ft MLLW[27] will also be sampled to assist Ecology in source control.

In 2016, Leidos produced maps for Ecology delineating exposed bank areas on the LDW that had not been characterized (LDWG 2016). This delineation was based on areas identified as exposed bank in the LDW FS (AECOM 2012), and on bank locations sampled in 2011 by Hart Crowser for Ecology (Hart Crowser 2012). Based on its assessment, Leidos identified 10 exposed banks that had not been characterized (LDWG 2016) (Map 4-7).

Uncharacterized exposed bank areas from the Leidos list were further screened relative to the criteria outlined in Figure 4-2. In addition, the location of the bank area relative to that of preliminary dredge/cap areas (as identified in ROD Figure 18 (EPA 2014b)) was considered in this assessment, although none of the banks were excluded based on this consideration.

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[27] This elevation is approximately equal to MHHW. NOAA reports MHHW at the Seattle station (Elliott Bay) as +11.36 ft MLLW (NOAA 2013).

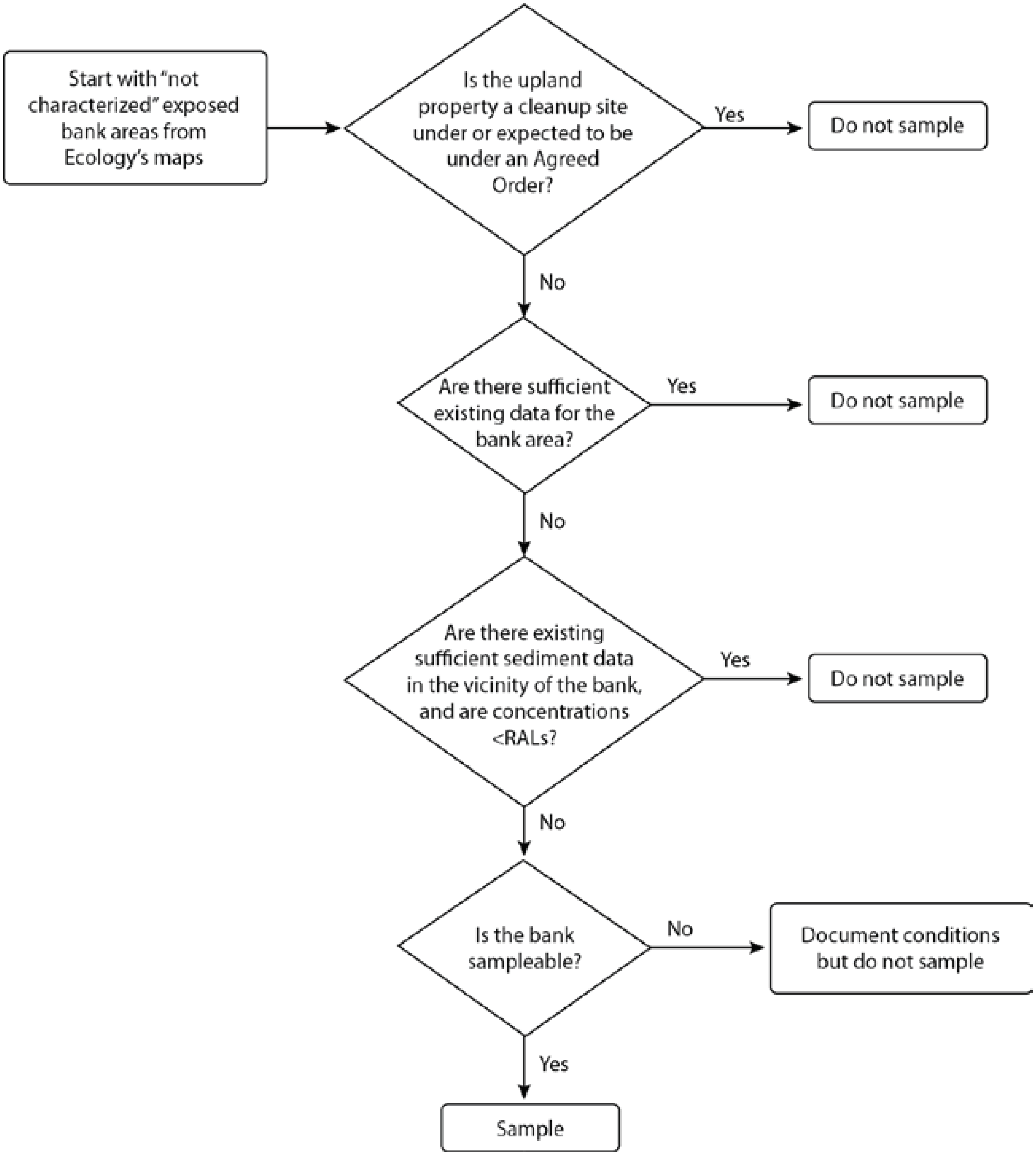

Figure 4-2.Selection criteria for sampling banks

Three of the 10 areas (RM 0.1 W, RM 4.2 to RM 4.3 W, and RM 4.8 to RM 5.0 E) were determined to be sufficiently characterized based on the existing bank and sediment sampling data (see Table 4-4 and Map 4-7). The seven remaining uncharacterized areas were then assessed in a field reconnaissance survey conducted by boat on August 31 and September 1, 2017, to determine whether the locations could be sampled.

Substrate conditions, the presence and condition of over-water structures (which can create unsafe sampling conditions), and the presence of armoring were observed to the extent possible (Appendix E). One of the seven areas (RM 4.7 E) was observed to have a steep slope with dense vegetation and riprap; this area was not considered sampleable. Of the other six areas, one area was subsequently determined to not need sampling based on input from Ecology. One additional bank area not assessed in the field reconnaissance survey was added in order to support Ecology's source control efforts. These areas will be targeted for bank soil sampling (see Table 4-4 and Map 4-8).

Table 4-4. Evaluation of exposed bank areas

"Not Characterized" Exposed Bank Area[a] (RM)	Cleanup site under or expected to be under an Agreed Order?	Are there sufficient existing data for the bank area and nearby sediment?	What data exist?	Is the bank sampleable?	Sample?	Rationale for Exclusion
0.1 W	no	yes (sediment within narrow slough)	3 nearby sediment samples analyzed for COCs; no RAL exceedances	na[b]	no	sufficient nearby sediment data in narrow slough
0.5–0.6 W[c]	no	no	no data	na[b]	yes	-
0.6–0.7 E	no	no	no data	yes	no	coordination with Ecology
0.9–1.0 W	no	no	no data	yes	yes	-
2.0–2.2 W	no	no	no data	yes	yes	-
2.5–2.7 W	no	no	no data	yes	yes	-
3.0–3.1 W	no	no	no data	yes	yes	-
4.2–4.3 W	no	yes (sediment/bank)	1 nearby bank/sediment sample analyzed for COCs; no RAL exceedances	yes	no	sufficient nearby sediment/bank data
4.6–5.0 W	no	no	no data	yes	yes	-
4.7 E	no	no	no data	no	no	not sampleable
4.8–5.0 E	no	yes (sediment/bank)	9 nearby sediment sample locations, 4 of which were analyzed for PCBs only. There have been 8 exceedances for total PCBs and 1 exceedance for 1,4-dichlorobenzene	na[b]	no	sufficient nearby sediment/bank data

[a] Based on Leidos's maps for Ecology.

[b] Banks were not surveyed in the reconnaissance survey.

[c] Bank area designated "characterized" on Leidos's maps for Ecology and added to analysis based on input from Ecology.

COC – contaminant of concern
Ecology – Washington State Department of Ecology
na – not available
PCB – polychlorinated biphenyl
RAL – remedial action level
RM – river mile

A total of 11 discrete samples (0–10 cm) will be collected from the 6 banks, per Ecology direction (Table 4-5). Each bank will have at least one discrete sample (Table 4-5). Specific locations may be sampled at more than one elevation based on field and tidal conditions, substrate material, bank slope, and exposed bank area. The number of elevations sampled will be determined during the field effort based on these considerations and past examples (Hart Crowser 2012), with potential oversight from Ecology.

Table 4-5. Number of proposed discrete samples per bank

Bank	Exposed Bank Area (approximate RM)	Proposed Number of Discrete Samples
1	0.5 – 0.6 W	1
2	0.9 – 1.0 W	1
3	2.0 – 2.2 W	3
4	2.5 – 2.7 W	3
5	3.0 – 3.1 W	1
6	4.6 – 5.0 W	2
Total	**-**	**11[a]**

[a] Additional samples may be collected if it is determined during the field effort that additional elevations are needed.

RM – river mile

Furthermore, an additional discrete sample will be collected at any location in the bank areas that appears to represent a unique potential source (i.e., area with discoloration or visible seepage of material).

Per the Work Plan (Windward and Integral 2017b), all bank sediment samples will be analyzed for the analytes listed in ROD Table 20. Dioxins/furans will also be analyzed in the sample(s) collected at Bank Area 2, based on existing surface sediment data (Map 4-6). Archives will be kept of all bank samples. Archived samples will be analyzed for dioxins/furans unless existing information indicates or suggests dioxins/furans data are not needed at a given location.[28] Data considered in these decisions will include all existing data and surface sediment data collected pursuant to this QAPP. EPA and Ecology will be consulted prior to finalizing which additional bank samples will be analyzed for dioxins/furans.

4.1.3 Intertidal surface sediment samples (0–45 cm)

This section presents the sampling design for the intertidal 0–45-cm surface sediment samples that will be collected to evaluate DQOs 7 through 10 (Table 2-2). The design to

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[28] Pursuant to Ecology's source control strategy, use of the RAL is sufficient for source control for constituents without SMS (e.g., dioxins/furans) (Ecology 2016).

measure conditions in the LDW-wide potential clamming areas and each of the eight beach play areas is spatially balanced and is based on composite samples. An overview is presented in Table 4-6, and details about sample sizes and how the sampling locations were selected for each DQO are presented in the subsections that follow.

Table 4-6. Overview of intertidal 0–45-cm surface sediment sampling approach

Design Component	Approach	
	DQOs 7 and 8 – Potential Clamming Area 95UCL and Mean	**DQO 9 and 10 – Beach Play Area 95UCLs and Means**
Sample type	composite samples	composite samples
Number of composite samples	3 site-wide composite samples (each consisting of sediment from up to 72 locations)	3 composite samples for each of the 8 beaches for a total of 24 composite samples (each consisting of sediment from 3 to 9 locations depending on the size of the beach)
Sampling locations	up to 216 intertidal locations site wide (i.e., up to 72 locations per composite); if the total sampleable area[a] is smaller than anticipated, fewer samples will be collected	9 to 27 locations per beach (129 locations in total); if the sampleable area at a given beach is smaller than anticipated, sampling locations will be adjusted (i.e., the total number of samples will not change).

[a] Areas that are not sampleable include those that are too unconsolidated to safely sample or areas that are below the water line when sampling under the targeted low tide conditions outlined in Section 2.2.

95UCL – 95% upper confidence limit for the mean

DQO - data quality objective

4.1.3.1 Potential clamming area composites

The potential clamming area identified in ROD Figure 6 (EPA 2014b)[29] will be characterized with three site-wide composite samples, each containing sediment from up to 72 locations distributed throughout the potential clamming area. Thus, a maximum of 216 locations will be sampled along the transects shown on Map 4-9. If the total sampleable area is smaller than anticipated, fewer samples will be collected. One-third of the total number of samples will be included in each of the three composite samples.

The total number of locations (≤ 216) was determined based on the requirements that every potential clamming subarea be sampled, and that the number of sampling locations within each subarea be approximately proportional to its area. In practice, a minimum of three sampling locations were placed in the smallest potential clamming subarea, and a proportionally larger number of sampling locations was placed in each of the larger potential clamming subareas. Thus, if the sampleable area is smaller than anticipated, fewer samples will be collected (i.e., the same general number of samples per accessible area will be maintained).

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[29] ROD Figure 6 is titled *LDW areas with parks and habitat restoration, beach play activities, and potential clamming*.

To determine actual sampling locations, a transect approach will be used. Transects were developed for each potential clamming subarea and points were set at equal distance along the transect lines (Map 4-9). Actual sampling locations will be determined in the field using a random-number table to determine varying distances from each point on the transect line. This approach is described in more detail in Section 4.2.2.3.

Overall, the areas represented by each sampling location range from 0.28 to 0.54 acres across the 16 potential clamming subareas, with an average of one sample per 0.45 acre (Table 4-7 and Map 4-9). The resulting data will represent an approximately spatially balanced dataset with which to assess baseline conditions in the potential clamming area throughout the LDW. In future monitoring, the sampling locations in the potential clamming subareas will be re-randomized to allow unbiased inference about potential site-wide clamming conditions at each point in time.

Table 4-7. Number of sampling locations per potential clamming subarea

Potential Clamming Subarea	Subarea Size (ac)	Maximum No. of Sampling Locations	Area per Sampling Location (ac)
1	2.3	6 (up to 2 per composite)	0.38
2	29	57 (up to 19 per composite)	0.51
3	4.8	9 (up to 3 per composite)	0.53
4	2.4	6 (up to 2 per composite)	0.40
5	1.8	6 (up to 2 per composite)	0.30
6	1.5	3 (up to 1 per composite)	0.50
7	2.8	6 (up to 2 per composite)	0.47
8	2.4	6 (up to 2 per composite)	0.40
9	2	6 (up to 2 per composite)	0.33
10	2.8	6 (up to 2 per composite)	0.47
11	0.85	3 (up to 1 per composite)	0.28
12	21	39 (up to 13 per composite)	0.54
13	5.3	12 (up to 4 per composite)	0.44
14	4.3	9 (up to 3 per composite)	0.48
15	16	30 (up to 10 per composite)	0.53
16	6.2	12 (up to 4 per composite)	0.52
Total	**105**	**216 (up to 72 per composite)**	**na**

na – not applicable

Samples from each potential clamming subarea will be assigned to one of three site-wide composite samples, each consisting of sediment from as many as 72 locations. Samples will be assigned to achieve spatial balance. Within each potential clamming subarea, the first location along a transect will be randomly assigned to one of the three composites, and the second location will be randomly assigned to one of the remaining two composites. Thereafter, the locations will follow the same systematic pattern, achieving a similar spatial distribution within each composite. The samples to be included in each composite sample will be documented in a compositing memorandum submitted for EPA approval.

The composite concentrations represent the average concentrations in the LDW-wide potential clamming area and the three composites will provide independent estimates of the LDW-wide potential clamming area average. Based on the assumption of normality, the 95UCL will be derived with the standard equation for a normally distributed population,[30] and the potential clamming area-wide mean concentration will be the arithmetic average of the three site-wide composite sample concentrations.

4.1.3.2 Beach play area composites

Each of the eight beach play areas identified in the ROD will be characterized using three composite samples. Sampling locations were randomly distributed throughout each of the eight beach play areas. The number of samples in each beach play area was determined based on the size of the beach play area.

The number of sampling locations contributing sediment to each beach play area composite ranges from three to nine per beach (i.e., 9 to 27 total locations per beach), with the locations spatially balanced within each beach (Map 4-10). The smallest beaches were assigned nine locations (i.e., 3 locations per composite); larger beaches were assigned a number of sampling locations approximately proportional to the physical size of each beach play area (Table 4-8). The sampling locations within each beach play area will be randomly located using a transect approach (as described above for clamming and in more detail in Section 4.2.2.3) to avoid clustering and obtain sufficient spatial separation among samples within each beach.

Table 4-8. Number of sampling locations per beach play area

Beach Play Area	Area Size (ac)	No. Sampling Locations	Area per Sampling Location (ac)
1	1.5	9 (3 per composite)	0.17
2	2.9	9 (3 per composite)	0.32
3	5	15 (5 per composite)	0.33
4	5	15 (5 per composite)	0.33
5	11.4	27 (9 per composite)	0.42
6	1	9 (3 per composite)	0.11
7	6.1	18 (6 per composite)	0.34

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[30] Because each analytical sample will represent the potential clamming area-wide mean based on a large number of field samples (up to n = 71) per composite, the Central Limit Theorem (CLT) will be invoked and normality assumed.

Beach Play Area	Area Size (ac)	No. Sampling Locations	Area per Sampling Location (ac)
8	11.1	27 (9 per composite)	0.41
Total	**44**	**129 (3 to 9 per composite)**	**na**

na – not applicable

For each beach play area, an equal number of samples will be included in the three beach-specific composite samples. The assignment of samples to each composite will be documented in a compositing memorandum submitted for EPA approval. In this way, each composite sample will represent an average for the beach-wide mean, and the three composites will be replicates of the beach-wide mean, capturing small-scale spatial variability as well as sampling and analytical error. The 95UCL for the baseline composite samples from each beach will be calculated using Chebyshev's inequality.[31] Each beach-wide mean will be the arithmetic average of the three beach-wide composites.

4.2 SAMPLING METHODS

Field sampling and sample identification will be performed according to the protocols described in this section. Contingencies may arise during field activities that will require modification of the general procedures outlined below. Such modifications will be at the discretion of the FC after consultation with the Windward TM and PM, the boat captain, and the EPA representative in the field, if applicable. LDWG and EPA will be consulted if significant deviations from the sampling design are required. All modifications will be recorded in the protocol modification form (Appendix B).

4.2.1 Sample identification

Unique alphanumeric ID numbers will be assigned to each sample and recorded on the surface sediment collection form (Appendix B).

The sample IDs for individual surface sediment samples and bank samples will include the following:

- Project area ID and two-digit year
- Sample type:
  - 0–10-cm samples will be SS (or SSOT for outfall samples)
  - 0–45-cm samples will be IT45
  - Bank soil samples will be BNK

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[31] The shape of the distribution cannot be properly evaluated with only three samples, so a non-parametric Chebyshev interval will be used.

- Location number (for the 0-10 cm samples, outfall samples, and bank soil samples) or location ID (for the 0-45-cm samples)

For example, a surface sediment sample from location 27 would be labelled LDW18-SS-027.

The location IDs for the 0-45 cm intertidal samples will be identified using the area number (e.g., CL for clamming areas and BP for beach play areas), transect identifier (e.g., A, B, C, etc.), and consecutive numbers for points along the transect line. For example, the third sample collected along transect A in clamming area 2 would be identified as LDW18-IT45-CL2-A3. Similarly, the first sample collected along transect C in beach play area 6 would be LDW18-IT45-BP6-C1.

In addition, individual samples will be combined to form composite samples, which will require composite IDs that will include the following:

- Project area ID and two-digit year
- Sample type:
  - 0–10-cm composites will be SS.
  - 0–45-cm samples will be IT45-CL for potential clamming area composites and IT45-B for beach composites.
- Composite number

For example, the surface sediment composite that contains sediment from sample Locations 1, 2, 3, 4, 6, 7, and 8 would be labelled LDW18-SS-Comp01. The three potential clamming area composites samples would be LDW18-IT45-CL-Comp1, LDW18-IT45-CL-Comp2 and LDW18-IT45-CL-Comp3. The three composite samples for Beach Area 3 will be LDW18-IT45-B3-Comp1, LDW18-IT45-B3-Comp2 and LDW18-IT45-B3-Comp3.

For the porewater samples, the sample ID will include the following:

- Project area ID and two-digit year
- PWPS (porewater passive sampler results)
- Surface sediment location ID

For example, the passive sampler associated with surface sediment Location 18 would be labelled LDW18-PWPS-SS018. The porewater concentrations calculated from the passive sampler results would be LDW18-PW-SS018.

All relevant information for each sample—including sample ID, sample date, sample time, and sample depth and location—will be recorded on the surface sediment collection form (Appendix B) and included as an appendix in the data report.

4.2.2 Surface sediment sampling methods

Surface sediment samples will be collected by boat or by land, and bank samples will be collected by land, as described in this section. For samples that will be collected by land, access agreements will be needed with property owners that are not LDWG parties and all parties (including tenants of LDWG parties) will be notified well in advance of sampling to coordinate access. The access agreement process will commence soon after the draft QAPP is submitted to EPA. In the event that LDWG and EPA cannot obtain access, alternative locations will be determined in consultation with EPA.

4.2.2.1 0–10-cm samples

Surface sediment grab sample collection and processing will follow standardized procedures for the Puget Sound area that have been developed by the Puget Sound Estuary Program (PSEP) (1997). Surface sediments will be collected from each location shown in Table 4-9[32] and on Map 4-1 using a pneumatic grab sampler from a sampling vessel, if feasible. In the event that a sample cannot be obtained at the target coordinates due to an obstruction or because the location is too shallow to sample by boat, the field crew will move the sample location—as little as possible and to an area that is as similar as possible in depth and character to the intended sampling location—to avoid the obstruction or enable sampling by boat. If the sample location needs to be moved more than 10 m (32 ft), EPA and LDWG will be consulted. To minimize the need to move the sample location, the field crew will notify property owners with barges ahead of the sampling event and will sample shallow areas during the highest tides during the field event.

Table 4-9. Surface sediment sampling location target coordinates for baseline 0–10-cm samples

Location ID	X	Y	Longitude	Latitude	River Mile	Estimated Depth Above or Below MLLW (ft)
1	1265898	211122	-122.350534	47.568659	0.0	-31
2	1266308	211198	-122.348881	47.56889	0.0	-16
3	1266484	211200	-122.348169	47.568907	0.1	na
4	1266936	211157	-122.346335	47.568812	0.1	-33
5	1266930	210796	-122.34633	47.567823	0.2	-34
6	1266734	210776	-122.347124	47.567756	0.2	-35
7	1266368	210935	-122.348618	47.568172	0.1	-39
8	1266096	211048	-122.349729	47.568469	0.1	-39
9	1266122	210482	-122.349577	47.566919	0.2	-16
10	1266461	210656	-122.348217	47.567413	0.2	-48

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[32] See Table 4-2 for locations where samples will be split.

Table 4-9. Surface sediment sampling location target coordinates for baseline 0–10-cm samples

Location ID	X	Y	Longitude	Latitude	River Mile	Estimated Depth Above or Below MLLW (ft)
11	1266745	210519	-122.347058	47.567054	0.2	-40
12	1267024	210662	-122.34594	47.567459	0.2	na
13	1266875	210133	-122.346499	47.566001	0.3	-32
14	1266466	210010	-122.348145	47.565642	0.3	-41
15	1266201	210156	-122.349231	47.566029	0.2	-15
16	1266232	209905	-122.349086	47.565342	0.3	-11
17	1266644	209847	-122.347414	47.565205	0.3	-42
18	1266889	209622	-122.346404	47.564603	0.4	-15
19	1266319	209596	-122.348709	47.564501	0.3	-34
20	1266847	209464	-122.34656	47.564167	0.4	-26
21	1266550	209331	-122.347753	47.563786	0.4	-39
22	1266747	209089	-122.346936	47.563133	0.5	-35
23	1266363	208911	-122.348474	47.562624	0.5	na
24	1266579	208918	-122.347602	47.562654	0.5	-30
25	1267134	208764	-122.345343	47.562263	0.5	-19
26	1267024	208491	-122.345764	47.561509	0.6	-29
27	1266802	208602	-122.346675	47.561801	0.5	-34
28	1266329	208526	-122.348584	47.561567	0.5	-29
29	1266042	208466	-122.349739	47.561387	0.5	-14
30	1266002	208294	-122.349889	47.560915	0.6	-3
31	1266264	208148	-122.348815	47.560529	0.6	-7
32	1266644	208081	-122.347272	47.560366	0.6	-9
33	1267052	208140	-122.345624	47.560549	0.6	-36
34	1267214	208118	-122.344965	47.560498	0.7	-16
35	1267256	207737	-122.344764	47.559456	0.7	-30
36	1266974	207912	-122.345923	47.559921	0.7	-25
37	1266553	207785	-122.347617	47.559549	0.7	na
38	1266280	207918	-122.348734	47.559899	0.6	2
39	1266162	207665	-122.349189	47.5592	0.7	-2
40	1266004	207450	-122.349814	47.558601	0.7	-1
41	1266368	207458	-122.348338	47.558642	0.7	na
42	1266895	207571	-122.346214	47.558982	0.7	-13
43	1267121	207330	-122.345282	47.558332	0.8	-19

Table 4-9. Surface sediment sampling location target coordinates for baseline 0–10-cm samples

Location ID	X	Y	Longitude	Latitude	River Mile	Estimated Depth Above or Below MLLW (ft)
44	1267607	207351	-122.343312	47.558415	0.8	3
45	1266041	207151	-122.349639	47.557782	0.8	-1
46	1266091	206997	-122.349426	47.557363	0.8	-1
47	1266488	206523	-122.347779	47.556085	0.9	0
48	1266751	206205	-122.346691	47.555229	1.0	-7
49	1267016	206290	-122.345624	47.555476	1.0	-30
50	1267297	206453	-122.344499	47.555939	1.0	-27
51	1266912	207202	-122.346115	47.557969	0.8	-10
52	1267110	207107	-122.345306	47.557719	0.8	-15
53	1267406	207198	-122.344117	47.557985	0.8	-34
54	1267118	206844	-122.345254	47.556999	0.9	3
55	1267692	206785	-122.342924	47.556869	0.9	-33
56	1268139	206923	-122.341128	47.557272	0.9	na
57	1268401	206659	-122.340044	47.556562	1.0	-13
58	1268244	206523	-122.340667	47.556181	1.0	-25
59	1267487	206483	-122.34373	47.556029	1.0	-31
60	1267555	206299	-122.343442	47.555531	1.0	-31
61	1267893	206373	-122.342077	47.555752	1.0	-15
62	1267652	205843	-122.343012	47.554284	1.1	-30
63	1268115	205914	-122.341143	47.554505	1.1	-16
64	1267854	205272	-122.342151	47.55273	1.2	-29
65	1268082	205536	-122.341248	47.553467	1.2	-25
66	1267894	205058	-122.341971	47.552148	1.2	na
67	1268140	205193	-122.340985	47.55253	1.2	-34
68	1268073	204702	-122.341217	47.55118	1.3	-24
69	1268369	204547	-122.340005	47.550771	1.4	-29
70	1268565	204399	-122.339201	47.550375	1.4	-5
71	1268176	204196	-122.340761	47.549798	1.4	-20
72	1268034	203890	-122.341312	47.548952	1.5	na
73	1268462	203887	-122.339578	47.548966	1.5	-36
74	1268695	203965	-122.338641	47.549194	1.5	-3
75	1268489	203423	-122.339432	47.547695	1.6	-35
76	1268728	203668	-122.338481	47.54838	1.5	-12

Table 4-9. Surface sediment sampling location target coordinates for baseline 0–10-cm samples

Location ID	X	Y	Longitude	Latitude	River Mile	Estimated Depth Above or Below MLLW (ft)
77	1268579	203250	-122.339055	47.547226	1.6	-34
78	1268935	203260	-122.337613	47.547275	1.6	na
79	1268510	202888	-122.339303	47.546231	1.7	-12
80	1269029	202885	-122.337203	47.546251	1.7	-25
81	1269420	203071	-122.335634	47.546782	1.7	-17
82	1269240	202747	-122.336338	47.545885	1.7	-13
83	1269216	202424	-122.336411	47.544997	1.8	na
84	1268686	202557	-122.338563	47.545334	1.7	-30
85	1268959	202210	-122.337431	47.544397	1.8	-27
86	1269283	202016	-122.336106	47.543884	1.9	-16
87	1269122	201791	-122.33674	47.543256	1.9	-17
88	1269507	201780	-122.335181	47.543248	1.9	-10
89	1269417	201489	-122.335521	47.542446	2.0	-13
90	1269724	201445	-122.334274	47.54234	2.0	-25
91	1269631	200964	-122.334612	47.541018	2.1	na
92	1269926	201145	-122.333436	47.541529	2.1	-25
93	1270676	201561	-122.330431	47.54271	2.1	-12
94	1270278	201326	-122.332025	47.542044	2.1	-17
95	1270077	201196	-122.332826	47.541679	2.1	-18
96	1270025	200739	-122.333001	47.540421	2.2	-12
97	1270241	201060	-122.332153	47.541314	2.1	-18
98	1270417	200365	-122.331387	47.539418	2.3	-11
99	1270602	200609	-122.330656	47.540098	2.3	-12
100	1270766	200063	-122.329947	47.53861	2.4	-12
101	1270882	200164	-122.329487	47.538893	2.4	-21
102	1271153	200301	-122.328401	47.539282	2.4	-8
103	1270932	199850	-122.329259	47.538033	2.4	-18
104	1271465	199584	-122.32708	47.537334	2.5	-21
105	1271190	199632	-122.328198	47.537451	2.5	-16
106	1271771	199291	-122.32582	47.536546	2.6	-15
107	1271637	199143	-122.326349	47.536134	2.6	na
108	1271805	199040	-122.325663	47.535861	2.6	-17
109	1272075	198943	-122.324563	47.535608	2.7	-18

Table 4-9. Surface sediment sampling location target coordinates for baseline 0–10-cm samples

Location ID	X	Y	Longitude	Latitude	River Mile	Estimated Depth Above or Below MLLW (ft)
110	1272289	198524	-122.323664	47.534472	2.8	-12
111	1272408	198862	-122.323208	47.535406	2.7	-1
112	1272495	198268	-122.32281	47.533782	2.8	-3
113	1273377	198991	-122.319296	47.535809	2.9	-10
114	1273308	198798	-122.319561	47.535275	2.9	-8
115	1272764	198446	-122.321735	47.534283	2.8	-17
116	1272726	198037	-122.321857	47.53316	2.9	na
117	1273138	198092	-122.320193	47.533332	2.9	-1
118	1273061	197783	-122.320481	47.532483	3.0	-8
119	1273404	197864	-122.3191	47.532721	3.0	-1
120	1273339	197476	-122.319332	47.531656	3.0	-1
121	1273991	197425	-122.316688	47.53155	3.1	2
122	1273879	197159	-122.31712	47.530814	3.2	-18
123	1274130	197272	-122.316114	47.531138	3.2	2
124	1274272	196754	-122.315498	47.529725	3.3	-13
125	1274746	196687	-122.313577	47.529567	3.3	-4
126	1274626	196474	-122.314046	47.528976	3.3	-10
127	1275014	196340	-122.312464	47.528629	3.4	-14
128	1274828	196306	-122.313214	47.528526	3.4	-13
129	1275208	196106	-122.311663	47.527997	3.5	-18
130	1275003	196019	-122.312484	47.527748	3.5	na
131	1275656	195800	-122.309825	47.527184	3.6	-7
132	1275797	195631	-122.309242	47.526727	3.6	-8
133	1275631	195313	-122.309888	47.525847	3.7	-1
134	1276003	195042	-122.308362	47.525124	3.7	-3
135	1275839	194644	-122.308996	47.524025	3.8	-6
136	1276120	194452	-122.30784	47.523514	3.8	-8
137	1275935	194525	-122.308596	47.523704	3.8	-15
138	1276137	194052	-122.30774	47.522416	3.9	-15
139	1275959	193974	-122.308456	47.522194	3.9	-1
140	1276224	193542	-122.307351	47.521024	4.0	-14
141	1275992	193564	-122.308293	47.521072	4.0	-4
142	1276531	193336	-122.306093	47.520476	4.1	2

Table 4-9. Surface sediment sampling location target coordinates for baseline 0–10-cm samples

Location ID	X	Y	Longitude	Latitude	River Mile	Estimated Depth Above or Below MLLW (ft)
143	1276205	193099	-122.307391	47.519809	4.1	-9
144	1276443	193101	-122.306429	47.519826	4.1	-8
145	1276137	192780	-122.307642	47.51893	4.1	na
146	1277290	192883	-122.302987	47.519274	4.2	-13
147	1276875	192673	-122.304649	47.518676	4.2	-9
148	1276648	192704	-122.30557	47.518748	4.2	-7
149	1276475	192369	-122.306243	47.51782	4.2	-13
150	1276712	192337	-122.305281	47.517746	4.3	-3
151	1276553	192135	-122.30591	47.517184	4.3	-15
152	1276733	191901	-122.305166	47.516552	4.3	-6
153	1276605	191548	-122.305655	47.515578	4.4	-6
154	1276842	191610	-122.304701	47.51576	4.4	-2
155	1276697	191198	-122.305254	47.514625	4.5	-7
156	1276962	191212	-122.304186	47.514675	4.5	1
157	1276780	190739	-122.304885	47.513371	4.6	-7
158	1276923	190811	-122.304309	47.513575	4.5	-12
159	1276938	190529	-122.30423	47.512802	4.6	-12
160	1276639	190539	-122.30544	47.512814	4.6	2
161	1277142	190006	-122.303364	47.51138	4.7	na
162	1277501	190103	-122.301917	47.511665	4.7	na
163	1277409	190229	-122.302298	47.512004	4.7	0
164	1277374	190425	-122.302456	47.512541	4.7	-6
165	1277714	190378	-122.301075	47.512428	4.8	-7
166	1278097	190240	-122.299515	47.512072	4.8	na
167	1278334	190209	-122.298556	47.512	4.9	na
168	1278730	189879	-122.296929	47.511114	5.0	na
169	1266890	209821	-122.346414	47.565148	0.3	-23
170	1267205	208553	-122.345038	47.561689	0.6	-7
171	1266888	208414	-122.34631	47.561291	0.6	-35
172	1265998	208009	-122.349882	47.560133	0.6	0
173	1267053	207802	-122.345593	47.559622	0.7	-29
174	1266158	207265	-122.349175	47.558102	0.7	na
175	1267252	207364	-122.344753	47.558433	0.8	-33

Table 4-9. Surface sediment sampling location target coordinates for baseline 0–10-cm samples

Location ID	X	Y	Longitude	Latitude	River Mile	Estimated Depth Above or Below MLLW (ft)
176	1267698	206352	-122.342866	47.555683	1.0	-33
177	1267971	203884	-122.341565	47.548933	1.5	na
178	1268747	203540	-122.338396	47.548031	1.6	-26
179	1269985	201460	-122.33322	47.542396	2.1	-14
180	1270227	200361	-122.332154	47.539397	2.2	4
181	1270186	200341	-122.332318	47.53934	2.2	na
182	1270183	200299	-122.332327	47.539225	2.2	na
183	1271056	199592	-122.328738	47.537333	2.5	na
184	1273135	197679	-122.320173	47.5322	3.0	0
185	1276034	194947	-122.308228	47.524865	3.7	-2
186	1275959	193974	-122.308456	47.522194	3.9	-1
187	1276803	190894	-122.304803	47.513796	4.5	-10
188	1278792	189794	-122.296671	47.510885	5	na

ID – identification
MLLW – mean lower low water
na – bathymetry is not available to estimate the depth

Sediment from the 0- to 10-cm depth interval represent the biologically active zone; such sediment will allow a direct comparison with sediment collected during previous surface sediment studies in the LDW. Sediment grab samples that are predominately composed of gravel will be rejected.

The surface sediment samples will be collected using a pneumatic sampler as described in the following steps:

1) Using a global positioning system (GPS), maneuver the sampling vessel to the sampling location.
2) Open the decontaminated grab sampler jaws to the deployment position.
3) Guide the sampler overboard until it is clear of the vessel.
4) Using GPS, position the sampling vessel such that the GPS receiver (located on top of the sampling frame) is within 1 to 2 m of the target sampling location.
5) Lower the sampler through the water column to the bottom at a speed of approximately 0.3 m/s.
6) Record the GPS location of the boat when the sampler reaches the bottom.
7) Record the water depth and time.

8) Retrieve the sampler, raising it at a speed of approximately 0.3 m/s.
9) Guide the sampler aboard the vessel and place it on the work stand on the deck, taking care to avoid jostling that might disturb the integrity of the sample.
10) Examine the sample using the following sediment acceptance criteria:
    - Sample contains sediment; samples that are predominately gravel will be rejected.
    - Sediment is not extruding from the upper face of the sampler.
    - Overlying water is present (indicating minimal leakage).
    - Sediment surface is relatively flat (indicating minimal disturbance or winnowing).
    - A penetration depth of at least 11 cm has been achieved.

If these sample acceptance criteria are not met, the sample will be rejected. If an acceptable grab sample cannot be obtained in three attempts, the sampling location will be moved as close as possible to the original target location and no further than 10 m (32 ft) away. If it is not possible to obtain a sample at this second location, EPA will be consulted to discuss repositioning the location.

After sample acceptance, the following observations will be noted in the field logbook:

- GPS location
- Depth as read by the boat's depth sounder and sample collection time
- Gross characteristics of the surficial sediment, including texture, color, biological structures, odor, and presence of debris or oily sheen
- Gross characteristics of the vertical profile (i.e., changes in sediment characteristics and redox layer, if visible)
- Maximum penetration depth (nearest 0.5 cm)
- Comments relative to sample quality

The sediment from the grab at each location will be transferred directly from the sampler into a pre-cleaned stainless steel bowl or cauldron, and stirred with a dedicated, clean, stainless steel spoon or spatula until texture and color homogeneity have been achieved (PSEP 1997). The required sediment volume for each sample will range from 24 oz. (if a location is sampled for baseline composite only) to 92 oz. (if a location is also sampled for RAO 3 and *ex situ* porewater investigation) (see Appendix C). Each sediment grab will collect approximately 135 oz. (4 L) of sediment.

Following homogenization, 3 8-oz. jars[33] will be filled at each of the 168 0–10-cm sample locations, with 1 jar for sediment to be used for the composite sample, 1 jar for archive, and 1 jar for the NOAA split sample.[34] Samples that will be analyzed as individual locations (DQOs 3, 4, and 5) will require additional jars, as specified in Appendix C (Table C-4). Composite samples will be prepared at ARI as described in Section 4.4.1.1. All jars will be stored in coolers on ice (≤ 4 ± 2°C) and transported to the laboratory at the end of the sampling day. Excess sediment will be returned to the sampling location. For decontamination procedures between collection activities, see Section 4.3.4.

4.2.2.2 Source samples (bank and outfall)

Surface sediment samples (0–10 cm) will be collected near 22 outfalls based on the selection process discussed in Section 4.1.2.1. The sediment samples will be collected following the methods discussed in Section 4.2.2.1 for samples collected by boat. Outfall locations that are accessible by boat will be sampled during the surface sediment Sampling Event 1. Outfall locations that are best sampled from land at low tide will be hand collected[35] in conjunction with intertidal sediment collection during Sampling Event 2.

The target outfall sediment locations are provided in Table 4-10. If a target location based on the coordinates below is not sampleable because of obstructions, or if three sampling attempts fail, then an alternate location will be identified within the target sampling area of 50 ft (for outfalls with a diameter less than or equal to 24 in.) or 100 ft (for outfalls with diameters greater than 24 in.) of the outfall. If a sample cannot be obtained after three attempts have been made at the alternate location, then either the deepest sample collected will be retained (3 to 10 cm in depth) or LDWG and EPA will be notified that no sample could be obtained within the targeted sampling area for that outfall, and the field crew will proceed to the next sampling location. In the case of unsafe sampling conditions, including derelict overwater structures or boat traffic, the field coordinator may deem a sampling area unsafe. Sampling will stop, conditions will be recorded in the field notes, and the sampling effort will continue at the next outfall. In the case of boat traffic, the field crew will return to the outfall at another time or on another day during that sampling event to reassess accessibility and will conduct sampling if possible.

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[33] DQOs 1 and 2 require 2 8-oz. jars. A 3rd 8-oz. jar will be filled for the NOAA split sample at each of the 168 0–10-cm locations, as sample volume allows.

[34] Through EPA, NOAA has requested split samples for baseline 0–10-cm surface sediment samples. NOAA will provide labelled jars and will be responsible for the handling and custody of these samples following sample collection.

[35] Each sample will be collected by hand from the 0- to-10-cm depth, transferred to a pre-cleaned stainless steel bowl or cauldron, and homogenized. Any large non-sediment items, such as rocks, shells, wood chips, or debris, will be removed prior to homogenization.

Table 4-10. Target coordinates for near-outfall surface sediment samples

Outfall ID	Location (approximate RM)	Sample	X	Y	Longitude	Latitude
2003	0.7 E	1	1267411	207959	-122.344157	47.560072
FedCtrS	0.8 E	1	1267479	207635	-122.343854	47.559188
GlacierNW-CBP	1.7 E	1	1269290	203021	-122.336156	47.546639
GenBiodiesel	1.7 E	1	1269568	203122	-122.335038	47.54693
Seattle Dist Ctr	2.1 E	1	1270759	201529	-122.330094	47.542626
Dawn Foods	2.3 E	1	1270793	200470	-122.329871	47.539725
CleanScapes B	2.7 E	1	1272373	198901	-122.323354	47.535509
8134	0.0 W	1	1265847	211069	-122.350737	47.568512
2226	0.5 W	1	1266089	208734	-122.349571	47.562126
T107 Park	0.6 W	1	1265912	207963	-122.350225	47.560003
2507	2.1 W	1	1269590	200843	-122.334769	47.540685
2510	2.1 W	1	1269490	200552	-122.335154	47.539881
2509	2.1 W	1	1269768	200745	-122.334044	47.540426
2114	2.4 W	1	1271013	199638	-122.328916	47.537456
5th Ave S	2.5 W	1	1271195	199431	-122.328161	47.5369
2109	2.9 W	1	1272875	197873	-122.321241	47.532718
2109	2.9 W	2	1272872	197814	-122.321247	47.532558
2215	3.4 W	1	1274590	196290	-122.314177	47.528471
2101	4.0 W	1	1275923	193792	-122.308588	47.521694
2100A	4.2 W	1	1275957	192684	-122.308363	47.518659
2100A	4.2 W	2	1276056	192766	-122.30797	47.518887
Delta Marine	4.2 W	1	1276282	192344	-122.307023	47.517743
DuwSD#3	4.4 W	1	1276394	191558	-122.306511	47.515595
Ditch #2	4.9 W	1	1278276	189978	-122.298772	47.511361

ID – identification RM – river mile

Bank samples will be collected from the six bank areas identified in Section 4.1.2.2. Each bank sample will be a discrete sample collected from a depth of 0–10 cm. Photographs will be taken of each bank area and each individual bank sample location.

The bank samples will be collected at the locations identified in Table 4-11. These locations are strictly target locations. Before sampling, the field crew will survey the bank to determine which areas are sampleable. If the target locations are not sampleable, the field crew will move the sampling location to a nearby area within the same bank (and property to the extent possible).

Table 4-11. Target coordinates for bank samples

Bank ID	Sample Location ID	Centroid				Upstream Boundary				Downstream Boundary			
		X	Y	Longitude	Latitude	X	Y	Longitude	Latitude	X	Y	Longitude	Latitude
1	LDW18-BNK1	1265858	208162	-122.350461	47.560545	1265895	207993	-122.350296	47.560082	1265834	208329	-122.350573	47.561
2	LDW18-BNK2	1266568	206212	-122.34743	47.555237	1266796	206143	-122.346501	47.555062	1266419	206359	-122.348046	47.555633
3	LDW18-BNK3	1269498	200911	-122.335149	47.540865	1269547	200733	-122.334937	47.54038	1269515	201171	-122.3351	47.541579
3	LDW18-BNK3	1269420	200541	-122.335436	47.539847	1269596	200529	-122.334723	47.539825	1269547	200733	-122.334937	47.54038
3	LDW18-BNK3	1269632	200793	-122.334597	47.540549	1269776	200908	-122.334022	47.540872	1269596	200529	-122.334723	47.539825
4	LDW18-BNK4	1271407	199154	-122.327284	47.536152	1271530	199057	-122.326776	47.535892	1271355	199298	-122.327506	47.536544
4	LDW18-BNK4	1271647	198950	-122.326295	47.535605	1271721	198834	-122.325986	47.535292	1271530	199057	-122.326776	47.535892
4	LDW18-BNK4	1271829	198710	-122.32554	47.534956	1271905	198578	-122.325223	47.534598	1271721	198834	-122.325986	47.535292
5	LDW18-BNK5	1273213	197401	-122.319836	47.531443	1273274	197395	-122.319589	47.53143	1273169	197458	-122.320019	47.531598
6	LDW18-BNK6	1277457	190047	-122.302093	47.51151	1277493	190006	-122.301944	47.511399	1277275	189885	-122.302814	47.511054
6	LDW18-BNK6	1277560	189850	-122.30166	47.510974	1277703	190100	-122.301099	47.511666	1277398	189601	-122.302295	47.510284

Note: These are target locations only. As described above, the field crew will use discretion to target sampleable locations.
ID – identification

If the GPS does not work in a bank area, bank samples will be collected as close to the target location as possible using Map 4-8 as guidance. Sample locations will be recorded using distances from landmarks. Additional photographs will be taken as needed in order to record the sample location.

As described in Section 4.1.2.2, in addition to the proposed discrete samples, additional discrete samples will be collected at any location in the bank areas that appears to be a unique potential source, or at banks where samples are being collected from more than one elevation, as appropriate.

Each bank sample will be collected by hand from the 0- to-10-cm depth, transferred to a pre-cleaned stainless steel bowl or cauldron, and homogenized. Any large non-sediment items, such as rocks, shells, wood chips, or debris, will be removed prior to homogenization.

Following homogenization, jars will be filled as specified in Appendix C (Table C-6). All outfall and bank samples will require 52 oz. of sediment/soil. Four 8-oz. jars, one 4-oz. jar, and one 16-oz. jar will be filled at each sampling location. All jars will be stored on ice in coolers (≤ 4 ± 2°C) and transported to the laboratory at the end of the sampling day.

4.2.2.3 0–45-cm samples (beach and potential clamming areas)

Intertidal (0–45-cm) sediment samples will be collected at low tide at each of the potential clamming subareas and beach play areas shown on Maps 4-9 and 4-10 using a transect approach to identify sampling locations. The subsections below describe the approach for establishing transects and how the 0-45 cm samples will be collected.

Establishing Transects

Transects will be set using pre-determined endpoints (or adjusting those endpoints as needed based on conditions in the field) and setting a specified number of points along each transect. Depending on the shape and size of a given area, multiple transects may be used to identify sampling locations in a given area. In general, transects were developed to run parallel to the shoreline and low-tide water line (see Maps 4-9 and 4-10 showing the potential clamming subareas and beach play area transects, respectively). For the beach play areas, the number of points along the transect line will remain the same, regardless of whether the sample-able area is smaller or larger than anticipated, because each beach is its own exposure area with a required number of samples to calculate a beach-specific UCL. For the potential clamming subareas, the sample density will remain the same regardless of the size of the intertidal area (i.e., the number of sample locations will be reduced if the sample-able area is smaller), because it will be important to represent the various potential clamming areas proportionally in the site-wide mean. Although the clamming and beach play areas overlap, transects established for these areas will be separate (i.e., different holes will be dug). A random number table will be used to set specific locations to the left and right of each transect. Figure 4-3 provides a general schematic for intertidal sediment sampling.

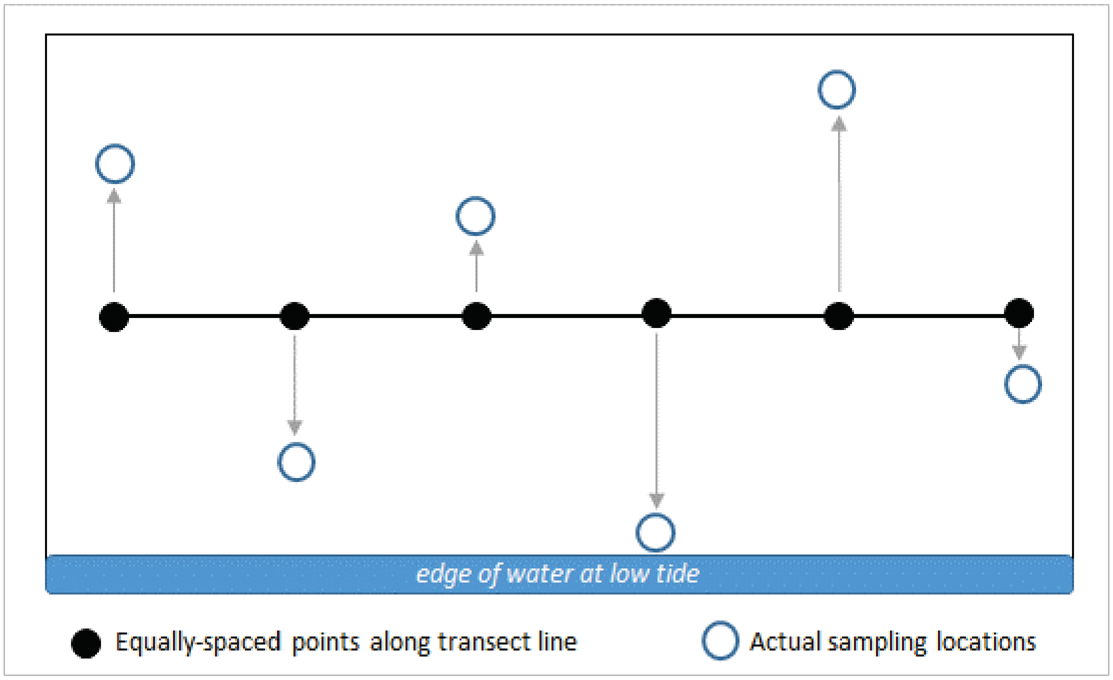

Figure 4-3. Schematic of intertidal sediment transect and sampling locations

Transects will be established prior to field sampling; both transect lines and target sampling locations will be loaded onto the GPS units for use by the field team. The following describes how transect lines were established and how target sampling points will be determined prior to the field event.

- **Transects** – Transect endpoints were established based on the size of the potential clamming subarea or beach play area. Based on the length of the transect lines, equally spaced points were placed along the transect lines, as shown in Maps 4-9 and 4-10.
- **Sampling locations** – To determine actual sampling locations prior to sampling, a random number table will be used. The range of possible numbers for a given area will be based on the approximate width of the area. At the first location along the transect line, a random number will be selected from the list; this number will indicate the distance (in meters) of that sampling location to the left or right of the transect line. At the second location along the line, the next number from the random number table will be selected; this number will indicate the distance (in meters) of that sampling location in the opposite direction of the transect line. These steps will be repeated, alternating station placement to the left or right of the transect line, until all locations are determined. The same process will be followed for both beach play and potential clamming areas.

Prior to the field event, transect lines and target sampling locations will be loaded onto the GPS unit for use by the field team. During sampling, the field team will locate and flag a target sampling location as shown on the GPS, moving the location as necessary to find a sampleable area. For example, if debris (e.g., a log or large rock) is obstructing the sampling location or the location is outside of the sampleable area (e.g., the area is too unconsolidated to safely sample or is below the low tide line), the sampling location will be relocated as near as possible to the original location, and the new location and reason for movement will be noted. GPS coordinates will be recorded in the field for all sampling locations.

In the event that the intertidal area is smaller than anticipated (i.e., the pre-established transect endpoints cannot be reached), it may be necessary to modify the transect lines and sampling locations in the field. For the potential clamming subareas, points that are not accessible will not be sampled, and no adjustment of the other transect points will be needed. However, for the beach play areas, smaller intertidal areas will result in the need to modify the transect lines. The following describes the steps that will be used to set transects for the beach play areas if needed:

1. **Locate transect endpoints** – If the intertidal area is smaller than anticipated (i.e., the pre-established endpoints cannot be reached), the transect endpoints will be re-located to the end of the available intertidal area.
2. **Determine spacing of sampling locations** – The spacing of the sampling locations will be determined as described below, and locations along the transect line will be marked with one color flag.
    a. Determine length of transect using rangefinder.
    b. Determine the distance needed between each point along the transect line to maintain the same total number of sampling locations at a given beach (the total number of samples at a given beach play area will always be a multiple of three; see Map 4-10).
    c. Mark these points along the transect line with the first color flag. For example, if the transect is 100 m in length and a total of 6 locations are specified, the distance between each location will be 20 m (i.e., one point at each end of the transect line, and four locations along the transect line at 20-m intervals along the transect line; see Figure 4-4).

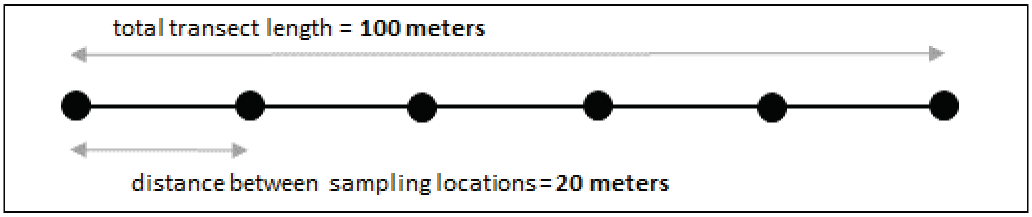

Figure 4-4. Schematic of spacing between intertidal sediment sampling locations in beach play areas

3. **Determine sampling locations** – As described above, a random number table will then be used to determine specific sampling locations at varying distances to the right and left of the transect line. These points will be marked with a second color flag.
4. **Record information on intertidal sediment transect form** – All relevant information will be recorded on the intertidal sediment transect form for the revised transect (e.g., transect length, distance between samples, and random numbers used to determine specific sampling locations). In addition, coordinates for each sampling location will be documented.

Sample Collection

The following steps will be taken to collect a sample at each individual sampling location identified during the establishment of transects. For samples located near the water line, the field crew will preferentially sample these locations during the time when the tide is lowest to ensure that the samples are successfully collected prior to the tide level rising. The field crew will have the discretion to use either of the following two options that is most suitable to the sampling location conditions. In addition, the field crew may use a combined or hybrid approach of the two methods, if necessary.

Option 1: Use shovel to dig 45-cm hole

One sampling option is to dig a hole using a shovel and collect the sample directly from the sidewall of the hole. This process is described as follows.

1. **Dig hole** – Using a transplanting spade (i.e., a shovel with a narrow blade), dig a 45 cm hole at the flagged location, or as near to the flag as possible based on the substrate and debris. If it is not possible to reach a depth of 45 cm, after up to three attempts, the deepest hole will be sampled using the methodology described below, and the depth of refusal will be recorded on the intertidal surface sediment collection form. At least one side of the hole should be approximately vertical to allow for the collection of the sample. Record any necessary revisions of the sampling location.
2. **Prepare for sampling** – Divide the vertical extent of hole into three 15-cm sections (i.e., the bottom section from 30-45 cm below the surface, the middle section from 15-30 cm below the surface, and the top section from the surface down to 15 cm). If possible, use a spoon to draw a line in the sidewall of the hole at these breakpoints. The bottom section will be sampled first to ensure that the sample is collected prior to the hole filling with water.
3. **Collect sediment** – Collect the same amount of sediment from each of the three 15 cm subsections along the vertical extent of the hole. When filling the jar as described in steps 3a-3c, exclude any debris larger than approximately 5 mm in width. If differences around the diameter of the hole are apparent (e.g., the

presence of different colored material), the resulting sample should proportionally represent all material in the hole.

   a. Starting with the bottom section of the hole (i.e., 45 cm to 30 cm), use a small spoon to carefully collect an even amount of sediment from the sidewall of the hole by scraping the sidewall from the bottom of the hole to the marked 30-cm line. Fill the first third of the jar[36] using this method.
   b. Repeat process in the middle section of the hole (i.e., scrape the sidewall from the 30-cm to the 15-cm line) and fill the next third of the jar.
   c. Repeat process in the top third of the hole (15 cm to the surface) and fill the final third of the jar, making sure to capture the full extent of this layer, including the surface material.

4. **Record information on the intertidal surface sediment collection form** – Record information regarding the depth of the hole (generally 45 cm), sediment characteristics (e.g., color, smell, grain size, presence of debris, etc.), presence/approximate depth of clams, and necessary revisions to the sampling location on the intertidal surface sediment collection form. Take photographs of anything of note.

Option 2: Use hand core tube to collect 45-cm core

Another sampling option is to use a hand-core to collect a 45-cm core, extrude the core, and then collect the sample from the interior of the core. This process is described as follows:

1. **Collect core** – Drive the hand core tube (internal diameter of 7 cm) into the sediment to 45 cm at the flagged location, or as near to the flag as possible based on the substrate and debris. Re-attach and tighten the top of the core tube and pull core out of the sediment. If it is not possible to reach a depth of 45 cm, up to three attempts should be made in that area (initial attempts will be retained in the core tube or extruded onto a piece of foil). After the third attempt, the deepest core will be sampled using the same methodology described below, and the depth of refusal will be recorded on the intertidal surface sediment collection form. Record any necessary movement of the sampling location.
2. **Prepare for sampling** – Extrude core on an aluminum foil-lined tray, and split core length-wise using a stainless steel spatula (or other similar stainless steel tool) to allow sample to be collected from the interior of the core (i.e., to avoid the outer material that has contacted the core tube). Lay ruler marked at 15-cm

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[36] For potential clamming areas, a 4-oz jar will be filled at each sampling location. For the beach play areas, an either 8-oz (for areas 5, 7, and 8) or 16-oz jar (for areas 1, 2, 3, 4, and 6) will be filled at each sampling location, depending on the total number of samples collected in a given beach play area (jar size based on sufficient mass to meet analytical requirements).

increments next to core and divide into three segments (i.e., 0-15 cm, 15-30 cm, and 30-45 cm).

3. **Collect sediment** – Following the procedures described in Step 3 above (for the shovel collection method), use a small spoon to collect an equal volume from each third of the core (starting with the bottom increment), and place sediment into the jar. Fill the first third of the jar using this method. Repeat process for the middle and top sections of the core to fill the remaining two thirds of the jar.
4. **Record information on the intertidal surface sediment collection form** – Record information regarding the depth of the core (generally 45 cm), sediment characteristics (e.g., color, smell, grain size, presence of debris, etc.), and necessary revisions to the sampling location on the intertidal surface sediment collection form. Take photographs of anything of note.

One 4-oz jar will be filled at each of the potential clamming area locations (up to 216 locations). For the beach play areas (129 locations), an either 8-oz (for areas 5, 7, and 8) or 16-oz jar (for areas 1, 2, 3, 4, and 6) will be filled at each sampling location, depending on the total number of samples collected in a given beach play area (jar size based on sufficient mass to meet analytical requirements).[37] All jars will be stored on ice in coolers (≤ 4 ± 2°C) and transported to the laboratory at the end of the sampling day. Following completion of the field effort, a compositing memorandum will be prepared for EPA approval to identify the samples selected for inclusion in each composite. Composite samples will be prepared at ARI as described in Section 4.4.1.2.

4.2.2.4 Sediment samples for ex situ *porewater investigation*

Twenty locations have been identified for the *ex situ* porewater investigation based on the range of PCB concentrations previously reported for these locations (Table 4-2). The *ex situ* porewater exposure investigation requires 1 kg wet weight (ww) of sediment. Based on an average sediment density of 2.0 g/ml, the required sediment volume is 18 oz.

At each of the 20 locations where sediment will be collected for the *ex situ* porewater investigation, a split sample will be collected from the homogenized sediment (Appendix C, Table C-4) and transported, on ice to ARI, for the *ex situ* porewater investigation. Sample packing, transport information, and custody procedures are described in Section 4.3, and the *ex situ* testing protocols are described in Section 4.5.

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[37] More sediment is needed for the beach play composite samples (i.e., an extra 4 to 12 oz per location as compared with the clamming locations) because fewer samples will be composited in the beach play areas.

4.3 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

Sample custody is a critical aspect of environmental investigations. Sample possession and handling must be traceable from the time of sample collection, through laboratory and data analyses, to delivery of the sample results to the recipient. Procedures to be followed for sample handling, custody, and shipping are detailed in this section. In addition, procedures for the decontamination of equipment and disposal of field-generated waste are described.

4.3.1 Sample handling procedures

At each laboratory, a unique sample identifier (termed either project ID or laboratory ID) will be assigned to each sample. The laboratory will ensure that a sample tracking record follows each sample through all stages of laboratory processing. The sample tracking record must contain, at a minimum, the name/initials of responsible individuals performing the analyses, dates of sample extraction/preparation and analysis, and types of analyses being performed.

4.3.1.1 Sediment samples

The FC will be responsible for reviewing sediment sample information recorded on field collection forms (Appendix B) and will correct any improperly recorded information. Sample labels will contain the project number, sampling personnel, date, time, and sample ID. A complete sample label will be affixed to each individual sample jar. Labels will be filled out as completely as possible prior to each sampling event.

Samples will be placed on ice after collection for transport to ARI, ALS, and Axys. Sample packaging and transport information is summarized in Section 4.3.3.

4.3.1.2 Porewater passive samplers

Following the 28-day porewater exposure, each strip will then be wrapped in clean aluminum foil envelopes, labeled, and inserted into a resealable plastic bag with corresponding labels. All resealable bags will be placed on ice in a cooler for transport to Axys. Sample packaging, transport information, and custody procedures are described in Section 4.3. Upon receipt, Axys will store all samplers in the freezer until analysis.

4.3.2 Sample custody procedures

Samples are considered to be in custody if they are: 1) in the custodian's possession or view; 2) in a secured place (under lock) with restricted access; or 3) in a container and secured with an official seal(s) such that the sample cannot be reached without breaking the seal(s). Custody procedures, described below, will be used for all samples throughout the collection, transportation, and analytical processes, and for all data and data documentation, whether in hard copy or electronic format. Custody procedures will be initiated during sample collection.

A chain of custody form will accompany all samples to the analytical laboratory. Each person who has custody of the samples will sign the chain of custody form and ensure that the samples are not left unattended unless properly secured. During the 28-day *ex situ* porewater exposure period, sediment samples will be agitated in a secure room at ARI and will be monitored daily by ARI staff. Minimum documentation of sample handling and custody will include:

- Sample location, project name, and unique sample ID
- Sample collection date and time
- Any special notations on sample characteristics or problems
- Name of the person who initially collected the sample
- Date sample was sent to the laboratory
- Shipping company name and waybill number

In the field and during the *ex situ* exposure, the FC or a designee will be responsible for all sample tracking and custody procedures. The FC will also be responsible for final sample inventory and will maintain sample custody documentation. The FC or a designee will complete chain of custody forms prior to transporting samples. At the end of each day, and prior to sample transfer, chain of custody entries will be made for all samples. Information on the sample labels will be checked against sample log entries, and sample tracking forms and samples will be recounted. Chain of custody forms, which will accompany all samples, will be signed at each point of transfer. Copies of all chain of custody forms will be retained and included as appendices to the data reports. Samples will be shipped in sealed coolers.

ARI, ALS, and Axys will ensure that chain of custody forms are properly signed upon receipt of the samples, and will note any questions or observations concerning sample integrity on the chain of custody forms. ARI, ALS, and Axys will contact the FC and project QA/QC coordinator immediately if discrepancies are discovered between the chain of custody forms and the sample shipment upon receipt.

4.3.3 Shipping requirements

Sediment samples will be transported directly to ARI (i.e., by field staff), composite and individual sediment samples will be shipped to ALS, and passive samplers and sediments will be transported to Axys via courier. Prior to shipping, containers with sediment samples will be wrapped in bubble wrap and securely packed inside a cooler with ice packs. Passive samplers will be wrapped in foil, placed in resalable plastic bags, and securely packed inside a cooler with ice packs. The original signed chain of custody forms will be placed in a sealed plastic bag and taped to the inside lid of the cooler. Fiber tape will be wrapped completely around the cooler. On each side of the cooler, a *This Side Up* arrow label will be attached; a *Handle with Care* label will be attached to the top of the cooler, and the cooler will be sealed with a custody seal in two locations.

The temperature inside the cooler(s) containing the sediment samples and *ex situ* samplers will be checked by the laboratory upon receipt of the samples. The laboratory will specifically note any coolers that do not contain ice packs, or that are not sufficiently cold[38] (≤ 4 ± 2°C) upon receipt. All samples will be handled so as to prevent contamination or sample loss. Any remaining sediment samples will be disposed of upon receipt of written notification by the Windward PM. Holding times will vary by analysis and are summarized in Section 4.4.2. Passive samplers will be held until the laboratory is notified by the Windward PM.

4.3.4 Decontamination procedures

Sampling requires strict measures to prevent contamination. Sources of extraneous contamination can include sampling gear, grease from ship winches or cables, spilled engine fuel (gasoline or diesel), engine exhaust, dust, ice chests, and ice used for cooling. All potential sources of contamination in the field will be identified by the FC, and appropriate steps will be taken to minimize or eliminate contamination. For example, during retrieval of sampling gear, the boat will be positioned, when feasible, so that engine exhaust does not fall on the deck. Ice chests will be scrubbed clean with Alconox® detergent and rinsed with distilled water after use to prevent potential cross contamination. To avoid contamination from melting ice, the wet ice will be placed in separate plastic bags.

All sediment sampling and homogenizing equipment, including the mixing bowl and stainless steel implements, will be decontaminated between sampling locations per PSEP guidelines (1997) and the following procedures:

1. Rinse with site water and wash with a scrub brush until free of sediment.
2. Wash with phosphate-free detergent.
3. Rinse with site water.
4. Rinse with distilled water.

Acid or solvent washes will not be used in the field because of safety considerations and problems associated with rinsate disposal and sample integrity, specifically:

- Use of acids or organic solvents may pose a safety hazard to the field crew.
- Disposal and spillage of acids and solvents during field activities pose an environmental concern.

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[38] As stated in validation guidance documents, sample shipping coolers should arrive at the laboratory with an internal temperature within the advisory range of 4 ± 2°C; however, due to the short transit distance and time from the site to ARI, all samples may not have reached this temperature by the time they arrive at the laboratory.

- Residues of solvents and acids on sampling equipment may affect sample integrity for chemical testing.

Any sampling equipment that cannot be cleaned to the satisfaction of the FC will not be used for further sampling activities.

4.3.5 Field-generated waste disposal

Excess sediment, generated equipment rinsates, and decontamination water[39] will be returned to each sampling location after sampling has been completed for that location. All disposable sampling materials and personal protective equipment (PPE) used in sample processing, such as disposable coveralls, gloves, and paper towels, will be placed in heavyweight garbage bags or other appropriate containers. Disposable supplies will be removed from the site by sampling personnel and placed in a normal refuse container for disposal as solid waste.

4.4 LABORATORY METHODS

ARI, ALS, and Axys will meet the sample handling requirements and follow the procedures described in this section. In addition, analytical methods and data quality indicator (DQI) criteria are provided herein.

4.4.1 Laboratory sample handling

Samples will be stored initially at ARI at ≤ 4 ± 2°C. Sediment compositing will be conducted in the laboratory for both the surface sediment composite samples and the intertidal sediment samples.

ARI, ALS, and Axys will preserve and store samples as described in Section 4.4.2. Once prepared, samples for Axys will be packed in coolers on ice and delivered via courier service, and samples for ALS will be shipped in coolers on ice. Archive samples will be stored, frozen, at ARI.

4.4.1.1 Surface sediment (0–10-cm) compositing

Surface sediment samples will be composited in the laboratory (Figure 4-5). For those samples collected for DQOs 1 and 2, the contents of the seven 8-oz. jars for the composite will be combined in a stainless steel bowl or cauldron and stirred with a clean stainless steel spoon or spatula until texture and color homogeneity have been achieved (PSEP 1997). Homogenized sediment will then be split into the appropriate sample containers as described in Appendix C, Table C-5. Excess sediment will be disposed at the laboratory.

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[39] Because decontamination water is an Alconox®/water solution (that is phosphate-free), it can be returned to the sampling location for disposal.

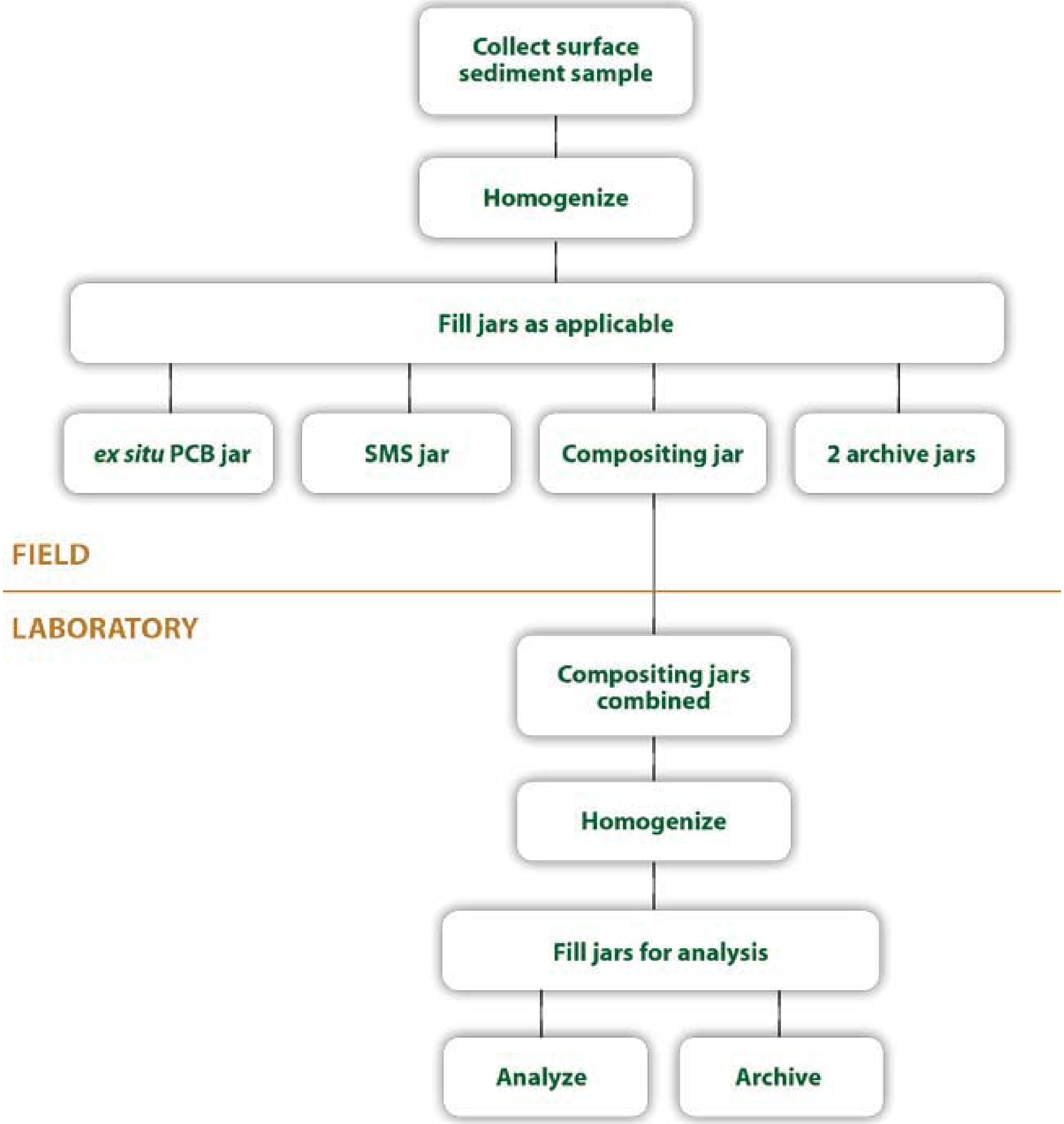

Figure 4-5.Compositing approach for 0–10-cm surface sediment samples

4.4.1.2 Intertidal sediment (0-45-cm) compositing

Intertidal 0-45-cm sediment composites will be created in the laboratory. Three potential clamming area composite samples (DQOs 7 and 8) will be created according to the SOP in Appendix D and as illustrated in Figure 4-6. Specifically, all of the sediment samples assigned to the first composite will be combined in stainless steel cauldron and homogenized using a motorized paddle mixer. Sediment will be homogenized for a minimum of 20 minutes. The homogenization will be considered complete when the sediment is visually uniform in color and consistency. Following homogenization, approximately equal volumes of sediment will be transferred into two stainless steel baking trays as described in the sediment compositing SOP (Appendix D). As specified in the SOP, a 30-square grid will be created and a stainless steel, square-edged scoop will be used to collect aliquots of the homogenized sediment from each grid to fill the analytical sample jars. The entire procedure will be repeated for the 2nd and 3rd composites. A triplicate sample will be collected for cPAH analysis for QC purposes (see Section 4.7.2.2).

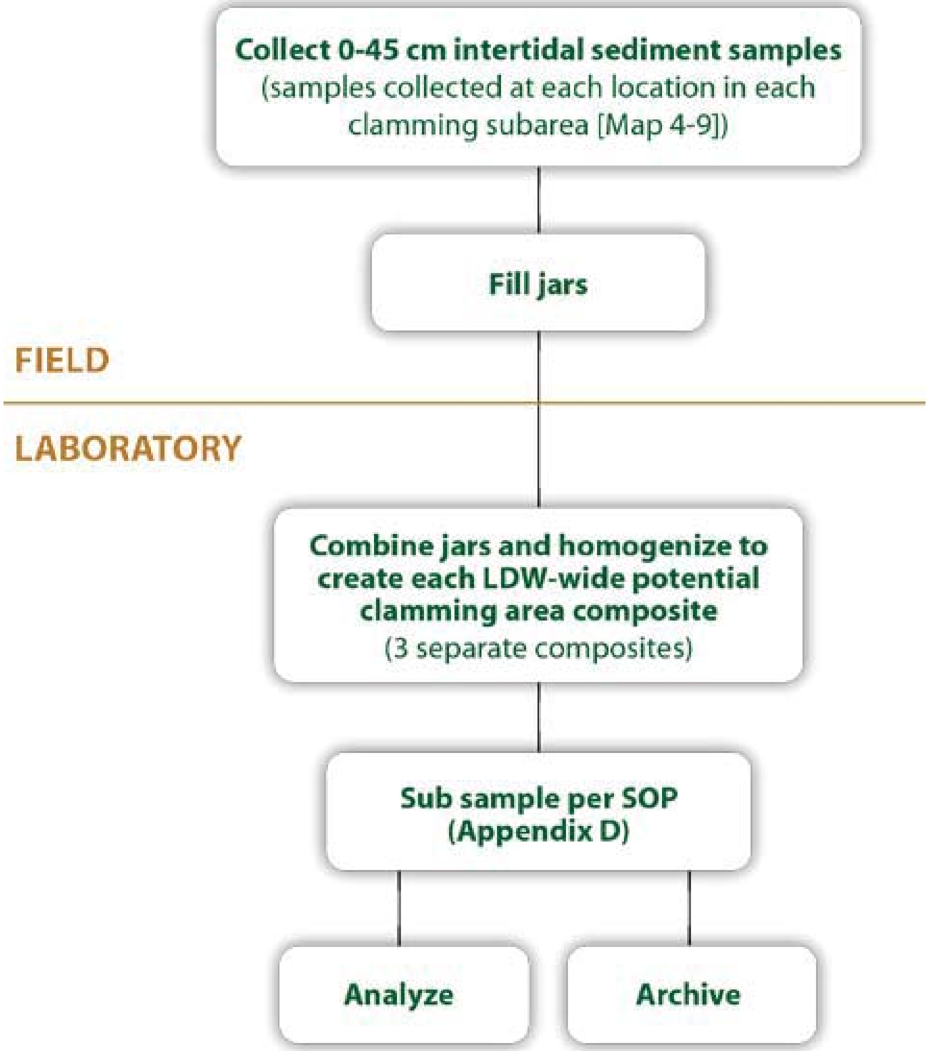

Figure 4-6.Compositing approach for 0–45-cm potential clamming area samples

The beach play area composites (DQOs 9 and 10) will be created using sediment samples from each beach play area (the number of sediment samples per composite will range from three to nine per beach play area, depending on beach size) (Figure 4-7). Samples will be designated for inclusion in one of the three composites for each beach in a compositing memorandum.

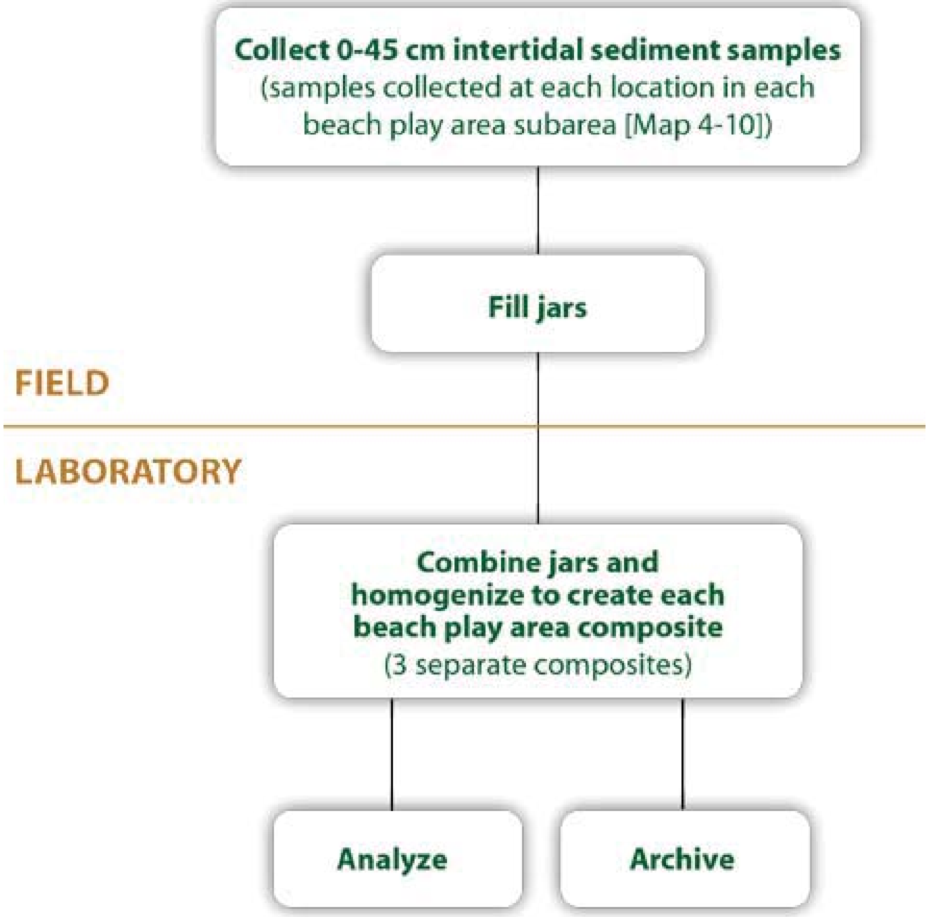

Figure 4-7.Compositing approach for beach play sediment samples

The contents of the jars for the composite will be combined in a stainless steel bowl or cauldron and stirred with a clean stainless steel spoon or spatula until texture and color homogeneity have been achieved (PSEP 1997). Homogenized sediment will then be split into the appropriate sample containers, as described in Appendix C, Table C-5. All sediment sample containers will be filled leaving a minimum of 1 cm of headspace to prevent breakage during shipping and storage. Excess sediment will be disposed at the laboratory.

4.4.2 Analytical methods

Chemical analysis of the surface sediment samples will be conducted at three different laboratories (ARI, ALS, and Axys) (Table 4-12). Analytical methods and laboratory sample handling requirements for all measurement parameters are presented in Table 4-13. The analytes for the 0-10-cm and 0-45-cm surface sediment composite samples are provided in Table 4-14. The analytes for each of the 30 individual surface sediment samples are provided in Table 4-15. The analytes for the near-outfall sediment samples and the bank samples are provided in Table 4-16.

Table 4-12. Sediment analyses to be conducted at each analytical laboratory

Laboratory	Analyses to be Conducted	Individual Analytes
ARI	conventionals	TOC, percent solids, grain size
	Metals	arsenic, cadmium, chromium, copper, lead, silver, zinc, mercury
	PAHs	acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 2-methylnaphthalene, naphthalene, phenanthrene, and pyrene
	PCB Aroclors[a]	Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260
	SVOCs	1,2-dichlorobenzene, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, 2,4-dimethylphenol, 4-methylphenol, benzoic acid, benzyl alcohol, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, dibenzofuran, dimethyl phthalate, hexachlorobenzene, n-nitrosodiphenylamine, PCP, and phenol
	toxaphene	toxaphene
Axys	dioxin/furan congeners	2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, OCDD, 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,7,8,9-HpCDF, and OCDF
	PCB congeners	all 209 congeners (refer to Appendix C)
ALS	black carbon	black carbon

[a] If none of the PCB Aroclors are detected, then the sample will be submitted to Axys for analysis of PCB congeners.

ALS – ALS Environmental-Kelso
ARI – Analytical Resources, Inc.
Axys – Axys Analytical Services Ltd.
HpCDD – heptachlorodibenzo-*p*-dioxin
HpCDF – heptachlorodibenzofuran
HxCDD – hexachlorodibenzo-*p*-dioxin
HxCDF – hexachlorodibenzofuran
OCDD – octachlorodibenzo-*p*-dioxin
OCDF – octachlorodibenzofuran
PAH –polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PCP – pentachlorophenol
PeCDD – pentachlorodibenzo-*p*-dioxin
PeCDF – pentachlorodibenzofuran
SVOC – semivolatile organic compound
TOC – total organic carbon
TCDD – tetrachlorodibenzo-p-dioxin
TCDF – tetrachlorodibenzofuran

Table 4-13. Analytical methods and sample handling requirements for surface sediment samples

Parameter[a]	Method	Reference	Extraction Solvent	Cleanup	Laboratory	Container	Preservative	Sample Holding Time
TOC	high-temperature combustion	EPA 9060	na	na	ARI	glass jar	cool to ≤ 4 ± 2°C	28 days
Percent solids	drying oven	SM 2540G	na	na	ARI	glass jar	cool to ≤ 4 ± 2°C	6 months
Grain size	Pipette/sieve	PSEP (1986)	na	na	ARI	plastic jar	cool to ≤ 4 ± 2°C	6 months
Metals	ICP-MS	EPA 3050B EPA 6020A UCT-KED	na	na	ARI	glass jar	cool to ≤ 4 ± 2°C	6 months
Mercury	CV-AFS	EPA 7471B	na	na	ARI	glass jar	cool to ≤ 4 ± 2°C	28 days
PAHs	GC/MS	EPA 3550C/ EPA 8270D-SIM	DCM/acetone	silica gel	ARI	glass jar	freeze to ≤ -10°C	1 year to extract if frozen;14 days until extraction if refrigerated or when thawed, 40 days after extraction; store extracts at ≤ 6°C and in the dark
PCB Aroclors	GC/ECD	EPA 3550C Mod EPA 8082A	hexane/acetone	silica gel sulfuric acid/ permanganate sulfur or acid/base partition (optional)	ARI	glass jar	freeze to ≤ -10°C	1 year to extract; analyze within 1 year of extraction
SVOCs	GC/MS	EPA 3550C/ EPA 8270D	DCM/acetone	GPC (optional)	ARI	glass jar	freeze to ≤ -10°C	1 year to extract if frozen;14 days until extraction if refrigerated or when thawed, 40 days after extraction; store extracts at ≤ 6°C and in the dark
Toxaphene	GC/ECD	EPA 3546/ EPA 8081B	hexane/acetone	GPC (optional)	ARI	glass jar	freeze to ≤ -10°C	1 year to extract if frozen;14 days until extraction if refrigerated or when thawed, 40 days after extraction; store extracts at ≤ 6°C and in the dark

Table 4-13. Analytical methods and sample handling requirements for surface sediment samples

Parameter[a]	Method	Reference	Extraction Solvent	Cleanup	Laboratory	Container	Preservative	Sample Holding Time
PCB congeners	HRGC/HRMS	EPA 1668c	DCM Optional: Dean-Stark Soxhlet extraction with toluene, or Soxhlet extraction with 1:1 hexane:acetone	multi-layered acid/base silica, alumina, florisil	Axys	glass jar	freeze to ≤ -10°C	1 year until extraction, 1 year after extraction (if in the dark at ≤ -10°C)
Dioxins/ furans	HRGC/HRMS	EPA 1613b	80:20 toluene:acetone or Dean-Stark with toluene	biobead multi-layered acid/base silica, florisil, alumina, carbon/celite	Axys	glass jar	freeze to ≤ -10°C	store in the dark at 0–4°C; store extracts for up to 1 year at ≤ 10°C
Black carbon	infrared	Gustafsson (2001) - CTO Pretreatment/ Combustion (950°C)/ EPA 440.0	na	na	ALS	glass jar	cool to ≤ 4 ± 2°C	no established holding time; samples kept cold until drying at 105°C, which prevents potential biological action from occurring

[a] Individual analytes are listed in Table 4-12.

ALS – ALS Environmental-Kelso
ARI – Analytical Resources, Inc.
Axys – Axys Analytical Services Ltd.
CTO – chemothermal oxidation
CV-AFS – cold vapor atomic fluorescence spectroscopy
DCM – dichloromethane
EPA – US Environmental Protection Agency
GC/ECD – gas chromatography/electron capture detection
GC/MS – gas chromatography/mass spectrometry
GPC – gel permeation chromatography
HRGC/HRMS – high-resolution gas chromatography/high-resolution mass spectrometry
ICP-MS – inductively coupled plasma-mass spectrometry
IR – infrared spectroscopy
na – not applicable or not available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PSEP – Puget Sound Estuary Program
SIM – selected ion monitoring
SM – Standard Methods
SVOC – semivolatile organic compound
TOC – total organic carbon
UCT-KED – universal cell technology-kinetic energy discrimination

Table 4-14. Analytes for composites samples (0–10-cm and 0–45-cm samples)

Sample Type	No. of Samples	PCB Aroclors, Arsenic, cPAHs, and Dioxins/Furans	Black Carbon	Toxaphene	Conventionals (TOC, Grain Size, and Total Solids)
0–10-cm surface sediment composite	24	X	X		X
0–45-cm intertidal beach play area composite	24	X		X	X
0–45-cm intertidal potential clamming area composite	3	X		X	X

cPAH – carcinogenic polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TOC – total organic carbon

Table 4-15. Analytes for each individual sediment sample (0–10-cm samples)

Sample ID	SMS Analytes[a]	PCB Aroclors	PCB Congeners	Black Carbon	Conventionals (TOC, Grain Size and Total Solids)
LDW18-SS08	X	X	-	-	X
LDW18-SS23	X	X	-	-	X
LDW18-SS40	X	X	-	-	X
LDW18-SS52	X	X	-	-	X
LDW18-SS69	X	X	-	-	X
LDW18-SS91	X	X	-	-	X
LDW18-SS101	X	X	-	-	X
LDW18-SS130	X	X	-	-	X
LDW18-SS143	X	X	-	-	X
LDW18-SS161	X	X	-	-	X
LDW18-SS169	X	X	TBD[b]	X	X
LDW18-SS170	X	X	TBD[b]	X	X
LDW18-SS171	-	X	TBD[b]	X	X
LDW18-SS172	-	X	TBD[b]	X	X
LDW18-SS173	-	X	TBD[b]	X	X
LDW18-SS174	X	X	TBD[b]	X	X
LDW18-SS175	-	X	TBD[b]	X	X
LDW18-SS176	-	X	TBD[b]	X	X
LDW18-SS177	-	X	TBD[b]	X	X
LDW18-SS178	X	X	TBD[b]	X	X
LDW18-SS179	X	X	TBD[b]	X	X
LDW18-SS180	-	X	TBD[b]	X	X

Sample ID	SMS Analytes[a]	PCB Aroclors	PCB Congeners	Black Carbon	Conventionals (TOC, Grain Size and Total Solids)
LDW18-SS181	-	X	TBD[b]	X	X
LDW18-SS182	-	X	TBD[b]	X	X
LDW18-SS183	X	X	TBD[b]	X	X
LDW18-SS184	X	X	TBD[b]	X	X
LDW18-SS185	-	X	TBD[b]	X	X
LDW18-SS186	X	X	TBD[b]	X	X
LDW18-SS187	X	X	TBD[b]	X	X
LDW18-SS188	X	X	TBD[b]	X	X

[a] SMS analytes include analytes listed in ROD Table 20 (metals, PAHs, and SVOCs).

[b] PCB congeners will be analyzed in the 10 PCB porewater samples selected for analysis based on the PCB Aroclor results.

ID – identification	SMS – Washington State Sediment Management Standards
PAH – polycyclic aromatic hydrocarbon	SVOC – semivolatile organic compound
PCB – polychlorinated biphenyl	TBD - to be determined
ROD – Record of Decision	TOC – total organic carbon

Table 4-16. Analytes for near-outfall and bank samples

Sample Type	No. of Samples	SMS Analytes[a]	Dioxins/Furans	Conventionals (TOC, Grain Size, and Total Solids)
Near-outfall sediment	24	X	X (Outfalls 2226, T107 Park, 2507, Seattle Dist Ctr, 5th Ave South, CleanScapes B, and 2100A)[b]	X
Bank	11[c]	X	X (Bank Area 2)[d]	X

[a] SMS analytes include analytes listed in ROD Table 20 (metals, PAHs, SVOCs, and PCB Aroclors).

[b] At all other outfalls, sediment will be archived for dioxin/furan analysis per Section 4.1.2.1.

[c] Additional discrete samples will be collected at any location in the bank areas that appears to be a unique potential source or from banks where samples are being collected from more than one elevation, as discussed in Section 4.1.2.2.

[d] At all other bank areas, bank soil will be archived per Section 4.1.2.2.

PAH – polycyclic aromatic hydrocarbon	SVOC – semivolatile organic compound
PCB – polychlorinated biphenyl	SMS – Washington State Sediment Management Standards
ROD – Record of Decision	TOC – total organic carbon

4.5 *EX SITU* POREWATER INVESTIGATION METHODS

This section describes the methods to be followed for the *ex situ* porewater investigation for PCBs.

4.5.1 Passive sampler preparation

Passive samplers will be prepared for exposure to the 20 sediment samples collected as discussed in Section 4.2.2.4. Ayxs will prepare the passive samplers and the exposures will be conducted at ARI.

Using methods based on those outlined by Gschwend et al. (2012), Axys will prepare the passive samplers by cleaning a known mass of 25-µm-thick PE sheeting using sequential extractions with solvent (e.g., dichloromethane [DCM], methanol) (Appendix D).

The cleaned PE sheeting will be loaded with PRCs to allow non-equilibrium conditions between the PE and the sediment porewater to be quantified. The degree of equilibrium reached by the PRCs during the exposure will be used to infer the degree of equilibrium reached by the target PCB analytes. This information will be used to correct for non-equilibrium conditions as described in Section 4.5.4. The carbon-13-labelled PCBs to be used for PRCs will include ^{13}C-PCB8, ^{13}C-PCB28, ^{13}C-PCB95, ^{13}C-PCB111, ^{13}C-PCB153 and ^{13}C-PCB178. These compounds represent a range of homologs, from dichlorobiphenyl (PCB8) to heptachlorobiphenyl (PCB178), and are representative of a wide range of hydrophobicities and kinetics. The dichlorophenyl and trichlorophenyl PRCs (PCB8 and PCB28, respectively) are expected to equilibrate fully, whereas the heptachlorobiphenyl PRC (PCB178) may not fully equilibrate over the period of exposure. The PRCs will be loaded by equilibrating the clean PE sheets with a methanol/water PRC solution in a glass container for at least seven days. Prior to delivery to ARI, the impregnated PE sheets will be submerged in ultra-clean water for three days to remove the methanol.

To accurately determine initial pre-exposure PRC concentrations, three 0.1-g PE strips will be cut from the PE sheets after the PRC loading is complete, wrapped in aluminum foil, and stored, frozen, at Axys. These day-zero PE strips will be analyzed along with the PE strips retrieved from the porewater exposure batch tests (Section 4.7.2.2). Pre- and post-exposure PRC concentrations will be used either to confirm that equilibrium has been reached for all PCB congeners, or to allow for the correction of non-equilibrium conditions between the PE and the sediment porewater.

The remaining clean PRC-impregnated PE sheets will be wrapped in aluminum foil and placed in a resealable plastic bag at < 4 ± 2°C for shipment to ARI for use in the porewater exposures. Upon delivery, ARI will store the PE sheets in the refrigerator until the exposures are started.

4.5.2 Porewater exposure batch tests

Exposures will be conducted in accordance with design guidelines laid out by EPA et al. (2017), as detailed in Appendix D. The range of targeted PCB concentrations and TOC concentrations has been used to determine the appropriate PE sampler mass. The sampler mass must be sufficient to accumulate detectable PCB concentrations but must not be so large as to deplete the sediment PCB concentration (i.e., less than 1% of the mass of PCBs in sediment). In the event that any exposure exceeds the 1% by mass target, corrections for depletion will be made assuming a linear relationship for partitioning characteristics of the sediment organic matter as described in Fagervold et al. (2010) and Ghosh et al. (2014), and the resulting values will be J-flagged.

Each sediment sample will be thoroughly homogenized, and approximately 1 kg ww of each sample will be placed in a wide-mouth glass jar with a Teflon™-lined cap. A 2-g/L sodium azide (biocide) solution will be added to each jar to achieve a well-formed slurry (80% water content) and inhibit microbial activity. A pre-weighed PRC-impregnated PE strip (0.1 g) will then be inserted into each jar. Sealed jars will be agitated in the dark on an orbital shaker table for 28 days to enhance contaminant mass transfer from the sediment porewater to the passive sampler, accelerating sampler equilibration rates. After the 28-day exposure period, the PE strips will be removed from their respective jars, rinsed with laboratory-grade deionized water, and gently wiped with clean laboratory wipes to remove any attached sediment. They will then be shipped to Axys as described in Section 4.3.3.

4.5.3 Passive sampler analysis

The PE strips will be extracted and analyzed for PCB congeners following EPA method 1668c (Table 4-13). The passive sampler handling protocols are provided in Appendix D.

The lowest possible DLs for PCB congeners in water based on the results from the PE passive samplers will be calculated using the laboratory analytical DLs for the PE strips, the partition coefficients between water and PE (from Gschwend et al. 2014), and equilibrium assumptions. Preliminary DLs calculated for each congener (assuming 100% equilibrium) are provided in Appendix C; however, these estimated DLs may be low and could be modified based on further analysis. Specifically, the more chlorinated PCB congeners may not achieve equilibrium. The actual DLs will be greater than those calculated for any PCB congener that does not reach equilibrium within the exposure period.

Chemical analyses of *ex situ* porewater samplers will be performed by Axys (Table 4-17).

Table 4-17. Analytical methods and sample handling requirements for the *ex situ* porewater passive samplers

Parameter	Method	Reference	Extraction Solvent	Cleanup	Labor-atory	Container	Preserv-ative	Sample Holding Time
PCB congeners	HRGC/HRMS	EPA 1668c	DCM	multi-layered acid/base silica, alumina, florisil	Axys	PE strip/ aluminum foil	cool to ≤ 4± 2°C	na

Axys – Axys Analytical Services Ltd.
DCM – dichloromethane
EPA – US Environmental Protection Agency
HRGC/HRMS – high-resolution gas chromatography/ high-resolution mass spectrometry
PCB – polychlorinated biphenyl
PE – polyethylene

4.5.4 Calculation of freely dissolved PCB congener concentrations from PE concentrations

Following PCB congener analysis of the PE strips by Axys, PCB congener concentrations in the PE strips will be used to calculate the concentrations of freely dissolved PCB congeners in the sediment porewater, as summarized in Figure 4-8.

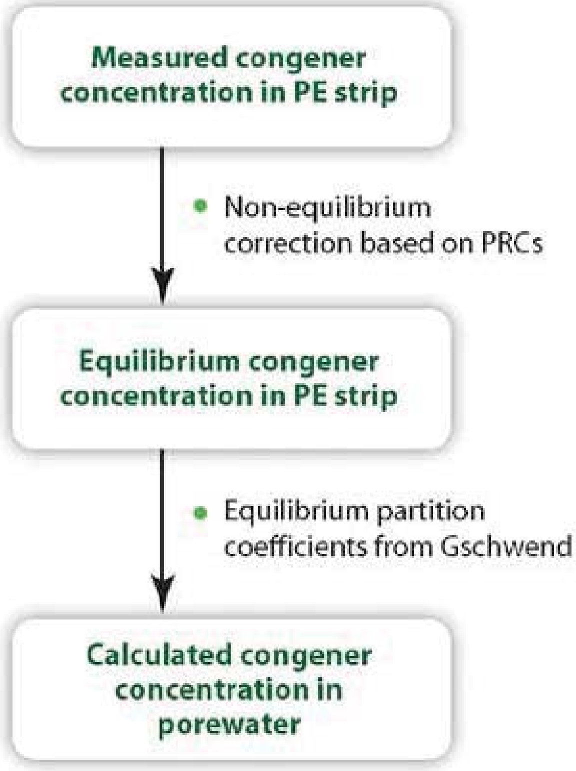

Figure 4-8. Calculation method for freely dissolved PCB congeners in porewater from passive sampler

The first step to converting the measured PE concentrations to equilibrium PE concentrations is based on the PRC concentrations in the samplers. PRC concentrations remaining in the PE sampler after the *ex situ* exposures will be used to estimate the degree of equilibrium between the sampler and the sediment porewater.

PRCs of a wide range of hydrophobicities have been selected, because the rates of mass transfer in and out of the sampler will depend on the hydrophobic properties of each congener. Measured fractions of PRCs lost after deployment will be used to calculate a regression line between the model-estimated partitioning constant (K_D) and the octanol-water partitioning constant (K_{OW}) (Apell and Gschwend 2014). This K_{OW}/K_D fit will be used to calculate the fractional equilibration for each PCB congener using a PRC correction calculator accessed via a graphical user interface, as described by EPA et al. (2017).

Appendix D presents the physical and chemical properties that will be used to correct for non-equilibrium conditions. PRC calculator default values will be used for the properties of the PCB congeners. If more than 90% loss is observed for a PRC, then analytes with a K_{OW} lower than or equal to this PRC will be assumed to be at equilibrium with porewater in that exposure (Gschwend et al. 2014). The equilibrium PE congener concentrations (C_{PE}) calculated using PRC data ,as described above, and the default PE-to-water partition constants (K_{PEW}) provided in Gschwend et al. (2014) (Appendix D), will then be used to calculate the freely dissolved PCB concentrations in porewater (C_{PW}) using the following equation:

$$CPW = CPE / KPEW \qquad \textbf{Equation 1}$$

4.6 ANALYTICAL DATA QUALITY OBJECTIVE AND CRITERIA

The analytical DQO for surface sediment samples and passive samplers is to develop and implement procedures that will ensure the collection of representative data of known, acceptable, and defensible quality. Parameters used to assess data quality are precision, accuracy, representativeness, completeness, comparability, and sensitivity (PARCCS). These parameters are discussed below, and specific DQIs are presented in Section 4.6.6.

4.6.1 Precision

Precision is the measure of reproducibility among individual measurements of the same property, usually under similar conditions, such as multiple measurements of the same sample. Precision is assessed by performing multiple analyses on a sample; it is expressed as a RPD when duplicate analyses are performed, and as a %RSD when more than two analyses are performed on the same sample (e.g., triplicates). Precision is assessed by laboratory duplicate analyses (e.g., duplicate samples, MSDs, and LCS duplicates) for all parameters. Precision measurements can be affected by the nearness of a chemical concentration to the DL, whereby the percent error (expressed as either %RSD or RPD) increases. The DQI for precision varies depending on the analyte. The equations used to express precision are as follows:

$$RPD = \frac{(\text{measured conc} - \text{measured duplicate conc})}{(\text{measured conc} + \text{measured duplicate conc}) \div 2} \times 100 \qquad \textbf{Equation 2a}$$

$$\%RSD = (SD/D_{ave}) \times 100$$

Where:

$$SD = \sqrt{\left(\frac{\sum (D_n - D_{ave})^2}{(n-1)} \right)}$$

Equation 2b

D = sample concentration
D_{ave} = average sample concentration
n = number of samples
SD = standard deviation

4.6.2 Accuracy

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Accuracy may be expressed as a percentage recovery for MS and LCS analyses. The DQI for accuracy varies depending on the analyte. The equation used to express accuracy for spiked samples is as follows:

$$\textbf{\% Recovery} = \frac{\textbf{spike sample results - unspiked sample results}}{\textbf{amount of spike added}} \times \mathbf{100}$$

Equation 3

4.6.3 Representativeness

Representativeness is an expression of the degree to which data accurately and precisely represent an environmental condition. The sampling approach was designed to address the specific objectives described in Section 2.1. Assuming those objectives are met, the samples collected should be considered adequately representative of the environmental conditions they are intended to characterize.

4.6.4 Comparability

Comparability is an expression of the confidence with which one dataset can be evaluated in relation to another dataset. Therefore, the sample collection and chemical and physical testing will adhere to the most recent PSEP QA/QC procedures (PSEP 1997) and EPA and Standard Methods (SM) analysis protocols.

4.6.5 Completeness

Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. The equation used to calculate completeness is as follows:

$$\textbf{Completeness} = \frac{\textbf{number of valid measurements}}{\textbf{total number of data points planned}} \times \mathbf{100}$$

Equation 4

The DQI for completeness for all components of this project is 90%. Data that have been qualified as estimated because the QC criteria were not met will be considered valid for the purpose of assessing completeness. Data that have been qualified as rejected will not be considered valid for the purpose of assessing completeness.

4.6.6 Sensitivity

Analytical sensitivity is the minimum concentration of an analyte above which a data user can be reasonably confident that the analyte was reliably detected and quantified. For this study, the MDL[40] or the LLOQ will be used as the measure of sensitivity for each analyte.

Tables 4-18 lists specific DQIs for laboratory analyses of sediment samples and *ex situ* porewater samplers.

Table 4-18. Data quality indicators for laboratory analyses

Parameter[a]	Unit	Precision[b]	Accuracy[b]		Completeness
			SRM/LCS[c]	Spiked Samples	
TOC	%	± 20%	80-120%	na	90%
Percent solids	%	± 20%	na	na	90%
Grain size	%	± 20%	na	na	90%
Metals	mg/kg dw	± 20%	80-120%	75–125%	90%
Mercury	mg/kg dw	± 20%	80–120%	75–125%	90%
PAHs	µg/kg dw	± 35%	30–160%	30–160%	90%
PCB Aroclors	µg/kg dw	± 35%	50–120%	50–120%	90%
SVOCs	µg/kg dw	± 35%	10–160%	10–160%	90%
Toxaphene	µg/kg dw	± 35%	30–160%	30–160%	90%
PCB congeners	µg/kg dw	± 20%	30–150%[d]/ 60–135%	5–145%[e]	90%
Dioxins/ furans	ng/kg dw	± 20%	70–130%[d]/ 63–170%	13–328%[e]	90%
Black carbon	wt%	± 20%	80–120%	na	90%

[a] Individual analytes are listed in Table 4-12.

[b] Values listed are performance-based limits provided by ARI, ALS, and Axys.

[c] An LCS may be used to assess accuracy when SRM is unavailable. An SRM will be analyzed for PAHs, PCB Aroclors, PCB congeners, and dioxins/furans only.

[d] The satisfactory acceptance limit for SRM recovery will include the uncertainty value of the CRM mean as well as the method measurement uncertainty.

[e] Labelled compound percent recovery range.

ALS – ALS Environmental-Kelso
ARI – Analytical Resources, Inc.
Axys – Axys Analytical Services Ltd.
na – not applicable
PAH - polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

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[40] The term MDL includes other types of DLs, such as EDL values calculated for PCB congeners and dioxin/furan congeners. Recent revisions to EPA SW846 methods no longer require the calculation of MDLs.

CRM – certified reference material
dw – dry weight
LCS – laboratory control sample
SRM – standard reference material
SVOC – semivolatile organic compound
TOC – total organic carbon

The laboratory MDL and RL values for each analytical method are compared to their respective cleanup level values in Tables 4-19 and 4-20. All of the analytical methods are sufficiently sensitive, with the exception of the PCB Aroclor method. For PCBs, the PCB Aroclor method (EPA 8082A) RL of 20 μg/kg dw is higher than the RAO 1 cleanup level of 2 μg/kg dw. However, PCBs in baseline sediment samples are likely to be detected at concentrations above 20 μg/kg dw, since they were detected in 94% of the 1,390 sediment samples in the FS dataset using the PCB Aroclor method. If none of the PCB Aroclors are detected in a particular composite sample, then that sample will be analyzed for PCB congeners with a method RL of 0.004 μg/kg dw.[41]

Table 4-19. RAO 1, 2, and 4 COCs and associated RLs and cleanup levels for baseline sediment samples

COC	Method	Unit	RL	Cleanup Levels		
				RAO 1	RAO 2[a]	RAO 4
PCBs	EPA 8082A (Aroclors)[b]	μg/kg dw	20	2	500	128
	EPA 1668c (congeners)	μg/kg dw	0.002[c]			
Total arsenic	EPA 6020A	mg/kg dw	0.500	na	7	na
cPAH	EPA 8270D-SIM	μg TEQ/kg dw	4.5[d]	na	90	na
Dioxins/furans	EPA 1613b	ng TEQ/kg dw	1.14[e]	2	13	na

[a] Cleanup level is minimum value for 0–10- or 0–45-cm compliance.

[b] If none of the PCB Aroclors are detected in a sample, then the sample will be submitted for analysis of PCB congeners.

[c] The PCB RL is based on the LMCL from Axys and represents the maximum value for an individual PCB congener. Individual congener LMCLs are listed in Appendix C. The reported LMCL will be adjusted based on the mass of each sample.

[d] The RL for the cPAH TEQ value was calculated using one-half the RL for each of the cPAH compounds and the appropriate TEF values (California EPA 2009).

[e] The dioxin/furan RL is based on the laboratory minimum calibration level from Axys; the dioxin/furan mammalian TEQ value was calculated using one-half the RL for each dioxin/furan compound and appropriate mammal TEF values (Van den Berg et al. 2006).

95UCL – 95% upper confidence limit for the mean
Axys – Axys Analytical Services, Ltd.
COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
EPA – US Environmental Protection Agency
LDW – Lower Duwamish Waterway
LMCL – lower method calibration limit
na – not applicable
PCB – polychlorinated biphenyl
RAO – remedial action objective
ROD – Record of Decision
RL – reporting limit
SIM – selective ion monitoring
TEF – toxic equivalency factor
TEQ – toxic equivalent

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[41] The PCB RL is based on the laboratory minimum calibration level (LMCL) from Axys and represents the maximum value for an individual PCB congener. Individual congener LMCLs are listed in Appendix C. The reported LMCL will be adjusted based on the mass of each sample.

Table 4-20. RAO 3 COCs and associated RLs and cleanup levels for individual 0–10-cm sediment samples

COC	Method	RL	Cleanup Levels for RAO 3[a]
Metals (mg/kg dw**)**			
Arsenic	EPA 6020A	0.2	57
Cadmium	EPA 6020A	0.1	5.1
Chromium	EPA 6020A	0.5	260
Copper	EPA 6020A	0.5	390
Lead	EPA 6020A	0.1	450
Silver	EPA 6020A	0.2	6.1
Zinc	EPA 6020A	4	410
Mercury	EPA 7471B	0.025	0.41
PAHs and SVOCs (µg/kg dw**)**			
Benzo(a)anthracene	EPA 8270D	20.0	2,200[b]
Benzo(a)pyrene	EPA 8270D	20.0	1,980[b]
Total benzofluoranthenes	EPA 8270D	40.0	4,600[b]
Chrysene	EPA 8270D	20.0	2,200[b]
Dibenzo(a,h)anthracene	EPA 8270D	20.0	240[b]
Indeno(1,2,3-cd)pyrene	EPA 8270D	20.0	680[b]
Anthracene	EPA 8270D	20.0	4,400[b]
Acenaphthene	EPA 8270D	20.0	320[b]
Acenapthylene	EPA 8270D	20.0	1,320[b]
Benzo(g,h,i)perylene	EPA 8270D	20.0	620[b]
Fluoranthene	EPA 8270D	20.0	3,200[b]
Fluorene	EPA 8270D	20.0	460[b]
Naphthalene	EPA 8270D	20.0	1,980[b]
Phenanthrene	EPA 8270D	20.0	2,000[b]
Pyrene	EPA 8270D	20.0	20,000[b]
Total HPAHs[c]	EPA 8270D	40.0	19,200[b]
Total LPAHs[d]	EPA 8270D	20.0	7,400[b]
2,4-dimethylphenol	EPA 8270D-SIM	25	29
2-methylnaphthalene	EPA 8270D	20.0	760[b]
4-methylphenol	EPA 8270D	20.0	670
Benzoic acid	EPA 8270D-SIM	50.0	650
Benzyl alcohol	EPA 8270D-SIM	5	57
Bis(2-ethylhexyl)phthalate	EPA 8270D	50.0	940[b]
Butyl benzyl phthalate	EPA 8270D	20.0	98[b]
Dibenzofuran	EPA 8270D	20.0	300[b]
Dimethyl phthalate	EPA 8270D	20.0	1,060[b]
Hexachlorobenzene	EPA 8270D-SIM	5.0	7.6[b]

Table 4-20. RAO 3 COCs and associated RLs and cleanup levels for individual 0–10-cm sediment samples

COC	Method	RL	Cleanup Levels for RAO 3[a]
n-Nitrosodiphenylamine	EPA 8270D-SIM	5	220[b]
PCP	EPA 8270D-SIM	20	360
Phenol	EPA 8270D	20.0	420
1,2,4-trichlorobenzene	EPA 8270D-SIM	5.00	16.2[b]
1,2-dichlorobenzene	EPA 8270D-SIM	5.00	46.0[b]
1,4-dichlorobenzene	EPA 8270D -SIM	5.00	62.0[b]
PCBs (µg/kg dw)			
PCBs	EPA 8082A (Aroclors)[e]	20.0	240[b,c,f]

[a] Per the ROD (EPA 2014b), cleanup levels for RAO 3 are based on the benthic SCO chemical criteria in the SMS (WAC 173-204-562). The compliance depth is the 0–10-cm interval.

[b] Organic carbon-normalized criteria were converted to non-normalized values using 2% TOC. Cleanup levels are assessed on organic carbon normalized basis. These values are presented as dry weight values for purposes of comparing to RLs only.

[c] HPAH compounds include fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3 cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

[d] LPAH compounds include naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, and 2-methylnaphthalene.

[e] If none of the PCB Aroclors are detected, then the sample will be submitted for analysis of PCB congeners by EPA method 1668c with an estimated RL of 0.002 µg/kg dw. The PCB RL is based on the LMCL from Axys and represents the maximum value for an individual PCB congener. Individual congener LMCLs are listed in Appendix C The reported LMCL will be adjusted based on the mass of each sample.

[f] All 0–10-cm samples analyzed for PCB Aroclors will be archived for potential PCB congener analysis.

Axys – Axys Analytical Services, Ltd.
COC – contaminant of concern
dw – dry weight
EPA – US Environmental Protection Agency
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LMCL – lower method calibration limit
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PCP – pentachlorophenol
RAO – remedial action objective
RL – reporting limit
ROD – Record of Decision
SCO – sediment cleanup objective
SIM – selective ion monitoring
SMS – Washington State Sediment Management Standards
SVOC – semivolatile organic compound
TOC – total organic carbon
WAC – Washington Administrative Code

Standard mass requirements are specified to meet RLs for each particular analytical method. Table 4-21 summarizes the sample volume needed for each sample type. The masses listed include those required for QC samples. The total jar volume required for standard analyses is 60 oz. One additional 8-oz. jar will be collected for each sample and archived.

Table 4-21. Sediment mass required per analysis

Analyte	Sediment Mass (ww)	Jar Size
TOC	6 g	4-oz. jar
Percent solids	45 g	
Grain size	600 g	16-oz. jar
Metals	3 g	8-oz. jar
Mercury	1 g	
PAHs	60 g	8-oz. jar
Toxaphene	75 g	
PCB Aroclors	75 g	8-oz. jar
SVOCs	60 g	
PCB congeners	40 g	8-oz. jar
Dioxins/furan congeners	40 g	
Black carbon	30 g	8-oz. jar
Ex situ porewater	1 kg	32-oz. jar
Archive	na	8-oz. jar

na – not applicable
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TOC – total organic carbon

4.7 QUALITY ASSURANCE/QUALITY CONTROL

The types of samples analyzed and the procedures conducted for QA/QC in the field and laboratory are described in this section.

4.7.1 Field quality control samples

Field QA/QC samples, such as field duplicates, are generally used to evaluate the efficiency of field decontamination procedures and the variability attributable to sample handling. A minimum of 1 field duplicate for every 20 samples will be collected for each sample type (individual 0–10-cm surface sediments, near-outfall sediments, and bank soils). In addition, one replicate *ex-situ* porewater exposure will be conducted.

To evaluate the variability in the 0-45 cm composite samples, two beach play areas (i.e., beach play areas 1 and 6) were selected for the collection of field duplicate samples. At each sampling location in these areas, two 16-oz jars (rather than one) will be collected from each hole. The field duplicates will be composited following the same methods used for the beach composite samples.

4.7.2 Laboratory quality control

Before analyzing the samples, the laboratory must provide written protocols for the analytical methods to be used, calculate RLs for each analyte in each matrix of interest as applicable, and establish an initial calibration curve for all analytes. The laboratory must also demonstrate its continued proficiency by participation in inter-laboratory comparison studies, and by repeated analysis of certified reference materials, calibration checks, laboratory reagent and rinsate blanks, and spiked samples.

For the *ex situ* porewater PE samples, a LCS and a duplicate sample will be included, as detailed in the QA/QC section of Appendix D. The inclusion of these samples will enable the evaluation of any potential contamination during laboratory procedures, and the assessment of the variability attributable to the laboratory method.

4.7.2.1 Sample delivery group

Project- and/or method-specific QC measures, such as MSs and MSDs or laboratory duplicates, will be used per sample delivery group (SDG) preparatory batch or per analytical batch, as specified in Table 4-22. A SDG is defined as no more than 20 samples, or a group of samples received at the laboratory within a 2-week period. Although a SDG may span two weeks, all holding times specific to each analytical method will be met for each sample in the SDG.

Table 4-22. Laboratory quality control sample analysis summary

Analysis Type	Initial Calibration	Initial Calibration Verification (2nd source)	Continuing Calibration Verification	SRM or LCS[a]	Laboratory Replicates	MSs	MSDs	Method Blanks	Surrogate Spikes
TOC	na	na	na	1 per 20 samples or per batch[b]	1 per 20 samples or per batch	1 per 20 samples or per batch	na	1 per 20 samples or per batch	na
Percent solids	na	na	na	na	1 per 20 samples or per batch	na	na	na	na
Grain size	na	na	na	na	Triplicate per 20 samples	na	na	na	na
Metals	prior to analysis	after initial calibration	every 10 samples	1 per prep batch[b]	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	na
Mercury	prior to analysis	after initial calibration	every 10 samples	1 per prep batch[b]	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	na
PAHs	prior to analysis	after initial calibration	every 12 hours	1 per prep batch[c]	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each sample
PCB Aroclors	prior to analysis	after initial calibration	every 10–20 analyses or 12 hours	1 per prep batch[d]	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each sample
SVOCs	prior to analysis	after initial calibration	every 12 hours	1 per prep batch[b]	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each sample
Toxaphene	prior to analysis	after initial calibration	every 10–20 analyses or 12 hours	1 per prep batch[b]	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each sample
PCB congeners	prior to analysis	after initial calibration	every 12 hours	1 per prep batch[d]	1 per prep batch	na	na	1 per prep batch	each sample
Dioxins/furans	prior to analysis	after initial calibration	every 12 hours	1 per prep batch[d]	1 per prep batch	na	na	1 per prep batch	each sample

Analysis Type	Initial Calibration	Initial Calibration Verification (2nd source)	Continuing Calibration Verification	SRM or LCS[a]	Laboratory Replicates	MSs	MSDs	Method Blanks	Surrogate Spikes
Black carbon	prior to analysis	after initial calibration	every 20 samples and at the end of run	3 (1 high and 2 low range) per batch or SDG	1 per batch or SDG	na	na	1 per batch or SDG	na

Note: A batch is a group of samples of the same matrix analyzed or prepared at the same time, not exceeding 20 samples.

[a] An LCS may be used to assess accuracy when SRM is unavailable.

[b] An LCS will be used to assess accuracy.

[c] CRM172-100G will be used to assess accuracy for PAHs.

[d] Puget Sound Sediment Reference Material will be used to assess accuracy for PCB Aroclors, PCB congeners, and dioxins/furans.

CRM – certified reference material
LCS – laboratory control sample
MS – matrix spike
MSD – matrix spike duplicate
na – not applicable or not available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SDG – sample delivery group
SRM – standard reference material
SVOC – semivolatile organic compound
TOC – total organic carbon

4.7.2.2 Laboratory quality control samples

The analyst will review the results of QC analyses from each sample group immediately after a sample group has been analyzed. The QC sample results will then be evaluated to determine whether control limits have been exceeded.

If control limits have been exceeded, then appropriate corrective action, such as recalibration followed by reprocessing of the affected samples, must be initiated before a subsequent group of samples is processed. The project QA/QC coordinator must be contacted immediately by the laboratory PM if satisfactory corrective action to achieve the DQIs outlined in this QAPP is not possible. All laboratory corrective action reports relevant to the analysis of project samples must be included in the data deliverable packages.

All primary chemical standards and standard solutions used in this project will be traceable to the National Institute of Standards and Technology (NIST), Environmental Resource Associates, National Research Council of Canada, or other documented, reliable, commercial sources. Standards will be validated to determine their accuracy by comparing them to independent standards. Laboratory QC standards are verified in a multitude of ways: second-source calibration verifications (i.e., same standard, two different vendors) are analyzed to verify initial calibrations; new working standard mixes (e.g., calibrations, spikes, etc.) are verified against the results of the original solution and must be within 10% of the true value; newly purchased standards are verified against current data. Any impurities found in the standard will be documented.

The following sections summarize the procedures that will be used to assess data quality throughout sample analysis. Table 4-22 summarizes the QC procedures to be performed by the laboratory, as well as the associated control limits for precision and accuracy.

Method Blanks

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis. A minimum of 1 method blank will be analyzed for each SDG or for every 20 samples, whichever is more frequent.

Axys has reported increased concentrations of PCB 11 in its method blank samples for the past year. The laboratory is actively working to resolve this issue and is monitoring the situation closely. In order to ensure the accuracy of the data, blank correction will be employed for PCB 11 on all samples.[42] The blank correction will be based on the mean PCB 11 concentrations in sediment laboratory method blanks for the three months preceding the analysis of the samples.

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[42] If the increased concentrations of PCB 11 are resolved, then the blank correction will not be required. EPA will be consulted before any changes are made.

Standard Reference Material

SRMs are samples of similar matrices and known analyte concentrations, processed through the entire analytical procedure and used as an indicator of method accuracy. A minimum of 1 SRM will be analyzed for each SDG or for every 20 samples, whichever is more frequent. SRMs will be analyzed for PAHs, PCB Aroclors, PCB congeners, and dioxins/furans. An LCS sample can be used to assess accuracy if appropriate SRM is not available. An LCS will be analyzed for conventional and organic analyses.

Laboratory Control Samples

LCSs are prepared from a clean matrix using the same process as the project samples that are spiked with known amounts of the target compounds. The recoveries of the compounds are used as a measure of the accuracy of the test methods.

Laboratory Replicate Samples

Laboratory replicate samples provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Laboratory replicates are subsamples of the original sample that are prepared and analyzed as a separate sample, assuming sufficient sample matrix is available. A minimum of 1 laboratory replicate sample will be analyzed for each SDG or for every 20 samples, whichever is more frequent, for metals, conventional parameters, dioxins/furans, and PCB congeners. In addition, in order to assess the variability of the composite samples, three samples will be created by subsampling the trays (described in Appendix D) three times to allow for a triplicate analysis of cPAHs for one of the three site-wide potential clamming area composite samples.

For the passive samplers, one sediment sample will be identified for replicate analysis. Two passive sampler samples will be inserted into one sample jar and analyzed as replicates. In order to ensure that doubling the samplers does not deplete the sediment PCB concentration (i.e., significantly affect the equilibrium), the replicate sample will be selected based on an assessment of the TOC.

Matrix Spikes and Matrix Spike Duplicates

The analysis of MS samples provides information on the extraction efficiency of the method on the sample matrix. By performing MSD analyses, information on the precision of the method is also provided for organic analyses. For organic analyses, a minimum of 1 MS/MSD pair will be analyzed for each SDG or for every 20 samples, whichever is more frequent, when sufficient sample volume is available, with the exception of PCB congeners and dioxins/furans. For inorganic analyses (i.e., metals), a minimum of one MS sample will be analyzed for each SDG, when sufficient sample volume is available.

Surrogate Spikes

All project samples analyzed for organic compounds will be spiked with appropriate surrogate compounds, as defined in the analytical methods. Surrogate recoveries will be reported by ARI, ALS, and Axys; however, no sample results will be corrected for recovery using these values.

Isotope Dilution Quantitation

All project samples analyzed for PCB and dioxin/furan congeners will be spiked with a known amount of surrogate compounds, as defined in the analytical methods. The labeled surrogate compounds will respond similarly to the effects of extraction, concentration, and gas chromatography. Data will be corrected for the recovery of the surrogates used for quantification.

Internal Standard Spikes

Internal standards may be used for calibrating and quantifying organic compounds and metals using MSs. If internal standards are required by the method, all calibration, QC, and project samples will be spiked with the same concentration of the selected internal standard(s). Internal standard recoveries and retention times must be within method and/or laboratory criteria.

Performance Reference Compounds

PRCs are used to determine the degree to which passive samplers have come to equilibrium during the period of deployment. The PE strips will be loaded with carbon-13-labelled PCBs prior to deployment. The carbon-13-labelled PCBs to be used for PRCs will include ^{13}C-PCB8, ^{13}C-PCB28, ^{13}C-PCB95, ^{13}C-PCB111, ^{13}C-PCB153, and ^{13}C-PCB178. The change in PRC concentration during deployment will be used to help quantify the non-equilibrium conditions between porewater and the PE for various PCB congeners.

PRC Day-zero Blank

PE samples will be set aside and analyzed to confirm PRC concentrations. These samples will be stored, frozen, at the laboratory and analyzed with the passive sampler replicates to measure PRC concentrations. PRC concentrations in the day-zero blanks will be used to establish pre-exposure PRC concentrations, which will be necessary to determine the fraction of PRC lost from each sampler during the sediment exposures. The change in PRC concentration during the exposures will be used to quantify non-equilibrium conditions, as described in Section 4.5.4.

Passive Sampler Exposure Blank

PE samples exposure blanks will be shipped from Axys to ARI and exposed only to double-distilled water on a shaker table throughout the passive sampler exposure period. The samplers will then be shipped to Axys and analyzed in order to determine if there was any exposure to PCBs during shipping and exposure that was not associated with LDW sediment.

4.8 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

Prior to each field event, measures will be taken to test, inspect, and maintain all field equipment. All equipment used, including the differential global positioning system (DGPS) unit and digital camera, will be tested for accuracy before leaving for the field event.

The FC will be responsible for overseeing the testing, inspection, and maintenance of all field equipment. The laboratory PM will be responsible for ensuring laboratory equipment testing, inspection, and maintenance requirements are met. The methods used in calibrating the analytical instrumentation are described in Section 4.9.

4.9 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Multipoint initial calibration will be performed on each analytical instrument at the start of the project, after each major interruption to the instrument, and when any continuing calibration does not meet the specified criteria. The number of points used in the initial calibration is defined in each analytical method. Continuing calibrations will be performed daily for organic analyses, every 10 samples for inorganic analyses, and with every sample batch for conventional parameters to ensure proper instrument performance.

Gel permeation chromatography (GPC) calibration verifications will be performed at least once every seven days, and corresponding raw data will be submitted by the laboratory with the data package. In addition, florisil performance checks will be performed for every florisil lot, and the resulting raw data will be submitted with the data package.

Calibration of analytical equipment used for chemical analyses includes the use of instrument blanks or continuing calibration blanks, which provide information on the stability of the baseline established. Continuing calibration blanks will be analyzed immediately after the continuing calibration verification, at a frequency of 1 blank for every 10 samples analyzed for inorganic analyses, and 1 blank every 12 hours for organic analyses. If the continuing calibration does not meet the specified criteria, the analysis must stop. Analysis may resume after corrective actions have been taken to meet the method specifications. All project samples analyzed by an instrument found to be out of compliance must be reanalyzed.

A Trimble© SPS461 or similar GPS receiver unit will be employed for the various sampling methods outlined in this QAPP. The GPS receiver will be calibrated daily to ensure that it is accurately recording positions from known benchmarks and functioning within the individual unit's factory specifications.

4.10 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The FC will gather and check field supplies daily for satisfactory conditions before each field event. Batteries used in the digital camera will be checked daily and recharged as necessary. Supplies and consumables for the field sampling effort will be inspected upon delivery and accepted if the condition of the supplies is satisfactory.

4.11 DATA MANAGEMENT

All field data will be recorded on field forms, which the FC will check for missing information at the end of each field day and amend as necessary. A QC check will be done to ensure that all data have been transferred accurately from the field forms to the database. Field forms will be archived in the Windward library.

ARI, ALS, and Axys are required to submit data in an electronic format, as described in Section 3.7.2. The laboratory PM will contact the project QA/QC coordinator prior to data delivery to discuss specific format requirements.

A library of routines will be used to translate typical electronic output from laboratory analytical systems, and to generate data analysis reports. The use of automated routines will ensure that all data are consistently converted to the desired data structures, and that operator time is kept to a minimum. In addition, routines and methods for quality checks will be used to ensure such translations are correctly applied.

Written documentation will be used to clarify how field and analytical laboratory duplicates and QA/QC samples were recorded in the data tables, and to provide explanations of other issues that may arise. The data management task will include keeping accurate records of field and laboratory QA/QC samples so that project team members who use the data will have appropriate documentation. All data management files will be secured on the Windward network. Data management procedures outlined in Appendix C of the Work Plan will be followed (Windward and Integral 2017b).

5 Assessment and Oversight

5.1 COMPLIANCE ASSESSMENTS AND RESPONSE ACTIONS

EPA or its designees may observe field activities during each sampling event, as needed. If situations arise wherein there is a significant inability to follow the QAPP methods precisely, the Windward PM will determine the appropriate actions and consult EPA (or its designee).

5.1.1 Compliance assessments

Laboratory and field performance assessments will consist of on-site reviews conducted by EPA of QA systems and equipment for sampling, calibration, and measurement. EPA personnel may conduct a laboratory audit prior to sample analysis. Any pertinent laboratory audit reports will be made available to the project QA/QC coordinator upon request. ARI, ALS, and Axys will be required to have written procedures addressing internal QA/QC. All laboratories and QA/QC coordinators will be required to ensure that all personnel engaged in sampling and analysis tasks have appropriate training.

5.1.2 Response actions for field sampling

The FC, or a designee, will be responsible for correcting equipment malfunctions throughout field sampling, and for resolving situations in the field that may result in nonconformance or noncompliance with this QAPP. All corrective measures will be immediately documented in the field logbook, and protocol modification forms will be completed.

5.1.3 Corrective action for laboratory analyses

ARI, ALS, and Axys will be required to comply with their current written SOPs, laboratory QA plan, and analytical methods. All laboratory personnel will be responsible for reporting problems that may compromise the quality of the data. The analysts will identify and correct any anomalies before continuing with sample analysis. The laboratory PMs will be responsible for ensuring that appropriate corrective actions are initiated as required for conformance with this QAPP.

The project QA/QC coordinator will be notified immediately if any QC sample exceeds the DQIs outlined in this QAPP (Table 4-17) and the exceedance cannot be resolved through standard corrective action procedures. A description of the anomaly, the steps taken to identify and correct the anomaly, and the treatment of the relevant sample batch (i.e., recalculation, reanalysis, and re-extraction) will be submitted with the data package using the case narrative or corrective action form.

5.2 REPORTS TO MANAGEMENT

The FC will prepare a summary email for submittal to LDWG and EPA following each sampling day. The project QA/QC coordinator will also prepare progress reports for submittal by email to LDWG and EPA on the following occasions: 1) after sampling has been completed and samples have been submitted for analysis, 2) when information is received from the laboratory, and 3) when analyses are complete. The statuses of the samples and analyses will be indicated, with emphasis on any deviations from this QAPP. For each sampling event (Sampling Event 1 and Sampling Event 2), a data report will be written after validated data are available, as described in Section 2.2.

6 Data Validation and Usability

6.1 DATA VALIDATION

The data validation process will begin in the laboratory with the review and evaluation of data by supervisory personnel or QA specialists. The laboratory analyst will be responsible for ensuring that the analytical data are correct and complete, that appropriate procedures have been followed, and that QC results are within acceptable limits. The project QA/QC coordinator will be responsible for ensuring that all analyses performed by ARI, ALS, and Axys are correct, properly documented, and complete, and that they satisfy the project DQIs specified in this QAPP.

Data will not be considered final until validated. Data validation will be conducted following EPA guidance (EPA 2016a, b, 2014a; USEPA 2016).

Independent third-party data review and summary validation of the analytical chemistry data will be conducted by EcoChem or a suitable alternative. All data will undergo summary-level data validation and a minimum of 10% or one SDG will undergo full data validation. Full data validation parameters will include:

- QC analysis frequencies
- Analysis holding times
- Laboratory blank contamination
- Instrument calibration
- Surrogate recoveries
- LCS/SRM recoveries
- MS recoveries
- MS/MSD RPDs
- Compound identifications—verification of raw data with the reported results (10% of analytes)
- Compound quantitations—verification of calculations and RLs (10% of analytes)
- Instrument performance check (tune) ion abundances
- Internal standard areas and retention time shifts
- Ion abundance ratio compared to theoretical ratios for samples analyzed by EPA methods 1613b and 1668c

If no discrepancies are found between reported results and raw data in the dataset that undergoes full data validation, then a summary validation of the rest of the data can proceed using all of the QC forms submitted in the laboratory data package. QA review of the sediment and passive sampler chemistry data will be performed in accordance with the QA requirements of the project, the technical specifications of the analytical methods indicated in Tables 4-18 through 4-21, and EPA guidance for organic and inorganic data review (EPA 2016a, b). The EPA PM may have EPA peer review the third-party validation or perform data assessment/validation on a percentage of the data.

All discrepancies and requests for additional, corrected data will be discussed with ARI, ALS, and Axys prior to issuance of the formal data validation report. The project QA/QC coordinator should be informed of all contacts with ARI, ALS, and Axys during data validation. Procedures used and findings made during data validation will be documented on worksheets. The data validator will prepare a data validation report that will summarize QC results, qualifiers, and possible data limitations. This data validation report will be appended to the data report. Only validated data with appropriate qualifiers will be released for general use.

6.2 RECONCILIATION WITH DATA QUALITY INDICATORS

Data QA will be conducted by the project QA/QC coordinator in accordance with EPA guidelines (EPA 2016a, b). The results of the third-party independent review and validation will be reviewed, and cases wherein the project DQIs were not met will be identified. The usability of the data will be determined in terms of the magnitude of the DQI exceedance.

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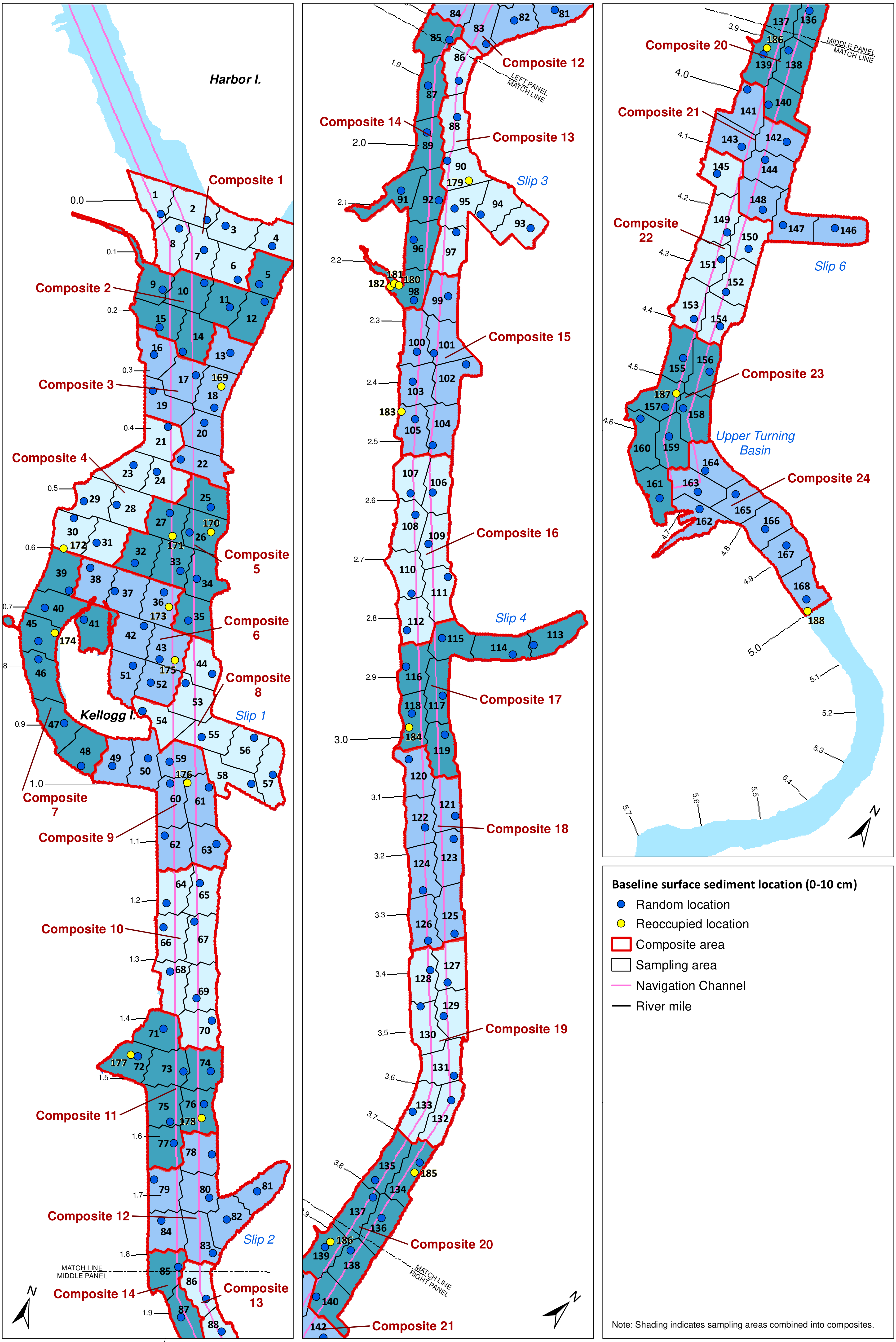

Scale is the same for each inset map

Baseline surface sediment location (0-10 cm)

- ● Random location
- ● Reoccupied location
- ▭ Composite area
- ☐ Sampling area
- — Navigation Channel
- — River mile

Note: Shading indicates sampling areas combined into composites.

Map 4-1. Baseline surface sediment (0-10 cm) composite areas

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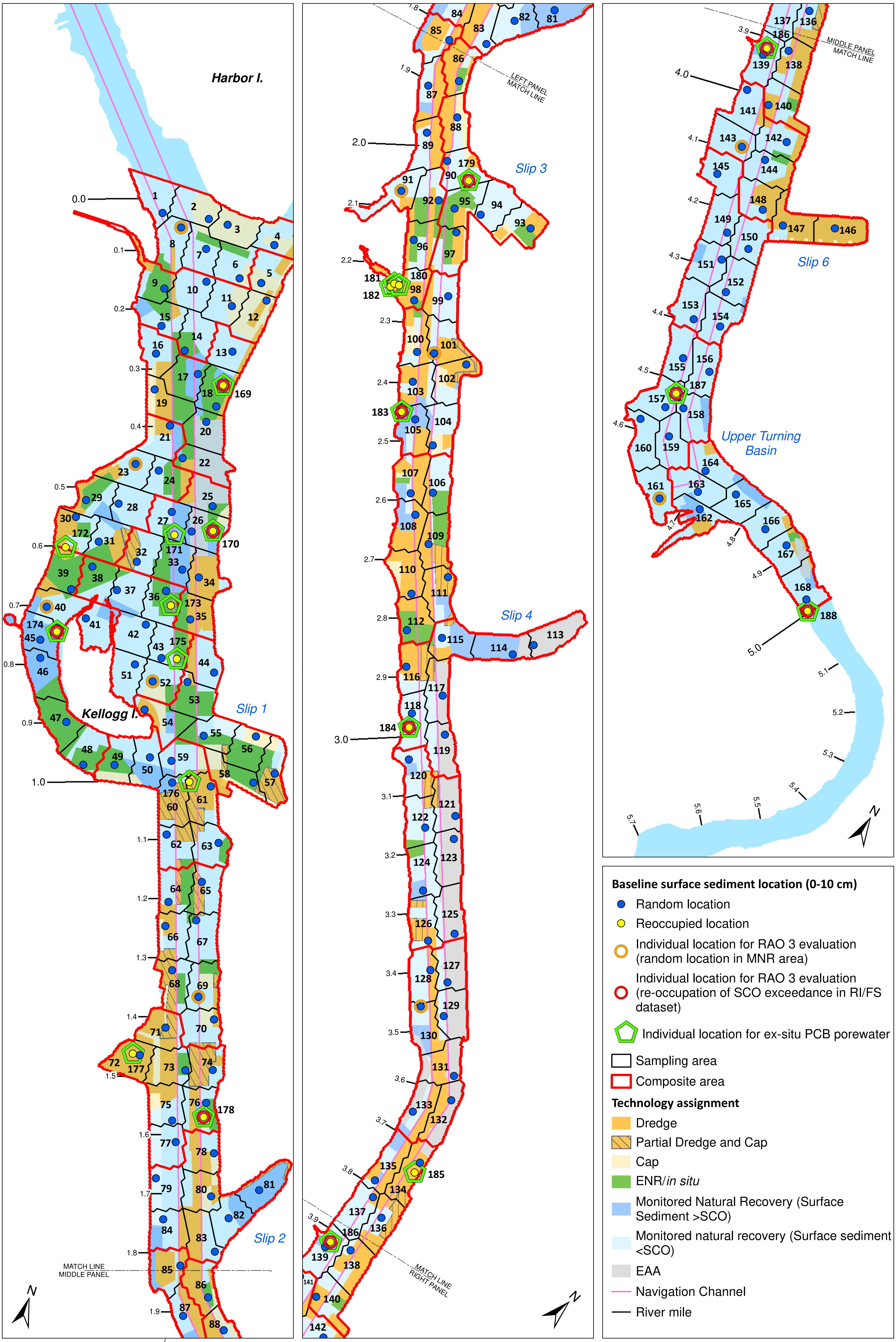
Prepared by craigh, 2/14/2018; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-1 6518 Surface sediment compositing plan.mxd



Map 4-2. Baseline surface sediment (0-10 cm) sampling locations with technology assignments

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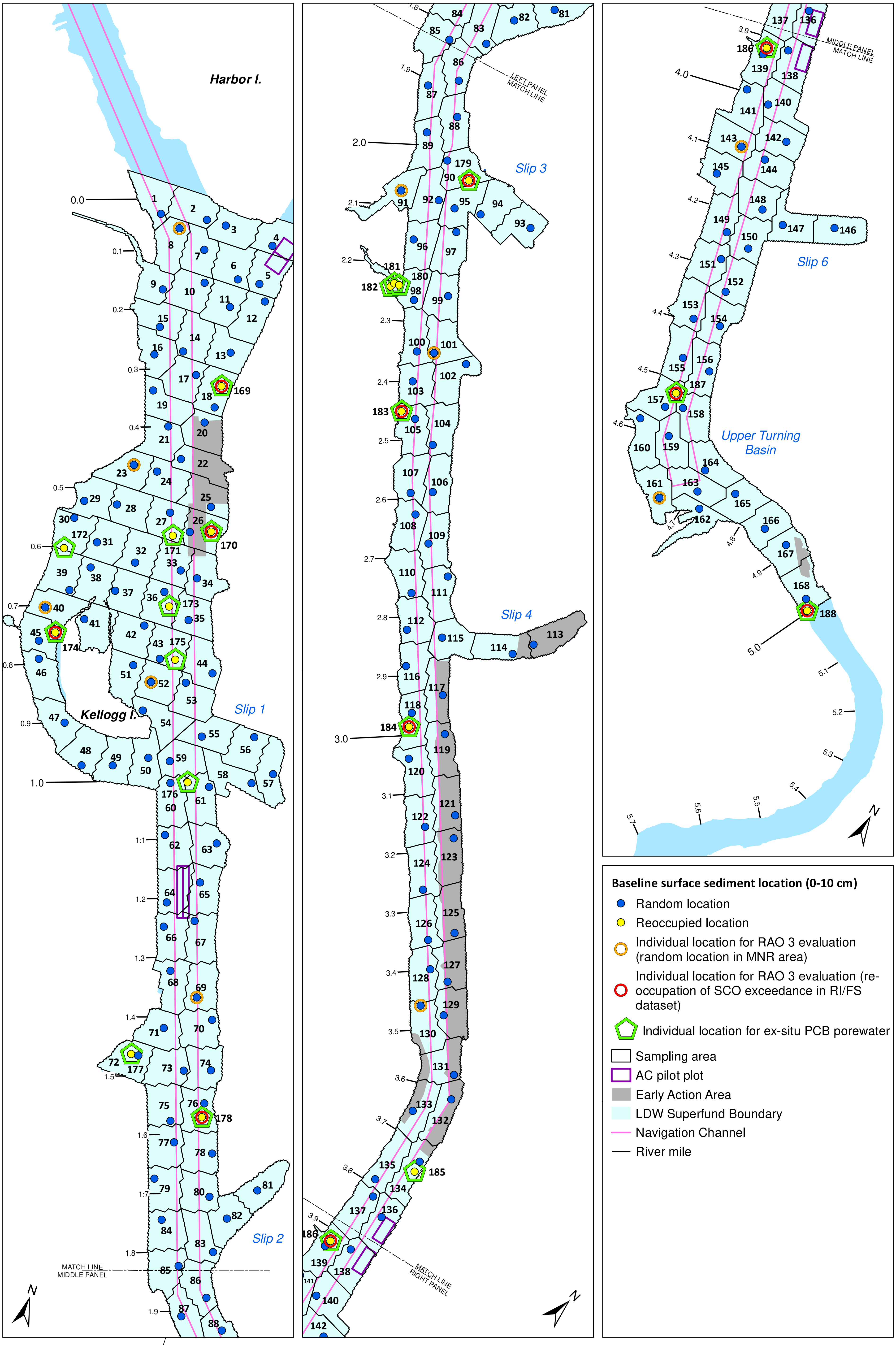
Prepared by craigh, 1/11/2018; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-2 6518 Surface sediment sampling plan wRemedy.mxd



Baseline surface sediment location (0-10 cm)

- ● Random location
- ● Reoccupied location
- ○ Individual location for RAO 3 evaluation (random location in MNR area)
- ○ Individual location for RAO 3 evaluation (re-occupation of SCO exceedance in RI/FS dataset)
- ⬠ Individual location for ex-situ PCB porewater
- ☐ Sampling area
- ☐ AC pilot plot
- ▨ Early Action Area
- ▨ LDW Superfund Boundary
- — Navigation Channel
- — River mile

0 0.1 0.2 Miles

0 0.2 0.4 Kilometers

Scale is the same for each inset map

Map 4-3. Baseline surface sediment (0-10 cm) sampling locations and sample uses

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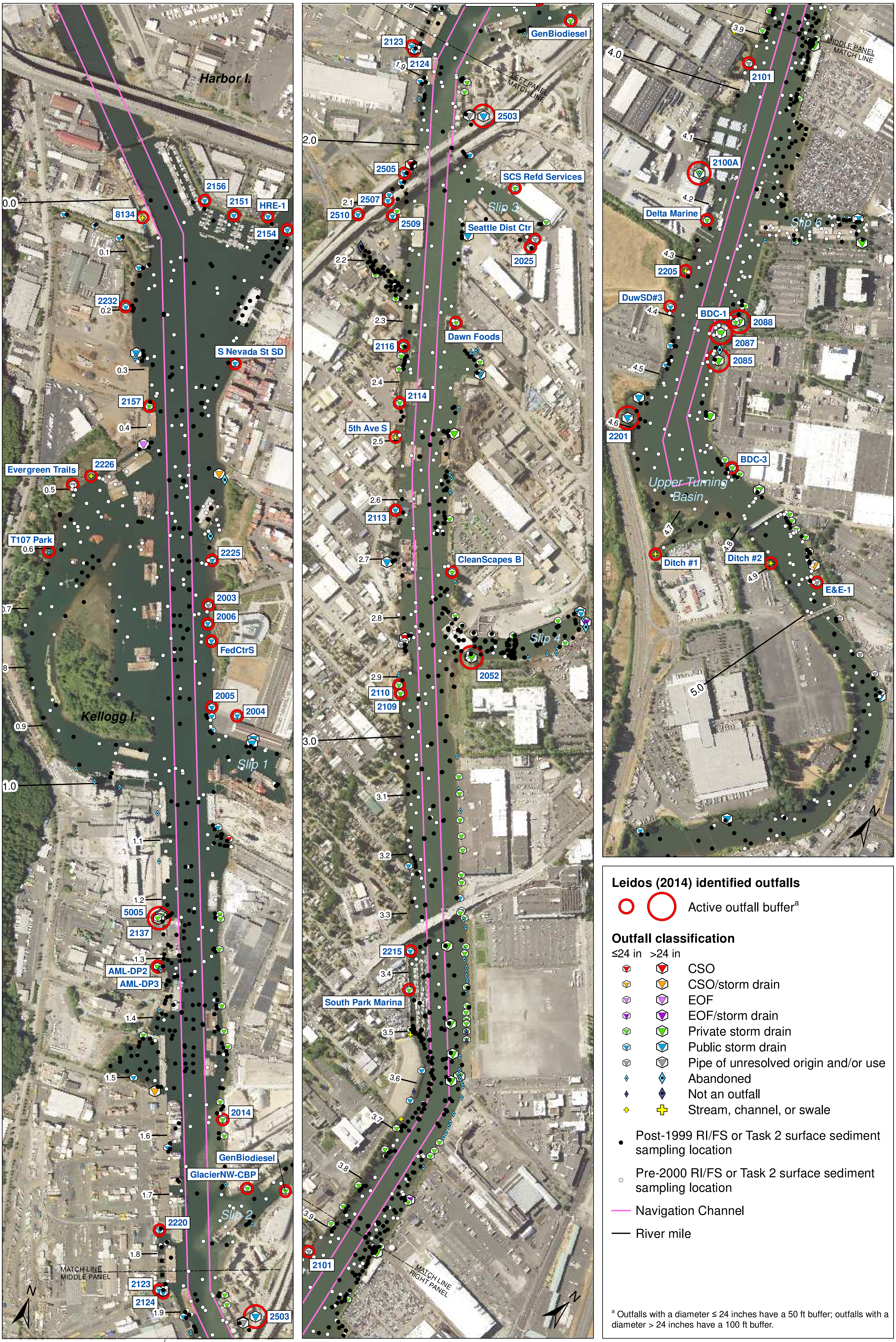
Prepared by craigh, 12/19/2017; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-3 6518 Surface sediment sampling plan.mxd



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Aerial photo: USDA FSA NAIP DOQQ, 1 m resolution, August 2015.

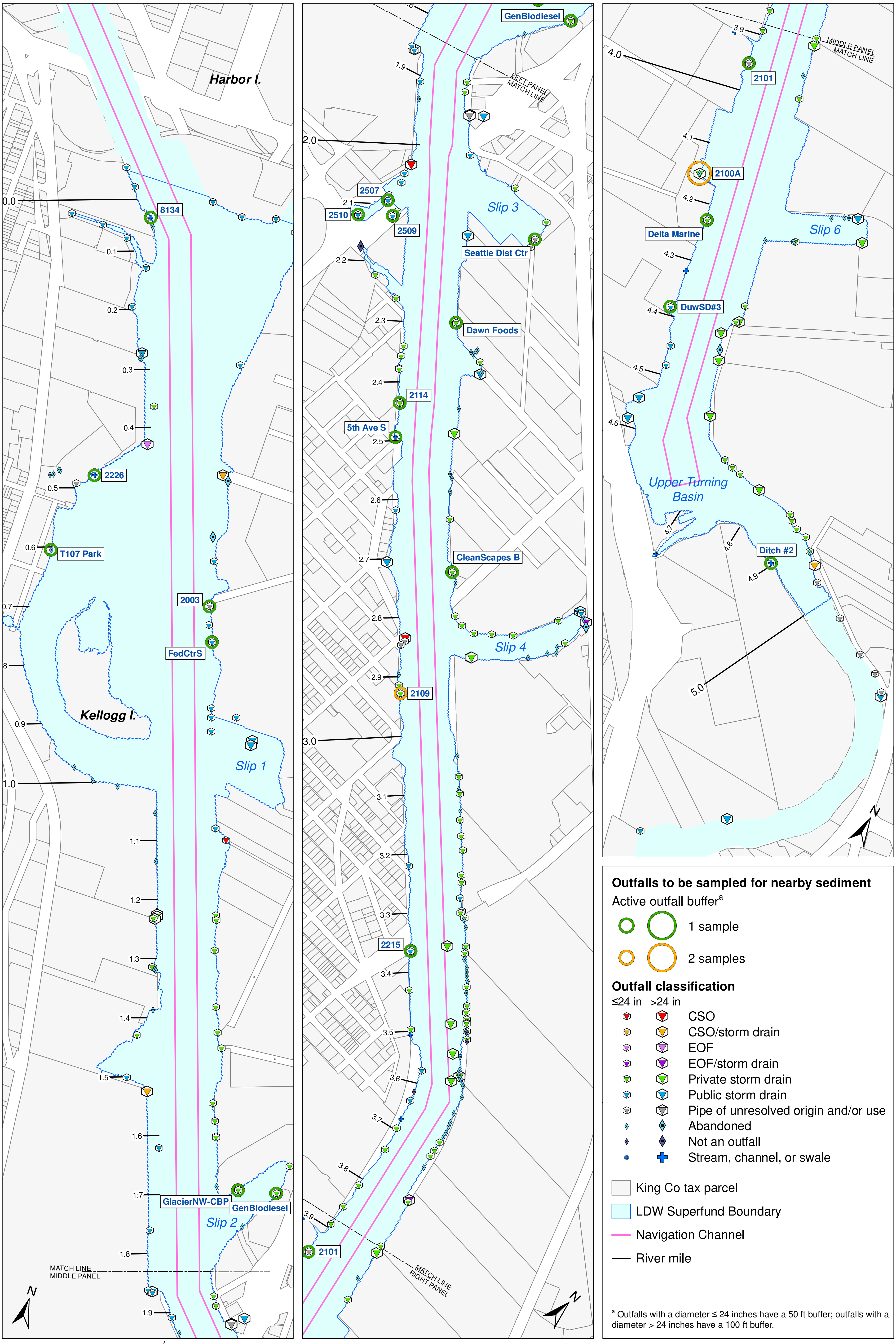
0 0.1 0.2 Miles

0 0.2 0.4 Kilometers

Scale is the same for each inset map

Map 4-4. Active outfalls within the LDW identified by Leidos (2014) for potential near-outfall sediment sampling

Prepared by: craigh, 12/19/2017; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 OAPPs\Surface Sediment\Map 4-4 6571 Active outfalls.mxd



[a] Outfalls with a diameter ≤ 24 inches have a 50 ft buffer; outfalls with a diameter > 24 inches have a 100 ft buffer.

Scale is the same for each inset map

Map 4-5. Outfalls for near-outfall sediment sampling

Prepared by craigh, 12/19/2017; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 OAPPs\Surface Sediment\Map 4-5 6666 Outfalls to be sampled.mxd

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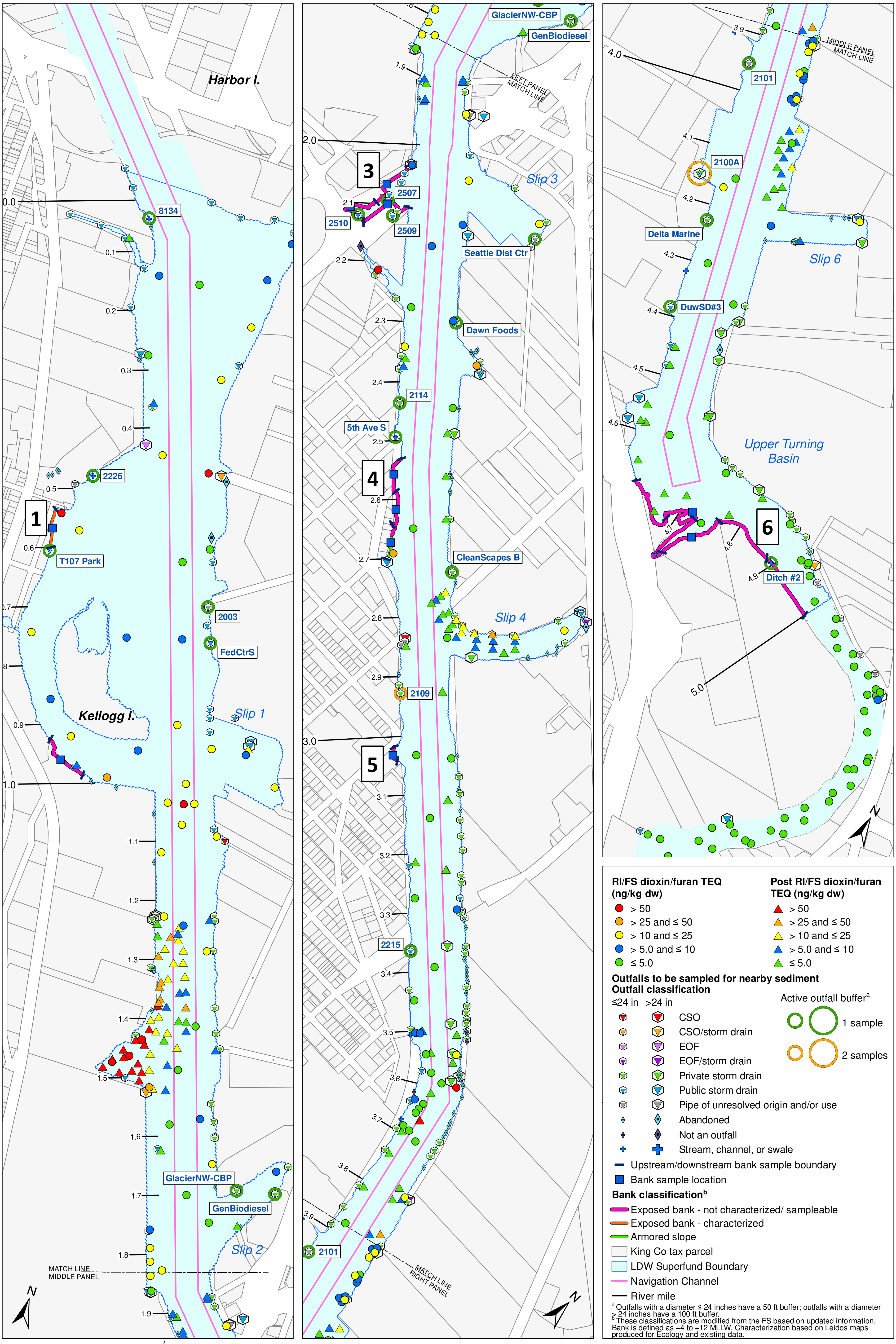

RI/FS dioxin/furan TEQ (ng/kg dw)
- 🔴 > 50
- 🟠 > 25 and ≤ 50
- 🟡 > 10 and ≤ 25
- 🔵 > 5.0 and ≤ 10
- 🟢 ≤ 5.0

Post RI/FS dioxin/furan TEQ (ng/kg dw)
- ▲ > 50
- ▲ > 25 and ≤ 50
- ▲ > 10 and ≤ 25
- ▲ > 5.0 and ≤ 10
- ▲ ≤ 5.0

Outfalls to be sampled for nearby sediment

Outfall classification

≤24 in >24 in
- CSO
- CSO/storm drain
- EOF
- EOF/storm drain
- Private storm drain
- Public storm drain
- Pipe of unresolved origin and/or use
- Abandoned
- Not an outfall
- Stream, channel, or swale

Active outfall buffer[a]
- ○ 1 sample
- ○ 2 samples

- Upstream/downstream bank sample boundary
- ■ Bank sample location

Bank classification[b]
- Exposed bank - not characterized/ sampleable
- Exposed bank - characterized
- Armored slope
- King Co tax parcel
- LDW Superfund Boundary
- Navigation Channel
- River mile

[a] Outfalls with a diameter ≤ 24 inches have a 50 ft buffer; outfalls with a diameter > 24 inches have a 100 ft buffer.

[b] These classifications are modified from the FS based on updated information. Bank is defined as +4 to +12 MLLW. Characterization based on Leidos maps produced for Ecology and existing data.

0 0.1 0.2 Miles

0 0.2 0.4 Kilometers

Scale is the same for each inset map

Map 4-6. Existing dioxin/furan sediment data and source-related sampling locations

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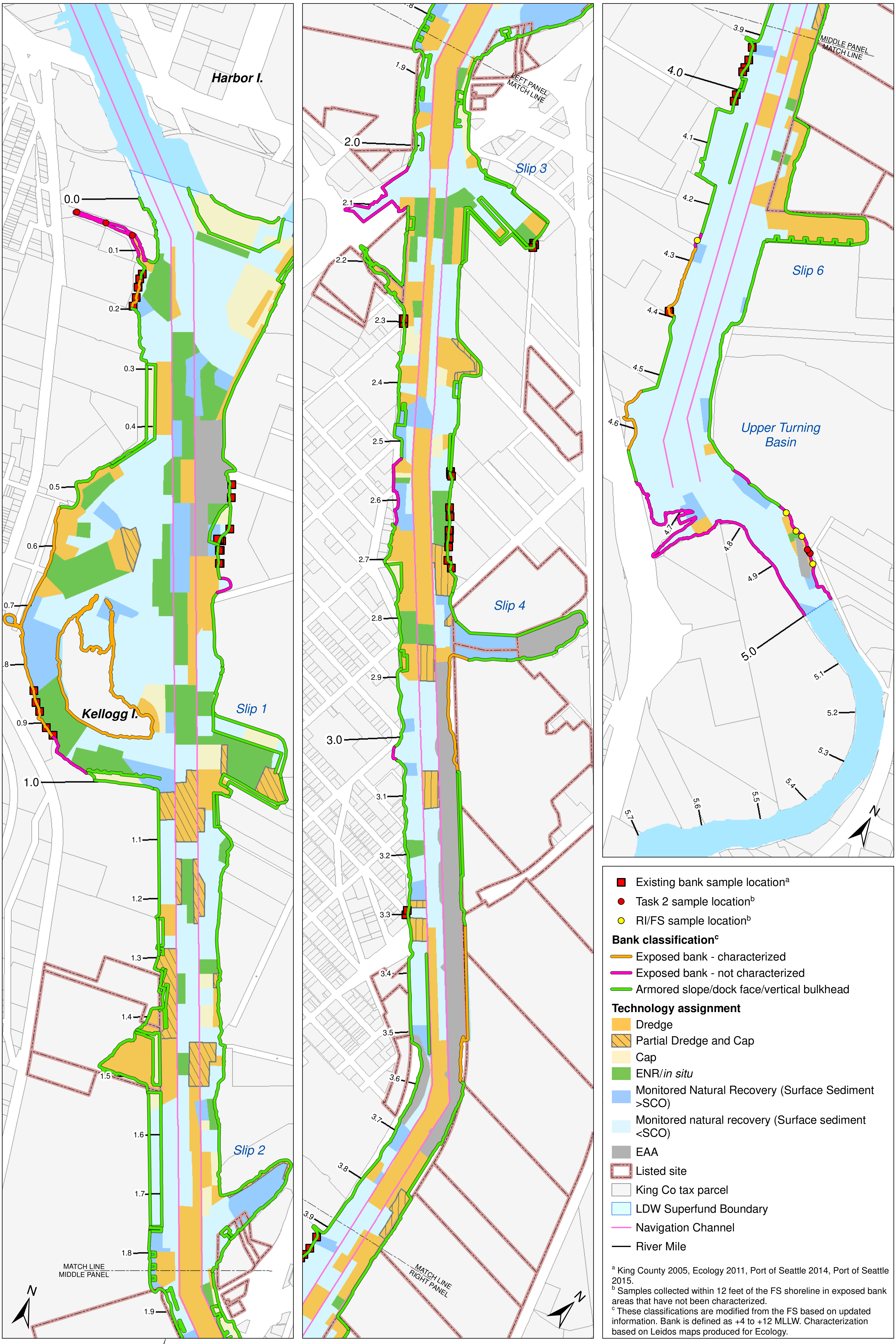
Prepared by craigh, 1/11/2018; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-6 6698 DF sediment data and source sampling locs.mxd



[a] King County 2005, Ecology 2011, Port of Seattle 2014, Port of Seattle 2015.

[b] Samples collected within 12 feet of the FS shoreline in exposed bank areas that have not been characterized.

[c] These classifications are modified from the FS based on updated information. Bank is defined as +4 to +12 MLLW. Characterization based on Leidos maps produced for Ecology.

0 0.1 0.2 Miles

0 0.2 0.4 Kilometers

Scale is the same for each inset map

Map 4-7. Bank classifications and existing bank sample locations

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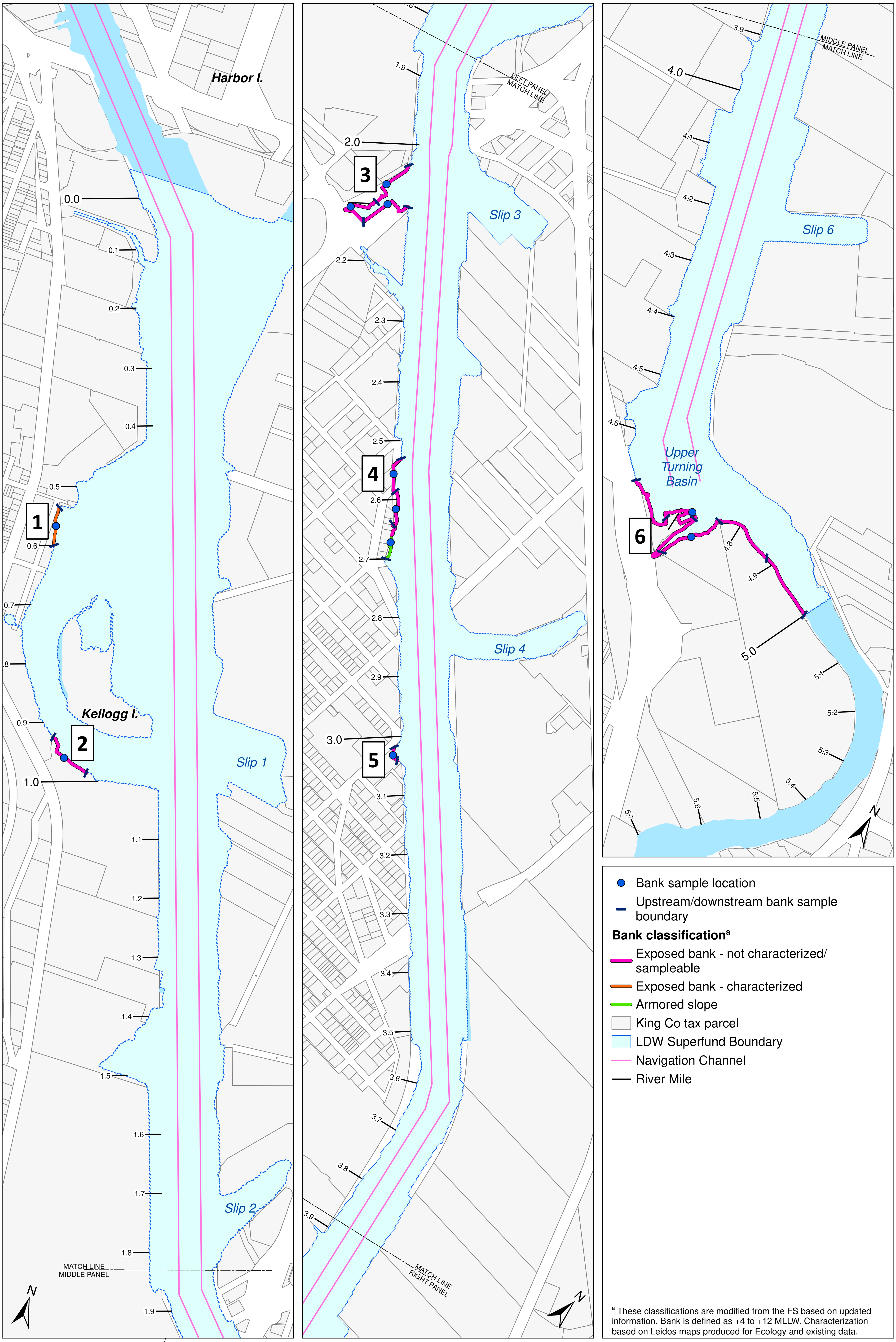
Prepared by craigh, 1/11/2018; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-7 6565 Bank samples and shoreline.mxd



[a] These classifications are modified from the FS based on updated information. Bank is defined as +4 to +12 MLLW. Characterization based on Leidos maps produced for Ecology and existing data.

Scale is the same for each inset map

Map 4-8. Bank sample locations

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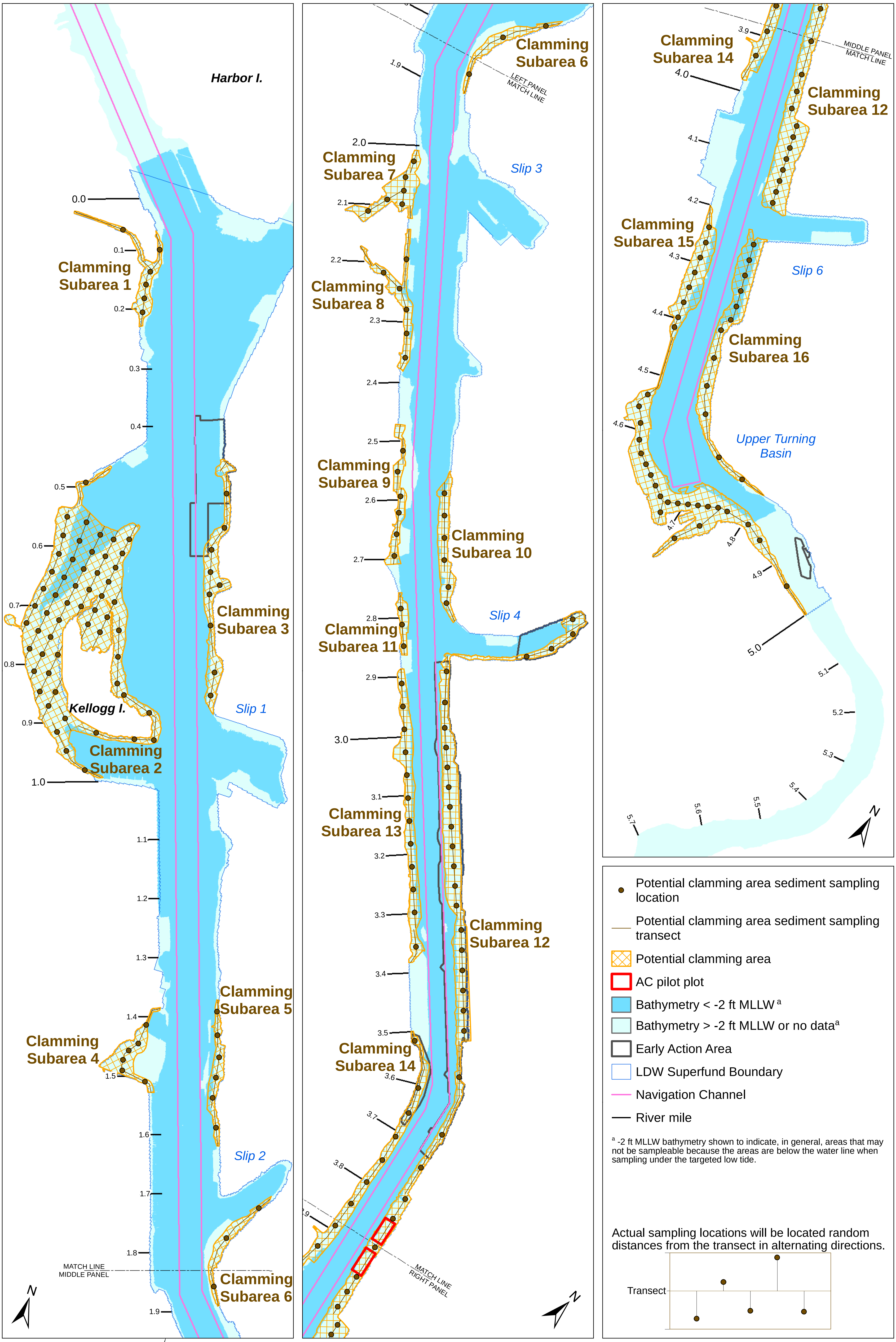
Prepared by craigh, 1/11/2018; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-8 6565 Proposed bank samples and shoreline.mxd



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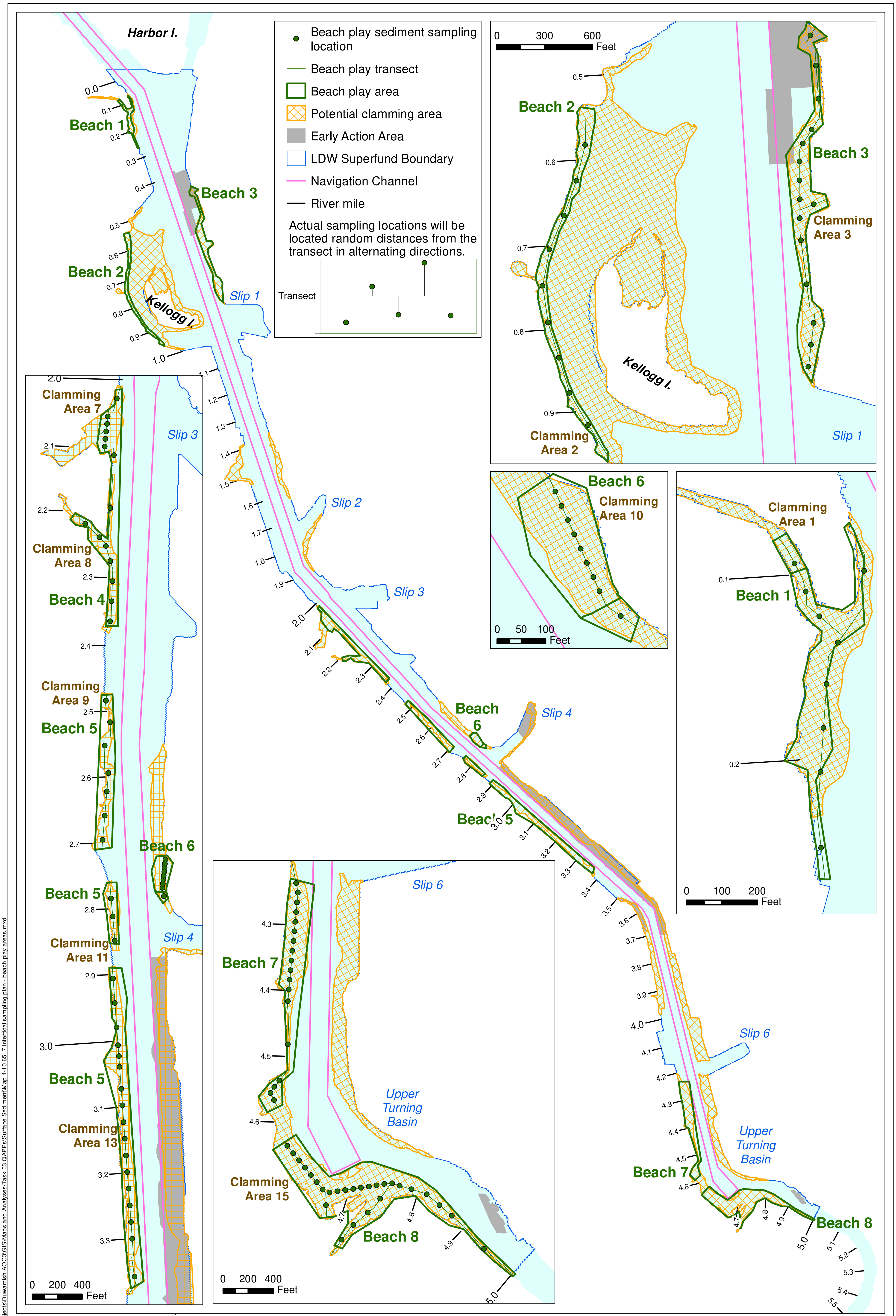
0 0.1 0.2 Miles

0 0.2 0.4 Kilometers

Scale is the same for each inset map

Map 4-9. Baseline potential clamming area surface sediment (0-45 cm) sampling locations

Prepared by mikey, 5/29/2018; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-9 6517 Intertidal sampling plan - clamming areas.mxd



0 0.2 0.4 Miles

0 0.4 0.8 Kilometers

N

Map 4-10. Baseline beach play area surface sediment (0-45 cm) sampling locations

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Prepared by craigh, 5/10/2018; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 03 QAPPs\Surface Sediment\Map 4-10 6517 Intertidal sampling plan - beach play areas.mxd

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LOWER DUWAMISH WATERWAY BASELINE SURFACE SEDIMENT COLLECTION AND CHEMICAL ANALYSES - QUALITY ASSURANCE PROJECT PLAN: APPENDIX A: HEALTH AND SAFETY PLAN

FINAL

Prepared for

Lower Duwamish Waterway Group

For submittal to

US Environmental Protection Agency

Prepared by:

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HEALTH AND SAFETY PLAN

Title and Approval Page: LDW Surface Sediment Sampling Health and Safety Plan

By their signature, the undersigned certify that this health and safety plan is approved and that it will be used to govern health and safety aspects of fieldwork described in the quality assurance project plan to which it is attached.

5/31/18

Name
Project Manager

Date

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Name
Corporate Health and Safety Manager

Date

5/31/18

Name
Field Coordinator/Health and Safety Officer

Date

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Acronyms

CFR	Code of Federal Regulations
CPR	cardiopulmonary resuscitation
FC	field coordinator
HSM	health and safety manager
HSO	health and safety officer
HSP	health and safety plan
LDW	Lower Duwamish Waterway
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PFD	personal flotation device
PM	project manager
PPE	personal protective equipment
QAPP	quality assurance project plan
TBT	tributyltin
TCDD	tetrachlorodibenzo-*p*-dioxin
USCG	US Coast Guard
Windward	Windward Environmental LLC

1 Introduction

This site-specific health and safety plan (HSP) describes safe working practices for conducting field activities at potentially hazardous sites and for handling potentially hazardous materials/waste products. This HSP covers elements specified in 29 Code of Federal Regulations (CFR) 1910§120. The procedures and guidelines contained herein are based on generally recognized health and safety practices. Any changes or revisions to this HSP will be made by a written amendment that will become a permanent part of this document. The goal of this HSP is to establish procedures for safe working practices for all field personnel and visitors.

This HSP addresses all activities associated with the collection and handling of surface sediment and bank soil samples from the Lower Duwamish Waterway (LDW) for chemical analyses. During site work, this HSP is to be implemented by the field coordinator (FC), who is also the designated site health and safety officer (HSO), in cooperation with the Windward Environmental LLC (Windward) health and safety manager (HSM) and the Windward project manager (PM).

All personnel involved in fieldwork on this project are required to comply with this HSP. The contents of this HSP reflect anticipation of the types of activities to be performed, knowledge of the physical characteristics of the site, and consideration of preliminary chemical data from previous investigations at the site. This HSP may be revised based on new information and/or changed conditions during site activities. Revisions will be documented in the project records.

2 Site Description and Project Scope

2.1 SITE DESCRIPTION

The sampling area is in the LDW (see Maps 4-1 through 4-9 in the quality assurance project plan [QAPP]). The QAPP to which this HSP is appended provides complete details of the sampling program. This section summarizes the types of work that will be performed during field activities.

2.2 SCOPE OF WORK

Specific tasks to be performed are as follows:

- Collection of sediment samples from a boat using a pneumatic grab sampler
- Collection of sediment and soil samples from intertidal areas using a stainless steel spoon, hand corer, or shovel
- Sample handling, processing, and shipping

Additional details on sampling design and methods are provided in Section 4 of the QAPP.

3 Health and Safety Personnel

Key health and safety personnel and their responsibilities are described below. These individuals are responsible for the implementation of this HSP; they will be responsible for informing all individuals who are assigned to work on the site, or who visit the site, of the contents of this plan, and for ensuring that each person signs the Health and Safety Plan Acknowledgment Form (Attachment 1). By signing the Health and Safety Plan Acknowledgment Form, individuals recognize the site health and safety hazards, known or suspected, and agree to adhere to the protocols required to minimize exposure to such hazards.

Project Manager: The PM will have overall responsibility for the successful outcome of the project. The PM will ensure that adequate resources and budget are provided for the health and safety staff to carry out their responsibilities during fieldwork. In consultation with the HSM, the PM will make final decisions concerning implementation of the HSP.

Field Coordinator/Health and Safety Officer: Because of the limited scope and duration of fieldwork for this project, the FC and HSO will be the same person. The FC / HSO will direct field sampling activities, coordinate the technical components of the field program with health and safety components, and ensure that work is performed according to the QAPP.

The FC / HSO will implement this HSP at the work location, and will be responsible for all health and safety activities and the delegation of duties to a health and safety technician in the field, if appropriate. The FC / HSO will also have stop-work authority, to be used if there is an imminent safety hazard or potentially dangerous situation. The FC / HSO or his designee will be present during sampling and operations.

Corporate Health and Safety Manager: The HSM will have overall responsibility for preparation, approval, and revisions of this HSP. The HSM will not necessarily be present during fieldwork, but will be readily available, if required, for consultation regarding health and safety issues during fieldwork.

Field Crew: All field crew members must be familiar and comply with the information in this HSP. They will also have the responsibility to report any potentially unsafe or hazardous conditions to the FC / HSO immediately.

4 Hazard Evaluation and Control Measures

This section covers potential physical and chemical hazards that may be associated with the proposed project activities, and presents control measures for addressing these hazards. The activity hazard analysis, Section 4.3, lists the potential hazards associated with each site activity and the recommended site control to be used to minimize each potential hazard.

Confined space entry will not be necessary for this project. Therefore, hazards associated with this activity are not discussed in this HSP.

4.1 PHYSICAL HAZARDS

For this project, it is anticipated that physical hazards will present a greater risk of injury than chemical hazards. Physical hazards are identified and discussed below.

4.1.1 Slips, trips, and falls

As with all field work, caution should be exercised to prevent slips on slick surfaces. In particular, sampling from a boat or other floating platform requires careful attention to minimize the risk of falling down or overboard. The same care should be used in rainy conditions or on the shoreline where slick rocks or debris can be found. Slips can be minimized by wearing boots with good tread, made of material that does not become overly slippery when wet.

Trips are always a hazard on the uneven deck of a boat, in a cluttered work area, or in the intertidal zone where uneven substrate is common. Personnel will keep work areas as free as possible from items that interfere with walking.

Falls may be avoided by working as far from exposed edges as possible, by erecting railings, and by using fall protection when working on elevated platforms. For this project, open hatches may present a fall hazard, so hatches will remained closed when not being accessed for storage. Personnel should be aware of the area around any open hatches and use extra caution when accessing them.

4.1.2 Sampling equipment deployment

A pneumatic grab sampler deployed from a sampling vessel will be used to collect surface sediment samples, as described in Section 4.2.2 of the QAPP. Before sampling activities begin, there will be a training session for all field personnel for the equipment that will be onboard the sampling vessel. For locations that cannot be accessed from a vessel, samples will be hand-collected using a stainless steel spoon, hand corer or shovel.

4.1.3 Falling overboard

Sampling activities will be conducted from a boat. As with any work from a floating platform, there is a chance of falling overboard. US Coast Guard-approved Type II or III personal flotation devices (PFDs) will be worn while working on the deck of the boat.

4.1.4 Manual lifting

Equipment and samples must be lifted and carried. Back strain can result if lifting is done improperly. During any manual handling tasks, personnel should lift with the load supported by their legs and not their backs. For heavy loads, an adequate number of people will be used, or if possible, a mechanical lifting/handling device will be used.

4.1.5 Heat stress

Heat stress could be an issue during summer. Heat-related problems include heat rash, heat cramps, heat exhaustion, and heat stroke if the person does not ingest sufficient fluids. Heat rash can occur when sweat is not allowed to evaporate, leaving the skin wet most of the time and making it subject to irritation. Heat cramps are painful spasms of the muscles from excessive salt loss associated with sweating. Excessive sweating can also lead to heat exhaustion, resulting in moist, clammy skin. Physical signs and symptoms of heat exhaustion include headache, nausea, vertigo, weakness, thirst, and giddiness. Heat exhaustion may progress to heat stroke if a worker is unable to cool and re-hydrate his or her body. The primary signs and symptoms of heat stroke are confusion, irrational behavior, loss of consciousness, convulsions, a lack of sweating, hot dry skin, and an abnormally high body temperature. Workers should be aware of the key differences between the signs and symptoms of heat stroke and those of heat exhaustion, such as the lack of sweating, the color of the skin (red), and the rise in body temperature associated with the former. Heat stroke is a medical emergency that requires immediate medical attention.

A person exhibiting any of the signs of heat stress should be removed from the work area to a shaded area. Immediate steps that can be taken to reduce the symptoms include using a fan or soaking with water to increase cooling and promote evaporation, rehydrating with electrolyte replacement fluids, and removing outer layers of clothing.

4.1.6 Hypothermia or frostbite

Hypothermia occurs when the body's core temperature falls below 95°F. The sampling will occur during the time of year when cold and wet weather conditions may occur, making hypothermia a concern. Hypothermia is also a risk when someone becomes wet from falling overboard. The FC/HSO will monitor all crew members for early symptoms of hypothermia (e.g., shivering, muscle incoordination, mild confusion). If such symptoms are observed, the FC/HSO will take immediate steps to reduce heat loss by providing extra layers of clothing, or by temporarily moving the affected crew member to a warmer environment.

All personnel will wear protective clothing appropriate for the weather conditions and physical activity. A person exhibiting any of the signs of hypothermia should be removed from the work area to a warmer environment. Immediate steps that can be taken to reduce the symptoms of hypothermia include minimizing exposure to cold and wet conditions, limiting sitting or standing still for long periods, rehydration with warm fluids, and the removal of any wet outer layers of clothing to permit sweat evaporation during rest periods in a warm environment.

Sampling operations and conditions that might result in the occurrence of frostbite are not anticipated. The sampling will take place during the time of year (i.e., August / September) when extreme weather conditions are not expected to occur.

4.1.7 Weather

In general, field team members will be equipped for the normal range of weather conditions. The FC / HSO will be aware of current weather conditions, and of the potential for those conditions to pose a hazard to the field crew. Some conditions that might force work stoppage are electrical storms, high winds, or high waves resulting from winds.

4.1.8 Vessel traffic

Because of the high volume of vessel traffic on the LDW, precautions and safe boating practices will be implemented to ensure that the field boat does not interrupt such traffic. As practical, the field boat will stay out of the navigation channel.

4.2 CHEMICAL HAZARDS

Previous investigations have shown that some chemicals are present at higher-than-background concentrations in the sampling area. For the purposes of discussing the potential exposure of individuals to chemicals in sediments, the chemicals of concern are metals, tributyltin (TBT), petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

4.2.1 Exposure routes

Potential routes of chemical exposure include inhalation, dermal contact, and ingestion. Exposure will be minimized by using safe work practices and by wearing the appropriate personal protective equipment (PPE). Further discussion of PPE requirements is presented in Section 7.

4.2.1.1 Inhalation

Inhalation is not expected to be an important route of exposure.

4.2.1.2 Dermal exposure

Dermal exposure to hazardous substances associated with sediments, surface water, or equipment decontamination will be controlled by the use of PPE, and by adherence to detailed sampling and decontamination procedures.

4.2.1.3 Ingestion

Incidental ingestion of sediment or surface water is not considered a major route of exposure for this project. Accidental ingestion of surface water is possible. However, careful handling of equipment and containers while onboard the boat should prevent water from splashing or spilling during sample collection and handling activities.

4.2.2 Description of chemical hazards

4.2.2.1 Metals and tributyltin

Exposure to metals may occur via ingestion or skin contact. As mentioned above, neither is a likely exposure route. Metal fumes or metal-contaminated dust will not be encountered during field and sample handling activities. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for metals to pass into the body. Field procedures require immediate washing of sediments from exposed skin.

4.2.2.2 Petroleum hydrocarbons and polycyclic aromatic hydrocarbons

Exposure to petroleum hydrocarbons and PAHs may occur via ingestion or skin contact. Inhalation, the most important human health exposure pathway for this group of chemicals, is not expected to occur at this site. Animal studies have also shown that PAHs can have harmful effects on the skin, body fluids, and the ability to fight disease after both short- and long-term exposure, but these effects have not been observed in humans. Some PAHs may reasonably be expected to be carcinogens. However, large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for compounds to pass into the body. Field procedures require immediate washing of sediments from exposed skin.

4.2.2.3 Polychlorinated biphenyls

Prolonged skin contact with PCBs may cause acne-like symptoms known as chloracne. Irritation to eyes, nose, and throat may also occur. Acute and chronic exposure can damage the liver and cause symptoms of edema, jaundice, anorexia, nausea, abdominal pains, and fatigue. PCBs are a suspected human carcinogen. Skin absorption may contribute substantially to the uptake of PCBs. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for compounds to pass into the body. Field procedures require immediate washing of sediments from exposed skin.

4.2.2.4 Dioxins/furans

Prolonged skin contact with dioxins/furans may cause acne-like symptoms known as chloracne. Other effects on the skin, such as red skin rashes, have been reported to occur in people following exposure to high concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). Acute and chronic exposure can damage the liver, increase the risk of diabetes and abnormal glucose tolerance, and possibly increase the risk for reproductive and developmental effects. 2,3,7,8-TCDD is a possible human carcinogen, and a mixture of dioxins/furans with six chlorine atoms (four of the six chlorine atoms at the 2-, 3-, 7-, and 8-positions) is a probable human carcinogen. Skin absorption may substantially contribute to the uptake of dioxins/furans. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of the compounds into the body. Field procedures require the immediate washing of sediments from exposed skin.

4.3 ACTIVITY HAZARD ANALYSIS

The activity hazard analysis summarizes the field activities to be performed during the project, outlines the hazards associated with each activity, and presents controls that can reduce or eliminate the risk of the hazard occurring.

Table 1 presents the activity hazard analysis for tissue sampling from a boat.

Table A-1. Activity hazard analysis

Activity	Hazard	Control
Sediment sampling[a]	slips and trips	Use extra care when walking on uneven and unstable surfaces along the shoreline, and under wet/slippery conditions. Wear boots with good tread.
	falling overboard	Use care in boarding/departing from the vessel. Deploy and recover the net or traps from the back deck of the boat. Wear a PFD.
	skin contact with contaminated sediments or liquids	Wear modified Level D PPE.
	back strain	Use appropriate lifting technique when deploying and retrieving pots, or seek help.
	overhead hazards	Use caution and be aware of overhead and gear hazards such as the grab sampler and A-frame. Wear a hard hat and modified Level D PPE when working on deck.
	open hatches	Keep hatches closed when not being accessed. Be aware around hatch area and use caution when entering/exiting hatch.
	heat stress	Monitor crew members for signs/symptoms of heat stress. Remove person to cool area and remove extra layers of clothing. Promote evaporative cooling and rehydrate with electrolytic fluids.
	hypothermia	Monitor crew members for signs/symptoms of hypothermia. Minimize prolonged exposure to wet and cold conditions. Remove person to warm area and remove wet clothing. Rehydrate with warm fluids.

[a] Hazards related to sampling from a boat are also applicable.

PFD – personal flotation device

PPE – personal protective equipment

5 Work Zones and Shipboard Access Control

During sampling and sample handling activities, work zones will be established to identify where sample collection and processing are actively occurring. The intent of the zones is to limit the migration of sample material out of its zone, and to restrict unauthorized access to active work areas by defining work zone boundaries.

5.1 WORK ZONE

A work zone will encompass the area where sample collection and handling activities are being performed. The FC / HSO will delineate the work zone as a particular area onboard the collection vessel or at each intertidal shoreline sampling location. Only persons with appropriate training, PPE, and authorization from the FC / HSO will be allowed to enter the work zone while work is in progress.

5.2 DECONTAMINATION STATION

A decontamination station where personnel will clean soiled boots and / or PPE prior to leaving the work zone will be set up. The station will have the buckets, brushes, soapy water, rinse water, or wipes necessary to clean boots, PPE, or other equipment leaving the work zone. Plastic bags will be provided for expendable and disposable materials. If the sampling location does not allow for the establishment of a decontamination station, the FC / HSO will provide alternatives to prevent the spread of contamination.

Decontamination of the boat will be completed at the end of each work day. Cockpit and crew areas will be rinsed down with water to minimize the accumulation of sediment.

5.3 ACCESS CONTROL

Security and control of access to the boat will be the responsibility of the FC / HSO and boat captain. Boat access will be granted to necessary project personnel and authorized visitors only. Any security or access control problems will be reported to the client or appropriate authorities.

6 Safe Work Practices

Following common sense will minimize the risk of exposure or accidents at a work site. The following general safety rules will be adhered to on-site:

- Do not climb over or under obstacles of questionable stability (e.g., docks, piers).
- Do not eat, drink, smoke, or perform other hand-to-mouth transfers in the work zone.
- Work only in well-lighted spaces.
- Never enter a confined space without the proper training, permits, and equipment.
- Make eye contact with equipment operators when moving within the range of their equipment.
- Be aware of the movements of shipboard equipment when not in the operator's range of vision.
- Get immediate first aid for all cuts, scratches, abrasions, or other minor injuries.
- Use the established sampling and decontamination procedures.
- Always use the buddy system.
- Be alert to your own and other workers' physical conditions.
- Report all accidents, no matter how minor, to the FC / HSO.
- Do not do anything dangerous or unwise even if ordered by a supervisor.

7 Personal Protective Equipment and Safety Equipment

Appropriate PPE will be worn as protection against potential hazards. In addition, a PFD will be required when working onboard the boat. Prior to donning PPE, the field crew will inspect their PPE for any defects that might render the equipment ineffective.

Fieldwork will be conducted in Level D or modified Level D PPE, as discussed in Sections 7.1 and 7.2. Situations requiring PPE beyond modified Level D are not anticipated. Should the FC / HSO determine that PPE beyond modified Level D is necessary, the HSM will be notified and an alternative selected.

New personnel or visitors will be informed of PPE requirements during their initial site briefing (see Section 3).

7.1 LEVEL D PERSONAL PROTECTIVE EQUIPMENT

Workers performing general activities during which skin contact with contaminated materials is unlikely will wear Level D PPE. Level D PPE includes the following:

- Cotton overalls or lab coats
- Chemical-resistant steel-toed boots
- Chemical-resistant gloves
- Safety glasses

7.2 MODIFIED LEVEL D PERSONAL PROTECTIVE EQUIPMENT

Workers performing activities during which skin contact with contaminated materials is possible, and during which inhalation risks are not expected, will be required to wear an impermeable outer suit. The type of outerwear will be chosen according to the types of chemical contaminants that might be encountered. Modified Level D PPE includes the following:

- Impermeable outer garb such as rain gear
- Waterproof and chemical-resistant steel-toed boots
- Waders and wader boots
- Chemical-resistant outer gloves
- Heavy-duty waterproof gloves
- Hard hats

7.3 SAFETY EQUIPMENT

In addition to PPE that will be worn by shipboard personnel, basic emergency and first aid equipment will be provided. Equipment for the field team will include:

- A copy of this HSP
- A first aid kit adequate for the number of personnel
- Emergency eyewash
- Sunscreen

The FC/HSO will ensure that the safety equipment is onboard. Equipment will be checked daily to ensure its readiness for use.

8 Monitoring Procedures for Site Activities

A monitoring program that addresses the potential site hazards will be maintained. For this project, air, dust, and noise monitoring will not be necessary. No volatile organic compounds have been identified among the expected contaminants, the sampled media will be wet and will not pose a dust hazard, and none of the equipment will emit high-amplitude (> 85 dBA) sound. For this project, the monitoring program will consist of all workers monitoring themselves and their co-workers for signs that might indicate physical stress or illness.

All personnel will be instructed to look for and inform each other of any deleterious changes in their physical or mental condition during the performance of all field activities. Examples of such changes are as follows:

- Headaches
- Dizziness
- Nausea
- Symptoms of heat stress
- Blurred vision
- Cramps
- Irritation of eyes, skin, or respiratory system
- Changes in complexion or skin color
- Changes in apparent motor coordination
- Increased frequency of minor mistakes
- Excessive salivation or changes in papillary response
- Changes in speech ability or speech pattern
- Shivering
- Blue lips or fingernails

If personnel develop any of these conditions, work will be halted immediately and the affected person(s) evaluated. If further assistance is needed, personnel at the local hospital will be notified, and an ambulance will be summoned if the condition is thought to be serious. If the condition is the direct result of sample collection or handling activities, procedures will be modified to address the problem.

9 Decontamination

Decontamination is necessary to prevent the migration of contaminants from the work zone(s) into the surrounding environment, and to minimize the risk of exposure of personnel to contaminated materials that might adhere to PPE. The following sections discuss personnel and equipment decontamination. The following supplies will be available to perform decontamination activities:

- Wash buckets
- Rinse buckets
- Scrub brushes
- Clean water sprayers
- Paper towels
- Plastic garbage bags
- Alconox® or similar decontamination solution

9.1 MINIMIZATION OF CONTAMINATION

The first step in addressing contamination is to prevent or minimize exposure to existing contaminated materials and the spread of those materials. During field activities, the FC / HSO will enforce the following measures:

Personnel:

- Do not walk through areas of obvious or known contamination, if avoidable.
- Do not handle, touch, or smell contaminated materials directly.
- Make sure PPE has no cuts or tears prior to use.
- Fasten all closures on outer clothing, covering with tape if necessary.
- Protect and cover any skin injuries.
- Stay upwind of airborne dusts and vapors.
- Do not eat, drink, chew tobacco, or smoke in the work zones.

Sampling equipment and boat:

- Place clean equipment on a plastic sheet or aluminum foil to avoid direct contact with contaminated media.
- Keep contaminated equipment and tools separate from clean equipment and tools.
- Clean boots before entering the boat.

9.2 PERSONNEL DECONTAMINATION

The FC / HSO will ensure that all site personnel are familiar with personnel decontamination procedures. Personnel will perform the following decontamination procedures, as appropriate, before eating lunch, taking a break, or leaving the work location:

1. If outer suit is heavily soiled, rinse it off.
2. Wash and rinse outer gloves and boots with water.
3. Remove outer gloves; inspect and discard if damaged.
4. Wash hands.

Before returning to work, personnel will re-don all necessary PPE. If leaving for the day, personnel will dispose of soiled, expendable PPE.

9.3 SAMPLING EQUIPMENT DECONTAMINATION

Sampling equipment will be decontaminated, as described in Section 4.4.4 of the QAPP, to minimize sample contamination and worker exposure to contamination from samples. The following practices will be followed:

- All utensils or equipment used directly in handling sediment (e.g., such as the grab sampler, hand corers, shovels, spoons and bowls) will be scrubbed with Alconox® detergent, rinsed with deionized water, and stored wrapped in aluminum foil until use.
- Sample processing surfaces will be cleaned and lined with aluminum foil to prevent direct contact with samples.
- Ice chests will be scrubbed with Alconox® detergent and rinsed with deionized water prior to any sampling activities.
- Wet ice used for sample storage during field activities will be contained in separate plastic bags, and samples will be placed in resealable, waterproof plastic bags to avoid contamination from melting ice.
- Sampling equipment will be free from contaminants such as oils, grease, and fuels.

10 Disposal of Contaminated Materials

Contaminated materials that may be generated during field activities include PPE and excess sample material. These contaminated materials will be disposed of as an integral part of the project.

10.1 PERSONAL PROTECTIVE EQUIPMENT

Gross surface contamination will be removed from PPE. All disposable sampling materials and PPE—such as disposable coveralls, gloves, and paper towels used in sample processing—will be placed in heavyweight garbage bags. Filled garbage bags will be placed in a normal refuse container for disposal as solid waste.

10.2 EXCESS SAMPLE MATERIALS

At each sampling location, excess or unwanted sediment collected will be returned to the collection site.

11 Training Requirements

Individuals performing work at locations where potentially hazardous materials and conditions may be encountered must meet specific training requirements. It is not anticipated that hazardous concentrations of contaminants will be encountered in sampled material, so training will consist of site-specific instruction for all personnel and oversight of inexperienced personnel by an experienced person for one working day. The following sections describe the training requirements for this fieldwork.

11.1 PROJECT-SPECIFIC TRAINING

In addition to HAZWOPER training, as described in Section 3.6 of the QAPP, field personnel will undergo training specifically for this project. All personnel and visitors must read this HSP and be familiar with its contents before beginning work or providing oversight. They must acknowledge reading the HSP by signing the HSP review form in Attachment 1. The signed form will be kept in the project files.

The boat captain and FC/HSO will also be required to have the US Coast Guard (USCG) Auxiliary Boating Safety certification. The boat captain or a designee will provide project-specific training prior to the first day of fieldwork and whenever new workers arrive. Field personnel will not be allowed to begin work until project-specific training has been completed and documented by the FC/HSO. Training will address the HSP and all health and safety issues and procedures pertinent to field operations. Training will include, but not be limited to, the following topics:

- Activities with the potential for exposure to chemicals
- Activities that pose physical hazards, and actions to control the hazards
- Ship access control and procedures
- Use and limitations of PPE
- Decontamination procedures
- Emergency procedures
- Use and hazards of sampling equipment
- Location of emergency equipment on the vessel
- Vessel safety practices
- Vessel evacuation and emergency procedures

11.2 DAILY SAFETY BRIEFINGS

The FC/HSO or a designee and the boat captain will present safety briefings before the start of each day's activities. These safety briefings will outline the activities expected for the day, update work practices and hazards, address any specific concerns associated with the work location, and review emergency procedures and routes. The FC / HSO or designee will document all safety briefings in the logbook.

11.3 FIRST AID AND CPR

At least two members of the field team must have first aid and cardiopulmonary resuscitation (CPR) training. Documentation of which individuals possess first aid and CPR training will be kept in the project health and safety files.

12 Medical Surveillance

A medical surveillance program conforming to the provisions of 29 CFR 1910§120(f) is not necessary for field team members on this project, because they do not meet any of the following four criteria outlined in the regulations for implementation of a medical surveillance program:

- Employees who are or may be exposed to hazardous substances or health hazards at or above permissible exposure levels for 30 days or more per year (1910.120(f)(2)(I).
- Employees who must wear a respirator for 30 days or more per year (1910.120(f)(2)(ii)).
- Employees who are injured or become ill as a result of possible overexposures involving hazardous substances or health hazards from an emergency response or hazardous waste operation (1910.120(f)(2)(iii)).
- Employees who are members of HAZMAT teams (1910.120(f)(2)(iv)).

As described in Section 8, employees will monitor themselves and each other for any deleterious changes in their physical or mental conditions during the performance of all field activities.

13 Reporting and Record Keeping

Each member of the field crew will sign the HSP review form (Attachment 1). If necessary, accident/incident report forms and Occupational Safety and Health Administration (OSHA) Form 200s will be completed by the FC/HSO.

The FC/HSO or a designee will maintain a health and safety field logbook with records of health- and safety-related details for the project. Alternatively, entries may be made in the field logbook, in which case a separate health and safety logbook will not be required. The logbook must be bound and the pages must be numbered consecutively. Entries will be made with indelible blue ink. At a minimum, each day's entries must include the following information:

- Project name or location
- Names of all personnel onboard
- Weather conditions
- Type of fieldwork being performed

The person maintaining the entries will initial and date the bottom of each completed page. Blank space at the bottom of an incompletely filled page will be lined out. Each day's entries will begin on the first blank page after the previous workday's entries.

14 Emergency Response Plan

As a result of the hazards onboard the sampling vessels and the conditions under which operations will be conducted, the potential exists for an emergency situation to occur. Emergencies may include personal injury, exposure to hazardous substances, fire, explosion, or release of toxic or non-toxic substances (spills). OSHA regulations require that an emergency response plan be available for use onboard to guide actions in emergency situations.

Onshore organizations will be relied upon to respond to emergency situations. Given the location of the site, the local fire department and ambulance service can provide timely response. Field personnel will be responsible for identifying an emergency situation, providing first aid if applicable, notifying the appropriate personnel or agency, and evacuating any hazardous area. Shipboard personnel will attempt to control only very minor hazards that could present an emergency situation, such as a small fire; otherwise, all personnel will rely on outside emergency response resources.

The following sections identify the onboard individual(s) who should be notified in case of emergency, provide a list of emergency telephone numbers, offer guidance for particular types of emergencies, and provide directions and a map for getting from any sampling location to a hospital.

14.1 PRE-EMERGENCY PREPARATION

Before the start of field activities, the FC / HSO will ensure that preparation has been made in anticipation of emergencies. Preparatory actions include the following:

- Meeting between the FC / HSO and equipment handlers concerning emergency procedures in the event that a person is injured
- A training session given by the FC / HSO informing all field personnel of emergency procedures, locations of emergency equipment and its uses, and proper evacuation procedures
- A training session given by senior staff on operating field equipment to apprise field personnel of operating procedures and specific risks associated with that equipment
- Ensuring that field personnel are aware of the existence of the emergency response plan in the HSP, and ensuring that a copy of the HSP accompanies the field team

14.2 PROJECT EMERGENCY COORDINATOR

The FC / HSO will serve as the project emergency coordinator in the event of an emergency. He will designate his replacement during those times when he is not onboard or is not serving as the project emergency coordinator; the designation will be noted in the logbook. The project emergency coordinator will be notified immediately when an emergency is recognized. The project emergency coordinator will be responsible for evaluating the emergency situation, notifying the appropriate emergency response units, coordinating access with those units, and directing interim actions onboard before the arrival of emergency response units. The project emergency coordinator will notify the HSM and the Windward PM as soon as possible after initiating an emergency response action. The Windward PM will have responsibility for notifying the client.

14.3 EMERGENCY RESPONSE CONTACTS

All onboard personnel must know whom to notify in the event of an emergency situation, even though the FC / HSO has primary responsibility for notification. Table 2 lists the names and phone numbers for emergency response services and individuals.

Table A-2. Emergency response contacts

Contact	Telephone Number
Emergency Numbers	
Ambulance	911
Police	911
Fire	911
Harborview Medical Center	206.323.3074
Emergency Responders	
US Coast Guard Emergency General information	 206.286.5400 206.442.5295 UHF Channel 16
National Response Center	800.424.8802
US Environmental Protection Agency	800.424.8802
Washington State Department of Ecology – Northwest Region Spill Response (24-hour emergency line)	206.649.7000
Emergency Contacts	
Windward Project Manager	
Kathy Godtfredsen	206.812.5413
Windward Corporate Health and Safety Manager	
Susan McGroddy	206.812.5421
Field Coordinator/ Field Health and Safety Officer	
Thai Do	206.812.5407

14.4 RECOGNITION OF EMERGENCY SITUATIONS

Emergency situations will generally be recognizable by observation. An injury or illness will be considered an emergency if it requires treatment by a medical professional and cannot be treated with simple first aid techniques.

14.5 DECONTAMINATION

In the case of evacuation, decontamination procedures will be performed only if doing so does not further jeopardize the welfare of site workers. If an injured individual is also heavily contaminated and must be transported by emergency vehicle, the emergency response team will be informed of the type of contamination. To the extent possible, contaminated PPE will be removed from the injured individual, but only if doing so does not exacerbate the injury. Plastic sheeting will be used to reduce the potential for spreading contamination to the inside of the emergency vehicle.

14.6 FIRE

Field personnel will attempt to control only small fires, should they occur. If an explosion appears likely, personnel will follow evacuation procedures specified during the training session. If a fire cannot be controlled with the onboard fire extinguisher that is part of the required safety equipment, personnel will either withdraw from the vicinity of the fire or evacuate the boat as specified in the training session.

14.7 PERSONAL INJURY

In the event of serious personal injury, including unconsciousness, possibility of broken bones, severe bleeding or blood loss, burns, shock, or trauma, the first responder will immediately do the following:

- Designate an individual to call 911 and administer first aid, if qualified.
- If not qualified, seek out an individual who is qualified to administer first aid, if time and conditions permit.
- Notify the project emergency coordinator of the incident, the name of the injured individual(s), the location of the individual, and the nature of the injury.

The project emergency coordinator will immediately do the following:

- Notify the boat captain and the appropriate emergency response organization.
- Assist the injured individual(s).
- Follow the emergency procedures for retrieving or disposing of equipment reviewed in the training session, and leave the site en route to the predetermined land-based emergency pickup.
- Designate someone to accompany the injured individual to the hospital.
- If a life-threatening emergency occurs (i.e., injury where death is imminent without immediate treatment), the FC / HSO or boat captain will call 911 and arrange to meet the ambulance unit at the nearest accessible dock.

- If a non-life-threatening emergency occurs (i.e., broken bones, minor lacerations, etc.), the project emergency coordinator will follow the procedures outlined above and proceed to the Harbor Island Marina, or to an alternative location of his choice if that would be more expedient.
- Notify the HSM and the PM.

If the project emergency coordinator determines that an emergency response is not necessary, he may direct someone to decontaminate and transport the individual by vehicle to the nearest hospital. Directions showing the route to the hospital are in Section 14.11.

If a worker leaves the boat to seek medical attention, another worker should accompany him to the hospital. When in doubt about the severity of an injury or exposure, always seek medical attention as a conservative approach, and notify the project emergency coordinator.

The project emergency coordinator will be responsible for completing all accident/incident field reports, OSHA Form 200s, and other required follow-up forms.

14.8 OVERT PERSONAL EXPOSURE OR INJURY

If an overt exposure to toxic materials occurs, the first responder to the victim will initiate actions to address the situation. The following actions should be taken, depending on the type of exposure.

14.8.1 Skin contact

- Wash/rinse the affected area thoroughly with copious amounts of soap and water.
- If eye contact has occurred, rinse the eyes for at least 15 minutes using the eyewash that is part of the onboard emergency equipment.
- After initial response actions have been taken, seek appropriate medical attention.

14.8.2 Inhalation

- Move victim to fresh air.
- Seek appropriate medical attention.

14.8.3 Ingestion

- Seek appropriate medical attention.

14.8.4 Puncture wound or laceration

- Seek appropriate medical attention.

14.9 SPILLS AND SPILL CONTAINMENT

No bulk chemicals or other materials subject to spillage are expected to be used during this project. Accordingly, no spill containment procedure is required for this project.

14.10 BOATING HAZARDS

Emergency responses to boating hazards are described in Table 3.

Table A-3. Potential boat emergency hazards and responses

Potential Emergency Hazard	Response
Fire or explosion	If manageable, attempt to put out a small fire with a fire extinguisher. Otherwise, call the USCG or 911, evacuate the area (by life rafts, rescue boat, or swimming), and meet at a designated location. The HSO will take roll call to make sure everyone has evacuated safely. Emergency meeting locations will be determined in the field during the daily safety briefings.
Medical emergency/ personal injury	At least two people with current first aid and CPR training will be onboard the vessel at all times. This person will attempt to assess the nature and critical path of the injury, call 911 immediately, and apply first aid/CPR if necessary. Stop work and wait for medical personnel to arrive. Fill out a site accident report.
Falling into an open hatch	Stop work and rescue the person, if safe and necessary. Assess the nature of the injury, and follow the response for medical emergency/personal injury.
Person overboard	Immediately throw a life ring to the person in the water. Have one onboard person keep an eye on the victim and shout the distance (boat lengths) and direction (o'clock) of the victim from the vessel. Stop work and use the vessel to retrieve the person in the water.
Sinking vessel	Call the USCG immediately. If possible, wait for a rescue boat to arrive to evacuate vessel personnel. See fire/explosion section (above) for emergency evacuation procedures. The HSO will take roll call to make sure everyone has evacuated safely.
Hydraulic oil spill or leak	If the leak/spill is small, immediately apply absorbent pads to control the leak and continue work. If the leak/spill is uncontainable, stop work, call 911 immediately, and wait for assistance. The vessel operator will assess the personal safety hazard associated with the leak/spill and begin evacuation procedures if necessary.
Lack of visibility	If navigation visibility or personal safety is compromised because of smoke, fog, or other unanticipated hazards, stop work immediately. The vessel operator and HSO will assess the hazard and, if necessary, send out periodic horn blasts to notify other vessels potentially in the area of the sampling vessel's location. Move to a secure location (i.e., berth) and wait for visibility to clear.
Loss of power	Stop work and call the USCG for assistance. Vessel personnel should watch for potential collision hazards and notify vessel operator if hazards exist. Secure vessel to a berth, dock, or mooring as soon as possible.
Collision	Stop work and call the USCG for assistance. HSO and vessel operator will assess damage and potential hazards. If necessary, vessel will be evacuated and secured until repairs can be made.

CPR – cardiopulmonary resuscitation
HSO – health and safety officer
USCG – US Coast Guard

14.11 EMERGENCY ROUTES TO THE HOSPITAL

The name, address, and telephone number of the hospital that will be used to provide medical care is as follows:

Harborview Medical Center
325 - 9th Avenue
Seattle, WA
206.323.3074

Directions from the vicinity of the LDW to Harborview Medical Center are as follows (Figure 1):

From the 1st Avenue South boat launch:

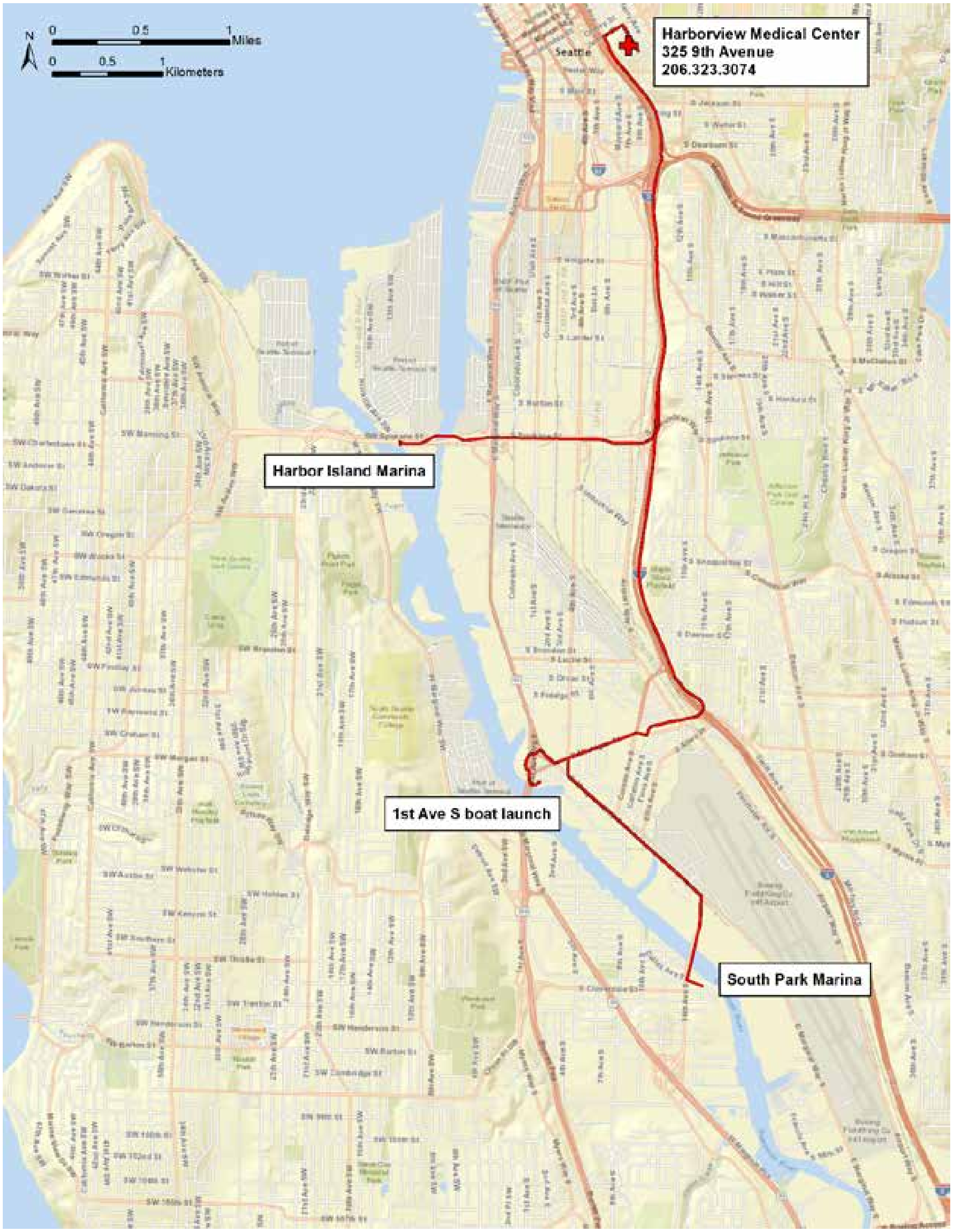
- Drive east on South River Street.
- Turn left on Occidental Avenue South.
- Turn left on East Marginal Way South.
- Turn right on South Michigan Street.
- Look for entrance ramps to I-5 Northbound.
- Drive north on I-5.
- Take the James Street exit.
- Drive east on James Street to 9th Avenue.
- Turn right on 9th Avenue.
- Emergency entrance will be two blocks south on the right.

From the Harbor Island Marina:

- From marina parking lot, turn sharp right onto Klickitat Way Southwest.
- Turn slight right onto Southwest Spokane Street
- Turn slight left to take the ramp toward WA-99 N/I-5/Columbian Way.
- Keep left at the fork in the ramp.
- Stay straight to go onto West Seattle Bridge.
- Merge onto I-5 North via the ramp on the left.
- Take the James Street exit.
- Head east on James Street to 9th Avenue.
- Turn right on 9th Avenue.
- Emergency entrance will be two blocks south on the right.

From South Park Marina:

- From marina parking lot, turn right onto Dallas Avenue South.
- Turn right onto 16th Avenue South.
- Turn left on East Marginal Way South.
- Look for entrance ramps to I-5 Northbound.
- Drive north on I-5.
- Take the James Street exit.
- Drive east on James Street to 9th Avenue.
- Turn right on 9th Avenue.
- Emergency entrance will be two blocks south on the right.



Map A-1. Emergency routes to Harborview Medical Center

Attachment 1. Health and Safety Plan Acknowledgment Form

I have read a copy of the Health and Safety Plan (HSP), which covers field activities that will be conducted to investigate potentially contaminated areas in the Lower Duwamish Waterway (LDW). I understand the health and safety requirements of the project, which are detailed in this HSP.

Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date

APPENDIX B. FIELD FORMS

- Surface Sediment Collection Form
- Bank Soil Collection Form
- Intertidal Sediment Transect Form
- Intertidal Surface Sediment Collection Form
- Percent Moisture Benchsheet for *Ex Situ* Porewater Investigation
- Exposure Setup Benchsheet for *Ex Situ* Porewater Investigation
- Daily Conditions Benchsheet for *Ex Situ* Porewater Investigation
- Protocol Modification Form

SURFACE SEDIMENT COLLECTION FORM

Project Name: ______________________ **Project no.:** ______________________

Date: ______________________ **Weather:** ______________________

Sampling Method: ______________________ **Crew:** ______________________

LOCATION	**Location ID:**			
Latitude/Northing(Y):				**Longitude/Easting(X):**
Time of sample	**Bottom depth (m)**	**Penetration depth (cm)**	**Acceptable sample (Y/N)**	**Comments**
SAMPLE DATA	Sample ID:			

Sediment type	**Sediment color**	**Sediment odor**		**Comments:**
cobble	brown surface	none	H_2S	
gravel	drab olive	slight	petroleum	
sand (F M C)	brown	moderate	other:	
silt	gray	strong		
clay	black			

LOCATION	**Location ID:**			
Latitude/Northing(Y):				**Longitude/Easting(X):**
Time of sample	**Bottom depth (m)**	**Penetration depth (cm)**	**Acceptable sample (Y/N)**	**Comments**
SAMPLE DATA	Sample ID:			

Sediment type	**Sediment color**	**Sediment odor**		**Comments:**
cobble	brown surface	none	H_2S	
gravel	drab olive	slight	petroleum	
sand (F M C)	brown	moderate	other:	
silt	gray	strong		
clay	black			

BANK SOIL COLLECTION FORM

Project Name/Number: ______________________ **Weather:** ______________________

Date: ______________________ **Crew:** ______________________

Sampling Method: ______________________ **Bank ID:** ______________________

Composite Sample ID: ______________________ ______________________

Location ID:	**Sample Time:**	**Sample Depth:**
Location Description (coordinates or distances from landmarks; elevation):		
Sample Description (i.e., including grain size, color, odor):		
Comments:		

Location ID:	**Sample Time:**	**Sample Depth:**
Location Description (coordinates or distances from landmarks; elevation):		
Sample Description (i.e., including grain size, color, odor):		
Comments:		

Location ID:	**Sample Time:**	**Sample Depth:**
Location Description (coordinates or distances from landmarks; elevation):		
Sample Description (i.e., including grain size, color, odor):		
Comments:		

INTERTIDAL SURFACE SEDIMENT COLLECTION FORM

Project Name: LDW AOC3 **Task No.:** __________

Date: __________ **Sampler(s):** __________

LOCATION DATA	**Area Type (circle):** Clam Beach			**Sampling Method (circle):** shovel core other
Location ID:				**Additional Notes**
Sample Time	**Penetration depth (cm)**	**Comments**		
SAMPLE DATA				
Sediment type	**Sediment color**	**Sediment odor**		
cobble	brown surface	none	H_2S	
gravel	drab olive	slight	petroleum	
sand (F M C)	brown	moderate	other:	
silt	gray	strong		
clay	black			

LOCATION DATA	**Area Type (circle):** Clam Beach			**Sampling Method (circle):** shovel core other
Location ID:				**Additional Notes**
Sample Time	**Penetration depth (cm)**	**Comments**		
SAMPLE DATA				
Sediment type	**Sediment color**	**Sediment odor**		
cobble	brown surface	none	H_2S	
gravel	drab olive	slight	petroleum	
sand (F M C)	brown	moderate	other:	
silt	gray	strong		
clay	black			

INTERTIDAL SEDIMENT TRANSECT FORM

Project Name: LDW AOC3

Weather:

Date:

Crew:

Beach Type (circle): clam beach play

Beach No.

Transect No.

No. of Points:

Transect Length:

Distance between Points:

Transect Details

Notes

Start coordinates:

Latitude/Northing(Y)

Longitude/Easting(X):

N

End coordinates:

Latitude/Northing(Y)

Longitude/Easting(X):

PERCENT MOISTURE BENCHSHEET

Pan ID	Sample ID	Tare (g)	Wet Wt. (g)	Tare + Dry Wt. (g)	Dry Wt. (g)	% Moisture

Oven ID: ____________________ **Thermometer ID:** ______________

Date/Time In: ____________________ **Temp In:** ______________

Date/Time Out: ____________________ **Temp Out:** ______________

Analyst: ____________________ **Balance ID:** ______________ **Calibration Date** ______________

EXPOSURES SETUP BENCHSHEET

Sample ID	Sediment Mass (g ww)	Passive Sampler Mass (g)	Biocide Solution Volume (mL)

Start Date: ______________________

Stop Date: ______________________

Analyst: ______________________

DAILY CONDITIONS BENCHSHEET

Date	Room Temperature	Orbital Shaker Performance Acceptable (Y/N)	Jars and Lids Intact (Y/N)	Comments	Analyst

Thermometer ID:_____________

Orbital Shaker ID:_____________

PROTOCOL MODIFICATION FORM

Project Name and Number:

Material to be Sampled:

Measurement Parameter:

Standard Procedure for Field Collection & Laboratory Analysis (cite reference):

Reason for Change in Field Procedure or Analysis Variation:

Variation from Field or Analytical Procedure:

Special Equipment, Materials or Personnel Required:

Initiator's Name: Date:

Project Officer: Date:

QA Officer: Date:

APPENDIX C. ANALYTICAL METHODS, REPORTING LIMITS, AND SEDIMENT COLLECTION JAR SUMMARIES

Tables

Table C-1.Methods and RL goals for PCB Aroclors, cPAHS, metals, SVOCs, and conventionals in sediment/soil

Analyte	Method	Unit	MDL	RL
PCBs as Aroclors (based on 12.5-g dw sample)				
Aroclor 1016	EPA 8082A	µg/kg dw	8.00[a]	20.0[b]
Aroclor 1221	EPA 8082A	µg/kg dw	8.00[a]	20.0[b]
Aroclor 1232	EPA 8082A	µg/kg dw	8.00[a]	20.0[b]
Aroclor 1242	EPA 8082A	µg/kg dw	8.00[a]	20.0[b]
Aroclor 1248	EPA 8082A	µg/kg dw	8.00[a]	20.0[b]
Aroclor 1254	EPA 8082A	µg/kg dw	8.00[a]	20.0[b]
Aroclor 1260	EPA 8082A	µg/kg dw	9.28[a]	20.0[b]
cPAHs (based on 10-g dw sample)				
Benzo(a)anthracene	EPA 8270D-SIM	µg/kg dw	0.537	5.00
Benzo(a)pyrene	EPA 8270D-SIM	µg/kg dw	0.915	5.00
Benzo(b)fluoranthene	EPA 8270D-SIM	µg/kg dw	1.37	5.00
Benzo(k)fluoranthene	EPA 8270D-SIM	µg/kg dw	0.760	5.00
Chrysene	EPA 8270D-SIM	µg/kg dw	0.488	5.00
Dibenzo(a,h)anthracene	EPA 8270D-SIM	µg/kg dw	1.53	5.00
Indeno(1,2,3-cd)pyrene	EPA 8270D-SIM	µg/kg dw	0.575	5.00
PAHs (based on 10-g dw sample)				
Acenaphthene[d]	EPA 8270D	µg/kg dw	5.13[a]	20.0[b]
Acenaphthylene[d]	EPA 8270D	µg/kg dw	4.77[a]	20.0[b]
Anthracene[d]	EPA 8270D	µg/kg dw	5.93[a]	20.0[b]
Benzo(a)anthracene[c]	EPA 8270D	µg/kg dw	5.18[a]	20.0[b]
Benzo(a)pyrene[c]	EPA 8270D	µg/kg dw	6.48[a]	20.0[b]
Benzo(b)fluoranthene[c]	EPA 8270D	µg/kg dw	7.02[a]	20.0[b]

Table C-1. Methods and RL goals for PCB Aroclors, cPAHS, metals, SVOCs, and conventionals in sediment/soil

Analyte	Method	Unit	MDL	RL
Benzo(k)fluoranthene[c]	EPA 8270D	µg/kg dw	5.01[a]	20.0[b]
Total benzofluoranthenes[c]	EPA 8270D	µg/kg dw	10.2[a]	40.0[b]
Benzo(g,h,i)perylene[c]	EPA 8270D	µg/kg dw	5.82[a]	20.0[b]
Chrysene[c]	EPA 8270D	µg/kg dw	5.22[a]	20.0[b]
Dibenzo(a,h)anthracene[c]	EPA 8270D	µg/kg dw	6.16[a]	20.0[b]
Fluoranthene[c]	EPA 8270D	µg/kg dw	4.52[a]	20.0[b]
Fluorene[d]	EPA 8270D	µg/kg dw	4.95[a]	20.0[b]
Indeno(1,2,3-cd)pyrene[c]	EPA 8270D	µg/kg dw	5.99[a]	20.0[b]
2-methylnaphthalene[d]	EPA 8270D	µg/kg dw	5.67[a]	20.0[b]
Naphthalene[d]	EPA 8270D	µg/kg dw	5.25[a]	20.0[b]
Phenanthrene[d]	EPA 8270D	µg/kg dw	4.69[a]	20.0[b]
Pyrene[c]	EPA 8270D	µg/kg dw	5.55[a]	20.0[b]
Metals (based on 1-g ww unless otherwise noted)				
Arsenic	EPA 6020A UCT-KED	mg/kg dw	na[e]	0.2[b]
Cadmium	EPA 6020A UCT-KED	mg/kg dw	na[e]	0.1[b]
Chromium	EPA 6020A	mg/kg dw	na[e]	0.5[b]
Copper	EPA 6020A UCT-KED	mg/kg dw	na[e]	0.5[b]
Lead	EPA 6020A	mg/kg dw	na[e]	0.1[b]
Silver	EPA 6020A	mg/kg dw	na[e]	0.2[b]
Zinc	EPA 6020A UCT-KED	mg/kg dw	na[e]	4[b]
Mercury (based on 0.2-g ww sample)	EPA 7471B	mg/kg dw	na[e]	0.025[b]
SVOCs (based on 10-g dw sample)				
2,4-dimethylphenol	EPA 8270D-SIM	µg/kg dw	10.2	25.0

Table C-1.Methods and RL goals for PCB Aroclors, cPAHS, metals, SVOCs, and conventionals in sediment/soil

Analyte	Method	Unit	MDL	RL
4-methylphenol	EPA 8270D	µg/kg dw	14.7[a]	20.0[b]
Benzoic acid	EPA 8270D-SIM	µg/kg dw	13.4	50.0
Benzyl alcohol	EPA 8270D-SIM	µg/kg dw	12.1	20.0
Bis(2-ethylhexyl)phthalate	EPA 8270D	µg/kg dw	28.8[a]	50.0[b]
Butyl benzyl phthalate	EPA 8270D	µg/kg dw	8.05[a]	20.0[b]
Dibenzofuran	EPA 8270D	µg/kg dw	4.61[a]	20.0[b]
Dimethyl phthalate	EPA 8270D	µg/kg dw	6.44[a]	20.0[b]
Hexachlorobenzene	EPA 8270D-SIM	µg/kg dw	2.11	5.00
n-Nitrosodiphenylamine	EPA 8270D-SIM	µg/kg dw	2.31	5.00
PCP	EPA 8270D-SIM	µg/kg dw	10.4	20.0
Phenol	EPA 8270D	µg/kg dw	8.23[a]	20.0[b]
1,2,4-trichlorobenzene	EPA 8270D-SIM	µg/kg dw	1.51	5.00
1,2-dichlorobenzene	EPA 8270D-SIM	µg/kg dw	1.32	5.00
1,4-dichlorobenzene	EPA 8270D -SIM	µg/kg dw	1.91	5.00
Toxaphene (based on 12.5-g dw sample)	EPA 8081B	µg/kg dw	4.48[a]	25.0[b]
Conventionals				
Grain size	PSEP 1986	%	na	0.1
Percent solids	SM 2540G	% dw	na	0.040
TOC (based on 1-g dw sample)	EPA 9060	% dw	0.018	0.02
Black carbon (based on 10-g dw sample)	Gustafsson, 2001 - CTO Pretreatment / Combustion (950°C) / IR detect EPA 440.0	wt%	0.2	0.6

[a] SW 846 no longer requires MDL values. The laboratories have the option to use these values to assess sensitivity for EPA 8000 series methods. ARI has continued to maintain MDL studies for these analytes.

[b] RL values are consistent with the LLOQ values required under EPA SW-846.

[c] Compound is a component of the HPAH sum.

[d] Compound is a component of the LPAH sum.

[e] SW 846 no longer requires MDL values.

BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LLOQ – lower limit of quantitation
MDL – method detection limit
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
na – not available
PCB – polychlorinated biphenyl
PCP – pentachlorophenol
PSEP - Puget Sound Estuary Program
RL – reporting limit
SIM – selective ion monitoring
SVOC – semivolatile organic compounds
TBT – tributyltin
TOC – total organic carbon
total DDx – DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
ww – wet weight

Table C-2. Method and RL goals for PCB congeners in sediment

Analyte	EPA Method 1668C				Estimated porewater DL (ug/L)[c]
	Sediment (ng/kg dw) Based on 10-g dw sample		Passive Sampler (pg/g) Based on 1-g PE sample		
	EDL[a]	LMCL[b]	EDL[a]	LMCL[b]	
PCB-1	0.1	2.0	1.0	4.0	0.6714
PCB-2	0.1	2.0	1.0	4.0	0.3954
PCB-3	0.1	2.0	1.0	4.0	0.7907
PCB-4	0.2	2.0	2.0	4.0	0.8670
PCB-5	0.2	2.0	2.0	4.0	0.4150
PCB-6	0.2	2.0	2.0	4.0	0.3373
PCB-7	0.2	2.0	2.0	4.0	0.3296
PCB-8	0.2	2.0	2.0	4.0	0.3296
PCB-9	0.2	2.0	2.0	4.0	0.3373
PCB-10	0.2	2.0	2.0	4.0	0.5598
PCB-11	0.2	2.0	2.0	4.0	0.2032
PCB-12/13	0.2	2.0	2.0	4.0	0.2160[d]
PCB-14	0.2	2.0	2.0	4.0	0.2032
PCB-15	0.2	2.0	2.0	4.0	0.1941
PCB-16	0.1	2.0	1.0	4.0	0.1340
PCB-17	0.1	2.0	1.0	4.0	0.1089
PCB-19	0.1	2.0	1.0	4.0	0.1849
PCB-21/33	0.1	2.0	1.0	4.0	0.0542[d]
PCB-22	0.1	2.0	1.0	4.0	0.0509
PCB-23	0.1	2.0	1.0	4.0	0.0521
PCB-24	0.1	2.0	1.0	4.0	0.0865
PCB-25	0.1	2.0	1.0	4.0	0.0414
PCB-26/29	0.1	2.0	1.0	4.0	0.0486[d]
PCB-27	0.1	2.0	1.0	4.0	0.0703
PCB-28/20	0.1	2.0	1.0	4.0	0.0486[d]
PCB-30/18	0.1	2.0	1.0	4.0	0.0909[d]
PCB-31	0.1	2.0	1.0	4.0	0.0414
PCB-32	0.1	2.0	1.0	4.0	0.0703
PCB-34	0.1	2.0	1.0	4.0	0.0424
PCB-35	0.1	2.0	1.0	4.0	0.0293
PCB-36	0.1	2.0	1.0	4.0	0.0255
PCB-37	0.1	2.0	1.0	4.0	0.0286
PCB-38	0.1	2.0	1.0	4.0	0.0337
PCB-39	0.1	2.0	1.0	4.0	0.0249
PCB-41/40/71	0.1	2.0	1.0	4.0	0.0341[d]
PCB-42	0.1	2.0	1.0	4.0	0.0337

Table C-2. Method and RL goals for PCB congeners in sediment

Analyte	EPA Method 1668C				Estimated porewater DL (ug/L)[c]
	Sediment (ng/kg dw) Based on 10-g dw sample		Passive Sampler (pg/g) Based on 1-g PE sample		
	EDL[a]	LMCL[b]	EDL[a]	LMCL[b]	
PCB-43	0.1	2.0	1.0	4.0	0.0344
PCB-44/47/65	0.1	2.0	1.0	4.0	0.0295[d]
PCB-45/51	0.1	2.0	1.0	4.0	0.0399[d]
PCB-46	0.1	2.0	1.0	4.0	0.0571
PCB-48	0.1	2.0	1.0	4.0	0.0321
PCB-50/53	0.1	2.0	1.0	4.0	0.0459[d]
PCB-52	0.1	2.0	1.0	4.0	0.0280
PCB-54	0.1	2.0	1.0	4.0	0.1194
PCB-55	0.1	2.0	1.0	4.0	0.0150
PCB-56	0.1	2.0	1.0	4.0	0.0150
PCB-57	0.1	2.0	1.0	4.0	0.0131
PCB-58	0.1	2.0	1.0	4.0	0.0131
PCB-59/62/75	0.1	2.0	1.0	4.0	0.0213[d]
PCB-60	0.1	2.0	1.0	4.0	0.0150
PCB-61/70/74/76	0.1	2.0	1.0	4.0	0.0141[d]
PCB-63	0.1	2.0	1.0	4.0	0.0131
PCB-64	0.1	2.0	1.0	4.0	0.0217
PCB-66	0.1	2.0	1.0	4.0	0.0122
PCB-67	0.1	2.0	1.0	4.0	0.0122
PCB-68	0.1	2.0	1.0	4.0	0.0106
PCB-69/49	0.1	2.0	1.0	4.0	0.0225[d]
PCB-72	0.1	2.0	1.0	4.0	0.0106
PCB-73	0.1	2.0	1.0	4.0	0.0177
PCB-77	0.1	2.0	1.0	4.0	0.0085
PCB-78	0.1	2.0	1.0	4.0	0.0086
PCB-79	0.1	2.0	1.0	4.0	0.0074
PCB-80	0.1	2.0	1.0	4.0	0.0064
PCB-81	0.1	2.0	1.0	4.0	0.0085
PCB-82	0.1	2.0	1.0	4.0	0.0122
PCB-83/99	0.1	2.0	1.0	4.0	0.0093[d]
PCB-84	0.1	2.0	1.0	4.0	0.0177
PCB-88/91	0.1	2.0	1.0	4.0	0.0154[d]
PCB-89	0.1	2.0	1.0	4.0	0.0165
PCB-92	0.1	2.0	1.0	4.0	0.0086
PCB-94	0.1	2.0	1.0	4.0	0.0144
PCB-95/100/93/102/98	0.1	2.0	1.0	4.0	0.0142[d]

Table C-2. Method and RL goals for PCB congeners in sediment

Analyte	EPA Method 1668C				Estimated porewater DL (ug/L)[c]
	Sediment (ng/kg dw) Based on 10-g dw sample		Passive Sampler (pg/g) Based on 1-g PE sample		
	EDL[a]	LMCL[b]	EDL[a]	LMCL[b]	
PCB-96	0.1	2.0	1.0	4.0	0.0378
PCB-103	0.1	2.0	1.0	4.0	0.0117
PCB-104	0.1	2.0	1.0	4.0	0.0300
PCB-105	0.1	2.0	1.0	4.0	0.0043
PCB-106	0.1	2.0	1.0	4.0	0.0044
PCB-108/124	0.1	2.0	1.0	4.0	0.0037[d]
PCB-109/119/86/97/125/87	0.1	2.0	1.0	4.0	0.0081[d]
PCB-107	0.1	2.0	1.0	4.0	0.0038
PCB-110/115	0.1	2.0	1.0	4.0	0.0063[d]
PCB-111	0.1	2.0	1.0	4.0	0.0034
PCB-112	0.1	2.0	1.0	4.0	0.0069
PCB-113/90/101	0.1	2.0	1.0	4.0	0.0074[d]
PCB-114	0.1	2.0	1.0	4.0	0.0043
PCB-117/116/85	0.4	2.0	1.0	4.0	0.0085[d]
PCB-118	0.4	2.0	1.0	4.0	0.0035
PCB-120	0.4	2.0	1.0	4.0	0.0031
PCB-121	0.4	2.0	1.0	4.0	0.0044
PCB-122	0.4	2.0	1.0	4.0	0.0044
PCB-123	0.4	2.0	1.0	4.0	0.0035
PCB-126	0.4	2.0	1.0	4.0	0.0025
PCB-127	0.4	2.0	1.0	4.0	0.0022
PCB-128/166	0.4	2.0	1.0	4.0	0.0029[d]
PCB-130	0.4	2.0	1.0	4.0	0.0031
PCB-131	0.4	2.0	1.0	4.0	0.0051
PCB-132	0.4	2.0	1.0	4.0	0.0051
PCB-133	0.4	2.0	1.0	4.0	0.0027
PCB-134/143	0.4	2.0	1.0	4.0	0.0052[d]
PCB-136	0.4	2.0	1.0	4.0	0.0117
PCB-137	0.4	2.0	1.0	4.0	0.0029
PCB-138/163/129/160	0.4	2.0	1.0	4.0	0.0027[d]
PCB-139/140	0.4	2.0	1.0	4.0	0.0041[d]
PCB-141	0.4	2.0	1.0	4.0	0.0029
PCB-142	0.4	2.0	1.0	4.0	0.0060
PCB-144	0.4	2.0	1.0	4.0	0.0041
PCB-145	0.4	2.0	1.0	4.0	0.0109
PCB-146	0.4	2.0	1.0	4.0	0.0025

Table C-2. Method and RL goals for PCB congeners in sediment

Analyte	EPA Method 1668C				Estimated porewater DL (ug/L)[c]
	Sediment (ng/kg dw) Based on 10-g dw sample		Passive Sampler (pg/g) Based on 1-g PE sample		
	EDL[a]	LMCL[b]	EDL[a]	LMCL[b]	
PCB-147/149	0.4	2.0	1.0	4.0	0.0043[d]
PCB-148	0.4	2.0	1.0	4.0	0.0036
PCB-150	0.4	2.0	1.0	4.0	0.0091
PCB-151/135/154	0.4	2.0	1.0	4.0	0.0041[d]
PCB-152	0.4	2.0	1.0	4.0	0.0117
PCB-153/168	0.4	2.0	1.0	4.0	0.0019[d]
PCB-155	0.4	2.0	1.0	4.0	0.0075
PCB-156/157	0.4	4.0	1.0	8.0	0.0013[d]
PCB-158	0.4	2.0	1.0	4.0	0.0018
PCB-159	0.4	2.0	1.0	4.0	0.0011
PCB-161	0.1	2.0	1.0	4.0	0.0016
PCB-162	0.1	2.0	1.0	4.0	0.0011
PCB-164	0.1	2.0	1.0	4.0	0.0018
PCB-165	0.1	2.0	1.0	4.0	0.0017
PCB-167	0.1	2.0	1.0	4.0	0.0010
PCB-169	0.1	2.0	1.0	4.0	0.0007
PCB-170	0.1	2.0	1.0	4.0	0.0010
PCB-171/173	0.1	2.0	1.0	4.0	0.0017[d]
PCB-172	0.1	2.0	1.0	4.0	0.0009
PCB-174	0.1	2.0	1.0	4.0	0.0015
PCB-175	0.1	2.0	1.0	4.0	0.0013
PCB-176	0.1	2.0	1.0	4.0	0.0034
PCB-177	0.1	2.0	1.0	4.0	0.0016
PCB-178	0.1	2.0	1.0	4.0	0.0014
PCB-179	0.1	2.0	1.0	4.0	0.0036
PCB-180/193	0.1	2.0	1.0	4.0	0.0007[d]
PCB-181	0.1	2.0	1.0	4.0	0.0015
PCB-182	0.1	2.0	1.0	4.0	0.0012
PCB-183/185	0.1	2.0	1.0	4.0	0.0014[d]
PCB-184	0.1	2.0	1.0	4.0	0.0027
PCB-186	0.1	2.0	1.0	4.0	0.0040
PCB-187	0.1	2.0	1.0	4.0	0.0013
PCB-188	0.1	2.0	1.0	4.0	0.0029
PCB-189	0.1	2.0	1.0	4.0	0.0004
PCB-190	0.1	2.0	1.0	4.0	0.0007
PCB-191	0.1	2.0	1.0	4.0	0.0005

Table C-2. Method and RL goals for PCB congeners in sediment

Analyte	EPA Method 1668C				Estimated porewater DL (ug/L)[c]
	Sediment (ng/kg dw) Based on 10-g dw sample		Passive Sampler (pg/g) Based on 1-g PE sample		
	EDL[a]	LMCL[b]	EDL[a]	LMCL[b]	
PCB-192	0.1	2.0	1.0	4.0	0.0006
PCB-194	0.1	2.0	1.0	4.0	0.0003
PCB-195	0.1	2.0	1.0	4.0	0.0005
PCB-196	0.1	2.0	1.0	4.0	0.0004
PCB-197/200	0.1	2.0	1.0	4.0	0.0010[d]
PCB-198/199	0.1	2.0	1.0	4.0	0.0008[d]
PCB-201	0.1	2.0	1.0	4.0	0.0005
PCB-202	0.1	2.0	1.0	4.0	0.0011
PCB-203	0.1	2.0	1.0	4.0	0.0004
PCB-204	0.1	2.0	1.0	4.0	0.0010
PCB-205	0.1	2.0	1.0	4.0	0.0002
PCB-206	0.1	2.0	1.0	4.0	0.0002
PCB-207	0.1	2.0	1.0	4.0	0.0004
PCB-208	0.1	2.0	1.0	4.0	0.0004
PCB-209	0.1	2.0	1.0	4.0	0.0001

[a] EDL is a sample-specific DL. The value provided here is an estimate, and the sample-specific values will vary based on sample mass and the analytical conditions at the time of analysis.

[b] LMCL is Axys's lowest calibration limit. Detected values below the LMCL are J-qualified. The reported LMCL will be adjusted based on the sample mass of each sample.

[c] Assuming 0.1g of PE and that full equilibrium is reached for all congeners.

[d] Detection limits for co-elutions were calculated based on the mean of the partition coefficients for the co-eluting congeners.

Axys – Axys Analytical Services, Ltd.
DL – detection limit
dw – dry weight
EPA – US Environmental Protection Agency
EDL – estimated detection limit
J – estimated concentration

LMCL – lower method calibration limit
PCB – polychlorinated biphenyl
RAO – remedial action objective
RL – reporting limit
ww – wet weight

Table C-3. Method and RL goals for dioxins/furan congeners in sediment

Analyte	EPA Method 1613B			
	Sediment (ng/kg dw) Based on 10-g sample		TEQ (ng/kg)	
	EDL[a]	LMCL[b]	TEF	TEQ[c]
2,3,7,8-TCDD	0.05	0.2	1	0.025
1,2,3,7,8-PeCDD	0.05	1.0	1	0.025
1,2,3,4,7,8-HxCDD	0.05	1.0	0.1	0.0025
1,2,3,6,7,8-HxCDD	0.05	1.0	0.1	0.0025
1,2,3,7,8,9-HxCDD	0.05	1.0	0.1	0.0025
1,2,3,4,6,7,8-HpCDD	0.05	1.0	0.01	0.00025
OCDD	0.05	2.0	0.0003	0.0000075
2,3,7,8-TCDF	0.05	0.2	0.1	0.0025
1,2,3,7,8-PeCDF	0.05	1.0	0.03	0.00075
2,3,4,7,8-PeCDF	0.05	1.0	0.3	0.0075
1,2,3,4,7,8-HxCDF	0.05	1.0	0.1	0.0025
1,2,3,6,7,8-HxCDF	0.05	1.0	0.1	0.0025
1,2,3,7,8,9-HxCDF	0.05	1.0	0.1	0.0025
2,3,4,6,7,8-HxCDF	0.05	1.0	0.1	0.0025
1,2,3,4,6,7,8-HpCDF	0.05	1.0	0.01	0.00025
1,2,3,4,7,8,9-HpCDF	0.05	1.0	0.01	0.00025
OCDF	0.05	2.0	0.0003	0.0000075

[a] EDL is a sample-specific DL. The value provided here is an estimate, and the sample-specific values will vary based on sample mass and the analytical conditions at the time of analysis.

[b] LMCL is Axys's lowest calibration limit. Detected values below the LMCL are J-qualified. The reported LMCL will be adjusted based on the sample mass of each sample.

[c] TEQ calculated using ½ RL value multiplied by the TEF.

Axys – Axys Analytical Services, Ltd.
DL – detection limit
dw – dry weight
EPA – US Environmental Protection Agency
EDL – estimated detection limit
HpCDD – heptachlorodibenzo-p-dioxin
HpCDF – heptachlorodibenzofuran
HxCDD – hexachlorodibenzo-p-dioxin
HxCDF – hexachlorodibenzofuran
LMCL – lower method calibration limit
OCDD – octachlorodibenzo-p-dioxin
OCDF – octachlorodibenzofuran
PeCDD – pentachlorodibenzo-p-dioxin
PeCDF – pentachlorodibenzofuran
RAO – remedial action objective
RL – reporting limit
TCDD – tetrachlorodibenzo-p-dioxin
TCDF – tetrachlorodibenzofuran
TEF – toxic equivalency factor
TEQ – toxic equivalent
ww – wet weight

Table C-4. Jars for 0–10-cm grab samples

Location	Baseline Composite DQOs 1 and 2 2-8-oz Jars	SMS Analysis (DQOs 3 and 4) 1–4-oz. Jar 2–8-oz. Jar 1–16-oz. Jar	PCB Porewater and SMS Analysis (DQOs 3-5) 4–8-oz. Jar 3–16-oz. Jars	PCB Porewater (DQO 5) 3–8-oz. Jar 3–16-oz. Jar
1 through 168	X[a]			
8	-	X	-	-
23	-	X	-	-
40	-	X	-	-
52	-	X	-	-
69	-	X	-	-
91	-	X	-	-
101	-	X	-	-
130	-	X	-	-
143	-	X	-	-
161	-	X	-	-
169	-	-	X	
170	-	-	X	
171	-	-	-	X
172	-	-	-	X
173	-	-	-	X
174	-	-	X	
175	-	-	-	X
176	-	-	-	X
177	-	-	-	X
178	-	-	X	
179	-	-	X	
180	-	-	-	X
181	-	-	-	X
182	-	-	-	X
183	-	-	X	
184	-	-	X	
185	-	-	-	X
186	-	-	X	
187	-	-	X	
188	-	-	X	

[a] An additional 8-oz jar for NOAA will be filled at each location as sample volume allows.

DQO – data quality objective
PCB – polychlorinated biphenyl
NOAA – National Oceanic and Atmospheric Administration
SMS – Sediment Management Standards

Table C-5. 0–10- and 0–45-cm composite sample jars

Sample	PCB Aroclors/cPAHs 1-8-oz. Jar	PCB Aroclors/ cPAHs/Toxaphene 1-8-oz. Jar	Arsenic/ TOC/TS 1-8-oz. Jar	Black Carbon 1-8-oz. Jar	Dioxin/Furan 1–8-oz. Jar[a]	Grain Size 1-16-oz. Jar	Archive 1–8-oz. Jar	Summary of Jars Needed
0–10-cm sediment	X	-	X	X	X	X	X	5–8-oz. jars 1–16-oz. jar
0-45 cm sediment	-	X	X	-	X	X	X	4–8-oz. jars 1–16-oz. jar

[a] If none of the PCB Aroclors are detected, then sediment from the dioxin/furan jar will be analyzed for PCB congeners.

cPAH – carcinogenic polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

TOC – total organic carbon

TS – total solids

Table C-6. Near-outfall sediment and individual bank sample collection jars

Sample	SMS Analysis (DQOs 3 and 4) 1–4-oz. Jar, 2–8-oz. Jar 1–16-oz. Jar	Dioxin/Furan 1–8-oz. Jar	Archive 1–8-oz. Jar	Summary of Jars Needed
Near-outfall 0–10-cm sediment	X	X	X	1–4-oz. jar 4–8-oz. jars 1–16-oz. jar
Individual bank samples	X	X	X	1–4-oz. jar 4–8-oz. jars 1–16-oz. jar

DQO – data quality objective

SMS – Washington State Sediment Management Standards

APPENDIX D. STANDARD OPERATING PROCEDURES FOR PASSIVE SAMPLERS AND SUBSAMPLING SEDIMENT

- **Attachment D-1**
    - Standard Operating Procedure LB-16: Ex Situ Determination of Porewater PCBs using Polyethylene Passive Samplers
    - Guidance Document: Passive Polyethylene Sampling in Support of In Situ Remediation of Contaminated Sediments: Standard Operating Procedure for PED Preparation
- **Attachment D-2**
    - Standard Operating Procedure: Lower Duwamish Waterway Clamming Area Sediment Compositing, Homogenization, and Aliquoting

Attachment D-1

STANDARD OPERATING PROCEDURE (SOP) LB-16

EX SITU DETERMINATION OF POREWATER PCBS USING POLYETHYLENE PASSIVE SAMPLERS

Note: This SOP is based upon guidance for the use of passive sampling in the evaluation of contaminated sediments (EPA et al., 2017).

METHOD DESCRIPTION

This SOP provides instruction on the use of polyethylene (PE) passives samplers in the laboratory for the estimation of polychlorinated biphenyl (PCB) porewater concentrations in sediments. PE samplers will be equilibrated with sediments for 1 month using an orbital shaker, ensuring that there is sufficient mass of PE sampler to achieve the lowest possible PCB detection limits, and utilizing sufficient mass of sediment in each exposure so the addition of the PE sampler does not deplete PCBs from the sediment significantly (i.e., < 1% of the mass of the PCBs in the sediment should be absorbed by the sampler).

Pre-cleaned and performance reference compound (PRC) impregnated PE sheets will be prepared by Axys Analytical Services Ltd. (Axys) using procedures described in Gschwend et al. 2012 (Attachment D1). The PE sheets will then be transported to Analytical Resources, Inc. (ARI) on ice as detailed in the accompanying Surface Sediment Quality Assurance Project Plan (QAPP), and stored in a freezer (<-4 °C) until the aqueous equilibrium exposures are started.

Sediment samples will be collected, transported and stored at ARI as detailed in the accompanying QAPP. Before starting the aqueous equilibrium exposures, a small sub-sample of each stored sediment sample will be taken to determine moisture content. This information will be used to determine the volume of sodium azide (biocide) solution to be added to the exposures to achieve a well-formed slurry (80% water content).

PCB analysis of the samplers will be conducted by Axys following methods described in the accompanying QAPP. PCB concentrations in the samplers will be used to estimate porewater concentration as described in the accompanying QAPP, using the physical and chemical properties presented in Table D-1.

MOISTURE CONTENT

Calibration

1. Verify the balance was calibrated by the laboratory prior to use.

Sample Preparation

1. Initiate a Percent Moisture Benchsheet and complete the required information.
2. Record the Analyst, Oven ID, Thermometer ID, and Balance ID on the Percent Moisture Benchsheet.
3. Label an aluminum dish with a unique numerical ID (1, 2, 3…) for each sample.
4. Weigh the aluminum dish using a calibrated analytical balance and record the weight measurement on the benchsheet to the nearest 0.01g in the "Tare" column.
5. Thoroughly mix the sample then measure 5-10 g of sample into the pre-weighed, pre-labeled aluminum dish. Weigh to the nearest 0.01 g and record the weight measurement onto the benchsheet in the "Wet Wt." column.
6. Place the dish in the drying oven maintained at a temperature of 105 ±2°C. Record the date and the time the samples were placed in the oven.
7. Dry the sample for a minimum of 12 hours but do not exceed 24 hours. After this time has elapsed, remove the samples from the oven and allow them to cool in a desiccator before weighing.
8. Reweigh the samples and record the weight measurements in the "Tare+Dry Wt." column of the benchsheet.
9. Record the oven temperature and time out of the oven on the benchsheet.
10. Calculate sediment moisture content using formula below and record on the benchsheet.

Calculations

$$\text{Percent moisture} = 100 - \left(\frac{[(Tare+Dry\ Wt.)-(Tare)]}{(Wet\ Wt.)}\ x\ 100\right)$$

AQUEOUS EQUILIBRIUM EXPOSURES

Passive Sampler Preparation

1. Prior to starting the equilibrium exposures, remove PE sheets from the freezer.

EQUIPMENT

- Drying Oven: Capable of maintaining a temperature of 105 ±2°C
- Aluminum Weighing Boats
- Top loading balance (readability = 0.01 g, capacity = 4000 g)
- Desiccator
- Laboratory grade deionized water
- Sodium azide
- Top loading balance (readability = 0.0001 g, capacity = 200 g)
- Pre-cleaned, PRC impregnated PE sheets
- Orbital shaker (capacity = > 20 kg)
- Stainless steel scissors
- Methanol

PERSONAL PROTECTIVE EQUIPMENT (PPE)

The analyst will be attired in the following PPE:

- Safety glasses
- Lab coat
- Nitrile gloves
- Long pants
- Closed-toe shoes

ATTACHMENTS

- Attachment D1 (Gschwend et al., 2012)

2. Cut PE sheets into 0.1 g PE strips using methanol wiped stainless steel scissors. Always handle the PE sheets and strips wearing nitrile gloves.

3. Wrap all PE strips in aluminum foil and store at 4ºC ± 2°C until all sediment slurries are ready as described below.

Exposure Preparation

1. Initiate an Exposure Setup Benchsheet and complete the required information.
2. Label 1 L wide mouth glass jars, with Teflon-lined caps, with unique sediment sample IDs.
3. Thoroughly homogenize the sediment samples with a stainless steel spoon in a stainless steel bowl, and place approximately 1 kg wet weight of each sample into its corresponding labeled jar.
4. Record the mass of sediment in each jar in the Exposure Setup Benchsheet to the nearest 0.1 g.
5. Accounting for the moisture content of each sediment sample, calculate the volume of 2 g/L sodium azide solution to be added to each glass jar to achieve a sediment slurry of 80% moisture content (see formula below). Add the corresponding volume of solution to each jar, and record the volume added in the Exposure Setup Benchsheet to the nearest ml.

$$\text{Volume (ml)} = (80\% - \text{percent moisture}) \times \text{sediment mass (g)}$$

6. Add a pre-weighed 0.1 g PE strip to each jar. Record the weight of each strip to 4 decimal points in the Exposure Setup Benchsheet.
7. Tightly seal the lid of each jar, and securely load all jars onto the orbital shaker. Jars should be positioned securely, ensuring they will be able to safely withstand 1 month of agitation without breakage.
8. Turn on the orbital shaker and gradually increase the shaking speed to around 100 rpm.
9. Monitor jars for the first hour to ensure jars remain securely in place during shaking, and make any packing adjustments if necessary.
10. Initiate a Daily Conditions Benchsheet and complete the required information.
11. Monitor temperature, shakers, and jars daily for 1 month, and record observations on the Daily Conditions Benchsheet. Jars should be maintained at room temperature (20-25°C) for the duration of the exposure.

Exposure Termination

1. After 1 month, stop the orbital shaker and remove all glass jars.
2. Gradually empty the contents of each jar into a beaker to recover each PE strip.
3. Rinse each PE strip with laboratory grade deionized water to remove all attached sediment.
4. Wipe each PE strip with clean laboratory wipes to remove any remaining sediment and water.
5. Wrap each PE strip in a clean labeled aluminum foil envelope. Insert each envelope in a resealable plastic bag with corresponding sample ID label.
6. Insert all resealable plastic bags into a larger resealable plastic bag, and place the large bag on ice in a cooler for transport to Axys for analysis. Sample packing, transport information, and sample custody procedures are described in accompanying QAPP.

QUALITY ASSURANCE AND QUALITY CONTROL SAMPLES

The following quality assurance and quality control samples will be included to support data validation and usability determination:

- Passive sampler exposure blank (5 percent frequency, or 1 per maximum 20 samples). For the laboratory blank, 900 ml laboratory grade deionized water and 100 ml of 2 g/L sodium azide solution will be added to a wide mouth glass jar. A pre-weighed 0.1 g PRC impregnated PE strip will be added to this jar, and the jar will be treated in the same way as jars containing sediment samples.

- Duplicate samples (5 percent frequency, or 1 per maximum 20 samples). Prepare duplicate aqueous equilibrium exposures for select samples.

DATA MANAGEMENT

All data will be recorded immediately, legibly and in ink on the appropriate benchsheets. Any recording mistakes will be struck out with a single line and initialed and dated by the analyst. Hard copies of completed forms will be compiled and stored. Forms will also be scanned electronically, and these electronic copies will be submitted to EPA as part of the Data Report.

WASTE DISPOSAL

The analyst will perform this analysis with the intent of obtaining the best quality analytical results while generating the minimum amount of waste.

Waste generated during this analysis will include the sediment from all aqueous equilibrium exposures. This waste will be composited and disposed appropriately per laboratory procedures.

REFERENCES

EPA, SERDP, ESTCP. 2017. Laboratory, field, and analytical procedures for using passive sampling in the evaluation of contaminated sediments: user's manual. EPA/600/R- 16/357. February 2017 final web version (1.0). US Environmental Protection Agency, US Department of Defense, Strategic Environmental Research and Development Program, and Environmental Security Technology Certification Program.

Gschwend P, MacFarlane J, Palaia K, Reichenbacher S, Gouveia D. 2012. Passive PE sampling in support of in situ remediation of contaminated sediments (standard operating procedure for the preparation of polyethylene devices). ESTCP Project ER-200915. SERDP/ESTCP

Table D1. Physicochemical Properties of PCBs

Constituent of Interest	CAS No.	log K_{ow}[a]	log K_{PEW} (L_W/kg_{PE})[a]	log D_{PE} (cm^2/s)[a]
PCB Congeners				
PCB 1	2051-60-7	4.46	4.17	-8.46
PCB 2	2051-61-8	4.69	4.40	-8.46
PCB 3	2051-62-9	4.69	4.40	-8.46
PCB 4	13029-08-8	4.65	4.36	-8.64
PCB 5	16605-91-7	4.97	4.68	-8.64
PCB 6	25569-80-6	5.06	4.77	-8.64
PCB 7	33284-50-3	5.07	4.78	-8.64
PCB 8	34883-43-7	5.07	4.78	-8.64
PCB 9	34883-39-1	5.06	4.77	-8.64
PCB 10	33146-45-1	4.84	4.55	-8.64
PCB 11	2050-67-1	5.28	4.99	-8.64
PCB 12	2974-92-7	5.22	4.93	-8.64
PCB 13	2974-90-5	5.29	5.00	-8.64
PCB 14	34883-41-5	5.28	4.99	-8.64
PCB 15	2050-68-2	5.3	5.01	-8.64
PCB 16	38444-78-9	5.16	4.87	-8.81
PCB 17	37680-66-3	5.25	4.96	-8.81
PCB 18	37680-65-2	5.24	4.95	-8.81
PCB 19	38444-73-4	5.02	4.73	-8.81
PCB 20	38444-84-7	5.57	5.28	-8.81
PCB 21	55702-46-0	5.51	5.22	-8.81
PCB 22	38444-85-8	5.58	5.29	-8.81
PCB 23	55720-44-0	5.57	5.28	-8.81
PCB 24	55702-45-9	5.35	5.06	-8.81
PCB 25	55712-37-3	5.67	5.38	-8.81
PCB 26	38444-81-4	5.6	5.31	-8.81
PCB 27	38444-76-7	5.44	5.15	-8.81
PCB 28	7012-37-5	5.67	5.38	-8.81
PCB 29	15862-07-4	5.6	5.31	-8.81
PCB 30	35693-92-6	5.44	5.15	-8.81
PCB 31	16606-02-3	5.67	5.38	-8.81
PCB 32	38444-77-8	5.44	5.15	-8.81
PCB 33	38444-86-9	5.6	5.31	-8.81
PCB 34	37680-68-5	5.66	5.37	-8.81
PCB 35	37680-69-6	5.82	5.53	-8.81
PCB 36	38444-87-0	5.88	5.59	-8.81
PCB 37	38444-90-5	5.83	5.54	-8.81
PCB 38	53555-66-1	5.76	5.47	-8.81
PCB 39	38444-88-1	5.89	5.60	-8.81
PCB 40	38444-93-8	5.66	5.37	-8.98
PCB 41	52663-59-9	5.69	5.40	-8.98
PCB 42	36559-22-5	5.76	5.47	-8.98
PCB 43	70362-46-8	5.75	5.46	-8.98
PCB 44	41464-39-5	5.75	5.46	-8.98
PCB 45	70362-45-7	5.53	5.24	-8.98
PCB 46	41464-47-5	5.53	5.24	-8.98
PCB 47	2437-79-8	5.85	5.56	-8.98
PCB 48	70362-47-9	5.78	5.49	-8.98
PCB 49	41464-40-8	5.85	5.56	-8.98
PCB 50	62796-65-0	5.63	5.34	-8.98
PCB 51	68194-04-7	5.63	5.34	-8.98
PCB 52	35693-99-3	5.84	5.55	-8.98
PCB 53	41464-41-9	5.62	5.33	-8.98
PCB 54	15968-05-5	5.21	4.92	-8.98

Table D1. Physicochemical Properties of PCBs

Constituent of Interest	CAS No.	log K_{ow}[a]	log K_{PEW} (L_W/kg_{PE})[a]	log D_{PE} (cm^2/s)[a]
PCB 55	74338-24-2	6.11	5.82	-8.98
PCB 56	41464-43-1	6.11	5.82	-8.98
PCB 57	74472-33-6	6.17	5.88	-8.98
PCB 58	41464-49-7	6.17	5.88	-8.98
PCB 59	74472-33-6	5.95	5.66	-8.98
PCB 60	33025-41-1	6.11	5.82	-8.98
PCB 61	33284-53-6	6.04	5.75	-8.98
PCB 62	54230-22-7	5.89	5.60	-8.98
PCB 63	74472-34-7	6.17	5.88	-8.98
PCB 64	52663-58-8	5.95	5.66	-8.98
PCB 65	33284-54-7	5.86	5.57	-8.98
PCB 66	32598-10-0	6.2	5.91	-8.98
PCB 67	73575-53-8	6.2	5.91	-8.98
PCB 68	73575-52-7	6.26	5.97	-8.98
PCB 69	60233-24-1	6.04	5.75	-8.98
PCB 70	32598-11-1	6.2	5.91	-8.98
PCB 71	41464-46-4	5.98	5.69	-8.98
PCB 72	41464-42-0	6.26	5.97	-8.98
PCB 73	74338-23-1	6.04	5.75	-8.98
PCB 74	32690-93-0	6.2	5.91	-8.98
PCB 75	32598-12-2	6.05	5.76	-8.98
PCB 76	70362-48-0	6.13	5.84	-8.98
PCB 77 - WHO 12	32598-13-3	6.36	6.07	-8.98
PCB 78	70362-49-1	6.35	6.06	-8.98
PCB 79	41464-48-6	6.42	6.13	-8.98
PCB 80	33284-52-5	6.48	6.19	-8.98
PCB 81 - WHO 12	70362-50-4	6.36	6.07	-8.98
PCB 82	52663-62-4	6.2	5.91	-9.16
PCB 83	60145-20-2	6.26	5.97	-9.16
PCB 84	52663-60-2	6.04	5.75	-9.16
PCB 85	65510-45-4	6.3	6.01	-9.16
PCB 86	55312-69-1	6.23	5.94	-9.16
PCB 87	38380-02-8	6.29	6.00	-9.16
PCB 88	55215-17-3	6.07	5.78	-9.16
PCB 89	73575-57-2	6.07	5.78	-9.16
PCB 90	68194-07-0	6.36	6.07	-9.16
PCB 91	68194-05-8	6.13	5.84	-9.16
PCB 92	52663-61-3	6.35	6.06	-9.16
PCB 93	73575-56-1	6.04	5.75	-9.16
PCB 94	73575-55-0	6.13	5.84	-9.16
PCB 95	38379-99-6	6.13	5.84	-9.16
PCB 96	73575-54-9	5.71	5.42	-9.16
PCB 97	41464-51-1	6.29	6.00	-9.16
PCB 98	60233-25-2	6.13	5.84	-9.16
PCB 99	38380-01-7	6.39	6.10	-9.16
PCB 100	39485-83-1	6.23	5.94	-9.16
PCB 101	37680-73-2	6.38	6.09	-9.16
PCB 102	68194-06-9	6.16	5.87	-9.16
PCB 103	60145-21-3	6.22	5.93	-9.16
PCB 104	56558-16-8	5.81	5.52	-9.16
PCB 105 - WHO 12	32598-14-4	6.65	6.36	-9.16
PCB 106	70424-69-0	6.64	6.35	-9.16
PCB 107	70424-68-9	6.71	6.42	-9.16
PCB 108	70362-41-3	6.71	6.42	-9.16
PCB 109	74472-35-8	6.48	6.19	-9.16

Table D1. Physicochemical Properties of PCBs

Constituent of Interest	CAS No.	log K_{ow}[a]	log K_{PEW} (L_W/kg_{PE})[a]	log D_{PE} (cm^2/s)[a]
PCB 110	38380-03-9	6.48	6.19	-9.16
PCB 111	39635-32-0	6.76	6.47	-9.16
PCB 112	74472-36-9	6.45	6.16	-9.16
PCB 113	68194-10-5	6.54	6.25	-9.16
PCB 114 - WHO 12	74472-37-0	6.65	6.36	-9.16
PCB 115	74472-38-1	6.49	6.20	-9.16
PCB 116	18259-05-7	6.33	6.04	-9.16
PCB 117	68194-11-6	6.46	6.17	-9.16
PCB 118	31508-00-6	6.74	6.45	-9.16
PCB 119	56558-17-9	6.58	6.29	-9.16
PCB 120	68194-12-7	6.79	6.50	-9.16
PCB 121	56558-18-0	6.64	6.35	-9.16
PCB 122	76842-07-4	6.64	6.35	-9.16
PCB 123 - WHO 12	65510-44-3	6.74	6.45	-9.16
PCB 124	70424-70-3	6.73	6.44	-9.16
PCB 125	74472-39-2	6.51	6.22	-9.16
PCB 126 - WHO 12	57465-28-8	6.89	6.60	-9.16
PCB 127	39635-33-1	6.95	6.66	-9.16
PCB 128	38380-07-3	6.74	6.45	-9.33
PCB 129	55215-18-4	6.73	6.44	-9.33
PCB 130	52663-66-8	6.8	6.51	-9.33
PCB 131	61798-70-7	6.58	6.29	-9.33
PCB 132	38380-05-1	6.58	6.29	-9.33
PCB 133	35694-04-3	6.86	6.57	-9.33
PCB 134	52704-70-8	6.55	6.26	-9.33
PCB 135	52744-13-5	6.64	6.35	-9.33
PCB 136	38411-22-2	6.22	5.93	-9.33
PCB 137	35694-06-5	6.83	6.54	-9.33
PCB 138	35065-28-2	6.83	6.54	-9.33
PCB 139	56030-56-9	6.67	6.38	-9.33
PCB 140	59291-64-4	6.67	6.38	-9.33
PCB 141	52712-04-6	6.82	6.53	-9.33
PCB 142	41411-61-4	6.51	6.22	-9.33
PCB 143	68194-15-0	6.6	6.31	-9.33
PCB 144	68194-14-9	6.67	6.38	-9.33
PCB 145	74472-40-5	6.25	5.96	-9.33
PCB 146	51908-16-8	6.89	6.60	-9.33
PCB 147	68194-13-8	6.64	6.35	-9.33
PCB 148	74472-41-6	6.73	6.44	-9.33
PCB 149	38380-04-0	6.67	6.38	-9.33
PCB 150	68194-08-1	6.33	6.04	-9.33
PCB 151	52663-63-5	6.64	6.35	-9.33
PCB 152	68194-09-2	6.22	5.93	-9.33
PCB 153	35065-27-1	6.92	6.63	-9.33
PCB 154	60145-22-4	6.76	6.47	-9.33
PCB 155	33979-03-2	6.41	6.12	-9.33
PCB 156 - WHO 12	38380-08-4	7.18	6.89	-9.33
PCB 157 - WHO 12	69782-90-7	7.18	6.89	-9.33
PCB 158	74472-42-7	7.02	6.73	-9.33

Table D1. Physicochemical Properties of PCBs

Constituent of Interest	CAS No.	log K_{ow}[a]	log K_{PEW} (L_W/kg_{PE})[a]	log D_{PE} (cm^2/s)[a]
PCB 159	39635-35-3	7.24	6.95	-9.33
PCB 160	41411-62-5	6.93	6.64	-9.33
PCB 161	74472-43-8	7.08	6.79	-9.33
PCB 162	39635-34-2	7.24	6.95	-9.33
PCB 163	74472-44-9	6.99	6.70	-9.33
PCB 164	74472-45-0	7.02	6.73	-9.33
PCB 165	74472-46-1	7.05	6.76	-9.33
PCB 166	41411-63-6	6.93	6.64	-9.33
PCB 167 - WHO 12	52663-72-6	7.27	6.98	-9.33
PCB 168	59291-65-5	7.11	6.82	-9.33
PCB 169	32774-16-6	7.42	7.13	-9.33
PCB 170	35065-30-6	7.27	6.98	-9.4
PCB 171	52663-71-5	7.11	6.82	-9.4
PCB 172	52663-74-8	7.33	7.04	-9.4
PCB 173	68194-16-1	7.02	6.73	-9.4
PCB 174	38411-25-5	7.11	6.82	-9.4
PCB 175	40186-70-7	7.17	6.88	-9.4
PCB 176	52663-65-7	6.76	6.47	-9.4
PCB 177	52663-70-4	7.08	6.79	-9.4
PCB 178	52663-67-9	7.14	6.85	-9.4
PCB 179	52663-64-6	6.73	6.44	-9.4
PCB 180	35065-29-3	7.36	7.07	-9.4
PCB 181	74472-47-2	7.11	6.82	-9.4
PCB 182	60145-23-5	7.2	6.91	-9.4
PCB 183	52663-69-1	7.2	6.91	-9.4
PCB 184	74472-48-3	6.85	6.56	-9.4
PCB 185	52712-05-7	7.11	6.82	-9.4
PCB 186	74472-49-4	6.69	6.40	-9.4
PCB 187	52663-68-0	7.17	6.88	-9.4
PCB 188	74487-85-7	6.82	6.53	-9.4
PCB 189 - WHO 12	39635-31-9	7.71	7.42	-9.4
PCB 190	41411-64-7	7.46	7.17	-9.4
PCB 191	74472-50-7	7.55	7.26	-9.4
PCB 192	74472-51-8	7.52	7.23	-9.4
PCB 193	69782-91-8	7.52	7.23	-9.4
PCB 194	35694-08-7	7.8	7.51	-9.66
PCB 195	52663-78-2	7.56	7.27	-9.66
PCB 196	42740-50-1	7.65	7.36	-9.66
PCB 197	33091-17-7	7.3	7.01	-9.66
PCB 198	68194-17-2	7.62	7.33	-9.66
PCB 199	52663-75-9	7.2	6.91	-9.66
PCB 200	52663-73-7	7.27	6.98	-9.66
PCB 201	40186-71-8	7.62	7.33	-9.66
PCB 202	2136-99-4	7.24	6.95	-9.66
PCB 203	52663-76-0	7.65	7.36	-9.66
PCB 204	74472-52-9	7.3	7.01	-9.66
PCB 205	74472-53-0	8	7.71	-9.66

Table D1. Physicochemical Properties of PCBs

Constituent of Interest	CAS No.	log K_{ow}[a]	log K_{PEW} (L_W/kg_{PE})[a]	log D_{PE} (cm^2/s)[a]
PCB 206	40186-72-9	8.09	7.80	-9.83
PCB 207	52663-79-3	7.74	7.45	-9.83
PCB 208	52663-77-1	7.71	7.42	-9.83
PCB 209	2051-24-3	8.18	7.89	-10

Notes:

PCB = polychlorinated biphenyl

K_{OW} = Octanol to Water Partition Constant

K_{PEW} = Polyethylene to Water Partition Constant

D_{PE} = Polyethylene Diffusivity

SDL = Sample Detection Limit

[a] Default values in PRC calculator: Gschwend, P.M., P. Tcaciuc, and J.N. Apell. 2014. Passive PE sampling in support of in situ remediation of contaminated sediments – Passive sampler PRC calculation software user's guide. ESTCP Project ER-200915..

[b] Provided by AXYS

[c] Assuming 0.1 gram of PE and that full equilibrium is reached. Note that full equilibrium may not be achieved for all congeners.

GUIDANCE DOCUMENT

Passive PE Sampling in Support of In Situ Remediation of Contaminated Sediments: Standard Operating Procedure for PED Preparation

ESTCP Project ER-200915

December 2012

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14. ABSTRACT

The purpose of this Standard Operating Procedure (SOP) is to provide a description of the methods used in the deployment and retrieval of polyethylene devices (PEDs) in sediment-pore water environments for the sampling of hydrophobic organic compounds (HOCs) such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). The overall objective of PED sampling is to determine the horizontal and vertical distributions of HOCs in pore waters of bed sediments. This SOP does not discuss deployment of PEDs in atmospheric or aqueous systems. This SOP should be used in conjunction with companion SOPs for Preparation of Polyethylene (PE) Media and Extraction Procedures for PE Media.

15. SUBJECT TERMS

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Reset

Standard Operating Procedure for the Preparation of Polyethylene (PE) and Polyethylene Devices (PEDs) Used for Passive Sampling

1.0 SCOPE AND APPLICATION

1.1 This method describes a procedure for preparing and handling polyethylene (PE) films that will be cut into strips and used in polyethylene devices (PEDs) to passively sample hydrophobic organic compounds (HOCs) in environmental media.

1.2 This method generates PE that can be deployed within PEDs for passive sampling of HOCs in atmospheric, aqueous, or sediment-porewater systems.

1.3 PE that is prepared by this method is suitable for laboratory or *in situ* field deployment.

2.0 SUMMARY OF METHOD

2.1 A known mass of low density polyethylene (LDPE) sheet, usually gram quantities, is cleaned by sequentially extracting with methylene chloride, methanol, and ultrapure water in a closed glass vessel.

2.2 Clean PE is equilibrated with performance reference compounds (PRCs) dissolved in water or methanol-water (see Appendix 1 for possible PRCs).

2.3 Prepared PE is stored in contaminant-free, sealed, glass vessels.

2.4 Shortly before deployment, the PE is cut into strips and either placed in aluminum mesh bags for water sampling water or aluminum frames for sediment sampling. PEDs are transported to the field wrapped in clean aluminum foil.

2.5 In the field, the PE is exposed to the environmental medium of concern. HOCs in the medium diffuse into the PE, while PRCs diffuse out.

3.0 INTERFERENCES

3.1 PE is susceptible to contamination from atmospheric vapors and contact with surfaces (e.g., worker hands), so it must remain in clean sealed vessels until deployment.

4.0 APPARATUS AND MATERIALS

4.1 Extraction vessels: 1-L glass bottles or screw capped jars (foil-lined lids).

4.2 Storage vessels: bottles with glass stoppers or amber jars (foil-lined lids).

4.3 Bottle/jar tumbler, shaker table, bottle roller, or equivalent.

4.4 Low density polyethylene (LDPE): commercial grade, large sheet at 25μm (1 mil) or 51μm (2 mil) thickness. The thickness is chosen to be strong enough to withstand stresses during deployment (e.g., insertion into sediment), but thin enough to exchange a significant fraction (e.g., >20%) of its PRCs during the deployment time to be used.

4.5 Food grade aluminum foil (solvent cleaned and/or combusted to remove any organic residue from foil production)

4.6 Stainless steel forceps

4.7 Teflon (or similar non-contaminating material) cutting board

5.0 REAGENTS

5.1 Methylene chloride, CH_2Cl_2, pesticide grade or equivalent

5.2 Methanol, CH_3OH, pesticide grade or equivalent

5.3 Organic-free reagent water (as defined in SW-846 Chapter 1)

5.4 Research grade PRCs certified >98+% pure.

Note: Specific standard materials, concentrations, solvents, and solvent purity requirements will be determined based upon that target HOCs of concern for the particular application

6.0 PRESERVATION AND HANDLING

6.1 Clean PE should be stored in clean sealed glass vessels.

6.2 Until deployment, prepared PE (PE loaded with PRCs) is stored in sealed glass containers with a few mL of organic-free reagent water added to maintain 100% relative humidity within the storage vessels (minimizing sorptive losses of PRCs to glass vessel walls).

6.3 Laboratory and field personnel should wear nitrile or latex gloves whenever handling clean PE.

6.4 Methylene chloride-rinsed, stainless steel forceps and scissors are used when manipulation of clean PE is required.

6.5 Methylene chloride-rinsed, aluminum foil is used to cover any surface that clean PE may encounter.

7.0 PROCEDURE

7.1 Polyethylene Cleaning Procedure: LDPE is purchased from hardware/painting stores in large sheets (‘dropcloth or plastic tarp’ material) with thickness of 25μm (1 mil) or 51μm (2 mil), depending on the user's need for strength (choose thicker) and desire to use short deployment times (used thinner). The sheet is cut into strips sized for environment and frames to be used. An organic solvent cleaning sequence is then used to prepare the PE. This process ensures that extractable oligomers, plasticizers, and contaminating organic chemicals are removed from the PE prior to use. All extractions are performed sequentially in the same container.

7.1.1 Methylene chloride is placed into the extraction vessel, and the PE strips are immersed in the container for 24 hours to enable time for diffusive transfers out of the PE. The initial methylene chloride extract is discarded and a second methylene chloride extraction is performed for 24 hours. The second methylene chloride extract is discarded and replaced by methanol in order to remove methylene chloride from the PE. Methanol immersion is also done for 24 hours. The initial methanol extract is discarded and followed by a second methanol soak for 24 hours. Finally, the second methanol extract is discarded and the PE undergoes three 24-hour soaks with organic-free reagent water (within the same extraction vessel) to remove residual methanol from the PE.

7.1.2 The cleaned PE is stored in organic-free reagent water in the extraction vessel until further processing.

7.2 Polyethylene Preparation with Performance Recovery Compounds (PRCs)**:** PRCs are loaded into the clean PE, prior to its field deployment, by utilizing either aqueous (Fernandez et al. 2009) or 80:20 methanol:water equilibrations (Booij et al., 2002). Depending on the hydrophobic organic compounds of interest, PRCs should be chosen which mimic mass transfer phenomena governing exchanges during field deployments. It is important to avoid adding PRCs that the analytical laboratory already uses as surrogate or injection standards. PRC loading is performed by placed the PE in pre-cleaned glass vessels containing known PRC solutions made up in organic-free reagent water with or without pesticide-grade methanol. The PE user should estimate the expected accumulation of target compounds in the passive sampler and seek to load with similar levels of PRCs to facilitate the eventual chemical analyses. Sufficient PRC equilibration time during this PE preparation step is necessary to ensure uniform PE loading across the entire PE thickness; hence thicker PE sheet is more robust for field use, but takes longer to load with PRCs.

7.2.1 Isotopically labeled compounds are useful internal standards when Gas Chromatography-Mass Spectrometry (GCMS) is the method of separation and detection. For example, deuterated polycyclic aromatic hydrocarbons (PAHs) and C13-labeled PCBs are effective methodological standards for PE passive sampling. One subset of compounds, distributed across the range of PAHs to be assessed (e.g., d10-phenanthrene, d10-pyrene, and d12-chrysene), should be used as PRCs, while another set (e.g., d10-anthracene, d10-fluoranthene, and d12-benz(a)anthracene) is used as surrogate (recovery) compounds during later analysis of field-deployed PE. Finally, compounds such as d10-acenaphthene, d14-*m*-terphenyl, and d12-perylene can be used as injection standards. Similar sets of labeled compounds should be used for other compound classes (see Appendix 1). Note: if PE samples are eventually to be analyzed at a contract laboratory, PRC choices must be made so as not to conflict with recovery and injection standards used by that laboratory.

7.2.2 As subsequent analysis (e.g., GCMS) is best achieved with both PRCs and target HOCs present at like concentrations in the PE extracts, the optimal concentration level of the PRC loaded into the PE is dependent on the environment in which the PE is to be deployed. For example, if a target HOC is expected to occur in the water or pore water near 1 ng/L levels, one can use that compound's LDPE-water partition coefficient (e.g., Fernandez et al., 2009; Lohmann, 2012) to estimate the expected levels in the PE after deployment:

$$\text{Concentration in PE (ng/kg)} \sim K_{LDPE\text{-}water} * \text{concentration in (pore)water (ng/L)}$$

So if the $K_{LDPE\text{-}water}$ for the target HOC of interest is 10^5 (L/kg), then the concentration of the target HOC in the PE will approach 100 ug/kg. Based on this estimate, the PRCs are loaded into the PE at similar concentrations. Appendix 2 shows a typical calculation used to design a PRC-containing MeOH:H_2O solution of PCBs suited for causing an 0.82 g strip of PE to acquire about 100 ug of each PRC per kg of PE (equivalent to 100 ng/g PE).

7.2.3 Aqueous PRC Loading: A solvent-cleaned and dried glass container is filled with ultrapure water that has been spiked with known concentrations of PRCs (e.g., using calculations like those shown in Appendix 2). A known mass of pre-cleaned PE is then added and weighted to insure complete PE submersion. The vessel is agitated to remove any air pockets adhering to the submerged PE. Equilibration times vary for different PRC/PE thickness combinations and the PE-water phase ratio. For PAHs and PCBs, use at least 30 days to insure homogeneous distributions of the PRCs throughout the entire thickness of the PE film unless faster equilibration has been confirmed. Confirmation can be done by time course measures of PRC concentrations in the PE or by showing that concentrations of PRCs are the same for films of different thicknesses, but the same masses. Generally, PE is stored in the PRC solution until it is to be deployed.

7.2.4 Methanol-Aided PRC Loading: A solvent-cleaned and dried glass container is filled with an 80:20 mixture of pesticide grade methanol and ultrapure water that has been spiked with known concentrations of PRCs (e.g., see calculations in Appendix 2). A known mass of pre-cleaned PE is then added and weighted to insure complete submersion. The vessel should be agitated to remove any air pockets adhering to the submerged PE. Equilibration times vary for different PRC/PE thickness combinations and the PE-solvent phase ratio, but typically this step is completed within 7 days since methanol swells the PE and thereby speeds PRC diffusion into the polymer sheet (Booij et al., 2002). Generally, the PE is stored in the PRC solution until shortly before it is to be deployed. Before deployment, the PRC-loaded PE is rinsed with ultrapure water, and then it is soaked in ultrapure water for 24 h to remove methanol from the PE. This methanol leaching step is repeated twice to insure complete methanol removal.

7.3 PED Assembly

7.3.1 PEDs can be pre-assembled with prepared PE strips up to a few days prior to deployment depending on the target compounds of interest.

7.3.2 FOR WATER SAMPLING WITH PE IN A STAINLESS STEEL MESH BAG. Since PE that is openly exposed in the water column has been observed to be eaten by aquatic organisms, the PE must be protected by deploying it in a mesh bag.

7.3.2.1 Cut rectangles from the mesh that are larger than the piece of PE to be deployed. Clean the mesh with methylene chloride, methanol, and water.

7.3.2.2 Wearing nitrile gloves, and using solvent-rinsed stainless steel forceps, lay a piece of the mesh on a clean surface such as an aluminum-foil covered lab bench. Remove the PE strip from its container and lay it on top of a stainless steel mesh. Place the second mesh on top. The two meshes are sealed together by folding the edges over on one another, and then sewing them together with nylon fishing line. Grommets can be added to the upper corners to facilitate mesh labeling and attachments in the field.

7.3.3 FOR SEDIMENT BED SAMPLING WITH PE IN AN ALUMINUM SHEET METAL FRAME. In order to insert the PE strips into a sediment bed, the PE must be carried by an aluminum frame (Figure 1).

7.3.3.1. Aluminum sheet metal is cut into two complementary pieces that can be bolted together such that a piece of PE sheet is held in place. After cutting, these pieces of aluminum must be washed with organic solvents (e.g., methylene chloride and methanol) and then rinsed with water.

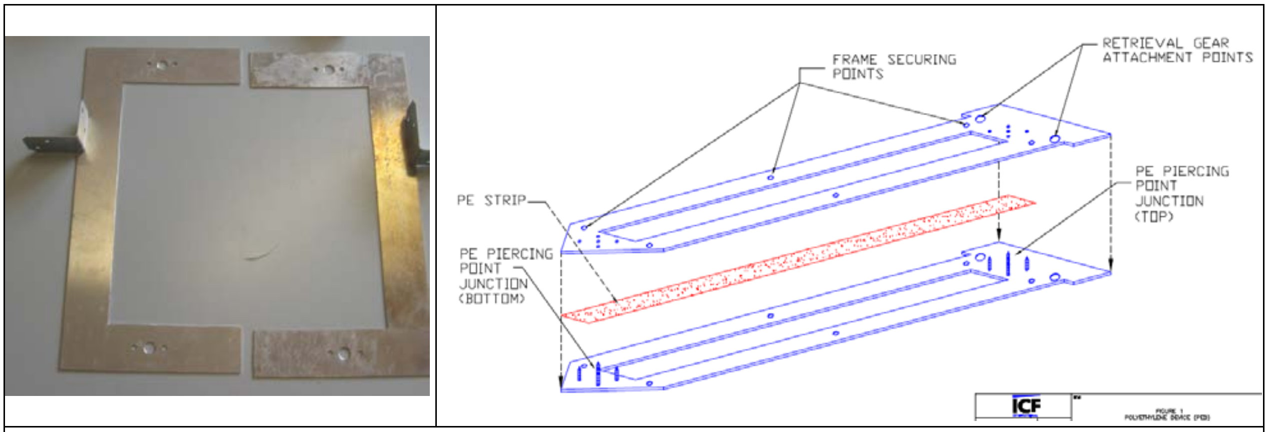

Figure 1.
(left panel) Aluminum sheet cut into two "C-shaped" pieces allowing the investigator to mount and hold ~25 cm strips of PE an open window when the two pieces are overlapped and bolted together.
(right panel) Drawing of two aluminum sheet pieces cut so as to sandwich a strip of PE and expose about 50 cm of length.

7.3.3.2 Wearing nitrile gloves, lay a piece of the aluminum frame containing the PE piercing points (sheet metal screws, see Figure 1), sharp side up, on a sheet of solvent-rinsed aluminum foil.

7.3.3.3 Using solvent-rinsed stainless steel forceps, remove the PE strip from its container and lay the strip lengthwise across both sets of PE piercing point junctions. PE strips should have been sized to fit the frame with a little extra length, allowing the investigator to cut a small strip of PE from one end to serve as sample for PRC concentration measures before the sampler is deployed. At one end of the PED frame, gently push the remainder of the PE strip onto the PE piercing points so all points penetrate the PE strip. Gently pull the other end of the PE strip over the adjacent PE piercing points, keeping the PE strip taut, and push that end of the PE strip into the PE piercing points. The tautness of the PE strip should have as minimal deflection as possible between the two PE piercing point junctions, but not too tight so that movement of the PE causes it to rip or tear. Place the other PED frame over the PED frame containing the PE strip so that each of the PE piercing point junctions meet and both PED frames are flush against each other. Secure the two frames together using the appropriate hardware (stainless steel machine screws, locking washers, and cap nuts).

7.3.3.4 Wrap the entire PED frame in solvent-rinsed aluminum foil to prevent exposure during transport and field preparation activities.

7.4 PE and PED Storage and Shipment*:*

7.4.1 Prepared PEDs in their foil envelops may be stored a few days at ambient temperature prior to deployment. Freezing or excessive heat should be avoided to minimize the likelihood of changing the polymer crystallinity. It is recommended that PEDs be hand carried or shipped in a timely fashion (Overnight or Next Day if possible) to minimize chances sampler contamination or damage.

7.4.2 If PE is to be shipped to another location for PED assembly, it is recommended that the PE strips are individually sealed in pre-cleaned glass vials that contain a little water. Freeze shipping should be avoided, but cold (refrigeration temperature) packing may be necessary depending on time of season and individual laboratory handling/quality control procedures.

8.0 QUALITY CONTROL

8.1 PRC Loading Validation: At least six representative samples of prepared PE should be collected (e.g., 6 x 10 mg pieces), extracted, and analyzed prior to field deployment to validate that the PRC concentrations are consistent with their intended loadings and these standards have uniform concentrations in a batch of PE.

8.2 Target HOC Blanks: Subsamples of prepared PE, commensurate in size with the planned environmental PE samples (e.g., 10 cm wide by 5 cm long by 25 um thick and therefore weighing about 120 mg), should be be collected, extracted, and analyzed prior to field deployment to demonstrate that other substances have not contaminated the PE which would contribute to interfering background for the target HOCs.

9.0 METHOD PERFORMANCE

9.1 PRC data, obtained from PE samples collected from >six parts of the prepared PE, should be consistent within about 10% (i.e., 100 x standard deviation / mean).

9.2 Target HOC concentrations should be undetectable in the prepared PE (e.g., < 1 ng/g PE assuming 100 mg PE subsamples).

10.0 REFERENCES

Adams, R.G., Lohmann, R., Fernandez L.A., MacFarlane, J.K., and Gschwend, P.M., Environ. Sci. & Technol. 2007, 41, 1317-1323.

Booij, K, Smedes, F., van Weerlee, E.M., Chemosphere 2002, 46, 1157-1161.

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Appendix 1 Suggested Performance Reference Compounds (PRCs), Surrogate Compounds (Recovery Standards), and Injection Standards.

A. PRCs, suitable for polycyclic aromatic hydrocarbon (PAH) determinations when Gas Chromatography-Mass Spectrometry (GCMS) is the preferred method of detection, include, but are not restricted to, deuterated PAH compounds. One subset should be used as PRCs, while reserving others for use as surrogate (recovery) compounds. Still other compounds such as terphenyl can be used as injection standards.

Targets: PAHs Method: GCMS Detection Limit ~ 100 pg / 100 mg PE			
PRCs	d10-phenanthrene	d10-pyrene	d12-chrysene
Surrogates	d10-anthracene	d10-fluoranthene	d12-benz(a)anthracene
Injection Standards	d10-acenaphthene	d14-*m*-terphenyl	d12-perylene

B. PRCs and surrogate compounds suitable for polychlorinated biphenyl (PCB) determinations when GCMS is the preferred method of detection include, but are not restricted to, ^{13}C-labeled or deuterated PCB congeners. One subset, for example including a tri-, tetra-, penta-, hexa-, and heptachloro-biphenyl, can be used as PRCs while reserving different tri-, tetra-, penta-, hexa-, and heptachloro-biphenyl congeners to serve as surrogate compounds. Still other compounds such as deuterated PAHs or rare PCBs (not contained in Aroclor/Clophan mixtures such as: PCB-39, PCB-55, PCB-104, PCB-150 and PCB-188) can be used as injection standards.

Targets: PCBs Method: GCMS Detection Limit ~ 100 pg / 100 mg PE						
PRCs	^{13}C PCB-28	^{13}C PCB-52	^{13}C PCB-101	^{13}C PCB-153	^{13}C PCB-180	
Surrogates	^{13}C PCB-19	d$_6$ PCB-77	^{13}C PCB-105	^{13}C PCB-167	^{13}C PCB-170	^{13}C PCB-194
Injection Standards	d17-39	d22-104	d34-55	d40-150	d52-188	

C. When analyzing for organochlorine pesticides such as DDT using GCMS, ^{13}C labeled compounds can serve as PRCs and surrogate standards. Since DDT has been seen to degrade to form DDE or DDD in certain situations, one should use the 4,4'- isomer of DDT and the 2,4'-isomers of DDE and DDD as PRCs to allow appearance of ^{13}C-labelled 4,4'-DDE of 4,4'-DDD to be interpreted as arising from reaction of the DDT PRC during the deployment. Deuterated or ^{13}C labeled PCBs can be used as surrogate (recovery) and injection standards.

Targets: DDTs Method: GCMS Detection Limit ~ 200 pg / 100 mg PE			
PRCs	^{13}C 2,4'-DDE	^{13}C 2,4'-DDD	^{13}C 4,4'-DDT
Surrogates	^{13}C-PCB111	^{13}C-PCB153	^{13}C 2,4'-DDT
Injection Standards	d6 PCB 77	^{13}C PCB 105	^{13}C PCB 167

Appendix 2. Example of spreadsheet used to design solution needed to impregnate PE with Performance Reference Compounds (PRCs) for PCB sampling. The leftmost section uses data from Booij et al. (2002) to establish a correlation between log K(polyethylene-80:20 MeOH:H2O) values and log K_{ow} values from Hawker and Connell (1988). With this relationship, the second section shows is use to estimate the PE-MeOH:H2O partition coefficients for PRCs of interest. Using these partition coefficients and a user-chosen mass of PE to prepare (here 0.82 g), the third section allows the user to find the PRC spiking solution concentration needed to obtain any desired initial PE concentration (here set to be 100 ng each PRC per g PE); for example, for congener 52, one needs to have 11 ng/mL of the initial 80:20 MeOH:H_2O solution to end up with about 100 ng/g PE. Finally, the right-most section uses the polyethylene-water partition coefficients (from Lohmann 2012) to check the importance of PRC losses from the PE when the MeOH is leached out in three successive steps after PRC loading. Successive calculations are described in the text below.

Example spreadsheet calculation for spiking PCBs into LDPE with 80:20 methanol-water solutions.

	Training data for estimation of Kpe-meoh:H2O		13C-labelled PRCs		use correlation to estimate	fraction in PE for PE mass (g)	0.82042	Solution concentration needed in ng/mL in order to get 100 ng/g PE		estim log Kpe-w	fraction in PE after each water soak to remove MeOH 1st leach	2nd leach	3rd leach
PCB congener	**log Kpe-meoh:water (ref 1)**	**log Kow (ref 2)**	**congener**	**log Kow (ref 2)**	**log Kpe-meoh:water(80:20)**	**with VMeOH:water (mL)**	**125**	**ng/mL MeOH:H2O**	**congener**	**log Kpew = 1.14*log Kow-1.14 (ref 3)**	**using**	**1000**	**mL water**
4	0.20	4.65	**52**	5.84	0.97	0.058		11.29	**52**	5.52	0.9966	0.9932	0.9898
29	1.05	5.6	**101**	6.38	1.26	0.107		6.15	**101**	6.13	0.9990	0.9980	0.9971
155	1.29	6.41	**153**	6.92	1.55	0.188		3.49	**153**	6.75	0.9997	0.9994	0.9991
204	1.67	7.3	**180**	7.36	1.78	0.284		2.31	**180**	7.25	0.9999	0.9998	0.9997
			28	5.67	0.88	0.048		13.75	**28**	5.32	0.9950	0.9900	0.9850
			47	5.85	0.98	0.059		11.16	**47**	5.53	0.9967	0.9934	0.9901
			111	6.76	1.46	0.160		4.10	**111**	6.57	0.9996	0.9992	0.9988
			153	6.92	1.55	0.188		3.49	**153**	6.75	0.9997	0.9994	0.9991
			178	7.14	1.66	0.233		2.82	**178**	7.00	0.9998	0.9997	0.9995

use to find following correlaltion:

log Kpe-mw(80:20) = 0.532 (+/- 0.094) * log Kow(Hawker) - 2.133 (+/- 0.572)

N = 4, R2 = 0.94, S.E. 0.18

PE mass		
number of strips	1	
PE density (g/cm3)	0.95	
PE thickenss (cm)	0.00254	for 1 mil sheet
PE length (cm)	68	
PE width (cm)	5	
length*width*thickness *number of strips*density		
mass of PE (g)	**0.82**	

references

1. Booij, K, Smedes, F., van Weerlee, E.M., Chemosphere 2002, 46, 1157-1161.
2. Hawker DW and Connell DW. 1988. Environ. Sci. Technol. 22: 382-387.
3. Lohmann, R. Environ. Sci. & Technol.; 2012, 46, 606–618.

Step 1: find/estimate PE-spiking solvent partition coefficients for PRCs in solvents of interest. Here 80:20 MeOH:H_2O values from Booij et al. (2002) are used to develop a LFER with K_{ow} values from the literature (Hawker and Connell, 1988); this relation is then used to estimate $K_{pe\text{-}meoh:h2o}$ values for other PCB congeners.

Step 2: choose the size of PE needed for the sampling exercise (here a single 1 mil-thick strip of 5 cm width and 68 cm length) and solve for the PE mass (here 0.82 g). Also choose a vessel which is large enough in volume to fit the PE inside without extensive PE-PE surface contact, but small enough so that unacceptably expensive masses of the labeled PRCs are not used (here 125 mL ground glass stopped flask). For this PE mass and solution volume, use the PE-solution partition coefficients from step 1 to solve for the fractions of each PRC that will be in the PE at equilibrium using:

$$\text{fraction in PE} = 1 - (1 / (1+\text{Mass}_{pe}*K_{pe\text{-}solution}/\text{Volume}_{solution}))$$

(e.g., 5.8% for congener #52)

Step 3. solve for spiking solution concentrations of PRCs that result in desired PRC loadings in the PE (here 100 ng/g_{PE}) using:

$$C_{initial\ spiking\ solution} = C_{desired\ in\ PE} * \text{Mass}_{pe} / \text{fraction in PE} / \text{Volume}_{solution}$$

(e.g., here find need about 11.3 ng congener #52 per mL to achieve 100 ng/g PE; this is concentration of the spiking solution that the investigator must make up to prepare PE for subsequent sampling at sites where it is expected that the (pore)water will cause the PE to accumulate about 10 to 100 ng of target PCBs/g_{PE}).

Step 4. PE is stored in the PRC loading solution until shortly before passive sampling use.

Step 5. if spiking solutions that contain organic cosolvents like MeOH were used, this MeOH must be leached out of the PE before it can be used for passive sampling. To insure that MeOH leaching will not substantially change PRC loading, calculate whether substantial fractions of the PRCs will be lost in subsequent steps required to leach the co-solvent from the PE. Since the leaching steps involve use of H_2O, use the PE-water partition coefficients; for PCBs, these are derived from a LFER found in the review by Lohmann (2012). With these values, we can solve for the fractional losses of individual PRCs to the leach water (assumes negligible MeOH builds up in the leach water) contained in 1000 mL ground glass stoppered flasks, using:

$$\text{fraction remaining in PE after a single leach step} = 1 - (1 / (1+K_{pe\text{-}H2O}*\text{Mass}_{pe} / \text{Volume}_{H2O}))$$

(e.g., in this case for congener #52, one finds 99.66% of the PRC remains in the PE after the first leach. Two additional leaches lower this to 99.32% and 98.98%, respectively. More hydrophobic congeners are leached even less.)

Attachment D-2

Standard Operating Procedure (SOP)
Lower Duwamish Waterway Clamming Area Sediment Compositing, Homogenization, and Aliquoting

METHOD DESCRIPTION

This SOP provides instruction on the methods and equipment required to composite, homogenize, and aliquot clamming area sediment in the laboratory. Three composite samples will be created according to the compositing memorandum as discussed in Section 4.1.3.1 of the Surface Sediment Quality Assurance Project Plan (QAPP). The accompanying QAPP details the methods for sediment sample collection, transport, and storage, as well as methods for chemical analyses.

EQUIPMENT

- Drill with stainless steel paddle
- Stainless steel pot, bowls, spoons, and measuring scoops
- Alconox
- Laboratory grade deionized (DI) water
- Camera
- Glass or stainless steel measuring cup
- 18 x 26 in. stainless steel baking trays (modified with evenly-spaced stainless steel screws along the rim to provide frame for demarcation of equal grids)
- Braided-nylon mason twine
- Top loading balance (readability = 0.1 g)
- Aliquot collection form
- 8-oz. wide-mouth glass jars
- 16-oz. wide-mouth plastic jars
- Kimwipes

PERSONAL PROTECTIVE EQUIPMENT

- Nitrile gloves
- Long pants
- Closed-toe shoes
- Safety glasses
- Lab coat

SAMPLE COMPOSITING AND HOMOGENIZATION

Clamming area sediment will be composited and homogenized according to the following steps:

1. Clean stainless steel spoons, bowls, pot, and mixing paddle with Alconox and rinse with DI water.
2. Retrieve field samples from the refrigerator. Check sample IDs and organize samples into three compositing groups as listed in the compositing memorandum. Return samples for the composites not being processed to the refrigerator.
3. Transfer the contents of one 4-oz. jar into a stainless steel mixing bowl. Use a stainless steel spoon to help transfer sediment to the bowl including scraping sediment from the jar. Using the spoon, locate any rocks or pieces of organic matter (e.g., wood debris, shells) larger than approximately 5 mm and remove them from the sample. Scrape sediment off the surface of large pieces as much as possible prior to removal. Pour or spoon the contents of the mixing bowl into a large stainless steel pot.
4. Repeat step 3 for the remaining 4-oz. jars included in the composite. Use a spoon to scrape residual sediment from the bowl into the pot.
5. Using a drill with a stainless steel paddle bit, blend the contents of the pot for at least 20 minutes. Scrape the sides of the pot with a stainless steel spoon during blending to ensure that all sediment is thoroughly mixed. If a uniform color and texture is not achieved after 20 minutes, continue blending as long as needed and document if the sample was blended for longer than 20 minutes. Homogenization will be complete when the sediment is visually uniform in color and consistency.
6. Photograph homogenized sediment.
7. Repeat steps 3-6 for the second and third composites.

COLLECTION OF ALIQUOTS FOR CHEMICAL ANALYSIS

Aliquots of homogenized sediment will be collected in jars for chemical analyses according to the following steps:

1) Prepare materials:
    a) Clean two 18 x 26 in. stainless steel baking trays with Alconox and rinse with DI water and dry. These trays will have evenly-spaced holes along the rim with screws that will be used to create a 30-square grid (i.e., 15 squares per tray) with string (Figure 1).

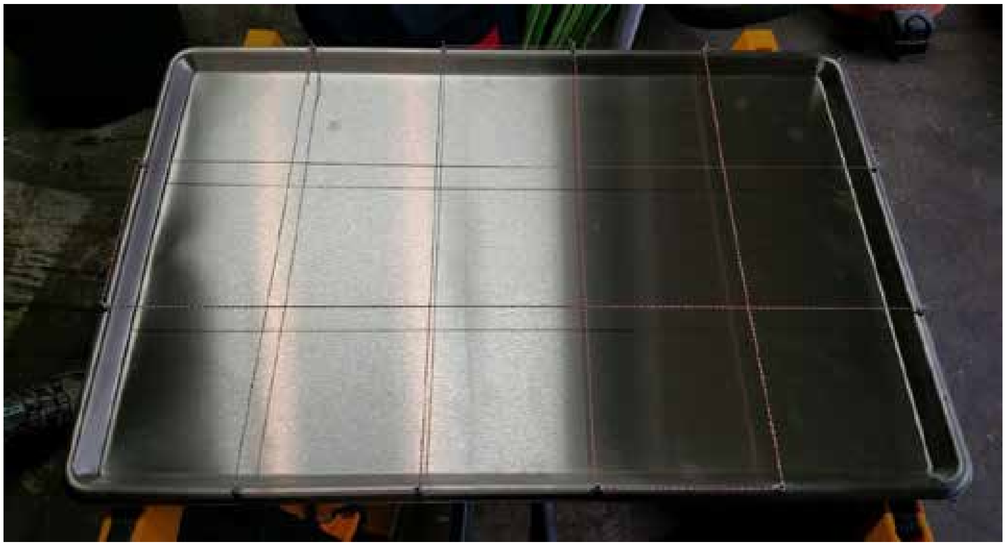

Figure 1. Baking tray with 15 grids

   b) Create grid labels adjacent to the baking trays using duct tape or bench liner to mark each square with a unique identifier (e.g., A1 corresponds to the first grid square and F5 corresponds to the last grid square).

   c) Clean stainless steel/glass spoons, scoops, measuring cups, and bowls with Alconox and rinse with DI water and dry.

   d) Label sample jars with composite sample IDs according to the QAPP.

2) Immediately after homogenizing the sediment, use a glass or stainless steel measuring cup to transfer the entire contents of the mixing pot in approximately equal masses onto two stainless steel baking trays. The aliquots collected in the measuring cup will be weighed to ensure that the sediment is evenly distributed between trays (total masses within 5% of each other). Scrape residual sediment from the pot and evenly distribute the sediment in each tray using a large stainless steel spoon.

3) Place string around the screws on the rim of the baking trays to create a 15-square grid above the surface of the sediment in each tray.

4) Document the composite sample ID, date, and time on the aliquot collection form.

5) Collect aliquots of sediment from each grid square:

   a) Tare sample jar on the balance.

   b) Based on the sample mass specified in Table 1, use an appropriately-sized square stainless steel measuring spoon to collect an aliquot of sediment from a random location within the first square of the grid that has not been previously sampled. The scoop will equally sample the full depth of sediment in the tray (e.g., a vertical aliquot will be collected evenly from the surface to the bottom).

c) Transfer the aliquot into the jar and weigh. Ensure that the aliquot mass falls within the range specified in Table 1. If the correct mass of sediment is not achieved, the sub-sampling procedure will be re-started using a clean jar. The sediment in the original jar will be disposed as laboratory waste.

d) If there is excess sediment on the scoop, rinse the scoop with DI water and dry with a Kimwipe before collecting the next subsample.

e) Check the appropriate box on the aliquot collection form to document which square was sub-sampled.

f) Repeat steps 5b-e for the remaining 29 squares.

Table 1. Sediment mass required for each aliquot by analytical jar

Lab	Analyte	Required Analytical Mass (g ww)	Jar Size	Target Mass (g ww)	Mass (and Range) of Acceptable Mass per Aliquot (g ww)
ARI	Grain size	600	16-oz. jar	600	20 (18–22)
ARI	TOC	6	8-oz. jar	90	3 (2–4)
	Percent solids	45			
	Metals (arsenic)	3			
ARI	cPAHs	60	8-oz. jar	240	8 (7–9)
	Toxaphene	75			
	PCB Aroclors	75			
Axys	Dioxins/furans	40	8-oz. jar	90	3 (2–4)
ARI	Archive	na	8-oz. jar	240	8 (7–9)

ARI – Analytical Resources, Inc.
Axys – Axys Analytical Services Ltd.
cPAH – carcinogenic polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TOC – total organic carbon
ww – wet weight

6) Repeat step 5 for the remaining sample jars for the composite. Collect each aliquot from a different random location within each grid.

7) Repeat steps 1-6 for the remaining two composites.

8) Five sample jars will be filled for each of the three composite samples. One composite will be selected for replicate analysis, this composite will be subsampled and analyzed for cPAHs in triplicate to assess variability. For this composite, two additional aliquots per grid will be collected in order to fill two additional 8-oz jars.

The procedure described above assumes the homogenized sediment is sufficiently thick to show where previous subsamples have been collected within each grid. In the event that a sediment composite contains enough liquid that previous subsamples are not expected to be visible, EPA will be contacted to discuss how to divide and subsample the composite.

QUALITY ASSURANCE AND QUALITY CONTROL SAMPLES

One sample will be selected for triplicate subsampling and analysis for PAHs in order to assess the variability of the composite samples.

DATA MANAGEMENT

All data will be recorded immediately, legibly, and in ink on the appropriate benchsheets. Any recording mistakes will be struck out with a single line and initialed and dated by the analyst. Hard copies of completed forms will be compiled and stored. Forms will also be scanned electronically and electronic copies will be submitted to EPA as part of the data report.

WASTE DISPOSAL

Waste generated during this procedure, including remaining sediment from the composite samples, will be disposed appropriately per laboratory procedures.

APPENDIX E. FIELD NOTES FROM RECONNAISSANCE

This appendix presents a summary of notes from field reconnaissance of uncharacterized exposed bank areas and selected outfalls with potential sampleability issues. This reconnaissance was performed on August 31, September 1, and September 25, 2017.

Table E-1. Uncharacterized exposed bank areas surveyed

Exposed Bank Area (RM)	Field Reconnaissance Notes	Select Photos
0.6–0.7 E	· Area is mostly exposed mud with some patches of vegetation. · Large exposed area exists for potential sampling. · Riprap exists around south area of bank.	
0.9–1.0 W	· North section has large exposed area. · South section has riprap but also an exposed area in the middle. · Cove in south area—difficult to see entire area from boat but may be sampleable. · Top portion of bank is steep, so may need to target low tide to access bank from river.	 

Exposed Bank Area (RM)	Field Reconnaissance Notes	Select Photos
2.0–2.2 W	- Bank is behind structure for 1st Avenue bridge. - Area was accessed from the south; boat access from north side of bridge seems difficult. - Small area of riprap exists on north bank area. - Most of bank area appears exposed and sampleable. - Some patches of vegetation exist. - Crew was unable to access inlet by boat.	 
2.5–2.7 W	- Two ramp structures, a catwalk, and a floating dock exist. - There appear to be two sampleable areas: one may not be accessible by boat and the other is adjacent to the southern ramp structure.	 

Exposed Bank Area (RM)	Field Reconnaissance Notes	Select Photos
3.0–3.1 W	- Exposed beach area (Duwamish Waterway Park) is sampleable.	
4.6–5.0 W	- Reeds exist, especially at north end. - Large amounts of vegetation exist. - Some exposed areas exist throughout and in northern inlet. - Southern portion of this area is not visible due to fishing boats/kayaks and bridge over river.	  

Exposed Bank Area (RM)	Field Reconnaissance Notes	Select Photos
4.7 E	· Lots of fisher boating activity occurs. · Riprap exists. · Slope is steep. · Dense vegetation exists. · Area did not look to be sampleable, but it was difficult to get close by boat because of fisher boating activities.	

Table E-2. Select outfalls surveyed

Outfall	Location (approx. RM)	Field Reconnaissance Notes	Select Photos
2503	2.0 E	· Team was unable to locate outfall, which was described as being at the head of a ditch. · Shoreline is armored with riprap and concrete slabs and has areas of dense vegetation.	
SCS Refd Services	2.1 E	· Team was unable to see outfall; it was likely under a structure. · A building, floating boathouse, and wooden pier structure line the shoreline, which is armored with wood piles and riprap. · The Muckleshoot Tribe fishing boats are tied up to the wooden pier.	 

Outfall	Location (approx. RM)	Field Reconnaissance Notes	Select Photos
8134	0.0 W	- Team was unable to see outfall; it is likely under the pier structure or behind the area where a barge was being loaded during the reconnaissance. - Shoreline is armored with riprap.	
2157	0.4 W	- Team was unable to see outfall; it was likely either under the dock or behind barges.	
2226 (Herring's House)	0.5 W	- There is a creek/inlet in this area that connects a lagoon to the river. - The creek was observed to be at least partially armored with riprap, but may be sampleable by hand. - Shoreline area north of creek/inlet is covered by a wooden pier.	  

Outfall	Location (approx. RM)	Field Reconnaissance Notes	Select Photos
2220	1.8 W	· Outfall is at edge of over-water structure. · Overhead cable exists in vicinity of outfall. · Riprap exists on bank in vicinity of outfall.	
2114	2.4 W	· Team was unable to see outfall because of boats and barges.	
2113	2.6 W	· Barges are present in vicinity of outfall. · It is difficult to tell where the outfall is located from boat; there appears to be an outfall just south of the blue catwalk and another outfall in the retaining wall just south of the small floating dock. · Riprap is present on slope but does not appear to be enough to necessarily impede sampling. · Of the two observed outfalls in this area, the northern outfall is likely accessible by boat and the southern outfall may need to be sampled by land.	 
2109 and 2110	2.9 W	· Team observed three outfalls in the vicinity: the northern outfall is under the edge of a structure (based on maps, this may be an inactive outfall); barges are tied to the second outfall; and the southern outfall is under light vegetation. · All three outfalls appear to be sampleable, barring refusal (due to riprap/rocky substrate). · Some riprap is present on the bank.