Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

Lower Duwamish Waterway Remedial Investigation

TASK 8: PHASE 2 RI WORK PLAN
FINAL

For submittal to:

The US Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Regional Office
Bellevue, WA

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List of Acronyms

Acronym	Definition
API	Asian and Pacific Islander
ARAR	applicable or relevant and appropriate requirement
COPC	chemical of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level of SMS
CSO	combined sewer overflow
CT	central tendency
DEA	David Evans and Associates, Inc.
DL	detection limit
DMMP	Dredged Material Management Program
DQO	data quality objective
dw	dry weight
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
FS	feasibility study
GIS	geographic information system
GPS	global positioning system
HHRA	human health risk assessment
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IDW	inverse distance weighting
K_{OW}	octanol-water partitioning coefficient
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MHHW	mean higher high water
ML	maximum level in DMMP
MLLW	mean lower low water
NMFS	National Marine Fisheries Service
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PRA	probabilistic risk assessment
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control

Acronym	Definition
QAPP	Quality Assurance Project Plan
QC	quality control
RBC	risk-based concentration
RBG	risk-based goal
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
ROC	receptor of concern
SL	screening level in DMMP
SMS	Washington State Sediment Management Standards
SQS	sediment quality standards of SMS
SVOC	semivolatile organic compound
TAT	turnaround-time
TBT	tributyltin
TEF	toxic equivalency factor
TEQ	toxic equivalency quotient
TOC	total organic carbon
TRV	toxicity reference value
USACE	US Army Corps of Engineers
VOC	volatile organic compound
WSOU	Waterway Sediment Operable Unit (Harbor Island)
ww	wet weight

Executive Summary

This work plan presents the approach for the Phase 2 remedial investigation (RI) being conducted for the Lower Duwamish Waterway (LDW) by the Lower Duwamish Waterway Group (LDWG) as part of the LDW remedial investigation and feasibility study (RI/FS). The Phase 2 RI will include collection of additional data to fill critical data needs identified in Phase 1. This document describes the technical work to be conducted for the Phase 2 RI, including both data collection and general data analysis efforts.

The Statement of Work (SOW) for the LDW RI/FS (Windward 2000a) identified five Phase 2 tasks:

- project plans for conducting field studies (Task 9)
- field studies (Task 10)
- baseline and residual risk assessments (Task 11)
- Phase 2 RI report (Task 12)
- FS work plan (Task 13)

The project plans for conducting field studies (Task 9) will be in the form of Quality Assurance Project Plans (QAPPs). One QAPP will be prepared for each field study to be conducted in Phase 2. This work plan describes the objectives and background, and the general study design, sampling methods, and analytical methods for ten separate field studies identified below.

- juvenile chinook salmon tissue sampling and chemical analyses
- clam, crab, and shrimp survey
- bathymetry
- groundwater seep survey and chemical analyses
- benthic invertebrate community characterization, including tissue and sediment sampling and chemical analyses
- fish and crab tissue sampling and chemical analyses
- sediment transport study
- surface sediment sampling, chemical analyses, and toxicity testing
- porewater sampling and chemical analyses
- subsurface sediment sampling and chemical analyses

In addition to these ten field studies, two reconnaissance surveys will be conducted in support of the risk assessments to characterize the following aspects of site use:

- sandpiper
- potential human use of shoreline access points

The approach for and results of these studies will be described in technical memoranda submitted for review and approval by EPA and Ecology. The potential need for a rockfish site use survey will also be addressed in a technical memorandum, and survey methods and results will be described in technical memoranda submitted to EPA and Ecology if the survey is conducted.

LDWG, EPA, and Ecology have been meeting regularly during 2003 and early 2004 to discuss the conceptual designs for many of the studies listed above. The level of detail in the description of each study reflects the level of discussion and agreement on approaches to address data needs. Those studies with more detailed study designs reflect the results of specific meetings devoted to working through technical approaches. Those with less detail represent topics that received little or no discussion among the parties. This work plan provides the objectives and background for each study, the conceptual study designs, general technical approach, and approximate level of effort that will apply to the various Phase 2 field studies. The numbers of samples described in this work plan are approximate, and the specific locations to be sampled are preliminary and subject to modification. Detailed study designs and methods will be finalized in the QAPPs or technical memoranda for each study.

Table ES-1 briefly describes the data needs addressed, the scope, and the key study design considerations for each of the ten field studies listed above that will have separate QAPPs, and for the three reconnaissance surveys for which technical memoranda will be prepared presenting the approach and results of the survey.

Table ES-1. Summary of field studies

Field Study	Data Need	Summary	Deliverable; Work Plan Section
Juvenile chinook salmon tissue collection and chemical analyses	Exposure assessment for juvenile chinook salmon and wildlife potentially preying on these juvenile fish	Wild and hatchery fish collection in spring 2003 at upstream and two LDW locations Chemical analysis of whole body and stomach content composite samples	Juvenile chinook salmon QAPP; Section 3.1.1
Clam, crab, and shrimp survey	Clam, crab, and shrimp site use and harvest sustainability information; results will inform tissue sampling design	Quarterly surveys of crabs and shrimp throughout the LDW for a single year, beginning summer 2003 Single intertidal clam survey in summer 2003	Clam, crab, and shrimp survey QAPP; Section 3.1.2

FIELD STUDY	DATA NEED	SUMMARY	DELIVERABLE; WORK PLAN SECTION
Bathymetric survey	Provides information for interpretation of sediment transport; habitat characterization; results will inform sediment chemistry, sediment transport, and tissue sampling designs	Single survey in 2003 covering entire LDW	Bathymetry survey QAPP; Section 3.1.3
Seep survey and seep water sampling and chemical analyses	Source characterization below mean higher high water (MHHW); ecological exposure assessment; results may inform sediment sampling design	Site survey and source identification information coupled to target worst-case locations for seep water collection and analysis	Seep survey and chemistry QAPP; Section 3.1.4
Benthic invertebrate community characterization and chemical analyses	Provides qualitative information regarding site use and exposure information for benthic invertebrates and species that prey on them; results will inform surface sediment sampling design	Benthic community samples to qualitatively characterize community composition Sediment collected synoptically with benthic invertebrate tissue sampling, including separate samples for market basket[a], clams, and gastropods	Benthic invertebrate QAPP; Section 3.1.5
Fish and crab tissue sampling and chemical analyses	Exposure assessment for human health, fish, shellfish, and wildlife	Collection and chemical analyses of tissue composite samples (several species) based on risk assessment data needs, species home range, sediment contamination pattern, and seasonal and sampling considerations	Fish and crab tissue QAPP; Section 3.1.6
Sediment transport study	Sediment erosion and deposition potential for sediment transport analysis; results will inform subsurface sediment sampling design	Collection of sediment erosion and deposition data	Sediment transport QAPP; Section 3.1.7
Surface sediment sampling, chemical analyses, and toxicity testing	Nature and extent characterization, ecological and human health exposure assessment, effects assessment for benthic invertebrates (toxicity testing); results will inform subsurface sampling design	Collection and chemical analyses of sediment from locations based on spatial coverage, existing data, habitat, and source information. Tiered approach to toxicity testing at locations based on existing data, location, and sediment quality standards and guidelines[b]	Surface sediment QAPP; Section 3.1.8

Field Study	Data Need	Summary	Deliverable; Work Plan Section
Porewater sampling and chemical analyses	Exposure assessment for benthic invertebrates	Collection and analyses of porewater samples based on a tiered process using source information to target worst-case areas for groundwater contaminated with volatile organic compounds (VOCs)	Porewater QAPP; Section 3.1.9
Subsurface sediment sampling and chemical analyses	Nature and extent characterization	Collection and chemical analyses of subsurface sediment samples based on existing chemistry data, source information and erosion potential	Subsurface sediment QAPP; Section 3.1.10
Sandpiper site use and habitat survey	Sandpiper exposure assessment; results will inform surface sediment sampling design	Assessment of existing bird site use surveys coupled with a qualitative field reconnaissance survey to assess site use and habitat availability	Sandpiper site use and habitat technical memorandum; Section 3.3.1.2
Rockfish survey for potential habitat use	Rockfish and potentially wildlife and human health exposure assessments; results will inform fish sampling design	Qualitative survey may be conducted by divers at targeted areas in the LDW considered to have sufficient habitat quality for rockfish to assess rockfish abundance and distribution. Rockfish tissue samples may be analyzed, depending on extent of site use.	Rockfish survey technical memorandum; Section 3.3.1.2
Survey of potential human use of shoreline access points	Exposure assessment for humans using intertidal areas; results will inform intertidal surface sediment sampling design	Qualitative reconnaissance survey to characterize public and non-public shoreline access points, focusing on potential intertidal use areas	Human shoreline access technical memorandum; Section 3.3.2.1

Note: Specific numbers of samples and sampling locations will be documented in QAPPs. Preliminary estimates are provided in various sections of this work plan.

[a] In the market basket approach, all benthic invertebrates (except larger bivalves and crustaceans) collected at a single targeted collection location are combined into a single composite sample.

[b] Additional toxicity test locations may be identified based on the results of the Tier 1 toxicity testing and chemical data from sediment locations not tested for toxicity during Tier 1.

The first three QAPPs (bathymetry; clam, crab, and shrimp abundance; and collection and chemical analyses of juvenile chinook salmon tissue) have been submitted to EPA and Ecology and approved. Work on these Phase 2 field studies has been completed (i.e., bathymetry, clam, and juvenile chinook) or is currently underway (crab and shrimp). These studies are being conducted prior to work plan approval because LDWG, EPA, and Ecology agree that the data are needed for the Phase 2 RI, and the results of these studies will inform the design of future planned studies. A summary of samples to be collected, by matrix, is presented in Table ES-2.

Table ES-2. Summary of samples to be collected for chemical analyses as part of Phase 2

Matrix	Section in Work Plan
Sediment	
Composite samples of surface sediment associated with benthic invertebrate tissue collection	Section 3.1.5
Grab samples of surface sediment	Section 3.1.8
Core samples of subsurface sediment	Section 3.1.10
Composite tissue samples	
Juvenile chinook salmon	Section 3.1.1
Benthic invertebrate market basket samples	Section 3.1.5
Clams	Section 3.1.5
Gastropods (if feasible)	Section 3.1.5
Crabs	Section 3.1.6
English sole	Section 3.1.6
Perch	Section 3.1.6
Sculpin	Section 3.1.6
Rockfish (if adults are sufficiently abundant)	Sections 3.1.6 and 3.3.1.2
Water	
Seep water	Section 3.1.4
Sediment porewater	Section 3.1.9

Task 10 of the Phase 2 RI includes both the conduct of the field studies and the preparation of data reports for each field study. Data reports will be prepared once the data have been validated. The data reports will include brief descriptions of the study design, methods, and summaries of all data collected, but will not include any data interpretation.

Task 11 is the baseline ecological and human health risk assessments (ERA and HHRA). The technical approach for these risk assessments will be similar to the approach used in the Phase 1 risk assessments. The additional data collected in Phase 2 studies, existing Phase 1 data, and data collected since the completion of Phase 1 that meet EPA's quality assurance requirements will be incorporated. The Phase 2 risk assessments will also include estimates of residual risks that would remain after completion of the early cleanup actions that are currently planned or underway. This work plan describes several other areas in which the Phase 2 risk assessments differ from those conducted in Phase 1, as shown in Table ES-3.

Table ES-3. Key differences in Phase 2 risk assessments compared to Phase 1

ECOLOGICAL RISK ASSESSMENT	RATIONALE FOR DIFFERENCE
Use of Pacific staghorn sculpin rather than bull trout [a] to represent piscivorous fish[b]	Sculpin can be collected in Phase 2 because they are not listed under the Endangered Species Act. Sculpin are expected to have greater site use and greater sediment exposure than bull trout.
Use of osprey rather than bald eagle [a] to represent piscivorous birds	Osprey have greater site fidelity to the LDW during their residence, have a higher ingestion rate-to-body weight ratio, and egg data will likely be available through a recent USGS study.
Use of LDW surface water chemistry data in the wildlife exposure estimates	Water exposure was assessed but not included in exposure estimates in Phase 1; it will be added for completeness in Phase 2.
Discussion of results of the water quality assessment for metals and PAHs in the fish risk characterization	Phase 1 provided a summary of results of the King County Water Quality Assessment, but these results were not discussed in the risk characterization section of the ERA. Water chemistry data and assessment results will be discussed in the Phase 2 risk characterization to acknowledge the water pathway for chemicals of potential concern (COPCs) addressed through a dietary pathway [c] (i.e., metals [except mercury] and PAHs)
Presentation of the range of relevant toxicity reference values in the risk characterization	Use of these approaches will provide risk managers with a range of risk estimates that more realistically portray site conditions compared to a single point estimate
Use of probabilistic risk analysis techniques in exposure estimates for fish and wildlife	
Assessment of sediment-based toxicity reference values for fish	Sediment-based toxicity reference values will be considered in Phase 2 because one of the Phase 2 RI goals is to develop risk-based goals for sediment.
Use of direct effects data (i.e., toxicity tests) for benthic invertebrate risk characterization	Sediment toxicity test data collected in Phase 2 will allow adverse effects to be measured, rather than predicted, as was done in Phase 1
Incorporation of PCB congener data to assess risk from dioxin-like PCBs for certain ecological receptors	Risks associated with dioxin-like PCBs were not quantified in Phase 1 because PCB congener data with sufficiently low detection limits are not available; such data will be collected in Phase 2
Assessment of background concentrations of dioxins/furans and arsenic	Samples from background areas will be compared to those collected within the LDW. For arsenic, incremental risks will be assessed. For dioxin/furans, the need for quantitative assessment will be determined.

HUMAN HEALTH RISK ASSESSMENT	RATIONALE FOR DIFFERENCE
Separate COPC identification in fish and invertebrates tissues	Bioaccumulation patterns may differ between fish and invertebrates
Alternative statistical methods for spatial analysis of intertidal exposure point concentrations (EPCs) based on potential human use	Intertidal sediment chemistry data used in Phase 1 were not collected for human use considerations
Potential use of alternative fish species in market basket approach for seafood consumption scenarios	Seafood consumers may not limit their intake to a small group of target species
Incorporation of clam tissue chemistry data	Phase 1 risk assessment excluded clams based on preliminary reconnaissance survey data, but Phase 2 clam survey results suggest clams may be present in harvestable numbers in some areas
Expansion of market basket approach to include whole-body samples for fish and crab	More realistic representation of exposure to potentially exposed population
Use of site-specific data on the percentage of inorganic arsenic in fish and crab tissue	Site-specific data to be collected in Phase 2 will be used in place of generic default assumptions
Incorporation of PCB congener data to assess risk from dioxin-like PCBs	Risks associated with dioxin-like PCBs were not quantified in Phase 1 because PCB congener data with sufficiently low detection limits are not available; such data will be collected in Phase 2
Potential use of probabilistic risk analysis techniques for the seafood consumption scenarios	Provides risk managers with a range of risk estimates that more realistically portray site exposures compared to a single point estimate
Assessment of background concentrations of dioxins/furans and arsenic	Samples from background areas will be compared to those collected within the LDW. For arsenic, incremental risks will be assessed. For dioxin/furans, the need for quantitative assessment will be determined based on background analysis.

[a] Although bull trout and bald eagle will not be directly assessed as Phase 2 ROCs, risks to these threatened species will be discussed in the ERA.

[b] Based on meetings with fish experts and stakeholders, an ideal representative of a piscivorous fish was not identified in the LDW. The ideal representative would be a resident fish with high site use, sufficient abundance for collection, and a 100% piscivorous diet. While fish are believed to be a more dominant prey item for bull trout than the sculpin that inhabit LDW, bull trout are also believed to have a much lower site use. Other fish species that consume fish that were considered (e.g., sand sole) are believed to have greater uncertainty in their home range than Pacific Staghorn sculpin, the selected ROC.

[c] Other COPCs will be addressed using a critical tissue residue approach which implicitly includes water exposure

Task 12 is preparation of the Phase 2 RI report. The outline of this report will be very similar to the Phase 1 RI report, but will include an additional appendix addressing risk implications associated with potential exposure to subsurface sediment. The Phase 2 RI report will also present preliminary risk-based goals (RBGs) for sediment. Phase 1 data of acceptable quality, all data collected in the Phase 2 field studies, and additional site characterization data of acceptable quality collected by others since completion of the Phase 1 RI, will be incorporated into the Phase 2 RI report.

Task 13 is the preparation of the FS work plan. Although this work plan identifies a preliminary due date for this deliverable, the technical scope of this task is not described in this document. LDWG is currently selecting a contractor to prepare the FS work plan and FS report. Once this contractor has been retained, LDWG, EPA, and Ecology will discuss the appropriate schedule for the FS work plan and FS.

This work plan also describes the relationship between the QAPPs and other Phase 2 RI deliverables, and proposes a schedule for all Phase 2 deliverables. The schedule is based on EPA and Ecology's approval of this work plan by April 12, 2004. Should that date not be met, the delivery dates for the 2004 QAPPs will also be delayed accordingly. Many of the studies are linked in such a way that a QAPP for one study can't be finalized until the results from a previous field study have been evaluated. If any QAPP approval dates proposed in this work plan are not met, subsequent studies linked to the results of the studies to be conducted under those QAPPs may be delayed by a corresponding length of time.

Many of the studies are linked, with the results of some field studies influencing overall scope and study design of other data collection efforts. For example, the results of the surface sediment and sediment transport investigations are needed to complete the study design for subsurface sediment sampling. Section 4 describes the relationships among the various field efforts and the effect of these relationships on the relative production schedule for the QAPPs.

LDWG will submit QAPPs to EPA and Ecology for review, comment, and approval based on the relationships discussed in Section 4. The first QAPPs to be submitted following approval of the Phase 2 work plan are the seep survey QAPP, the benthic invertebrate QAPP, and the fish and crab tissue QAPP (in that order). Sampling based on these QAPPs is expected to begin in 2004. The draft risk assessments and draft Phase 2 RI report will be submitted to EPA and Ecology approximately 6 and 13 months, respectively, after submittal of the porewater data report.

1.0 Introduction

The Lower Duwamish Waterway (LDW) was added to the US Environmental Protection Agency's (EPA's) National Priorities List under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, on September 13, 2001. Under Superfund regulations, EPA requires that a remedial investigation and feasibility study (RI/FS) be conducted for all listed sites. An RI identifies areas that should be remediated because they pose an unacceptable risk to human health or the environment; an FS proposes a number of alternative approaches to remediating the areas with unacceptable risk, and analyzes and compares these alternatives.

The key parties involved in the LDW RI/FS are the City of Seattle, King County, the Port of Seattle, and The Boeing Company, working together for this project as the Lower Duwamish Waterway Group (LDWG), in addition to EPA and the Washington State Department of Ecology (Ecology). These parties agreed (in an Administrative Order on Consent) to conduct the RI for the LDW in two phases. The LDW RI/FS Statement of Work (SOW) that was completed in June 2000 described eight tasks[1] associated with Phase 1 and four tasks associated with Phase 2 (described below), in addition to the FS, which was identified as Task 13 (Windward 2000a). The Phase 1 RI (Windward 2003a), which incorporated the first 6 tasks identified in the SOW, was a thorough exploration of what is already known from previous studies of the LDW, aimed at answering three questions:

- Based on existing data, what are the risks to human health and the environment from sediment-associated chemicals in the LDW?
- Are there areas within the LDW that might be candidates for early remedial action because of their relatively higher levels of risks?
- What additional information is needed to understand the nature and extent of sediment-associated chemical distributions in the LDW and to characterize risks to human health and the environment sufficiently to make final remedial decisions in the LDW?

One of the key documents produced as part of Phase 1 was the memorandum on Identification of Data Needs (Task 7). The data needs memorandum evaluated the results of the Phase 1 RI and risk assessments and developed lists of specific information necessary for completion of the risk assessments and RI for the LDW site (Windward 2003f). The data needs identified in the memorandum form the basis of

[1] The 8 Phase 1 tasks include communications (Task 1), site characterization (Task 2), risk assessment study design (Task 3), risk characterization and priority area identification (Task 4), identification of candidate areas for early action (Task 5), RI report production (Task 6), identification of data needs (Task 7), and Phase 2 RI work plan (Task 8)

the present work plan for Phase 2 (Task 8). One of the primary goals of the Phase 2 RI is to collect additional information to fill critical data gaps identified in the data needs memorandum. This work plan describes how the four Phase 2 RI tasks will be conducted, including writing project plans and conducting field studies (Tasks 9 and 10, respectively), conducting the baseline risk assessments (Task 11), and writing the Phase 2 RI report (Task 12). The field studies will be conducted in a tiered fashion whereby the results of the first studies will influence the design of subsequent studies. The tiered approach to study design is described more fully in Section 3 of this work plan. Baseline ecological and human health risk assessments (ERA and HHRA) will be conducted in Phase 2 to include newly collected data and additional technical approaches, such as probabilistic analysis, not used in the Phase 1 scoping-phase assessments. The Phase 2 risk assessments will also estimate residual risks to human health and the environment after completion of the early remedial actions.

The Phase 2 RI will address the following questions:

- Based on both existing and newly collected data, what are the risks to human health and the environment from sediment-associated chemicals in the LDW in the absence of early actions?
- Based on both existing and newly collected data, what are the residual risks to human health and the environment from sediment-associated chemicals following planned early actions?
- What risk-based goals (RBGs) are appropriate for the site?
- Do chemical concentrations in site sediments exceed RBGs?

1.1 SITE BACKGROUND

Site background and other site characteristics are described in detail in the Phase 1 RI (Windward 2003a). A brief summary of the site background and physical characteristics is provided here.

The Duwamish River originates at the confluence of the Green and Black Rivers near Tukwila, WA, then flows northwest for approximately 21 km (13 mi), bifurcating at the southern end of Harbor Island to form the East and West Waterways prior to discharging into Elliott Bay. The LDW consists of the downstream manmade portion of the Duwamish River that is maintained by the US Army Corps of Engineers (USACE) as a federal navigation channel (i.e., the reach downstream of Turning Basin 3), excluding the East and West Waterways (Weston 1999) (Figure 1-1). Although an upstream boundary of the Superfund site has not been formally defined, the reach immediately upstream of Turning Basin 3 was evaluated in the Phase 1 RI using sediment chemistry data collected up to approximately river mile (RM) 6.0.

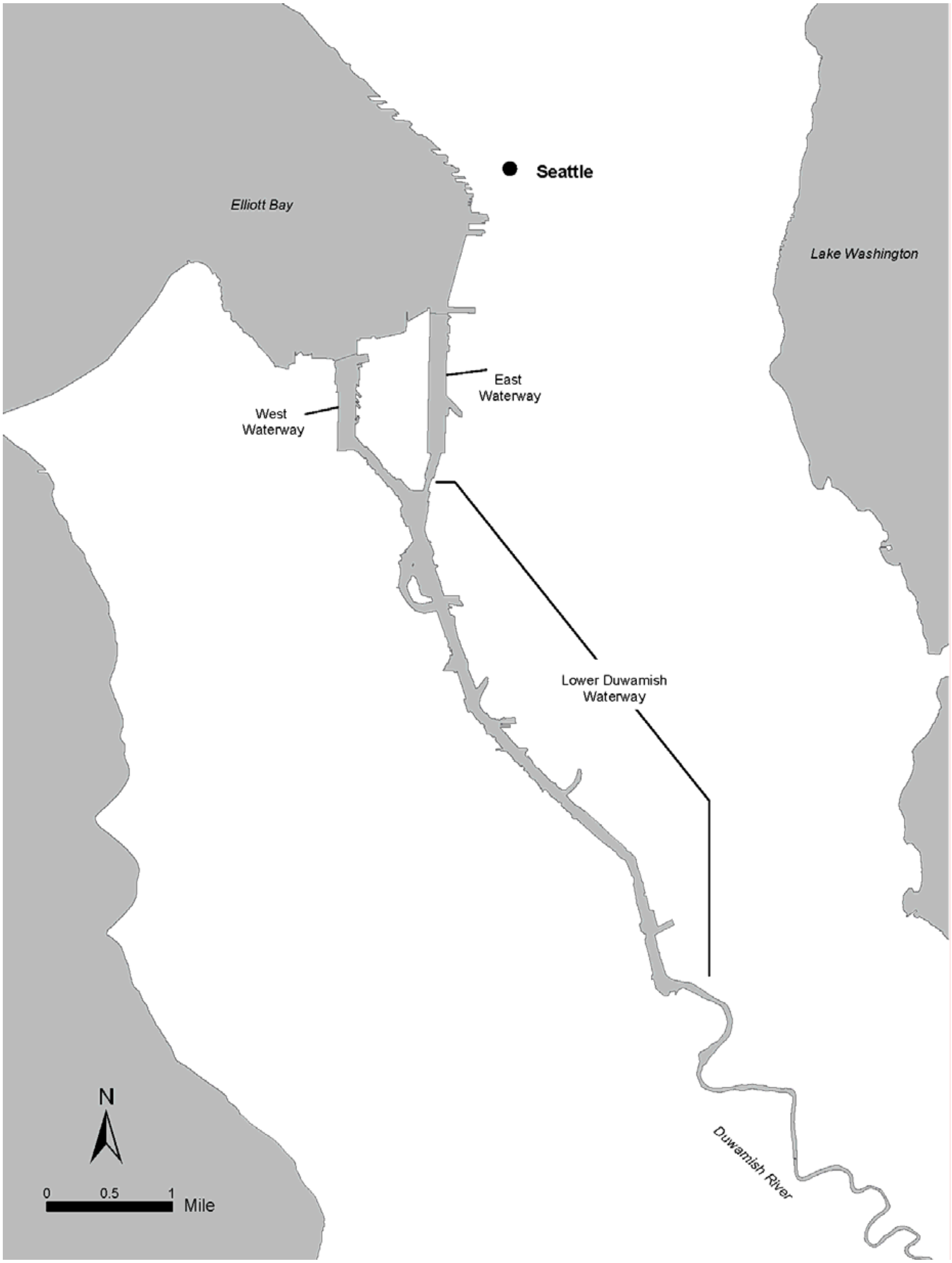

Figure 1-1. Overview of the LDW region, Seattle, WA

The shorelines along the majority of the LDW have been developed for industrial and commercial operations; the waterway serves as a major shipping route for containerized and bulk cargo. In addition, the LDW has historically received, and currently receives, discharges from industrial and municipal sources, including numerous storm drains and combined sewer overflows that discharge to the LDW.

Common shoreline features within the LDW include constructed bulkheads, piers, wharves, buildings extending over the water, and steeply sloped banks armored with riprap or other fill materials (Weston 1999). Intertidal habitats are dispersed in discontinuous patches, with the exception of Kellogg Island, the largest contiguous area of intertidal habitat remaining in the LDW (Windward 2003a).

1.2 DOCUMENT ORGANIZATION

This document is organized in accordance with EPA (1988) RI/FS guidance. Section 2 summarizes the findings presented in the Phase 1 RI. Section 3 discusses the tasks to be conducted for the Phase 2 RI. Section 4 discusses the schedule for the Phase 2 RI tasks and a list of deliverables. Section 5 consists of references cited in the work plan. Appendix A contains a summary of the data needs memo, and Appendix B contains a memorandum related to evaluating exposures of benthic invertebrates to tributyltin (TBT).

2.0 Initial Evaluation

This section provides brief summaries of the Phase 1 RI, and the Phase 1 ERA and HHRA conducted as part the Phase 1 RI (Windward 2003a). The results of the Phase 1 RI and risk assessments were used to identify data needed to complete the Phase 2 RI (Windward 2003f). These reports served as critical components in the project planning process described in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988). Table 2-1 lists project planning elements described in this EPA guidance document. As shown in this table, many of the planning elements have already been included in previous Phase 1 documents so they are only briefly summarized in this section.

Table 2-1. RI project planning elements

PLANNING ELEMENT	WHERE DOCUMENTED
Project meeting	Several planning meetings between LDWG and agencies, culminating in Statement of Work (SOW) (Windward 2000a)
Collect and analyze existing data	Phase 1 RI report (Windward 2003a)
Preliminary identification of applicable and relevant requirements (ARARs)	Phase 1 RI report (Windward 2003a)
Identify data needs	Data needs memorandum (Windward 2003f)
Design data collection program	Conceptual design described in Section 3 of this document; additional details to be provided in study-specific Quality Assurance Project Plans (QAPPs)
Develop work plan	Work plan elements were described in SOW (Windward 2000a); the remaining work plan elements are presented in this document
Health and safety protocols	Health and safety plans will be developed for all Phase 2 fieldwork
Conduct community interviews	EPA and Ecology are responsible for this portion of the project; a community involvement plan has been prepared (EPA and Ecology 2002)

2.1 PHASE 1 REMEDIAL INVESTIGATION REPORT

The Phase 1 RI report (Windward 2003a) was divided into the following topics:

- the environmental setting of the LDW
- previous environmental investigations in this area
- rules and regulations that apply to the site
- the nature and extent of chemicals of concern in environmental media and in animals that inhabit the site, including available information about possible sources of those chemicals, and the processes that affect their fate and transport within the LDW
- summaries of the ecological and human health risk assessments

The Phase 1 RI report findings are summarized briefly below. The presence of chemical contamination in the LDW has been recognized for many years, prompting numerous environmental studies. To focus on current conditions, the Phase 1 RI considered only data from investigations conducted since 1990. The primary focus of investigations of the LDW has been on sediments, although fish and invertebrate (i.e., crab, mussel, and amphipod) samples have also been collected for assessing risks to ecological and human receptors. Approximately 1,200 surface sediment samples (all but 7 samples were 10 cm or less), 230 subsurface sediment samples, and 200 fish and invertebrate tissue samples have been collected and analyzed for metals and organic compounds. In total, these data were used to address the goals of the Phase 1 investigation, as outlined in Section 1.0.

Based on the existing dataset, the Phase 1 RI concluded that the distributions of chemicals in sediment are not uniform throughout the LDW, but that higher chemical concentrations are generally found in discrete locations separated by sections of the river in which chemical concentrations are lower. The distribution patterns for chemicals in sediment indicate that candidate sites for early remedial action could be identified with a relatively high level of certainty. In addition, the existing data set was used to conduct the Phase 1 ERA and HHRA and to calculate preliminary risk estimates.

While the Phase 1 RI was not intended to identify specific sources of these chemicals, general information on potential sources was summarized. General categories of potential sources included historical land use and disposal practices, industrial or municipal releases (including both permitted and unpermitted wastewater and stormwater discharges), spills or leaks, atmospheric deposition, and waste disposal either on land or in landfills (Figure 2-1).[2] In many cases, there is reason to believe that chemicals currently found in the sediments result from historical practices dating back many years. In more recent years, there have been well-documented efforts to either eliminate or substantially reduce releases of chemicals to the LDW from multiple sources. While it is recognized that additional information both on specific sources and on sediment and chemical fate and transport will need to be assembled for the Phase 2 RI, there is sufficient information to conclude that early actions to remediate sediment in the LDW will likely result in significant reductions in contamination.

Existing data indicate that almost all sediment transported into the LDW from upstream sources is deposited in the upper reaches of the LDW near Turning Basin 3. Based on an evaluation of multiple bathymetric surveys, water depths generally are either stable or decrease with time, indicating a predominantly depositional or dynamic equilibrium environment. Transport of resuspended sediment occurs on a local scale as a result of episodic events such as propeller scour, dredging, and other erosional events. However, available data and modeling suggest that bottom currents are rarely high enough to initiate motion of bedded sediments outside the navigation channel. Available evidence thus suggests that erosion and transport of resuspended sediment is not a system-wide phenomenon. Additional work on sediment stability, fate, and transport will be conducted in Phase 2.

[2] Where practical, figures are inserted in the text following their first citation. To minimize disruption of the text flow, oversized GIS map figures are at the back of the document (hard copy) or published in a separate PDF file (electronic copy).

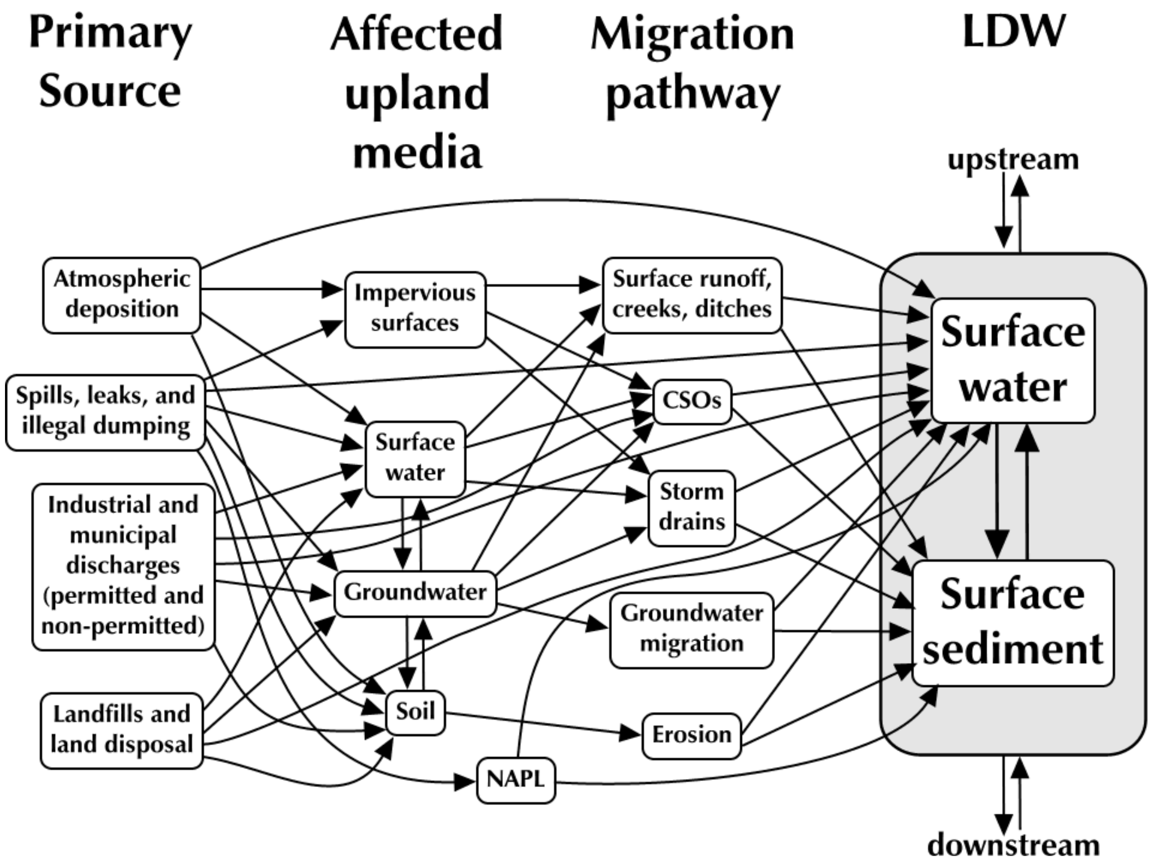

Figure 2-1. Phase 1 conceptual model of chemical sources and pathways to the LDW

Site-specific groundwater data were examined for 12 sites identified by EPA and Ecology during the Phase 1 RI. Preliminary analysis of available data in Appendix G of the Phase 1 RI report did not indicate that chemicals of concern in groundwater are accumulating in sediment nor likely posing a risk to benthic invertebrates at most sites. Four sites have associated seep data. These data indicate that chlorinated solvents have been detected at low concentrations in seeps at two of these sites (i.e., Great Western and Boeing Plant 2). The significance of these seeps in the LDW is unknown. As expected due to their low affinity to sediments and high solubility and volatility, chlorinated solvents have not been detected in sediment at any of the potential discharge zones, based on the data currently available. Metals have been detected in seeps at the Boeing Isaacson, Boeing Plant 2, and Rhône-Poulenc properties; metals in seep samples exceeded ambient water quality criteria at the latter two sites. Metals did not exceed the sediment quality standards (SQS) of the Washington State Sediment Management Standards (SMS) in sediment adjacent to Rhône-Poulenc, whereas metals did exceed the SQS in sediment adjacent to Boeing Plant 2, although likely due to fill material (FSM and Pentec 2002). The seep data, particularly at Boeing Plant 2, are difficult to interpret with respect to the likely chemical source because of additional influences (i.e., chemicals in seeps may be due to a mix of inputs from LDW water, groundwater, and sediment).

The preliminary analysis of the available groundwater data in the Phase 1 RI suggested that groundwater chemicals are unlikely to present a risk to benthic organisms, and are unlikely to pose a potential for future recontamination if sediment is remediated at locations adjacent to these sites. Additional sampling for Phase 2, as described in this work plan, will determine whether chemicals entering the LDW via groundwater are likely to result in adverse effects to the benthic community.

2.2 PHASE 1 ECOLOGICAL RISK ASSESSMENT

The Phase 1 ERA evaluated risks from sediment-associated chemicals to benthic invertebrates, fish, and wildlife species that may reside or forage in the LDW for at least a portion of their lives. Risks to rooted aquatic plants were also evaluated, although there is relatively little suitable habitat presently available within the LDW for this group. An earlier risk assessment (King County 1999c) evaluated risks to ecological receptors from chemicals in LDW surface water, and concluded that risks posed by surface water were low (see Attachment A-2 in Appendix A of the RI report—Windward 2003a). Therefore, the Phase 1 ERA focused on whether there are risks from exposure to sediment-associated chemicals in the LDW. The Phase 1 ERA did not determine whether unacceptable risks exist or whether risk management is warranted, only whether further assessment is required based on conservative exposure assumptions meant to provide protection of LDW aquatic life and wildlife.

Because it is impractical to evaluate every potentially exposed species, it is standard ERA practice to focus on representative receptor species, called receptors of concern (ROCs), that typify groups of organisms with specific exposure pathways. One objective of selecting representative ROCs is to choose species for which the risk conclusions will be protective of other species that are not explicitly evaluated. Representative ROCs selected for the Phase 1 ERA were crabs, English sole, juvenile chinook salmon, bull trout, great blue heron, spotted sandpiper, bald eagle, river otter, and harbor seal. The primary reason for selecting juvenile chinook salmon and bull trout was because they are federally protected species with the potential for exposure in the LDW. Risks to the benthic invertebrate and rooted aquatic plant communities were also evaluated.

The manner in which ROCs may be exposed to chemical stressors can be graphically represented in a conceptual site model. Separate models were derived for aquatic species (Figure 2-2) and wildlife (Figure 2-3). Exposure pathways for sediment-associated chemicals to ROCs in the LDW were designated in one of four ways: complete and significant, complete and significance unknown, complete and insignificant, or incomplete. An exposure pathway is considered complete if a chemical can travel from a source to ecological receptors and is available to the receptors via one or more exposure routes (EPA 1997a, b).

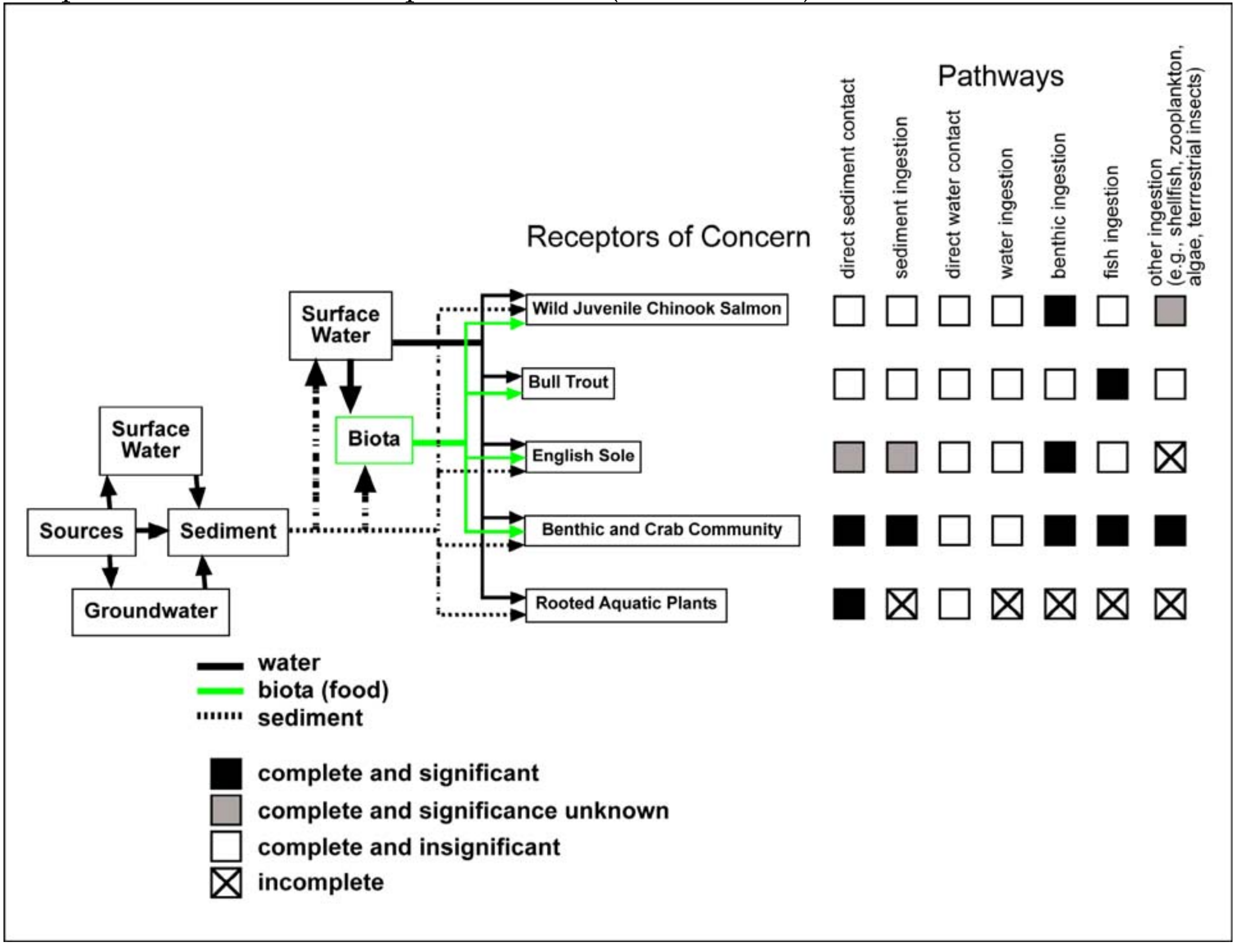

Figure 2-2. Conceptual site model for fish, benthic invertebrates, and plants in the Phase 1 ecological risk assessment

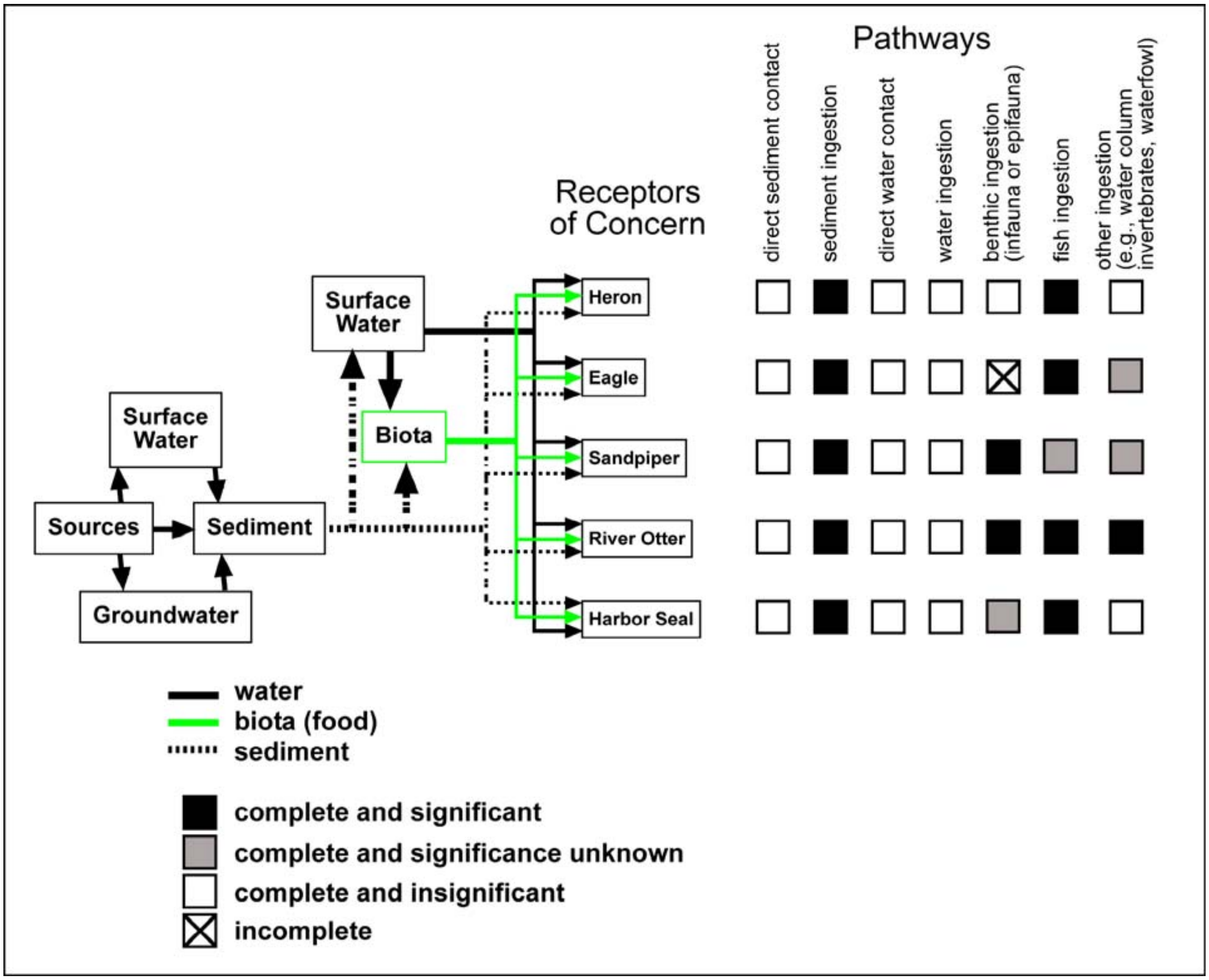

Figure 2-3. Conceptual site model for wildlife in the Phase 1 ecological risk assessment

For each representative species selected, sediment-associated chemicals of potential concern (COPCs) were identified in the first step of the assessment, the problem formulation, using existing data. An initial screen, using conservative assumptions, identified 59 COPCs for benthic invertebrates and crabs, seven COPCs for at least one fish species, seven COPCs for at least one wildlife species, and four COPCs for plants. Following the initial risk-based screen, more detailed analyses were conducted to conservatively estimate the potential exposure of each representative species to COPCs, and the risk of adverse effects resulting from exposure. Based on these analyses of existing data, the Phase 1 ERA calculated preliminary risk estimates for each of the ROC/COPC pairs and discussed uncertainty associated with these estimates. ROC/COPC pairs selected for further evaluation in Phase 2 will be based on the results of the Phase 1 ERA (Appendix A of the Phase 1 RI report – Windward

2003a) and on interpretation of data collected in Phase 2. Below is a summary of recommendations from the Phase 1 ERA.

Benthic invertebrates—All Phase 1 COPCs are recommended for further analysis in Phase 2. Risks to crabs should also be further evaluated in Phase 2, although risks appear to be low based on existing Phase 1 data, with the possible exception of arsenic.

Fish—Based on the existing data, six of the seven Phase 1 COPCs (arsenic, copper, polycyclic aromatic hydrocarbons [PAHs], mercury, tributyltin [TBT], and polychlorinated biphenyls [PCBs]) arising from the initial screen are recommended for further analysis in Phase 2 for one or more of the fish species.[3] All six of these COPCs are recommended because the exposure estimate exceeded a "no effects" level. In addition to exceeding the "no effects" level, three of the COPCs (PCBs, arsenic, and copper) exceeded an established effects level in at least one fish species. Regional and natural background issues for arsenic will be further addressed as part of Phase 2 according to EPA (EPA 2002a, b) guidance.

Wildlife—Four of the seven Phase 1 COPCs (lead, mercury, arsenic, and PCBs) arising from the initial conservative screen are recommended for further analysis in Phase 2 for at least one or more of the wildlife species.[4] However, none of the COPCs had dietary exposure estimates greater than doses associated with adverse effects to any wildlife species (i.e., all are recommended only because the exposure estimates exceeded a "no effects" level). In contrast, preliminary risk estimates of PCBs to great blue heron using egg data indicated that exposure may be occurring at levels associated with adverse effects.

Rooted aquatic plants—Of the four COPCs evaluated for plants (lead, mercury, PCBs, and zinc), concentrations in marsh sediments were less than soil concentrations associated with no effects for PCBs, but were within the low end of the range of concentrations associated with effects for lead and zinc.[5] Due to the uncertainty in effects data, estimates of risk to plants are highly uncertain but do not generally appear to be significantly greater than risks associated with background chemical concentrations in marsh areas. Plants were not recommended in the Phase 1 ERA for further evaluation in Phase 2.

The findings of Phase 1 did not constitute a definitive characterization of ecological risk. A recommendation for additional assessment resulting from this conservative screen does not necessarily indicate that high or unacceptable levels of risk exist for a given receptor species or chemical, only that the possibility of significant risk cannot

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[3] In addition to data collection for the six COPCs listed, the collection of additional fish tissue for analysis of DDT is also recommended

[4] In addition to data collection for the four COPCs listed, the collection of additional sandpiper prey tissue for analysis of zinc and copper is also recommended, as discussed in Appendix A, Section A.7.3, of the Phase 1 ERA.

[5] Effects data were not available for mercury.

be ruled out. In the Phase 2 ERA, risks associated with exposure of ecological receptors to COPCs within the LDW will be quantitatively characterized in a manner designed to support sound risk management decisions. The insights gained in the Phase 1 ERA are valuable in supporting early remedial action decisions by providing a risk-based rationale for selecting candidate areas for such action and by identifying critical data needs for Phase 2.

2.3 PHASE 1 HUMAN HEALTH RISK ASSESSMENT

The Phase 1 HHRA identified ways that people could be exposed to chemicals found in LDW sediments (termed exposure pathways), the potential extent of such exposures, and exposure pathways grouped into exposure scenarios (Figure 2-4). Direct contact with sediments during commercial netfishing or beach play in the LDW and consumption of seafood from the LDW were identified as primary exposure scenarios through input from site users, including the Muckleshoot and Suquamish Tribes; through review of prior risk assessments conducted in the LDW and Harbor Island; and through review of other relevant reports and studies conducted in the vicinity of the LDW, including a study of seafood consumption habits of Asians and Pacific Islanders who presently reside near the LDW. Quantitative risk estimates for swimming in the LDW were included in the Phase 1 HHRA, based on calculations in a previous risk assessment (King County 1999c); the risk estimates for swimming were at least two orders of magnitude lower than risk estimates associated with seafood consumption.

In keeping with EPA risk assessment guidance, reasonable maximum exposure (RME) estimates were selected for all exposure scenarios to avoid underestimating risks. For example, the exposure duration for the tribal seafood consumption scenario was derived from the 90th percentile of demographic data provided by the Muckleshoot Tribe. Consequently, risk estimates may be overestimated for many individuals. However, this approach is consistent with EPA's RME policy, which uses estimates of exposure that are in the upper range of possibilities, but still plausible for assessing risks for current use scenarios, while also being reasonable for future use scenarios.

Once the exposure scenarios were identified, the chemical concentrations in samples from surface sediments and in fish and shellfish tissue were screened, and 43 chemicals were identified as COPCs for at least one of the three scenarios. COPC identification for all scenarios will be repeated in Phase 2 using appropriate existing and newly collected Phase 2 tissue and sediment chemistry data. Carcinogenic risks and noncarcinogenic health effects were evaluated separately.[6]

[6] Carcinogenic risks and noncarcinogenic health effects are evaluated separately in HHRAs because of fundamental differences in their critical toxicity values. Cancer risk is expressed as a lifetime excess cancer risk within a population of individuals exposed at the levels assumed in the risk assessment; a zero threshold is assumed. Chemicals with noncarcinogenic health effects are generally not toxic below a certain threshold; a critical chemical dose must be exceeded before health effects are observed. The

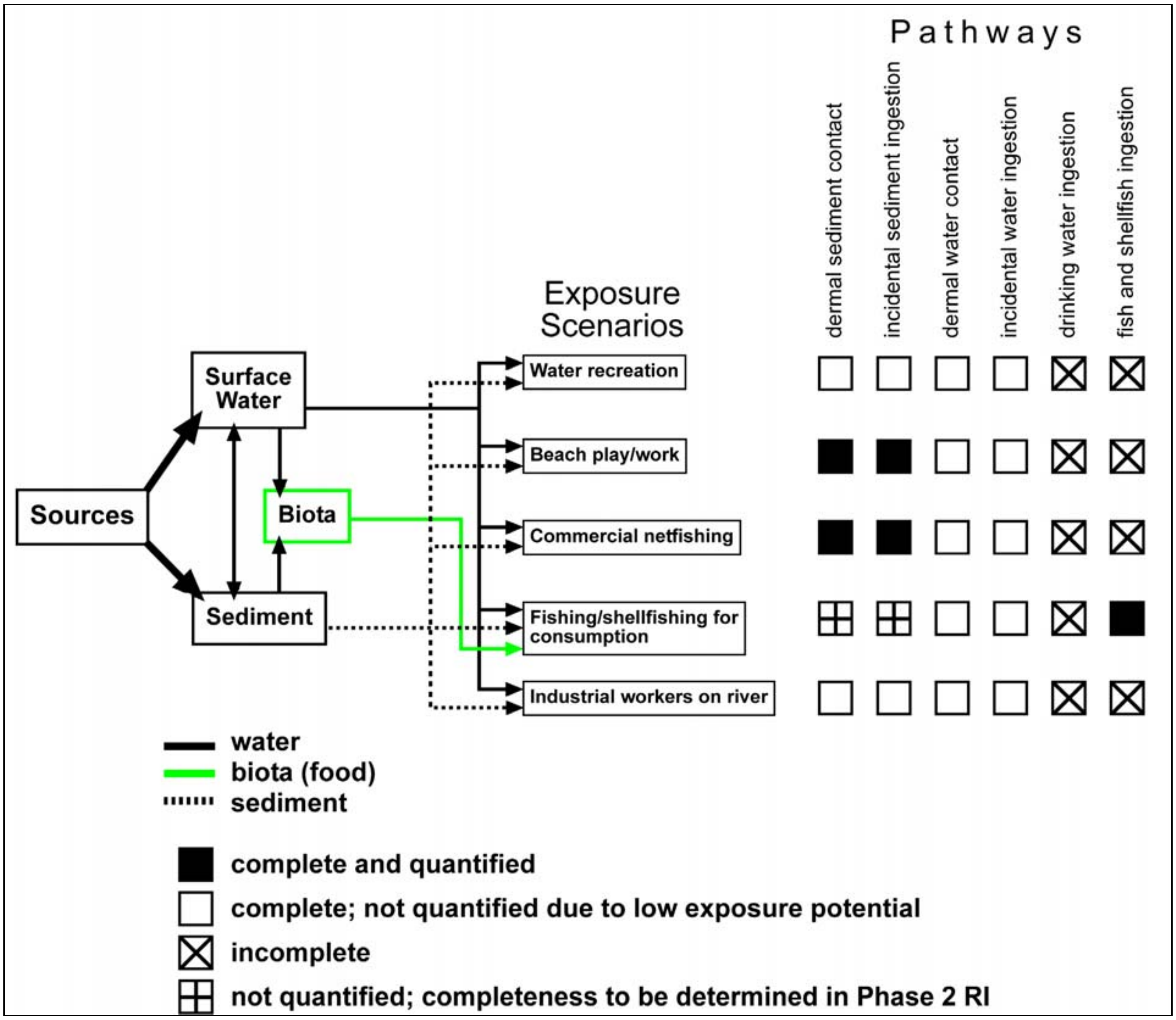

Figure 2-4. Conceptual site model for Phase 1 human health risk assessment

Using health-protective exposure assumptions, estimated cancer risks in the LDW were found to be highest for the seafood consumption scenario; the cumulative risk for all carcinogenic chemicals was 2 in 1,000, with the primary contributors being arsenic (1 in 1,000), carcinogenic PAHs (cPAHs) (1 in 10,000), and PCBs (4 in 10,000). Cancer risks for the netfishing and beach play scenarios were much lower (i.e., all risk estimates were less than 1 in 100,000, including a risk estimate for dioxins and furans of 1 in 1,000,000 in each of these scenarios). In an evaluation of noncancer risks, only the seafood consumption scenario had a hazard index (which incorporates hazard quotients for all chemicals) greater than 1, including hazard quotients greater than 1 for arsenic, PCBs, TBT, and mercury. These results suggest a possible risk for adverse

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potential for noncarcinogenic health effects is expressed as a hazard quotient for an individual chemical and as a hazard index for summed hazard quotients from multiple chemicals.

effects other than cancer associated with seafood consumption. Based on the exposure scenarios evaluated in the Phase 1 HHRA, the following chemicals were identified as chemicals of concern (COCs)[7] for one or more scenarios: PCBs, arsenic, cPAHs, dioxins/furans, TBT, and mercury.

These findings do not constitute a definitive characterization of human health risk. There are many uncertainties associated with the site-specific risk estimates for each exposure scenario. Risks calculated for arsenic are particularly uncertain because arsenic concentrations in the Puget Sound area are influenced by emissions from the former Asarco smelter northwest of Tacoma and by naturally occurring arsenic. It has not been determined how the LDW-specific risks for arsenic compare to risk estimates associated with background arsenic concentrations in areas outside the LDW. Another primary source of uncertainty with regard to arsenic is the fraction of arsenic present in seafood tissue in the toxic inorganic form. At the request of EPA, an inorganic arsenic fraction of 10% was assumed, although there is evidence that the actual inorganic arsenic fraction may be much lower, which would lower the risks calculated for arsenic.

Uncertainties in the risk estimates could be reduced through the collection of additional data or performance of additional analyses. Data collected in Phase 2 may result in the identification of additional COCs or eliminate COCs, and refine exposure pathways (e.g., shellfish consumption). The results of the Phase 1 HHRA were useful in supporting early remedial action decisions by providing a risk-based rationale for selecting candidate areas and by identifying critical data needs to be addressed in Phase 2. In addition to the collection of additional chemistry data, the Phase 1 HHRA recommended that additional habitat use data be collected during Phase 2. Specifically, additional data are needed to estimate the harvestable populations of some invertebrate species, such as clams and crabs, and a more complete characterization of potential public access is needed to quantify the beach play exposure scenario.

2.4 PHASE 2 DATA NEEDS

As described in the introduction to this work plan, one of the primary objectives of the Phase 1 RI and associated risk assessments was to identify critical data needs for the Phase 2 RI. A technical memorandum prepared to summarize these data needs (Windward 2003f) was approved by EPA and Ecology in May 2003. The data needs memorandum provides the basis for the fieldwork described in Section 3.1 of this work plan, as well as the collection of additional information and evaluation of studies performed by others outside of the Phase 2 RI. The conclusions from the data needs memorandum are briefly described below. Details on the specific data needs

[7] A COC has a cancer risk estimate greater than 1 in 1,000,000 or a hazard quotient greater than 1.

associated with sediment chemistry, tissue chemistry, and site use are presented in Appendix A of this work plan.

Data needs were grouped into three general types: chemical, physical, and biological. Collection of additional sediment, porewater, and tissue samples for chemical analyses is needed to reduce uncertainties in the exposure assessment of the Phase 1 ERA and HHRA (see Sections 3.1.1, 3.1.2, and 3.1.5 through 3.1.10). The primary physical data need is a complete bathymetric survey of the LDW (see Section 3.1.1), although some additional data on physical sediment stability properties will also be collected (see Sections 3.1.7, 3.1.8, and 3.1.10). Such a survey will provide valuable data to better characterize the existing and potential habitat distribution within the site, and will be useful in designing future sampling studies and potential remedial actions. Coupled with other information to be collected for characterizing sediment fate and transport (see Section 3.1.7), the bathymetric survey will provide information to help interpret the location of erosional and depositional areas. Better site use data are needed for some of the receptors of concern characterized in the Phase 1 risk assessments, including crabs and clams (see Section 3.1.2), rockfish,[8] and sandpiper (see Section 3.3.1.2), and for recreational users of the intertidal zone (e.g., beach play areas; see Section 3.3.2). These data will reduce uncertainties in the exposure assessments and provide additional information to assess links between COPC concentrations in fish and shellfish tissue and COPC concentrations in sediment, using a food web model (see Section 3.3.3). Additional sediment toxicity tests will also be conducted in Phase 2 (see Section 3.1.8).

3.0 Phase 2 Remedial Investigation Tasks

As discussed in Section 1, the SOW for the LDW RI/FS (Windward 2000a) identified five Phase 2 tasks:

- project plans for conducting field studies (Task 9)
- field studies (Task 10)
- baseline and residual risk assessments (Task 11)
- Phase 2 RI report (Task 12)
- FS work plan (Task 13)

This work plan describes the approaches to the collection of field data and other information to support the Phase 2 risk assessments and RI, and for performing the analyses and documenting the RI tasks in various Phase 2 reports. Each of the five Phase 2 tasks, with the exception of the FS work plan (Task 13), is described in a

[8] Rockfish were not assessed as a ROC in the Phase 1 ERA, but are being considered as a potential ROC in the Phase 2 ERA if adults are sufficiently abundant and widespread.

separate section below. Tasks 9 and 10 (Sections 3.1 and 3.2, respectively) will be completed over many months in a tiered fashion so that designs of later studies can be based directly on data collected in earlier studies. Data collected during Phase 2 field studies and information collected by others during the same timeframe will be combined and analyzed in Tasks 11 and 12 (Sections 3.3 and 3.4, respectively). The FS work plan (Task 13) will be prepared as a separate deliverable.

3.1 PROJECT PLANS FOR CONDUCTING FIELD STUDIES

The data needs memorandum (Windward 2003f) identified field studies that should be conducted as part of the Phase 2 RI. A separate project plan, specifically a Quality Assurance Project Plan (QAPP), will be prepared for most of the field studies. Two reconnaissance surveys that will focus on potential sandpiper habitat and site use and potential human access to shoreline areas will not have separate QAPPs, but will have technical memoranda prepared prior to the surveys describing the proposed approaches; separate technical memoranda will be prepared after the surveys to report the results. The potential need for a rockfish site use survey will also be addressed in a technical memorandum, and survey methods and results will be described in technical memoranda submitted to EPA and Ecology if the survey is conducted. These technical memoranda and surveys will support the risk assessments,[9] and are described in Section 3.3.

Each QAPP will follow current EPA Quality System guidance (EPA 2000b) and requirements (EPA 2001). Table 3-1 lists the standard elements that will be incorporated into each QAPP. Although all QAPP elements are required, some may not be applicable for a particular field study. In these cases, the QAPP will include the appropriate section title, but will note that the contents of the section are not applicable. Because the QAPP elements include sampling design and methods, a separate sampling and analysis plan will not be prepared for each study. Project-specific health and safety plans will be prepared as an appendix to each QAPP.

The field studies described in the data needs memorandum (Windward 2003f) can be grouped into 10 separate activities, based primarily on the sampling medium and the anticipated schedule for completing the field activity:

- juvenile chinook salmon tissue sampling and chemical analyses
- clam, crab, and shrimp survey
- bathymetry
- groundwater seep survey and chemical analyses

[9] Data collected from these surveys will also be used to support the study design for the benthic invertebrate QAPP, fish and crab tissue QAPP, and the surface sediment QAPP.

- benthic invertebrate community characterization, including tissue and sediment sampling and chemical analyses
- fish and crab tissue sampling and chemical analyses
- sediment transport study
- surface sediment sampling, chemical analyses, and toxicity testing
- porewater sampling and chemical analyses
- subsurface sediment sampling and chemical analyses

Table 3-1. QAPP elements

QAPP elements Group A: Project Management Elements	
A1	Title and approval sheet
A2	Table of contents
A3	Distribution list
A4	Project/task organization
A5	Problem definition/background
A6	Project/task description
A7	Quality objectives and criteria
A8	Special training/certification
A9	Documents and records
QAPP elements Group B: Data generation and acquisition elements	
B1	Sampling process design (experimental design)
B2	Sampling methods
B3	Sample handling and custody
B4	Analytical methods
B5	Quality control
B6	Instrument/equipment testing, inspection, and maintenance
B7	Instrument/equipment calibration
B8	Inspection/acceptance of supplies and consumables
B9	Non-direct measurements
B10	Data management
QAPP elements Group C: Assessment and oversight elements	
C1	Assessments and response actions
C2	Reports to management
QAPP elements Group D: Data validation and usability elements	
D1	Data review, verification, and validation
D2	Verification and validation methods
D3	Reconciliation with user requirements

LDWG, EPA, and Ecology have been meeting regularly in 2003 and early 2004 to discuss the conceptual designs for many of the studies listed above. For example, separate meetings have been devoted to discussing Phase 2 approaches for collecting additional data on sediment chemistry, sediment toxicity, and tissue chemistry. Accordingly, the discussion presented below for some studies includes more detail for topics that have been discussed in detail among LDWG, EPA, and Ecology than for studies that have not been discussed in detail (e.g., seep survey and sediment transport study). Preliminary study designs are presented in this work plan to provide all stakeholders with a common understanding of the general technical approach and approximate level of effort for each of the Phase 2 data collection efforts. Sample locations and numbers of samples presented in this section are preliminary and are included to establish a general level of effort for specific studies. These details are subject to modification during finalization of the QAPPs.

Study-specific QAPP will be developed to describe the sampling design and methods in detail. These QAPPs will be developed in consultation with EPA and Ecology, and will, when finalized, supersede the language in this work plan regarding study details (e.g., specific sample locations). The objectives, background, and conceptual design of each field study is described below.[10]

3.1.1 Juvenile chinook salmon tissue sampling and chemical analyses

A QAPP for the collection of juvenile chinook salmon (Windward 2003d) was submitted in April 2003 and was approved by EPA and Ecology in May 2003. Field work was conducted in May and June 2003. The May QAPP addressed the field sampling component of this study and a revised final QAPP, which incorporated the analytical methods described in Section 3.1.1.4, was approved in October 2003. QAPP elements are excerpted below. Full progress and data reports will be submitted to EPA and Ecology documenting the sampling and analysis activities, including any deviations from the final, approved QAPP (Windward 2003d). These details are not reflected in the following sections, except as a footnote, where appropriate.

3.1.1.1 Objectives and background

The Puget Sound chinook salmon, listed as a threatened species under the Endangered Species Act, was an ROC in the Phase 1 ERA and will be an ROC in the Phase 2 ERA. Analysis of additional juvenile chinook salmon tissue samples was identified as a data need in the data needs memorandum (Windward 2003f) to supplement the existing tissue chemistry data. Additional juvenile chinook salmon tissue samples for chemical analyses are needed to:

[10] QAPPs for three of the studies (i.e., juvenile salmon tissue collection and chemical analyses; clam, crab, and shrimp survey; and bathymetry) have already been reviewed and approved by EPA and Ecology. Following the excerpts from each of those three QAPPs (i.e., Sections 3.1.1, 3.1.2, and 3.1.3), a summary of the current status of each study is provided.

- estimate body burdens of PCBs, TBT, and organochlorine pesticides in wild and hatchery-reared juvenile chinook salmon for use in a critical tissue residue risk approach
- estimate exposure of hatchery-reared juvenile chinook salmon through the chemical analyses of PAHs and select metals in stomach contents for use in a dietary risk approach
- estimate piscivorous wildlife exposure to PCBs and organochlorine pesticides through the ingestion of juvenile chinook salmon
- estimate chemical concentrations in wild and hatchery-reared juvenile chinook salmon upstream of the LDW

Tissue samples will be collected in May and June 2003 based on the methods described in the QAPP. The target analytes were selected based on a consideration of the results of the Phase 1 ERA, the limited amount of wild fish available due to take permits, and the limited available mass of stomach contents.

3.1.1.2 Study design

The exposure scenarios and study design to address these scenarios were determined in consultation with EPA and Ecology. The timing and locations for sample collection were selected to represent a reasonable range of exposure of juvenile chinook salmon in the LDW, taking into account uncertainty in juvenile chinook salmon behavior and the limited sampling possible due to take-permit limitations for wild fish.

Composite whole-body and stomach content samples will be collected at two general areas in the LDW in May and June (Table 3-2). Figure 3-1 presents the primary and alternative sampling locations. The two primary locations in the LDW are Slip 4 (MWa), an area with some of the highest sediment PCB concentrations in the LDW, and the downstream terminus of the LDW below Kellogg Island (LWa), representing exposure following juvenile chinook salmon passage through the entire LDW. The Slip 4 location was selected, in part, because juvenile chinook salmon collected previously from this location had higher whole-body PCB concentrations relative to those collected near Kellogg Island (NMFS 2002). The LDW terminus location was selected because, in theory, concentrations of chemicals in juvenile chinook salmon at the downstream end of their outmigration should reflect an integration of their exposure throughout the LDW site.

Alternative locations, noted in Figure 3-1 as MWb, LWb, etc., may also be sampled if sufficient numbers of fish cannot be collected at the primary locations.

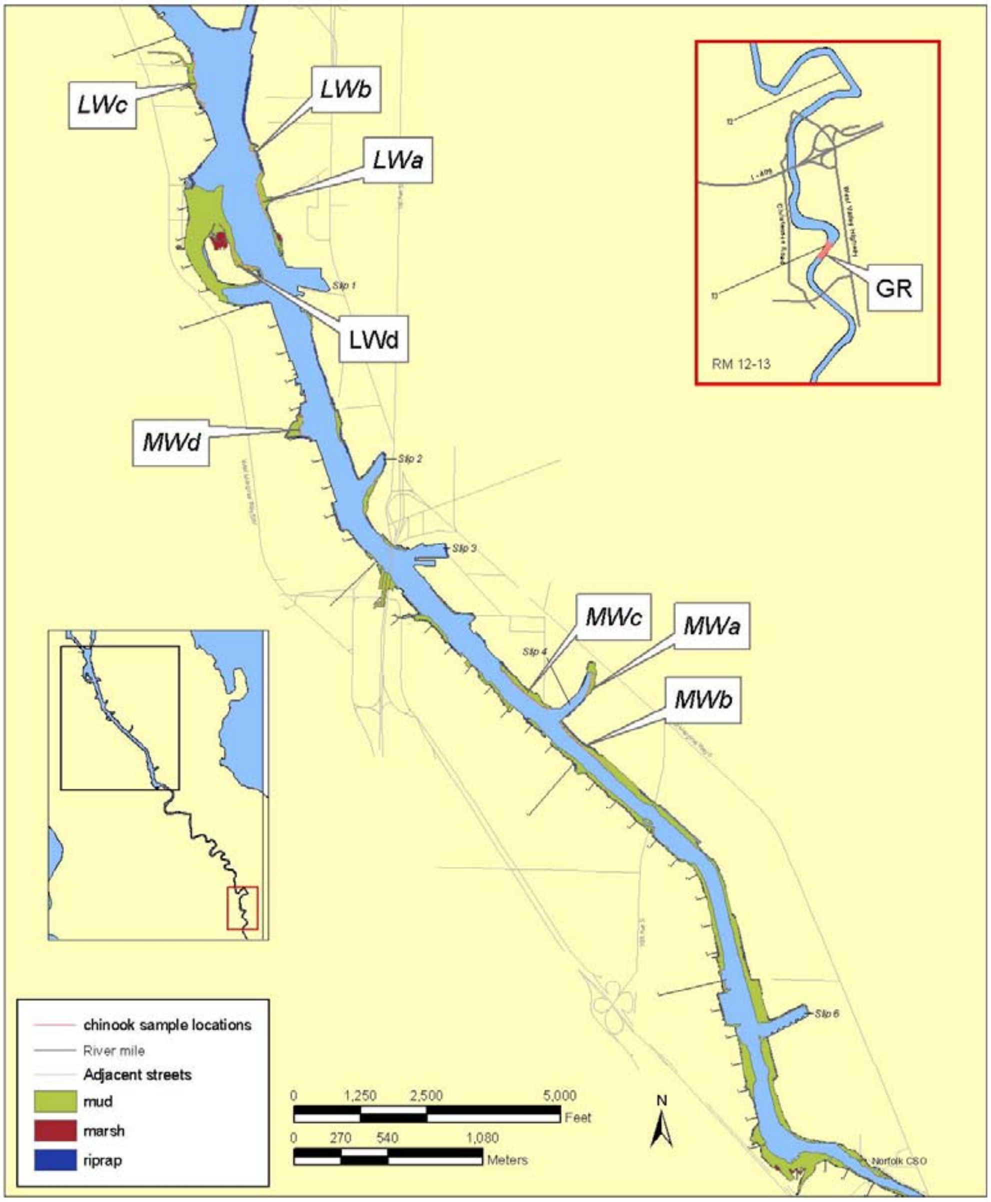

Figure 3-1. LDW juvenile chinook salmon sampling areas

Wild fish will be collected before the first hatchery release in May 2003, and both hatchery and wild fish will be collected after the last release of hatchery-raised juvenile chinook salmon into the Green-Duwamish River in 2003. Collection of fish prior to the first release of hatchery fish into the Green-Duwamish River is intended to provide assurance that sub-yearling fish with adipose fins are wild-spawned. Fish collection after the hatchery release is intended to characterize the tissue residues of both hatchery and wild fish following the peak of outmigration. All fish collected in the May sampling event are expected to be wild because the hatchery fish will not have been released yet. For the June/July sampling event, all unclipped fish without coded wire tags will be assumed to be wild. The purpose of the upstream and hatchery samples is to evaluate exposure attributable to maternal transfer of chemicals (e.g., PCBs) or from sources outside the LDW.

Table 3-2. Number of composite samples targeted for collection at each area

	May				June/July		
	MW[a]	LW[a]	Hatchery	RM 13	MW[a]	LW[a]	RM 13[b]
Wild fish [c]	3	3		3	3	3	3
Hatchery fish			1		3	3	3
Hatchery fish stomach contents					1[d]	1	1[d]

Note: Each wild fish composite will consist of 9 individual whole-body fish in the May samples and 8 individual whole-body fish in the June/July samples; hatchery fish composites will consist of a sufficient number of individual whole-body fish to make a composite sample weighing at least 50 g.

[a] MW represents a mid waterway station; LW represents a lower waterway station (see Figure 3-1)

[b] Fish were collected from the screw trap at RM 18 when insufficient numbers of fish were available from RM 13.

[c] A small percentage of hatchery fish are not clipped or tagged before release. Unclipped fish without coded wire tags collected in the June/July sampling event were not verified as wild.

[d] Insufficient hatchery fish were available from these locations to allow collection of a stomach content composite sample.

3.1.1.3 Sampling methods

Fish will be captured in the field using a standard beach seine. When possible, the net will be deployed at low tide, close to slack water. A handheld global positioning system (GPS) receiver unit will be used to obtain approximate coordinates in the sampling areas. Coordinates will be taken at the starting and ending location of each beach seine deployment. Locations of seining activities will also be identified by reference to landmarks.

Juvenile chinook salmon will be removed from the seine and fish of similar size will be preferentially selected. All fish will be inspected carefully to ensure that their skin and fins have not been damaged by the sampling equipment; damaged specimens will not be accepted. Once the sampling is completed at an area, whole fish will be rinsed with distilled water to remove any debris, measured and weighed, individually wrapped in aluminum foil, and bagged with an identification label. Fish will be measured and weighed, and checked for the presence of a coded wire tag. If a tag is detected it will be excised for later determination of the origin of the fish. Fish used for stomach content analysis will be collected and processed separately from those used for whole-body tissue analysis. The stomach will be removed in the laboratory, cut open, and the gut contents scraped out. Fullness of the gut and distinguishable prey contents will be noted. Gut contents will be weighed and composited together with those from all fish from a collection area. A composite of stomach content samples will be considered to be complete when the accumulated gut contents weigh 15 g and gut contents from at least 20 fish have been combined.

For whole-body samples, 8 or 9 wild fish, depending on the sampling event, or at least 50 g of whole hatchery fish, will be composited and homogenized to form one composite sample. Individual fish will be homogenized together to form a whole-body sample according to the compositing groups submitted by Windward. These groups will be based on the length and weight of individual fish as well as their sampling location.

3.1.1.4 Analytical methods

Analytical methods and quality control considerations for chemical analyses are described in the final QAPP. Whole-body tissue samples will be analyzed for PCB Aroclors, organochlorine pesticides, TBT, and lipid content. Stomach contents will be analyzed for PAHs (including alkylated PAHs) and select metals (except mercury[11]). A list of analytical methods is provided in Table 3-3.

Table 3-3. Analytical methods for juvenile chinook salmon

PARAMETER	METHOD	NOTES
PAHs (including alkylated PAHs)	GC/MS (EPA 8270)	Alkylated PAHs will also be analyzed per the selected laboratory SOP
PCBs (as Aroclors)	GC/ECD (EPA 8082)	
Organochlorine pesticides	GC/ECD (EPA 8081)	
Metals	ICP-AES (EPA 6010) [a]	
TBT	GC/FPD (Stallard et al. 1988)	
Lipids	Bligh-Dyer modified	

GC/MS – gas chromatography/mass spectrometry

SOP – standard operating procedure

ECD – electron capture detection

ICP AES – inductively coupled plasma-atomic emission spectrometry

FPD – flame photometric detection

[a] Other methods (i.e., GFAA or ICP-MS) may be used for metals depending on the detection limit goals to be specified in the QAPP

[11] Mercury will not be analyzed in stomach contents because it was evaluated using a critical tissue residue approach in the Phase 1 ERA, and risks to juvenile chinook salmon from mercury were found to be low.

STATUS: Juvenile chinook tissue chemistry

- Collection QAPP approved in May 2003; Collection and chemistry QAPP approved in October 2003
- Sampling completed in May/June 2003
- Draft data report was submitted in March 2004; report presented results and any deviations from the QAPP, including collection of single stomach content sample from LW locations vs. planned collection of stomach content composite samples from LW, MW, and RM 13 locations, and collection of fish from RM 18 instead of RM 13 in June.

3.1.2 Clam, crab, and shrimp survey

A QAPP for the clam, crab, and shrimp survey (Windward 2003c) was submitted in May 2003 and approved by EPA and Ecology in August 2003. Fieldwork described in this QAPP was initiated in July 2003. Quarterly surveys of crabs and shrimp began in September 2003 and will be completed in May 2004. QAPP elements are excerpted below.

3.1.2.1 Objectives and background

The objectives of the surveys outlined in this section are to provide the necessary data to assess the abundance and sustainability of harvestable populations of clams, crabs, and shrimp. The data obtained from these surveys will be compared to similar data collected from other Puget Sound areas to determine how shellfish consumption should be quantified for the Phase 2 HHRA. LDWG will meet with EPA, Ecology, and representatives from the Muckleshoot and Suquamish tribes to discuss this topic and a technical memorandum will also be submitted. Two additional objectives are to identify depths to which intertidal clams burrow in the LDW, and to characterize crab distribution so that crab collection for chemical analyses, which would follow as a second-tier study (see Section 3.1.6), can be conducted more efficiently. The clam burrowing depth is needed to determine the likelihood that intertidal clams are exposed to sediments deeper than 15 cm, which was the operational definition for surface sediments in the Phase 1 RI.

The HHRA for the Phase 1 RI estimated risks from consuming seafood caught in the LDW. Separate consumption rates specific to the LDW were derived for benthic fish, pelagic fish, and shellfish, including crabs and mussels. These consumption rates were derived from studies of human populations that harvest seafood from throughout King County (Asian and Pacific Islanders - EPA 1999a) and Puget Sound (Suquamish

Tribe 2000), including areas outside the LDW. However, the LDW-specific clam consumption rate was assumed to be zero for the Phase 1 HHRA because of the uncertainty associated with the presence of harvestable populations of these animals in the LDW.

Marine shellfish species may be more abundant in Puget Sound than in the estuarine LDW, but available data are insufficient to evaluate this hypothesis. Qualitative data compiled as part of the Phase 1 RI indicate that crabs, clams, and mussels are present in the LDW (ESG 1999; King County 1999c; Windward 2000b), but harvestability estimates for these species could not be made. Other marine invertebrate species consumed by the Suquamish Tribe, such as oysters, geoduck, scallops, squid, sea urchins, and sea cucumbers, have not been observed in the LDW. For the purposes of the Phase 2 RI, information from local biologists and past field work/surveys will be used to confirm that these other species are not expected to be present in the LDW.

3.1.2.2 Study design

Windward will conduct semi-quantitative surveys of select invertebrate populations in the LDW. This study will be done in two parts: 1) crab and shrimp survey, and 2) intertidal clam survey.

The first part of the study will be conducted to estimate crab and shrimp harvestability in the study area. The first survey will be conducted in July 2003. Crab and shrimp pots will be deployed at 38 locations throughout the study area, covering the depth range of the LDW, but avoiding areas where shallow depths and tidal fluctuation may expose the pots at low tide (Figure 3-2, located at end of document). Sampling locations have been placed throughout the study area with a relatively uniform sampling density. Catch-per-unit-effort on a per-pull basis will be calculated for each trap to determine potential harvest rates by recreational fishers. This procedure will be repeated on a quarterly basis for four quarters to gain representative harvest rate data during each season.

The second part of the study will provide data to estimate the potential harvest of clams in the exposed intertidal zone of the LDW by surveying potential clam beaches throughout the LDW during a low tide event. A reconnaissance survey will be completed in July 2003 to locate beaches in the study area that may support clams. These areas will then be revisited during low tide in August 2003 and sampled for clams using methods based on WDFW clam and oyster guidance (Campbell 1996). Each beach will be surveyed and a general description of the beach recorded, including percent fines and interstitial salinity. Mean number and weight of clams per species will be calculated per productive beach area. Harvestability, defined as the harvest rate that is sustainable over time without depleting the resource between years, will also be estimated. The method for estimating harvestability will be determined from consultation with WDFW, the Suquamish and Muckleshoot tribes, EPA, and Ecology. Physical measurements of beach substrate will be made because these characteristics may constrain the ability of the habitat to support clams. Observations of other intertidal invertebrates, such as oysters, mussels, and shore crabs, will also be recorded during this survey because these species may also be consumed by people. Additional observations of mussels on hard surfaces other than intertidal beaches (e.g., pilings) will be made during transit between beaches. Observations of these other species will provide qualitative data that will be used to supplement the more quantitative data derived from the crab/shrimp and clam surveys.

3.1.2.3 Sampling methods

Crab and Shrimp Survey

Sampling locations will be identified in the field through the use of a Global Positioning System (GPS). Pots will be placed more than 100 m apart to avoid pot competition. Thirteen pots will be deployed and/or retrieved each day. Pots will be allowed a 24-hour soak time after deployment.[12] This schedule will allow for sampling during both high and low tide, during which time crab and shrimp densities may change. Samples will be collected using Ladner 30-in SS rubber-wrapped crab traps and Ladner 30-in nestable shrimp pots. After 24 hours, the pots will be revisited and all species caught will be examined and their pertinent information recorded. Specimens will then be returned to the area from which they were caught.

After retrieval and data collection, pots will be rebaited and moved to the next upstream sampling locations. This process will be repeated for three consecutive days until all locations have been sampled.

Intertidal Clam Survey

The Phase 1 RI for the LDW (Windward 2003a) identified intertidal areas based on aerial photos taken during a negative tide (-2 ft mean lower low water [MLLW]). These areas will be visited during the first phase of the clam survey, in addition to any other beaches that may potentially support clams based on substrate and beach size. All beaches will be ranked based on best professional judgment of the quality of the habitat and the presence of clams and placed in three categories: good, medium, and poor. Sampling in the second phase of the survey will focus on the good quality beaches but medium and poor quality beaches will also be included. Sampling events of the second phase will take place during a 4-hour period centered on low tide on days with the lowest negative tide (-2 to -3 ft MLLW). Conducting surveys at the lowest negative tide will ensure that the maximum area is exposed for sampling clams to assess the maximum potential harvest.

Clam survey methods will be based on the WDFW guidance (Campbell 1996). The study area of each beach will be defined by designated physical boundaries

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[12] Based on the results of the pilot study conducted in August 2003, the soak time for all crab and shrimp traps was changed from 24 hours to 4 hours, with the approval of EPA and Ecology.

perpendicular to the shoreline and by the highest elevation where clams would be expected. For each survey, transects will be laid out perpendicular to the water and sampling points will be located along each transect. Sampling point densities will depend on the size of the beach (see invertebrate survey QAPP, Windward 2003c). At each sampling point, 0.028 m^3 of substrate will be removed and placed in a sorting bin. All clams present within the substrate will be removed, identified, measured, and replaced with the removed substrate in the original hole.

3.1.2.4 Analytical methods

Crab and shrimp data collected during the survey will be summarized by number and mean length of each species per sampling pot. Catch-per-unit-effort will be calculated for each crab and shrimp species on a "per pull" basis by summing the number of a particular species caught in a pot. Crab and shrimp harvest data will be summarized per sampling pot and for the entire LDW and presented in tables in the data reports.

Clam abundance data collected during the intertidal clam survey will be summarized by mean number and weight of each clam species per productive beach and for the whole LDW and presented in tables in the survey data report. Percent fine substrate will be calculated using the wet-sieve method for each beach included in the clam survey by dividing the volume of the fine-grained fraction by the volume of the total sample. In addition, evidence of other shellfish such as shore crabs and mussels that were found during the clam survey will be presented in a table in the clam survey report. This table will include type of organism, species identification (if possible), location, and estimated number of individuals.

STATUS: Clam, crab, and shrimp survey

- QAPP approved in August 2003
- Clam field work completed in August 2003
- 1^{st}, 2^{nd}, and 3^{rd} quarter crab and shrimp surveys completed in September 2003, November 2003, and February 2004; 4^{th} quarter surveys are planned for May 2004
- Final data reports will include results and any deviations from the QAPP, such as the soak time change from 24 to 4 hours; submittal dates are shown in Figure 4-1

3.1.3 Bathymetry

A QAPP for the bathymetric survey (Windward 2003b) was submitted to EPA and Ecology in June 2003. In August 2003, the QAPP was approved and the field work was conducted. QAPP elements are excerpted below.

3.1.3.1 Objectives and background

The objective of this survey is to produce accurate bank-to-bank data of current riverbed elevations in the LDW study area as part of the Phase 2 RI. This survey will produce an up-to-date bathymetric data set with a high level of detail and accuracy. Results of the survey may be used to support the following RI/FS activities:

- placement of additional sediment sampling locations
- evaluation of benthic invertebrate, fish, and wildlife habitat
- analysis of bottom substrate composition
- evaluation of potential sediment transport conditions
- preparation for remedial options

Bathymetric surveys of the LDW have been conducted in the past by the United States Army Corps of Engineers (USACE) to determine the need for dredging for navigational purposes within the federally maintained navigation channel. Surveys were conducted approximately every other year from 1963 to 1983 between RM 2.6 and 4.0[13] (Figure 3-3). More recent bathymetric surveys were conducted in 1998, 2000, and 2001 in this same region (Windward 2003a). In the spring of 2003, the USACE completed a survey of the entire navigation channel (up to RM 4.7), limited to the area within the channel. These USACE surveys were conducted using single beam methodology. Other remediation project proponents (e.g., King County, the Boeing Company) have sponsored site-specific bathymetric surveys in the vicinity of their projects. None of the existing surveys have covered the entire LDW bank-to-bank.

3.1.3.2 Study design

The primary survey area will cover approximately 8 km (5 mi) of the waterway from the southern tip of Harbor Island to just south of Turning Basin 3 (Figure 3-3). An additional survey area extends from RM 5, as shown in Figure 3-3, to just upstream of RM 6. This additional area will be surveyed as conditions allow. Multibeam sonar will be used to collect high-resolution data with up to 100% coverage of the riverbed. The multibeam bathymetric data will be used to create a digital terrain model of the riverbed morphology from which hill-shade images will be generated.

[13] Dates and locations of bathymetric surveys were obtained from the USACE and compiled in Table 4-19 of the Phase 1 RI.

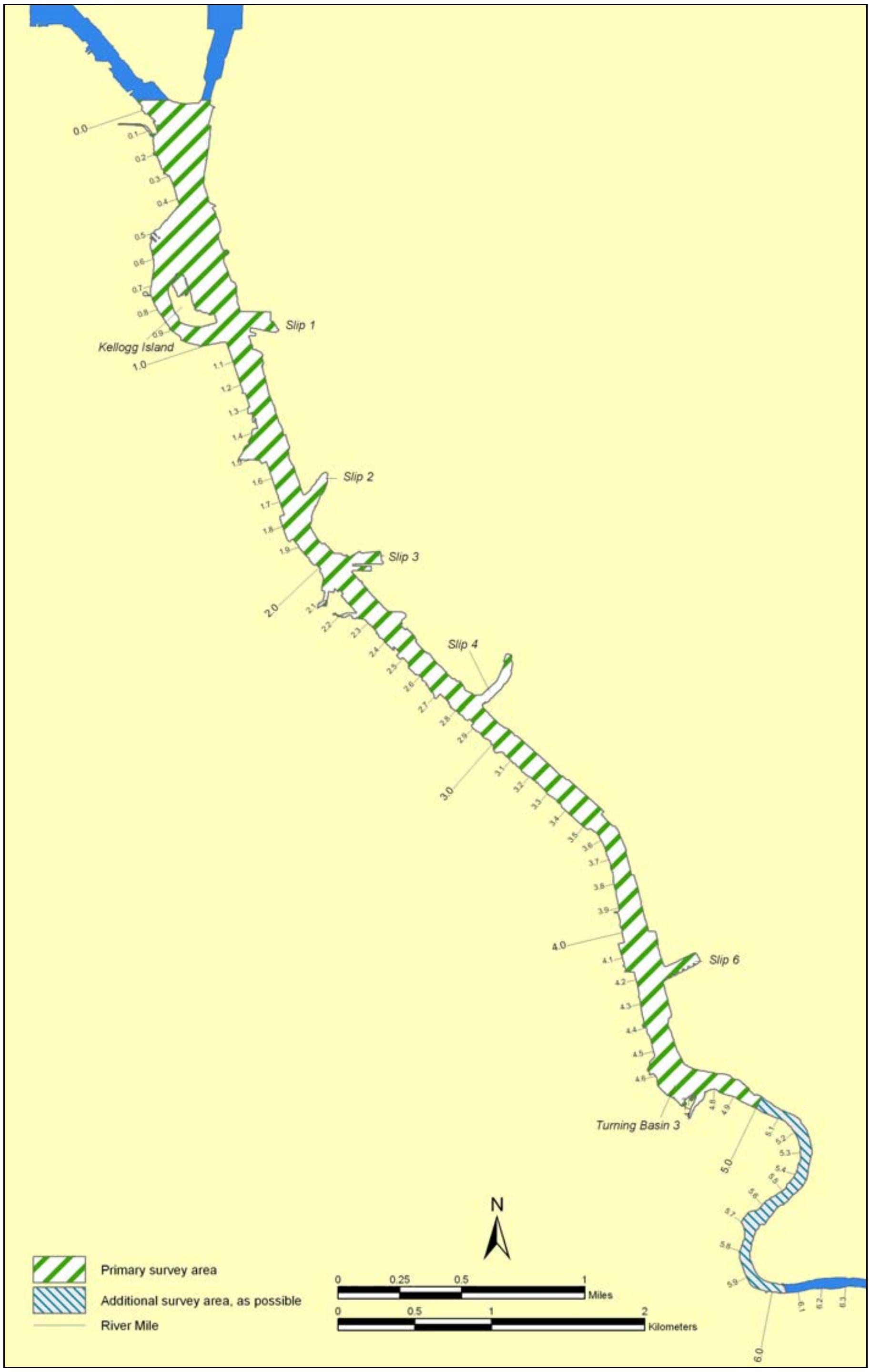

Figure 3-3. Coverage for bathymetric survey of the LDW

3.1.3.3 Survey methods

David Evans and Associates, Inc. (DEA) will conduct the bathymetric survey. The survey will be conducted on an established coordinate system, referenced by monuments established or recovered during a geodetic control survey. The horizontal datum for this survey is North American Datum of 1983 through the 1991 adjustment (NAD83/91), State Plane Coordinate System, Washington North Zone, measured in US Survey Feet. The vertical datum for this survey will be mean lower low water (MLLW).

The precision water depth measurements will be collected from a survey vessel owned and operated by DEA. This vessel will be equipped with an integrated navigation and data acquisition system and a custom mount for a Reson SeaBat 8101 sonar head used to collect the bathymetric data. Horizontal positions will be acquired with an Applanix Position and Orientation System for Marine Vessels differential global positioning system. Water surface measurements will be obtained by real-time kinematic GPS with on-the-fly ambiguity resolution.

Multibeam data will be collected by running lines parallel with the shoreline. The multibeam sonar head will be mounted with a 15° offset angle for horizontal orientation of the outer starboard beam. This position will enable coverage every 1.5° over a range of 90° from nadir (straight down) to starboard and 60° from nadir to port. With this configuration, shoreline data will be collected as far up the bank as possible, on a steep bank, by making shoreline runs with the starboard side toward shore. Survey lines offshore of the shoreline runs will clip the starboard beams at 60° (or less depending on refraction and cross-line analysis) during processing. Running with a 120° swath (60° to port and starboard), the system will provide 3.5 times the water depth coverage in a single pass. If ships or barges obstructing a planned survey transect are shallow draft and not too wide, it may be possible to survey under them with the wide swath of the SeaBat 8101 system.

During the survey, preliminary multibeam bathymetric data will be displayed in real time using HyPack software. Pixels color-coded by depth will be drawn on screen, showing the coverage and agreement between adjacent swaths. At the end of each day, screen grabs of the preliminary coverage will be forwarded to Windward for review, to determine whether additional lines should be run to fill gaps in coverage. These coverage maps are preliminary, and additional data needs may not become apparent until after data processing. Quality control and data validation procedures for the survey are described in the QAPP.

3.1.3.4 Data processing methods

Post-processing of multibeam data will be conducted utilizing Caris® HIPS multibeam analysis and presentation software. The Caris® HIPS system allows for simultaneous viewing of the sidescan and multibeam data to analyze anomalies on the riverbed during post-processing. To take advantage of the level of detail, the multibeam survey will provide a 1-m resolution hill-shade model and 1-m gridded data set that will be exported from Caris® HIPS. This gridding process will use an inverse distance weighting (IDW) algorithm. The 1-m grid size will allow for comparisons with previous bathymetric surveys that were conducted with similar high-resolution methods, in order to interpret the possibility of shoaling or scouring, while keeping the file size at a manageable level. All original data will be archived at full resolution. If required at a later date, specific areas of interest can readily be remodeled at a higher resolution.

The hill-shade plots will be exported as one or more georeferenced TIFF files that can be imported into AutoCAD® or any geographic information system (GIS) program for final presentation and plotting. Export of accepted multibeam data will be imported into TerraModel® software for generation of a digital terrain model from which contours will be generated.

STATUS: Bathymetric Survey

- QAPP approved in August 2003
- Survey completed in August 2003
- Final data report was submitted and approved by EPA and Ecology in February 2004; report presented results and any deviations from the QAPP

3.1.4 Seep survey and chemical analyses

A QAPP for a seep survey and collection and chemical analyses of seep samples will be submitted to EPA and Ecology for review, comment, and approval following their approval of this work plan. This section describes the general scope for that QAPP. Numbers of samples presented in this section are preliminary and are included to establish a general level of effort for specific studies. Sample numbers are subject to modification during finalization of the QAPP.

3.1.4.1 Objectives and background

The objective for the seep survey and chemical analyses of seep water samples is to investigate whether groundwater discharging in intertidal areas (i.e., below mean higher high water [MHHW] and above mean lower low water [MLLW]) may serve as a source of chemical contaminants to the LDW.[14]

The Phase 1 RI included a summary of groundwater data from 12 sites within the LDW basin identified on a preliminary basis by EPA and Ecology as sites of interest

[14] Sources with potential chemical discharge to the LDW through subtidal seeps below MLLW may not be identified during this survey. Areas above MHHW are not part of the LDW study area, so data collection for source characterization above MHHW is the responsibility of EPA and Ecology.

for Phase 1. Seep data were collected at four of those sites: Boeing Isaacson, Boeing Plant 2, Great Western International, and Rhône-Poulenc. No comprehensive or detailed reviews of existing data related to potential sources, such as groundwater or seeps, were conducted as part of the Phase 1 RI for areas other than the 12 sites identified. In general, a thorough characterization of potential sources over the entire LDW site has not been performed. The LDW source control workgroup, which includes Ecology, EPA, King County, the City of Seattle, the City of Tukwila, and the Port of Seattle, is currently conducting a search to identify additional potential sources of chemicals to the LDW, although a detailed review of groundwater chemistry data is being conducted by that group only for selected properties at this time. Based on the lack of detailed information on all potential sources in the LDW, chemical analysis of seeps will be conducted based on results from a visual reconnaissance survey and review of available source information, as described in the following section.

3.1.4.2 Study design

The study design for the seep survey and chemical analyses will consist of an evaluation of existing source information and chemical distribution in sediment, as well as two separate field events: a visual seep reconnaissance survey followed by sampling of select seeps for chemical analyses. Sites with groundwater contamination in upland areas that have the potential to discharge to the LDW will be identified through a review of the Phase 1 groundwater appendix and source information collected by the source control workgroup and other local sources (e.g., DRCC, Puget Soundkeeper, and Green-Duwamish Watershed Alliance). The list of sites where seep water is to be sampled for chemical analyses will be developed in coordination with EPA and Ecology.

The visual seep survey will be conducted in May 2004 by boat to obtain access to all observed seeps along the shoreline. The lowest low tides will be targeted for the seep survey to increase the area of exposed bank and beach in which seeps might be observed. Each seep will be documented with digital photos and video, coordinates will be sited with GPS, and the site will be physically marked with a stake. As time permits,[15] a flow rate estimate and general water quality information (see Section 3.1.4.3) will also be collected at each seep. It will also be noted if any observable characteristics indicate a potential source of contamination. These characteristics include staining or discoloration where seeps emerge, oily sheen, bacterial slime, obvious odor, and the presence of anthropogenic fill or waste material.

Following the visual seep survey, a meeting will be held with EPA and Ecology to select approximately 10 to 15 worst-case locations for seep water collection and

[15] The ability to estimate flow rate and general water quality parameters at all seeps during the visual survey will depend on the nature of the seep and the sampling window allowed based on tidal limitations.

chemical analyses. Where available, the following information will be considered for each of the seeps:

- Information from the visual seep survey including:
  - observed characteristics at the seep
  - the presence of anthropogenic fill or waste material
  - estimated flow rate
  - water quality parameters (e.g., conductivity)
  - seep type (examples of some seep types might include linear seepage at base of embankment, point seepage at foot of beach, or seepage surrounding outfall pipe)
- Information from the Phase 1 RI and Source Control Work Group, including:
  - locations of potential upland sources in relation to seeps
  - nature and extent of upland contamination in the potential source area, if sufficient data are available
  - potential presence of preferential pathways or hydrologic connection between the potential source area and the LDW
  - nature and extent of elevated surface sediment chemical concentrations in existing data collected near seep
  - existing seep data (i.e., if data of acceptable quality have been collected for a given seep, there may not be a need to resample it)

Based on the above considerations, best professional judgment will be used to prioritize expected worst-case locations for chemical discharge at seeps. Approximately 10 to 15 seep water samples will be collected at worst-case locations and submitted for chemical analyses. Resulting seep chemistry data will be compared to Washington State water quality standards, or EPA's water quality criteria when state standards are not available. The results will also be used to determine if additional surface sediment samples (see Section 3.1.8) are needed from seep areas.

3.1.4.3 Seep reconnaissance survey methods

The reconnaissance seep survey will be conducted by boat during low tide (when tidal elevations are at or below +1 ft MLLW). The shoreline and riverbank will be observed from the boat for signs of groundwater seepage. When potential groundwater seeps are observed, the boat will be stopped and beached so that the field crew can examine the seep on shore. The following will be recorded at each seep, as time allows:

- date and time
- GPS coordinates

- seep substrate material
- estimate of seep flow rate
- seep observations (e.g., bacterial slime, oily sheen, staining, obvious smells)
- salinity, temperature, pH, dissolved oxygen, conductivity, and oxidation-reduction potential
- description of embankment substrate including possible presence of anthropogenic fill or waste material
- seep location relative to vertical changes in embankment or beach substrate.

A photograph will be taken of each identified seep. Seep locations will be mapped using GIS.

3.1.4.4 Seep water sampling methods

Locations for collection of seep water samples for chemical analyses will be chosen using the reconnaissance survey results and the information bulleted above in Section 3.1.4.2. Seep water samples will be collected during the period of June 30 to July 6, 2004, following the approval of the seep QAPP. GPS will be used to relocate seeps identified during the reconnaissance survey, although it is possible that some previously identified seeps may not be flowing at the time of the sampling event. Seep water samples will be collected during low tide, and collection locations will be marked with a stake to enable reoccupation of a site for sediment sampling (see Section 3.1.8) if deemed necessary based on the results of the seep water chemical analyses. Seep water will be sampled using various techniques depending on the type of seep (flow rate and spatial extent). Sampling method options will to be outlined in the seep QAPP. The most appropriate method will be selected at the time of sampling. Upon sample collection, the VOC container will be filled first with no headspace to minimize volatilization. Other containers will be filled and preserved in the field if required by the analytical method. General water quality information, as described in Section 3.1.4.3, will also be measured. Samples will be stored in a cooler until delivery to the analytical laboratory. The flow rate will be measured at seeps where all of the flow can be captured and quantified, using a stop-watch to measure the rate at which seep water fills a container of known volume.

3.1.4.5 Analytical methods

Seep water samples will be analyzed for site-specific chemicals using the methods presented in Table 3-4. Specific data quality objectives and target detection limits for each method will be specified in the seep QAPP. Analytical methods in Table 3-4 may change in the seep QAPP, once detection limit requirements are identified. Dissolved chemical concentrations will be measured using appropriate methods, which will be specified in the seep QAPP (i.e., filtration or centrifugation).

Table 3-4. Analytical methods for seep water samples

Parameter	Method
Semivolatile organics[a]	GC/MS (EPA 8270C)
Volatile organics	GC/MS (EPA 8260B)
PCBs (as Aroclors)	GC/ECD (EPA 8082)
Mercury	CVAF (EPA 1631E)
Arsenic	GFAA (EPA 7060A)
Other metals	ICP-MS (EPA 200.8)
Organochlorine pesticides	GC/ECD (EPA 8081A)
Conductivity	Conductivity meter (EPA 120.1)

CVAF – cold vapor atomic fluorescence
ECD – electron capture detection
FPD – flame photometric detection
GC – gas chromatography
ICP – inductively coupled plasma-atomic emission spectrometry
MS – mass spectrometry
GFAA – graphite furnace atomic absorption

[a] 1,4-dioxane will also be analyzed with this method in samples collected in the vicinity of the Georgetown plume downgradient from Philip Services or at other locations if potential upgradient sources of this chemical are identified in groundwater in ongoing source control work

3.1.5 Benthic invertebrate community characterization and tissue and sediment sampling and chemical analyses

A QAPP for the benthic community characterization and for the collection and chemical analyses of co-located benthic invertebrate tissue and surface sediment samples will be submitted to EPA and Ecology for review, comment, and approval following their approval of this work plan. This section describes the general scope for that QAPP. Numbers of samples presented in this section are preliminary and are included to establish a general level of effort for specific studies. Sample numbers are subject to modification during finalization of the QAPP.

3.1.5.1 Benthic community characterization

Objectives and Background

The benthic invertebrate community is one of the ROCs identified in the Phase 1 ERA and will also be a Phase 2 ROC. In addition, benthic invertebrates are important prey items for other Phase 2 ROCs, including numerous fish species and spotted sandpiper. Consequently, the primary objective of the benthic community characterization task is to collect additional data within representative LDW habitats on the general composition, relative abundance, and distribution of the diverse group of animals within this community.

To date, seven studies have been conducted in the LDW to characterize the benthic invertebrate community (Table 3-5). Figure 3-4 (located at end of document) shows the historical benthic invertebrate community sampling locations in the LDW. Most of the sampling has been conducted near intertidal restoration sites (Cordell et al. 1996, 1997, 1999), particularly around Kellogg Island. Reconnaissance-level surveys have been limited to three samples collected as part of the Puget Sound Ambient Monitoring

Program (Ecology 2000). Additional details of these studies will be provided in the benthic invertebrate QAPP.

Table 3-5. Benthic invertebrate datasets collected in the LDW

Report Title	Year Conducted	Citation	Study Details
Sediment Quality in the Puget Sound	1998	Ecology (2000)	3 benthic community samples
King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay - Benthic Task	1997	King County (1999c)	6 benthic community samples
Duwamish Coastal America Restoration and Reference Sites: Results from 1997 monitoring studies	1997	Cordell et al. (1999)	21 benthic community samples
Duwamish Coastal America Restoration and Reference Sites: Results from 1996 monitoring studies	1996	Cordell et al. (1997)	21 benthic community samples
Duwamish Coastal America Restoration and Reference Sites: Results from 1995 monitoring studies	1995	Cordell et al. (1996)	6 benthic community samples
Terminal 107 (Kellogg Island) biological assessment	1989	Williams (1990)	34 benthic community samples (18 stations)
Benthic community impact study for Terminal 107 (Kellogg Island) and vicinity	1976, 1977	Leon (1980)	48 benthic community samples (13 stations)

Study Design

A qualitative benthic community survey will be conducted to provide general information related to benthic invertebrate resources in the LDW in various habitat types. A quantitative survey would only be justified if there were to be statistical comparisons with reference area results. Because the LDW channel has been channelized and deepened to accommodate navigation, this system hydraulically functions differently from other river estuaries in Puget Sound that could be used as a potential reference site. Therefore, interpreting a quantitative comparison with reference areas is technically difficult and benthic community structure is not likely to be an effective endpoint to assess risks to the benthic community. The primary data to be collected in Phase 2 to quantitatively evaluate risks to the benthic community are surface sediment chemistry data and the results of site-specific sediment toxicity tests, as described in Section 3.1.8.2.

The benthic community results may also provide information to guide benthic tissue sampling locations to those with greater abundance (particularly if issues arise regarding the ability to collect sufficient tissue mass), and will be useful in assessing the ability of the market basket tissue samples to represent benthic invertebrate communities from different habitat types.

Most existing benthic community data from the LDW were collected in the region between Kellogg and Harbor Islands. Only a few samples have been collected upstream of Kellogg Island. The small amount of existing data may not be representative of all important benthic habitats present throughout the LDW, and two of the datasets are greater than 10 years old so they will not be used in Phase 2. Physical, chemical, and biological factors that can influence benthic community composition vary over the 5 mi of the LDW. Those that are likely to be important are:

- salinity range
- water depth
- sediment grain size
- sediment total organic carbon (TOC) content
- flow regime (e.g., depositional vs. erosional)
- dissolved oxygen concentration range
- aquatic macrophyte presence and/or abundance
- sediment chemical concentrations

Many of these factors correlate with one another (e.g., sediment grain size usually correlates with TOC content and both are heavily influenced by the local flow regime). Benthic community characterizations will be conducted at approximately 10 to 15 locations (single composite sample per location) in the LDW, which, together with existing data, will provide a qualitative characterization of the types of benthic invertebrate communities found within the LDW. Replicated samples at each location are not necessary because there is no intent to statistically compare the communities among LDW locations or with a reference area. Specific sampling locations from representative LDW habitats will be described in the benthic invertebrate QAPP.

Sampling Methods

At each intertidal and subtidal location, three samples will be collected and composited into one sample. The samples will be sieved in the field using a 0.5-mm mesh sieve. The material in the sieve will be broken up with a gentle spray of water and rinsed to separate the organisms from sediment and organic matter. Once the sieving is complete, the remaining material from all three samples will be combined to form a single composite sample and rinsed into wide-mouthed plastic jars to which a buffered preservative (7-10% formalin) has been added.

Analytical Methods

Samples collected for benthic community characterization will be sorted to remove benthic invertebrates from debris in the sample. At the taxonomy laboratory, the entire sample will be emptied into a 0.5-mm mesh sieve and then washed into a shallow pan of water. Large pieces of debris will be inspected for attached invertebrates and then removed from the sample. The sample will be gently agitated to separate organic matter from inorganic sediments, and the lighter organic matter will be poured back into the 0.5-mm sieve. The inorganic material remaining in the pan will be repeatedly washed and decanted until no organic material remains. It will then be visually inspected under a dissecting microscope for any remaining invertebrates. This sorting method is best suited for coarser sediment grains containing small amounts of organic matter. If this sorting method is deemed unsuitable, small amounts of the samples will be placed into a Petri dish and the laboratory technician will systematically sort through the samples removing each organism with a pair of fine forceps. Each dish will be sorted twice to ensure that all organisms have been removed. Each organism removed from the sample will be placed in one of the following major taxonomic groups: Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous phyla. The samples will be preserved with 95% ethanol, with the objective of achieving a final concentration of 70–80% ethanol (water entrained in the sample will dilute the preservative). The actual volume of ethanol added to each sample may vary, depending on sample characteristics. In general, a 1:1 ratio (by volume) of preservative to sample material will achieve the desired concentration.

Sorted organisms will be identified and keyed to the lowest taxonomic level practical, generally the species level, by an experienced taxonomist. Only those taxonomic keys that have been peer-reviewed and are available to other taxonomists will be used. At least one specimen of each taxon will be placed in the project synoptic reference collection. Once the sample is completed, the organisms will be returned to the original vial. Numerical abundance data will be reported for each sample by the lowest taxa practical and by major taxonomic groups (e.g., Annelida, Crustacea, Mollusca). Biomass will also be calculated and presented for the same major taxonomic groups.

Laboratory quality control (QC) procedures include resorting of 20% of each sample to estimate percent efficacy and re-identification of 5% of the samples by a second taxonomist. A second taxonomist will also examine the synoptic reference collection. Upon completion of sample identification and QC, the archived and reference specimen vials (grouped by station and date) will be placed in jars with a small amount of 70% ethanol and tightly capped. Complete details of the benthic community characterization will be documented in the benthic invertebrate QAPP.

3.1.5.2 Synoptic benthic invertebrate tissue and sediment sampling and chemical analyses

The benthic invertebrate community is one of the ROCs identified in the Phase 2 ERA, and also serves as important prey items for other Phase 2 ROCs, including numerous fish species and spotted sandpiper. Therefore, additional co-located tissue and sediment chemistry data are needed to assess risks in Phase 2.

To date, one study has been conducted in the LDW to characterize chemical concentrations in benthic invertebrate tissue samples. The King County Water Quality Assessment (King County 1999b) collected four composite tissue samples of approximately 2000 amphipods each near Kellogg Island with sediment samples collected in the general vicinity of the island. These samples were analyzed for metals, TBT, semivolatile organic compounds, and PCBs. The WQA also included results of the analysis of 22 composite tissue samples of mussels (each representing 50 to 100 mussels) from the LDW, which were analyzed for metals, TBT, semivolatile organic compounds, and PCBs. No tissue data exist for clams collected from the LDW.

This section describes the following three study components: benthic invertebrate market basket and surface sediment sampling to support fish and sandpiper exposure analyses, benthic invertebrate exposure to TBT, and collection of clams and associated sediments to support human health and ecological exposure analyses. Study design, sampling methods, and analytical methods are discussed for each.

Benthic Invertebrate Market Basket and Surface Sediment Samples

Study design

Benthic invertebrate tissues will be collected and chemically analyzed to serve two objectives:

- to estimate exposure of fish and spotted sandpipers (a wildlife ROC) to chemicals in their prey
- to support the food web model

To support these objectives, synoptic benthic invertebrate tissue and sediment samples will be collected throughout the LDW. Benthic invertebrates are expected to be present site-wide, but their abundance and diversity are expected to vary both temporally and spatially. Benthic invertebrate tissue sampling will occur in late summer, when abundance and diversity are expected to be greatest. The tissue sampling approach for benthic invertebrates will address this spatial diversity, with a focus on both:

- spatial distribution of sediment concentrations of COPCs for sandpiper and fish
- preferred fish and wildlife habitats, to the extent known[16]

All three fish ROCs (juvenile chinook salmon, English sole, and Pacific staghorn sculpin) consume benthic invertebrates. The preferred habitat for English sole and sculpin includes both intertidal and subtidal locations (Jones 1962; Lassuy 1989), although English sole primarily reside in subtidal habitat (Day 1976); intertidal habitat is generally assumed to be preferred by juvenile chinook salmon (Beauchamp et al. 1983). Spotted sandpiper is the only wildlife ROC with significant benthic invertebrate ingestion. Spotted sandpipers forage in intertidal habitats along the LDW, with an estimated foraging range of about 1.5 km along the LDW (Norman 2002). Therefore, the primary foraging habitat is expected to be in areas within about 0.75 km of their nesting sites, which have been observed on Kellogg Island (Canning et al. 1979). The

[16] The bathymetric survey, benthic community characterization, and sandpiper site use assessment and habitat survey will inform the benthic invertebrate tissue sampling design.

extent to which sandpiper or other shorebirds could use other intertidal habitat along the LDW is not known. To further delineate sandpiper exposures, as discussed in Section 3.3.1, a qualitative sandpiper habitat survey will also be conducted as part of Phase 2 prior to benthic invertebrate tissue collection.

Based on the above considerations, benthic invertebrates will be collected from approximately 10 subtidal and 10 intertidal sites located throughout the LDW (for a total of approximately 20 composite samples). At each benthic invertebrate collection location, a "market basket" benthic invertebrate tissue sample will be collected. In the market basket approach, all benthic invertebrates collected within a given sampling area are combined into a single composite sample. The general composition of each composite sample will be noted, as described in more detail below. The size of the area over which benthic invertebrates are composited will depend on their abundance in a particular target area. This sampling approach will provide a snapshot of available prey for fish and wildlife in that area. Because these samples are intended to reflect prey types accessible to fish and sandpiper, larger bivalves and crustaceans will not be included.

Sample locations will be chosen to cover a range of sediment concentrations for PCBs and COPCs recommended for additional evaluation for sandpiper or fish through dietary exposure, based on the Phase 1 ERA. Phase 1 COPCs evaluated using a dietary approach were lead for sandpiper, and arsenic, copper, and PAHs for fish. Other considerations for placement of sampling locations include the distribution of relevant habitat for sandpiper and fish and the distribution of benthic communities in different habitat types. The process for determining specific locations will be documented in the benthic invertebrate QAPP, developed in coordination with EPA and Ecology.

The market basket benthic invertebrate tissue data and synoptic sediment data will be evaluated to develop a biota-sediment accumulation factor (BSAF) for each of the COPCs,[17] which will then be used to estimate benthic tissue concentrations in areas where only sediment data were collected. The applicability of the BSAFs to sediment locations in the LDW where site-specific benthic tissue data are not available will depend on an analysis of the data generated for different market basket compositions or sediment concentrations/types. The synoptic sampling event will be designed to meet the objective of assessing the relationship between sediment and benthic tissue concentrations. Data regarding the relationship between concentrations of risk-driving bioaccumulative chemicals, such as PCBs, in sediment and benthic invertebrate tissue may also be useful in development of the food-web model (Section 3.3.3).

[17] The standard derivation of a BSAF applies to organic chemicals and includes lipid-normalized tissue chemistry and organic carbon-normalized sediment chemistry data. A similar ratio may be calculated for metals, but the tissue and sediment chemistry data are not typically normalized for these chemicals. Some researchers may use the term BSAF for this ratio for metals, but it is also referred to as a bioaccumulation factor (BAF).

Sampling methods

Benthic invertebrate tissue samples will be collected in conjunction with sediment sample collection. Subtidal samples will be collected with a 0.1-m^2 double van Veen grab sampler, as described in Section 3.1.8.1. Intertidal samples will be collected by digging the sediment from a 0.1-m^2 square to a depth of 10 cm. Multiple samples will be collected at each area until enough tissue mass is obtained for the required analyses. Subtidal sites will be located using GPS and the samples will be collected within 1-2 m of the intended location. The intertidal samples will be collected along transects running perpendicular to the waterline between MLLW and MHHW. A minimum of five grab sediment samples will be collected at each location and composited. If insufficient tissue mass is collected after 10 grabs per station, EPA and Ecology will be consulted to determine a course of action.

Sediment containing benthic invertebrates for tissue analysis will be removed from the collection device and transferred directly to a 0.5-mm mesh sieve. The sediment in the sieve will be broken up with a gentle spray of water and rinsed to separate the organisms from sediment and organic matter. Once the sieving is complete, the remaining material will be rinsed into wide-mouthed plastic jars and stored on ice.

A synoptic composite sediment sample will be collected along with each benthic invertebrate tissue sample. Each composite sediment sample will be prepared by removing an equal portion of sediment from each benthic grab sample prior to sieving. Once enough benthic grabs have been obtained to provide sufficient tissue sample mass for analyses, this composite sediment sample will be completely mixed. These synoptic sediment samples are in addition to surface sediment chemistry samples identified in Section 3.1.8.

Following collection of benthic tissue, organisms will be roughly sorted in the Windward laboratory and a qualitative description of organism class composition, including orders or families, if practical, will be reported. Easily identifiable organisms will be identified to genus or species. A photograph will be taken of each sorted composite sample to document the approximate distribution and abundance of major taxonomic groups, and ancillary notes will be recorded. If subsamples are composited from large areas (> 10 m apart) due to a paucity of benthic invertebrates, the community composition will be documented per subsample in each composite. All organisms except larger mollusks or crustaceans will be used for the benthic invertebrate market basket samples.

Analytical methods

Benthic invertebrate tissue samples will be analyzed chemically to address data needs of the Phase 2 ERA and HHRA. Chemicals have been grouped into analyte classes based on analytical methodology (e.g., semivolatile organic compounds [SVOCs]), and evaluated to determine which class of analytes should be analyzed and for what reason (Tables 3-6 through 3-9). In these tables, the yes/no statements regarding potential individual pathways were used to arrive at an overall decision (**YES/NO** in bold type) regarding the analysis of each analyte. Based on this evaluation, all chemicals or groups of chemicals that were considered are proposed for analysis in benthic invertebrate market basket tissue samples. These chemicals include SVOCs (including PAHs), metals, PCBs as Aroclors, total PCB congeners, mercury, and organochlorine pesticides. The need for dioxin/furan tissue analysis will be determined if the results of the urban background sediment chemical analyses indicate quantitative risk characterization is needed (see Section 3.1.8.1). If sufficient sample mass can be collected, a portion of the tissue samples will be archived for potential dioxin/furan analysis or additional PCB congener analysis (see Section 3.1.6.4). Volatile organic compounds (VOCs) will not be analyzed; they do not tend to bioaccumulate in tissue because of their low hydrophobicity.

Table 3-6. Analyses of TBT and SVOCs (including PAHs) in benthic invertebrate tissue

Tissue Type	Applicable ROC and Exposure Pathway	TBT	SVOCs (including PAHs)
Benthic invertebrates	Fish (ingestion)	no: exposure assessed via tissue residue	yes: exposure assessed via diet
	Birds (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Mammals (ingestion)	no: small component of diet	no: small component of diet
	Benthic (ROC)	yes: exposure assessed via tissue residue	no: exposure/effects assessed by toxicity testing or comparison to SMS
		YES[b]	**YES**

a The King County wildlife risk assessment was conducted as part of the King County Water Quality Assessment for the Duwamish River and Elliott Bay; assumptions in this assessment will be documented in the fish and crab tissue QAPP

b Neogastropod or mesogastropod species (or a surrogate if insufficient tissue is available). See benthic invertebrate and TBT subsection below.

Table 3-7. Analyses of mercury and metals in benthic invertebrate tissue

Tissue Type	Applicable ROC and Exposure Pathway	Mercury	Metals
Benthic invertebrates	Fish (ingestion)	no: exposure assessed via fish tissue residue, not diet	yes: exposure assessed via diet
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	no: small component of diet	no: small component of diet
	Benthic (ROC)	no: exposure/effects assessed by toxicity testing or comparison to SMS	no: exposure/effects assessed by toxicity testing or comparison to SMS
		YES	**YES**

Table 3-8. Analyses of PCB Aroclors and PCB congeners in benthic invertebrate tissue

Tissue Type	Applicable ROC and Exposure Pathway	PCB Aroclors	Total PCB Congeners (subset of samples) [a]
Benthic invertebrates	Fish (ingestion)	no: exposure assessed via fish tissue residue, not diet	no: exposure assessed via fish tissue residue, not diet
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	no: small component of diet	no: small component of diet
	Benthic (ROC)	no: exposure/effects assessed by toxicity testing or comparison to SMS	no: exposure/effects assessed by toxicity testing or comparison to SMS
		YES	**YES**

[a] Tissue samples will all be analyzed for Aroclors and a subset of these samples will be analyzed for total PCB congeners to cover the range of total PCBs (Aroclor sum) and to represent different reaches in the LDW. If the relationship is highly variable between an Aroclor sum or a sum of peaks obtainable through a low resolution analysis and total PCBs based on congener sum, the data will be evaluated to assess whether analysis of all benthic invertebrate samples for total congeners is likely to reduce the variability. If yes, then all tissue samples will be analyzed for total PCB congeners.

Table 3-9. Analyses of organochlorine pesticides in benthic invertebrate tissue

Tissue Type	Applicable ROC and Exposure Pathway	Organochlorine Pesticides
Benthic invertebrates (market basket)	Fish (ingestion)	no: exposure assessed via fish tissue residue, not diet
	Birds (ingestion)	yes: exposure assessed via diet
	Mammals (ingestion)	no: small component of diet
	Benthic (ROC)	no: exposure/effects assessed by toxicity testing or comparison to SMS
		YES

The analytical methods are listed in Table 3-10. Risk-based concentration (RBC) goals which are developed to identify desired detection limits) and specific data quality objectives and target detection limits for each method will be specified in the benthic invertebrate QAPP. The analytical methods in Table 3-10 may change in the QAPP, once detection limit requirements are identified.

Table 3-10. Analytical methods for benthic invertebrate tissue and synoptic sediment

PARAMETER	METHOD	NOTES
Semivolatile organics, including PAHs	GC/MS (EPA 8270)	
PCBs (as Aroclors)	GC/ECD (EPA 8082)	
Organochlorine pesticides	GC/ECD (EPA 8081)	
PCB congeners	HRGC/HRMS (EPA 1668A)	
Mercury	CVAA (EPA 7471)	
Other metals	ICP-AES (EPA 6010)[a]	specific analyte list to be determined
TBT[b]	GC/FPD (Krone et al. 1989)	
Lipids	Gravimetric (NOAA 1993)	

CVAA – cold vapor atomic absorption
ECD – electron capture detection
FPD – flame photometric detection
GC – gas chromatography
HRGC – high-resolution gas chromatography
HRMS – high-resolution mass spectrometry
ICP-AES – inductively coupled plasma-atomic emission spectrometry
MS – mass spectrometry
TBT – tributyltin

[a] Other methods (i.e., GFAA or ICP-MS) may be used for metals depending on the detection limit goals to be specified in the benthic invertebrate QAPP

[b] TBT will be analyzed in gastropod tissue or a surrogate taxon if gastropods are not sufficiently abundant

Benthic Invertebrates and TBT

Study design

Benthic invertebrate tissue chemistry data will be collected to assess risks to benthic invertebrates from exposure to TBT. Benthic invertebrate tissue samples for assessing TBT exposure will not be collected using a market basket approach, but will instead target the species most sensitive to TBT (neo- and meso-gastropod species), based on a tiered approach as described below. This approach will be further documented in the benthic invertebrate QAPP and a technical memorandum.

Prior to the final benthic invertebrate QAPP, a technical memorandum will be submitted to EPA and Ecology outlining methods for a pilot study to assess sampling techniques and the feasibility of collecting sufficient gastropod tissue for chemical analysis from locations representing a broad range of sediment TBT concentrations. All benthic invertebrates collected in the pilot survey samples will be photographed (in the sieve) and sorted and weighed by class. Following the pilot study, the results of the study and recommendations regarding preferred sampling techniques and which tissue samples (i.e., gastropod, surrogate taxon, or market basket) to analyze for TBT will be presented to EPA and Ecology. A surrogate taxon of benthic invertebrates will be recommended for analysis in the event that sufficient gastropod tissue cannot be collected but gastropods are present in sufficient abundance to warrant concern. Market basket samples will be analyzed for TBT if gastropods do not appear to utilize the site to any significant degree. A meeting will be held with EPA and Ecology to reach consensus on the selection of these samples.

Following approval of the benthic invertebrate QAPP, surface sediment and tissue will be collected and analyzed from areas expected to cover a wide range of TBT concentrations. The number of samples, tissue type, collection methods, and location of samples will be specified in the QAPP, based in part on the results of the pilot survey, the range of TBT concentrations in sediment based on existing data, and possibly the statistical analysis of existing sediment/tissue data from West and East Waterways. Tissue type to be collected (i.e., gastropod, surrogate taxon, or market basket) will be dependent on the results of the pilot study. Final decisions regarding locations and tissue types to analyze will be made in consultation with EPA and Ecology.

The relationship between TBT concentrations in sediment and tissue will be evaluated, in consultation with EPA and Ecology, potentially following the approach outlined in Appendix B. If a sufficient relationship is found between sediment and tissue concentrations of TBT, no porewater collection for TBT analysis will be required to assess risks. If an insufficient relationship is found between sediment and tissue concentrations of TBT, and the newly collected data indicate a reasonable potential for unacceptable risk, synoptic sediment, porewater, and (potentially) tissue data will be collected from the same locations the tissue samples were collected to determine if the porewater data provide a more robust predictive relationship between tissue-based risks and site media (sediment or porewater).

Sampling methods

The key objective of the pilot survey for gastropods is to assess the feasibility of collecting sufficient gastropod tissue for chemical analysis of TBT. More than one method of collection may be attempted to assess feasibility, including, for example, an epibenthic sled, a larger grab sample than a typical van Veen grab, or a bullrake. The pilot survey will determine the most appropriate method and the feasibility of collecting gastropods for inclusion in the benthic invertebrate QAPP. A method for sediment sampling compatible with the selected tissue sampling method will be outlined in the benthic invertebrate QAPP.

Analytical methods

Gastropod samples (or a surrogate) and associated sediment samples will be analyzed for TBT,[18] moisture, and TOC (sediment only). Analytical methods are summarized for these analytes in Table 3-10.

[18] Wherever TBT is listed, all butyltins will be analyzed, although only TBT data will be used to assess risks.

Synoptic Clam and Sediment Sampling and Chemical Analyses

Study design

The primary objectives of the synoptic clam and sediment chemistry sampling are to:

- provide chemical concentrations in clam tissue (no tissue data currently exist for LDW clams)
- evaluate the relationship between chemical concentrations in synoptically-collected clam and sediment samples for possible use in the food web model
- evaluate the relationship between chemical concentrations in synoptically-collected clam and sediment samples for use in exposure analyses of wildlife and human health, as appropriate

The key consideration for study design is to collect composite clam tissue samples from portions of the LDW where they occur. Humans may collect clams wherever clams are of harvestable size. The results of the clam abundance survey described in Section 3.1.2 will be used in the benthic invertebrate QAPP to determine target sampling locations and the appropriate number of composite clam tissue samples to collect.

Sampling methods

Clams will be collected by hand and shovel in the summer at low tide. One composite surface sediment sample will be collected synoptically at each clam sampling location using methods specified in the benthic invertebrate QAPP. Specific sampling considerations will be documented in the benthic invertebrate QAPP, developed in coordination with EPA and Ecology.

Analytical methods

Because the primary use of these data is for the Phase 2 HHRA, the clam samples will be analyzed for the same target analytes as other fish and crab samples to be used in the HHRA: SVOCs, metals, PCB Aroclors, PCB congeners (subset of samples), and organochlorine pesticides. The analytical methods are the same as those shown in Table 3-10. Clam samples will be analyzed for arsenic species to determine the fraction of inorganic arsenic in the samples. The number of clam samples analyzed for arsenic speciation and the arsenic speciation method will be specified in the benthic invertebrate QAPP.

3.1.6 Fish and crab tissue sampling and chemical analyses

A QAPP for the collection and chemical analyses of fish and crab tissue samples will be submitted to EPA and Ecology for review, comment, and approval following their approval of this work plan. This section describes the general scope for that QAPP. Numbers of samples presented in this section are preliminary and are included to establish a general level of effort for specific studies. Sample numbers are subject to modification during finalization of the QAPP.

3.1.6.1 Objectives and background

In addition to the juvenile chinook salmon and benthic invertebrate tissue collection and chemical analyses described in Sections 3.1.1 and 3.1.5, the data needs memorandum (Windward 2003f) identified the need for analysis of additional fish and crab tissue samples to support the Phase 2 RI and associated risk assessments. In particular, additional tissue samples are needed to:

- supplement existing fish and crab tissue chemistry data to estimate fish and crab exposure to bioaccumulative chemicals for the assessment of risks using a critical tissue residue approach
- supplement existing fish and crab tissue chemistry data to estimate human, fish,[19] and wildlife exposure to bioaccumulative chemicals through a dietary approach
- provide an indication of spatial variability in chemical concentrations in fish and crab tissue throughout the site for species with both small and large home ranges to assist in the food web model (Section 3.3.3)
- provide PCB congener-specific tissue chemistry data for critical prey species to supplement existing PCB Aroclor tissue chemistry data, for the assessment of PCB risks to wildlife and humans
- further characterize human exposure to chemicals through ingestion of fish and crab that may be obtained currently or in the future from the LDW
- analyze total arsenic concentrations (and arsenic speciation in a subset of samples) in English sole, perch, and crabs collected from the LDW for the Phase 2 HHRA
- characterize both total and inorganic arsenic concentrations in fish and shellfish from background areas outside the LDW

Tissue samples will be collected during Phase 2 to supplement existing tissue chemistry data collected since 1990. Existing tissue chemistry data for the study area are available from six studies (Table 3-11). The tissue collection locations by event and sample type are shown in Figure 3-5 (located at end of document). Existing tissue chemistry data are most abundant for adult chinook and coho salmon, followed by English sole, mussels, perch, and crabs. PCBs (as Aroclors) were analyzed in most samples. Pesticides and SVOCs were also analyzed frequently. Mercury, arsenic, lead, copper, and TBT were analyzed in fewer samples.

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[19] Metals (except mercury) and PAHs will be assessed using a dietary approach; all other chemicals will be assessed using a critical tissue residue approach.

Table 3-11 includes all available tissue chemistry data collected in the LDW since 1990 and indicates which samples were used in the Phase 1 RI and risk assessments. EPA (2003) concluded that not all data listed in Table 3-11 are acceptable for use in the Phase 2 risk assessments because of data quality considerations, availability of QA/QC documentation, or the adequacy of previously conducted data validations. For example, the two juvenile chinook salmon studies listed at the end of the table (shown in italics) were used in the design for the juvenile chinook salmon study (see Section 3.1.1). EPA is continuing discussions with NOAA regarding the usability of these data in Phase 2, because the QA/QC documentation for these datasets is not readily available. If concerns regarding QA/QC documentation cannot be resolved, the NOAA data will be discussed in the uncertainty assessment, but will not be used for risk characterization in the Phase 2 ERA.

Additional tissue chemistry data have been collected within the last 2 years but were collected after the cutoff date for incorporation into Phase 1. For example, juvenile chinook salmon were collected in June 2002 near Kellogg Island by Windward Environmental as part of a study of the East Waterway. Before preparing the fish and crab tissue QAPP, a technical memorandum containing an updated list of tissue data sets to be used in Phase 2 and the rationale for their inclusion will be submitted to EPA and Ecology. This updated list of tissue data sets to be used for the Phase 2 RI will be included in the fish and crab tissue QAPP.

Table 3-11. Tissue chemistry samples collected from the LDW since 1990

Title	Year	Species	N [a]	Sample type	Number of Animals per Sample	Chemicals	RI [b]	HHRA [c]	ERA Benthic [d]	ERA Fish [d]	ERA Wildlife [d]
Waterway Sediment Operable Unit Harbor Island Superfund Site - Assessing human health risks from the consumption of seafood (ESG 1999)	1998	English sole	3	skinless fillet	5	Hg, TBT, PCBs	X	X			
		red rock crab	3	edible meat	5		X	X	X		
		Dungeness crab	1	edible meat	1		X	X	X		
		striped perch	3	skinless fillet	1-5		X	X			
King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay (King County 1999c)[e]	1996-1997	Dungeness crab	2	edible meat	3	metals, TBT, semivolatiles, PCBs	X	X	X	X	X
			1	hepatopancreas	3			X	X	X	X
		English sole	3	skinless fillet	20		X	X		X	
			3	whole body [f]	20		X			X	X
		amphipods	4	whole body	~ 2000		X		X	X	X
		shiner surfperch	3	whole body	10		X			X	X
		mussels	22	whole body	50-100		X	X		X	X
Puget Sound Ambient Monitoring Program – annual sampling (West et al. 2001)	1992	English sole	3	skinless fillet	10-20	semivolatiles, pesticides, PCBs, As, Cu, Pb, Hg	X	X		X	
	1992	Coho salmon	6	skinless fillet	5		X				
	1992	Chinook salmon	6	skinless fillet	5		X				
	1993	Coho salmon	5	skinless fillet	5	pesticides, PCBs, As, Cu, Pb, Hg	X				
	1993	Chinook salmon	6	skinless fillet	5		X				
	1994	Coho salmon	5	skinless fillet	5		X				
	1994	Chinook salmon	7 [g]	skinless fillet	1-5		X				
	1995	Coho salmon	7 [g]	skinless fillet	1-5		X				
	1995	Chinook salmon	15 [h]	skinless fillet	1-5		X				
	1995	English sole	3	skinless fillet	10-20		X	X		X	
	1996	Chinook salmon	49 [i]	skinless fillet	1		X				
	1996	Coho salmon	19 [j]	skinless fillet	1-5		X				
	1997	English sole	3	skinless fillet	10-20	Hg, pesticides	X	X		X	
	1998	Coho salmon	13	skinless fillet	4		X				

Title	Year	Species	N [a]	Sample type	Number of Animals per Sample	Chemicals	RI [b]	HHRA [c]	ERA Benthic [d]	ERA Fish [d]	ERA Wildlife [d]
Elliott Bay/Duwamish River Fish Tissue Investigation (Battelle 1996; EVS unpublished; Frontier Geosciences 1996)	1995	English sole	3	skinless fillet	6	PCBs, Hg, MeHg, TBT	X	X		X	
NMFS Duwamish injury assessment project (NMFS 2002)	*2000*	*Chinook salmon (juveniles)*	*29*	*whole body*	*1-10*	*PCBs, pesticides*	*X*			*X*	*X*
			6	*stomach contents*	*5-10*					*X*	
Contaminant exposure and associated biochemical effects in outmigrant juvenile chinook salmon from urban and non-urban estuaries of Puget Sound (Varanasi et al. 1993) [k]	*1989-1990*	*Chinook salmon (juveniles)*	*14*	*whole body*	*2-10*	*pesticides, PCBs, PAHs*	*X*			*X*	*X*
			6	*stomach contents*	*10*					*X*	

MeHg – methylmercury

Italicized studies will be used for qualitative purposes only in Phase 2 due to the inadequacy of available QA/QC documentation (EPA 2003).

[a] Number of individual or composite samples

[b] Phase 1 RI, Section 4.2.7

[c] Phase 1 HHRA (Appendix B)

[d] Phase 1 ERA (Appendix A)

[e] Data from crab and English sole samples that were cooked were collected during the King County Water Quality Assessment, but were not used in the Phase 1 RI or in the quantitative sections of the Phase 1 risk assessment. These data were used by King County (1999a) in their HHRA. Approximately 30 additional mussel samples, beyond those indicated in the table, were analyzed as part of four- to six-week caged mussel deployments designed to assess the portion of bioaccumulative chemicals from CSO inputs. Data from these samples were not used in the Phase 1 RI or risk assessments because the resident mussel tissue chemistry data are more representative of natural exposure conditions.

[f] Samples are remnants following the subsampling of fillet tissue. In addition, livers were removed from some fish in the composite samples.

[g] One sample was an individual fish, not a composite sample

[h] Two samples were individual fish, not composite samples

[i] All samples were individual fish, not composite samples

[j] Five samples were individual fish, not composite samples

[k] Six composite samples of juvenile chinook salmon livers were also analyzed. Data from these samples were not used in the Phase 1 RI or risk assessments because whole-body concentrations were available for the purpose of the RI and toxicological data based on liver concentrations were unavailable for comparison in the Phase 1 ERA.

3.1.6.2 Study design

Various tissues will be collected to supplement the existing tissue chemistry dataset for use in the Phase 2 risk assessments. Table 3-12 summarizes the tissue types that will be collected as well as the information these samples will provide in support of the risk assessments. The tissue sampling design is based on the following considerations (consistent with EPA (2000a) guidance):

- expected home range of each species, including any known habitat preferences
- specific risk assessment and food-web modeling data needs
- spatial pattern of sediment contamination
- logistical considerations (e.g., sampling methods) including public access and preferred fishing locations

Table 3-12. Summary of data needs for fish and crab tissue samples

Tissue Type	HHRA Data Need	ERA Data Needs
English sole, whole body	Site-wide data needed for ingestion dose estimate	Site-wide data needed for critical tissue residue approach for fish; and ingestion dose estimate for sculpin and wildlife
English sole, fillet	Site-wide data needed for ingestion dose estimate	Not used
Perch, whole body	Site-wide data needed for ingestion dose estimate[a]	Site-wide data needed for ingestion dose estimate for sculpin and wildlife
Sculpin, whole body	Not used	Site-wide data needed for critical tissue residue approach for fish; and ingestion dose estimate for wildlife
Crab, edible meat	Site-wide data needed for ingestion dose estimate	Site-wide data needed for critical tissue residue approach for crab; and ingestion dose estimate for fish and wildlife
Crab, hepatopancreas	Site-wide data needed for ingestion dose estimate	Site-wide data needed for critical tissue residue approach for crab (hepatopancreas-based TRVs); and ingestion dose estimate for fish and wildlife[b]
Rockfish, whole body and fillets	Need for chemical analyses will be based on site use, abundance, and size of fish	Need for chemical analyses will be based on site use, abundance, and size of fish

Note: The collection of juvenile chinook salmon tissue samples for chemical analyses is described in Section 3.1.1.

a If a sufficient number of adult striped or pile perch are caught while sampling for other fish species, fillets from these fish will be composited in consultation with EPA and Ecology, and chemically analyzed.

b Crab hepatopancreas data will be combined with edible crab meat data to estimate whole-body crab concentrations for use in fish and wildlife dietary dose estimates.

The primary use for the tissue chemistry data is for the risk assessments. The study design for this primary use should thus include a sufficient number of samples to adequately characterize the exposure of people or animals eating the target species.

Because the objective of the risk assessments is to estimate average chemical concentrations for exposure of humans, fish, and wildlife over time rather than to estimate individual variability, composite rather than individual samples will be collected. Data sufficiency is a function of the adequacy of spatial coverage and the total number of samples needed to derive an exposure point concentration (EPC) for use in the risk assessments. The adequacy of spatial coverage can be ensured by collecting fish or crabs throughout the portions of the LDW where they are found. Although EPCs can technically be calculated for any number of samples, the preferred statistic is the 95% upper confidence limit (UCL) on the mean, which typically requires at least 6 composite samples, depending on the among-sample variability in concentrations. With a smaller number of samples, the 95% UCL on the mean may be higher than the maximum concentration, in which case the maximum is used as the EPC. Therefore, a minimum of 6 composite samples will be collected throughout the LDW for each species for which an EPC is to be calculated. However, because a secondary use for tissue chemistry data is to calibrate the food-web model, additional samples may be needed, as discussed below.

The food web model, which may be used to estimate sediment RBGs for the site for bioaccumulative, risk-driver chemicals such as PCBs, provides a link between chemical concentrations in tissue and sediment over a particular spatial scale. If a given composite sample of fish or crabs consists of animals that were exposed to sediment contamination throughout the site, then the study design needed to satisfy the food web model may be identical to the study design needed for site-wide risk assessment purposes. If, however, the "home range" of the target fish or crab species is less than the entire site, or a species' natural distribution is less than the entire site, it may be appropriate to include sampling areas for the food web model that are smaller than the entire site. Site-specific home ranges or distributions for LDW fish have not been determined, but it is known that some of the target species do not inhabit all areas in the LDW. For example, Seattle Aquarium divers trying to collect striped and pile perch during a 1998 sampling event were unable to locate them south (upstream) of Kellogg Island (ESG 1999).

The appropriate number and size of sampling areas is dependent on the expected home range or distribution of each species, the variability in sediment concentrations, and logistical considerations related to trawling (i.e., it may be difficult to effectively deploy a trawl within very small areas) and fish abundances (i.e., the level of effort to acquire the desired number of an individual species in a very small area may be prohibitive). If tissue concentrations vary among areas in a reasonably consistent manner with sediment concentrations in those areas, it may be appropriate to conduct food-web modeling for areas smaller than the entire LDW. Given the inherent uncertainties in food-web modeling (Gobas 1993; Morrison et al. 1997), if differences in tissue or sediment concentrations among areas are less than a factor of two, modeling multiple areas will be of limited usefulness and may not be performed.

Both risk assessment and food web model data needs were considered in selecting the number and location of tissue sampling areas. One of the key data needs was to provide paired sediment and tissue data over a range of PCB sediment concentrations. Therefore, the distribution of PCB concentrations in the sediment was reviewed to delineate key sampling areas. These areas were defined through the use of a rolling average PCB concentration in sediment (as described below). Area-weighted average sediment PCB concentrations were used to select tissue sampling areas, rather than PCB concentrations at individual sediment sampling locations, because fish species will integrate exposure over their home ranges.

Using inverse distance weighting analysis in the project GIS, an interpolated grid of total PCB concentrations was calculated using Phase 1 surface sediment chemistry data. From this grid, average total PCB concentrations were calculated for 0.5- and 1.0-mi river segments at 0.1-mi intervals. River segments were set in this range of segment length to account for the fact that fish will integrate sediment contamination over their home ranges as well as a recognition that trawls over an area of this size may be needed to collect a sufficient number of targeted fish species for chemical analysis.

The following text describes how the rolling averages were calculated for the 1-mi segment case, as shown in Figure 3-6. The total PCB concentration for each 1.0-mi segment was assigned to the mid-point of each area and plotted. Average PCB concentrations were calculated from 0.0 to 1.0 RM, 0.1 to 1.1 RM, 0.2 to 1.2 RM, etc. A line was drawn through each mid-point, as shown on Figure 3-6. The maximum concentrations (> 1,200 µg/kg dw) occur at approximately RM 3.1 – 3.2, which correspond to the areas between RM 2.6 and 3.7 where there are higher concentrations of PCBs in three early action areas. Downstream of this area, the average PCB concentration is much lower (< 400 µg/kg dw). Average PCB concentrations of intermediate magnitude (800 µg/kg dw) were calculated at the upstream end of the study area. Based on the 0.5- and 1.0-mile segment analyses and the other sample design considerations, four discrete sampling areas are proposed, centered on approximately RM 0.6, 2.0, 3.3, and 4.6,[20] respectively. The fish and crab tissue QAPP will provide more specific details on each sampling area, such as river mile boundaries and sampling methods for obtaining representative tissue samples of the targeted species from each area.

[20] RM 4.6 was selected as the centroid rather than RM 4.8 because of pragmatic sampling issues.

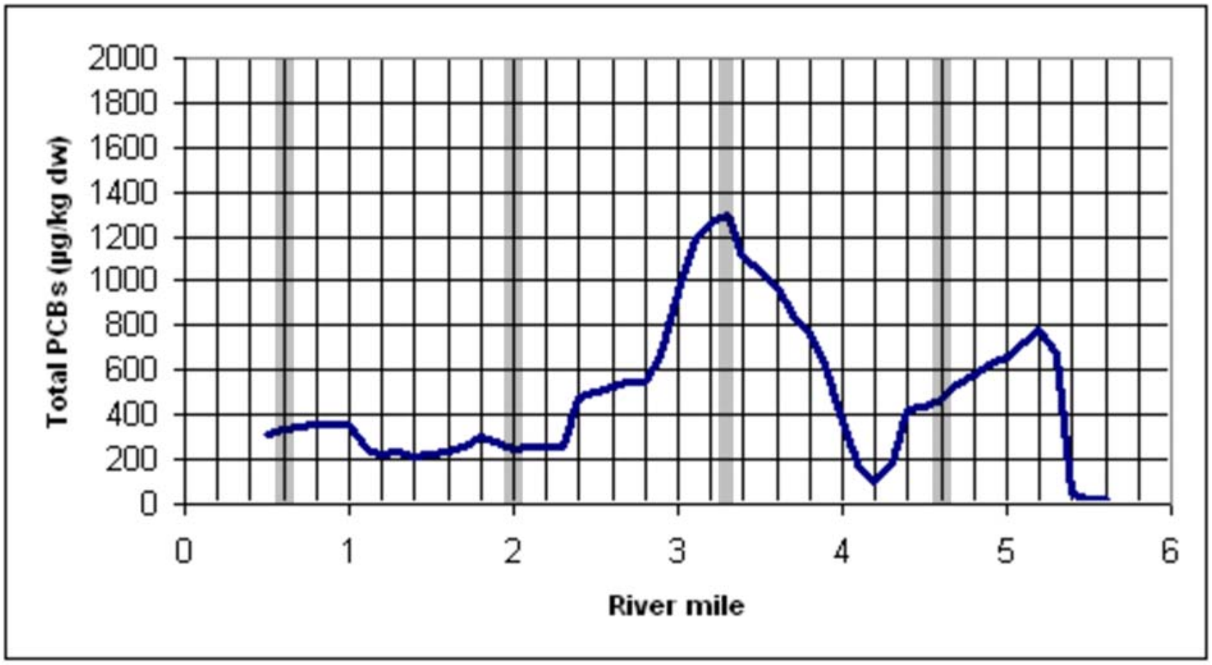

Figure 3-6. One-mile rolling average total PCB concentrations in LDW surface sediment

Note: Vertical gray bars represent the centers of the four discrete sampling areas.

The tissue sampling areas selected do not provide complete coverage of the LDW, nor are they spaced at equal distances. However, the tissue sampling areas do represent the major PCB sediment concentration ranges present in the LDW, and they are distributed at approximately equal intervals. EPA, Ecology, and LDWG agreed on this sampling scheme because it offers the best support for deriving river-wide and area-specific chemical concentrations in tissues to support risk assessment and food-web modeling.

The appropriate number of samples per area could theoretically be estimated based on the statistical power needed to determine significant differences in PCB concentrations between areas and the minimum number of samples needed to calculate a 95% UCL, should area-specific EPCs be needed for risk assessment. However, a robust power analysis is not possible given the relatively small amount of existing data and the difficulty in establishing a meaningful target for the minimum detectable difference between areas. Consequently, the number of samples per area was set at 6 to match the site-wide study design consideration described above to calculate a 95% UCL for risk assessment purposes.

Based on the analysis presented above for determining the appropriate numbers of sampling areas and composite tissue samples per area, a proposed sampling design for collecting approximately 80 composite fish tissue samples and 32 composite crab tissue samples is presented in Table 3-13. The exact locations and number of samples will be specified in the fish and crab tissue QAPP. Additional details on the number of fish or crabs per composite, sampling methods, and analytical methods will be provided in the fish and crab tissue QAPP. The notes on Table 3-13 also describe the existing data that will be used in the Phase 2 risk assessments in combination with the data collection proposed in this work plan.

Table 3-13. Proposed LDW tissue sampling design for fish and crabs

Species	Sample Type	Area 1	Area 2	Area 3	Area 4	Notes
English sole	Whole body	6	6	6	6	Starry flounder may be surrogate in areas where enough English sole cannot be caught
English sole	Fillet	2	2	2	2	6 samples/area not needed because food web model to be conducted for whole-body fish; fillet-to-whole body ratio will be developed; all samples to be skin-on; 15 existing skin-off samples with 12 from area 1 and 1 each from areas 2-4; starry flounder may be surrogate in areas where enough English sole cannot be caught
Sculpin	Whole body	6	6	6	6	No existing data;adequate numbers of sculpin of sufficient size may be difficult to collect; a surrogate species may be proposed in the QAPP
Shiner surfperch[a]	Whole body	6	6	6	6	3 existing samples of shiner surfperch from area 1
Crab	Whole body	6	6	6	6	2 existing samples (all analytes) from area 1; crab may be difficult to find in area 4
Crab	Hepato-pancreas	2	2	2	2	1 existing sample from area 1; 6 samples/area not needed because this sample type plays only a minor role in risk assessments; crabs may be difficult to find in area 4
Total		28	28	28	28	
Grand total					112	

Area 1 centered around RM 0.6, Area 2 centered around RM 2.0, Area 3 centered around RM 3.3, Area 4 centered around RM 4.6

Rockfish tissue may be analyzed if a sufficient number of adult rockfish are observed, but expected abundance is likely to be too low to support study design shown above for other species

Existing data are noted for information purposes, but the proposed study design is generally not reliant on the existence of those data

[a] Fillets of shiner surfperch will not be analyzed because fish of this small size would not be filleted prior to human consumption. If a sufficient number of adult striped or pile perch are caught while sampling for other fish species, fillets from these fish will be composited in consultation with EPA and Ecology, and chemically analyzed.

Data from appropriately sized fish will be used to assess exposure for each ecological receptor of concern and for humans. To the extent possible, each composite sample will contain the same number of male and female specimens because chemical concentrations might vary by sex. Fish will not be collected just prior to or just after spawning periods to avoid biasing results in female specimens. Because human consumers may consume fish with skin-on or skin-off, both types of samples will be collected, as listed in Table 3-13. Additional study design considerations specific to each target species are summarized below.

English Sole

English sole are expected to be present throughout the LDW. The home range of individual fish within the LDW is not known, but is suspected to be between 0.5 and 2 km based on data collected from several sites within Puget Sound (Stern et al. 2003). Human fishing activity is expected to be greater during the summer and fall months as compared to the spring months. During the winter, the majority of adult English sole migrate outside the LDW to spawn (Day 1976). English sole will be collected in the early fall, based on fishing preferences, sampling conditions, and prior to winter spawning periods when abundance is much lower.

Perch

Several perch species are found in the LDW, including striped perch, pile perch, and shiner surfperch. One or more of these perch species are expected to be present in the LDW, but striped and pile perch may be absent in upstream portions of the LDW, as suggested by the results of the Harbor Island Waterway Sediment Operable Unit (WSOU) sampling event (ESG 1999). Shiner surfperch, which are the most abundant perch species in the LDW (Matsuda et al. 1968; Miller et al. 1975; Miller et al. 1977; Warner and Fritz 1995), and striped perch generally favor nearshore vegetated habitats, and pile perch generally favor environments with vertical structure such as pilings. Composite tissue samples of shiner surfperch will be collected using the same general study design selected for English sole in the fish and crab tissue QAPP (see above discussion).

Shiner surfperch are the targeted perch species because they are highly abundant, and thus are likely consumed by wildlife. Shiner surfperch are also consumed by humans (ATSDR 2003). Further, they have similar diets to striped perch (see Section 3.3.4.1), and should thus serve as a suitable surrogate for striped perch, which could also be consumed by humans. Striped perch, especially adults, are not targeted for sampling because their abundance is low and inconsistent. Pile perch are not targeted because their abundance is inconsistent, less is known about their prey preferences, and they prefer somewhat different foraging habitat than shiner surfperch. However, if a sufficient number of adult striped or pile perch are caught while sampling for other fish species, fillets from these fish will be composited in consultation with EPA and Ecology, and chemically analyzed. Shiner surfperch will be collected in the early fall to coincide with the English sole collection period and to avoid their period of parturition (live birthing period).

Sculpin

Pacific staghorn sculpin are expected to be present throughout the LDW, but the home range of individual fish within the LDW is not known. Sculpin generally do not have strong specific habitat preferences. Sculpin whole-body composite samples will be collected using the same general study design selected for English sole and perch (discussed above). Fish will be collected in the early fall, when sculpin are expected to be largest in the LDW.

Crabs

Adult Dungeness and rock crabs are expected to be present downstream of the 1st Avenue South bridge (RM 2.0) based on the results of the WSOU sampling event (ESG 1999); only juveniles were found upstream of that bridge. To better focus the crab sampling design, site use by crabs will be further investigated prior to tissue collection for chemical analyses (see Section 3.1.2).

Humans are expected to capture crabs wherever they are of harvestable size; wildlife will capture crabs throughout the site wherever they are present. Risks to crabs are typically assessed using larger crabs because they tend to have higher chemical exposures as they age and their diet changes. Crabs will likely be collected using crab pots during the late summer/early fall, as shown in the study design of Table 3-13, if results of the seasonal crab surveys described in Section 3.1.2 indicate that adult crabs are sufficiently abundant during that time. Crab collection locations will also be determined based on the crab survey results.

Rockfish

Rockfish tissue samples may be collected for chemical analyses if there is sufficient site use by adult fish, as determined in consultation with EPA and Ecology. If rockfish are collected, the key objective of the rockfish sampling design will be to collect representative adult rockfish tissue samples to assess their exposure to sediment-associated chemicals. As with other fish ROCs, a critical tissue residue approach will be used to estimate risks to rockfish from bioaccumulative chemicals, such as PCBs. Rockfish tissue may also be used to estimate exposures to wildlife and human consumers depending on rockfish age, abundance, and distribution.

Rockfish may be present in the downstream, more saline portion of the LDW. Rockfish generally favor environments below the freshwater lens with some structure, such as submerged tires, riprap, or pilings (Richards 1987), and they can be long lived. The abundance of adult rockfish will be used to determine whether they will be analyzed for bioaccumulative chemicals and how these data will be used in the Phase 2 risk assessments. Both wildlife and humans consume rockfish, but they must be present as adults in sufficient numbers to represent a significant exposure pathway. The decision criteria to collect and/or analyze rockfish will be made in consultation with EPA and Ecology, and will be outlined in the rockfish technical memorandum (Section 3.3.1.2).

Other Fish and Crabs

The seafood consumption scenarios for the Phase 1 HHRA was based on tissue chemistry data for English sole, striped perch, and Dungeness crab. These species will also be targeted in Phase 2, but chemistry data from other species may also be collected and analyzed. For example, if English sole are difficult to catch in sufficient numbers in the upper reaches of the LDW, starry flounder may be collected instead as the flatfish/demersal representative. If starry flounder are captured during collection efforts for English sole, one or more composite samples may be created and analyzed. Any additional composites created from other fish species will consist of one fish type only; that is, fish will not be composited across species. The fish and crab tissue QAPP will provide additional details on decision rules to be applied for tissue collection efforts. See Section 3.3.2.1 for additional discussion of how tissue chemistry data will be used in the Phase 2 HHRA.

Tissue Samples from Background Areas

Arsenic has been identified for background sampling in tissues because high risk estimates were calculated in the Phase 1 HHRA, and background arsenic concentrations in the LDW watershed may be elevated as a result of the upstream influences and the ASARCO smelter plume.[21] Background concentrations of inorganic arsenic in tissue are needed for each of the HHRA market basket components (i.e., English sole, crab, mussels, perch, and clams). Total arsenic data for many of these species have been collected from various locations in the Puget Sound basin, but inorganic arsenic has not been frequently analyzed in Puget Sound tissue samples. Samples of multiple market basket components will be collected from background areas during Phase 2 and analyzed for both total and inorganic arsenic.

Background arsenic data (both total and inorganic) for each of the HHRA market basket components will be statistically compared to LDW arsenic data. Both LDW and background arsenic data will be reviewed according to EPA (EPA 2002a) guidance to determine the appropriate statistical tests to be used. The sampling design and statistical tests used to compare background and LDW arsenic concentrations will be based on EPA guidance, and will be described in detail in the fish and crab tissue QAPP.

3.1.6.3 Sampling methods

Sampling methods for each of the tissue types discussed in Section 3.1.6.2 will be documented in the fish and crab tissue QAPP. Both preferred methods and contingency plans will be described in the QAPP. The location of all tissues collected will be documented using a handheld GPS receiver unit.

[21] Ecology Tacoma Smelter Plume Study, South King County mainland soil study. http://www.ecy.wa.gov/programs/tcp/sites/tacoma_smelter/soil_study.htm

Fish Tissue

Fish will be collected using an otter trawl or other methods determined to be most suitable for capturing fish in relevant exposure habitats. If sufficient fish are not collected using the primary technique specified in the fish and crab tissue QAPP, other fish collection methods will be considered. These include a standard beach seine, gill nets, baited setlines, traps, collection by divers, and hook and line. The use of these methods will be detailed in the fish and crab tissue QAPP, along with contingency plans for their implementation.

Each fish will be individually wrapped in aluminum foil and placed in a watertight, resealable plastic bag along with a sample identification label. All individual samples from a particular location will be kept together in a large, watertight, resealable plastic bag. The sex of each fish specimen will be determined in the laboratory during sample processing. To the extent possible, each composite sample will contain a similar size range of specimens and contain the same number of male and female specimens because chemical concentrations may vary by size and sex.

Crab Tissue

Crabs will be collected using crab pots allowed a 4-hour soak time after deployment. Samples will be collected using Ladner 30-in SS rubber-wrapped crab traps. After 4 hours, the pots will be revisited and all species caught will be examined and their pertinent information recorded. Target species will be removed from the pot. Any unused specimens will then be returned to the area from which they were caught. This process will be repeated until enough tissue has been collected from each location.

3.1.6.4 Analytical methods

This section presents the chemicals to be analyzed in each fish and crab tissue type collected for the Phase 2 ERA and HHRA. Chemicals were grouped into analyte classes based primarily on analytical methodology (e.g., SVOCs), and evaluated to determine which class of analytes should be analyzed in which tissue type and for what reason (Tables 3-14 through 3-17). The chemicals or groups of chemicals under consideration for analysis are TBT, SVOCs (including PAHs), metals, PCBs as Aroclors, PCB congeners, mercury, and organochlorine pesticides.

All 209 PCB congeners will be analyzed in a subset of tissue samples of each tissue type using a tiered approach. In this approach, all tissue samples will first be analyzed for total PCBs (as an Aroclor sum) and a split sample will be archived. One third of the samples from each tissue type will be selected for PCB congener analysis to cover the range of total PCB concentrations (Aroclor sum) and to provide spatial coverage within the LDW. The relationships between total PCBs (congener sum), dioxin-like PCB congeners (TEQ), sum of selected peaks, and total PCBs (Aroclor sum) will be assessed to determine the ability of the Aroclor sum to estimate the total PCB concentration in tissue. If the Aroclor sum underestimates the total or the relationship between Aroclor and total congener sums is not consistent enough to be useful, and the data suggest that an increased sample size will improve the fit, all of the tissue samples will be analyzed for all 209 PCB congeners.

Dioxin/furan analysis in tissue will be conducted if the results of the urban background analysis in sediments indicate that quantitative risk characterization is needed (see Section 3.1.8.1). If sufficient sample mass can be collected, a portion of the tissue samples will be archived for potential dioxin/furan analysis. Volatile organic compounds (VOCs) will not be analyzed; they do not bioaccumulate in tissue because of their low hydrophobicity.

The preliminary analytical methods are listed in Table 3-18. These methods are commonly used in environmental investigations conducted under Superfund. RBC goals will be developed as part of the fish and crab tissue QAPP. RBC goals for tissue will be based on the seafood consumption scenario in the Phase 2 HHRA. Some of the RBC goals may be lower than detection limits that can routinely be achieved by commercial laboratories. In these cases, the proposed methods will be reviewed to determine if modifications can be made to achieve lower detection limits, or if other methods might be more appropriate. Given the relatively strict data quality requirements under Superfund, it is likely the available methods for a particular analyte class will be limited to EPA-approved methods. Specific data quality objectives and target detection limits for each method will be specified in the fish and crab tissue QAPP.

In Tables 3-14 through 3-17, the yes/no/maybe statements regarding potential individual pathways are used to arrive at an overall decision (**YES/NO/MAYBE** in bold type) regarding the analysis of each analyte for each tissue type. A key consideration in the analyte-specific data needs is the risk approach to be used in Phase 2 (see Sections 3.3.1 and 3.3.2). For example, metals do not need to be analyzed in juvenile chinook salmon tissue because risks to juvenile chinook salmon from metals exposures will be analyzed using a dietary approach. Decisions on tissues marked as **MAYBE** will be made based on the results of field surveys and consultation with EPA and Ecology.

Table 3-14. Analyses of TBT and SVOCs (including PAHs)

Tissue Type	Applicable ROC and exposure pathway	TBT	SVOCs (including PAHs)
English sole (whole body)	Sole (ROC)	yes: exposure assessed via tissue residue	yes: SVOC exposure will be assessed via tissue residue, except for PAHs, which will be assessed using a dietary approach
	Sculpin (ingestion)	no: exposure assessed via tissue residue	yes: PAHs will be assessed using a dietary approach, although PAHs are not expected to accumulate in fish tissue
	Birds (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Mammals (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet (subset of samples[b])
		YES	**YES**
English sole (fillet)	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet (subset of samples[b])
		YES	**YES**
Juvenile chinook[b] (whole body)	Chinook (ROC)	yes: exposure assessed via tissue residue	no: PAH exposure assessed via diet, not tissue residue, and SVOC concentrations expected to be <DL based on perch data
	Birds (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Mammals (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: perch will act as surrogate
		YES	**NO**
Sculpin (whole body)	Sculpin (ROC)	yes: exposure assessed via tissue residue	yes: exposure assessed via tissue residue for some SVOCs, except for PAHs which will be assessed using a dietary approach
	Birds (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Mammals (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
		YES	**YES**
Perch (whole body)	Sculpin (ingestion)	no: exposure assessed via tissue residue	yes: PAHs will be assessed using a dietary approach, although PAHs are not expected to accumulate in fish tissue
	Birds (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Mammals (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Rockfish (whole body)	Rockfish (ROC)	yes: if sufficient site use by adult rockfish, exposure assessed via tissue residue	yes: if sufficient site use by adult rockfish, exposure assessed via tissue residue for some SVOCs, but not PAHs
	Birds (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
	Mammals (ingestion)	no: risks low based on the King County wildlife risk assessment[a]	no: risks low based on the King County wildlife risk assessment[a]
		MAYBE	**MAYBE**
Rockfish (fillet)	Human (ingestion)	yes: if sufficient site use by adult rockfish	yes: if sufficient site use by adult rockfish
		MAYBE	**MAYBE**
Crab (edible meat)[c,d]	Crab (ROC)	yes: exposure assessed via tissue residue TRV for whole body	yes: exposure assessed via tissue residue TRV for whole body
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**

Tissue Type	Applicable ROC and exposure pathway	TBT	SVOCs (including PAHs)
Crab (hepatopancreas only)[c,d]	Crab (ROC)	yes: exposure assessed via tissue residue TRV for whole body	yes: exposure assessed via tissue residue TRV for whole body
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**

[a] The King County wildlife risk assessment was conducted as part of the King County Water Quality Assessment for the Duwamish River and Elliott Bay; assumptions in the assessment will be documented as part of the fish and crab tissue QAPP

[b] Although birds and mammals may consume juvenile chinook salmon, salmon are considered a small component of their diet, and perch can serve as a reasonably conservative surrogate to estimate exposure

[c] Sculpin, sandpiper, and heron may consume small crabs, but these are assumed to be covered by market basket approach for benthic invertebrates

[d] Edible meat and hepatopancreas concentration and weight data will be used to estimate concentrations in whole-body soft tissue

Table 3-15. Analyses of mercury and metals

Tissue Type	Applicable ROC and exposure pathway	Mercury	Metals[a]
English sole (whole body)	Sole (ROC)	yes: exposure assessed via tissue residue	no: exposure assessed via diet
	Sculpin (ingestion)	no: exposure assessed via tissue residue	yes: exposure assessed via diet
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	no: risks low based on screens in the King County wildlife risk assessment and the Phase 1 ERA[b]	yes: exposure assessed via diet
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
English sole (fillet)	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Juvenile chinook[c] (whole body)	Chinook (ROC)	no: Phase 1 risk low	no: exposure assessed via diet, not tissue residue
	Birds (ingestion)	no: perch will act as a surrogate	no: perch will act as a surrogate
	Mammals (ingestion)	no: perch will act as surrogate	no: perch will act as surrogate
		NO	**NO**
Sculpin (whole body)	Sculpin (ROC)	yes: exposure assessed via tissue residue	no: exposure assessed via diet, not tissue residue
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	no: risks low based on screens in the King County wildlife risk assessment and the Phase 1 ERA[b]	yes: exposure assessed via diet
		YES	**YES**
Perch (whole body)	Sculpin (ingestion)	no: exposure assessed via tissue residue	yes: exposure assessed via diet
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	no: risks low based on screens in the King County wildlife risk assessment and the Phase 1 ERA[b]	yes: exposure assessed via diet
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Rockfish (whole body)	Rockfish (ROC)	yes: if sufficient site use by adult rockfish, exposure assessed via tissue residue	no: exposure assessed via diet, not tissue residue
	Birds (ingestion)	yes: if sufficient site use by adult rockfish, exposure may be assessed via diet	yes: if sufficient site use by adult rockfish, exposure may be assessed via diet
	Mammals (ingestion)	no: risks low based on screens in the King County wildlife risk assessment and the Phase 1 ERA[b]	yes: if sufficient site use by adult rockfish, exposure assessed via diet
		MAYBE	**MAYBE**
Rockfish (fillet)	Human (ingestion)	yes: if sufficient site use by adult rockfish	yes: if sufficient site use by adult rockfish
		MAYBE	**MAYBE**

Tissue Type	Applicable ROC and exposure pathway	Mercury	Metals[a]
Crab (edible meat)[d,e]	Crab (ROC)	yes: exposure assessed via tissue residue TRV for whole body	yes: exposure assessed via tissue residue TRV for whole body
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Crab (hepatopancreas only)[d,e]	Crab (ROC)	yes: exposure assessed via tissue residue TRVs for hepatopancreas	yes: exposure assessed via tissue residue TRVs for hepatopancreas and whole body
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**

[a] Arsenic speciation will be analyzed in a subset of tissues that may be consumed by humans

[b] The King County wildlife risk assessment was conducted as part of the King County Water Quality Assessment for the Duwamish River and Elliott Bay; assumptions in the assessment will be documented as part of the fish and crab tissue QAPP

[c] Although birds and mammals may consume juvenile chinook salmon, salmon are considered a small component of their diets, and perch can serve as a reasonably conservative surrogate to estimate exposure

[d] Sculpin, sandpiper, and heron may consume small crabs, but these are assumed to be covered by market basket approach for benthic invertebrates

[e] Edible meat and hepatopancreas concentration and weight data will be used to estimate concentrations in whole-body soft tissue.

Table 3-16. Analyses of PCB Aroclors and PCB congeners

Tissue Type	Applicable ROC and exposure pathway	PCB Aroclors	All PCB Congeners (subset of samples)
English sole (whole body)	Sole (ROC)	yes: exposure assessed via tissue residue	maybe: because of uncertainty in the fish TEFs
	Sculpin (ingestion)	no: exposure assessed via tissue residue	no: exposure assessed via tissue residue
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
English sole (fillet)	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Juvenile chinook[a] (whole body)	Chinook (ROC)	yes: exposure assessed via tissue residue	no: due to fish TEF uncertainty
	Bird (ingestion)	yes: exposure assessed via diet	no: perch will act as surrogate
	Mammals (ingestion)	yes: exposure may be assessed via diet	no: perch will act as surrogate
		YES	**NO**
Sculpin (whole body)	Sculpin (ROC)	yes: exposure assessed via tissue residue	maybe: because of uncertainty in the fish TEFs
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Perch (whole body)	Sculpin (ingestion)	no: exposure assessed via tissue residue	no: exposure assessed via tissue residue
	Birds (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Mammals (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Rockfish (whole body)	Rockfish (ROC)	yes: if sufficient site use by adult rockfish, exposure assessed via tissue residue	maybe: if sufficient site use by adult rockfish, exposure assessed via tissue residue, although there is still uncertainty in the fish TEFs
	Birds (ingestion)	yes: if sufficient site use by adult rockfish, exposure may be assessed via diet	yes: if sufficient site use by adult rockfish, exposure may be assessed via diet
	Mammals (ingestion)	yes: if sufficient site use by adult rockfish, exposure assessed via diet	yes: if sufficient site use by adult rockfish, exposure assessed via diet
		MAYBE	**MAYBE**
Rockfish (fillet)	Human (ingestion)	yes: if sufficient site use by adult rockfish	yes: if sufficient site use by adult rockfish
		MAYBE	**MAYBE**

Tissue Type	Applicable ROC and exposure pathway	PCB Aroclors	All PCB Congeners (subset of samples)
Crab (edible meat)[b,c]	Crab (ROC)	yes: exposure assessed via tissue residue TRV for whole body	no: no congener-based TRVs available
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**
Crab (hepatopancreas only)[b,c]	Crab (ROC)	yes: exposure assessed via tissue residue TRV for whole body	no: no congener-based TRVs available
	Human (ingestion)	yes: exposure assessed via diet	yes: exposure assessed via diet
		YES	**YES**

TEFs – toxic equivalency factors

[a] Although birds and mammals may consume juvenile chinook salmon, salmon are considered a small component of their diets, and perch can serve as a reasonably conservative surrogate to estimate exposure.

[b] Sculpin, sandpiper, and heron may consume small crabs, but these are assumed to be covered by market basket approach for benthic invertebrates.

[c] Edible meat and hepatopancreas concentration and weight data will be used to estimate concentrations in whole-body soft tissue.

Table 3-17. Analyses of organochlorine pesticides

Tissue Type	Applicable ROC and Exposure Pathway	Organochlorine Pesticides
English sole (whole body)	Sole (ROC)	yes: exposure assessed via tissue residue
	Sculpin (ingestion)	no: exposure assessed via tissue residue
	Birds (ingestion)	yes: exposure assessed via diet
	Mammals (ingestion)	no: risks low based on a conservative screen in the Phase 1 ERA
	Human (ingestion)	yes: exposure assessed via diet
		YES
English sole (fillet)	Human (ingestion)	yes: exposure assessed via diet
		YES
Juvenile chinook[a] (whole body)	Chinook (ROC)	yes: exposure will be assessed via tissue residue
	Birds (ingestion)	yes: exposure assessed via diet
	Mammals (ingestion)	no: risks low based on conservative screen in Phase 1 ERA
		YES
Sculpin (whole body)	Sculpin (ROC)	yes: exposure assessed via tissue residue
	Birds (ingestion)	yes: exposure assessed via diet
	Mammals (ingestion)	no: risks low based on a conservative screen in the Phase 1 ERA
		YES
Perch whole body)	Sculpin (ingestion)	no: exposure assessed via tissue residue
	Birds (ingestion)	yes: exposure assessed via diet
	Mammals (ingestion)	no: risks low based on a conservative screen in the Phase 1 ERA
	Human (ingestion)	yes: exposure will be assessed via diet
		YES
Rockfish (whole body)	Rockfish (ROC)	yes: if sufficient site use by adult rockfish, exposure assessed via tissue residue
	Birds (ingestion)	yes: if sufficient site use by adult rockfish, exposure may be assessed via diet
	Mammals (ingestion)	no: risks low based on a conservative screen in the Phase 1 ERA
		MAYBE
Rockfish (fillet)	Human (ingestion)	yes: if sufficient site use by adult rockfish
		MAYBE
Crab (edible meat)[b,c]	Crab (ROC)	yes: exposure assessed via tissue residue TRV for whole body
	Human (ingestion)	yes: exposure assessed via diet
		YES
Crab (hepatopancreas only)[b,c]	Crab (ROC)	yes: exposure assessed via tissue residue TRV for whole body
	Human (ingestion)	yes: exposure assessed via diet
		YES

[a] Although birds and mammals may consume juvenile chinook salmon, salmon are considered a small component of their diets, and perch can serve as a surrogate.

[b] Sculpin, sandpiper, and heron may consume small crabs, but these are assumed to be covered by market basket approach for benthic invertebrates.

[c] Edible meat and hepatopancreas concentration and weight data will be used to estimate concentrations in whole-body soft tissue.

Table 3-18. Analytical methods for fish and shellfish

Parameter	Method	Notes
Semivolatile organics, including PAHs	GC/MS (EPA 8270)	
PCBs (as Aroclors)	GC/ECD (EPA 8082)	
Organochlorine pesticides	GC/ECD (EPA 8081)	
PCB congeners	HRGC/HRMS (EPA 1668A)	
Mercury	CVAA (EPA 7471)	
Other metals	ICP-AES (EPA 6010) [a]	specific analyte list to be determined
Arsenic speciation	to be determined	
TBT	GC/FPD (Krone et al. 1989)	
Lipids	Gravimetric (NOAA 1993)	

CVAA – cold vapor atomic absorption
ECD – electron capture detection
FPD – flame photometric detection
GC – gas chromatography
HRCG – high-resolution gas chromatography
HRMS – high-resolution mass spectrometry
ICP-AES – inductively coupled plasma-atomic emission spectrometry
MS – mass spectrometry
TBT – tributyltin

[a] Other methods (i.e., GFAA or ICP-MS) may be used for metals depending on the detection limit goals to be specified in the fish and crab tissue QAPP

3.1.7 Sediment transport study

The section presents the approach for characterizing sediment transport in the LDW for the Phase 2 RI. A more detailed QAPP for the sediment transport study will be submitted to EPA and Ecology for review, comment, and approval following their approval of this work plan. As part of the development of the QAPP, LDWG will meet with EPA and Ecology to discuss study design and methodology. Because of the preliminary nature of the study design, sampling and analytical methods will not be described in this work plan, but will be provided as part of the sediment transport study QAPP.

3.1.7.1 Objectives and background

The Phase 1 RI documented existing information related to sediment transport and concluded that additional data collection and analysis would be required for the Phase 2 RI. The sediment transport study will be performed through multiple components. The primary objective of this section of the work plan is to document how each field component of the study will be completed, particularly the collection of additional critical shear stress and sedimentation rate data, and to describe how the information will be synthesized into a comprehensive conceptual framework, either through a weight-of-evidence approach or a numeric model. The methods for synthesizing the field data will be described in the QAPP.

There are three primary components within the conceptual framework for sediment transport in the LDW: 1) hydrodynamics, 2) sediment transport, and 3) chemical transport and fate. Quantification of the third component relies on an adequate characterization of the first two components, in conjunction with site-specific sediment chemistry data. Each of these components can be modeled, and if so, modeling will be aided by focused field data for verification and/or calibration.

Existing LDW-specific hydrodynamic data include detailed hydrographic surveys and transport modeling performed by USGS (Prych et al. 1976; Santos and Stoner 1972), as well as current meter deployments and resultant hydrodynamic modeling conducted by King County (King County 1999a). King County (1999a) integrated available current meter and sediment deposition data for the LDW with default assumptions of sediment erosion (i.e., critical shear stress) into the three-dimensional Environmental Fluid Dynamics Code (EFDC). The EFDC model is capable of integrating location-specific shear stress and deposition rate data (Imhoff et al. 2003).

During the King County Water Quality Assessment study, current measurements were obtained at 15-minute intervals at stations SBW (RM 1.1) and BOE (RM 3.5) using acoustic Doppler methods during August to November 1996. The maximum flow recorded during this period at the Auburn USGS gage was approximately 140 m^3/s (5,000 cfs). King County is currently planning an additional acoustic Doppler meter deployment in the LDW to support refinements of its existing fate and transport modeling near combined sewer overflow (CSO) outfall locations. Plans for modeling that may be conducted by King County or any other party in the LDW will be incorporated into the study design of the sediment transport QAPP. The resultant data are expected to be available in time for incorporation into the Phase 2 RI.

As discussed in the Phase 1 RI, sediment transport within the LDW is influenced by many variables, including hydrodynamic forces attributable to estuarine circulation, tide-induced circulation, freshwater flow into the upstream end of the LDW, sediment loading from upstream and upland sources, channel morphology, and resuspension processes such as propeller scour, bioturbation, flow-induced bedload shear stress, wave action, and dredging. Through the comprehensive framework, different sources of sediment transport may be identified and compared, including resuspension events that result in little net transport. The methods for evaluating the various scenarios will be described in detail in the sediment transport QAPP. Sediment transport may be quantified through the use of numerical models that require empirical data for key parameters such as the critical shear stress, settling speed, and net sedimentation rate. The need for making such site-specific measurements will be explored in the sediment transport QAPP, based on the method selected to synthesize the field data.

Sediment erosion is characterized by a critical value, called the critical shear stress for initiation of motion, where a significant number of particles begin to erode under an applied force or current velocity. Sediment erosion rates can be measured using a flume, either in the laboratory or *in situ*. No sediment flume studies have been conducted in the LDW, although a 1985 *in situ* flume study was conducted in Elliott Bay at Duwamish Head (Striplin et al. 1985). This study indicated a critical bottom velocity threshold for initiation of significant sediment erosion of roughly 40–60 cm/s (1.3–2.0 ft/s). The 1985 flume data were summarized in the Phase 1 RI because no other site-specific data exist; however, these data will not be used in Phase 2 to assess sediment transport because Elliott Bay sediment properties may differ from LDW sediment properties. Instead, site-specific data collection is proposed. Site-specific measurements of the critical shear stress will make it possible to characterize sediment transport conditions within the LDW.

There is considerable information available to characterize sediment deposition rates and characteristics within the LDW area. This information has been used in a range of prior water and sediment quality assessments, and has supported development of sediment remediation plans at early action areas in the LDW, including the Duwamish/Diagonal CSO/storm drain and Boeing Plant 2. Sediment deposition rates within the LDW have been estimated by multiple authors, as reported in the Phase 1 RI. Many of the earlier estimates were based on evaluations of channel condition maps and sediment loading mass balance data from 1960 to 1980. Interpretation of sediment PCB concentration profiles in cores collected at the Duwamish/Diagonal CSO/storm drain site (King County 2000a) as well as sediment traps deployed south of Harbor Island (EVS and Hart Crowser 1995) have also been used to estimate net sedimentation rates in the LDW, generally corroborating rates based on channel condition maps and sediment loading mass balance data. Site-specific measurements of sedimentation rates within the LDW would improve characterization of sediment transport.

3.1.7.2 Study design

The sediment transport field component is intended to acquire data on sediment erosion and deposition rates. As discussed above, additional data on LDW currents influencing sediment erosion, deposition, and transport are being collected by King County. Once the results of King County's study are available, LDWG, EPA, and Ecology will assess the need for and (as needed) the scope of additional current data collection to support the Phase 2 RI.

Although different instruments are needed to collect each type of data, field efforts will be coordinated to collect multiple data types from each location. The locations to be sampled will be based on the following considerations: sediment physical characteristics such as grain size and TOC content, hydrological regime (water depth, expected current speed, channel configuration), and sediments known to contain relatively high chemical concentrations (based on the data summarized in the Phase 1 RI). The last consideration addresses the need to understand sediment transport dynamics in areas potentially subject to remedial action. Sediment bulk density data may be collected to help further evaluate sediment transport pathways for areas where erosion data are not collected.

Sediment Erosion Rates

Transport, shear stress, and in some cases erosion rates can be measured in both the laboratory and the field using straight flumes, rotating cylinders, annular flume/sea carousels, shaker flumes, Sedflumes, ASSET flumes, or SEAWOLF flumes (Jepsen 2002). Annular flumes and shaker devices have been used for many years, and provide data that can be used to assess the potential for sediment erosion. These devices measure net resuspension for an event. In a tidally-driven estuary such as the LDW, net resuspension data are not very helpful in characterizing sediment fate and transport because of the complicated hydrodynamics influenced by the tidal cycle. More recently developed devices, such as the Sedflume (McNeil et al. 1996) and Ravens' inverted flume (Ravens and Gschwend 1999), measure gross erosion rates.

The Sedflume apparatus tests a 1-m sediment core in the laboratory to measure both the total load (bed and suspended) and the erosion rate at shear stresses from 0–10 Pascal. This device can also provide erosion with depth data, often demonstrating that larger shear stresses are needed to remove sediments at depth (e.g., greater than 1 cm below mudline) (Jepsen 2002). Ravens' inverted flume is deployed *in situ* to provide a representative field measurement of shear stresses associated with initiation of bed sediment movement.

The erosion potential in the LDW will be evaluated in two steps. First, the critical shear stress will be estimated at multiple locations using Ravens' inverted flume. These data, in combination with the hydrodynamic data described below, will be used to determine areas where scour may be important. Additional lines of evidence, such as data from acoustic Doppler current profilers and hydrodynamic model storm simulations, may also suggest areas where scour could occur. In the second step, areas identified as potential scour zones will be further evaluated to determine how much material would be scoured from those locations and under what circumstances scour would occur. The sediment characteristics determined by Sedflume provide a more appropriate basis for this analysis.

The sediment transport QAPP will identify locations and a detailed study design for the deployment of one or both of these sediment flumes.

Sediment Deposition and Sedimentation Rates

Several methods can be used to measure sediment deposition and net sedimentation (i.e., the combined result of deposition and resuspension) rates at specific locations, including particle settling speeds, sediment traps, and age-dated sediment cores.

These tools may be used at some of the same locations characterized using the flume devices described above. Sediment traps can generate data on mass accumulation (g/cm^2-yr) and accumulation rates (cm/yr). However, sediment traps generally do not allow for resuspension, so they only provide estimates of gross sedimentation, not net sedimentation rates. Age-dated sediment cores can be used to estimate net sedimentation rates, but they may provide ambiguous data at locations where sediments have been agitated, eroded, or mixed. A detailed study design for the measurement of sediment deposition and sedimentation rates will be included in the sediment transport QAPP.

Current Speeds

As described in Section 3.1.7.1, two acoustic Doppler current profilers have been deployed in the LDW. A third deployment by King County is currently underway. As part of the development of the sediment fate and transport QAPP, LDWG, EPA, and Ecology will evaluate the need for additional current meter data.

Synthesis of Field Data

The field data collected as outlined above, in conjunction with the bathymetric data collected as described in Section 3.1.3, will be combined into a comprehensive sediment transport framework in the Phase 2 RI. One data analysis option that will be considered is the use of a numeric model (e.g., EFDC) for predicting sediment and chemical fate and transport across the entire LDW. The EFDC model originally used by King County (1999a) may be reparameterized using a different grid size and incorporation of the Phase 2 physical data described above. Depending on the sediment transport model selected, existing data related to boundary conditions outside the LDW (e.g., East and West Waterways) may also be needed. Boundary condition data have already been compiled by King County as part of their EFDC application. LDWG will meet with EPA and Ecology prior to completing the sediment transport QAPP to determine how the data to be collected in Phase 2 will be used to determine the need for numeric modeling of sediment fate and transport in the LDW.

3.1.8 Surface sediment sampling, chemical analyses, and toxicity testing

A QAPP for the collection of surface sediment samples for chemical analyses and toxicity testing will be submitted for review, comment, and approval following EPA and Ecology approval of this work plan. This section describes the general scope for that QAPP. Locations and numbers of samples presented in this section are preliminary and are included to establish a general level of effort for specific studies. These details are subject to modification during finalization of the QAPP.

3.1.8.1 *Surface sediment sampling and chemical analyses*

Objectives and Background

Collection of additional surface sediment samples for chemical analyses was recommended in the data needs memorandum (Windward 2003f) for specific areas of the LDW to support the Phase 2 RI and associated risk assessments. In particular, additional sediment chemistry data are needed to:

- better understand the areal extent of COPCs where concentrations have exceeded the SQS or the CSL of the SMS[22]
- provide additional characterization of areas with low sampling density based on Phase 1 results
- further characterize the concentration and distribution of Phase 1 COPCs with relatively low sampling frequency (e.g., TBT, DDT, dioxins/furans, PCB congeners) or with elevated detection limits relative to SQS or CSL
- further characterize the nature and extent of chemical contamination in sediments near potential current or historic chemical sources (see Section 3.4.4)
- further characterize the nature and extent of chemical concentrations in sediments near seeps if seep water chemistry data indicate a cause for concern (see Section 3.1.4)
- further characterize human and wildlife exposures in intertidal areas below MHHW that may be used for recreation or foraging, respectively (see Sections 3.3.2.1 [human] and 3.3.1.2 [wildlife])
- characterize arsenic and dioxin/furan concentrations in background sediments outside the LDW
- delineate the upstream boundary of the study area
- use with synoptic tissue chemistry data in support of food web modeling

Approximately 1,200 surface sediment samples have been collected from the LDW since 1990 (Table 3-19). Nearly all of these samples were collected from the uppermost 10 cm, although a few were collected from the uppermost 15 cm. The data from these samples were summarized in the Phase 1 RI.

Additional surface sediment chemistry data have been collected within the last 2 years that were not included in the Phase 1 RI because they were collected after the cutoff date for incorporation into Phase 1. For example, additional sediment sampling was

[22] WAC 173-204. The SQS represent numeric chemical concentrations below which sediments are designated as having no adverse effects on biological resources. At chemical concentrations above the SQS but below the CSL, sediments are designated as having minor adverse effects on biological resources. At chemical concentrations above the CSL, there is a potential for more pronounced adverse affects.

conducted in August 2003 at Boeing Plant 2. Before preparing the surface sediment QAPP, a technical memorandum containing an updated list of sediment chemistry data sets to be used in Phase 2 and the rationale for inclusion will be submitted to EPA and Ecology. This technical memorandum will also summarize the suitability for use of all datasets previously used in Phase 1, in addition to the more recently collected datasets, for use in Phase 2. This updated list of sediment chemistry data sets to be used for the Phase 2 RI will be included in the surface sediment QAPP. In addition, the results of a data review conducted by EPA (2003) will be incorporated in the Phase 2 RI database. This data review focused on many of the King County events listed in Table 3-19 and resulted in recommendations for data qualifier changes.[23] Some datasets used in the Phase 1 RI may not be used in the Phase 2 RI because the available quality control data may not meet EPA's data quality standards for Superfund (EPA 2003). The technical memorandum containing the updated list of sediment chemistry data sets will also present a list of data sets to be excluded from Phase 2, any limitations on the use of data for Phase 2, and any data sets for which modifications were made as a result of EPA's or Windward's data review (e.g., modifications to data qualifiers). For example, the total PCB sediment data generated by NOAA (1997; 1998) are generally comparable to total PCB sediment data generated by other investigators, even though the analytical methods differ. However, the PCB congener sediment data generated by NOAA (1997; 1998) and EPA (1999) are generally not sufficient for risk assessment purposes because the low-resolution analytical methods used were not able to achieve low enough detection limits for dioxin-like PCB congeners, which tend to be of greatest concern with respect to ecological and human health risks. The rationale for each of these decisions will also be presented in the technical memorandum.

Table 3-19. Surface sediment samples collected since 1990 that were used in the Phase 1 RI

Event	Chemical Groups Analyzed	Surface Sediment Samples	Reference
Norfolk CSO five-year monitoring program, Year Two (2001)	metals, PCB Aroclors, SVOCs	8	King County (2001)
Norfolk CSO five-year monitoring program – Twelve-month post construction (2000)	metals, PCB Aroclors, SVOCs	8	King County (2000c)
Norfolk CSO five-year monitoring program – Supplemental nearshore sampling (2000)	PCB Aroclors	6	King County (2000b)
Norfolk CSO five-year monitoring program – Six-month post construction (1999)	metals, PCB Aroclors, SVOCs	8	King County (2000d)

[23] The primary qualifier change will be to add an 'R' qualifier (rejected) to approximately 700 of the non-detect results for several semi-volatile organic compounds with poor recovery of surrogate compounds or very low matrix spike recoveries. Approximately one-half the samples analyzed for semi-volatile organic compounds will be affected by this change.

Event	Chemical Groups Analyzed	Surface Sediment Samples	Reference
Norfolk CSO five-year monitoring program – Post backfill (1999)	metals, PCB Aroclors, SVOCs	4	King County (1999d)
EPA Site Inspection: Lower Duwamish River (1998)	metals, pesticides, PCB Aroclors, selected PCB congeners, dioxins/ furans, TBT, SVOCs, VOCs	300	Weston (1999)
Sediment quality in Puget Sound. Year 2 – Central Puget Sound (1998)	Metals, PCB Aroclor & selected congeners, pesticides, SVOCs, TBT	3	Ecology (2000)
King County combined sewer overflow water quality assessment for the Duwamish River and Elliott Bay (1997)	metals, PCB Aroclors, SVOCs, TBT	57	King County (1999c)
Duwamish Waterway Phase 1 site characterization [a] (1997)	metals, PCB Aroclors, SVOCs	88	Exponent (1998)
Duwamish Waterway sediment characterization study (1997)	total PCBs, selected PCB congeners, total PCTs	328	NOAA (1997; 1998)
Seaboard Lumber site, Phase 2 site investigation (1996)	metals, PCB Aroclors, SVOCs	20	Herrera (1997)
RCRA Facility Investigation Duwamish Waterway sediment investigation, Plant 2 – Phase 2b (1996)	metals, PCB Aroclors, SVOCs	39	Weston (1998)
Duwamish/Diagonal cleanup study – Phase 2 (1996)	metals, PCB Aroclors, SVOCs, TPH	36	King County (2000a)
Duwamish/Diagonal cleanup study – Phase 1.5 (1995)	metals, PCB Aroclors, SVOCs, TBT	12	King County (2000a)
Norfolk CSO sediment cleanup study – Phase 3 (1995)	PCB Aroclors	16	King County (1996)
Norfolk CSO sediment cleanup study – Phase 2 (1995)	metals, pesticides, PCB Aroclors and selected congeners, SVOCs, VOCs, TPH	12	King County (1996)
RCRA Facility Investigation Duwamish Waterway sediment investigation, Plant 2 – Phase 2a (1995)	metals, PCB Aroclors SVOCs	54	Weston (1998)
RCRA Facility Investigation Duwamish Waterway sediment investigation, Plant 2 – Phase 1 (1995)	metals, PCB Aroclors, TPH, SVOCs, VOCs	65	Weston (1998)
Duwamish/Diagonal cleanup Study – Phase 1 (1994)	metals, pesticides, PCB Aroclors, SVOCs, TBT	40	King County (2000a)
Norfolk CSO sediment cleanup study – Phase 1 (1994)	metals, pesticides, SVOCs, PCB Aroclors, VOCs	21	King County (1996)
Rhône-Poulenc RCRA Facility Investigation for the Marginal Way facility – Round 2 (1994)	metals, SVOCs, PCB Aroclors 1254 and 1260, pesticides	7	Rhône-Poulenc (1995)
Rhône-Poulenc RCRA Facility Investigation for the Marginal Way facility – Round 1 (1994)	metals, SVOCs, PCB Aroclor 1254, pesticides	7	Rhône-Poulenc (1995)
Harbor Island Remedial Investigation (1991)	metals, pesticides, PCB Aroclors, SVOCs, VOCs, TPH, TBT	34	Weston (1993)

Taken together, the sampling events summarized in Table 3-19 were used to characterize the nature and extent of sediment contamination in the LDW during the Phase 1 RI. However, data needs still remain, as described in the summary tables in Appendix A and Windward (2003f). The study design presented below is intended to fill those data needs based only on those sediment sampling events listed in Table 3-19. The surface sediment QAPP will present the final study design based on existing data and the additional sediment chemistry data that have been incorporated in the Phase 2 RI database.

Study design for sampling locations

This section describes considerations for selecting additional surface sediment sampling locations, based on each of the data collection objectives listed above. Note that in addition to the sample collection described in this section, additional surface sediment samples are also being collected synoptically with benthic invertebrate tissue samples, as described in Section 3.1.5. These synoptically collected sediment samples will be collected using different compositing methods and analyzed for different chemicals (e.g., those collected with gastropod [or suitable surrogate] tissue will only be analyzed for TOC and TBT), thus they are not described in this section. Approximately 20 composite surface sediment samples will be collected with benthic invertebrate market basket samples. Composite surface sediment samples will also be collected with clams and gastropods (or surrogate). The number of the latter samples will be determined in the benthic invertebrate QAPP.

In addition to the samples described above, six primary considerations were used to determine where to collect additional surface sediment chemistry data for Phase 2:

- low historical spatial coverage, particularly at sites where single SQS or CSL exceedances were observed with few nearby sampling locations
- special use areas (e.g., intertidal areas with public access or used by wildlife) that have been incompletely characterized
- potential historic or current chemical sources,[24] including seeps of concern (if any are identified)
- chemical concentrations elevated relative to SQS or CSL
- co-location with Phase 2 sediment toxicity tests (see description of toxicity test study design in Section 3.1.8.2)
- analyte considerations including chemicals with relatively low numbers of historical samples or historical locations that did not have sufficiently low detection limits for certain chemicals

[24] Source characterization is described in greater detail in Section 3.4.4, but dredged material characterization data may also be used to identify a potential source

These considerations were first described in the data needs memorandum that was approved by EPA and Ecology, and are also listed in Appendix Table A-1. Each of the surface sediment chemistry sampling locations described below is based on at least one of the six considerations; many locations are based on multiple considerations.

A seventh consideration was also applied regarding the seven identified early action areas (Windward 2003e). Sponsors have been identified and cleanup action planning[25] is underway at four of the seven candidate sites shown in Figure 3-7 (Areas 1, 3, 4, and 5). Additional sediment chemistry data have been or will be collected within the next year, prior to any sediment cleanup, at three of the seven candidate areas, Slip 4 (Area 3), Boeing Plant 2 (Area 4), and Terminal 117 (Area 5). In addition, sediment samples will be collected at Duwamish-Diagonal (Area 1) following the remedial action as part of a monitoring program. The location of post-cleanup samples for any completed early action areas will be incorporated into the sampling design decision framework documented in the surface sediment QAPP. Additional sediment chemistry data will be collected at two other candidate areas (Areas 2 and 6) as part of the Phase 2 RI based on one or more of the considerations described above. The need for Phase 2 sampling at Area 7 (Norfolk), beyond the single additional location shown in Figure 3-8e, will be determined before completing the surface sediment QAPP based, in part, on the evaluation of new data from a recent sediment sampling event (Ecology 2003), which covered part of the area of concern. Collection and chemical analyses of additional samples from early action areas will be discussed with the agencies on an as-needed basis to determine if they are necessary to meet specific data needs (e.g., PCB congeners in sediment).

The locations of sediment samples presented in this work plan are preliminary. EPA and Ecology have provided additional information that will be considered during QAPP development that could increase the number of sampling locations by approximately 30-35 locations. The final locations will be specified in the surface sediment QAPP. Some of the studies and data collection efforts that will form the basis for final sediment chemistry sample locations include qualitative surveys of special use areas and intertidal habitat use by shorebirds, and identification of potential chemical sources to the LDW, including seeps. For example, evaluations of special use areas and potential chemical sources were applied in this work plan based on the information on these topics compiled in the Phase 1 RI. Further information will be developed as part of the Phase 2 RI, including the surveys described in Sections 3.1.4, 3.3.1.2 and 3.3.2.1. Additional source characterization data being collected by the source control work group are described in Section 3.4.4.

[25] Cleanup actions at Duwamish/Diagonal (early action area 1) were completed in winter 2004.

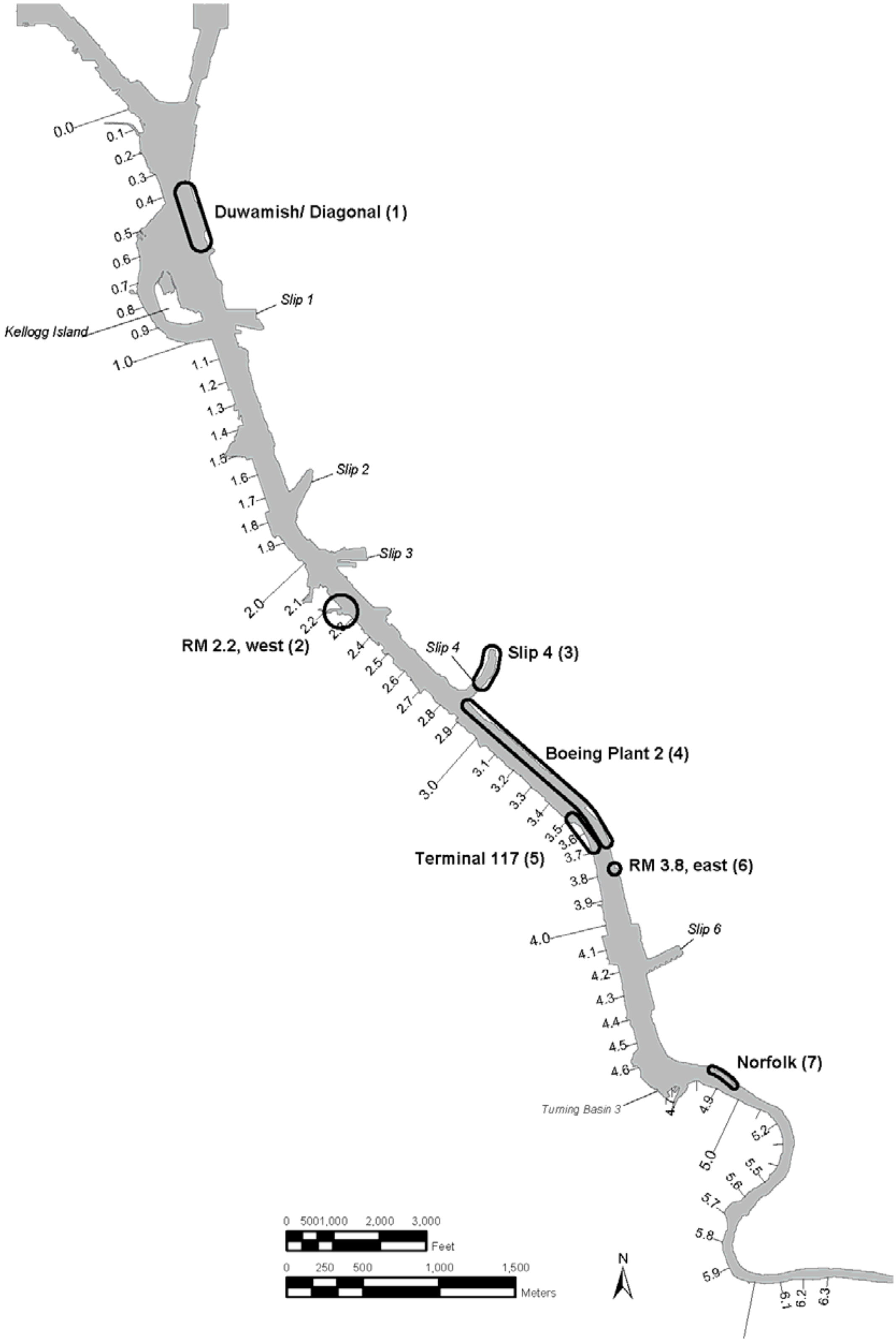

Figure 3-7. Candidate areas proposed by LDWG for early cleanup action

The considerations listed above were applied using best professional judgment, not through a formal decision tree with numerical boundaries. A brief description of the judgment applied within each consideration is provided below.

Low historical spatial coverage – New locations under this consideration are generally at least 50–100 m from any location previously sampled. Areas closer to either bank were given higher priority than areas in the center of the LDW, particularly in the navigation channel. Based on Phase 1 data, the latter areas generally contain much lower chemical concentrations than many areas closer to shore. Also, areas with existing data showing elevated concentrations (relative to SQS or CSL) were given higher priority than areas without any elevated concentrations.

Special use areas – These areas are limited to intertidal habitat that could potentially be used by humans and/or certain ecological receptors (e.g., sandpipers). Larger intertidal habitat areas were preferred over small intertidal habitat areas. The value of any of the special use areas for particular receptors has not been confirmed at this time, but additional research on this topic will be conducted early in Phase 2 (e.g., see Sections 3.3.1.2 and 3.3.2.1).

Near potential chemical sources – Identification of potential chemical sources is based on existing information and the preliminary source control investigations of waterfront properties and outfalls by member agencies of the LDW source control work group, including review of historic aerial photos, records, and agency files. In some cases, the results of regulatory program investigations from upland activities not summarized in the Phase 1 RI were used. Additional research on potential chemical sources to be conducted early in Phase 2, including the source information described in Sections 3.1.4 and 3.4.4, will be incorporated into the surface sediment QAPP. A survey of visible outfalls/pipes within the LDW was recently completed by the City of Seattle. Results from this survey were used to identify some sediment sampling locations and the report will be appended to the surface sediment QAPP.

Additional characterization needed of elevated chemical concentrations – Areas where one or more samples had concentrations in excess of the CSL, or where clusters of samples had concentrations in excess of the SQS, warrant additional investigation. Some of these areas were carefully reviewed during the candidate site identification process and found to have insufficient sampling density to identify the site for early cleanup action (Windward 2003e). Additional data from nearby locations not previously sampled will provide important information to better characterize these areas.

Co-located with sediment toxicity test locations – As described in more detail in Section 3.1.8.2, multiple locations will be sampled for sediment chemistry in conjunction with sediment toxicity testing. Many of the locations selected for surface sediment chemistry are close to previously sampled locations with SMS exceedances. New chemistry data are needed from these locations because the precise locations that were sampled previously cannot be relocated with accuracy and the chemical conditions documented previously may have changed. A subset of the stations analyzed for chemistry will have split samples tested for toxicity. Selection of specific toxicity locations will be made in coordination with EPA and Ecology when the sediment chemistry data are available, based on the criteria and approach described in Section 3.1.8.2.

Analyte considerations – Many samples without any detected concentrations above the SQS or CSL had detection limits for one or more semi-volatile organic compounds (e.g., 1,2,4-trichlorobenzene, hexachlorobenzene) above the SQS or CSL. The elevated detection limits were attributable to various reasons (e.g., matrix effects, high concentrations of other analytes). In some cases, an apparent exceedance of the SQS or CSL by a detection limit may have been caused by a low TOC content of the sediment, because the SQS or CSL for these chemicals is expressed on a carbon-normalized basis. Also, the detection limits for many of these analyses were elevated because concentrations of one or more compounds in the target analyte list were high enough to require sample dilution, thus artificially elevating the detection limit for the remainder of the compounds. For all Phase 2 semivolatile analyses, concentrations for a given sample will be taken either from the original sample or the diluted sample, depending on the compound. Use of this approach will ensure that the lowest possible detection limit is reported for a given compound. The rules for selecting the appropriate concentration from more than one analysis of a given sample will be specified in the QAPP. Additional characterization of areas with detection limits above SQS or CSL is warranted, particularly in areas with multiple samples in this category. Not every area with samples in this category will be resampled.

For each chemical that was rarely or never detected, a list of common sources will be cataloged using chemical databases such as the Hazardous Substances Data Bank and summaries from ATSDR Toxicological Profiles. Available site history information previously compiled by the LDW Source Control Work Group will be reviewed to identify whether any known sources are or were present in the LDW. If such sources are identified, additional focused sampling for specific chemicals may occur. The information described above for chemicals that were rarely or never detected will be summarized in the surface sediment QAPP.

It is assumed that the additional data with sufficiently low detection limits, as described above, coupled with the large existing database for these chemicals, will provide an adequate level of information to determine whether the semi-volatile organic compounds that will be identified with the above approach pose a significant risk to ecological or human receptors. Lastly, some chemical groups (e.g., dioxins/furans, chlorinated pesticides, PCB congeners) have been analyzed less frequently than SMS chemicals, so additional data collection is warranted for these chemicals.

Based on these 6 considerations, 119 surface sediment chemistry sampling locations[26] are proposed for the Phase 2 RI (Table 3-20; Figures 3-8a to 3-8e, located at end of document). Table 3-20 lists each location and applicable considerations regarding its placement. These sampling locations are preliminary and may be revised in the final surface sediment QAPP. The chemical analysis plan for the sediment samples to be collected from these proposed locations is described later in this section and in Table 3-21.

[26] The 119 total does not include the 20+ composite surface sediment samples discussed in Section 3.1.5 that will be collected synoptically with benthic invertebrate tissue. In addition, EPA and Ecology have provided additional information that will be considered during QAPP development that could increase the number of sampling locations by approximately 30-35 locations.

Table 3-20. Preliminary surface sediment chemistry sampling locations for the Phase 2 RI

Location Name	Considerations for Placing Locations					Notes
	Spatial Data Gap	Special Use Area	Near Potential Chemical Source	Additional Characterization of Elevated Concentrations Needed	Analyte Considerations [A]	
LDWG-1				x		Resample area with phenol and PCB SQS exceedances
LDWG-2				x	x	Resample area with phenol CSL exceedance; need reduced SVOC DLs based on historical data near location
LDWG-3	x			x	x	Near BEHP CSL exceedance
LDWG-4				x		Resample area with BEHP CSL exceedance
LDWG-5			x	x	x	Near phenol CSL exceedance; adjacent to historical sources of metals to sediments
LDWG-6	x		x		x	Adjacent to historical sources of metals to sediments
LDWG-7				x		Resample area with PCB SQS exceedance
LDWG-8	x	x	x			Additional intertidal habitat characterization needed in this area; adjacent to drainage channel running through Terminal 105
LDWG-9	x	x	x		x	Additional intertidal habitat characterization needed in this area
LDWG-10				x		Resample area with phenol CSL exceedance
LDWG-11	x					No data within 100 m of location
LDWG-12				x		Resample area with PCB SQS exceedance
LDWG-13	x		x		x	Near probable source of cement kiln dust, arsenic, and lead
LDWG-14				x	x	Near BEHP and phenol SQS exceedances
LDWG-15					x	Need reduced hexachlorobenzene DL based on historical data near location
LDWG-16				x		Resample area between two locations with BEHP SQS exceedances
LDWG-17			x	x	x	Resample area with elevated dioxins/furans
LDWG-18			x	x	x	Resample area with elevated dioxins/furans
LDWG-19				x		Resample area with phenol SQS exceedance
LDWG-20				x		Within group of 3 locations with PCB SQS exceedance
LDWG-21		x	x	x	x	Near PCB CSL exceedance from NOAA SiteChar; near GSA facility; within potential sandpiper habitat
LDWG-22	x	x	x		x	More data needed in this intertidal area; near two locations with PCB SQS exceedance from NOAA SiteChar (1997); near source of cement kiln dust

Location Name	Considerations for placing locations					Notes
	Spatial Data Gap	Special Use Area	Near Potential Chemical Source	Additional Characterization of Elevated Concentrations Needed	Analyte Considerations [A]	
LDWG-23	x	x				Need additional intertidal data in this area
LDWG-24				x		Resample area with PCB SQS exceedance
LDWG-25	x	x			x	More data needed in this intertidal area; sample near phenol SQS exceedance
LDWG-26				x	x	Between two locations with benzyl alcohol and PAH CSL exceedances and PCB SQS exceedance (NOAA SiteChar)
LDWG-27				x		Resample area with zinc, arsenic, mercury CSL exceedance
LDWG-28				x	x	Between two locations with benzyl alcohol, arsenic, mercury, and zinc CSL exceedances
LDWG-29	x	x			x	More data needed in this intertidal area; near two locations with PCB SQS exceedance from NOAA SiteChar
LDWG-30	x	x				Need additional intertidal data in this area
LDWG-31	x		x		x	More data needed in this intertidal area; adjacent to cement plant loading berth
LDWG-32				x		Resample area with PCB and acenaphthene SQS exceedance
LDWG-33			x		x	Adjacent to cement plant, a potential source of metals
LDWG-34				x		Resample area with PCB SQS exceedance
LDWG-35	x				x	Only data near this location for PCBs only (NOAA SiteChar)
LDWG-36			x	x	x	Near BEHP CSL exceedance; adjacent to 24” storm drain from cement plant
LDWG-37				x		Resample area with BEHP CSL exceedance
LDWG-38			x	x	x	Near BEHP CSL exceedance; near shipyard
LDWG-39				x		Resample area with PCB, mercury, BEHP CSL exceedance
LDWG-40				x	x	Within insufficiently characterized area of 3 CSL exceedances
LDWG-41				x		Resample area with PAH CSL exceedances
LDWG-42			x			Near Duwamish Shipyard and storm drain
LDWG-43				x	x	Within insufficiently characterized area of 3 CSL exceedances
LDWG-44				x		Within insufficiently characterized area of 3 CSL exceedances
LDWG-45				x	x	Within area of 3 locations with SVOC SQS DL exceedances; resample area with elevated dioxins/furans; adjacent to cement plant and former PCP manufacturer

LOCATION NAME	CONSIDERATIONS FOR PLACING LOCATIONS					NOTES
	SPATIAL DATA GAP	SPECIAL USE AREA	NEAR POTENTIAL CHEMICAL SOURCE	ADDITIONAL CHARACTERIZATION OF ELEVATED CONCENTRATIONS NEEDED	ANALYTE CONSIDERATIONS [A]	
LDWG-46				x	x	Resample area with PCB SQS exceedance; resample area with elevated dioxins/furans; adjacent to cement plant and former PCP manufacturer
LDWG-47	x	x	x	x	x	Near cement plant and former PCP manufacturer; within under-sampled intertidal area; need additional TBT data; resample area with elevated dioxins/furans
LDWG-48			x	x	x	Near cement plant and former PCP manufacturer; resample area with elevated dioxins/furans
LDWG-49	x				x	Within area of 4 locations with SVOC SQS DL exceedances
LDWG-50	x					No data within 100 m of location
LDWG-51			x		x	Resample area with PCB SQS exceedance; near cement plant
LDWG-52	x				x	Adjacent to 2 locations with SVOC SQS DL exceedances
LDWG-53	x	x			x	Additional intertidal data needed
LDWG-54			x	x		Adjacent to 2 locations with phthalate CSL exceedances and 72" storm drain
LDWG-55	x		x		x	Adjacent to Michigan St CSO
LDWG-56				x	x	Adjacent to 2 locations with BEHP or PCB CSL exceedances
LDWG-57				x		Resample area between 2 locations with BEHP or PCB CSL exceedances, and 1 locations with PCB SQS exceedance
LDWG-58				x	x	Resample area with DDT ML exceedance
LDWG-59				x	x	Between DDT ML and benzyl alcohol CSL exceedances
LDWG-60				x	x	Between DDT ML and PCB CSL exceedance and PCB CSL exceedance from NOAA SiteChar
LDWG-61	x	x			x	Lack of intertidal data in this area; adjacent to W Michigan CSO
LDWG-62	x	x			x	Lack of intertidal data in this area; potential sandpiper habitat
LDWG-63				x	x	Resample area with PCB CSL exceedance
LDWG-63	x	x	x	x	x	Within candidate site for early cleanup action; near PCB CSL exceedance; near 36" storm drain
LDWG-64	x				x	Just downstream of early action candidate site; near locations with SVOC SQS DL exceedances
LDWG-66	x	x			x	Just upstream of early action candidate site; lack of intertidal data in this area

Location Name	Considerations for placing locations					Notes
	Spatial Data Gap	Special Use Area	Near Potential Chemical Source	Additional Characterization of Elevated Concentrations Needed	Analyte Considerations [a]	
LDWG-67	x	x			x	Just upstream of early action candidate site; lack of intertidal data in this area
LDWG-68				x		Resample area with PCB SQS exceedance from NOAA SiteChar
LDWG-69				x		Resample area with hexachlorobenzene and PAH SQS exceedance
LDWG-70				x		Resample area between 2 locations with PCB SQS exceedance from NOAA SiteChar
LDWG-71					x	Resample area with PCB SQS exceedance from NOAA SiteChar
LDWG-72	x	x				Lack of intertidal data in this area
LDWG-73				x	x	Resample area with multiple PAH SQS and CSL exceedances
LDWG-74				x		Between 3 locations with PCB SQS exceedance from NOAA SiteChar
LDWG-75		x			x	Need additional intertidal data in Duwamish Waterway Park; resample area with PCB SQS exceedance from NOAA SiteChar
LDWG-76		x				Need additional intertidal data in Duwamish Waterway Park
LDWG-77		x			x	Need additional intertidal data in Duwamish Waterway Park
LDWG-78		x		x	x	Resample area with hexachlorobenzene CSL exceedance and near locations with SVOC SQS DL exceedances; adjacent to Duwamish Waterway Park beach
LDWG-79				x	x	Resample area with phenol CSL exceedance and near locations with SVOC SQS DL exceedances
LDWG-80	x				x	No data within 100 m upstream or downstream of location
LDWG-81	x				x	No data within 100 m upstream or downstream of location
LDWG-82			x		x	Near marina
LDWG-83				x		Within 3 locations with CSL exceedances for PCBs or metals
LDWG-84			x	x	x	Between 2 locations with CSL exceedances for PCBs and zinc
LDWG-85				x		Within 4 locations with PCB SQS exceedances
LDWG-86	x	x		x	x	Need additional intertidal data in this area; just downstream of early action candidate site; resample area with PCB SQS exceedance from NOAA SiteChar
LDWG-87	x	x		x	x	Just downstream of early action candidate site; PCB SQS exceedance from NOAA SiteChar; potential sandpiper habitat
LDWG-88			x	x		Within candidate site for early cleanup action; adjacent to 48” CSO and 24” storm drain

Location Name	Considerations for placing locations					Notes
	Spatial Data Gap	Special Use Area	Near Potential Chemical Source	Additional Characterization of Elevated Concentrations Needed	Analyte Considerations [A]	
LDWG-89				x		Resample area with PCB SQS exceedance
LDWG-90				x	x	Just upstream of early action candidate site; resample area between 2 PCB SQS exceedances
LDWG-91				x	x	Just upstream of early action candidate site; near PCB and BBP SQS exceedances
LDWG-92				x		Resample area with BEHP CSL exceedance
LDWG-93				x		Resample area with PCB CSL exceedance and BBP SQS exceedance
LDWG-94				x		Resample area with BBP SQS exceedance
LDWG-95				x	x	Resample area with PCB CSL exceedances from NOAA SiteChar
LDWG-96	x	x				Need additional intertidal data in this area; resample area with PCB CSL exceedances from NOAA SiteChar
LDWG-97				x	x	Between DDT ML exceedance and benzyl alcohol CSL exceedance
LDWG-98				x		Resample area with DDT ML exceedance
LDWG-99				x		Resample area with PAH CSL exceedances
LDWG-100			x	x	x	Adjacent to locations with multiple PAH CSL exceedances and 6" and 8" storm drains
LDWG-101	x		x		x	Additional nearshore data needed; within marina
LDWG-102						Resample area with PAH CSL exceedances; near old shipyard
LDWG-103				x		Resample area with PAH CSL exceedances
LDWG-104	x		x		x	Additional nearshore data needed; within marina and adjacent to S 96th St storm drain; potential source of cement kiln dust
LDWG-105	x			x		Adjacent to multiple locations with SVOC SQS DL exceedances
LDWG-106	x	x			x	Need additional intertidal data in this area
LDWG-107	x		x		x	Need additional intertidal data in this area; adjacent to area with historic dredge fill and two locations with SVOC SQS DL exceedances
LDWG-108	x		x			Need additional intertidal data in this area; adjacent to location with historic dredge fill; adjacent to new Hamm Creek outlet
LDWG-109	x	x				Need additional intertidal data in this area; potential sandpiper habitat
LDWG-110				x	x	Adjacent to lead CSL exceedance and multiple locations with SVOC SQS DL exceedances
LDWG-111					x	Need co-located dioxin/furan and PCB congener data

Location Name	Considerations for placing locations					Notes
	Spatial Data Gap	Special Use Area	Near Potential Chemical Source	Additional Characterization of Elevated Concentrations Needed	Analyte Considerations [a]	
LDWG-112	x	x				Need additional intertidal data in this area
LDWG-113	x	x		x	x	Need additional intertidal data in this potential human use area; adjacent to PCB CSL exceedance
LDWG-114		x		x		Resample area with PCB CSL exceedance; potential sandpiper habitat
LDWG-115	x	x			x	Need additional intertidal data in this area
LDWG-116	x	x		x	x	Need additional intertidal data in this potential human use area; adjacent to PCB CSL exceedance
LDWG-117	x					Needed to establish upstream boundary of study area
LDWG-118	x				x	Needed to establish upstream boundary of study area
LDWG-119	x					Needed to establish upstream boundary of study area

[a] Some of the analyte considerations, primarily elevated detection limits, are listed in the notes column. Other analyte considerations include the need for additional data on specific chemicals or chemical groups, as described in Table 3-21.

BBP – butyl benzyl phthalate

BEHP – bis(2-ethylhexyl)phthalate

CSL – cleanup screening level (SMS)

DL – detection limit

ML – maximum level (DMMP)

SQS – sediment quality standard (SMS)

SVOC – semivolatile organic compound

Background sampling – In addition to the locations listed in Table 3-20, sediment samples from outside the LDW will be collected to characterize background concentrations of arsenic and dioxins/furans. Because these samples are unrelated to delineating the boundaries of the study area, they will only be analyzed for chemicals for which a background analysis is warranted. Based on the results of Phase 1 and planning meetings with EPA and Ecology, background sampling will be limited to arsenic and dioxins/furans, but background sampling for additional chemicals could be conducted if Phase 2 results identify additional chemicals for which such an analysis might be appropriate (e.g., pesticides).

Arsenic was identified as one of primary risk drivers in the Phase 1 HHRA based on concentrations in seafood collected from the LDW. However, Puget Sound sediments are known to have elevated concentrations of arsenic compared to other regions of the country (Ecology 2000), and there are regional anthropogenic arsenic sources outside the LDW (e.g., the former ASARCO smelter in Ruston) that may have caused arsenic concentrations within the LDW to be elevated. Dioxins and furans were also identified as chemicals of potential concern in the Phase 1 HHRA. These chemicals are produced by industrial and naturally occurring combustion processes, and some chemical manufacturing processes. Because dispersion of air emissions is one of the most common mechanisms for transport of dioxins and furans in the environment, these chemicals are usually ubiquitous in urban areas. Consequently, dioxins and furans in LDW sediments may be partially or fully attributed to background sources in the Puget Sound basin.

Arsenic concentrations in LDW sediment will be statistically compared to arsenic concentrations at reference sites in the Green/Duwamish River upstream of the LDW. Non-statistical comparisons to other regional datasets (e.g., Elliott Bay, Lake Washington, Lake Union, Lake Sammamish) will also be made for the purposes of describing a regional urban background for arsenic in sediment. These comparisons will be part of the risk assessment uncertainty analysis (see Section 3.3.2.4). The statistical approach for comparing dioxins/furans in LDW sediments to sediments in background areas will be based on the urban background concept (EPA 2002b) and a threshold minimum detectable difference (MDD). The threshold MDD will be negotiated with EPA and Ecology and will be based on identifying a meaningful difference from a risk management perspective. The exact number and location of samples for the background sampling will be specified in the surface sediment QAPP. This QAPP will also include a technical appendix that describes the statistical basis for the proposed sampling design and how the results will be evaluated statistically.

Study Design for Target Analytes

With respect to target analytes for the surface sediment study design, chemistry data collected from the locations listed in Table 3-20 will satisfy multiple objectives and will be used for multiple purposes in the Phase 2 RI. One of the objectives of this study design is to characterize the nature and extent of sediment contamination. Because existing data do not fully address all SMS parameters or all the parameters significant to human and ecological risk assessment, each sample proposed for the Phase 2 RI will be analyzed for multiple chemicals. At a minimum, every sediment sample from the LDW will be analyzed for all SMS chemicals and conventional parameters. The conventional parameters to be analyzed are sediment grain size, TOC, total sulfides, ammonia, and total solids. Grain-size data will be useful for interpretation of sediment transport and they are needed for additional habitat characterization and to inform the selection of appropriate toxicity test species and associated reference samples. TOC data are needed to normalize concentrations of some organic compounds for comparison to the SQS or CSL. Sulfides and ammonia may adversely affect some bioassay test organisms, so data are needed for these parameters to correctly interpret toxicity test data. Total solids data are needed to correctly report sediment chemistry data on a dry weight basis.

Some samples will also be analyzed for specific chemicals or chemical groups that have been analyzed less frequently in the LDW than SMS chemicals: organochlorine pesticides, PCB congeners, dioxins/furans, and TBT. Table 3-21 presents the chemical analysis plan and supporting rationale for each location listed in Table 3-20. Locations for analyses of three chemicals or chemical groups in addition to SMS chemicals are shown in Figures 3-9 (organochlorine pesticides), 3-10 (dioxins/furans), and 3-11 (TBT). These figures (located at end of document) show the existing surface sediment chemistry data used in the Phase 1 RI and the preliminary Phase 2 sampling locations for these chemicals (also shown in Figures 3-8a to 3-8e). A subset of the surface sediment samples will also be analyzed for PCB congeners,[27] but these samples will not be selected until after the Aroclor results are reviewed. Additional details on the iterative approach for PCB congener analysis are provided later in this section.

Table 3-21. Surface sediment chemistry analysis plan for Phase 2 RI

Location	SMS Chemicals	Organo-chlorine Pesticides	Dioxins/ Furans	TBT	Rationale
LDWG-1	x				
LDWG-2	x			x	Elevated TBT concentrations; GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-3	x			x	Elevated TBT concentrations
LDWG-4	x				
LDWG-5	x			x	Near cement plant; elevated TBT concentrations; dioxins/furans previously sampled in this area
LDWG-6	x			x	Elevated TBT concentrations
LDWG-7	x				

[27] The PCB congeners to be analyzed in sediment include the 12 dioxin-like congeners described by the World Health Organization (i.e., PCBs 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189) and potentially one or more other prevalent congeners that may provide other useful data for characterizing the nature and extent of PCB contamination and validating the food-web model.

Location	SMS Chemicals	Organo-chlorine Pesticides	Dioxins/ Furans	TBT	Rationale
LDWG-8	x				
LDWG-9	x			x	Elevated TBT concentrations
LDWG-10	x				
LDWG-11	x				
LDWG-12	x				
LDWG-13	x		x	x	Near source of cement kiln dust at current mouth of Puget Creek; elevated TBT concentrations
LDWG-14	x			x	Elevated TBT concentrations
LDWG-15	x			x	Elevated TBT concentrations
LDWG-16	x				
LDWG-17	x		x		Elevated dioxins from previous sampling
LDWG-18	x		x		Elevated dioxins from previous sampling
LDWG-19	x				
LDWG-20	x				
LDWG-21	x	x		x	Pesticide spatial data gap; elevated TBT concentrations; potential sandpiper habitat
LDWG-22	x	x	x	x	Pesticide spatial data gap; elevated TBT concentrations; near source of cement kiln dust at historic mouth of Puget Creek
LDWG-23	x				
LDWG-24	x				
LDWG-25	x				
LDWG-26	x	x		x	Pesticide spatial data gap; elevated TBT concentrations
LDWG-27	x				
LDWG-28	x			x	Elevated TBT concentrations
LDWG-29	x			x	Elevated TBT concentration; potential sandpiper habitat
LDWG-30	x				
LDWG-31	x	x	x		Pesticide spatial data gap; near former cement plant
LDWG-32	x				
LDWG-33	x			x	Elevated TBT concentrations
LDWG-34	x				
LDWG-35	x	x		x	Pesticide spatial data gap; elevated TBT concentrations
LDWG-36	x		x	x	Elevated TBT concentrations; near storm drain from cement plant
LDWG-37	x				
LDWG-38	x			x	Elevated TBT concentrations
LDWG-39	x				
LDWG-40	x				
LDWG-41	x				
LDWG-42	x				
LDWG-43	x	x			Pesticide spatial data gap
LDWG-44	x				
LDWG-45	x		x	x	Near potential dioxin sources; elevated dioxin/furan concentrations; elevated TBT concentrations; GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-46	x		x		Near potential dioxin sources; elevated dioxin/furan concentrations

Location	SMS Chemicals	Organo-chlorine Pesticides	Dioxins/ Furans	TBT	Rationale
LDWG-47	x		x	x	Near potential dioxin sources; elevated dioxin/furan concentrations; elevated TBT concentrations
LDWG-48	x		x		Elevated dioxins from previous sampling
LDWG-49	x				GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-50	x				
LDWG-51	x	x	x		Pesticide spatial data gap; near cement plant
LDWG-52	x				GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-53	x	x			Elevated DDT concentration
LDWG-54	x				
LDWG-55	x		x		Near CSO
LDWG-56	x	x			Pesticide spatial data gap
LDWG-57	x				
LDWG-58	x	x		x	Elevated DDT and TBT concentrations
LDWG-59	x	x			Elevated DDT concentrations
LDWG-60	x	x		x	Elevated DDT and TBT concentrations
LDWG-61	x	x			DDT spatial data gap
LDWG-62	x	x			Pesticide spatial data gap; potential sandpiper habitat
LDWG-63	x	x			Pesticide spatial data gap
LDWG-63	x	x	x[a]		Near DDT ML exceedance; co-located dioxin/furan and PCB congener data
LDWG-64	x	x			Elevated DDT concentration; GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-66	x	x			Elevated DDT concentration
LDWG-67	x				
LDWG-68	x				
LDWG-69	x				
LDWG-70	x				
LDWG-71	x	x			Pesticide spatial data gap
LDWG-72	x				
LDWG-73	x				
LDWG-74	x	x			Potentially elevated DDT concentration (DL)
LDWG-75	x	x			Pesticide spatial data gap
LDWG-76	x				
LDWG-77	x				
LDWG-78	x				GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-79	x				GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-80	x			x	Adjacent to marina (potential TBT source)
LDWG-81	x	x		x	Potentially elevated DDT concentration (DL); adjacent to marina (potential TBT source)
LDWG-82	x			x	Potential TBT source from South Park Marina
LDWG-83	x				
LDWG-84	x		x[a]		Co-located dioxin/furan and PCB congener data
LDWG-85	x				
LDWG-86	x				
LDWG-87	x				
LDWG-88	x				
LDWG-89	x				
LDWG-90	x	x			Potentially elevated DDT concentration (DL)
LDWG-91	x				

Location	SMS Chemicals	Organo-chlorine Pesticides	Dioxins/ Furans	TBT	Rationale
LDWG-92	x				
LDWG-93	x				
LDWG-94	x				
LDWG-95	x		x[a]		Co-located dioxin/furan and PCB congener data
LDWG-96	x				
LDWG-97	x	x			Elevated DDT concentrations
LDWG-98	x	x			Elevated DDT concentrations
LDWG-99	x				
LDWG-100	x	x			Potentially elevated DDT concentration (DL > SL)
LDWG-101	x			x	Near potential source of TBT
LDWG-102	x				
LDWG-103	x				
LDWG-104	x	x	x	x	Elevated DDT concentrations; near potential source of TBT and dioxins/furans
LDWG-105	x				
LDWG-106	x	x			Pesticide spatial data gap
LDWG-107	x				GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-108	x				
LDWG-109	x				
LDWG-110	x	x			Pesticide spatial data gap; GC/MS-SIM to achieve lower DLs for SVOCs
LDWG-111	x		x[a]		Co-located dioxin/furan and PCB congener data
LDWG-112	x				
LDWG-113	x				
LDWG-114	x				
LDWG-115	x	x			Pesticide spatial data gap
LDWG-116	x	x			Pesticide spatial data gap
LDWG-117	x				
LDWG-118	x	x			Pesticide spatial data gap
LDWG-119	x				
Total number of analyses	119	32	17	26	

[a] Analysis will be conducted if PCBs elevated in initial Aroclor analysis

SL – screening level (DMMP)　　ML – maximum level (DMMP)

DL – detection limit　　SVOC – semivolatile organic compound

GC/MS-SIM – gas chromatography/mass spectrometry with selective ion monitoring

The locations where these additional chemicals or chemical groups will be analyzed are based on the following general considerations: 1) existing data showing elevated concentrations of these chemicals or chemical groups in surface sediment samples from surrounding locations, 2) proximity to potential sources of these chemicals, or 3) relatively large areas where no such data exist in the Phase 1 database. Considerations specific to each chemical or chemical group are described below.

Organochlorine pesticides – Approximately 100 locations sampled for chlorinated pesticides (e.g., DDT) were included in the Phase 1 database. These samples provide a reasonable overall characterization of the LDW, but some spatial data gaps remain. Also, some elevated concentrations of DDT, which is used as a surrogate for chlorinated pesticides for the purposes of this work plan, warrant additional characterization. As shown in Table 3-21 and Figure 3-9, 32 of the proposed 119 surface sediment sampling locations shown in Figures 3-8a to 3-8e will be analyzed for chlorinated pesticides. Because there are no known sources of chlorinated pesticides within the LDW, the considerations used for identifying a location for pesticide analysis include, in priority order: 1) proximity to previously sampled location with either an ML or SL[28] exceedance for DDTs, 2) pesticide spatial data gap, and 3) proximity to potentially elevated DDT concentration, as demonstrated by a detection limit exceedance of the SL for DDTs. The first consideration, if based on an ML exceedance, warranted two additional samples because of the risks associated with the relatively high concentration.

PCB congeners – Approximately 600 locations were sampled for PCB congeners during the late 1990s. However, these data are not suitable for use in the Phase 2 risk assessments because the low-resolution analytical methods used were not able to achieve low enough detection limits for the dioxin-like PCB congeners, which tend to be of greatest concern with respect to ecological and human health risks. Consequently, high resolution PCB data for the dioxin-like congeners are needed for a subset of the sediment samples for use in the risk assessments and to assess the general pattern of potent PCB congeners within the LDW. To address these data needs, dioxin-like and selected principal PCB congeners will be analyzed at approximately 25 to 30 of the 119 surface sediment sampling locations. To determine which surface sediments samples will be analyzed for these congeners, all sediment samples will first be analyzed for total PCBs (based on an Aroclor sum). This dataset will be reviewed to select the subset of stations for dioxin-like and select PCB congener analysis to represent the overall range and distribution of total PCB concentrations necessary to address risk assessment or food web model data needs. As part of the overall study design, samples for PCB congener analysis may also be collected in early action areas[29] if needed to cover the overall range of PCB concentrations. In addition, sample locations will be selected to achieve spatial coverage of all reaches of the LDW as supporting information for food web modeling. Locations used by sandpiper and people directly (e.g., as beaches) will be preferred because concentrations of dioxin-like PCB congeners in these areas will be used directly in the risk assessments.

Dioxins/furans – The Phase 1 database includes reconnaissance-level data for dioxins/furans consisting of surface sediment samples from 29 locations throughout the LDW. Samples from two of these locations had concentrations an order of magnitude higher than concentrations from the other locations. One of these locations is within the Duwamish/Diagonal early action area, which has recently been dredged. The other is within the intertidal zone on the west side of the LDW near RM 1.5. Based

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[28] The SL and ML are part of the Dredged Material Management Program sediment quality guidelines. These values are used for the evaluation of DDT because no SQS or CSL exist for this chemical.

[29] The specific approach for these samples will be described in the surface sediment QAPP.

on the results summarized in the Phase 1 RI, it appears that any concerns associated with dioxins and furans in the LDW may be limited to isolated areas. Consequently, one of the Phase 2 sampling objectives for dioxins/furans is to provide additional characterization in those areas. The other key objective is to focus sampling on potential source areas. Research conducted by EPA and Ecology as part of Phase 2 work plan scoping suggests that cement kiln dust (a byproduct from cement manufacturers) may be a source of dioxins/furans in the LDW. Therefore, many of the 17 Phase 2 locations proposed for dioxin/furan sampling are near potential sources of cement kiln dust (Table 3-21, Figure 3-10). Four locations were chosen to investigate the potential co-location of PCBs and dioxins/furans at locations with elevated PCB concentrations. Given the relatively uniform distribution of the 29 locations previously sampled for dioxins/furans, and the relatively low concentrations at all but two of those locations,[30] additional reconnaissance-level data to fill spatial data gaps for dioxins/furans does not appear to be warranted.

TBT – Reconnaissance-level data for TBT have been previously collected and analyzed at approximately 100 locations, as summarized in the Phase 1 RI and Figure 3-11. Concentrations were generally higher in the northern half of the LDW than the southern half. Research conducted by EPA and Ecology as part of Phase 2 work plan scoping suggests that marinas and shipyards may be TBT sources in the LDW. Thus, two primary considerations for selecting locations for TBT sampling in Phase 2 are proximity to elevated TBT concentrations from the Phase 1 RI database and proximity to potential TBT sources. Of the 26 locations selected for TBT sampling in Phase 2, 21 are in the northern half of the LDW (Figure 3-11). In each area with the higher TBT concentrations in the Phase 1 database (i.e., greater than 200 µg/kg), two locations are identified in Figure 3-11 for additional TBT sampling in Phase 2. Additional sediment samples not shown in Figure 3-11 will be collected in conjunction with gastropod collection and analyzed for TBT to evaluate the relationship between tissue and sediment TBT concentrations (see Section 3.1.5.2 for additional discussion of this study design).

Sampling Methods

Surface sediment collection and processing will follow standardized procedures for the Puget Sound area that have been developed by PSEP (1997). Surface sediments will be collected from each location shown in Figures 3-8a to 3-8e using a double 0.1-m^2 van Veen grab sampler. The 0-10-cm sediment interval will be collected to represent the biologically active horizon and to compare directly with previous

[30] The range of dioxin TEQ concentrations detected in the LDW (1.2 to 16.1 ng/kg, excluding the two locations with elevated concentrations) is similar to the range of concentrations detected in 11 lakes and reservoirs throughout the US selected by EPA (2000c) to represent background conditions (0.12 to 16.3 ng/kg dw). Both the LDW and the EPA background concentrations were calculated using mammalian TEFs from Van den Berg et al. (1998) and one-half the detection limit for undetected dioxins. TEQs were calculated for these sediment samples for inter-sample comparisons only.

surface sediment studies conducted in the LDW.[31] Multiple grab samples for a given location might be necessary to collect sufficient volume. Sediment from each location will be archived for potential analysis of dioxin-like and selected principal PCB congeners. Additional details of sample compositing will be provided in the surface sediment QAPP.

Analytical Methods

The preliminary chemical analytical methods for surface sediment are identified in Table 3-22. These methods are commonly used in environmental investigations conducted under Superfund. Selected analytical methods and associated detection limits, which will be identified in the sediment chemistry QAPP, will be appropriate for the RBC goals associated with surface sediments. RBC goals will be developed in the sediment chemistry QAPP. The proposed analytical methods will be reviewed in the context of the RBC goals. Some of the RBC goals may be lower than detection limits that can be routinely achieved by commercial laboratories. In these cases, the proposed methods will be reviewed to determine if modifications can be made to achieve lower detection limits, or if other methods might be more appropriate. Given the relatively strict data quality requirements under Superfund, it is likely the available methods for a particular analyte class will be limited to EPA-approved methods.

SMS chemicals and conventional parameters will be analyzed in every surface sediment sample, while the chemicals listed under "other chemicals" in Table 3-22 will be analyzed in only a subset of the samples, as described in Table 3-21. Specific data quality objectives and target detection limits for each method will be specified in the surface sediment QAPP.

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[31] The Phase 1 RI and associated risk assessments operationally defined "surface sediments" from 0 to 15 cm; however, all but 7 samples collected using a grab sampler and included in the Phase 1 dataset included the top 10 cm only. The 0.1-m^2 van Veen grab sampler commonly used in Puget Sound can achieve a penetration depth of approximately 13 cm, but the sediment touching the sampler bottom is typically not included in the sample because of sample integrity concerns.

Table 3-22. Analytical methods for surface sediment

PARAMETER	METHOD	NOTES
SMS Chemicals		
Semivolatile organics	GC/MS (EPA 8270) [a]	GC/MS-SIM for a subset of samples to achieve lower detection limits
PCBs (as Aroclors)	GC/ECD (EPA 8082)	
Mercury	CVAA (EPA 7471)	
Other metals	ICP-AES (EPA 6010) [b]	arsenic, cadmium, chromium, copper, lead, nickel, silver, zinc
Other Chemicals		
TBT	GC/FPD (Krone et al. 1989)	subset of samples (see Table 3-21)
PCB congeners	HRGC/HRMS (EPA 1668A) [c]	subset of samples
Dioxins/furans	HRGC/HRMS (EPA 1613B)	subset of samples (see Table 3-21)
Organochlorine pesticides	GC/ECD (EPA 8081)	subset of samples (see Table 3-21)
Conventional Analyses		
TOC	Combustion (Plumb 1981)	
Total sulfides	Spectrophotometer (PSEP 1986)	
Ammonia	Colorimetric (EPA 350.1)	
Total solids	Oven-dried (PSEP 1986)	
Grain size	Sieve/pipette (PSEP 1986)	

[a] Some compounds (e.g., 1,2-dichlorobenzene, 1,4-dichlorobenzene, and 1,2,4-trichlorobenzene) can be quantified using both the semivolatile (8270) and volatile (8260) analytical methods. However, some of the historical studies that collected data for these compounds using the semivolatile analytical method (8270) failed to achieve detection limits low enough for comparison of results to the SQS or CSL. The need to use EPA Method 8260 to achieve lower detection limits for these compounds will be reviewed with the laboratory selected to analyze the sediment samples.

[b] Other methods (i.e., GFAA or ICP-MS) may be used for metals depending on the detection limit goals to be specified in the QAPP

[c] The specific congeners to be quantified will be specified in the QAPP

CVAA – cold vapor atomic absorption
ECD – electron capture detection
FPD – flame photometric detector
GC – gas chromatography
HRGC – high resolution gas chromatography
HRMS – high resolution mass spectrometry
ICP – inductively coupled plasma-atomic emission spectrometry
MS – mass spectrometry
PSEP – Puget Sound Estuary Program
SIM – selected ion monitoring
TBT – tributyltin
TOC – total organic carbon

3.1.8.2 Sediment toxicity testing

Objectives and Background

As identified in the data needs memorandum (Windward 2003f), additional toxicity testing data are needed to assess risks to benthic invertebrates using site-specific data and to supplement the relatively few (10) toxicity test results available for the LDW. The objective of the toxicity testing is to assess effects on benthic invertebrates through the use of site-specific toxicity testing and synoptic chemistry.

A large amount of surface sediment chemistry data have been collected in the LDW over the last 13 years (see Table 3-19), but only two studies (Ecology 2000; King County 2000a) have conducted sediment toxicity tests on surface sediments during that time. Collection locations for the 10 samples analyzed for sediment toxicity in these studies are shown in Figure 3-5 (located at end of document). The samples analyzed for the Duwamish/Diagonal cleanup study (King County 2000a) were collected in an area with moderately high chemical concentrations to help define cleanup boundaries. Five of the seven locations sampled were within an area proposed for cleanup by King County (2000a) and have since been removed. The three samples tested by Ecology (2000) were for reconnaissance purposes and were not targeted on a particular contaminant source.

Study Design

The size of the LDW makes testing toxicity at every sediment location with a SQS or CSL exceedance impractical from a cost-benefit perspective. Therefore, a two-tiered approach was developed, in consultation with EPA and Ecology, to identify locations where toxicity testing should occur. The tiered approach evaluates risks to the benthic invertebrate community through direct measurement of toxicity in standardized laboratory toxicity tests. Where appropriate and in consultation with EPA and Ecology, toxicity test response data may be used to estimate risks to the benthic community in adjacent areas where only sediment chemistry data are available.

The agreed approach includes the following elements:

- Sediment collection and toxicity testing will be conducted using a two-tiered approach (Figure 3-12).
- In both tiers, sufficient sediment will be collected at each station to conduct both chemical analyses (with an expedited turn-around-time) and toxicity testing. In this way, a subset of the sediment sampling locations can be selected for toxicity testing based on concurrent chemistry data rather than using historical sediment chemistry data.

The tiered approach consists of three decision points. First, approximately 80 to 100 locations will be selected for the first tier of sediment sampling. Sample locations will be selected based on any of the six primary considerations identified in Section 3.1.8.1, and will be identified in the surface sediment QAPP based on future discussions with EPA and Ecology.

Second, up to 50 to 60 of these locations will be selected for Tier 1 toxicity testing. This number is based on the approximate upper limit of the testing laboratory to simultaneously conduct multiple toxicity tests. When the chemistry data from the samples become available, locations for Tier 1 toxicity testing will be selected (in consultation with EPA and Ecology) based on sediment chemistry and location (i.e., proximity to potential or known sources and proximity to each other).

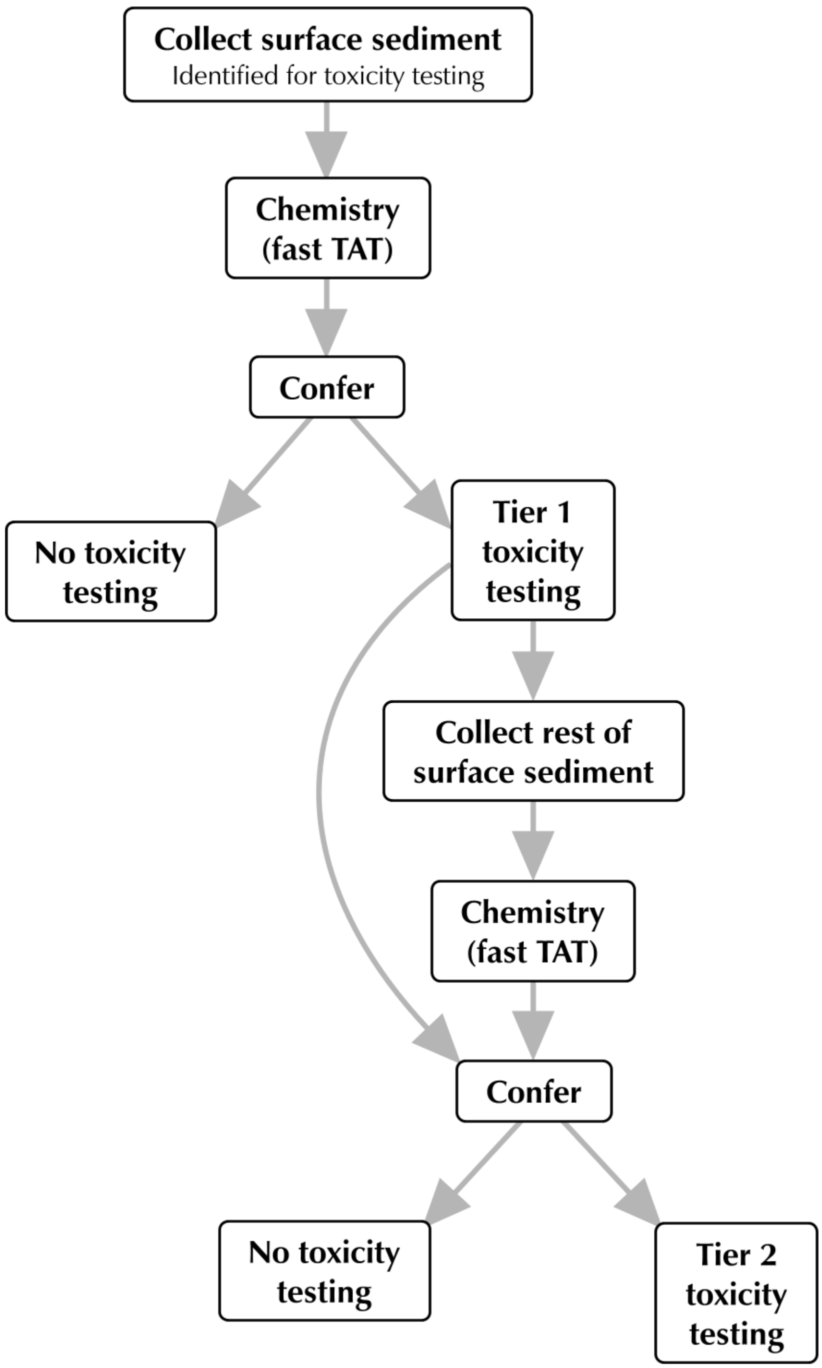

Figure 3-12. Proposed tiered approach for sediment toxicity testing

TAT – turnaround time

Third, after the Tier 1 toxicity test results have been interpreted and discussed with EPA and Ecology, surface sediment samples will be collected from the remaining locations. When the chemistry data from these samples become available, locations for

Tier 2 toxicity testing will be selected (in consultation with EPA and Ecology) based on sediment chemistry, station location, and the results of the Tier 1 toxicity testing.

In both Tier 1 and 2, toxicity testing will occur at some, but not all, stations with an SQS exceedance. For stations not tested, risks to benthic invertebrates at these stations will be assessed based on sediment chemistry, with additional information from the toxicity test results from other stations as appropriate. "Management" of these stations (e.g., decisions regarding the potential need for sediment remediation) will be determined in the feasibility study stage of the project.

No locations in early action areas with active sponsors are planned for toxicity testing because these areas are known to require some level of remediation, and further work associated with them will be done as part of the site-specific remediation process. If sediment toxicity data or other data relevant to assessment of benthic community risks are generated from separate investigations of any of the early action areas, these data will be incorporated into the Phase 2 ERA.

Sampling Methods

Sediment samples will be collected with a 0.1-m^2 double van Veen grab sampler, as described in Section 3.1.8.1. Sediment samples for toxicity testing will be removed from the homogenized composite sample and placed in appropriate containers for delivery to the toxicity testing laboratory.

Analytical Methods

Three sediment toxicity tests will be conducted on each sample collected from locations identified for toxicity testing. Standard SMS toxicity tests will be used, such as:

- Acute 10-day amphipod mortality test (*Eohaustorius estuarius*). This species is well suited for testing with Puget Sound sediment and can be used for testing over grain-size distributions ranging from 0.6–100% sand (DMMP 1999) and interstitial salinities ranging from 2–28 ppt (PSEP 1995). If interstitial salinities are outside this range, other amphipod species will be considered.
- Acute bivalve larvae combined mortality test (*Mytilus galloprovincialis*)
- Chronic 20-day juvenile polychaete survival and growth test (*Neanthes arenaceodentata*)

Biological testing will be conducted according to *Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments* (PSEP 1995), with modifications as periodically specified in annual Sediment Management Annual Review Meetings.

Ammonia unrelated to anthropogenic chemicals may cause toxic effects to amphipods (DMMP 2001). False positive toxicity results can be caused by increased concentrations of ammonia, making it impossible to determine the toxicity attributable to the COPCs.

If elevated ammonia concentrations are present in test sediment, a positive control test for ammonia in sediment may be conducted.

Toxicity testing protocols require that test sediments be matched and tested simultaneously with appropriate reference sediment to factor out sediment grain-size and TOC effects on bioassay organisms. Three reference sediment samples will be collected from Carr Inlet, corresponding to the following ranges of percent fines: 70–90%, 40–60%, and 10-30%. TOC content will also be matched to the test sediments as closely as possible (PSEP 1995). Each reference sediment sample will be tested for toxicity using the same three test organisms. The appropriate reference sediment for each LDW test sediment sample will be determined in consultation with EPA and Ecology after reviewing the results of TOC and grain-size analyses for those samples.

3.1.9 Porewater sampling and chemical analyses

A QAPP for the collection and chemical analyses of porewater samples will be submitted to EPA and Ecology for review, comment, and approval following their approval of this work plan. This section describes the general scope for that QAPP.

3.1.9.1 Objectives and background

The data needs memorandum (Windward 2003f) identified the need for the collection and chemical analyses of porewater samples. In particular, these samples are needed to:

- collect or supplement existing porewater data at locations expected to have the highest concentrations of VOCs in groundwater near the LDW based on input from the source control work group
- assess exposure of benthic invertebrates to VOCs in porewater that may be entering the LDW from groundwater

Because of their low affinity for sediment and potential for rapid volatilization and biodegradation, VOCs are not expected to accumulate in sediment, but they may be present in sediment porewater if there is a continuing source from groundwater to the LDW that discharges through the sediment-surface water interface. Risk from other more stable compounds with a higher affinity for sediment (i.e., metals, PCBs, PAHs), will be evaluated using sediment chemistry and toxicity test data.[32] Because VOCs may not be detected in sediment or persist in sediments used in toxicity tests as a result of their volatility and instability, porewater will be sampled for VOCs *in situ*. Concentrations of VOCs in porewater would then be compared to available effects data for VOCs and aquatic organisms (e.g., Washington State water quality standards; individual toxicity studies) to evaluate risks to benthic invertebrates. The porewater

[32] If areas with highly elevated VOCs in porewater are identified, then the potential for co-solvency of PCBs or metals will be discussed with the agencies.

QAPP will also contain a general conceptual model regarding potential exposure pathways from groundwater to the sediment-surface water interface.

The Phase 1 RI (Appendix G) presented groundwater data from 12 upland sites that were identified as preliminary sites of interest for Phase 1. Data from these sites will be reviewed to identify a few sites where the greatest discharge of VOCs is expected. The identified sites would then be sampled to represent the worst-case exposure scenarios. It is assumed that risk predicted at these sites would be greater than risk in other areas where groundwater VOC concentrations are lower or plumes are more distant from the LDW.

3.1.9.2 Study design

Porewater will be collected and analyzed following a tiered approach. The first tier will consist of porewater sampling near known sources of VOCs to cover areas representing the worst-case scenarios of exposure. If adverse effects are not predicted in areas with the greatest exposure potential, then no additional sampling will be conducted. However, if effects are predicted, then a second tier of sampling will be designed to cover other areas in the LDW where exposure may occur, or where sources have not yet been identified.

In the first tier, existing shoreline groundwater data and seep data summarized in the Phase 1 RI will be evaluated for potential VOC discharge to the LDW. Based on this evaluation, porewater sampling will be conducted at a few expected worst-case exposure areas. To locate the area where groundwater VOCs would be most likely to discharge, site-specific data on plume locations, groundwater elevations, and groundwater flow directions will be reviewed from existing reports. The number of sampling stations at each site will depend on the size of the groundwater plume and potential spatial extent of the discharge. These locations may be in either intertidal or subtidal areas. Porewater will be sampled from the top 10 cm of sediment, the biotic zone where most benthic invertebrates could be exposed to VOCs. If the risk evaluation indicates that additional sampling should be conducted at other sites or using other methods, the second tier of sampling would be planned in consultation with EPA and Ecology. The porewater chemical concentrations will be compared to appropriate toxicity information from the literature, in addition to Washington State water quality standards, or EPA's water quality criteria when state standards are not available.

3.1.9.3 Sampling methods

Sampling locations will be identified in the field through the use of a GPS. Porewater will be collected using peepers, which are small chambers with membrane walls containing clean water similar in salinity and hardness to that expected at the sampling location. The peepers are buried in the sediment and surrounding interstitial waters are allowed to infiltrate. Any solutes dissolved in the porewater will diffuse through the porous material of the membrane walls until the water within the chambers reaches equilibrium with the ambient interstitial water. After deployment, the peepers will be left in place for a sufficient period to allow for equilibration. The exact equilibration time is a function of sediment type, study objectives, chemicals of concern, temperature, membrane pore size, and peeper volume (EPA 2001). These factors will be reviewed and the rationale for the chosen equilibration time will be presented in the porewater QAPP.

Upon retrieval of interstitial water from the peepers, sample containers will be filled immediately without headspace to minimize oxidative changes or volatilization. Samples will be placed in a cooler until delivery to the analytical laboratory.

3.1.9.4 Analytical methods

Porewater samples will be analyzed using EPA Method 8260B (GC/MS with purge and trap) for analysis of VOCs in water. Specific data quality objectives and target detection limits will be specified in the QAPP.

3.1.10 Subsurface sediment sampling and chemical analyses

A QAPP for the collection and chemical analyses of subsurface sediment samples will be submitted to EPA and Ecology for review, comment, and approval following their approval of this work plan, and the completion of the bathymetry, sediment transport, and surface sediment chemistry studies. This section describes the general scope for that QAPP. Locations and numbers of samples presented in this section are preliminary and are included to establish a general level of effort for specific studies. These details are subject to modification during finalization of the QAPP.

3.1.10.1 Objectives and background

Collection of additional subsurface sediment chemistry data is recommended in specific areas of the LDW to support the Phase 2 RI (Windward 2003f). In particular, additional subsurface sediment samples are needed to fulfill the following objectives:

- provide additional characterization of the nature and extent of subsurface chemical concentrations in selected areas where surface concentrations are elevated but subsurface data are not available
- investigate subsurface chemical concentrations in areas that may be subject to erosion or adjacent to potential chemical sources

While the additional subsurface sediment chemistry data may also support the FS, data needs specific to the FS will be identified in the FS work plan. The subsurface sampling design as presented in this section may be modified based on results from surface sediment sampling, bathymetry, and sediment transport studies. Proposed locations, sample depths, and analytes may be revised in the QAPP after review of these other sampling investigations.

Although there have been many different sampling events since 1990 that collected subsurface sediment chemistry data, most have focused on specific areas that were to be dredged (Table 3-23). Because the sediment characterized by these dredged material studies (shown in italics in Table 3-23) is no longer present, the chemistry data from these samples are not useful for characterizing the current nature and extent of chemical concentrations that could affect human or ecological receptors. Subsurface sediment sampling conducted at two early action sites, Duwamish/Diagonal CSO/storm drain and Boeing Plant 2, included cores as deep as 360 cm (12 ft) for the purposes of remedial action design. Other subsurface sediment sampling on a reconnaissance-level was conducted during EPA's 1998 Site Inspection. During this survey, cores up to 120 cm (4 ft) were collected and analyzed.

Table 3-23. Subsurface sediment samples collected since 1990 and used in the Phase 1 RI

Event	Chemical Groups Analyzed	Subsurface (> 15 cm) Samples Analyzed	Reference
Dredge material characterization Duwamish Yacht Club (1999)	metals, pesticides, PCB Aroclors, SVOCs, VOCs, TBT	6	Hart Crowser (1999)
Dredge material characterization Hurlen Construction Company & Boyer Alaska Barge Lines berthing areas (1998)	metals, pesticides, PCB Aroclors, SVOCs, TBT, TPH	6	Hart Crowser (1998)
EPA Site Inspection: Lower Duwamish River (1998)	metals, pesticides, PCB Aroclors & selected congeners, dioxins & furans, TBT, SVOCs, VOCs	33	Weston (1999)
RCRA Facility Investigation Duwamish Waterway sediment investigation, Plant 2 – Phase 2b (1996)	metals, PCB Aroclors, SVOCs	44	Weston (1998)
Proposed dredging of Slip No. 4, Duwamish River, Seattle, WA (1996)	metals, pesticides, PCB Aroclors, SVOCs, VOCs, TBT	4	PTI (1996)
Duwamish/Diagonal cleanup study – Phase 2 (1996)	metals, PCB Aroclors, SVOCs, TPH	53	King County (2000a)
Norfolk CSO sediment cleanup study – Phase 2 (1995)	metals, pesticides, PCB Aroclors and selected congeners, SVOCs, VOCs, TPH	27	King County (1996)
RCRA Facility Investigation Duwamish Waterway sediment investigation, Plant 2 – Phase 1 (1995)	metals, PCB Aroclors, TPH, SVOCs, VOCs	22	Weston (1998)
Duwamish/Diagonal cleanup Study – Phase 1 (1994)	metals, pesticides, PCB Aroclors, SVOCs, TBT	12	King County (2000a)
Norfolk CSO sediment cleanup study – Phase 1 (1994)	metals, pesticides, SVOCs, PCB Aroclors, VOCs	3	King County (1996)
Lone Star Northwest – West Terminal USACE – Seattle (1992)	metals, pesticides, PCB Aroclors, SVOCs, VOCs	1	Hartman Associates (1992)

Events in italics characterized subsurface sediment that was subsequently dredged

Data from a total of 68 locations from previous sampling events currently exist to characterize subsurface chemistry in the LDW. Forty of these 68 locations are within the Duwamish/Diagonal and Boeing Plant 2 early action areas. At this stage of the LDW RI/FS, additional nature and extent data for subsurface sediment from selected locations are needed. The following section discusses how additional locations will be selected for subsurface sediment sampling to supplement existing data.

3.1.10.2 Study design

One of the general considerations for subsurface sediment sampling is that chemical concentrations in subsurface sediments could potentially be higher than chemical concentrations in surface sediments for some chemicals and areas. Therefore, Phase 2 subsurface sediment sample locations were identified based on the following key considerations:

- **Erosion potential –** Erosion potential was determined, in part, by reviewing USACE (2002), which describes LDW Port of Seattle facilities, including docks, wharves, and other locations, where propeller scour could be important. Additional documentation was provided by USACE during work plan scoping meetings. Phase 2 data collected during the bathymetry and sediment transport studies will also be used in identifying areas with erosion potential.
- **Proximity to potential chemical sources –** Proximity was based on existing information, including existing dredged material characterization data, and the preliminary source control investigations of waterfront properties and outfalls by member agencies of the LDW source control work group, including review of historic aerial photos, records, and files. If additional research on potential current and historic chemical sources is conducted early in Phase 2, it will be incorporated into the subsurface sediment QAPP.
- **Elevated existing surface concentrations –**Areas where elevated chemical concentrations in surface sediments were found, but where no data on subsurface contamination exist.

Information on dredging events since 1990 in LDW areas where the sediments were determined to be suitable for open-water disposal was also used to inform the placement of the proposed subsurface sampling locations, although this study design consideration is secondary to the primary considerations listed above. For example, subsurface sediment sampling in the vicinity of Terminal 105 (RM 0.1 to 0.3 W) may not be warranted because existing data collected by the Port of Seattle in 1985 indicate that the subsurface sediments there have relatively low chemical concentrations . Although these data were collected prior to 1990, chemical concentrations in the deeper sections of the subsurface sediments characterized during this event are unlikely to be much different now because they are not likely to have been exposed since 1985. The Terminal 105 data were never published, but the data will be provided to EPA and Ecology for review prior to their use in the subsurface QAPP.

In addition to the 68 existing subsurface core locations, 21 Phase 2 subsurface sediment sampling locations are proposed; these are shown in Figures 3-13a to 3-13e (located at end of document). The locations in Figures 3-13a to 3-13e are intended to represent a preliminary estimate of the number and location of sediment samples. The exact sampling locations will be specified in the subsurface sediment QAPP, which will be submitted after the results of the surface sediment chemistry and sediment transport studies are available. Additional subsurface sediment sampling locations may be identified after the results from these studies are evaluated. The proposed locations are based largely on proximity to potential chemical sources and/or elevated surface sediment chemical concentrations. While some locations are based on erosion potential, additional data to be collected on sediment erosion rates (see Section 3.1.7) will be used to refine the study design with respect to identifying potentially erosive areas. Table 3-24 lists each station and the factors that were considered for placing the stations at those locations. The chemical analysis plan for sediment samples collected from these locations is described in Section 3.1.10.4.

Table 3-24. Subsurface sediment chemistry sampling locations for the Phase 2 RI

Location	Considerations for Placing Sampling Locations			
	Potential Area of Erosion	Near Potential Chemical Source	Elevated COPC Concentration in Surface Sediment	
LDWG-5		x	x	Near phenol CSL exceedance in surface sediment; adjacent to potential source of metals to sediments
LDWG-16		x		Near 2 locations with multiple chemical SQS and BEHP CSL exceedances in surface sediment
LDWG-22		x	x	Near potential source of cement kiln dust; near PCB SQS exceedances in surface sediment
LDWG-26	x		x	In area with possible propeller scour effects ; near locations with multiple SQS and CSL exceedances
LDWG-38		x	x	Near BEHP CSL exceedance in surface sediment; near shipyard
LDWG-42			x	Adjacent to Duwamish shipyard outfall
LDWG-53			x	Near PCB SQS exceedance in surface sediment
LDWG-54	x	x	x	Adjacent to 2 locations with phthalate CSL exceedances in surface sediment; located adjacent to area of heavy barge traffic and 72” storm drain
LDWG-55		x		Near upland cleanup site for PCBs, bunker C, metals, and PAHs; near Michigan CSO
LDWG-60	x		x	In area with possible propeller scour effects; adjacent to DDT ML exceedance in surface sediment
LDWG-63			x	Near PCB CSL exceedance in surface sediment
LDWG-73	x		x	In area with possible propeller scour effects; near location with multiple PAH SQS and CSL exceedances in surface sediments

Location	Considerations for Placing Sampling Locations			
	Potential Area of Erosion	Near Potential Chemical Source	Elevated COPC Concentration in Surface Sediment	
LDWG-79			x	Near phenol CSL exceedance in surface sediment
LDWG-95		x	x	Near storm drain; near PCB CSL exceedance in surface sediment
LDWG-98			x	Near DDT CSL exceedance in surface sediment
LDWG-110			x	Adjacent to lead CSL exceedance in surface sediment
LDWG-120 [a]	x		x	Area with barge traffic; near PCB and zinc SQS exceedances in surface sediment
LDWG-121 [a]	x			Area with barge traffic
LDWG-122 [a]		x		Adjacent to cement plant
LDWG-123 [a]			x	Adjacent to 2 locations with BEHP or PCB CSL exceedances in surface sediment
LDWG-124 [a]	x			Area with heavy barge traffic

[a] Location for subsurface sample only. No co-located surface sample will be collected during the surface sediment sampling event (see Section 3.1.8).

Note - At locations where both surface and subsurface sediment samples will be collected, the samples will be collected using separate sampling equipment (i.e., two separate samples will be collected).

At each location, single cores (up to 300 cm [10 ft] or until refusal, whichever is less) will be collected. Up to 6 samples will be created from each sediment core. The top two samples from each core will be analyzed initially; deeper samples will be archived. The decision to analyze the archived samples will be based on results from the initial chemical analyses of the first two horizons, as well as sediment transport analysis.

The decision tree for establishing sample intervals at each location will be provided in the subsurface sediment QAPP. In addition, the need for finer-resolution sampling will be considered based on the results of the sediment transport study. Finer-resolution sampling (i.e., more samples within a core) may also be conducted during the FS.

3.1.10.3 Sampling methods

Methods for collecting sediment core samples will be described in detail in the subsurface sediment QAPP, but are briefly described here. Continuous core samples will be collected to a 300-cm depth or until refusal, whichever is less. The depth of core penetration will be measured and recorded. The internal recovery will be measured down the inside of the core tube from the top of the tube to the surface of the sediment and recorded. The overall percent recovery is determined by dividing the internal recovery by the penetration depth. The core sample will be evaluated at the visible ends of the core tube to verify retention of the sediment in the core tube. Core samples will be taken immediately to the processing facility following collection or kept on ice in an insulated core box until transport to the processing facility. Sediment sample logging and compositing will be done at the processing facility. Each sediment core will be divided into the intervals described in the preceding section.

3.1.10.4 Analytical methods

Each subsurface sediment sample identified for chemical analyses will be analyzed for SMS chemicals and conventional parameters. The analytical methods for subsurface sediment are identified in Table 3-25. Specific data quality objectives and target detection limits for each method will be specified in the QAPP.

Several other parameters may be added in the QAPP depending upon the results of the surface sediment sampling and the sediment transport study. These parameters include bulk density, dioxins/furans, pesticides, and TBT.

Table 3-25. Analytical methods for subsurface sediment

PARAMETER	METHOD	NOTES
SMS Chemicals		
Semivolatile organics	GC/MS (EPA 8270) [a]	
PCBs (as Aroclors)	GC/ECD (EPA 8082)	
Mercury	CVAA (EPA 7471)	
Other metals	ICP-AES (EPA 6010) [b]	arsenic, cadmium, chromium, copper, lead, nickel, silver, zinc
Conventional Analyses		
TOC	Combustion (Plumb 1981))	
Total solids	Oven-dried (PSEP 1986)	
Grain size	Sieve/pipette (PSEP 1986)	

[a] Some compounds (e.g., 1,2-dichlorobenzene, 1,4-dichlorobenzene, and 1,2,4-trichlorobenzene) can be quantified using both the semivolatile (8270) and volatile (8260) analytical methods. However, some of the historical studies that collected data for these compounds using the semivolatile analytical method failed to achieve detection limits low enough for comparison to the SQS or CSL. The need for EPA Method 8260 for these compounds will be reviewed with the laboratory selected to analyze the sediment samples.

[b] Other methods (i.e., GFAA or ICP-MS) may be used for metals depending on the detection limit goals to be specified in the QAPP

CVAA – cold vapor atomic absorption
ECD – electron capture detection
GC – gas chromatography
ICP – inductively coupled plasma-atomic emission spectrometry
MS – mass spectrometry
PSEP – Puget Sound Estuary Program

3.2 FIELD STUDIES IMPLEMENTATION

Once the individual QAPPs are approved by EPA and Ecology, the studies will be conducted (Task 10 of the SOW). Following the completion of each study and the validation of all data, a data report will be completed and submitted to EPA and Ecology. Data reports will contain the following elements:

- brief review of the study design and methods
- data tables and maps summarizing the field event
- deviations from the project-specific QAPP

- copies of field logs (appendix)
- data validation report (appendix)
- tables of all raw data (appendix)

Chemistry data will also be submitted electronically to EPA and Ecology in the SEDQUAL database format.

3.3 BASELINE AND RESIDUAL RISK ASSESSMENTS

Baseline and residual ERAs and HHRAs will be conducted after the field data identified in Section 3.1 have been collected, validated, and analyzed (Task 11 of the SOW), and after additional information is collected and evaluated as described below. The risk assessments will be conducted for two exposure regimes: 1) baseline sediment conditions in the absence of any early action, and 2) residual sediment conditions accounting for the effects of the planned early action projects. The latter assessments will be conducted by assuming that contamination of sediments within early action areas has been reduced in severity and extent because of cleanup activities; sediments in areas outside the early actions will reflect baseline conditions. These assessments will provide an estimate of residual risks following early actions, and will be used to determine whether remedial actions, beyond the early actions, are warranted for the remainder of the LDW. Because some of the early actions may not be completed when the residual risk assessments are conducted, some uncertainty will remain regarding sediment contamination and associated ecological and human health risk reduction that might occur as a result of ongoing early actions. The assumptions to be made for the residual risk assessments are not outlined in this work plan, but will be described in the residual risk analysis technical memorandum that will be submitted to EPA and Ecology to outline an approach for predicting exposures in the post-cleanup exposure regime at early action areas.

Phase 2 risk assessments will be based on existing surface sediment data approved for Phase 2[33] as well as surface sediment data collected as part of the benthic invertebrate study (Section 3.1.5) and the surface sediment study (Section 3.1.8). Potential exposures to subsurface sediment and risk implications associated with these exposures will be addressed in a separate appendix to the RI.

The fundamental technical approach for the Phase 2 risk assessments will be similar to the Phase 1 risk assessments, but there will be added complexity in some areas. Key differences from the Phase 1 risk assessments include:

- increased sample size and type of biotic and abiotic media for estimating chemical exposures
- modified exposure scenarios

[33] To be outlined in a historical data technical memorandum (Section 3.1.8).

- probabilistic risk characterization and uncertainty analysis
- inclusion of PCB congener information

Additional specific differences are provided in Sections 3.3.1 (ERA) and 3.3.2 (HHRA).

Draft baseline and residual ERA and HHRA reports will be submitted to EPA and Ecology for review and comment. The final baseline and residual risk assessment reports will be included in the Phase 2 RI report (Section 3.4).

Sections 3.3.1 (ERA) and 3.3.2 (HHRA) below provide additional details on the technical approach for the baseline risk assessments, focusing in particular on important differences compared to Phase 1. Section 3.3.3 presents considerations for the food web model that will be used to predict concentrations of bioaccumulative, risk-driver chemicals in tissue of fish and shellfish, as appropriate,[34] in the residual risk assessments. The food web model will also be used to relate risks from risk-driving, bioaccumulative chemicals in tissues to sediment RBGs, as discussed in Section 3.4.

3.3.1 Ecological risk assessment

A scoping-phase ERA was conducted for the LDW as part of the Phase 1 RI (see Section 2.2). In the scoping-phase ERA, risks to ecological receptors were estimated using existing data and conservative assumptions about exposures to site chemicals and toxicity of those chemicals. Approaches used in Phase 1 were developed through considerable agency and stakeholder comment. As part of the Phase 2 ERA, additional data (as described in Section 3.1) will be collected to fill critical data needs identified in Phase 1 and displayed in Appendix A (Windward 2003f). These data will be combined with existing field and analytical data, as well as additional information gathered since the Phase 1 ERA to assess risks to ecological receptors in the absence of any early actions, and to estimate risks at the site following completion of early remedial actions (i.e., residual risk).

The Phase 2 baseline ERA will be conducted using many of the approaches used in Phase 1. However, the Phase 2 approach will be somewhat modified from Phase 1, as summarized in Table 3-26. This table also provides the rationale for the differences in approach from Phase 1.

[34] A Gobas-type food web model is appropriate for nonionic hydrophobic chemicals. If risk-driving chemicals are identified that do not meet these criteria, alternative models will be reviewed in consultation with EPA and Ecology.

Table 3-26. Key differences in the Phase 2 ERA compared to Phase 1

Difference	Rationale
Use of Pacific staghorn sculpin rather than bull trout[a] to represent piscivorous fish[b]	Sculpin can be collected in Phase 2 because they are not listed under the Endangered Species Act. Sculpin are expected to have greater site use and greater sediment exposure than bull trout.
Use of osprey rather than bald eagle[a] to represent piscivorous birds	Osprey have greater site fidelity to the LDW during their residence, have a higher ingestion rate-to-body weight ratio, and egg data will likely be available through a recent USGS study.
Use of LDW surface water chemistry data in the wildlife exposure estimates	Water exposure was assessed but not included in exposure estimates in Phase 1; surface water chemistry data will be used in dose calculations for water ingestion by wildlife in Phase 2.
Discussion of the results of the water quality assessment for metals and PAHs in the fish risk characterization	Phase 1 provided a summary of results of the King County water quality assessment, but these results were not discussed in the risk characterization section of the ERA. The water chemistry data and assessment results will be discussed in the Phase 2 risk characterization to acknowledge the water pathway for COPCs addressed through a dietary pathway[c] (i.e., metals [except mercury] and PAHs)
Assessment of sediment-based toxicity reference values for fish	Sediment-based toxicity reference values will be considered in Phase 2 because one of the Phase 2 RI goals is to develop risk-based goals for sediment.
Use of probabilistic risk analysis techniques in exposure estimates for fish and wildlife	Use of these approaches will provide risk managers with a range of risk estimates that more realistically portray site conditions compared to a single point estimate
Presentation of the range of relevant toxicity reference values in the risk characterization	
Use of direct effects data (i.e., toxicity tests) for benthic invertebrate risk characterization	Sediment toxicity test data collected in Phase 2 will allow adverse effects to be measured, rather than predicted, as was done in Phase 1
Incorporation of PCB congener data to assess risk from dioxin-like PCB congeners for certain ecological receptors	Risks associated with dioxin-like PCB congeners were not quantified in Phase 1 because PCB congener data with sufficiently low detection limits were not available; such data will be collected in Phase 2
Assessment of background concentrations of dioxins/furans and arsenic	Samples from background areas will be compared to those collected within the LDW. For arsenic, incremental risks will be assessed. For dioxin/furans, the need for quantitative assessment will be determined.

[a] Although bull trout and bald eagle will not be directly assessed as Phase 2 ROCs, risks to these threatened species will be discussed in the ERA.

[b] Based on meetings with stakeholders, an ideal representative of a piscivorous fish was not identified in the LDW. The ideal representative would be a resident fish with high site use, sufficient abundance for collection, and a 100% piscivorous diet. While fish are believed to be a more dominant prey item for bull trout than the sculpin that inhabit LDW, bull trout are also believed to have a much lower site use. Other fish species that consume fish that were considered (e.g., sand sole) are believed to have greater uncertainty in their home range than Pacific staghorn sculpin, the selected ROC.

[c] Other COPCs will be addressed using a critical tissue residue approach, which implicitly includes water exposure.

These modifications, discussed for each major section of the baseline ERA, are the focus of this section. In addition, a field effort involving sandpiper site use and habitat is discussed, as well as a technical memorandum involving site use by rockfish.

3.3.1.1 Problem formulation

The Phase 2 ERA problem formulation will establish the scope of the assessment, including ROCs, COPCs, assessment endpoints, and exposure pathways. ROCs for the Phase 2 ERA will be the benthic invertebrate community, crabs, fish (juvenile chinook salmon, English sole, Pacific staghorn sculpin, and rockfish [if adults present in sufficient abundance]), birds (osprey, spotted sandpiper, and great blue heron), and mammals (river otter and harbor seal). ROCs differ slightly from those in the Phase 1 assessment and were selected based on results of the Phase 1 ERA, the data needs memorandum, and consultation with EPA, Ecology, and stakeholders. For example, sculpin will replace bull trout as a representative for all piscivorous fish, osprey will replace bald eagle as a representative for all piscivorous birds, rockfish will be considered based on abundance of adults (see Section 3.3.1.2), and aquatic plants will not be evaluated during Phase 2. The Phase 2 problem formulation will discuss how protection of these selected receptor species will provide protection for other LDW species not selected as ROCs, including threatened or endangered species. Assessment endpoints will be mortality (including mortality attributable to reduced juvenile chinook salmon immunocompetence), growth, and reproduction. Revised conceptual site models for Phase 2 are presented in Figures 3-14 and 3-15.

COPCs in Phase 2 will be determined through a screen conducted using existing site-specific exposure data and data collected as part of Phase 2 (Section 3.1). Conservative exposure assumptions (e.g., maximum chemical concentrations in fish tissue) will be used in this screen to determine which COPC/ROC pairs should be further evaluated in the Phase 2 ERA.

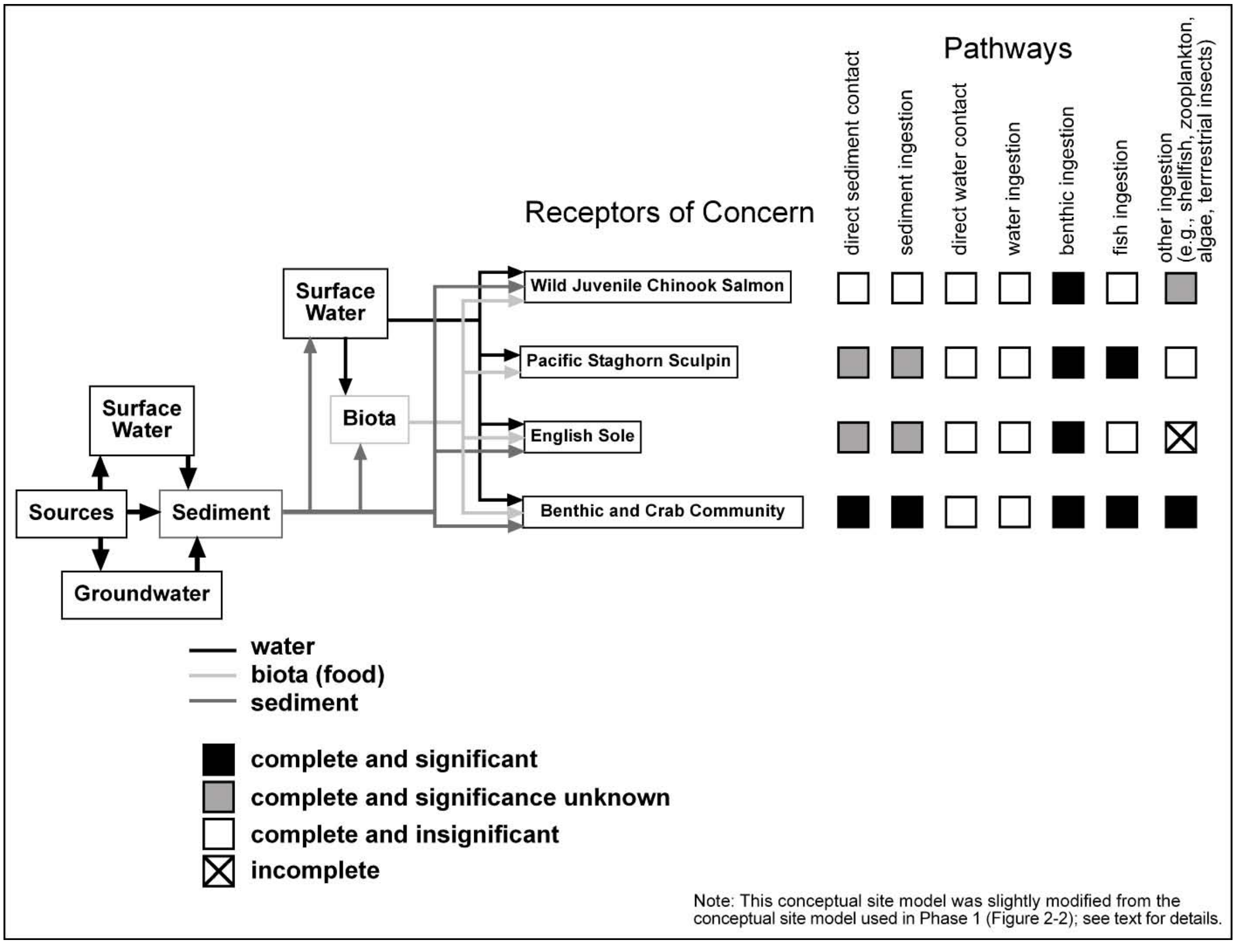

Figure 3-14. Conceptual site model for fish and benthic invertebrates in the Phase 2 ecological risk assessment

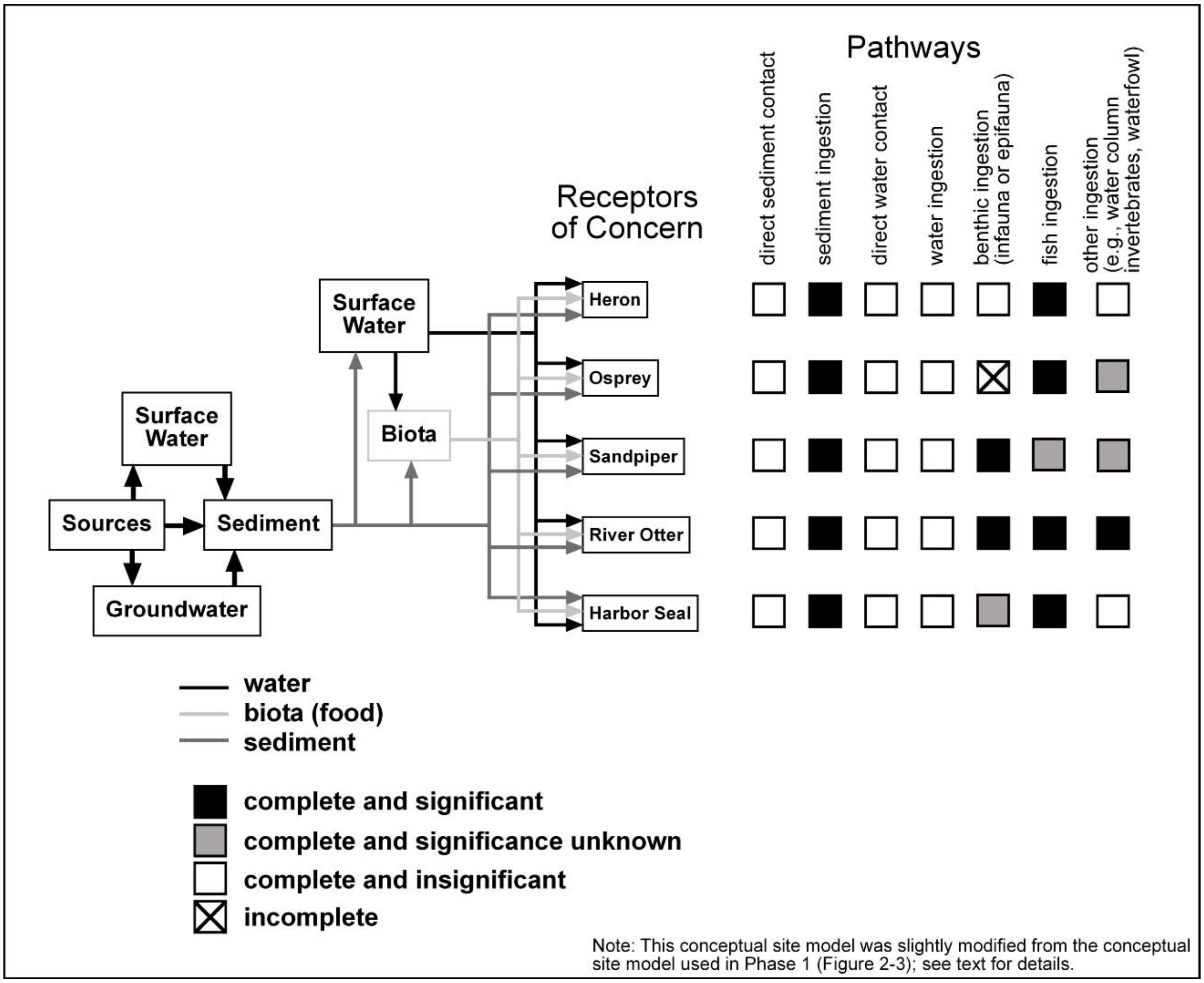

Figure 3-15. Conceptual site model for wildlife in the Phase 2 ecological risk assessment

3.3.1.2 Exposure assessment

The analysis phase consists of an exposure assessment and an effects assessment. In the exposure assessment, measures of exposure refer to how the exposure of each ROC will be estimated. These measures do not explicitly state all exposure pathways to an ROC, but rather provide an estimate of integrated exposure through all significant pathways (e.g., using a critical tissue approach accounting for all exposure pathways). Measures of exposure must also provide data that can be compared directly to toxicity data in the risk characterization. Thus, the matrix (e.g., sediment or tissue) of each measure is important. Measures of exposure for the Phase 2 ERA are described in this section for each of the ROCs. The sampling approach for each of the tissues to be collected for analysis is described in greater detail in Sections 3.1.1, 3.1.5, and 3.1.6.

Benthic Invertebrates

Exposure of benthic invertebrates, as a community, will be based on concentrations of chemicals in sediment for all chemicals, except TBT. Interpretation of sediment chemical exposures will be aided in the risk characterization with site-specific, SMS-approved toxicity tests (see Section 3.3.1.3).

For TBT, exposure will be based on TBT concentrations analyzed in neo- or meso-gastropods if sufficient tissue mass is available. If sufficient gastropod tissue mass is not available at target locations but gastropods are sufficiently abundant elsewhere in the LDW to be on concern,[35] a surrogate benthic invertebrate class will be collected according to a contingency plan that will be outlined in the benthic invertebrate QAPP (see Section 3.1.5.2). Concentrations of TBT in tissue and sediment will be analyzed. These data will be used to evaluate whether a relationship exists between these two matrices for potential use in the risk assessment, and if a sediment RBG for TBT and benthic invertebrates is needed. If a sufficient relationship[36] between tissue and sediment is not seen in the sediment and tissue data, synoptic sediment, porewater, and potentially tissue data may be collected at the locations where co-located sediment and tissue were collected initially, if warranted by the risk estimates associated with the first round of tissue chemistry data.

As in Phase 1, crabs will be assessed to evaluate exposures of higher-trophic-level benthic invertebrates. Crab exposure to sediment-associated chemicals will be estimated based on tissue residues (either edible meat or hepatopancreas, depending on the available toxicity information for each COPC) collected at various locations within the LDW.

Fish

As in Phase 1, fish exposure will be estimated using a critical tissue residue approach (whole-body tissue residues) in all three fish ROCs for chemicals such as PCBs, mercury, DDT, and TBT. A dietary approach will be used to estimate fish exposure to PAHs and metals because these chemicals are either metabolized or actively regulated by fish. Water quality data and assessment results from the King County Water Quality Assessment (1999) will also be discussed in the Phase 2 fish risk characterization to acknowledge fish exposure to metals and PAHs in the water column.[37] The tissue chemistry data that will be used for the dietary pathway for each fish ROC are discussed below.

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[35] If gastropods are not sufficiently abundant in the LDW to be of concern, TBT will be analyzed in market basket samples and risks will be assessed for the benthic community in general (i.e., the imposex endpoint for gastropods will not be used). These decisions will be made in consultation with EPA and Ecology based on the results of the gastropod pilot survey (see Section 3.1.5.2).

[36] Per the general approach outlined in the Terrastat memo (Appendix B).

[37] Water column exposures of chemicals other than PAHs and metals are implicitly included in the critical tissue residue approach, which accounts for all exposure pathways.

For juvenile chinook salmon, dietary exposure to metals (except mercury) and PAHs will be estimated using benthic invertebrate market basket tissue residue data and juvenile chinook stomach content data.[38] In the market basket approach, all benthic invertebrates collected from a location are combined and analyzed as a composite sample. Although benthic invertebrates will not be composited by phylum, general taxonomic information, including the biomass of each general component, will be compiled to characterize each composite sample. By evaluating the chemical concentrations in each market basket sample in combination with its contents, this dataset should enable conservative assumptions to be made for the dietary approach. In addition, the market basket approach maximizes the sample mass that will be available for analysis. Use of both the market basket and stomach content data will provide two lines of evidence to assess exposure. Uncertainties in both approaches will be acknowledged.

For English sole, benthic invertebrate market basket tissue residue data will be used to estimate dietary exposure for metals (except mercury) and PAHs. English sole will also be assumed to incidentally ingest sediment throughout their home range in the LDW. Uncertainties in home range and site use will be addressed by considering a range of exposure scenarios. Sculpin exposures to PAHs and metals will be assessed using similar methods to those described for English sole, but fish tissue data will also be included for the prey ingestion component (using adult English sole and perch to conservatively represent prey items) in the exposure assessment.

Wildlife

Wildlife exposure will be estimated using a dietary approach for all COPCs. Exposure estimates will be based on prey preference information and other dose calculation variables, such as the receptor's food and water ingestion rates and body weight. Exposure through water ingestion will also be included in the dose calculations. Water data from the King County water quality assessment (King County 1999c) will be used in the dose calculations. Tissue concentrations in wildlife prey (or appropriate conservative surrogate species) will be analyzed in the LDW (see Section 3.1.6). Available data on chemical concentrations in the eggs of fish-eating birds collected by other parties in the vicinity of the site will also be discussed in the Phase 2 ERA, including data from the USGS osprey monitoring program. The quantitative use of these data will be based on the sufficiency of the QA/QC documentation for these data and site use scenarios.

PCB exposure for wildlife ROCs will be assessed by analyzing PCB Aroclors in all samples, all 209 PCB congeners in a subset of all tissue types, and dioxin-like PCB congeners in a subset of sediment samples (see Sections 3.1.5, 3.1.6, and 3.1.8). These data will enable wildlife risks to be assessed two ways: 1) using a total PCBs approach,

[38] As described in Section 3.1.3, juvenile chinook stomach content data will be collected from the LDW. Stomach contents will be analyzed for PAHs (including alkylated PAHs) and metals (except mercury).

and 2) using a TEQ-based approach for dioxin-like PCB congeners. In addition, collection of these data will allow for evaluation of the dioxin-like potency[39] of the PCB congener mixture present in environmental media within the LDW as well as an assessment of the spatial variability of these data. The potency information will provide a site-specific means to assess the risk relevance of differential fate and transport among various PCB congeners in the environment.

Many of the exposure parameters of interest in the approaches outlined above will vary within the site (e.g., tissue or sediment concentrations) or within the literature (e.g., body weights, ingestion rates). Other important variables, such as temporal and spatial site use or prey preferences, are uncertain because of limited site-specific data. Additional site use and prey preference studies were not proposed in the data needs memorandum, except for a limited habitat survey for sandpiper and a site use assessment of rockfish (as discussed below), because these studies are generally resource-intensive and unlikely to significantly reduce uncertainties commensurate with their costs. Instead, these assumptions will be incorporated into a probabilistic exposure estimate and/or a sensitivity analysis for each ROC/COPC pair. This approach will be developed in consultation with EPA and Ecology during Phase 2.

Supplemental Field Exposure Assessments

Two field surveys were identified in the data needs memorandum to provide additional exposure assessment information regarding site use. These surveys are discussed below, and will be outlined in technical memoranda produced in consultation with EPA and Ecology prior to their implementation.

Sandpiper Habitat Assessment

Sandpipers are common shorebirds in the LDW. Sandpipers feed in the intertidal mudflats along the LDW and nest along the LDW (Canning et al. 1979). Most of the nests have been observed in the Kellogg Island area (Canning et al. 1979). Spotted sandpipers are likely to have a feeding range substantially smaller than the size of the LDW. Although limited information is available to estimate the potential size of the feeding range, it has been estimated at 1.5 km (1 mi) along the LDW (Norman 2002). Sandpipers can ingest a relatively large amount of sediment when foraging compared to other wildlife ROCs, so the area in which sandpipers feed and the sediment concentration of COPCs within that area may have a strong influence on the exposure estimate. Therefore, a limited habitat assessment will be conducted in Phase 2 to

[39] Potency is defined as µg TCDD equivalents/g total PCBs. It is calculated for each sample by dividing the sample-specific TEQ (µg/kg) by the Aroclor sum (mg/kg) and multiplying by 1,000. In essence, potency calculations allow for a direct comparison of dioxin-like toxicity among samples with varying total PCB concentrations.

determine the abundance and location of habitats preferred by sandpipers in the LDW, so that exposure estimates from appropriate habitats can be calculated.[40]

The assessment will use a weight-of-evidence approach involving a comprehensive review of past avian use surveys (i.e., People for Puget Sound, Fisheries Research Institute, USFWS, and Washington Department of Transportation), discussions with local experts (e.g., Lewis Oring and the Canadian Wildlife Service), and a review of published literature to assess site-specific shorebird use, preferred habitat conditions, and survey coverage in the LDW. Once specific habitat preferences are determined, , a one-time field survey will be conducted in late spring 2004 to compare preferred sandpiper foraging areas with higher sediment chemical concentration areas, because past avian surveys were not targeted at sites with the highest sediment chemical concentrations in the LDW. Any site use by sandpipers will be documented during this survey. In combination, this information will be used to assess whether sandpiper (or other resident or nesting shorebirds) potentially forage at locations with higher sediment chemical concentrations. Technical memoranda describing the methods (prior to the survey) and the results of the habitat survey will be submitted to EPA and Ecology.

Rockfish Site Use Assessment

Thirteen Puget Sound rockfish species have been listed by WDFW as state candidates for protective status, but none are currently listed under the Federal Endangered Species Act. Because rockfish can be long-lived and have a higher trophic status, they can accumulate higher chemical concentrations than other piscivorous fish species.

Relatively few rockfish have been caught in trawls or beach seines in the LDW. However, because rockfish tend to have a strong affinity for particular marine locations with structure (Richards 1987), the abundance and site use of rockfish may not be accurately assessed based on trawl or beach-seining techniques employed to collect other fish for the ERA. Juvenile rockfish have occasionally been observed by divers in the LDW in areas with overhanging concrete or riprap. The trophic status of juvenile rockfish is similar to that of adult Pacific staghorn sculpin, so they would be represented by sculpin in the Phase 2 ERA. Adult rockfish, however, have a higher trophic status than sculpin in the LDW.

Available information regarding site use by adult rockfish will be summarized in a technical memorandum and submitted to EPA and Ecology. Based on this information, a recommendation will be made in the memo regarding the need for an additional site survey for rockfish. This recommendation will be predicated on whether a sufficient number of adult rockfish are likely to use the LDW, and thus provide a significant pathway to piscivorous wildlife and humans.

[40] The goal of the sandpiper habitat survey is not to determine the percentage of time spotted sandpiper are spending in foraging areas with different exposure concentrations, but instead to determine the location of preferred sandpiper habitat.

If the survey is conducted, divers will target areas in the LDW considered to have sufficient habitat quality for rockfish to qualitatively assess rockfish abundance and distribution. These areas will be identified based on the results of the bathymetric survey (Section 3.1.3) and expert opinion, and will be surveyed in a single field event. Survey methods will be documented in the technical memorandum and submitted for approval by EPA and Ecology prior to survey initiation. A technical memorandum describing the results of the qualitative survey (if conducted) will also be submitted to EPA and Ecology.

Following the survey, adult rockfish tissue will be collected for chemical analyses (Tables 3-15 through 3-18) if, based on consultation with EPA and Ecology, it is determined that adult rockfish are sufficiently abundant and widespread to be a suitable fish ROC or prey item.

3.3.1.3 Effects assessment

The second part of the ERA analysis phase is the effects assessment, in which measures of adverse effects are presented. The effects data are used to estimate risks associated with exposure estimates in the risk characterization. These data can be literature-based or based on site-specific studies or experiments (e.g., sediment toxicity testing).

For the benthic invertebrate community, two approaches will be used. First, the results of sediment chemistry and site-specific toxicity tests will be used to assess effects associated with exposure to contaminated sediment (see Section 3.1.8.2). Second, a critical tissue residue approach will be used to assess effects from exposure to TBT because bulk sediment-based quality standards and guidelines have not been promulgated and because the tissue approach has been recommended by EPA (1999b). For the tissue-based TBT assessment, all relevant tissue-based toxicity reference values (TRVs) involving survival, growth, and reproduction will be gathered and assessed. TRVs associated with sterilization attributable to imposex resulting from exposure to TBT will also be evaluated if gastropods are found to be sufficiently abundant to be of concern.

For crabs, a critical tissue residue approach will be used to assess effects from exposure to sediment-associated chemicals. All relevant tissue-based toxicity reference values (TRVs) involving survival, growth, and reproduction will be gathered and assessed.

For all fish and wildlife ROCs, data from the literature will be used to estimate COPC concentrations or doses (TRVs) associated with adverse effects as well as concentrations at which no effects were observed for population-level endpoints (survival,[41] growth, and reproduction[42]). Threatened and endangered species (e.g., juvenile chinook salmon) will be assessed using the same toxicological data, but greater emphasis in the risk characterization will be placed on the no-effects data. Selection of relevant toxicity data[43] from the literature will be based on the following preferred conditions:

- chronic exposure period (more than one year for mammals, more than 10 weeks for birds, or more than 10% of species' lifespan) or during a critical life stage (reproduction, gestation, or development)
- non-domesticated wildlife species used as test species; if domestic species are used (because of lack of wildlife studies), the egg production endpoint (e.g., for chickens or Japanese quail) is of low priority
- controlled laboratory experiments with single chemical (or specific mixtures, such as Aroclors or PAHs) exposures
- relevant chemical form (e.g., studies with lead shot are not preferred)
- wildlife exposure pathway through food ingestion, rather than water ingestion, IP injection or gavage
- preferred test species for juvenile chinook salmon are fish of the family Salmonidae and involve exposures to life stages beyond egg and larval development

If studies with the above preferred conditions are not available, then other studies will be considered. The primary literature will be carefully reviewed, including data identified in Phase 1 and any recent publications, and all relevant toxicity data will be summarized in tables for each ROC/COPC pair. An additional literature search will be conducted for PAH-related TRVs for fish. For effects of PCBs on wildlife, both dioxin-like (2,3,7,8 TCDD-based, for comparison to TEQs) and Aroclor-based TRVs will be evaluated.

For fish, the Phase 1 ERA reviewed field and laboratory studies of PAH exposure reporting effects on survival, growth, and reproduction. Effects data for growth and

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[41] Because it is a threatened species and site-specific studies are available, juvenile chinook salmon will also be assessed for mortality attributable to reduced immunocompetence potentially associated with exposure to PCBs and PAHs.

[42] Juvenile chinook salmon will not be assessed for reproductive endpoints because no data have been identified linking exposure as juveniles to chemicals, such as PCBs, and later reproductive impacts.

[43] TRVs will be collected only for chemicals detected in tissue or sediment with sufficient frequency. Therefore, using both existing and newly collected Phase 2 data, TRVs will only be acquired for chemicals meeting two of the three criteria: 1) detection in at least 5% of LDW surface sediment samples, 2) identification as a bioaccumulative chemical in EPA (2000a), and 3) detection in LDW-collected tissue. If a chemical is detected in fewer than 5% of the surface sediment samples, but is detected with a pattern, grouping, or association with sources, it will be acknowledged and either carried through the risk assessment or discussed in the uncertainty assessment.

reproduction have been related to sediment concentrations in a few studies, e.g., Kubin (1997) (growth) and Johnson et al. (2002) (reproduction). Results from site-specific studies with English sole in the LDW will be discussed in the uncertainty assessment.

3.3.1.4 Risk characterization

The risk characterization section of the Phase 2 ERA will consist of a risk estimation, uncertainty assessment, and risk conclusion for each receptor group (benthic invertebrates [including crabs], fish, and wildlife). In the risk estimation, the results of the exposure and effects assessments are combined to calculate risk estimates. The general approach in the Phase 1 ERA was to compare a single no-effects and a single effects TRV to the mean 95% upper confidence limit on the mean exposure data to calculate deterministic risk estimates presented as hazard quotients (HQs).[44] In the Phase 2 ERA, both deterministic and probabilistic approaches will be used to calculate baseline risk estimates, and to estimate residual risks at the site following completion of early actions.

Deterministic risk estimates (using HQs), similar to those in the Phase 1 approach, will be calculated based on a clearly delineated set of assumptions. To supplement these estimates, risks will also be presented as probabilistic exposure estimates with the range of relevant no-effects and effects TRVs superimposed (for chemicals with the highest risk estimates). This presentation provides risk managers with information regarding uncertainties in differential species sensitivity in addition to exposure uncertainties. This range is important because ROCs selected for the ERA represent a diversity of species that likely have a range in exposure and sensitivity to LDW chemicals.

The results of the risk estimates and the uncertainty assessment (see below) will be integrated in the risk conclusion section of the ERA, which will provide an estimate of baseline risk and residual risks following early actions, and in combination with the HHRA and RI, will be used by EPA and Ecology to determine whether remedial actions beyond the early actions are warranted.

3.3.1.5 Uncertainty assessment

Uncertainties inherent in Phase 2 problem formulation, exposure and effects assessment, and risk estimates will be discussed in the uncertainty assessment. The discussion of uncertainties in the problem formulation will focus on selection of ROCs, assessment endpoints, and exposure pathways. The discussion of uncertainties in the exposure assessment will focus on the availability or relevance of site-specific data to estimate or measure exposure, as well as any parameters used in modeling exposure. The discussion of uncertainties in the effects assessment will focus on the availability and relevance of toxicological data, the majority of which were selected from the

[44] HQ = [exposure concentration (or dose)/concentrations (or dose) associated with adverse effects]

literature, except for the site-specific toxicity test results for benthic invertebrates. A sensitivity analysis of the risk estimates will also be conducted to identify key uncertainties in the probabilistic exposure estimates (i.e., to identify those parameters with a strong influence on risk conclusions).

3.3.2 Human health risk assessment

A scoping-phase HHRA was conducted for the LDW as part of Phase 1 (see Section 2.3). Approaches used in Phase 1 were developed through considerable agency and stakeholder comment. As part of the Phase 2 HHRA, additional data (as described in Section 3.1) will be collected to fill critical data needs identified in Phase 1 (Windward 2003f). These data will be combined with existing field and analytical data, and additional information described below, to revise risk estimates made in the Phase 1 HHRA.

The technical approach used for the Phase 2 baseline HHRA will be a somewhat modified version of the technical approach used in Phase 1. The key differences between the Phase 2 technical approach and the approach used in Phase 1 are listed in Table 3-27. This table also provides the rationale for these differences.

Table 3-27. Key differences in the Phase 2 HHRA compared to Phase 1

Difference	Rationale
Separate COPC identification in fish and invertebrate tissues	Bioaccumulation patterns may differ between fish and invertebrates
Alternative statistical methods for spatial analysis of intertidal exposure point concentrations (EPCs) based on potential human use	Intertidal sediment chemistry data used in Phase 1 were not collected for human use considerations
Potential use of alternative fish species in market basket approach for seafood consumption scenarios	Seafood consumers may not limit their intake to a small group of target species
Incorporation of clam tissue chemistry data	Phase 1 risk assessment excluded clams based on preliminary reconnaissance survey data, but Phase 2 clam survey results suggest harvestable numbers of clams are present in some areas
Expansion of market basket approach to include whole-body samples for fish and crab	More realistic representation of exposure to potentially exposed population
Use of site-specific data on the percentage of inorganic arsenic in fish and crab tissue	Site-specific data to be collected in Phase 2 will be used in place of generic default assumptions
Incorporation of PCB congener data to assess risk from dioxin-like PCB congeners	Risks associated with dioxin-like PCB congeners were not quantified in Phase 1 because PCB congener data with sufficiently low detection limits were not available; such data will be collected in Phase 2
Incorporation of arsenic and dioxin/furan data from background areas into the risk characterization	Potentially unacceptable risk levels are associated with background concentrations of arsenic and dioxin/furans. Samples from background areas will be compared to those collected within the LDW. For arsenic, incremental risks will be assessed, as described in EPA guidance. For dioxin/furans, the need for quantitative assessment will be determined based on background analysis.

DIFFERENCE	RATIONALE
Potential use of probabilistic risk analysis techniques for the seafood consumption scenarios	Provides risk managers with a range of risk estimates that more realistically portray site conditions compared to a single point estimate

These modifications, discussed for each major section of the baseline HHRA, are the focus of this section. This section also describes a survey for potential public access of the shoreline that was first introduced in Section 3.1. Technical approaches for topics not specifically addressed here will be as described in the Phase 1 HHRA.

EPA has identified several other areas where differences might exist between Phase 1 and Phase 2 (i.e., alternate approaches for developing spatially weighted 95% UCLs, discussion of a human breast milk/PCB exposure scenario, development of a recreational consumer-only fish consumption scenario, and revision of the Asian and Pacific Islander [API] consumption scenario). EPA has also been developing a regional policy on tribal seafood exposure assessment that may result in modifications to the Phase 2 HHRA. The extent to which these differences are incorporated into the Phase 2 HHRA will be determined based on future discussions between LDWG, EPA, and Ecology.

3.3.2.1 Exposure assessment

The Phase 1 HHRA provided numerical risk estimates for four exposure scenarios: beach play, netfishing, seafood consumption, and swimming. Risks for the same four exposure scenarios will also be presented in the Phase 2 HHRA, although the conceptual site model used in Phase 1 has been altered slightly to reflect the possibility of sediment contact while harvesting clams (Figure 3-16). Risk estimates associated with swimming were previously calculated by King County (1999c) and incorporated into the risk characterization for Phase 1. A similar presentation of swimming-associated risks will be made in Phase 2. A fifth exposure scenario, clam harvesting, will be considered after evaluating the results of the clam, crab, and shrimp surveys described in Section 3.1.2. Each of these exposure scenarios will consider the future use of the LDW.

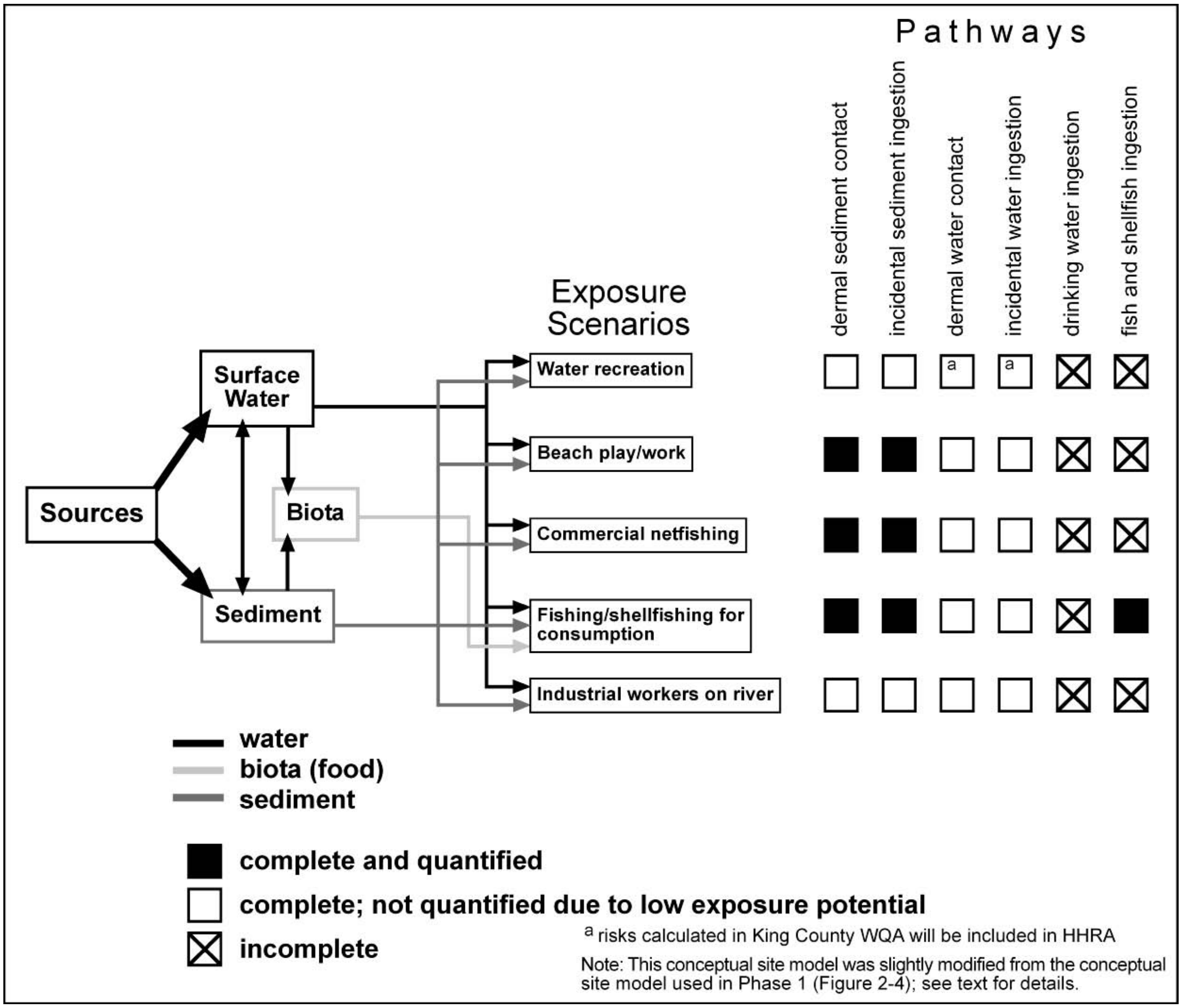

Figure 3-16. Conceptual site model for Phase 2 human health risk assessment

Multiple risk estimates will be made for each exposure scenario, reflecting different target populations, exposure parameters, and exposure areas (Table 3-28). Each scenario will include exposure assumptions consistent with EPA's reasonable maximum exposure (RME), which is defined as the "highest exposure that is reasonably expected to occur at the site" (EPA 1989). A central tendency (CT) scenario will also be quantified for netfishing, and for any exposure scenario with an excess cancer risk estimate for the RME scenario of greater than 1 in 100,000 (1×10^{-5}). CT assumptions represent more typical or likely exposure.

Summing risks from multiple exposure pathways may be reasonable if multiple pathways are relevant to the same receptor. EPA (1989) suggests that summing risks from multiple RME scenarios that do not occur simultaneously could be overly health protective. Consequently, risk estimates for the netfishing CT scenario will be combined with risk estimates for the seafood consumption RME scenario (see Section 3.3.2.3).

Table 3-28. Exposure scenarios to be included in the Phase 2 HHRA

		COMMENTS
Netfishing		
Source medium: Exposure medium: Exposure point: Target population: Exposure route:	Sediment Sediment LDW-wide netfishing locations Muckleshoot commercial fishermen Dermal and incidental ingestion	Both RME and CT scenarios will be quantified
Beach play		
Source medium: Exposure medium: Exposure point: Target population: Exposure route:	Sediment Sediment Various intertidal areas with public access Resident children Dermal and incidental ingestion	Separate risk estimates to be made for various exposure areas, to be identified and characterized after conducting reconnaissance survey of LDW to identify intertidal areas where children might play
Seafood consumption		
Source medium: Exposure medium: Exposure point: Target population: Exposure route:	Sediment Seafood LDW fishing locations Tribal adults and children Asian and Pacific Islander adults [a] Ingestion	Three separate risk estimates will be made; one for each target population
Swimming		
Source medium: Exposure medium: Exposure point: Target population: Exposure route:	Sediment Surface water LDW swimming locations Adult and child swimmers Dermal and incidental ingestion	Separate risk estimates previously made by King County (1999c) will be incorporated into the Phase 2 risk characterization. No attempt will be made to recalculate risk estimates to be consistent with EPA's RME approach because King County risk estimates included scenarios with assumed exposure both greater and lesser than the exposure likely to be associated with an RME scenario, thus bracketing the RME risk estimate.

[a] Risks to Asian and Pacific Islander children will not be quantified because there are no seafood consumption data available for this group

Equations for calculating chronic daily intake in the Phase 2 HHRA will be identical to those used in the Phase 1 HHRA. Table 3-29 lists the values to be used for calculating the chronic daily intake in the Phase 2 HHRA. None of the values shown are different than those used in the Phase 1 HHRA. Those that are shown as "tbd" (to be determined) require collection of additional Phase 2 data before values can be calculated. The site-specific fish and shellfish consumption rates may be modified in Phase 2 for two reasons. First, in Phase 1, assumptions about shellfish harvestability were made in the absence of site-specific data on this topic. In Phase 2, rates will be proposed to EPA and Ecology in the form of a technical memorandum following completion of the clam, crab, and shrimp surveys described in Section 3.1.2. Second, EPA has been developing a regional policy on tribal seafood exposure assessment that may result in modifications to the Phase 2 tribal consumption rates.

COPCs will be identified with generally the same decision rules used in the Phase 1 HHRA, except as discussed below. In Phase 1, COPCs in tissue were identified using the combined tissue chemistry database for all HHRA species of interest. Because bioaccumulation kinetics may be different between fish and invertebrates, COPC identification in tissue for Phase 2 will be done separately for fish and invertebrate species. Those COPCs identified in Phase 1 because of detected concentrations greater than risk-based concentrations (RBCs) will likely remain COPCs for Phase 2 because almost all the historical data used in Phase 1 will be used in Phase 2 as well (see Section 3.1.8.1 for a discussion of incorporation of Phase 1 data into Phase 2). The Phase 2 COPC list may be different from the Phase 1 COPC list because additional chemistry data collected in Phase 2 will be incorporated into the COPC screening process. Also, risk-based screening concentrations for identifying COPCs may change if the shellfish consumption rate is recalculated based on clam consumption, which was not included in Phase 1.

Exposure point concentrations (EPCs) will generally be calculated as they were in the Phase 1 HHRA after incorporation of the additional Phase 2 data, although the approach for calculating spatially-weighted 95% UCLs in sediment may change. There are two notable differences, however, in how EPCs will be calculated for the beach play and seafood consumption scenarios. These scenarios are discussed in separate sections below.

Table 3-29. Exposure parameters to be used for daily intake calculations in Phase 2 HHRA

Parameter	Units	Netfishing				Seafood Ingestion			Beach Play	
		Sed ingestion, adult RME	Sed ingestion, adult CT	Sed dermal contact, adult RME	Sed dermal contact, adult CT	Adult tribal RME	Adult API RME	Child tribal RME	Sed ingestion, child RME	Sed dermal contact, child RME
Exposure point concentration	mg/kg	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd	tbd
Ingestion rate – sediment	g/day	0.050	0.050	na	na	na	na	na	0.200	na
Ingestion rate – pelagic fish	g/day	na	na	na	na	16	2.7	3.9	na	na
Ingestion rate – benthic fish	g/day	na	na	na	na	15	1.4	0.97	na	na
Ingestion rate – shellfish	g/day	na	na	na	na	tbd	tbd	tbd	na	na
Fractional intake derived from source	unitless	1	1	1	1	1	1	1	1	1
Dermal absorption factor	unitless	na	na	Table B-13 (Phase 1 HHRA)	Table B-13 (Phase 1 HHRA)	na	na	na	na	Table B-13 (Phase 1 HHRA)
Skin surface area exposed	cm^2	na	na	3,600	3,600	na	na	na	na	Table B-8i (Phase 1 HHRA)
Adherence factor	mg/cm^2	na	na	0.2	0.02	na	na	na	na	0.2
Exposure frequency	days/yr	119	63	119	63	365	365	365	41	41
Exposure duration	years	44	29	44	29	55	30	6	6	6
Body weight	kg	79	79	79	79	79	63	17	Table B-8h (Phase 1 HHRA)	Table B-8i (Phase 1 HHRA)
Averaging time – cancer	days	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550
Averaging time – noncancer	days	16,060	10,585	16,060	10,585	20,075	10,950	2,190	2,190	2,190

tbd = to be determined, na = not applicable

Beach Play Scenario and Reconnaissance Survey of Potential Public Use of the Shoreline

For the beach play scenario in the Phase 1 HHRA, three separate EPCs were calculated for each COPC, corresponding to the available intertidal sediment chemistry data in the Kellogg Island, Southeast, and Southwest regions of the study area. The decision to calculate three EPCs was based primarily on data availability rather than expected human use in the intertidal region. A reconnaissance survey will be conducted early in Phase 2 to determine potential human use areas for the beach play scenario. The focus will be on identification of those intertidal areas where public access may occur from the shoreline. This survey will be conducted prior to the completion of the surface sediment QAPP so that the sampling design is consistent with the survey findings. Once a better understanding of potential beach play locations is obtained and additional sediment chemistry data are obtained from these locations, as needed, discrete exposure areas for EPC quantification will be selected for use in the HHRA.

The reconnaissance survey will be conducted in two parts, one from a boat in the LDW, the other on foot from both sides of the LDW. Prior to conducting the survey, local community groups will be contacted so they can provide input on use frequency and duration at specific public access sites. The two parts of the survey will complement each other in that each potential access site will be surveyed on foot from both the water and upland sides. The survey by land will note public access and non-public access points to the LDW. Using this approach, sites that are accessible to the public without trespassing can be distinguished from sites that are accessible only to people with authorized access to the shoreline at that location. For example, there may be sites where industrial workers can sit by the LDW during their lunch break, but are not accessible to the general public because the site is on private property. As described in the Phase 1 HHRA, risks to LDW industrial workers and habitat restoration workers are assumed to be much lower than risk estimates for the beach play scenario because of the much lower exposure frequency and duration. Each potential public access site will be photographed and described in detail in a field notebook. GPS coordinates will also be obtained in the field so that the site can be accurately mapped. The methods and results of the qualitative reconnaissance survey will be summarized in a technical memorandum that will be submitted to EPA and Ecology. This technical memorandum will also describe how data will be selected to represent these areas and how data needs, if any, will be filled.

Seafood Exposure Scenarios

For Phase 1 seafood exposure scenarios, chronic daily intake calculations, and the corresponding EPCs, were based on the market basket approach.[45] The rationale and methods for the market basket approach are described in detail in the Phase 1 HHRA,

[45] The market basket approach associates species- or species-group-specific consumption rates with chemical concentrations in those species or species groups, thereby providing a more realistic assessment of exposure compared to the use of a single seafood consumption rate.

but are briefly summarized here. The seafood consumption surveys used to quantify seafood ingestion rates (EPA 1999a; Suquamish Tribe 2000) included consumption rates for individual species and species groups. Consumption rate estimates for market basket components (i.e., pelagic fish, benthic fish, shellfish) were tied to EPCs specific to those components in Phase 1, thus yielding a chronic daily intake estimate that accurately reflected the potential exposure of the target populations. In Phase 1, only a single type of tissue sample was included in each market basket EPC. For example, the EPC for the benthic fish component was based on skinless fillets of English sole.

The Phase 2 market basket approach for the seafood exposure scenario will incorporate knowledge that multiple species and fish/shellfish parts may be consumed within each market basket component by individuals in the target populations. For example, the API seafood consumption survey documented consumption of fish fillets and the skin, bones, eggs, and heads of fish (EPA 1999a). The Phase 2 HHRA will utilize separate consumption rate estimates, where appropriate, for different types of tissues within each market basket component. Table 3-30 lists the specific consumption rates that will be used for each type of tissue within each market basket component. Clam consumption rates will be based on all edible tissues.

Table 3-30. Consumption rates for each market basket component tissue type

Tissue Type	Consumption Rates		
	Adult Tribal RME	Adult API RME	Child Tribal RME
Benthic fish group – g/day (total)	15	1.4	0.97
Fillet - % of total	90	80	100
Whole body - % of total	10	20	0
Pelagic fish group – g/day (total)	16	2.7	3.9
Fillet - % of total	96	80	100
Whole body - % of total	4	20	0
Crabs – g/day (total)	tbd	tbd	tbd
Edible meat - % of total	76	57	100
All other edible tissues - % of total	24	43	0

Sources:

Adult tribal RME – Tables T-10 (Fish) and T-12 (crabs) in Suquamish Tribe (2000)

Adult API RME – Tables R-8 (Fish) and R-10 (crabs) in EPA (EPA 1999a)

Child tribal RME – Tables T-15 (Fish) and T-16 (crabs) in Suquamish Tribe (2000)

tbd – to be determined

For the adult RME scenarios, separate EPCs will be calculated for the four different fish tissue types (benthic fillet, benthic whole body, pelagic fillet, and pelagic whole body). Each EPC will represent the entire LDW (i.e., all seafood consumption is from the LDW), as was done for the Phase 1 HHRA, although EPCs that represent more localized areas of exposure may also be developed as part of the risk characterization or the uncertainty assessment. These EPCs will be associated with consumption rates for each tissue type, as described in Table 3-30. For example, the consumption rate for benthic fillets in the adult API RME scenario will be 1.1 g/day, which is calculated by applying the percentage of the total benthic diet (1.4 g/day) represented by fillets (80%). The manner in which the crab consumption rate is factored in the overall shellfish consumption rate will be determined after the completion of the clam, crab, and shrimp surveys described in Section 3.1.2. Because the consumption data presented in Suquamish Tribe (2000) indicate that children do not typically eat fish parts other than fillets, or crab parts other than the edible meat, the market basket for the child tribal RME scenario will be quantified for the Phase 2 HHRA using the same approach as in the Phase 1 HHRA.

In the Phase 1 HHRA, a single species represented each market basket component: English sole for the benthic fish group, striped perch for the pelagic group, and Dungeness crab for the crab portion of the shellfish group. EPCs were calculated from tissue chemistry data for each individual species. Although these species will also be targeted during Phase 2 data collection efforts (see Section 3.1.6), additional species may be incorporated into the group-specific EPCs if they are encountered during field collection efforts. For example, starry flounder is a common benthic fish species in the LDW. Because this species may be consumed in addition to English sole, it may be appropriate to include tissue chemistry data from this species in the calculation of the benthic group EPC. The manner in which specific EPCs are calculated will be discussed with EPA and Ecology following completion of the Phase 2 tissue chemistry data collection.

An important Phase 1 HHRA assumption regarding inorganic arsenic will be revisited in Phase 2 based on the incorporation of additional data. The arsenic EPCs for all tissue types in Phase 1 were based on the assumption that inorganic arsenic, the most toxic form, made up 10% of the total arsenic concentration detected in the previously conducted studies. The 10% factor was recommended by EPA Region 10 as a default to be used in the absence of site-specific data. Site-specific arsenic speciation data will be collected in Phase 2, as described in Section 3.1.6. These data will be used to derive representative site-specific inorganic arsenic percentages to be applied in deriving seafood EPCs for arsenic in Phase 2.

3.3.2.2 Toxicity assessment

The toxicity assessment section of the Phase 2 HHRA will be very similar to that of the Phase 1 HHRA. Any reference doses or cancer slope factors that have been updated since the completion of the Phase 1 HHRA will be incorporated into Phase 2. The toxicity profile section in Phase 2 will be different than Phase 1. The Phase 1 HHRA presented toxicity profiles for each COPC in an appendix. Each COPC was described using a similar level of detail, regardless of the potential risk magnitude associated with that COPC. In Phase 2, COPCs responsible for the majority of the risk will be described in much greater detail in the body of the document, while a summary of toxicological profiles published by ATSDR will be provided for the remainder of the COPCs. Toxicity values for all COPCs, regardless of whether they have changed from the values used in Phase 1, will be summarized in tables in the Phase 2 HHRA.

3.3.2.3 Risk characterization

The risk characterization section of the Phase 2 HHRA will consist of risk estimations, an uncertainty assessment, and risk conclusions for each exposure scenario evaluated. In the risk estimation, the results of the exposure and toxicity assessments are combined to calculate risk estimates. The risk characterization in the Phase 1 HHRA applied a deterministic approach in which exposure and risk estimates were presented as single estimates (e.g., cancer risk estimate of 2 in a million or hazard quotient of 2). A deterministic risk characterization will also be presented in the Phase 2 HHRA using the same format as Phase 1.

An alternative risk characterization format uses probabilistic methods to calculate risk estimate ranges, thus providing risk managers with more information on which to make decisions about the need for cleanup. Probabilistic risk assessment (PRA) requires knowledge about the range and distribution of possible values for exposure parameters. The assumed range and distribution can be derived empirically using existing data. Although there are benefits to using PRA, implementation of the necessary techniques requires more effort than deterministic methods. Accordingly, the use of PRA may be warranted only for exposure scenarios that result in risk estimates that could trigger remedial action. Based on the Phase 1 risk characterization, the seafood exposure scenario falls in that category. Consequently, PRA methods may be employed for one or more of the seafood exposure scenarios in the Phase 2 HHRA. If PRA is conducted, the methods will follow risk assessment guidance for Superfund (EPA 1999c).

Within the seafood exposure scenario, there are several exposure parameters with sufficient site-specific data to make reasonable estimates of the range and underlying distribution of expected values. In turn, there are other parameters with few or no site-specific data; PRA methods would likely not be appropriate for these parameters. Table 3-29 presented the exposure parameters to be used for the deterministic portion of the Phase 2 HHRA. Table 3-31 is a similar listing of exposure parameters with an indication of whether a point estimate (i.e., data presented in Table 3-29) or a distribution would be appropriate for the PRA portion of the risk characterization for the seafood exposure scenarios. The source of the data from which a distribution would be derived is also indicated on the table. A technical memorandum describing the details of the PRA parameterization will be prepared and submitted to EPA and Ecology prior to conducting the Phase 2 HHRA.

Table 3-31. Exposure parameters to be utilized in the probabilistic risk assessment for the seafood ingestion exposure scenarios

Parameter	Seafood Ingestion, Adult Tribal RME	Seafood Ingestion, Adult API RME	Seafood Ingestion, Child Tribal RME
Exposure point concentration	distribution [a]	distribution [a]	distribution [a]
Ingestion rate – pelagic fish	distribution [b]	distribution [c]	distribution [b]
Ingestion rate – benthic fish	distribution [b]	distribution [c]	distribution [b]
Ingestion rate – shellfish	distribution [b]	distribution [c]	distribution [b]
Fractional intake derived from source	point	point	point
Exposure frequency	point	point	point
Exposure duration	distribution [d]	point	point
Body weight	distribution [b]	distribution [c]	distribution [b]
Averaging time – cancer	point	point	point
Averaging time – noncancer	distribution [d]	point	point

Point = value presented in Table 3-29 to be used in the PRA

Distribution = a range and distribution of values to be used in the PRA; data sources given below

Sources:

[a] Site-specific tissue chemistry data

[b] Suquamish Tribe (2000)

[c] EPA (1999a)

[d] Demographics data for Muckleshoot Tribe, as summarized in Subappendix B.4 in the Phase 1 HHRA

Risk estimates derived from PRA methods will be presented in a separate section of the risk characterization from the results based on deterministic methods.

Risks associated with PCBs can be examined on the basis of Aroclor toxicity as well as the dioxin-like toxicity of certain PCB congeners. The assessment of PCB risks on the basis of Aroclor toxicity will be estimated similarly to Phase 1 (i.e., sum of Aroclors). The assessment of PCB risks on the basis of dioxin-like congener toxicity will be conducted using the PCB congener data collected during Phase 2. LDWG, EPA, and Ecology have discussed various methods for characterizing the risks associated with both non-dioxin-like and dioxin-like PCB congeners. The parties will continue to discuss the equations to be used for PCB risk characterization and will reach a decision on calculation methods prior to LDWG beginning the Phase 2 HHRA.

Arsenic has been identified as a COPC in the Phase 1 HHRA, but arsenic concentrations may be high enough to represent unacceptable risk in background areas. EPA (2002a) guidance discusses the approach that will be used in the Phase 2 HHRA. This approach quantifies the total risk associated with a chemical. However, in the risk characterization section, the components of risk associated with site-specific chemical exposure, as well as the components of risk associated with background chemical exposure, will be identified. The incremental risk approach allows risks associated with background areas to be subtracted from site-specific risks. Dioxins/furans will also be assessed relative to background to determine whether quantitative risk characterization is needed. This approach will be discussed among LDWG, EPA, and Ecology prior to beginning the Phase 2 HHRA.

3.3.2.4 Uncertainty assessment

The content and format of the Phase 2 HHRA uncertainty assessment will be very similar to that of the Phase 1 HHRA. Quantitative uncertainty estimates will be made where possible. One important area of the Phase 2 HHRA uncertainty assessment will be the discussion of chemical concentrations in background areas. In particular, this will be done for arsenic, which was identified as a risk driver in the seafood consumption scenarios in the Phase 1 HHRA, and because arsenic concentrations are influenced in the Puget Sound area from the former historical Asarco smelter northwest of Tacoma and by naturally occurring arsenic. Additional sediment and tissue chemistry data for arsenic will be collected in Phase 2 (see Sections 3.1.4 and 3.1.6).

3.3.3 Food-web modeling

In addition to the baseline risk assessments[46] to be conducted as part of Phase 2, residual risks need to be estimated. Steady-state concentrations of risk-driver chemicals in fish tissue will need to be predicted under various early action remediation scenarios. To predict these concentrations, a mechanistic, steady-state bioaccumulation model such as that developed by Gobas (1993) will likely be used for the purpose of modeling the relationship[47] between chemicals in sediment and those in the key human and wildlife prey species (English sole, sculpin, perch, and crabs) as depicted in Figure 3-17 (a simplified conceptual site model). This type of mechanistic model relates the concentrations of hydrophobic, nonionic chemicals in sediment and water with various components of a food web based on the physical-chemical characteristics of the chemical as well as the food web structure and species characteristics (such as lipid content). The final determination of the specific model to be used for this project, and the way in which it will be used, will be made after EPA and Ecology review the technical memorandum that will be prepared on this topic. This technical memorandum will be submitted prior to initiation of the residual risk assessments.

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[46] The baseline risk assessment will estimate risks assuming none of the early action areas have been remediated.

[47] The Gobas-type model would not be used to estimate exposure to wildlife and humans; only the relationship between their prey and sediment would be modeled. Exposure estimates to wildlife and humans would be based on the exposure assessment approaches described in Sections 3.3.1.2 and 3.3.2.1. Also, the Gobas-type model was designed for nonionic, hydrophobic chemicals. If risk-driving chemicals are identified that do not meet this definition, other models will be considered.

This section provides an overview of data needs for a Gobas-type model (focusing on field collected data[48]). If unacceptable risks are identified in the residual risk assessments, this model would also be used to calculate sediment RBGs for nonionic, hydrophobic chemicals with the highest risk estimates (likely to be PCBs for wildlife and human receptors exposed via diet). This application of the model is discussed in Section 3.4.6.

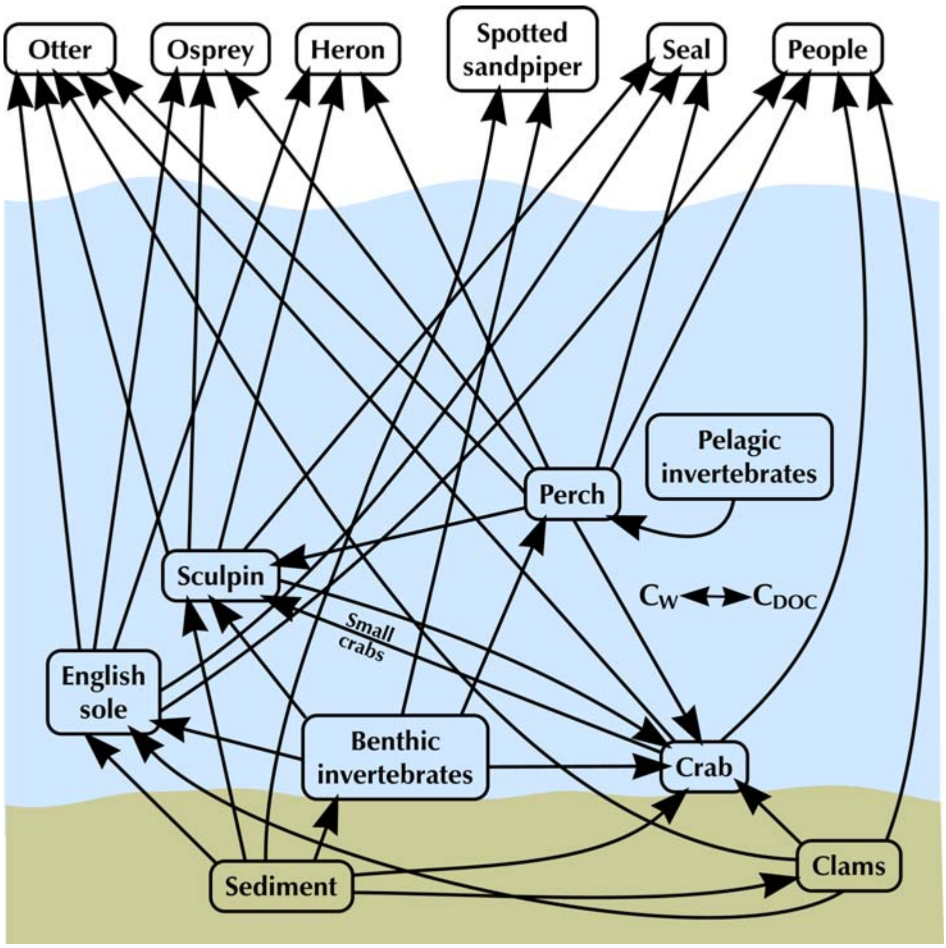

Figure 3-17. Simplified conceptual model for food-web modeling

3.3.4 Gobas models

Gobas has updated and adapted his fish bioaccumulation model many times since his first publication (Gobas 1993). Therefore, many versions of the "Gobas" model exist. The model selected affects the data needed to run the model. The original Gobas model (Gobas 1993) requires the following literature and field-derived data:

- dry-weight chemical concentrations in sediment

[48] In addition to the field data needs discussed in this section, data from the literature (e.g., Kow values) will also be needed to support the Gobas-type model.

- freely dissolved chemical concentrations in water
- chemical octanol-water partitioning coefficient (K_{OW})
- water temperature
- TOC content of sediment
- lipid content of plankton, benthic invertebrates, and fish
- body weights of fish
- general dietary assumptions for fish in food web
- chemical concentrations in fish tissue for calibration

Data for the variables related to sediment and tissue will be collected in Phase 2. Freely dissolved chemical concentrations in water can be predicted from chemical concentrations in sediment using equilibrium partitioning theory, although some site-specific data exist (see Section 3.3.4.2). Water temperature data are available from various ambient monitoring programs conducted by King County and Ecology. Literature-based Kows are available for use in the model. The dietary assumptions for fish in the food web will be based, in part, on the results of the benthic invertebrate surveys to be conducted in Phase 2 (see Section 3.1.5). Additional discussion of dietary preferences in provided in Section 3.3.4.1.

Sensitive parameters in the model include the chemical's log K_{OW}, chemical concentrations and TOC content of sediment, lipid content of food web organisms, and fish dietary composition (Burkhard 1998; Gobas 1993). Of these parameters, the key areas of uncertainty are the specific prey items in fish diets and their associated lipid content, and the site use of the modeled species in the LDW, which determines what chemical and TOC data for sediment will be needed.

As shown in Figure 3-17, benthic invertebrates are a prey item for many of the modeled species. The original Gobas model (1993) contains one compartment for benthic invertebrates where equilibrium partitioning[49] is the basis for estimating tissue concentrations. Thus, using this version of the model did not require species-specific lipid contents or tissue concentrations for benthic invertebrates (i.e., benthic invertebrates are modeled as a single group). A market basket approach to benthic invertebrate tissue collection and chemical analyses, as described in Section 3.1.5.2, would allow calibration of this component of the model, or direct input to the model, depending on the specific model used.

The benthic invertebrate submodel was updated by Morrison et al. (1997); benthic invertebrates were split into two compartments, benthic detritivores and benthic filter-

[49] Equilibrium partitioning is a theory wherein concentrations in various matrices are related based on thermodynamic partitioning among organic components such as sediment organic carbon or organism lipid content.

feeders, and modeled by estimating uptake and loss processes instead of using equilibrium partitioning theory. In this latter approach, separate tissue estimates for benthic invertebrates with two different feeding strategies are generated. To employ the updated Gobas model with two benthic compartments (Morrison et al. 1997), the following additional site-specific data would be needed:

- lipid content of filter-feeding benthic invertebrates and benthic detritivores (site-specific or literature-derived)
- chemical concentrations in tissues of filter-feeding benthic invertebrates and benthic detritivores for calibration or direct input
- total suspended solids concentration in the water column

Modeling separate benthic invertebrate compartments would be justified if: 1) it is known what percentage each represents of the dietary preferences for fish or other species being modeled, and 2) significantly different chemical concentrations are expected in these two groups of benthic invertebrates. This approach would not be amenable to market basket sampling of the benthic community. Instead, if justified, it would require specification of fish preferences for benthic detritivores and benthic filter-feeders and chemical concentrations in these tissues for calibration or direct input to the model, depending on the specific model used.

3.3.4.1 Dietary preferences for fish and crabs

Three Puget Sound studies (Table 3-32; Fresh et al. 1979; Wingert et al. 1979; Miller et al. 1977) suggest that prey for English sole in the LDW most likely includes gammarid amphipods, polychaetes, and to a lesser extent bivalves. English sole are noted to be opportunistic foragers, and would likely consume numerically dominant benthic prey in the LDW that is small enough for them to eat. No data were identified on the size of prey consumed. However, prey similar in size to gammarid amphipods would likely be preferred. Pacific staghorn sculpin are also opportunistic foragers. Although larger sculpin may be primarily piscivorous, sculpin may also ingest gammarid amphipods, shrimp, small brachyuran crabs (cancer crabs and their relatives), and, to a lesser extent, polychaetes (Table 3-32). Shiner surfperch consume a mix of epibenthic and planktonic invertebrates; amphipods (gammarids and caprellids) were the most common prey of shiner surfperch in all three nearshore surveys of Puget Sound (Fresh et al. 1979; Miller et al. 1977; Wingert et al. 1979). Striped and pile perch consume primarily epibenthic prey. Polychaetes, copepods, and *Cumacea* sp. were also locally abundant prey items for shiner surfperch (Table 3-32). Most amphipods, polychaetes, and *Cumacea* sp. are epibenthic invertebrates but copepods tend to be more pelagic (Brusca and Brusca 2003). Copepods were not found in appreciable amounts in any of the striped or pile perch stomachs analyzed (Table 3-32). Therefore, a market basket collection of abundant benthic invertebrate species in these groups would likely be most representative of English sole, sculpin, and perch prey; these feeding habits suggest that separate collection and chemical analyses of filter-feeding benthic invertebrates and benthic detritivores is not justified at this site.

Table 3-32. Summary of prey preference studies for English sole, Pacific staghorn sculpin, and perch

Species	Fresh et al. (1979)			Wingert et al. (1979)			Miller et al. (1977)		
	n	Dominant Food Items	Fish % IRI	n	Dominant Food Items	Fish % IRI	n	Dominant Food Items	Fish % IRI
English sole	63	polychaetes, gammarid amphipods, bivalve siphons	0	99	polychaetes, gammarid amphipods, bivalves	0	46	cumaceans, polychaetes, gammarid amphipods	0
Pacific staghorn sculpin	57[a], 85[b]	benthic and epibenthic crustaceans (gammarid amphipods, shrimp, brachyuran crabs, mysids), fish	29.1[a], 1.2[b]	25	gammarid amphipods, fish, crabs	17.5	51	polychaetes, isopods, bivalve siphons, crabs, fish (including juveniles and larvae)	3.2-51.7
Shiner surfperch	24	epibenthic and planktonic invertebrates (copepods, amphipods)	0	10	gammarid and caprellid amphipods, copepods	0	31	gammarid and caprellid amphipods, polychaetes, cumaceans	0
Striped perch	2	amphipods, polychaetes, shrimp, and crabs	0	18	gammarid and caprellid amphipods	0	6	gammarid amphipods, isopods, crabs and shrimp	0
Pile perch	--	--	--	--	--	--	8	isopods, bivalves, crabs, gammarid amphipods	0

[a] Samples collected in 1977

[b] Samples collected in 1978

IRI – index of relative importance. IRI = % frequency of occurrence of prey group x (% stomach content by number items from prey group + % stomach content by weight of all items from prey group). The fish % IRI is the percent of the total IRI made up of fish.

In addition, based on a review of three laboratory and five field studies (both freshwater and marine), BSAFs in general do not differ significantly among infaunal deposit feeders, epibenthic scavengers, and epifaunal filter feeders (Tracey and Hansen 1996). The authors conclude that within-species variability (e.g., analytical, experimental, and/or site-specific factors) is a greater contributor to overall BSAF variation than between-species variability. Consequently, based on the present understanding of the available information, if a Gobas-type model is selected for food web modeling, it will be used without collecting data for separate invertebrate compartments.

Red rock and Dungeness crabs (*Cancer productus* and *C. magister*) are both predators primarily on other invertebrates. Dungeness crabs prey on bivalves as juveniles and can incorporate shrimp, snails, and juvenile fish into their diet as adults (Pauley 1988). Red rock crab are not as well studied, but one recent study suggests that they specialize on shelled invertebrates such as snails and bivalves (Yamada and Boulding 1998). The smaller slender crab (*C. gracilis*) may also be found in the LDW. If crabs are modeled in the food-web model, data from snails, fish, and clams (if analyzed) could be used; distinguishing between filter-feeding and detrivorous benthic invertebrates in the model would not decrease the uncertainty in the crab exposure modeling.

3.3.4.2 Water component of model

Data on freely dissolved PCB concentrations in the water column are also required for use in the food web model. Available data regarding freely dissolved PCB concentrations include field data from lipid bag deployment in the LDW as part of the King County Water Quality Assessment. Lipid bags were deployed at two sites (near Duwamish/Diagonal and Brandon CSOs) at two depths each from March 26 to April 8, 1997. A subset of congeners was quantified to estimate a total PCBs concentration. These data were collected to calibrate a highly parameterized hydrodynamic model used to estimate concentrations of PCBs in LDW water throughout the site.

Thus, some site-specific water data are available to use in the food-web model. The sensitivity of the model to these data would determine whether existing data are sufficient. Based on a rough sensitivity analysis conducted by Windward using the Gobas (1993) model, it appears that the sensitivity of the model to water parameters is a function of the dietary assumptions of the fish being modeled. The sensitivity of the freely dissolved PCB concentration parameter was tested to determine the effect on predicted fish PCB concentrations. Because sensitivity of the freely dissolved concentration parameter depends on fish diet composition, two fish diet scenarios were tested: one with 10% zooplankton and one with 60% zooplankton. In the former scenario, an order of magnitude increase in the freely dissolved PCB concentration resulted in a predicted fish PCB concentration 1.6 times greater. In the latter scenario, the predicted fish concentration was nearly a factor of 5 greater (4.7). Therefore, in this test, the diets assumed for the fish species modeled determined the significance of the water parameter. Additional sensitivity analyses associated with model input parameters will be conducted and documented as part of the model selection process described in the food web technical memorandum.

The food-web model will be applied to English sole and sculpin,[50] neither of which is a specialized plankton consumer nor consume a significant portion of plankton relative to other prey items. Planktonic prey for perch could be more of an issue, although available studies indicate a great deal of uncertainty on this question. Miller et al. (1977) did not identify any pelagic prey in 31 samples of shiner surfperch stomach contents, whereas (Fresh et al. 1979) reported few planktonic prey in sample collected

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[50] Crabs, and possibly clams, may also be modeled for the HHRA.

in 1977 samples, but an average of 41% of planktonic prey in samples collected in 1978. (Wingert et al. 1979) reported 4.8% planktonic prey in shiner surfperch collected from Central Puget Sound (e.g., Alki Point). Planktonic prey appear to be much less common in striped and pile perch stomach contents, although the level of taxonomic identification associated with the available data makes it difficult to calculate a planktonic prey percentage (Table 3-32). For example, there are a few pelagic amphipod species known within the Gammaridea and Caprellidea suborders.

For the benthic-dominated food web that appears to be present in the LDW, the water concentration parameter appears to have a relatively minor effect on the fish tissue concentration, and therefore does not seem to justify the collection of additional water data for Phase 2. The need for these data will be determined based on the ability of the model to predict fish tissue concentrations and a sensitivity analysis conducted to determine which variables are most influential on the predictiveness of the model.

3.4 PHASE 2 RI REPORT

The Phase 2 RI report will include a presentation of all data collected during Phase 2 and a complete evaluation of the nature and extent of contamination based on both historical[51] and Phase 2 data (Task 12 of the SOW). The final baseline and residual risk assessments for human and ecological health will also be included as appendices. The approaches for the Phase 2 risk assessments are described in Sections 3.3.1 (ERA) and 3.3.2 (HHRA), respectively. A third appendix will also be produced that will evaluate the risk implications of potential exposure to subsurface sediments. This appendix will be based on the results of the ERA and HHRA (and data used in these assessments), the sediment transport study, and subsurface sediment chemistry data.

The RI report will also describe a process for identifying ARARs that govern remedial actions beyond the early actions identified in the Phase 1 RI. In addition, the report will specify sediment RBGs.

The organization of the Phase 2 RI will be very similar to the organization of the Phase 1 RI (Windward 2003a), although the content will be updated with additional information and data collected during Phase 2, results of the residual risk assessments, and any additional modeling conducted. After the introduction, the main section headings will be:

- environmental setting and previous investigations
- summary of nature and extent of contamination
- sources, pathways, and source control
- fate and transport of sediment and sediment-associated chemicals

[51] A historical data technical memorandum will be produced to document which existing data are acceptable for the Phase 2 RI.

- summaries of ERA and HHRA
- calculation of sediment RBGs for chemical risk drivers

The technical approach for each topic is described in separate sections below.

3.4.1 Environmental setting and previous investigations

The environmental setting section of the Phase 2 RI, which will include sections on both physiography and physical characteristics, will be very similar to that of the Phase 1 RI report. The results of the bathymetric survey conducted in August 2003 (Windward 2003b) will be summarized in this section, as will additional information on sediment characteristics such as grain size, TOC content, and bulk density. Sediment characteristics data will be collected during the Phase 2 sediment sampling efforts (see Sections 3.1.8 and 3.1.10). The dredging history of the LDW will also be summarized, based on available information from USACE and other sources.

The description of previous investigations will be very similar to that of Phase 1, but EPA (2003) has concluded that not all chemistry data summarized in Phase 1 are acceptable for use in Phase 2 because of data quality considerations or the adequacy of previously conducted data validations. In addition, data collected after the Phase 1 RI will be included, provided that they are of acceptable quality, as determined by EPA and Ecology. LDWG, EPA, and Ecology will continue to discuss the suitability of Phase 1 data sets and other historical data sets not included in Phase 1 prior to beginning work on the Phase 2 RI report.

The discussion of habitat in the Phase 1 RI report will be supplemented in Phase 2 by additional spatial analysis of sediment characteristics using GIS software and the results of the bathymetric survey (see Section 3.1.3) and sandpiper habitat survey (Section 3.3.1.2).

The description of human characteristics such as demography and land use will be updated with any new information on these topics that can be obtained from governmental agencies responsible for collecting such data. Human site use will be an important component of the baseline HHRA. Additional qualitative information on this topic will be collected, as described in Section 3.3.2.1, and summarized in the Phase 2 RI report.

3.4.2 ARARs

A large list of potential ARARs was presented in the Phase 1 RI report. ARARs are typically presented in the FS, but were included in the Phase 1 RI report because they were required in the statement of work. For Phase 2, the ARAR list compiled in Phase 1 will be updated, as necessary. A more extensive discussion of ARARs will also occur in the FS, where the degree to which cleanup alternatives comply with ARARs will be discussed.

The current Administrative Order on Consent is a joint EPA/Ecology order, and ARARs from all applicable regulations will be considered. Early action and long-term cleanups may proceed under joint orders, EPA-only orders, Ecology-only orders, or some combination of these. Specific ARARs for these cleanups will be determined on a case-by-case basis.

3.4.3 Summary of nature and extent of contamination

The presentation on nature and extent of contamination will be similar in content and format to that presented in the Phase 1 RI. Additional data collected during Phase 2 will be incorporated into the presentation as will data of acceptable quality collected by LDWG members or other parties (e.g., T-117, Slip 4, Boeing Plant 2) since the completion of the Phase 1 RI. A more complete discussion of the subsurface distribution of contaminants will be presented in the Phase 2 RI. Data presentation techniques used in Phase 1, such as Thiessen polygons[52] and averaging of duplicate and replicate analyses, will be reevaluated, in consultation with EPA and Ecology, prior to beginning the Phase 2 RI report.

The Phase 1 RI report did not consider temporal variability in chemical concentrations. A temporal analysis of spatial trends may be included in the Phase 2 RI. Such an analysis may also be useful for the FS because it may indicate the progress of natural attenuation of contamination in some areas.

3.4.4 Sources, pathways, and source control

The sources, pathways, and source control section of the Phase 2 RI will be similar to that presented in Phase 1, but will incorporate additional data collected during Phase 2, including:

- a survey conducted by the City of Seattle of private and public outfalls potentially discharging to the LDW
- a compilation by Environmental Data Resources, Inc. (EDR 2002) of information from regulatory agency databases on potentially hazardous sites in the vicinity of the LDW
- historical aerial photographs compiled by EPA
- detailed review of selected regulatory files

The LDW Source Control Work Group, which includes Ecology, EPA, King County, the City of Seattle, and the Port of Seattle, is focusing its efforts on the early action areas. Beginning with the Diagonal/Duwamish early action area, the group is engaged in identifying ongoing sources of the sediment contamination and preventing

[52] Thiessen polygons are a method commonly used in spatial analysis to account for spatial variability in sampling intensity. The Thiessen polygon associates each point in a plane with the closest sampling location for which a measurement is available (Burmaster and Thompson 1997).

recontamination to concentrations exceeding the SMS and the LDW sediment cleanup goals (Ecology 2004). Source control activities that are currently underway include inspecting businesses, reviewing agency files, researching possible sources of the LDW contaminants, and delineating drainage basins in the LDW. In addition to general source control activities, the LDW Source Control Work Group will develop area-specific Source Control Action Plans. During the time that the Phase 2 RI is being developed, the work group will be focusing primarily on action plans for the first four early action areas (i.e., Areas 1, 3, 4, and 5).

Information collected by this group will be incorporated into the Phase 2 RI. For example, one of the data needs identified during Phase 1 was the identity (i.e., owner) and characteristics (i.e., type of discharge, size of pipe, drainage basin) of each outfall that potentially discharges to the LDW. The City of Seattle has completed a survey of private and public outfalls discharging into the LDW. The information from this survey will be included in the Phase 2 RI. Additional data on industrial storm drains may be collected by LDWG during Phase 2.

3.4.5 Fate and transport of sediment and sediment-associated chemicals

Sediment fate and transport within the LDW may be influenced by many variables, including hydrologic regime, water depth, sediment characteristics, and industrial activities such as boat traffic. The Phase 1 RI summarized available data on sediment fate and transport. Although considerable work on this topic has been conducted in the LDW, data gaps remain. Several different types of data will be collected in Phase 2 to supplement the sediment fate and transport information presented in Phase 1, as described in Section 3.1.7. The sediment fate and transport data collected in Phase 2, and the comprehensive framework within which these data will be placed (i.e., a weight-of-evidence approach or a numeric model) will be incorporated into the Phase 2 RI. This section of the Phase 2 RI report will be taken largely from the sediment transport data analysis report produced as part of the sediment transport study (see Section 3.1.7).

As described in the Phase 1 RI, there are three different habitat types characterized by different depth regimes in the LDW, each of which might be expected to have different sediment fate and transport characteristics: navigation channel, intertidal and shallow subtidal benches, and the slopes between the navigation channel and benches. The comprehensive bathymetry data (see Section 3.1.3) will assist in the identification of these regions. The bathymetry data will also be incorporated into the comprehensive sediment fate and transport framework described in Section 3.1.7.

3.4.6 Modeling protective sediment concentrations

Depending on the results of both the ERA and HHRA, it may be necessary to calculate concentrations of chemicals in sediment that if left in place would not result in adverse effects on ecological or human health. These concentrations are referred to as RBGs, and would be calculated using Phase 2 risk results and the food web model (Section 3.3.3). Based on the results of the Phase 1 risk assessments, it is likely that food web modeling for PCBs will be warranted. If other risk-driving, bioaccumulative chemicals[53] are associated with unacceptable risks in the Phase 2 residual risk assessments, modeling of these other chemicals may also be conducted.

Calculating an RBG for PCBs is a multi-step process. The first step is to determine the fish or benthic invertebrate tissue concentration that is protective of the ROC. This tissue concentration is equivalent to the highest tissue concentration not associated with adverse effects (ERA) or associated with an acceptable level of human health risk (HHRA).[54] The second step is to estimate the sediment concentration (i.e., RBG) that could lead to bioaccumulation at the protective tissue concentration. A bioaccumulation model such as a Gobas-based model may be used for this purpose in the LDW, pending the Phase 2 risk results and EPA and Ecology's review of the food web model technical memorandum describing the proposed modeling approach. This model will be run with information from the literature and field-derived tissue and sediment data (both existing data and data gathered in Phase 2, see Sections 3.1.5, 3.1.6, and 3.1.8, respectively). The third step is to relate the RBG to a sediment PCB concentration in a form amenable to remediation (i.e., a concentration suitable for a record of decision).

This section discusses the second step of the process described above (i.e., modeling either specific congeners or total PCBs to estimate a RBG based on risk results). The data needs and benefits differ according to whether total PCBs or individual PCB congeners are modeled, as discussed below.

In the environment, complex mixtures of PCB congeners are present. The fate, transport, bioaccumulation, and toxicity of these congeners are dependent on their individual physical-chemical characteristics. One of the key parameters is the octanol-water partition coefficient[55] (K_{OW}) for each congener. K_{OW} is a very sensitive model parameter that varies by orders of magnitude among PCB congeners (DeBruijn et al. 1989; EPA 1995; Rapaport and Eisenreich 1984; Shiu and Mackay 1986). Uncertainty exists regarding the K_{OW}s for some individual PCB congeners, and the range of K_{OW} s for all 209 PCBcongeners varies by over four orders of magnitude (DeBruijn et al. 1989). Therefore, the treatment of K_{OW} when modeling PCBs is important. When PCBs are modeled as a mixture of congeners (either as a "total" or as a group of PCB congeners such as a homolog group), the K_{OW} for that mixture must be estimated.

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53 The Gobas model was designed for nonionic, hydrophobic chemicals. If risk-driving chemicals are identified that do not meet this definition, other models will be considered.

54 Protective if equaled or not exceeded; for wildlife and human health, this concentration is calculated using the dietary exposure model.

55 An octanol-water partition coefficient is a standard way to measure the hydrophobicity of a compound (i.e., its preference to partition to organic phases rather than water).

Options for estimating the Kow to be used in the model as well as uncertainties associated with its selection will be described in the food web model memorandum.

For the LDW, the decision to model either as a total PCB sum or as specific PCB congeners must consider the following:

- **existing sediment chemistry data—**Almost 1,000 surface sediment samples have been analyzed for total PCBs relative to approximately 600 samples analyzed for PCB congeners using low resolution methods[56]
- **relative uncertainty in relating derived RBG to total PCBs RBG—**The LDW site is a complex site with numerous potential sources of PCBs, which may or may not result in a consistent congener pattern throughout the LDW. Without a consistent dioxin-like PCB congener pattern, it may not be possible to relate the coplanar congener pattern in sediment to that in tissue through modeling.
- **relative uncertainty in modeling—**If an Aroclor-based total PCBs sum is modeled, an approach to estimate the K_{OW} will need to be agreed to by EPA and Ecology; selection of a K_{OW} for individual PCB congeners would also need to be discussed
- **risk results—**The model would be used to relate the results of the risk assessment to a RBG. The results of both the risk characterization and the uncertainty assessment will be considered in assessing the relative risk and reliability of Aroclor- or congener-based (TEQ) risk estimates
- **cost—**If a congener-specific approach were selected, additional samples of both tissue and sediment may be needed for both Aroclor analysis and high resolution analysis of dioxin-like PCB congeners. Future monitoring costs would also be much higher if they are based on specific congeners.

In sum, these considerations do not unequivocally indicate a preference for either Aroclor-based total PCB modeling or congener-specific modeling until the Phase 2 risk assessments are complete. If, at the conclusion of the risk assessments, TEQ-based risks (from dioxin-like PCB congeners) appear to be driving PCB risks for the site, then the sufficiency (i.e., number and distribution of samples) of the congener data would be re-evaluated and a final modeling approach would be determined in consultation with EPA and Ecology. Alternatively, if risk estimates based on total PCBs appear to dominate or be inclusive of dioxin-like PCB effects, and the distribution of dioxin-like PCB congeners in sediment is reasonably consistent with the pattern of total PCBs (Aroclor sum), the food web modeling may be conducted on a total PCBs basis. The food web model technical memorandum will further discuss this issue.

[56] Detection limits in this low resolution analysis were too high to detect many of the dioxin-like PCB congeners.

3.4.7 Risk implications of potential exposure to subsurface sediments

The risk estimates presented in the Phase 2 ERA and HHRA will not be based on subsurface sediment chemistry data, or any surface sediment chemistry data that are collected from the sediment cores, because these data will not be available in time for producing the draft risk assessment reports. EPA, Ecology, and LDWG have agreed to a schedule that overlaps the risk assessments with the collection of subsurface sediment chemistry data because the parties believe that remedial decision-making will be based primarily on surface sediment and tissue chemistry data. However, the risk implications for humans and ecological receptors potentially exposed to subsurface sediment will be described in an appendix to the Phase 2 RI report. The implications will depend on the chemical concentrations detected in subsurface sediment and the magnitude and probability of sediment erosion and subsequent resuspension and transport estimated during the sediment transport study described in Section 3.1.7.

4.0 Schedule and Deliverables

Various QAPPs, data reports, technical memoranda, as well as the Phase 2 RI and risk assessments, will be generated following EPA and Ecology approval of this work plan. The project schedule, in the form of a Gantt chart (Figure 4-1, located at back of document) lists the deliverables discussed in this work plan that are required to complete the Phase 2 RI tasks. Other deliverables not yet identified, such as technical memoranda on specific issues, may be required to complete the Phase 2 RI tasks, but are not shown in Figure 4-1. Any requirement to produce documents other than those identified in Figure 4-1 will be determined in consultation with EPA and Ecology. As described in this work plan, LDWG plans to prepare technical memoranda on the following topics:

- incorporation of clam, crab, and shrimp survey results (Section 3.1.2) into the exposure assessment for the HHRA seafood consumption scenarios (Section 3.3.2.1)
- historical chemistry data to be used in the Phase 2 RI (Sections 3.1.6, 3.1.8, and 3.1.10)
- methods to be used in the gastropod pilot study (Section 3.1.6)
- sediment transport data analysis report presenting the incorporation of field-collected data with any subsequent modeling (Section 3.1.7)
- technical approach for PRA in the Phase 2 ERA (Section 3.3.1.4)
- methods and results of the reconnaissance survey for potential public use of the shoreline (Section 3.3.2.1)

- methods and results of the habitat survey and one-time site use assessment for sandpiper (Section 3.3.1.2)
- site use assessment for rockfish, and survey methods and results, if survey is justified based on the assessment (Section 3.3.1.2)
- technical approach for PRA in the Phase 2 HHRA (Section 3.3.2.4)
- technical approach for the residual risk analysis to be conducted as part of the Phase 2 risk assessments (Section 3.3)
- technical approach for the food-web model (Section 3.3.3)

SOW Task 9 includes production of QAPPs for all field work required to complete the RI. As noted in Figure 4-1, three QAPPs have already been submitted to EPA and Ecology and approved. Field work for these QAPPs has already been completed or is underway. Other than these three QAPPs, no QAPPs will be submitted to EPA and Ecology for review, comment, and approval until after this work plan has been approved by EPA and Ecology.

Many of the Phase 2 studies are interlinked, with the results of some field studies influencing the overall scope and study design of other data collection efforts. Table 4-1 lists the dependencies between the various Phase 2 elements. For example, the results of the surface sediment and sediment transport investigations are needed to complete the study design for subsurface sediment sampling.

Table 4-1. Dependencies between Phase 2 study elements

Phase 2 Element	First Deliverable to EPA/Ecology [a]	Past Dependencies	Future Dependencies
Juvenile salmon study	April 2003	none	ERA, RI
Bathymetry study	May 2003	none	sandpiper, rockfish, benthic invertebrate, fish and crab tissue chemistry, surface and subsurface sediment, sediment transport, RI
Clam, crab, and shrimp surveys	May 2003	none	benthic invertebrate, fish and crab, ERA, HHRA, RI
Historical sediment and tissue chemistry data tech memo	April 2004	none	surface sediment, ERA, HHRA, RI
Seep survey	April 2004	work plan	surface sediment, RI
Sandpiper site use survey	April 2004	bathymetry, work plan	benthic invertebrate, fish and crab, surface sediment, ERA, RI
Rockfish site use assessment	May 2004	work plan	fish and crab, ERA, HHRA, RI
Benthic invertebrate study	April 2004	bathymetry, sandpiper site use, clam survey, work plan	ERA, HHRA, food web model, RI

PHASE 2 ELEMENT	FIRST DELIVERABLE TO EPA/ECOLOGY [a]	PAST DEPENDENCIES	FUTURE DEPENDENCIES
Potential public access of the shoreline survey	April 2004	work plan	surface sediment, fish and crab, HHRA, RI
Fish and crab tissue chemistry study	May 2004	crab and shrimp survey, rockfish, potential public use of the shoreline survey, work plan	ERA, HHRA, food web model, RI
Gastropod pilot study tech memo	May 2004	work plan	benthic invertebrate
HHRA tech memo – incorporation of clam, crab, and shrimp survey data	July 2004	crab/clam/shrimp survey	HHRA
Sediment transport study	August 2004	bathymetry, work plan	subsurface sediment, RI
Surface sediment chemistry study	October 2004	bathymetry, historical sediment data tech memo, seep survey, potential public use of the shoreline survey, sandpiper habitat, work plan	subsurface sediment, ERA, HHRA, food web model, RI, FS
FS work plan	November 2004	none	FS
HHRA probabilistic risk analysis tech memo	December 2004	surface sediment, benthic invertebrate, fish and crab tissue chemistry	HHRA, RI, FS
Porewater chemistry study	January 2005	work plan	ERA, RI
ERA probabilistic risk analysis tech memo	January 2005	surface sediment, benthic invertebrate, fish and crab tissue chemistry	ERA, RI, FS
RI food web model tech memo	March 2005	surface sediment, benthic invertebrate, fish and crab tissue chemistry	RI, FS
Residual risk analysis tech memo	June 2005	surface sediment, benthic invertebrate, fish and crab tissue chemistry, sediment transport	ERA, HHRA, RI, FS
Subsurface sediment chemistry	July 2005	surface sediment, sediment transport	RI, FS
Phase 2 HHRA report	February 2006	crab/clam/shrimp, potential public use of the shoreline survey, benthic invertebrate, fish and crab tissue chemistry, surface sediment, residual risk analysis, HHRA probabilistic risk analysis	RI, FS
Phase 2 ERA report	February 2006	crab/clam/shrimp, juvenile salmon, rockfish site use, sandpiper habitat, benthic invertebrate, fish and crab tissue chemistry, surface sediment, porewater, residual risk analysis, ERA probabilistic risk analysis	RI, FS
Phase 2 RI report	October 2006	all elements	FS
FS report	April 2007	FS work plan, RI	none

[a] First deliverable for each study element is either a QAPP, technical memorandum, or report. Dates shown are for draft documents. A complete list of Phase 2 deliverables is included in Figure 4-1.

LDWG proposes to submit draft QAPPs to EPA and Ecology for review, comment, and approval in the order shown in Table 4-1 and Figure 4-1. The first QAPPs to be submitted following approval of the Phase 2 work plan are the seep survey QAPP, the benthic invertebrate QAPP, and the fish and crab chemistry QAPP (in that order). Sampling based on these QAPPs is expected to begin in 2004.

Figure 4-1 includes delivery dates for every Phase 2 deliverable currently identified. Many of the 2004 dates are based on the approval of this work plan by April 12, 2004. Should that date not be met, the delivery dates for the first 2004 QAPPs will be delayed accordingly as will the rest of the linked schedule. As noted in Table 4-1, many of the studies are linked in such a way that a QAPP can't be written until the results from a previous study have been evaluated. If any QAPP approval dates shown in Figure 4-1 are not met, the dependent deliverables associated with these and other linked studies will likely be delayed by a corresponding length of time. In addition, dates beyond submittal of draft documents are approximate and will be dependent on the time required for resolution of any issues identified in the draft documents.

Dates for submittal of the FS work plan and FS report are shown in Figure 4-1, but these dates should be considered preliminary because a separate contractor, that has yet to be officially retained, will conduct the FS. Once this contractor has been retained, LDWG, EPA, and Ecology will discuss the appropriate schedule for the FS work plan and FS.

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Appendix A: Data Needs

The tables in this appendix are reproduced from the data needs memorandum (Windward 2003f) as a reminder of the data needs agreed to by LDWG, EPA, and Ecology. They are identical to Tables 3-1, 3-2, and 3-3, respectively, from that document.

Table A-1. Sediment chemistry data needs and proposed actions

Data Type	Assessment with Data Need	Purpose	Locations
Surface sediment	benthic invertebrate risk	to better characterize benthic invertebrate exposure, including exposure to COPCs that were previously analyzed in relatively few samples	Sample locations will be co-located with toxicity test locations, and benthic invertebrate tissue collection locations.
	human health and benthic invertebrate risk	to analyze additional sediment samples with attention to achieving lower detection limits because detection limits for existing data exceeded risk-based screening concentrations and/or SQS/CSL	Collect samples in select areas in LDW.
	human health risk	to better characterize exposure during beach play	Collect samples in intertidal areas where human exposure is likely to occur.
	human health risk	to evaluate arsenic[a] risk relative to background	Collect samples upstream of the LDW.
	remedial investigation	to collect data for additional nature and extent characterization	Sample locations will be targeted based on the following key considerations: 1) areas with low spatial coverage, particularly at sites where single SQS or CSL exceedances were observed with few nearby stations, near special use areas (e.g., beaches), or near probable chemical sources; 2) co-located with SMS-approved toxicity tests and certain tissue collection locations; and 3) analyte considerations including chemicals with relatively low numbers of historical samples or historical locations that did not have sufficiently low detection limits for certain chemicals. Criteria will be outlined in the Phase 2 work plan.
Subsurface sediment	remedial Investigation	to collect data for additional nature and extent characterization, particularly in areas potentially subject to erosion	Sample locations will be targeted based on the following key considerations: 1) erosion potential, 2) proximity to probable chemical sources, and 3) existing surface and subsurface chemistry data. Criteria will be outlined in the Phase 2 work plan.

[a] A few additional chemicals may also be analyzed from background locations. The background sampling approach will be discussed with EPA and Ecology and described in more detail in the Phase 2 work plan.

Table A-2. Tissue chemistry data needs and actions

Target Tissue	ROC	Type of Data	Purpose
Benthic invertebrates	benthic invertebrates	neo- and mesogastropods[a]	These data will make it possible to evaluate the imposex endpoint for these two orders of snails.
	juvenile chinook salmon and English sole	epibenthic and infaunal invertebrates, as prey items (combined, using a market basket approach)	Existing tissue chemistry data are few, potentially not representative of all prey, and potentially not spatially representative of LDW.
	spotted sandpiper	epibenthic and infaunal benthic invertebrates, as prey items (combined, using a market basket approach)	Existing tissue chemistry data are limited and were not collected from areas with highest concentrations that may be sandpiper habitat.
Crab[b]	crab	adult whole body and hepatopancreas	Existing tissue chemistry data are limited from both an analyte and spatial perspective.
	human shellfish consumers	adult edible crab meat, hepatopancreas (separate samples)	These data will make it possible to increase confidence in existing exposure point concentrations, and to evaluate arsenic speciation in a subset of samples.
Pacific staghorn sculpin	piscivorous fish[d]	whole body (>15 cm[c])	There are no existing data to estimate exposure to piscivorous fish.
	heron, eagle, otter, seal	whole body (typically <30 cm for heron, eagle, and seal, up to 40 cm for otter)	There are no existing data for piscivorous fish as prey items for wildlife.
English sole	English sole	whole body adult	Existing data are too few (3 composites of 20 fish each) and compromised (portions of those fish removed for other analyses).
	otter, seal	whole body (typically <30 cm for seal, up to 40 cm for otter)	Existing data are few (3 composites of 20 fish each) and compromised (portions of those fish removed for other analyses).
	human fish consumers	fillets, potentially whole body minus guts	Existing data are too few to characterize exposure by subpopulations with alternative consumption patterns.
Juvenile chinook salmon	juvenile chinook salmon	whole body	Existing data may be qualified due to insufficient QA/QC documentation.
	piscivorous wildlife and fish	whole body	Existing data may be qualified due to insufficient QA/QC documentation; perch data may also be used as a surrogate for certain analytes.

Target Tissue	ROC	Type of Data	Purpose
Shiner surfperch	sculpin, heron, eagle, otter, seal, human consumers (potentially)	whole body fish as prey items; fillet and some whole body samples for human health	Existing data are limited
Clams	human consumers	edible meat	Clams may be collected for chemical analyses if abundance survey indicates harvestable populations are present.
Other fish species	human consumers	mostly fillet, some whole-body	The number of fish species for the benthic and pelagic components of the market basket may include more than one species for each component if these species can be harvested using conventional fishing techniques likely to be used by the potentially exposed population.

[a] If sufficient neo- and mesogastropod tissue is not available, a surrogate benthic invertebrate group (phylum) will be collected for TBT analysis.

[b] Crab data could also be used for river otter exposure, although limited crab data were not identified as a primary uncertainty for otter risk estimates.

[c] Defined by Weitkamp and Campbell (1980) as size of fish with piscivorous diet.

[d] Rockfish tissue samples may also be collected for chemical analyses if warranted based on site use data.

Table A-3. Site use data needs and actions

ROC	Purpose	Details
Crab	to assess relative abundance and habitat use needed to determine relevance of existing data and to determine locations for additional tissue collection	Conduct a survey in LDW assessing crab site use during different seasons.
Benthic community (i.e., burrowing organisms)	to evaluate presence of clams for exposures in subsurface sediments (below 15 cm)	Evaluate depth of clam occurrence during the clam abundance survey for the human health assessment.
Benthic community	to generally characterize types of benthic invertebrates found in LDW sediments	Conduct limited benthic community surveys
Rockfish	to assess presence/absence of rockfish in the LDW to evaluate potential inclusion as a fish ROC	Conduct a limited survey to assess site use, based on habitat identified in the bathymetric survey.
Sandpiper	to reduce uncertainty in the sandpiper exposure assessment	Conduct a limited visual survey of the suitability of intertidal habitats for use by sandpipers near sites with high COPC concentrations.

ROC	PURPOSE	DETAILS
Human fish and shellfish consumers	to determine harvest sustainability in the LDW	Conduct clam and crab surveys, and a limited shrimp survey, to determine relative abundance and distribution. In addition, the presence of marine shellfish species in the LDW will be determined based on literature reviews and interviews with biologists that have conducted LDW field work.
Human users of the intertidal zone	to reduce uncertainty in the potential use of intertidal areas for recreational purposes (e.g., beach play)	Conduct additional qualitative reconnaissance of potential intertidal human use areas.

Appendix B: Terrastat Memorandum regarding TBT

Quantitative Analysis for the Natural Sciences
10636 Sand Point Way NE
Seattle, WA 98125
206-362-3299

MEMORANDUM

To: Windward Environmental and Lower Duwamish Waterway Group
From: Alice Shelly
Subject: Recommendation for TBT regression sufficiency
Date: 12/17/03

This memorandum recommends a process to determine whether the relationship between sediment and tissue TBT concentrations in the LDW is sufficient for the environmental risk assessment. If the relationship is not sufficient, additional samples, including porewater, will be analyzed.

Regressions are often judged by the coefficient of determination, R^2, which measures the degree of linear association between the regression variables, or by the significance of the slope parameter (using t-test or F-test). However, for the purposes of the risk assessment, the usefulness of the regression relationship lies in the precision of estimates or predictions. Therefore, the width of confidence intervals surrounding the predictions of tissue concentration should be used as the primary basis for judging sufficiency.

The precise uses for the regression relationship have not been fully determined. However, it is anticipated that the process may unfold as follows:

1) The most important risk determination will be comparisons of detected tissue concentrations to TRVs.
2) If the observed sediment concentrations for the paired data are lower than the full range of sediment concentrations in the LDW, then the regression relationship may be used to approximate tissue concentrations for higher sediment concentrations.

IMPORTANT STATISTICAL WARNING:

Predictions from the regression are valid for sediment TBT concentrations in the range of the observed data. If the sediment TBT concentrations for which a tissue prediction is required are not far above this range, the regression relationship can be used to extrapolate with some confidence. However, the farther the concentration is from the range of observed sediment TBT concentrations, the less certainty we have that the relationship is valid. In addition, the confidence limits rapidly grow wider as the concentration increases from the observed mean.

The regression relationship is not relevant to the comparison in #1 above. For #2 above, the regression will be used to predict the expected tissue concentration at a given sediment concentration, X_h. Assuming normal distribution of the regression residuals, a confidence interval on the expected tissue concentration, $\hat{Y}_h$, is formed as follows:

$$\hat{Y}_h \pm t \cdot s\{\hat{Y}_h\},$$

where t is the 1- $\alpha/2$ quantile of the t-distribution with (n-2) degrees of freedom, n is the number of samples used to fit the regression,

$$s\{\hat{Y}_h\} = MSE\left[\frac{1}{n} + \frac{(X_h - \overline{X})^2}{\sum(X_i - \overline{X})^2}\right],$$

MSE is the mean squared error for the regression, and $\overline{X}$ is the average sediment concentration from the regression.

We define the upper half-width of this confidence interval as [(upper bound)-(expected value)]/(expected value) in original units, expressed as a percent.

Because of the mechanics of least squares fit, outliers tend to have undue influence on the parameter estimates, and may skew the variance estimates used to evaluate the fit of the model. Suspected outliers in tissue concentrations should be identified by an examination of the residuals of the fitted regression. The residuals are assumed to have an approximate normal distribution in order for the confidence intervals to be valid. If one or two residuals cause severe departure from normality, these points are suspected outliers. I recommend that the regression be evaluated with all data, and also with suspected outliers removed. The regression should be considered sufficient if it passes criteria without suspected outliers. If it does not pass the criteria with all data included, a decision on whether to include the outlier in the prediction and confidence interval will be required. As shown in Table B-1, the outlier in the East Waterway regression for *Macoma* has a large effect on the uncertainty in the prediction. The decision on whether or not to include this point in the analysis depends on how much influence one sample should have on conclusions and estimates of risk.

In the previous TerraStat memo (Shelly, 2003), four linear regression models predicting tissue concentrations from normalized sediment are described and compared in detail. Upper half-widths of confidence intervals for tissue TBT concentrations predicted from the mean and the maximum observed log (base 10)-transformed normalized sediment concentrations are summarized in Table B-1. We consider these models (with outliers removed) to provide reasonable fits, with the exception of the East Waterway *Nephtys* model, which has an R^2 value of 0.22.

Therefore, the sufficiency criteria are based on the premise that the LDW regression should be at least as good as the previous models with good fit, and no worse than the EW *Nephtys* model.

The following sufficiency criteria are recommended, based on the regression after outliers are accounted for:

1. If the upper half-width of the confidence interval on the tissue prediction at the mean normalized sediment concentration is less than or equal to 39% of the tissue prediction, the regression will be considered sufficient for the ecological risk assessment.
2. If the upper half-width of the confidence interval on the tissue prediction at the mean normalized sediment concentration is greater than or equal to 47% of the tissue prediction, the regression will be considered insufficient.
3. If the upper half-width of the confidence interval on the tissue prediction at the mean normalized sediment concentration is between 39% and 47% of the tissue prediction, the regression will be further evaluated based on the magnitude of R^2 and the F-test for significance of the slope parameter.

Table B-1. R^2, p-values for slope significance, and upper half-widths of confidence intervals on predicted tissue TBT concentrations, expressed as percent of the predicted value. Predicted values are given in parentheses.

		R^2	p-value	Upper Half-Width of CI	
				Mean	**Max**
East Waterway (Normalized sediment concentration mean = **3.6**, max = **4.8** ppb OC)	Macoma: Outlier Removed	0.78	2.2E-06	**35%** (25)	**120%** (300)
	Macoma: Outlier Included	0.62	0.00011	**57%** (30)	**260%** (420)
	Nephtys	0.22	0.047	**47%** (19)	**180%** (49)
West Waterway (Normalized sediment concentration mean = **4.6**, max = **5.4** ppb OC)	Macoma	0.47	0.000014	**39%** (33)	**48%** (63)
	Nephtys: Outlier Removed	0.73	1.1E-09	**11%** (110)	**13%** (150)
	Nephtys: Outlier Included	0.74	2.5E-10	**13%** (100)	**15%** (160)

CI – confidence interval

In summary, this memorandum provides steps that will be used in determining whether additional data beyond sediment and tissue (i.e., porewater) will be collected in the LDW for bioaccumulation analysis. Previous TBT bioaccumulation regression analyses in the East and West Waterways have provided some information from which to judge the LDW relationship between sediment and tissue TBT. The width of the confidence interval on tissue predictions will be the main criterion because tissue predictions are expected to be the primary use of the regression. However, there is no absolute criterion that can be used to judge the regression before the data are examined. Therefore, we have allowed some flexibility in the decision if the width of the confidence intervals on predictions are somewhat wider than ideal.

References

Shelly, Alice (2003). TBT Bioaccumulation East and West. Memo to Kathy Godtfredsen of Windward Environmental from TerraStat Consulting Group, 6/24/03.

Oversize GIS Maps and Project Schedule

Located in separate file.