EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
FINAL CONCEPTUAL SITE MODEL AND DATA GAPS ANALYSIS REPORT

For submittal to

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Prepared by

ANCHOR ENVIRONMENTAL, L.L.C.
1423 3rd Avenue ♦ Suite 300
Seattle, Washington ♦ 98101

Windward environmental LLC
200 West Mercer Street ♦ Suite 401
Seattle, Washington ♦ 98119

Battelle Memorial Institute | KPFF | Coast and Harbor Engineering

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ACGs	analytical concentration goals
ADP	acoustic Doppler profiler
API	Asian and Pacific Islander
ASAOC	Administrative Settlement Agreement and Order on Consent
AVS	acid volatile sulfides
AWQC	ambient water quality criteria
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
City	City of Seattle
COI	chemicals of interest
COPC	chemical of potential concern
County	King County
CPUE	catch-per-unit-effort
CSL	Cleanup Screening Level
CSM	Conceptual Site Model
CSO	combined sewer overflow
DDT	dichloro-diphenyl-trichloroethane
DMMP	Dredged Material Management Program
DMMU	Dredged Material Management Unit
DPS	distinct population segment
Ecology	Washington State Department of Ecology
EE/CA	Engineering Evaluation/Cost Analysis
EISR	Existing Information Summary Report
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESA	Endangered Species Act
EW	East Waterway
EWG	East Waterway Group (Port of Seattle, City of Seattle, and King County)
FS	Feasibility Study
H:V	horizontal to vertical
HHRA	Human Health Risk Assessment
LDW	Lower Duwamish Waterway
MDL	method detection limit

MHHW	mean higher high water
ML	maximum level
MLLW	mean lower low water
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
Port	Port of Seattle
PPE	Personal Protective Equipment
PRGs	Preliminary Remediation Goals
PSDDA	Puget Sound Dredged Disposal Analysis
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RBCs	risk-based concentrations
RI	remedial investigation
RL	reporting limit
RM	River Mile
ROC	receptor of concern
ROD	Record of Decision
SCE	Source Control Evaluation
SCEAM	Source Control Evaluation Approach Memorandum
SCUBA	self-contained underwater breathing apparatus
SL	screening level
SMS	Sediment Management Standards
SOW	Statement of Work
SPI	sediment profile imaging
SQS	Sediment Quality Standards
SRI	Supplemental Remedial Investigation
SRI/FS	Supplemental Remedial Investigation/Feasibility Study
STE	Sediment Transport Evaluation
STEAM	Sediment Transport Evaluation Approach Memorandum
SVOC	semivolatile organic compound

T&E	threatened and endangered
TBD	to be determined
TBT	tributyltin
TOC	total organic carbon
TRV	toxicity reference value
TSS	total suspended solids
U&A	Usual and Accustomed
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
WA WQC	Washington water quality criteria
WDFW	Washington Department of Fish and Wildlife
WQA	King County Water Quality Assessment (King County 1999)
WQM	water quality monitoring
WQS	Water Quality Standards
WW	West Waterway

1 INTRODUCTION

This Conceptual Site Model (CSM) and Data Gaps Analysis Report has been prepared as part of the Supplemental Remedial Investigation/Feasibility Study (SRI/FS) for the East Waterway (EW) Operable Unit (OU) of the Harbor Island Superfund Site as ordered by the U.S. Environmental Protection Agency (EPA) per the process defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund.

This report is a required deliverable set forth in Sections 3.2 and 3.3 of the SRI/FS Workplan for the EW OU (Anchor and Windward 2007), prepared in response to the Administrative Settlement Agreement and Order on Consent (ASAOC) and Statement of Work (SOW) (EPA 2006a).

1.1 Purpose

The purpose of the CSM and Data Gaps Analysis Report is to first present an integrated overview of the physical, ecological, and human health conceptual models for the EW. The physical processes description synthesizes what is known about important hydrodynamic and physical processes within the EW, focusing specifically on the processes that govern sediment transport within the waterway. The Physical Processes CSM will also serve to inform subsequent steps in the SRI/FS and design process, including investigation of the nature and extent of contamination and feasibility of remedial alternatives. The Risk Assessment (Ecological and Human Health) CSMs summarize important physical and biological processes that influence pathways of potential exposure. The Risk Assessment CSMs identify receptors of concern (ROCs) and pathways of exposure in order to characterize ecological and human health risks. The Physical Processes and Risk Assessment CSMs are preliminary based on current information presented in the Existing Information Summary Report (EISR; Anchor and Windward 2008a). The CSMs will be refined throughout the SRI process as additional data collection and analysis are completed.

The CSMs will also facilitate identification of data needs for the Supplemental Remedial Investigation (SRI), Ecological Risk Assessment (ERA), Human Health Risk Assessment (HHRA), and Feasibility Study (FS). Additional data collected as part of the SRI/FS process will supplement existing data presented in the EISR (Anchor and Windward 2008a) and will be used to refine the CSMs, complete the evaluation of the nature and extent of contamination in the EW, and to conduct the ERA and HHRA.

The data gaps analysis in this report reviews existing data and identifies data that are needed to complete the SRI/FS (e.g., data needs). Detailed study designs to fill these data needs will be presented in separate Quality Assurance Project Plans (QAPPs), as outlined in the SRI/FS Workplan (Anchor and Windward 2007). Following collection and incorporation of newly collected data, the CSMs will be refined as needed during the SRI/FS process.

The Physical Processes CSM is presented to describe the current understanding of EW hydrodynamics and processes that govern sediment transport. As discussed in the SRI/FS Workplan (Anchor and Windward 2007), the data gaps analysis for sediment transport processes (and the Physical Processes CSM) will be presented in the Sediment Transport Evaluation Approach Memorandum (STEAM; Anchor and Battelle 2008). The objective of the STEAM is to identify the approach to further characterize sediment transport dynamics within the EW. To the extent feasible, certain data gaps identified in the STEAM will be integrated into the overall data gaps collection effort. The STEAM document is being prepared concurrently with this report to most efficiently identify data needs, and will be submitted to EPA in March 2008. The Physical Processes CSM will be updated as needed in the SRI as more information becomes available through the Sediment Transport Evaluation (STE).

Additional data gaps relating to sources of contamination to the EW are not addressed in this document, but will be identified in the Initial Source Screening and Data Gaps Memorandum as part of the Source Control Evaluation (SCE) process. The Source Control Evaluation Approach Memorandum (SCEAM; Anchor and Windward 2008b) describes a plan for the evaluation of potential contaminant sources to the EW, including the objectives and approach for source control integration into the SRI/FS. Potential sources of contamination to EW sediments are identified in Section 5 of the EISR (Anchor and Windward 2008a) and may include overwater uses and spills, industrial wastewater discharges, combined sewer overflow (CSO) discharges, stormwater discharges, nearshore cleanup sites, and atmospheric deposition. The relationship between physical transport and chemical transport will be addressed during the Sediment Transport Evaluation.

1.2 Site Description

This section presents an overview of the EW physical site characteristics pertinent to development of the CSMs. Additional detailed information on the environmental setting of the EW is presented in Section 2 of the EISR (Anchor and Windward 2008a). This information includes habitat and biological conditions (EISR Section 2.3) and human use characteristics (EISR Section 2.4). Section 1 of the EISR also presents a detailed site history of the EW and surrounding areas.

The EW is located approximately 1 mile southwest of downtown Seattle, in King County, Washington. It is part of the greater Duwamish River estuary, which includes the freshwater/salt water interface extending as far as 10 miles upstream. At the southern end of Harbor Island, the river splits into the EW and the West Waterway (WW). From there, the EW and the WW extend to Elliott Bay at the north end of Harbor Island. The EW runs along the entire eastern shore of Harbor Island (Map 1-1). The Lower Duwamish Waterway (LDW) Superfund Site is located immediately upstream of the EW (i.e., upstream of Harbor Island).

The EW is approximately 7,600 feet long, and for most of its length is 750 feet wide. It is channelized and has a south-to-north orientation. Four bridges cross over the EW along the Spokane Street corridor, located approximately at Station 6850 (Map 1-2). The Spokane Street corridor includes three lower bridges and one high bridge (West Seattle Bridge). The lower bridges include (from north to south) the Spokane Street Bridge (which includes a fishing pier bridge along the north side), the Railroad Bridge, and the Service Road Bridge. Immediately north of the Service Road Bridge, the EW is approximately 250 feet wide. It narrows to approximately 150 feet wide south of the Service Road Bridge (see Map 1-2).

As shown in Maps 1-3A, B, C, and D, existing bathymetry varies from approximately -40 to -60 feet mean lower low water (MLLW) (near the mouth) in the 750-foot-wide portion of the EW (DEA 2003). Mudline elevations rise to between -13 and -6 feet MLLW in the vicinity of the Spokane Street corridor (DEA 2003). However, besides limited water depth sounding in the EW south of the Spokane Street corridor (NOAA 2004), no detailed bathymetry exists in the vicinity of the Spokane Street corridor and south of the Spokane Street corridor. The shallow water depths associated with this "sill" along the Spokane Street corridor form a physical constriction across the entry to the EW that causes the Duwamish River to primarily flow through the WW. The presence of the bridges along the Spokane Street corridor also prohibits any type of boat passage, except at low tide by small, shallow-draft boats (e.g., kayaks and skiffs).

South of the Spokane Street corridor, the EW consists of riprap banks extending to the southern tip of Harbor Island. The shoreline within the EW is highly developed and primarily composed of piers, riprap, constructed seawalls, and bulkheads constructed for industrial and commercial use. In addition, three CSOs and 39 storm drains are present along the EW that contribute freshwater and solids to the waterway (Map 1-2).

The EW north of the Spokane Street corridor experiences regular vessel traffic of various sizes and types, including significant tug and barge traffic. Container ships call at Terminals 18 (T-18), 25 (T-25), and 30 (T-30). Cruise ships currently call at T-30, however, cruise ships are planned to be moved to Pier 91 in 2009 (previously identified as 2008 in the EISR). T-30 will then be utilized as a container terminal. U.S. Coast Guard (USCG) vessels frequent Pier 36. The EW is used for Tribal Usual and Accustomed (U&A) fishing. A public fishing pier is present along the north side of the Spokane Street Bridge. South of the Spokane Street corridor, the Harbor Island Marina is located on the southern tip of Harbor Island and is used by recreational and commercial boats. Also present south of the Spokane Street corridor, a 750-foot dock along Harbor Island is used for commercial moorage.

1.2.1 Shoreline Characteristics

The majority of the EW shoreline is composed of riprap, pier aprons, or sheet piling (Tanner 1991). The shoreline of the EW is approximately 16,000 linear feet (excluding Slip 27 and Slip 36). Sixty-one percent of the shoreline is covered by pier aprons with engineered riprap slopes, 30 percent of the shoreline is covered with armored riprap with no pier apron structure, and the remaining shoreline is predominately characterized as bulkhead (9 percent). The area in the vicinity of the Spokane Street Bridge includes a restoration bench on the east side of the channel and gravelly sand and mud beaches exposed beneath the riprap at low tide. The shoreline within Slip 27 and Slip 36 is predominately armored riprap slope with limited pier structures.

Shoreline armoring is usually present at the top of the intertidal zone, but a few areas of sloping mud and sandflats exist below the armoring (Battelle et al. 2001). However, due to the shoreline armoring, these intertidal flats are isolated from each other and this isolation degrades the habitat quality of these flats. In addition, overwater structures, which are common throughout the EW, shade shallow and intertidal habitats, alter microclimates, and inhibit growth of plant communities, thus further degrading nearshore habitats for native fauna (Battelle et al. 2001). A summary of potential intertidal habitat areas, as identified by previous surveys, is provided in Section 4 (see Map 4-1). Additional information on habitat quality is included in the ERA CSM in Section 4.

The standard concrete container aprons in the EW are approximately 100 feet wide from the outer edge to the sheetpile walls at +9 feet MLLW. Vertical bulkheads are usually present above +9 feet MLLW due to Washington Department of Fish and Wildlife (WDFW) requirements limiting their intertidal range. Below the bulkhead is an engineered riprap slope (1 horizontal to 3 or 4 vertical [1H:3 or 4V]) extending to approximately -40 to -50 feet MLLW. South of the Spokane Street corridor, the east and west shorelines are comprised of engineered riprap slopes. Shorelines under the bridges in the Spokane Street corridor are also comprised of engineered riprap slopes, but contain other concrete rubble and other debris.

1.2.2 Hydrology

The EW receives freshwater flows from the Green/Duwamish River watershed. The Howard Hanson Dam impounds the Green River at River Mile (RM) 64.5 (USACE 2005) and was constructed to provide flood control in the Lower Green River (USACE 2007). The Green River becomes the Duwamish River at the historical confluence of the Green and former Black Rivers. The Duwamish River estuary flows into Elliott Bay through the EW and the WW. A figure of the Green River watershed and the location of the Howard Hanson Dam is included in the EISR (Figure 2-1; Anchor and Windward 2008a).

The EW is also subject to tidal forcing from Elliott Bay. The average tidal range measured at the Seattle waterfront is 11.36 feet, with an extreme low of -5.04 feet MLLW and an extreme high of +14.48 feet MLLW.

The EW is influenced by the freshwater flows from the Duwamish River and the tidal conditions of Elliott Bay. The freshwater from the Duwamish River overrides the saline waters from Elliott Bay, producing a salt water wedge in the Duwamish River and a thin surface layer of slightly lower salinity water in Elliott Bay. The salt water wedge present in the Duwamish River is reported to travel as far as 10 miles upriver (McLaren and Ren 1994). Salinity measurements from the bottom of the channel at the Duwamish Yacht Club (RM 4.1) vary with the tide from near zero to approximately 29 parts per thousand, indicating the salt water wedge movement with the tide (King County 1999).

The outflow of freshwater from the Duwamish River along with the marine tidal waters entering from Elliott Bay produces the estuarine conditions in the EW, with the characteristic increase in salinity with water depth and net outflow to Elliott Bay. Freshwater also enters the EW from 39 storm drains and three CSOs. The freshwater flows in the EW are generally characterized by an outflow to Elliott Bay in the surface layer with marine inflow to the EW near the bottom. These conditions influence the hydrodynamics and sediment transport in the system.

Shallow groundwater also enters the EW from the east and west. Net flow into the EW generally occurs independent of tidal effects. However, groundwater discharge varies with individual tidal cycles. Along T-18 on the west side of the EW, groundwater flow enters the EW from beneath the steel sheetpile wall. Groundwater flow into the remainder of the EW is not limited by sheetpile to the same extent due to the presence of riprap or shallow sea walls. In those areas, less dense, fresh groundwater tends to migrate above the higher density saline water. The density difference between the freshwater aquifer system and the salt water of the EW tends to focus the outflow of the surficial aquifer into the intertidal area. A summary of existing groundwater conditions and studies is included in the EISR (Anchor and Windward 2008a).

A detailed summary of the current understanding of EW hydrodynamics is included in the Physical Processes CSM in Section 2. Other information is also included in the STEAM (Anchor and Battelle 2008) on the approach recommended to further understand hydrodynamic and sediment transport characteristics in the EW.

1.2.3 Sediment Characteristics

Surface sediments within the EW have been extensively reworked as a consequence of dredging and shoreline development. A summary of existing grain size, total solids, and total organic carbon (TOC) data is presented in the EISR (Anchor and Windward 2008a). In general, surface sediments tend to be dominated by silt and clay with smaller portions of sand, and very little gravel. More fines are present in sediments in the northern portion of the EW than in the vicinity of the Spokane Street corridor. Total solids content is generally between 40 and 60 percent. Surface sediments contain less than 2 percent TOC over nearly all of the EW, with small patches above 2 percent over the remainder, including Slip 27.

1.3 Proposed Study Area Boundaries

The proposed study area boundaries for the EW SRI/FS were described in the EISR (Anchor and Windward 2008a) and are shown on Map 1-1. The proposed southern study area boundary of the EW is identical to the northern study area boundary of the LDW Superfund Site. The proposed northern boundary of the EW that was used in the 2003 Phase 1 Remedial Action Engineering Evaluation/Cost Analysis (EE/CA; Windward 2003) is shown on Map 1-1. The current proposed northern EW OU study boundary is also shown on Map 1-1.

The proposed northern EW OU study boundary has been revised based primarily on bathymetric changes in areas north of the mouth of the EW. As shown on Figure 1-4, the boundary has been moved north to include areas up to the point at which depths steeply slope beyond -60 feet MLLW. The proposed northern EW OU study boundary extends along the western pierhead line to the north until water depths reach -60 feet MLLW. The boundary follows the approximate upper edge of this naturally occurring slope at about -60 feet MLLW, then turns to perpendicularly intersect the bulkhead along Terminal 46 (T-46).

The location of the proposed northern EW OU study boundary that perpendicularly intersects the bulkhead along T-46 is also based on previous dredging events conducted along T-46. Sediment at the northern end of the EW was dredged in 2000 as part of Stage 1 dredging to a depth of -45 feet MLLW (see EISR Figure 1-4; Anchor and Windward 2008a). The proposed northern EW OU study boundary bisects the northernmost Stage 1 Dredged Material Management Unit (DMMU), which was determined to be suitable for open-water disposal by the Dredged Material Management Program (DMMP) prior to dredging in 2000.

Additional dredging, to a depth of -51 feet MLLW, was conducted along T-46 in the vicinity of the northern proposed EW OU study boundary in 2005 (see EISR Figure 1-4; Anchor and Windward 2008a). The proposed northern EW OU study boundary bisects the DMMU dredged in 2005, which was also determined to be suitable for open-water disposal by the DMMP. Current sediment elevations are the deepest compared to historical dredging activities (see EISR Section 1.4.4; Anchor and Windward 2008a). Following dredging in this area as part of the Stage 1 and T-46 projects, the newly exposed sediment surface was established on either side of the northern proposed EW OU study boundary that had never been exposed by dredging. The east and west boundaries of the EW OU are defined by mean higher high water (MHHW), as shown in Map 1-2. These proposed EW OU study boundaries will be utilized during the SRI/FS. The EW Record of Decision (ROD) will ultimately establish the cleanup boundary for the site.

1.4 Report Organization

The CSM and Data Gaps Analysis Report provides information on the Physical Processes CSM, HHRA CSM, and ERA CSM and identifies associated data needs for the SRI and FS. This section provides a summary of the information contained in each section of the report.

Section 2 presents the current understanding of the Physical Processes CSM, including key processes that affect the hydrodynamics and sediment transport in the EW. These physical processes are summarized in Section 2 based on a review of the existing data that was presented in the EISR (Anchor and Windward 2008a).

Section 3 provides the HHRA CSM, which presents potentially exposed populations, general exposure scenarios, and related exposure pathways and exposure routes for exposed populations. The detailed exposure scenarios to be evaluated in the HHRA will be presented in the HHRA Technical Memorandum.

Section 4 provides the ERA CSM, which presents ecological ROCs, exposure pathways, and exposure routes. The rationale for the selected ROCs, as well as assessment and measurement endpoints, are also presented. The detailed exposure scenarios for each ROC will be presented in the ERA Technical Memorandum.

Section 5 presents a summary of the data gaps identified for the SRI and FS, including those associated with refining any of the CSMs and those associated with defining the nature and extent of contamination in the EW. A separate data gaps assessment is conducted in the STEAM (Anchor and Battelle 2008) for data needs to perform the STE. Section 5 also presents data needs for the purposes of the FS based on the understanding of available existing data.

2 PHYSICAL PROCESSES CONCEPTUAL SITE MODEL

The Physical Processes CSM focuses on the important processes that affect hydrodynamics and sediment transport in the EW. This initial CSM is based on the current understanding of the EW system derived from the information in the EISR (Anchor and Windward 2008a) and also reviewed in the STEAM (Anchor and Battelle 2008). Two maps have been created to depict the Physical Processes CSM in the EW. Map 2-2 presents the hydrodynamic processes and Map 2-3 presents the accompanying sediment transport processes, as driven by the hydrodynamics. The processes depicted on these maps are discussed in further detail in this section.

Existing information reviewed to develop the Physical Processes CSM included the tidal elevations from Elliott Bay, flow data from the Green River, velocity profile measurements south of the Spokane Street Corridor (e.g., in the Junction Reach) and in Elliott Bay, and sedimentation data from the EW. Principles consistent with typical estuarine systems like the EW were generally used when EW-specific information was not available. The elements of the Physical Processes CSM, including Maps 2-2 and 2-3, will be updated as additional information is collected to fill identified data gaps. A separate data gaps assessment is conducted in the STEAM (Anchor and Battelle 2008) for data needs to perform the STE. These data and the results of the modeling effort will be used to update the Physical Processes CSM.

2.1 Current Understanding of Sediment Transport in the East Waterway

The EW is physically divided into three reaches (Maps 2-1, 2-2, and 2-3). The first reach encompasses the main body of the EW between the Spokane Street corridor and the EW mouth that opens into Elliott Bay (Main Body Reach). The Main Body Reach is approximately 7,400 feet long. The second reach is under the bridges in the Spokane Street corridor (Sill Reach), which has rarely, if ever, been dredged. The Sill Reach is approximately 350 feet long. The third reach is south of the Spokane Street corridor and north of the junction with the WW and LDW (Junction Reach). The Junction Reach is approximately 500 feet long. The hydrodynamics of the EW are governed largely by flows at the northern and southern boundaries; that is, at the open boundary with Elliott Bay to the north and at the junction with the WW and LDW to the south. The geometry of the EW at the Sill is also important for EW hydrodynamics, because of the reduced cross-sectional area in the Sill and Junction Reaches. The Sill Reach serves to limit flows typical of estuarine systems, including underlying salt water flows in the lower part of the water column below the surficial freshwater layers. The Sill will restrict all flows between the Junction and Main Body Reaches because its width and cross-sectional area are smaller than in the adjacent two reaches. The effect will occur when LDW flows are high, producing flows to the north through the Sill. The effect will also occur when LDW flows are low during tidal flooding, producing flows to the south. Both of these conditions can be seen in Figure 1 and are discussed further in Section 2.1.1.

Lateral loads from storm drains and CSOs contribute freshwater and solids into each reach of the EW; however, the CSOs are located only in the Main Body Reach of the EW. Deposition of solids from the lateral loads depends on the characteristics of each lateral load (e.g., flow and solids characteristics) and tidal and EW flow conditions at the time of discharge. It is also possible that impacts from some lateral loads are undetectable.

The following sections discuss hydrodynamic and sediment transport processes in the EW due to natural and anthropogenic processes.

2.1.1 Hydrodynamics

The tidally-induced fluctuations of the water surface in Elliott Bay at the northern boundary of the EW result in a tidally-influenced system in all reaches of the EW. At the southern boundary of the EW, inflows from the LDW (and freshwater flow originating from the Green River) enter the EW. The tidal influence extends beyond the southern boundary and strongly influences the inflows from the LDW. The influence of the tide on inflows to the EW from the LDW depends on the flows in the Green River. Velocity data from the station located at the southern boundary of the EW (see STEAM for exact location; Anchor and Battelle 2008), as presented in Figure 1, were used as the basis for conceptualizing the hydrodynamic processes. Estuarine hydrodynamic processes were used to expand upon these data to describe the conceptual understanding of hydrodynamics in the system. This includes the presence of lighter freshwater flows moving above denser salt water layers. The relative proportion of LDW flow that enters the EW is not known; however, based on velocity profile measurements in the EW and WW presented in the STEAM (Anchor and Battelle 2008), it can be surmised that the EW receives less than one-third of the flow. This assumption will be confirmed during the STE.

The freshwater flow from lateral loads to the EW will respond to the direction of flow into which the loads discharge. CSO and storm drain discharges may occur at any time during a tidal cycle. The likelihood of discharges is higher during periods of high flow, when storm events are more frequent.

The ranges of hydrodynamic conditions that are presented in Figure 1 at the Junction Reach include high and low freshwater flows in the Green River and LDW and ebbing and flooding tides from Elliott Bay. These hydrodynamic conditions influence the currents and salinity in the Junction, Sill, and Main Body Reaches of the EW.

The general velocity pattern during low-flow periods is northward-directed flow during tidal ebbing, with the higher velocities in the water column at the surface (Figure 1). When the tide reverses to flooding, the velocity is directed southward throughout much of the water column with the higher velocities near the bottom of the water column, though smaller northward-directed flows may continue at the surface (Figure 1).

During high-flow periods, the surface layer freshwater inflows dominate the general velocity pattern seen in Figure 1 at the Junction Reach so that during most of the tidal period the net velocity is directed northward. During tidal flooding, there is a slight reversal of flow at the bottom, but this is much smaller in magnitude than during low-flow conditions.

These velocity patterns are expected to occur in the Junction and Sill Reaches, though the shallower depths in the Sill Reach are expected to increase the velocity magnitudes. Within the Main Body Reach, the larger cross-sectional area is expected to reduce any velocity magnitudes in comparison to the Sill and Junction Reaches with their narrower cross sections. These velocities are expected to continue to decrease with the increasing cross-sectional area that results from deeper water depths in the northern portion of the Main Body Reach. During low-flow periods, tidal forcing is expected to dominate the velocity profile of the Main Body Reach, so that velocities are generally directed southward during tidal flood and northward during tidal ebb. During high-flow periods, the inflow of freshwater from the LDW, via the Junction and Sill Reaches, will interact in the Main Body Reach with marine waters from Elliott Bay. It is likely during the highest flows that the surface layers will largely be freshwater, or of low salinity, so that the surface velocities are directed northward during both tidal flood and tidal ebb. During this same period, the velocities in the bottom layers will likely vary direction with the tide. It should be noted that the Main Body Reach has a net velocity[1] near the bottom that is directed to the south. The net flow at the bottom is likely an indicator of the net circulation pattern in the EW produced by the freshwater from the Sill Reach that flows along the surface to the north.

Lateral load discharges of freshwater from CSOs and storm drains will likely be near-surface plumes that move in the direction of the surface layer flows. During periods of high river flow, the plume would be directed northward during both ebb and flood tides. During ebb tide (regardless of river flow condition), a plume will be directed northward, while during flood tide conditions, a plume may be directed northward or southward (depending on river flow conditions). If the lateral load discharges are small, they will likely stay close to the shore.

[1] Net velocity in an estuarine system is the residual of the ebb and flood velocity and is calculated over a tidal averaging period.

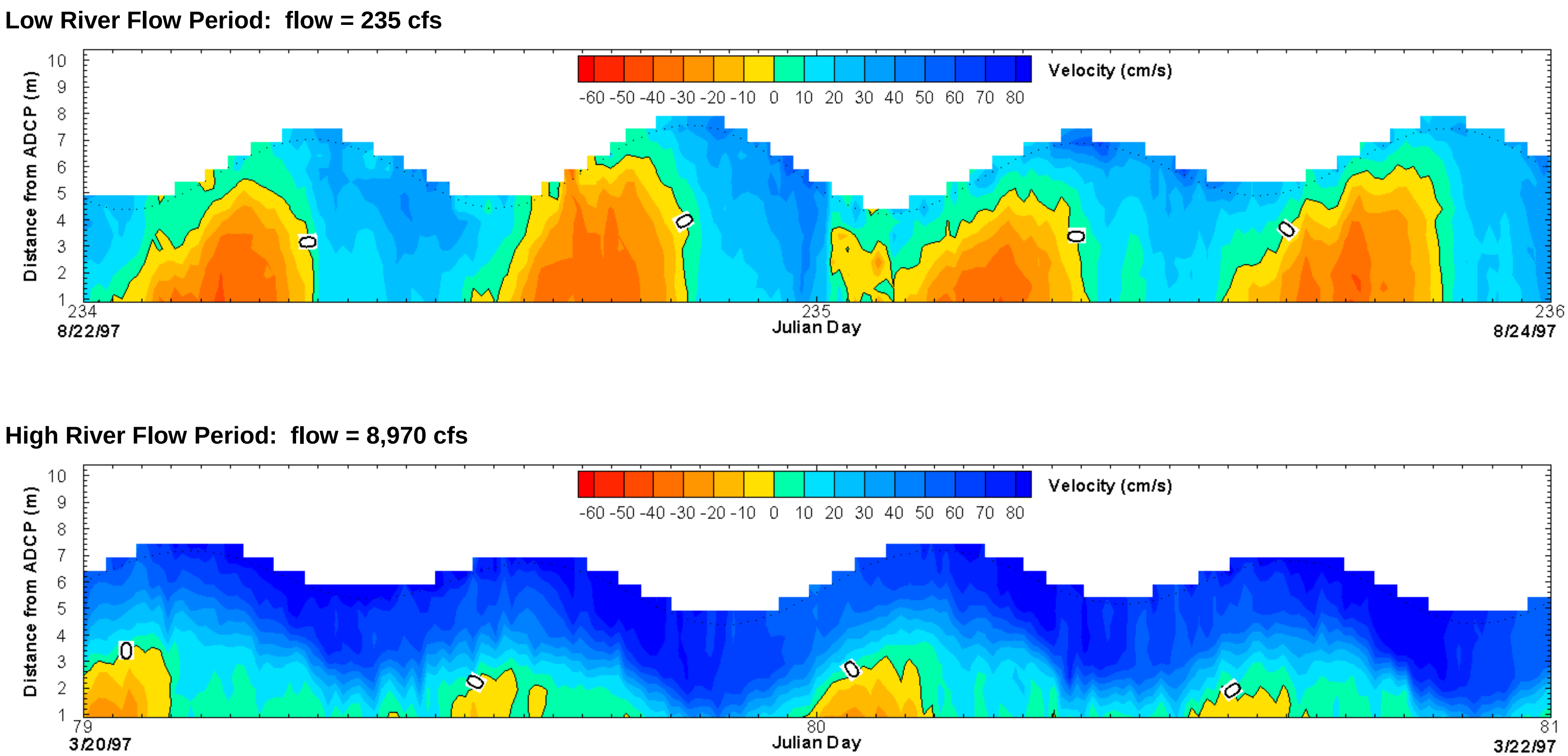

Figure 1 ADP Velocity Profiles During High Flow and Low Flow Conditions at the Southern Boundary of the EW (EWW Station, described in the STEAM [Anchor and Battelle 2008])

2.1.2 Sediment Transport in the Water Column

Flow enters the EW from the LDW with suspended and bed-load sediment. The sediment in the LDW is largely derived from the Green River (QEA 2007), with a small fraction input from lateral sources. Consequently, it is thought that the bulk of the sediment reaching the EW is also largely derived from Green River sediments. The sediment concentrations carried by the Green River vary with the flow, and sediment rating curves for both suspended and bed load sediment have been used to estimate Green River sediment concentrations and loads (Harper-Owes 1983; Embry and Frans 2003; QEA 2007). The suspended sediment composition (particle size distribution) in the Green River has also been estimated in the draft Sediment Transport Modeling Report for the Lower Duwamish Waterway (QEA 2007).

From the draft sediment transport model constructed for the LDW, an estimated 50 percent of the sediment load from the Green River reached the junction of the EW and WW over a 30-year period (QEA 2007). The draft report also estimated that during a 100-year flood event, up to 97 percent of the Green River sediment entering the LDW upstream reached the junction with the EW and WW (QEA 2007).

For the 30-year period, the model-estimated sediment load transported through the LDW to the junction with the EW and WW was 3,213,700 metric tons, with 17,100 metric tons of that being from lateral sources. This information indicates that more than 99 percent of the sediment reaching the junction with the EW and WW was from the Green River. The draft study did not estimate the sediment load entering the EW or the WW; however, the expectation is that it would generally follow the distribution of flow (expected to be approximately one-third of the total), with the majority of the sediment load to the EW delivered during high river flow periods. However, given less load input from the Green River to the EW, the relative scale of each load input is more uncertain.

Solids loads from CSOs and storm drains discharge into the EW. From the LDW analysis (QEA 2007), the estimated 30-year sediment load from the Green River at the downstream end of the LDW was approximately 3,100,000 metric tons, while the lateral source load contribution was less than 1 percent of that. This trend is also expected in the EW. In general, the plume from a lateral load to the EW will respond to the direction of flow into which it discharges. It is possible that a lateral load that has discharged intermittently over a period of years will show a distribution in the sediment bed reflecting the net flow at that location.

The primary sediment processes that may be relevant to the EW include the following:

- Advective transport (including turbulence) through the water column
- Sediment settling through the water column
- Flocculation[2] and floc breakup within the water column
- Sedimentation and resuspension of the sediment bed, including compaction and consolidation with sediment depth
- Bioturbation within the sediment bed (sediment mixing from benthic infauna), influencing the bed shear strength
- Bed armoring of the sediment surface, influencing the bed shear strength

Bed load[3] from the LDW into the EW is not expected to be significant because of the adverse bed gradient between the LDW and the Junction Reach of the EW, though bathymetry data are not available to verify this assessment. There is a potential for bed load to be significant in the Sill Reach, where the velocities near the bed could be large enough to move coarse-grained sediment, though any coarse-grained bed-load sediment would have to originate from a local lateral source discharging to the Sill. There is also the potential for bed load to be deposited during storm events from storm drains flowing into the Main Body Reach of the EW. Bed load from storm drains is expected to settle out rapidly over a relatively short distance from the mouth of the outfall because the bottom velocities in the Main Body Reach are not likely to sustain significant bed load transport. Bed load from Elliott Bay into the EW is not expected because velocities are not sufficient. Consequently, bed load is not considered as a significant component of sediment dynamics in the EW.

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[2] Flocculation is the process of aggregation of smaller-sized particles into a cohesive particle with limited shear strength.

[3] As defined by USACE (2002), bed load is "sediment transport that takes place as individual grains rolling, sliding, and/or jumping (saltating) along the bed."

The EW is expected to receive the majority of the total suspended solids (TSS) load[4] from the LDW during high-flow events of the Green River. It is at high flows that TSS moves through the reduced cross-sectional areas of the Junction and Sill Reaches to the Main Body Reach. During these high-flow events, the velocity is strongest in the northward direction during ebb tides, so that the TSS load will also be carried into the Sill and Main Body Reaches of the EW. Deposition from the water column is expected to be small in the Junction and Sill Reaches due to the relatively high velocities that occur during the high-flow events.

Within the Main Body Reach, a significant fraction of the TSS in the bottom layers is expected to settle to the sediment bed. The gross sedimentation rate[5] is expected to be higher at the south end of the Main Body Reach due to the reduced velocities from an increased cross-sectional area. Although the cross-sectional area continues to increase to the north because of deeper water depths, the cross-sectional area increase from increased width in the southern portion causes velocities to have a higher rate of reduction and associated sedimentation. High concentrations of TSS being transported into the Main Body Reach from the LDW over the Sill during periods of high river flows results in higher deposition rates (settling is a first-order process and depends on the concentration of TSS). As the water from the LDW moves further to the north, the TSS concentration drops and so does the deposition rate. In addition, gross sedimentation could be higher in the southern portion of the Main Body Reach because TSS that has settled into the lower water column will have a net flux to the south due to the net southerly velocities near the bottom. Suspended sediments may also enter the northern portion of the EW from Elliott Bay during incoming tides, however, this load is expected to be insignificant.

[4] Load is defined as the mass added per unit time. This could have the units metric tons/year or kg/s, for example. Load is calculated as the flow times the concentration (m^3/s x mg/L x 1000 L/m^3, for example).

[5] Gross sedimentation rate is the rate of deposition from the water column due to the settling of sediment particles.

The net sedimentation[6] would be expected to follow the same trend as for the gross sedimentation. However, net sedimentation rates estimated from sediment cores collected in the Main Body Reach during the Harbor Island RI (Weston 1993) showed lower net sedimentation rates in the south end of the Main Body Reach than the north end. This may have resulted from the lower cross-sectional area in the south end of the Main Body Reach, which could have resulted in higher water velocities and greater associated resuspension, thus lowering net sedimentation rates. In addition, anthropogenic disturbance (e.g., propeller-induced currents [propwash]) can cause atypical trends to occur, which, in general, make it difficult to predict sedimentation patterns.

The TSS in the lateral-loads discharge plumes will immediately begin to settle through the water column in the Main Body Reach, while in the Junction and Sill Reaches, it is expected that the level of turbulence will be higher, thus preventing significant sediment settling of all but the heavier fraction. As the plume mixes with the waters in the Main Body Reach, the TSS pathways through the water column will be the same as that for TSS entering from the LDW. This includes transport along the Main Body Reach, settling through the surface layers and being refluxed back southward during flood tides, and deposition on the sediment bed. If the transport velocities are low, the contribution of flocculation to settling flux of TSS could be significant. Flocculation of TSS in the freshwater plumes is possible as it mixes with the higher salinity water from Elliott Bay.

2.1.3 Sediment Bed and Sediment Transport

The sediment bed thickness increases as a consequence of the net build-up of TSS settling from the water column. The rate of sedimentation depends on the balance between the rate of deposition of TSS from the water column and the rate of resuspension of bed sediment back into the water column. The resuspension rate is influenced by the velocity field above the sediment bed and the shear stress it applies to the sediment bed.

[6] Net sedimentation rate is the accumulation rate of sediment in the bed following deposition of sediment from the water column and erosion of sediment from the bed.

In the sediment bed, sediments derived from lateral sources are deposited along with the sediments from upriver sources in the LDW and Green River. However, the sediment bed composition will largely be derived from the upriver sources. The footprint of the lateral sources will be influenced by the net direction of flow. However, the presence of stratified flow conditions will also influence the deposition footprint as TSS settles through the water column and is transported by the different layers either northward or southward.

As sediment builds up on the bed, it is compressed by the overlying sediment and water is squeezed from the interstitial voids between the sediment particles. The compression and consolidation of the sediment bed is expected to result in increasing shear strength with depth. However, the bed shear strength can also be influenced by the rate of sedimentation, bioturbation, and anthropogenic disturbances.

Sedimentation in the Junction and Sill Reaches is expected to be low due to the relatively high velocities, while in the Main Body Reach, sedimentation is expected to be higher than in the Junction and Sill Reaches. These differences in sedimentation are expected due to the large differences in velocity between the Main Body Reach and the Sill and Junction Reaches.

In the Junction Reach, sedimentation is expected to occur primarily during periods of slack tide. The velocities near the bed during the times of maximum ebb and flood tides are likely large enough to resuspend at least the finer sediments (silts and clays), which are the primary sediment types expected in this reach.

In the Sill Reach, no significant net sedimentation is expected, except possibly of the coarsest material. This would lead to armoring of the sediment bed, such that fine sediments are removed and only the coarse materials remain.

In the Main Body Reach, the gross sedimentation rate is expected to be highest at the southern end of the Main Body Reach because of the high sediment concentrations in LDW inflow. Net sedimentation is also expected to be high at the south end of the Main Body Reach, unless there is some other disturbance of the deposited sediments (e.g., LDW inflows or anthropogenic disturbances). In addition, anthropogenic disturbance (e.g., propwash) can cause atypical trends to occur that may make it difficult to predict sedimentation patterns.

2.2 Vessel-induced Hydrodynamic Effects on Sediment Resuspension

Hydrodynamic forces generated by deep-draft ships, tug boats, and other watercraft traveling through and/or operating in the EW may be important factors causing resuspension and influencing deposition of sediment in the EW. These vessel-induced hydrodynamic forces are typically associated with propwash, vessel wakes, and hydrodynamic pressure fields ("drawdown," or Bernoulli effects). These forces impact sediment resuspension and deposition differently depending on the types of vessels, vessel operational conditions, geometry of the waterway, bottom sediments, and shoreline structures. It is likely that propwash may be a major factor controlling resuspension of bottom sediment in the EW. However, the magnitude and extent of vessel-generated effects in the EW are not known.

Sediment resuspension may occur when a propeller generates currents in the near-bottom layer that exceed threshold velocities of initiation of the motion for the sediment grains. These steady propeller-generated velocities typically may occur only during docking and undocking operations. Although propwash is expected to be the dominant vessel effect on sediment resuspension, a limited analysis of vessel wake and hydrodynamic pressure fields is required to determine the relative importance these forces have on sediment resuspension. It is not expected that speeds of vessels in the EW are sufficient to cause sediment resuspension due to the effects of hydrodynamic pressure fields. In addition, shoreline armoring along the EW is expected to decrease the potential that vessel wakes induce sediment movement.

3 HUMAN HEALTH RISK ASSESSMENT CONCEPTUAL SITE MODEL

A CSM is a graphical representation of exposure media, transport mechanisms, exposure pathways, exposure routes, and potentially exposed populations. It provides the basis for developing exposure scenarios to be evaluated in the exposure assessment component of the HHRA. As specified in the Workplan (Anchor and Windward 2007), the details of specific exposure scenarios will be presented in the HHRA Technical Memorandum.

The HHRA CSM for the EW is presented in Figure 2. For the purposes of this HHRA, sediments are the assumed source of chemicals for all exposures at the site, regardless of the actual exposure medium (e.g., tissue, sediment, or surface water). Information on potential chemical contaminant sources to sediments, such as direct discharges (CSOs and storm drains), groundwater, and atmospheric deposition, will be discussed in the Initial Source Screening and Data Gaps Memorandum. The exposure assessment focuses only on scenarios that include a direct (i.e., ingestion or dermal contact) or indirect (i.e., consumption of fish or shellfish) pathway of exposure to chemicals in sediments.

For each pathway and media combination in the EW CSM, a determination has been made as to whether the pathway is complete or incomplete. A complete exposure pathway includes the following components: an exposure medium, an exposure point, a potentially exposed population, and an exposure route. Pathways that do not include all four components are incomplete. Incomplete pathways cannot be evaluated quantitatively in the risk assessment because both exposure (i.e., a complete pathway) and toxicity are required to quantify risk. An example of an incomplete pathway for the EW is surface water as a source of drinking water for people. The saline conditions of the EW prevent this from being a viable and complete pathway.

Surface water exposure pathways are indirectly linked to sediment via flux from sediment to the water (Figure 2). The risks from direct exposure to surface water were previously evaluated quantitatively by King County (1999) and found to be lower than risks associated with both the sediment contact and seafood consumption pathways. The direct water contact exposure pathway will be evaluated by comparing the current surface water Exposure Point Concentrations (EPCs) to the EPCs used in the King County (1999) risk assessment. If the current EPCs are found to exceed the previously measured levels (King County 1999) to such a degree that different risk conclusions would be reached, then new risk estimates will be calculated for the EW HHRA. Details regarding how the direct contact surface water pathway will be addressed are presented in Section 3.1.1.

For simplicity, the inhalation pathway is not shown in Figure 2 because of the combination of low concentrations of volatile organic compounds (VOCs) and limited exposure area. Existing sediment chemistry data for VOCs indicate that these chemicals were rarely detected in EW sediments (Anchor and Windward 2008a). Other organic chemicals, such as polychlorinated biphenyls (PCBs), are not expected to volatilize significantly from sediment. HHRAs conducted for the Hudson River in New York, where PCB concentrations are much higher than they are in the EW, concluded that the calculated cancer risk from the inhalation of volatilized PCBs was insignificant (TAMS and Gradient 2000).

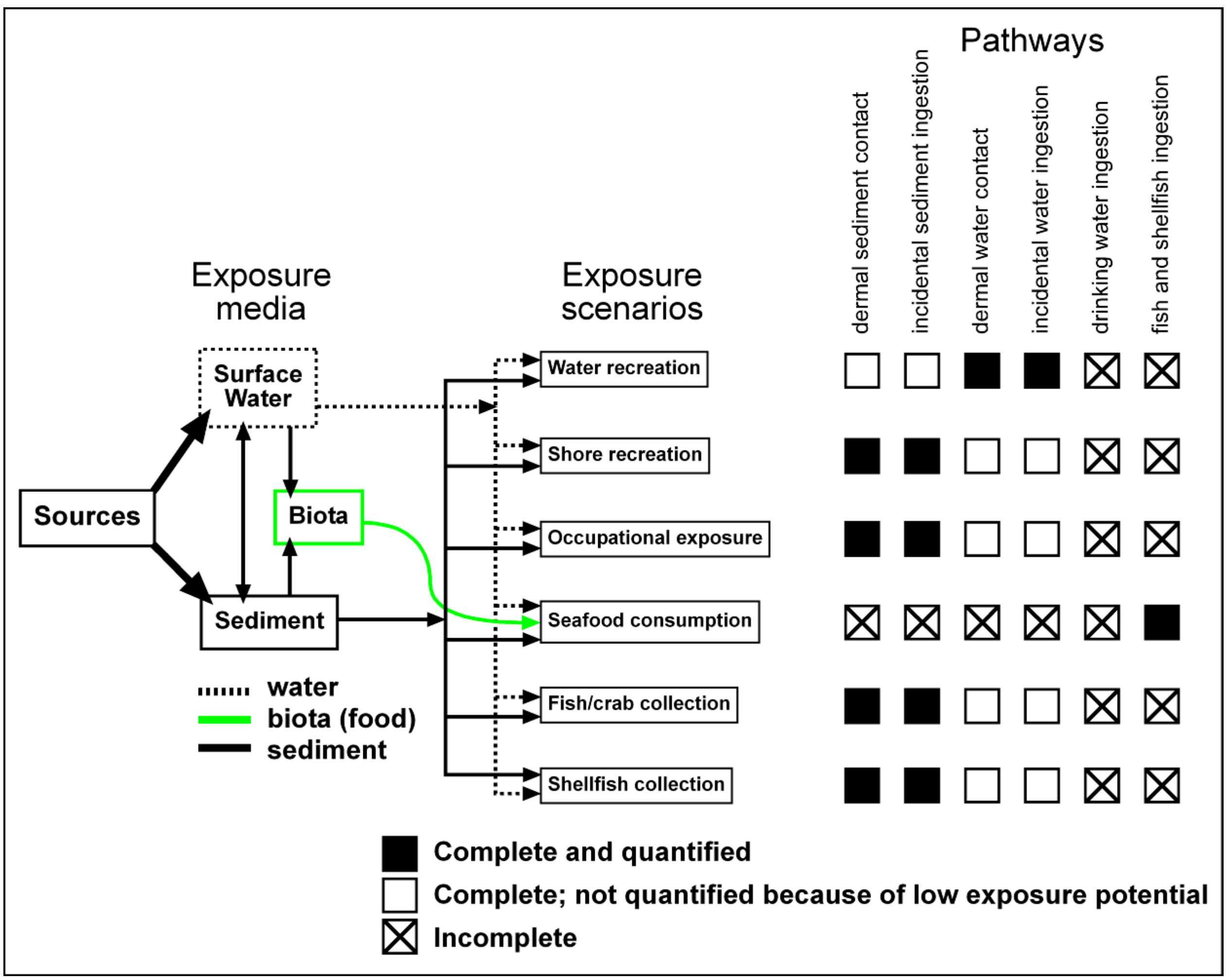


Figure 2 Conceptual Site Model for the Human Health Risk Assessment

The risk associated with all complete exposure pathways that have the greatest exposure potential will be evaluated in the HHRA. Some pathways identified as complete but with low exposure and risk potential relative to other evaluated pathways may be discussed in the HHRA for risk communication purposes (for example, exposure to water during shore recreation). Qualitative assessment of pathways with low exposure potential is appropriate because such pathways have minimal potential for causing excess risk or adverse health effects. For example, if there are no excess risks or adverse health effects as a result of exposure during water recreation (a high water-contact exposure scenario), then there would be no excess risk or adverse health effects as a result of water contact occurring during shore recreation (a largely land-based activity with very limited water contact, which might occur during wading or rinsing off muddy hands).

The identification of complete pathways is used to inform the data gaps analysis. Figure 2 presents a characterization of the completeness of each pathway or potential pathway in the HHRA CSM. Some pathways will require further evaluation (after collection of data to fill data gaps) before they can be classified as complete and quantified or complete but not quantified because of low exposure potential.

Sediment exposure is expected to occur during general beach play and clamming activities, as documented by Shoaf et al. (2005). Existing data are insufficient to quantify the potential for exposure to sediment during clamming activities, thus, further site assessment will be required. The proposed site assessments (including a clam habitat assessment and clam survey) are discussed in the data gaps analysis (Section 5.2). The site assessment will reduce the uncertainty associated with both clam consumption and direct sediment contact during clamming activities. The clam survey results will be used identify clam habitat areas for assessment of exposure due to dermal contact resulting from clamming. The survey will also provide some current site-specific information that will help inform the development of input parameters in the HHRA, which will be developed in future documents in consultation with EPA and the Tribes. The following items will be determined in consultation with the Tribes and EPA:

- The extent and quality of current clam habitat (based on clam habitat survey)
- The potential for future clam habitat in the EW

- The effect of intertidal clam habitat areas on the direct sediment contact clamming scenario
- The effect of presence or absence of clams in the EW on the fish and shellfish consumption scenarios

The exposure pathways and scenarios presented for the EW are based on the scenarios used in the LDW HHRA (Windward 2007), the specific geography and ecology of the EW, and the human activities known or expected to occur there under current conditions or reasonable future use scenarios.

Important distinctions exist between the EW and LDW in terms of physical characteristics and human use that dictate differences in the CSMs for the two sites. As described in Section 1.1, the EW is highly channelized and supports a high level of industrial shipping activity. The intertidal areas of the EW that are available to support harvesting of clams, other shellfish, and human recreational activities are limited (Maps 3-1a and b). Further, the extent of subtidal clam habitat in the EW, and its potential to support subtidal shellfish species, is unknown. The EW also has fewer public access areas than the LDW (in the form of parks, public right-of-way areas, and access from private properties). The vast majority of the property adjacent to the EW is owned by the Port of Seattle (Port), and public access is prohibited as part of standard security measures (Anchor and Windward 2008a). In addition, in contrast to the LDW, there are no residences adjacent to or near the EW (Map 3-2 shows the extent of the industrial facilities bordering the waterway, as well as public access points). Consequently, a smaller range of human activities are considered in the evaluation of exposure pathways and scenarios in the EW CSM as compared to the LDW CSM.

The Suquamish and Muckleshoot Tribes fish in the EW, which is part of their U&A fishing areas. As such, the tribes can use the EW for commercial, ceremonial, or subsistence fishing purposes. Consequently, the availability of public access points is not an issue for tribes that have rights to harvest seafood from the EW. Tribal use of the EW, in accordance with their U&A rights, is reflected in the exposure pathways evaluated in the CSM.

Four general exposure scenarios are presented in the HHRA CSM (Figure 2). Each scenario is discussed in Section 3.1. Each exposure scenario involves at least one potential exposure pathway to contaminated sediments (e.g., dermal contact with sediments or incidental ingestion of sediments) and a potential exposure route through which contaminants can enter the body of an exposed individual (e.g., dermal absorption of contaminants through exposed skin surfaces or gastrointestinal absorption of ingested contaminants), although the importance of some pathway and route combinations) may be minor (i.e., low exposure potential) or the pathways may be incomplete. The scenarios presented are not mutually exclusive, and combinations of different pathways may be considered in the HHRA.

3.1 General Exposure Scenarios

Each of the general exposure scenarios shown in Figure 2 is discussed qualitatively in the subsections that follow. Several types of exposure scenarios may be used in the HHRA to describe different exposure intensities (e.g., frequency and duration) of activities or rate of seafood consumption. The specific quantitative details of these scenarios will be described in the HHRA Technical Memorandum.

3.1.1 Water Recreation

Water recreation can include activities such as swimming, self-contained underwater breathing apparatus (SCUBA) diving, and pleasure boating, where exposure to surface water constitutes the major exposure pathway. To that end, this general scenario is focused on surface water pathway exposures related to water recreation. Although direct contact with sediments might occur during some water recreational activities, the frequency and magnitude of this contact during such activities would be much lower than those associated with shore recreation or other exposure scenarios, so these pathways will not be quantified in the HHRA because of low exposure potential.

The extent to which the EW is used for swimming is unknown. King County, in their issue paper on human site use in Elliott Bay and the Duwamish River, including the EW and the WW (King County 1999), indicated that swimming rarely occurred in those water bodies. The EW is accessible to the general public via boat, but fewer recreational opportunities exist in the EW compared to Elliott Bay and the LDW because the EW has limited public access and a greater concentration of commercial shipping activity (Map 3-2). Future remedial and restoration actions that may be conducted within the EW are unlikely to change the frequency of these water-specific recreational activities.

However, the Port does plan to make improvements to the shoreline near the Spokane Street Bridge. These changes would most likely affect shoreline use rather than water use, and are discussed further in Section 3.1.2. The amount of commercial shipping traffic is also unlikely to change within the foreseeable future, inasmuch as the Port has stated in its shoreline plan (POS 2007) that it aims to "preserve, maintain, enhance, and expand maritime industrial and commercial uses throughout Seattle harbor and its waterways." Specific, long-term goals for terminals along the EW (T-18, T-25, and T-30) include the preservation of existing uses and the expansion of both cargo and passenger terminal capacities. Dock reconstruction, upgrade, and expansion are planned at all three terminals to attract additional industrial maritime traffic (POS 2007).

A water recreation scenario may be developed for the EW, but it is dependent on results of proposed sampling. A risk assessment conducted by King County (1999) characterized the risks associated with swimming in the Duwamish River (including the EW), and Elliott Bay, and found that the risks associated with surface water contact are very low.[7] In addition, the report found that risks associated with the water component of the swimming scenario were small compared to the risks associated with the sediment component (e.g., risks from water exposure made up 25 percent or less of the total risk). Rather than repeat work that has previously been completed, a variety of analyses will be conducted to determine if the results of the King County risk assessment are consistent with current conditions in the EW. The EPCs used in the King County risk assessment will be compared to EPCs derived from newly collected surface water samples (See Section 5.1.3). If the current surface water EPCs are equal to or below those used in the King County risk assessment, then the results of the County's assessment will be considered protective of current uses and incorporated into the EW HHRA. However, if the EPCs in the newly collected samples are higher than previously

[7] The King County risk assessment (1999) included both water and sediment exposure and estimated health risks associated with swimming in the LDW, EW, WW, and Elliott Bay. The report concluded that the risks from chemical exposure during swimming were generally within the range of risks considered to be acceptable by EPA. Excess cancer risks associated with swimming events in the LDW (exposure duration 2.6 hours/day and event frequency 24 days/year) were highest for arsenic and PCBs, ranging from 2×10^{-7} for adults (exposed to PCBs) to 4×10^{-6} for young children (exposed to arsenic). All non-cancer hazard quotients were less than 1.

measured EPCs and result in different risk conclusions, then risk associated with surface water exposure in the EW will be quantified using current surface water data. For example, if application of current EPCs increases the surface water exposure risk estimates such that one of EPA's defined risk thresholds are exceeded (e.g., a shift in excess cancer risk from below 1×10^{-6} to greater than 1×10^{-6}, or from a non-cancer Hazard Quotient of less than 1 to greater than 1, new risk estimates will be presented in the EW HHRA. If risk conclusions do not change, then the results of the King County (1999) risk assessment will be summarized and presented in the EW HHRA.

The magnitude of sediment contact likely to occur during water recreation activities (including swimming and the launching and retrieval of small boats) is likely to be lower than that described in the exposures that are covered under other sediment direct-contact risk scenarios included in this risk assessment. Thus, any risks related to sediment-specific exposure during water recreation scenarios may be considered through review of the other direct-contact scenarios (e.g., netfishing and/or shore recreation).

3.1.2 Shore Recreation

Shore recreation can include activities such as park visits, playing in the mud, or walking along the shoreline, where exposure to sediments constitutes the major exposure pathway. Exposure to sediment by volunteers performing habitat restoration or other stewardship activities may also occur. Thus, shore recreation scenarios focus on sediment pathway exposures (dermal contact with and incidental ingestion of intertidal sediment) related to potential shore recreation activities.

Sediment exposure pathways associated with other activities such as collection of clams from the intertidal beach areas, and incidental sediment contact during netfishing are discussed in Sections 3.1.5 and 3.1.6, respectively. Although direct contact with surface water might occur during shore recreation, the frequency and magnitude of water contact would be much lower than during water recreation. An exposure scenario specifically evaluating the combined exposure to both surface water and sediment will not be evaluated in the EW HHRA. However, the total risks associated with such exposures may be quantified by summing the risks from EW direct contact sediment exposure scenarios with either the water exposure evaluated in the King County (1999) swimming scenario, or from the EW water contact scenario, in the event that one is required based on the EPCs derived for current water samples collected as part of the SRI.

There are currently only two areas along the EW that have public access from the shore where people could potentially contact sediment: on the southeast bank near the Spokane Street Bridge, and at Jack Perry Memorial Park to the northeast (Map 3-2). The potential for public access to sediment under the Spokane Street Bridge on both the east and west sides of the EW will be reviewed with EPA and stakeholders. The intertidal sediments at these areas are generally exposed only at low tides; cobble covers the upper portions of the banks. There are other areas of the EW where people may contact intertidal sediment, but these areas are only accessible by boat. The general public[8] is not allowed in some areas (e.g., the outcrop at the mouth of Slip 27; Map 3-2) due to security measures at the container shipping terminals. Several shore recreation exposure scenarios were developed for the LDW, but most of these are not appropriate for the EW because of differences in waterway characteristics and human access.

In the LDW HHRA (Windward 2007), a beach play scenario was developed to assess risks to young children (i.e., up to 6 years of age) from playing in intertidal sediments at LDW beaches that have public access from the shore. Assumptions in the LDW HHRA included unlimited public access from the shore, including from residential areas directly adjacent to the shore. The exposure parameters for this scenario were based on a survey of recreational lake use in King County (Parametrix 2003). However, public access areas on the EW, unlike the LDW, are not adjacent to or even within a half-mile of residential areas, and there are no residential areas directly adjacent to the EW. The public access areas within the boundaries of the EW are also much smaller than many of the parks on the LDW, and the degree and duration of sediment exposure are more limited in the EW because of the channelized nature of EW, armoring, and steepness of the banks. Map 3-2 shows the location and nature of the public access areas on the EW. As noted in Section 3.1.1, future land use plans by the Port (POS 2007), which owns the majority of the property along the EW, do not indicate that the number of EW human

[8] Tribal members with rights to the waterway are not included in general public.

access locations will change significantly in the future[9]. Thus, the physical nature of the EW, which has limited intertidal beach areas; steep, armored banks; lacks nearby residential areas; and is characterized by industrial facilities, suggests a much lower pattern of human use than that of the LDW. Because of the limited public access and very low potential for exposure to intertidal EW sediments, the beach play exposure scenario developed for the LDW (with significant sediment coverage of children's bodies occurring on 65 different days of the year) would not be appropriate for the EW. A beach play exposure scenario may be developed for the EW, based on the results of the shoreline survey (see Section 5). The specific exposure parameters for the child beach play scenario will be presented in the HHRA Technical Memorandum if the results of a shoreline survey suggest that a child beach play scenario is appropriate.

Another recreational exposure scenario evaluated in the LDW HHRA consisted of an adult who may be exposed to intertidal sediment in parks and public access beaches while playing with or walking a dog (Windward 2007). Any exposure associated with similar activities in the EW would likely be lower than that in the LDW for two reasons. First, the public access areas on the EW are much smaller than many of the parks on the LDW. Second, the degree and duration of intertidal sediment exposure at low tides is more limited in the EW compared with the LDW because of the steepness of the banks and armoring. Therefore, because of physical differences in the two sites, the adult dog-walker exposure scenario evaluated for the LDW would not be appropriate for the EW.

The potential for beach play and other shore recreation activities, including park visits and habitat restoration work that would involve exposure to intertidal sediments in the EW, will be evaluated as part of a physical site survey and assessment of bathymetric data. Planned site improvements regarding public access at the Spokane Street Bridge will also be considered. However, proposed changes to that site will favor walking,

[9] Shoreline conditions are expected to change at Terminal 24 (T-24), near the eastern end of the Spokane Street Bridge, as a result of improvements planned by the Port of Seattle (D. Hotchkiss pers. comm. 2008). Proposed changes include installation of a walking path and dredging and regrading a portion of the bank with clean fill material to enhance riparian and intertidal aquatic habitat. The final size of the public access location at T-24 will remain small, with only approximately 0.55 acres of improved upland human access area and 1 acre of enhanced fish and wildlife habitat.

picnicking, and other activities above the intertidal area and may not increase direct water or sediment contact (Hotchkiss 2008). Section 5 presents an approach for an evaluation of the potential for shore recreation based on a survey of the size of human access areas and the size and location of areas of tidally-exposed sediment. The results of the physical site survey and bathymetric data assessments will be used to determine whether the shore recreation exposure pathways will be quantitatively or qualitatively evaluated. Specific details and exposure parameters for the shore recreation scenarios will be presented in the HHRA Technical Memorandum. It should be noted that exposure to sediments through direct contact will be evaluated through the netfishing scenario (see Section 3.1.4).

3.1.3 Occupational Exposure

Individuals with the potential for occupational exposure to contaminated sediments of the EW include commercial fishers, workers on vessels or docks, and habitat restoration biologists. Exposure of workers engaged in fishing activities are addressed in Section 3.1.4, including the collection of fish and crab.

The EW supports a large number of water-dependent commercial uses. Almost all of the facilities adjacent to the EW rely on vessel traffic on the waterway. Much of the occupational work on the EW, other than commercial fishing, takes place on piers and large ships, and is associated with daily shipping terminal operations. Workers on these large vessels or on docks could potentially come into contact with sediment and surface water through work on maintenance projects, piers, piles, and boat bottoms, but most workers are typically aboard vessels and well above the water surface (generally 20 or more feet above MLLW). Thus, worker exposure to EW water and sediment would be relatively infrequent, resulting in potentially complete but low exposures. The occupational exposure of shipping terminal workers will be qualitatively evaluated in the EW HHRA.

Another potential exposure scenario is the performance of repairs and maintenance on structures by SCUBA divers. The infrequency of such activity and the small amount of skin surface area likely to be exposed (because most commercial divers use dry suits) would lead to much lower exposure than would occur through swimming

(Section 3.1.1). Overall, the sediment contact frequencies of the commercial uses of the EW are expected to be low relative to other direct-contact scenarios assessed in this HHRA CSM, such as netfishing. As such, the commercial uses of the EW will not be quantitatively evaluated in the HHRA.

Other occupational scenarios involving sediment exposure, such as a biologist conducting restoration work, were evaluated in the uncertainty section of the LDW HHRA. The risks associated with these other types of occupational exposures were determined to be much lower than those for netfishing, largely because of lower exposure frequency and duration of exposure (Windward 2007). Certain occupational exposures may occur during the shoreline improvements planned by the Port near the Spokane Street Bridge. Because the potential for adverse health effects as a result of exposure to certain chemicals is known, the workers participating in the project will be required to wear special equipment to protect them. However, in order to fully understand the risk associated with exposure and to identify the proper level of equipment that workers will be required to wear, the excess risk associated with habitat restoration activities will be quantitatively evaluated in the EW HHRA.

3.1.4 Fish and Crab Collection

Fish collection is known to occur in the EW. Both occupational netfishers and other individuals fishing from piers and bridges have been observed (King County 1999). Workers involved in commercial netfishing and subsistence fishers in the EW may come in contact with sediment and surface water. Individuals from the Muckleshoot Indian Tribe participate annually in a commercial gillnetting operation in the EW. The gillnet lead lines typically come in contact with sediments during normal operations. The netfishers contact this sediment incidentally upon net retrieval and also have incidental contact with surface water and sediment suspended in the surface water. Therefore, the exposure pathways for this scenario include dermal contact with and incidental ingestion of sediment. Although expected to be lower than exposure occurring during swimming, exposures related to surface water while netfishing could be considered by summing the risks from EW netfishing and the water exposure evaluated in the King County risk assessment (1999) swimming scenario. The exposure area for netfishing is assumed to cover the entire EW study area. Data from sediment samples collected throughout the EW, including intertidal and subtidal areas, will be included in this assessment. The exposure parameters for the fish and crab collection scenarios (e.g., netfishing) will be presented in the HHRA Technical Memorandum.

3.1.5 Shellfish Collection

The risks associated with sediment exposure during clamming in the intertidal portions of the EW will be evaluated. The results of the clam habitat survey will inform a discussion between EPA, the Tribes, and the East Waterway Group (EWG) regarding the calculation of EW shellfish consumption rates. More than one clamming scenario may be required because tribal fishermen belonging to tribes with U&A fishing rights can engage in clamming activities (by means of boat access) in nearly all areas of the EW where sediments are exposed at low tide (Maps 3-1a and b). The potential exposure area for the general public is much smaller because there are only two places where the public can gain access to intertidal areas of the EW (Map 3-2). The spatial extent of the clamming exposure areas will be presented in the HHRA Technical Memorandum, along with other parameters such as frequency and duration of exposure. It is unknown whether and at what rate clamming currently occurs in the EW or may occur in the future. Both the rate at which clamming occurs and the potential for new and/or expanded EW shellfish beds in the future will be established in consultation with the Tribes and EPA.

Collection of geoducks may occur at subtidal locations in the EW. However, risks associated with dermal sediment exposure are unlikely because individuals engaged in geoduck collection must wear SCUBA gear, (e.g., wet- or dry-suits, face masks, and gloves), which would insulate them from the cold water as well as protect them from sediment exposure. Thus, an exposure scenario specific to geoduck collection (i.e., a subtidal sediment exposure specific to clamming) will not be evaluated in the EW HHRA. However, exposure to subtidal sediment will be addressed in the fish collection (netfishing) scenario, which includes exposure to all surface sediment in the EW, both intertidal and subtidal.

3.1.6 Fish and Shellfish Consumption

Ingestion of seafood from the EW is a complete exposure pathway because harvesting of fish and shellfish by recreational and Asian and Pacific Islander (API) fishers, as well as tribal members, is known to occur in the EW (King County 1999)[10]. Recreational fishing also occurs in the EW, particularly for salmon (EPA 1999) and crabs (King County 1999); however, no specific studies to quantify the frequency or catch rates of recreational fishing are available for the EW, WW, or LDW. The harvesting of seafood from the EW is likely affected by the posting of seafood consumption advisories and would potentially be greater in the absence of such advisories.

Seafood consumed by people fishing in the EW may be contaminated following exposures to chemicals in EW sediments and surface water. As previously noted, people may also contact surface water and sediment during fishing and shellfishing activities; however, the risks associated with such exposures are quantified under the fish and shellfish collection scenarios (Sections 3.1.4 and 3.1.5). The consumption scenarios are designed to specifically address the risks associated with seafood consumption, not a combination of dermal exposure and consumption. Cumulative exposure pathway risks will be evaluated separately in the HHRA.

Several seafood consumption scenarios, including adult and child tribal scenarios and an adult API scenario, may be evaluated for the EW. EPA has provided a tribal framework for developing tribal fish and shellfish consumption rates for sites in Puget Sound (EPA 2007). The tribal framework was recently applied in the LDW and will be applied in the EW. The tribal framework includes an assessment process for shellfish habitat quality to determine if "the site or its environs have (existing or potential) high quality shellfish physical habitat to support substantial shellfish harvest in the absence of contamination" (EPA 2007). In consultation with EPA and the local tribes, the outcome of this assessment will be used to develop the most appropriate tribal seafood

[10] King County has a large and diverse API population (EPA 1999). A creel survey by King County indicated that some API individuals, as well as some recreational fishers, use the EW as a fishing resource (King County 1999). The survey identified species of fish and shellfish caught in the EW and Elliott Bay, and found that crab is the seafood type most commonly collected. Other popular species for harvesting include: salmon, herring, flounder, perch, sculpin, rockfish, and shrimp.

exposure scenarios for the EW, including seafood consumption rates that meet EPA approval. The results of the evaluation of current and future clam habitat will be discussed with EPA and the Tribes in order to develop EW shellfish consumption rates. The results of the clam habitat assessment and the parameters selected for the tribal seafood consumption scenarios will be presented in the HHRA Technical Memorandum. The cumulative risks associated with other potentially related exposures (e.g., clamming and netfishing) will be evaluated separately in the HHRA.

3.2 Selection of Exposure Scenarios for Quantification

Specific exposure assumptions will be developed to quantify the complete pathways with significant exposure potential shown in Figure 2. A complete exposure pathway includes an exposure medium, exposure point, a potentially exposed population (including age category [i.e., adult versus child]), and an exposure route. The HHRA Technical Memorandum will discuss exposure parameters and present details on the individual and combined scenarios (as needed) that will be evaluated.

The exposure scenarios evaluated in this HHRA CSM will represent both current and future conditions. Separate scenarios for current and future land use will not be evaluated for the following reasons:

- Future land use within the EW is not expected to differ greatly from current land use (POS 2007). The use of the EW for commercial and industrial purposes is expected to continue into the foreseeable future, although certain recreational and tribal activities that are consistent with these land uses may be more common in the future as habitat improves.
- Because site-specific parameters based on current land use practices are not available, reasonable maximum values will be selected. These values will overestimate current exposure but will be derived to provide information to risk managers that will allow them to evaluate risk assuming increased site exposure in the future.

Table 3-1 documents the decision process for selecting exposure pathways for quantification. Risk estimates may not be quantified in the risk characterization for occupational exposure scenarios other than for habitat biologists/restoration workers because such exposures are likely to be much lower than those associated with restoration work. Additional discussion and analysis of the health protectiveness of the sediment exposure scenarios may be provided in the HHRA Technical Memorandum and in the uncertainty section of the EW HHRA.

Table 3-1
Rationale for the Selection or Exclusion of Exposure Pathways

General Exposure Scenario	Exposure Point	Exposure Medium	Exposed Population	Age Category	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Water recreation	Water recreation areas in the EW	sediment	resident	adult	dermal, ingestion[a]	qualitative	Exposure via swimming is lower than exposure via other pathways.
				child	dermal, ingestion[a]	qualitative	Exposure via swimming is lower than exposure via other pathways.
		surface water	resident	adult	dermal, ingestion[b]	qualitative or numeric	EPCs in surface water quantified by King County (1999) will be compared to current EPCs from newly collected samples. A numeric risk assessment will be conducted if the EPCs in current water samples exceed those used in the King County risk assessment and result in different risk conclusions. The comparison of EPCs or new risk estimates will be reported in the EW HHRA.
				child	dermal, ingestion[b]	qualitative or numeric	EPCs in surface water quantified by King County (1999) will be compared to current EPCs from newly collected samples. A numeric risk assessment will be conducted if the EPCs in current water samples exceed those used in the King County risk assessment and result in different risk conclusions. The comparison of EPCs or new risk estimates will be reported in the EW HHRA.
Shore recreation	Exposed EW intertidal areas	sediment	resident	adult	dermal, ingestion[a]	qualitative or numeric	To be further evaluated. There are no residential areas adjacent to or within a few blocks of EW public access areas, and areas of tidally exposed sediment at public access locations are relatively small.
				child	dermal, ingestion[a]	qualitative or numeric	To be further evaluated. There are no residential areas adjacent to or within a few blocks of EW public access areas, and areas of tidally exposed sediment at public access locations are relatively small.
		surface water	resident	adult	dermal, ingestion[b]	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared to that from direct contact with bedded sediment. Exposure is expected to be much lower than that evaluated in the swimming scenario.
				child	dermal, ingestion[b]	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared to that from bedded sediment. Exposure is expected to be much lower than that evaluated in the swimming scenario.

General Exposure Scenario	Exposure Point	Exposure Medium	Exposed Population	Age Category	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Occupational exposure	Industrial facilities adjacent to the EW	sediment	worker	adult	dermal, ingestion[a]	qualitative	Exposure is expected to be much lower than that evaluated in the netfishing sediment exposure scenario.
		surface water	worker	adult	dermal, ingestion[b]	qualitative	Exposure expected to be much less than that evaluated in the swimming scenario.
	Habitat restoration and EW cleanup locations	sediment	worker	adult	dermal, ingestion[a]	numeric	Workers engaged in habitat restoration or site cleanup projects may come in contact with sediment. Risk estimates will help to identify what level of PPE is appropriate for these workers.
		surface water	worker	adult	dermal, ingestion[b]	qualitative	Exposure is expected to be much less than that evaluated in the swimming scenario.
Fish and crab collection	Commercial netfishing locations in the EW, which potentially include all EW sediments	sediment	worker	adult	dermal, ingestion[a]	numeric	Commercial fishers are active at the site throughout the fishing season; nets contact the sediment.
		surface water	worker	adult	dermal, ingestion[b]	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared to that from bedded sediment.
	Fishing locations in the EW	sediment	resident	adult	dermal, ingestion[a]	qualitative or numeric	Exposure is difficult to quanitify, and likely to be lower than occupational exposure. Incidental exposure during finfishing and crabbing is insignificant.
		surface water	resident	adult	dermal, ingestion[b]	qualitative	Incidental exposure is insignificant.

General Exposure Scenario	Exposure Point	Exposure Medium	Exposed Population	Age Category	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Shellfish collection	Exposed EW intertidal areas	sediment	resident	adult	dermal, ingestion[a]	numeric	One or more clamming exposure scenarios will be evaluated in the EW HHRA. Selection of exposure parameters will depend upon results of the clam habitat survey.
		surface water	resident	adult	dermal, ingestion[b]	qualitative	Exposure attributable to resuspended sediment in the water column is insignificant compared to that from bedded sediment. Exposure is expected to be much lower than that evaluated in the swimming scenario.
Human consumption of resident seafood	Not relevant	resident fish and shellfish tissue (biota)	resident	adult, child	ingestion	numeric	Although available data suggest current seafood consumption from the EW is low, tribal members have treaty harvest rights; thus, fish and shellfish consumption will be evaluated based on EPA Tribal Framework guidance for assessing tribal risks. An API consumption scenario will be evaluated using consumption rates derived from a recent survey of the API community. Some subsistence harvesting may also occur in the EW, and the public has recreational expectations for a fishable and swimmable estuary. A one-meal-per-month consumption scenario will be evaluated to provide individuals with a scalable tool to assess risks associated with their consumption habits.

a Incidental sediment ingestion associated with dermal contact.

b Incidental water ingestion associated with dermal contact.

API – Asian and Pacific Islander

EPC – Exposure Point Concentration

EPA – U.S. Environmental Protection Agency

EW – East Waterway

HHRA – Human Health Risk Assessment

PPE – Personal Protective Equipment

TBD – to be determined

4 ECOLOGICAL RISK ASSESSMENT CONCEPTUAL SITE MODEL

This section presents a description of the CSM for ecological ROCs in the EW, including a graphical representation of chemical sources, transport mechanisms, and exposure pathways. Based on this model, assessment endpoints, measures of exposure, and measures of effect (i.e., lines of evidence) are selected for each ROC. Methods of evaluation for each line of evidence are also presented. This section discusses the background information used in developing the ERA CSM, including the environmental setting, provides a description of resources potentially at risk, and provides the rationale for the selection of the ROCs.

4.1 Environmental Setting

The EW is part of the Duwamish River and discharges to Elliott Bay near downtown Seattle (Map 1-1). Dredging and development have substantially altered nearshore environments in Elliott Bay and the lower Duwamish River. Prior to the channelization and industrialization of the Duwamish River, the habitat associated with the river's mouth was predominately an intertidal/shallow subtidal estuarine mudflat. Of the pre-development habitat in the Duwamish River estuary, most (98 percent) of the approximately 5.14 square kilometers (km^2) of tidal marsh and 5.9 km^2 of flats and shallows, and all of the 5 km^2 of tidal wetland have been either filled or dredged (Blomberg et al. 1988). Currently, there is no natural shoreline in the EW. The remaining aquatic habitats in the EW are intertidal and subtidal sediment habitats, as well as habitat in the water column. The EW is predominately an industrial waterway. The federally maintained shipping channel is -52 feet MLLW for much of the EW, and the shoreline is dominated by pier aprons. The southern end of the EW (south of Station 5000) has not been dredged in the past 20 years, and in this area, the EW is shallower than -50 feet MLLW with a minimum sediment elevation of -6 to -12 feet MLLW under the bridges. This area does not support shipping activity and is the area of greatest freshwater influence.

The shoreline of the EW is approximately 16,000 linear feet (excluding Slip 27 and Slip 36). The majority of the EW shoreline is composed of riprap, pier aprons, or sheet piling (Tanner 1991). Most of the shoreline (61 percent) is covered by pier aprons with engineered riprap slopes, roughly a third (30 percent) of the shoreline is covered with armored riprap with no pier apron structure, and the remaining shoreline is predominately characterized as bulkhead (9 percent). The shoreline within Slip 27 and Slip 36 is predominately armored riprap with limited pier structures (Map 4-1).

The standard concrete pier aprons in the EW are 100 feet wide from the outer edge to the inner bulkhead at +9 feet MLLW. Vertical bulkheads are usually present above +9 feet MLLW because WDFW requirements limit their intertidal range. Below the bulkheads is an engineered riprap slope to approximately -50 feet MLLW (with some areas to -40 feet MLLW).

Shoreline armoring is usually present in the upper intertidal zone, but a few areas of sloping mud and sand flats exist in the lower intertidal zone. These lower intertidal flats are isolated from each other because of the shoreline armoring. In addition, overwater structures, which are common throughout the EW, shade shallow water and intertidal habitats, alter microclimates, and inhibit the growth of plant communities, thus further degrading nearshore habitats for native fauna (Battelle et al. 2001). A more detailed description of the EW can be found in the EISR (Anchor and Windward 2008a).

4.2 Resources Potentially at Risk

This section provides an overview of the ecological resources that use the EW, including threatened, endangered, and sensitive species. These resources, which include species that could be directly or indirectly exposed to contaminated sediments, include the benthic invertebrate community, fish, birds, and mammals. Reptiles and amphibians are not likely to be exposed to sediment contamination in the EW because habitat for these species is limited (no persistent freshwater habitat exists in the EW), and their presence has not been reported in any wildlife surveys conducted in the LDW (Canning et al. 1979; Cordell et al. 1996; 1997; 1999). Therefore, reptiles and amphibians are not included as ecological resources within the EW. In addition, risks to vascular plants will not be evaluated because of the limited plant communities in the EW (Battelle et al. 2001). The limited exposed shallow water habitat and the presence of engineered riprap slopes throughout the EW are physical constraints that limit the vascular plant communities. There are small kelp beds (e.g., *Nereocystis* and *Laminaria*) found in the south end of the EW. These beds are growing on rubble as well as on substrates enhanced by the Port for kelp growth (PIE 1999).

4.2.1 The Benthic Invertebrate Community

Benthic invertebrate assemblages in temperate marine environments comprise a variety of species from diverse phyla (e.g., mollusca, arthropoda, annelida, and echinodermata). Benthic invertebrates can be classified as infaunal (living within the sediment) and epifaunal (living on the sediment or other substrates) and, by definition, are in direct contact with the sediment during part or all of their life. Most benthic invertebrates tend to be sessile (i.e., stay in place) or have limited mobility as adults. Benthic invertebrates exhibit all types of feeding modes that expose them to sediments, including filtering suspended sediment, plankton, and detritus from the water column; gathering detritus or sediment grains coated with organic material from the sediment surface or near-bottom nepheloid layer; engulfing subsurface sediment to process the associated organic material; parasitizing other sediment-dwelling organisms; and preying on other invertebrates.

The diversity and abundance of benthic invertebrates is an important contributor to and indicator of ecosystem health. Benthic invertebrates that burrow and process sediment or detritus support essential functions such as nutrient cycling and sediment oxygenation. Benthic invertebrates are an important food source for other invertebrates and fish; larger invertebrates are also a major part of the diet of selected birds and mammals.

In general, key physical factors that may influence the distribution and abundance of benthic invertebrates are salinity, tidal elevation (affecting the duration of exposure to air or heat), water depth, substrate composition, organic carbon content, rates of sediment deposition or erosion, wave and current magnitude, and frequency of disturbance (e.g., flooding, propwash, and anchor drag).

Limited benthic invertebrate community sampling in the EW was conducted as part of a 1999 epifaunal survey assessing salmonid prey (Taylor et al. 1999) and a 2005 bioaccumulation study that sampled crab and other epibenthic macroinvertebrates (Windward 2006a). No infaunal sampling has been conducted; however, information from surveys conducted in the LDW downstream (i.e., north) of Kellogg Island and in nearshore Elliott Bay may provide a general indication of the invertebrates that could be present in the EW because these areas are adjacent to the EW and Elliott Bay acts as a source of plankton that may settle out in the EW. A summary of existing EW epifaunal invertebrate data, along with relevant supporting infaunal assemblage information from the northern portion of the LDW and nearshore Elliott Bay are presented in Section 4.2.1.1; additional detail is provided in the EISR (Anchor and Windward 2008a).

Crab represent some of the larger benthic invertebrates inhabiting the EW. Crab species that are known to occur in the EW include Dungeness crab (*Cancer magister*), red rock crab (*C. productus*), and graceful crab (*C. gracilis*). Dungeness crab are the largest crab species observed in the EW, and graceful crab tend to be the most abundant. Mating typically takes place in deeper, offshore locations, but may occasionally occur in estuaries (Pauley et al. 1988). Gravid females migrate to shallow estuarine habitats or other protected areas until their eggs hatch; planktonic larvae tend to settle in vegetated estuaries, which also serve as nurseries for juvenile crab. The highest densities of juvenile crab are usually associated with eelgrass or other aquatic vegetation.[11]

Although crab are primarily carnivores and scavengers, crab diets are dependent on their life stage and size (Pauley et al. 1986). Planktonic larval crab ingest both zooplankton and phytoplankton. Following metamorphosis, the diet of juvenile crab consists largely of very small fish, mollusks, and crustaceans. Adult crab primarily prey on clams, crustaceans, and fish. Juvenile and adult crab may incidentally ingest sediment when preying on clams and benthic fish, but the rate of ingestion is likely to be low since many prey species are epibenthic (e.g., mussels and barnacles on pilings, and shrimp). Crab prey size changes with age; crab tend to eat clams in their first year, shrimp in their second year, and small fish in their third year. Planktonic crab larvae (megalopae[12]) are preyed upon by many fish, including juvenile salmon. Juvenile crab are eaten by various demersal fish in the nearshore area. Flatfish, such as starry flounder (*Platichthys stellatus*) and English sole (*Parophrys vetulus*), are the most

[11] No eelgrass is found in the Duwamish River, and habitats with aquatic vegetation are rare (Battelle et al. 2001).

[12] Crab larvae progress through five zoeal states before molting into megalopae. Megalopae first appear in April in Washington waters, with abundance peaking in May through June, after which they molt into juveniles (Pauley et al. 1988).

important predators in Puget Sound. Adult and juvenile crabs are preyed upon by river otters, fish, and octopuses. Cannibalism is also common among crabs.

4.2.1.1 Existing East Waterway Benthic Invertebrate Data

Taylor et al. (1999) conducted a survey of epibenthic invertebrates in several intertidal areas in the lower Duwamish River and Elliott Bay as part of a juvenile salmonid prey assessment in support of disposal site selection for an EW navigation project. Sampling was conducted within the EW in Slip 27 (at the head and at the entrance); epifaunal samples (primarily crustaceans) were collected at 0 and -2 feet (-0.6 meters) MLLW using a suction pump. The dominant species at Slip 27 were harpacticoid copepods and gammarid amphipods.

Limited information exists on the presence of larger invertebrates in the EW. There have been no surveys of bivalve communities in intertidal or subtidal areas of the EW. The only survey documenting larger epibenthic invertebrates in the EW (Windward 2006a) was conducted in 2005 using trawls to collect tissue for a bioaccumulation study. The larger invertebrates identified in this survey included crab (*C. gracilis* and *C. productus*), shrimp (*Pandalus danae*), sea stars (*Pycnopodia helianthoides*), nudibranchs, and anemones (Windward 2006a).

4.2.1.2 Other Relevant Benthic Invertebrate Information

Benthic invertebrate data from the northern portion of the LDW and nearshore Elliott Bay may provide useful information regarding infaunal assemblages that may be present in the EW. Several studies are summarized below; additional detail is provided in the EISR (Anchor and Windward 2008a).

The benthic assemblages in the northern portion of the LDW near and downstream of Kellogg Island are generally dominated by annelids, crustaceans, and mollusks (Windward 2005a; Cordell et al. 2001; Williams 1990; Leon 1980). The dominant intertidal bivalve was the eastern softshell clam, *Mya arenaria*. Common intertidal annelids included subsurface deposit feeders from the *Capitella capitata* complex, the filter feeder *Manayunkia aestuarina*, the surface detrital feeder *Pygospio elegans,* and oligochaetes. Common intertidal crustaceans included *Americorophium* and

Grandidierella japonica, which feed on detrital material on the sediment surface or in the water column (Windward 2005a). Very small invertebrates (meiofauna) in intertidal habitats were generally dominated by nematodes and epibenthic harpacticoid copepods (Cordell et al. 2001).

The predominant species in the subtidal zone in the LDW included annelids, such as the deposit feeder *Aphelochaeta* cf *glandaria,* the deposit feeder *Lumbrineris californiensis* (which may also ingest tiny organisms that are present in the sediment), the surface deposit/detrital feeders *Scoletoma luti* and *Prionospio steenstrupi*, and oligochaetes. The amphipod *Anisogammarus* sp. was among the crustaceans common in subtidal habitats (Leon 1980). The subtidal epibenthos was dominated by nematodes, oligochaetes, small harpacticoids, and cumaceans (Williams 1990). Bivalves common in subtidal habitats included the surface deposit feeders *Axinopsida serricata, Parvilucina tenuisculpta*, and *Macoma* sp. (Windward 2005a). The most common gastropod was *Alvania compacta*.

Sediment profile imaging (SPI), sediment toxicity testing, and benthic community sampling were conducted by the Washington State Department of Ecology (Ecology) in the LDW in 2006 (Ecology 2007) to assess the feasibility of using SPI technology to predict chemical impacts to benthic communities in lieu of performing more direct toxicity testing. Community information from stations downstream of Kellogg Island was evaluated to provide an indication of benthic invertebrate assemblages that may be present in the EW. Benthic organisms were abundant and relatively diverse in the seven samples evaluated. Polychaetes were typically the most abundant organisms, followed by mollusks, and then crustaceans. Dominant taxa were similar to those reported in previous studies in the LDW and included the polychaete *Aphelochaeta glandaria*; the mollusks *Axinopsida serricata*, *Macoma carlottensis*, *Nutricola lordi*, and *Parvilucina tenuisculpta*; and the crustacean *Euphilomedes carcharodonta*.

Numerous benthic invertebrate species have been found in Elliott Bay, including polychaetes, crustaceans, mollusks, echinoderms, nemerteans, and cnidarians. A large survey conducted in Puget Sound documented the benthic invertebrates present in both the outer bay and along the shoreline of Elliott Bay (NOAA and Ecology 2000). Data from locations with similar water depths, substrates, and salinities may be relevant to the EW. The benthic assemblages from comparable habitats found in Elliott Bay tended to exhibit greater diversity than those found in the LDW but had many species in common (e.g., *Lumbrineris californiensis*, *Scoletoma luti*, *Prionospio steenstrupi*, *Axinopsida serricata*, *Parvilucina tenuisculpta*, *Nutricola lordi*, and *Alvania compacta)*. Larger predatory and scavenging crustaceans found in Elliott Bay included Dungeness crab (*C. magister*), rock crab (*Cancer* sp.), sidestripe shrimp (*Pandalopsis dispar*), spot shrimp (*Pandalus platyceros*), humpback shrimp (*Pandalus goniurus*), and pink shrimp (*Pandalus* sp.) (Dinnel et al. 1986).

4.2.2 Fish

Fish in the EW can be classified as demersal (living on or near the sediment and feeding on benthic organisms), benthopelagic (living and feeding near the sediment as well as in the water column), and pelagic (living and feeding in open water) (FishBase 2008). Demersal fish are, by definition, in direct contact with sediment during part or all of their life, whereas, benthopelagic and pelagic fish have less direct contact with sediment.

Fish species present in the EW are generally mobile predators and are exposed to chemicals through the ingestion of contaminated prey, incidental ingestion of sediment during prey capture, and uptake of chemicals in surface water through the gills during respiration. Fish are an important food source for other fish, some larger invertebrates, birds, and mammals. Fish from the EW also provide important recreational value and are a source of food for people.

The most extensive surveys of fish populations in the EW have been conducted for the Port by Taylor Associates using beach seines, which tend to capture small fish in nearshore habitats. Taylor Associates sampled fish at the head and mouth of Slip 27 in 1998, 2000, 2002, and 2003. The head of the EW was also sampled in 2000. Sampling was conducted in April through August 1998, April through October 2000 and 2002, and February through April 2003 (Shannon 2006). Additional sampling was conducted February 15 through March 2, 2004, at Slip 27 and nearby locations (Taylor Associates 2005). Twenty-two species of fish were captured in these studies. The top three numerically dominant species at the Slip 27 station were juvenile chum salmon (*Oncorhynchus keta*), juvenile Chinook salmon (*Oncorhynchus tshawytscha*), and shiner surfperch (*Cymatogaster aggregata*). Together, these species represented 98 percent of the total catch at Slip 27. Additional species commonly captured in beach seines included juvenile coho salmon (*Oncorhynchus kisutch*), Pacific staghorn sculpin (*Leptocottus armatus*), Pacific herring (*Clupea pallasi*), surf smelt (*Hypomesus pretiosus*), and three-spine stickleback (*Gasterosteus aculeatus*).

Trawling throughout the EW was conducted one day in July 2005 to capture fish for tissue sampling (Windward 2006a). Seventeen species of fish were captured in nine trawls. [13] English sole was the most abundant species and constituted more than 50 percent of the total catch. Pacific tomcod (*Microgadus proximus*), rock sole (*Lepidopsetta bilineata*), sand sole (*Psettichthys melanostictus*), surf smelt, and shiner surfperch were also abundant with a catch-per-unit-effort (CPUE) greater than or equal to three individuals per trawl. Sanddab (*Citharichthys* species), Pacific staghorn sculpin, starry flounder, and Pacific herring were also common with a CPUE greater than one individual per trawl. All fish species collected in the EW are listed in Table 2-6 of the EISR (Anchor and Windward 2008a).

In the Duwamish Waterway, 53 resident and non-resident fish species were captured during recent LDW RI sampling events (Windward 2004, 2005a, 2006b). In earlier studies, Warner and Fritz (1995) recorded 33 resident and seasonal fish species, Miller et al. (1975, 1977a) observed a total of 29 species, and Matsuda et al. (1968) recorded a total of 28 species. Dominant species were similar to those observed in the EW, with shiner surfperch, snake prickleback (*Lumpenus saggita*), Pacific sandlance (*Ammodytes hexapterus*), Pacific staghorn sculpin, longfin smelt (*Spirinchus thaleichthys*), English sole, and starry flounder being particularly abundant; as were juvenile Chinook, chum, and coho salmon. Fish numerical abundance reached its maximum in late summer to early fall and was generally lowest in winter (Miller et al. 1977a; Dexter et al. 1981). Based on otter trawl data, species richness was shown to follow a similar trend but did not vary greatly with season (Miller et al. 1977a). The following subsections detail the dominant species likely to be encountered in the EW.

[13] Average trawl length was 530 meters.

4.2.2.1 Anadromous Salmonids – Pacific Salmon

Five species of juvenile salmon (Chinook, chum, coho, pink [*Oncorhynchus gorbuscha*], and steelhead) have been documented in the EW. Juvenile chum and Chinook salmon were the most abundant salmonid species captured in Slip 27 (Taylor Associates 2004; Shannon 2006). Sockeye salmon (*Oncorhynchus nerka*) have been found in the LDW (Kerwin and Nelson 2000).

Salmon use the Duwamish Waterway for rearing and as a migration corridor for adults and juveniles. Adult salmon found in the LDW and EW spawn mainly in the middle reaches of the Green River and its tributaries (Grette and Salo 1986). Among the beneficial uses identified for the Duwamish Waterway, habitat for outmigrating juvenile salmonids was one of the most important (Harper-Owes 1983). The peak timing of outmigration for juveniles of all salmon species generally corresponds with March-to-June high flows. Peak outmigration usually lasts from mid-July through early August for most species (Warner and Fritz 1995; Nelson et al. 2004). In the EW, juvenile salmon were caught in seine nets from April through September, with peak numbers in April through July (Shannon 2006). During this time, juveniles have completed their physiological adaptation to higher salinity, and they use the estuary to feed on epibenthic and neritic food sources (Salo 1991). No specific information is available on their residence time in the EW.

4.2.2.2 Non-salmonid Fish

Of non-salmonid fish, surf smelt, three-spine stickleback, English sole, Pacific tomcod, rock sole, sand sole, shiner surfperch, sanddab species, Pacific staghorn sculpin, starry flounder, and Pacific herring are at least seasonally abundant in the EW. Pacific herring, Pacific sandlance, surf smelt, and longfin smelt were encountered infrequently in recent beach seine and trawl samples in the EW but occasionally occurred in large numbers (Shannon 2006; Windward 2006a). Three-spine stickleback were abundant in monthly beach seine samples at both Slip 27 and Kellogg Island sampling locations (Shannon 2006). Longfin smelt abundance was highest in the summer, fall, and early winter based on historical otter trawl data from the LDW (Miller et al. 1977a). Miller et al. (1977a) suggested that the fall-winter peak abundance period (with 80- to 115-millimeter [mm]-long fish) may represent part of a spawning run and that the late summer peak (with 30- to 50-mm-long fish) may represent downstream migrant young of the year individuals. Pacific herring were reported in purse seine samples from the LDW in May, June, July, November, and December (Shannon 2006; Weitkamp and Campbell 1980) and were present in trawl samples in July, August, and September in the EW (Windward 2005a, 2006b). In Puget Sound, three-spine stickleback and surf smelt feed on both epibenthic and pelagic invertebrates. Epibenthic invertebrates constitute a slight majority of their diet (Miller et al. 1977b; Fresh et al. 1979). Pacific herring and longfin smelt generally feed on pelagic invertebrates, but also ingest epibenthic invertebrates to a lesser extent (Miller et al. 1977b; Fresh et al. 1979). Pacific tomcod is a demersal species that is associated with sandy bottoms (Cohen et al. 1990); they feed primarily on amphipods and shrimp (Fresh et al. 1979).

In the LDW, shiner surfperch abundance peaks in summer during the bearing of young (Miller et al. 1975). Taylor Associates recorded abundant shiner surfperch in the EW and LDW in May through October, with peak abundance in July (Shannon 2006). Shiner surfperch are opportunistic omnivores, feeding primarily on benthic invertebrates including polychaetes, mollusks, and other benthic organisms (Fresh et al. 1979; Wingert et al. 1979; Miller et al. 1977b). Shiner surfperch are also noted to feed on zooplankton, small crustaceans, algae, and detritus (Gordon 1965; Bane and Robinson 1970).

English sole were the most abundant fish captured in recent trawl sampling of the EW, constituting more than 50 percent of the total catch (Windward 2006a). In Puget Sound, adult English sole are typically found on soft sand or mud bottoms at depths of 80 to 150 feet (25 to 50 meters) (Smith 1936). English sole may exist in discrete populations with some site fidelity. Day (1976) conducted a tagging study in Puget Sound that suggested that fish captured and released at the same location remained within an area approximately equal to 5 to 10 km^2. In addition, catch rates for fish captured and released dozens of miles from their original capture site were higher at their original capture site than at the release site or other sites sampled (Day 1976).

English sole migrate to their spawning grounds in Puget Sound in winter (Forrester 1969) and typically spawn in Puget Sound during February and March (Smith 1936). In central Puget Sound, adult populations of English sole spawn in Elliott Bay and Port Gardner, but disperse after spawning (Pallson 2001). Angell et al. (1975; as cited in King County 1999) reported offshore migration in winter and spring of all age groups of central Puget Sound English sole from Meadow Point to Carkeek Park (northwest Seattle) at depths of 3 to 30 meters. Juveniles (10 to 25 mm standard length), not all completely metamorphosed, migrated from spawning areas to nursery grounds as pelagic fish and moved to benthic habitats in December or May and June (King County 1999). Data from Malins et al. (1982) indicated that during the winter and spring, more than 50 percent of the English sole in the LDW are juveniles (less than 150 mm standard length). Juvenile English sole (those less than 110 mm long) ingest annelids (Smith 1936), copepods, amphipods, and mollusks (Holland 1954). Adult English sole studied in Puget Sound ingest clams, clam siphons, small mollusks, marine worms, small crabs, and small shrimp (Wingert et al. 1979; Fresh et al. 1979).

Rock sole was among the most common species of fish captured in recent trawl sampling in the EW; starry flounder were somewhat less common (Windward 2006a). Similar to English sole, starry flounder and rock sole are also noted to migrate from shallow water and estuaries during the summer into deeper water in the winter (Morrow 1980; NOAA 2008). Young and adult starry flounder are tolerant of freshwater (Morrow 1980). Rock sole tend to be found on rocky or gravel substrates, but are also found on sand and mud bottoms (NOAA 2008). Because they have larger mouths, starry flounder and rock sole are capable of consuming somewhat larger organisms than those consumed by English sole, although their diets greatly overlap. Starry flounder and rock sole in Puget Sound were reported to consume primarily benthic invertebrates, with bivalves, amphipods, and shrimp serving as important prey items for starry flounder and polychaetes, amphipods, and bivalves the primary prey for rock sole (Fresh et al. 1979).

Other flatfish that were common in recent EW trawl sampling included the Pacific sanddab and sand sole (Windward 2006a). Pacific sanddab are found on sand and mud bottoms and consume a mixture of benthic invertebrate and pelagic invertebrate prey (Fresh et al. 1979). Sand sole are found over sandy bottoms and consume primarily fish from the water column, such as shiner surfperch (Love 1996).

The highest trophic level fish species identified in the EW or the LDW below Kellogg Island include brown rockfish (*Sebastes auriculatus*), quillback rockfish (*Sebastes maliger*), Pacific staghorn sculpin, Pacific tomcod, spotted ratfish (*Hydrolagus colliei*), sand sole, and starry flounder. Dietary studies from Puget Sound show that of these species, fish constitute a large fraction of the diets for sand sole and brown rockfish, whereas the others consume primarily invertebrates and are at a lower trophic level (Miller et al. 1977b; Wingert et al. 1979; Fresh et al. 1979). Wingert et al. (1979) report that brown rockfish and quillback rockfish from central Puget Sound had similar diets in that both species primarily consumed caridiean shrimp and fishes. Tagging studies show that quillback and brown rockfish show limited movement with home ranges on the order of 30 to 1,500 square meters (m^2) (Matthews 1990a). In the EW, only two adult and one juvenile brown rockfish were captured during 2006 trawl sampling (Windward 2006a). This may under-represent their relative abundance in the EW; however, because brown rockfish are associated with structures such as riprap, piers, or submerged debris (Matthews 1990a; Love 2002)—substrates that are not effectively sampled using a trawl.

4.2.3 Birds

There is relatively little EW-specific information on bird populations. Surveys of the bird community have been primarily conducted upstream of the EW in the LDW, where there is a greater diversity of bird habitat. The aquatic and semi-aquatic habitats of the LDW up to the Upper Turning Basin support a diversity of bird species. Formal studies, field observations, and anecdotal reports indicate that up to 87 species of birds use the LDW during at least part of the year to feed, rest, or reproduce (see Table 2-10 of the EISR [Anchor and Windward 2008a] for a list of species observed in the LDW).

In contrast to the LDW, the EW has very little riparian, intertidal, or shallow water habitat, which limits the presence of bird species that depend on those conditions.

Instead, birds that feed in the pelagic zone or dive in deeper waters to feed on benthic fish and invertebrates are more likely to frequent the EW.

This section provides a general description of birds expected to use the EW based on formal surveys or other types of observations conducted in the LDW upstream of the EW, or based on informal observations of birds in the EW. No studies of bird populations have been conducted in the EW. Formal surveys conducted in the LDW include a year-round survey conducted of the entire waterway in 1977-1978 (Canning et al. 1979) and a monitoring study conducted over 14 seasons at three general areas of the LDW (Terminal 105 [T-105], Kellogg Island, and the Upper Turning Basin) between 1995 and 2000 (Cordell et al. 2001). Passerine/upland birds, raptors, shorebirds/waders, waterfowl, and seabirds are described in the subsections that follow.

4.2.3.1 Passerine/upland Birds

Passerine and upland bird species that have been observed during surveys of the LDW are generally associated with terrestrial habitats, although they may occasionally forage in exposed mudflats or freshwater habitats (Canning et al. 1979). Therefore, these species are not expected to frequent the EW. Passerine and upland species that have been observed along the EW include northwestern crow (*Corvus corrinus*), rock pigeon (*Columba livia*), European starling (*Sturnus vulgaris*), English (house) sparrow (*Passer domesticus*), and belted kingfisher (*Ceryle alcyon*).

4.2.3.2 Raptors

Osprey (*Pandion haliaetus*) and bald eagle (*Haliaeetus leucocephalus*) have been observed in the vicinity of the EW. Two osprey nest boxes are located along the EW at Terminal 104 (T-104) and T-18 (Blomberg 2007). In 2006, WDFW reported 10 osprey nest sites located along the LDW, in addition to the nests along the EW (Thompson 2006). Osprey feed almost exclusively on fish captured from the water surface by hunting over open water (Poole et al. 2002). Overwintering migrant eagles have been routinely observed in the vicinity of the LDW from the beginning of October through late March (King County 1999). Five bald eagle nests within 8 km of the EW were occupied in 1999 (King County 1999). The closest nest is located in West Seattle, within 1.6 km of the EW. Bald eagles feed primarily on fish, but may also feed on waterfowl during winter months (Buehler 2000). Other raptors in the LDW (e.g., merlin [*Falco columbarius*] and several species of hawks) feed primarily on upland birds or rodents and are not substantially exposed to aquatic species from the EW.

4.2.3.3 Shorebirds/waders

Of the nine species of shorebirds and wading birds that have been documented during monitoring studies conducted by Cordell et al. (2001) in the LDW, great blue heron (*Ardea herodias*) was the most abundant species recorded, and great blue heron have also been observed using the EW. The closest great blue heron colonies are located about 14 km south of the EW in Renton, and 10 km northwest near Salmon Bay. A colony of up to 37 active great blue heron nests was located in West Seattle a few hundred meters from Kellogg Island until 1999, but the nests were abandoned in 2000 (Norman 2002). Great blue heron feed in shallow water, primarily on fish, but they may also consume benthic invertebrates (Butler 1992). Other common shorebirds observed in the LDW were spotted sandpiper (*Actitis macularia*) and killdeer (*Charadrius vociferous*). Sandpipers probe in the sediment while feeding on benthic invertebrates in intertidal areas, resulting in exposure to sediment contamination through incidental sediment ingestion. The small amount of shallow water and intertidal habitat in the EW is likely to limit the use of the EW by shorebirds and waders, as discussed in more detail in Section 4.3.3.

4.2.3.4 Waterfowl

Waterfowl species commonly observed in the EW include common and red-breasted merganser (*Mergus merganser* and *Mergus serrater*, respectively), Barrow's goldeneye (*Bucephala islandica*), Canada goose (*Branta canadensis minima*), and bufflehead (*Bucephala albeola*). Cordell et al. (2001) and Canning et al. (1979) observed 20 waterfowl species during monitoring studies conducted in the nearby LDW. In general, the waterfowl species observed in the EW and along the LDW overwinter in the Puget Sound area (and farther south) and migrate north in the summer, although there are some non-migratory populations. Bufflehead, Barrow's goldeneye, and common and red-breasted mergansers are species that dive deeper than other ducks and eat benthic invertebrates and fish; these species are more likely to use the EW for foraging than are other duck species.

4.2.3.5 Seabirds

Seabirds observed using the EW include pelagic and double-crested cormorants (*Phalacrocoranx pelagicus* and *Phalacrocorax auritus*, respectively), pigeon guillemot (*Cepphus columba*), grebes (especially Western grebe [*Aechmophorus occidentalis*]), and gulls (especially glaucous-winged gull [*Larus glaucescens*]). Sixteen species of seabirds were documented in the nearby LDW by Cordell et al. (2001) and Canning et al. (1979).

Pigeon guillemot nests have been observed under the T-18 piers (Hotchkiss 2007). Pigeon guillemots are present in the Puget Sound region year-round (Seattle Audubon Society 2008). Wintering cormorants use the LDW from November to May, with large numbers present from December to April (Canning et al. 1979; Cordell et al. 1996). Grebes arrive from October to November and depart by early May. Several species of gulls use the LDW and EW; glaucous-winged and mew gulls (*Larus canus*) are the only species reported to use the area in large numbers.

Pelagic cormorants and pigeon guillemot are both deep divers and feed primarily on bottom-dwelling fish, but may also consume some benthic invertebrates (Ewins 1993; Hobson 1997). Double-crested cormorants feed primarily on fish in shallower waters. Western grebe feed primarily on fish (Storer and Nuechterlein 1992). Gulls are omnivorous scavengers, consuming a wide variety of fish and shellfish.

4.2.4 Mammals

There is very little information on mammal populations in the vicinity of the EW or the LDW. The relatively large home ranges associated with many mammal species make the LDW data relevant to the EW.

Three marine mammal species enter the EW and LDW from Elliott Bay: harbor seal (*Phoca vitulina*), California sea lion (*Zalophus californianus*), and harbor porpoise (*Phocoena phocoena*) (Dexter et al. 1981). Harbor seals and California sea lions have been observed in the EW (Walker 1999). Recent information on harbor porpoise usage was not available, although it has been noted that they occasionally enter the LDW (Dexter et al. 1981).

A survey was conducted to monitor for the presence of California sea lions and harbor seals in the EW on 30 individual days between December 1998 to June 1999 (Walker 1999). California sea lions were observed on 8 days, and harbor seals were observed on 1 day. California sea lions, harbor seals, and harbor porpoise are opportunistic feeders, consuming various fish species depending on availability (Marine Mammal Center 2002; Pitcher 1980; Pitcher and Calkins 1979; Schaffer 1989). Harbor seals may also feed on invertebrates such as squid, and California sea lions and harbor porpoises may also feed on squid and octopus.

Three species of semi-aquatic terrestrial mammals use the LDW: raccoon (*Procyon lotor*), muskrat (*Ondatra zibethicus*), and river otter (*Lutra canadensis*). Raccoons are reported to be common along the forested ridge slopes to the west of the LDW. Raccoons are scavengers that feed on carrion and occasionally on fish. Muskrat populations were reported to exist at Terminal 107 (T-107) and at the Upper Turning Basin (Canning et al. 1979). Muskrats are herbivores, feeding primarily on aquatic and semi-aquatic plants. The EW has limited aquatic and semi-aquatic plant populations because of limited shallow water habitat, thus muskrats are less likely to use EW habitat. Anecdotal information indicates that a river otter family lives year-round on Kellogg Island in the LDW. Local river otters feed primarily on fish but will also feed on crabs and sometimes on mussels and clams (Strand 1999).

4.3 Receptors of Concern Selection

This section presents the ROCs selected to represent benthic invertebrate, fish, bird, and mammal species evaluated in the ERA based on a set of key considerations. It would not be practical to evaluate risks to all species in the EW individually because of the large number and variety of species present. Therefore, representative species were chosen as ROCs using a systematic process based on the available information for the resources presented in Section 4.2. This process is consistent with Sediment Management Standards (SMS), available EPA guidance, and the process used in Superfund ERAs.

Key considerations in the selection of ROCs included:

- Potential for direct or indirect exposure to sediment-associated chemicals
- Human and ecological significance
- Site usage
- Sensitivity to chemicals at the site
- Susceptibility to biomagnification of chemicals (i.e., higher trophic level species)

This section provides the rationale for each of the ROCs selected based on these key considerations. To ensure that ROCs were selected to represent all important exposure pathways for sediment-associated chemicals, key direct and indirect exposure routes from sediment were identified (e.g., direct exposure to sediment or ingestion of prey associated with sediment either directly or indirectly). Groups of organisms that may be exposed via these pathways were then identified, and representative species expected to be most exposed were selected from these groups in order to represent the greatest potential for exposure. Next, human or ecological significance was considered (i.e., species valued by society, species with a special regulatory status [e.g., threatened or endangered], or species that serve a unique ecological function).

Site usage and sensitivity to chemicals often detected at the site were also evaluated to determine the final list of ROCs. Site usage is an important consideration because it determines the exposure of a species; species that occupy the EW during a significant part of the year or during sensitive periods, such as gestation and rearing of young, were preferred. Sensitivity to chemicals was evaluated based on available toxicological data, although in many cases, the availability of toxicological data specific to species residing in the EW is low. Therefore, where necessary, toxicological information from surrogate species, or a wide range of species, was used because species-specific data were not available.

Finally, susceptibility to biomagnification because of trophic status, resulting in higher exposure to chemicals that biomagnify (e.g., PCBs), was considered in selecting ROCs based on an understanding of the trophic relationships among the animals living in or feeding from the EW. Organisms higher in the food web are likely to have higher exposure to bioaccumulative chemicals than receptors lower in the food web. In estuarine food webs, the lowest trophic level organisms are primary producers (i.e., those that rely on phytosynthesis for energy), such as phytoplankton, algae, and aquatic plants (Figure 3). Primary consumers, such as some amphipods, clams and mussels, some of the diving ducks, and muskrat, are herbivores and feed almost exclusively on plants. Some of the organisms feeding at the highest trophic level in estuarine food webs that can also be found in the EW include rockfish, sand sole, osprey, eagle, river otter, and marine mammals (Figure 3). Many organisms found in estuarine environments and in the EW are omnivores, feeding from multiple trophic levels or changing trophic status with life stage or size.

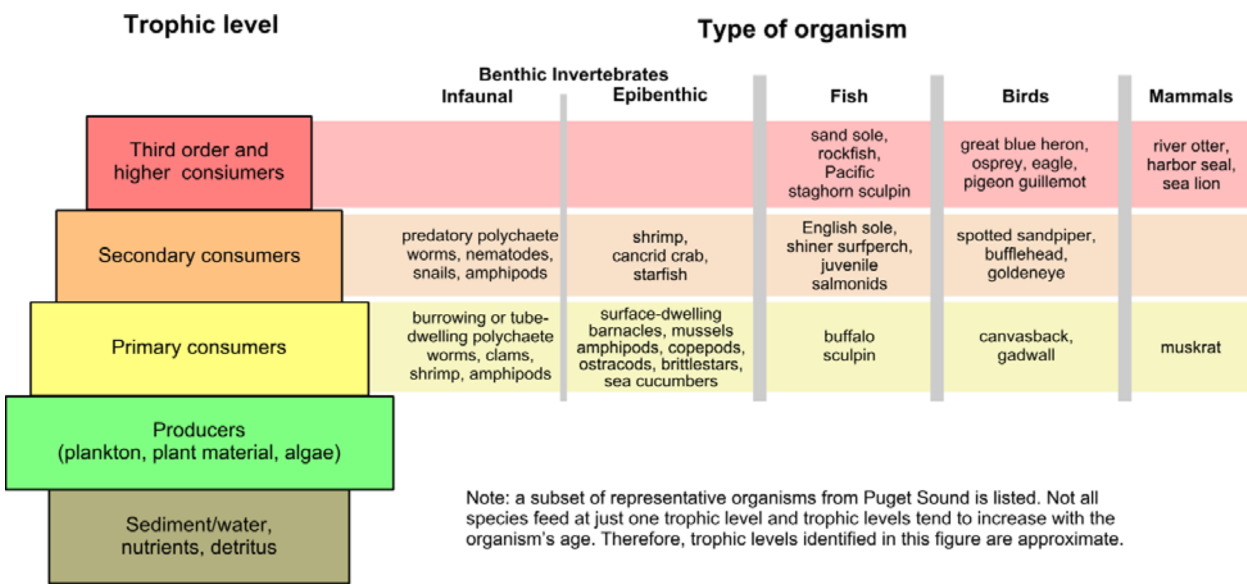


Figure 3 Trophic Levels of Select Organisms in Puget Sound Estuaries

4.3.1 Benthic Assemblages

The benthic invertebrate community, as a whole, and cancrid crab were selected as benthic ROCs. Sessile benthic invertebrate assemblages are directly exposed to sediment and integrate both long- and short-term exposures. Numerous benthic species are known to be sensitive to the effects of a number of chemicals, including metals and polycyclic aromatic hydrocarbons (PAHs). In addition, sampling protocols and analytical techniques to assess the health of benthic assemblages are well established. The presence and abundance of clams within available EW intertidal and subtidal habitats is unknown and will be assessed as part of the initial SRI field program. Benthic invertebrates, including clams, are important prey items for ROCs, including fish, birds, and mammals.

Cancrid crabs were selected because they are ecologically and recreationally important and have a higher trophic level than do other benthic invertebrates. Although no individual is likely to be a long-term resident of the EW (adult crab often exhibit seasonal use of shallow habitats and select protected environments as juveniles), cancrid crab are anticipated to be present in the EW. Graceful crab are typically the most abundant, but red rock and Dungeness crab have also been found in the EW. Cancrid crab of any species collected in the EW will be considered the ROC because they all have similar exposure regimes, and it may be difficult to collect a sufficient number of any one species. In addition, the crab data will be used for the evaluation of risk to birds, mammals, and people, all of which may consume any cancrid crab species.

4.3.2 Fish

For the purpose of ROC selection, the fish community was grouped into the following four broad categories based on habitat use, life stage, and trophic level to represent their potential sediment exposure at the site:

- **Anadromous juvenile salmonids** – representing juvenile salmon that commonly feed on plankton and epibenthic organisms in shallow nearshore areas of estuaries during their outmigration, including juvenile Chinook, chum, and coho salmon. Juvenile Chinook salmon are also listed as a threatened species under the Endangered Species Act (ESA).
- **Planktivorous fish** – representing fish that live primarily in the water column and feed primarily on water column or encrusting organisms, including herring, pile perch, surf smelt, longfin smelt, and three-spine stickleback.
- **Benthivorous fish –** representing benthic fish that live on or near the sediment and primarily feed on infaunal and epifaunal organisms, including English sole, rock sole, starry flounder, and shiner surfperch. Fish in this category are more exposed than fish such as Pacific herring and pile perch, which prey on lower-trophic-level water column and encrusting organisms.
- **Upper-trophic-level fish –** representing higher-trophic-level organisms that have multiple exposure pathways and a higher potential to bioaccumulate selected chemicals, including brown rockfish, quillback rockfish, sand sole, and Pacific staghorn sculpin.

Based on the key considerations outlined in Section 4.3, the following three fish species were selected as ROCs to represent the four broad categories of fish in the EW:

- Juvenile Chinook salmon
- English sole
- Brown rockfish

The subsections that follow discuss the rationale for selecting each fish ROC and how these species serve as surrogates for the protection of other similar and important species within the EW.

4.3.2.1 Juvenile Chinook Salmon

Juvenile Chinook salmon were selected primarily because the Puget Sound evolutionary significant unit of Chinook salmon (to which the Green River belongs) is a federally threatened species under ESA. In addition, juvenile Chinook salmon serve as a surrogate for other juvenile anadromous salmon. Based on beach seine data, juvenile Chinook salmon are also among the most abundant fish in the EW during their spring outmigration (Shannon 2006) and are an important prey item for birds, piscivorous fish (Davis 2007; Warner and Fritz 1995), and possibly marine mammals. Residence times of all species of juvenile salmonids in the EW are uncertain; however, juvenile Chinook salmon are generally regarded as the most estuarine-dependent juvenile salmonid and their exposure to sediment-associated chemicals is likely equal to or greater than that of other juvenile salmonids.

Juvenile Chinook salmon are exposed to sediment-associated chemicals primarily through their ingestion of benthic invertebrates, which are an important prey item in their early estuarine residence (Cordell et al. 1999). Juvenile Chinook salmon have been studied in the LDW. Whole-body and stomach contents tissue chemistry data are available to characterize their exposure within the EW and just upstream in the LDW. Although toxicity data are available for several salmonid species, there are insufficient data to suggest that any one juvenile salmon species is more sensitive than another; therefore, available toxicity data did not affect the selection of juvenile Chinook as an ROC over other juvenile salmonids. Chinook salmon are also culturally and economically important in the Pacific Northwest. Adult Chinook salmon have been used for centuries by indigenous people as a primary food source and are an economic resource for the region as a commercial fishery species.

4.3.2.2 English Sole

English sole (*Pleuronectes vetulus*) were selected to represent benthivorous and planktivorous fish in the EW. English sole live in close proximity to sediment and, thus, have a high potential for direct exposure to sediment-associated chemicals. In addition, English sole feed extensively on infaunal and epifaunal invertebrates and, thus, are exposed to sediment-associated chemicals through their diet. Based on trawl data, English sole are one of the most abundant fish in the EW (Windward 2006a).

As discussed in Section 4.2.2.2, English sole may exist in discrete populations with some site fidelity (Day 1976); however, home ranges of English sole in the EW likely extend beyond the boundaries of the EW. A few home range estimates have been developed for English sole using best professional judgment; these include a 9-km^2 home range, as reported in the Puget Sound Dredged Disposal Analysis (PSDDA) Report (PSDDA 1988), and a 2-km^2 home range based on a literature review (Stern et al. 2003).

English sole whole-body tissue chemistry data are available to characterize their exposure within the EW and the LDW. A number of studies have examined the potential effects of sediment-associated chemicals (e.g., PAHs) on flatfish in the LDW, particularly English sole (e.g., Johnson et al. 1997). Several toxicology studies have used data from English sole collected in the Duwamish Waterway upstream of the EW, near Kellogg Island (Casillas et al. 1991; Johnson and Landahl 1994; Johnson et al. 1988, 1997, 1998, 1999; Kubin 1997; Malins et al. 1984, 1985a, 1985b; Schiewe et al. 1989). National Marine Fisheries Service (NMFS) data suggest English sole are as sensitive to the effects of PAHs as other flatfish species tested (Myers et al. 1998). Available toxicity data are not sufficient to suggest that English sole are more or less sensitive than other EW species represented by English sole. Therefore, except for regionally specific studies conducted with English sole, no preference has been given to toxicological data for fish closely related to English sole. English sole are caught recreationally in the EW and have some value as a commercial fishery species in northern Puget Sound. The south Puget Sound fishery was closed in 1989 due to declining abundance (Pallson 2001); however, multi-agency efforts to restore Puget Sound are expected to result in increasing abundances of many declining species. Puget Sound-wide restoration efforts could increase English sole abundance to a point where a viable south Puget Sound fishery is possible.

English sole is a surrogate for other pelagic, benthopelagic, and demersal fish species. In general, benthic organisms preyed on by other fish in the EW are similar to those preyed on by English sole, so its primary exposure route to sediment-associated chemicals is similar to that of other fish with similar diets. English sole likely has higher exposure to sediment-associated chemicals than other demersal fish because it prefers to live on fine-grained sediments, which tend to accumulate chemical contaminants more readily than coarse-grained sediments. English sole also likely has a relatively smaller home range than other demersal benthivores at a similar trophic level, resulting in relatively greater site-specific exposure. Therefore, exposure of English sole to sediment-associated chemicals is assumed to be greater than or similar to that of fish with similar habitat and prey preferences (e.g., starry flounder, rock sole, and sanddab species).

Other EW fish, such as pile perch, ingest organisms that encrust pilings and other hard structures. However, because these prey organisms do not have direct contact with sediment, this exposure route is not likely to result in a greater exposure to sediment-associated chemicals than would the ingestion of benthic invertebrates. Similarly, fish species at a trophic level similar to that of English sole, such as herring, surf smelt, longfin smelt, and three-spine stickleback, which ingest significant quantities of pelagic prey, are likely to have less exposure to sediment-associated chemicals than do English sole that consume benthic prey exclusively. English sole are also present in the EW year round, except during spawning migrations; therefore, these other fish are not likely to have a higher residence time in the EW than English sole. The available information thus indicates that the assessment of risks associated with exposure to sediment-associated chemicals for

English sole will be protective of fish with benthopelagic, demersal, and benthic habitat preferences.

4.3.2.3 Brown Rockfish

Brown rockfish were selected to represent upper-trophic-level fish in the EW. Brown rockfish are long-lived demersal fish that feed on fish and larger invertebrates than do English sole, thus increasing their potential exposure to bioaccumulative and biomagnifying chemicals, such as mercury and PCBs. Upper-trophic-level fish may have higher body burdens of biomagnifying chemicals than do lower-trophic-level fish, such as English sole, that ingest primarily invertebrates. Because brown rockfish are long-lived compared to some other upper-trophic level fish in the EW, they can be exposed for longer periods and, thus, have a greater potential to bioaccumulate chemicals over time.

Brown rockfish are noted to be relatively sedentary, with home ranges that range from 30 m^2 or less on artificial and high-relief reefs to 90 to 1,500 m^2 on low-relief reefs where bull kelp is present (Matthews 1990b). Their home range in the EW is uncertain because the availability of these habitats in the EW is uncertain. Based on reported habitat preferences (Love 1996; Matthews 1990b), brown rockfish in the EW are likely to be associated with pier structures, riprap, or other debris (e.g., old tires).

Brown rockfish likely serve as a food resource for piscivorous wildlife such as harbor seals (NMFS 1997) and river otters (Strand 1999; as cited in King County 1999). Brown rockfish tissue data are available from the EW and Elliott Bay. Limited toxicity data were identified for brown rockfish or closely related species; therefore, it is not known whether brown rockfish are more or less sensitive than other higher-trophic-level fish species. Brown rockfish are a valuable sport fish in Puget Sound and brown rockfish catch is increasing relative to copper and quillback rockfish (Pallson 2001). In the Pacific, brown rockfish is a commercially valuable species (although not in Puget Sound) (Love 2002).

Other piscivorous fish, including quillback rockfish, copper rockfish, Pacific staghorn sculpin, and sand sole, are also upper-trophic-level species that have been observed in the EW or close by. It is believed that sandsole foraging ranges likely extend beyond the EW and that brown rockfish feed at a higher trophic level than Pacific staghorn sculpin. Based on habitat preferences and trawl data, brown rockfish are probably more abundant in the EW than copper or quillback rockfish, so brown rockfish better represent exposure in the EW than these other piscivores.

4.3.3 Wildlife

Potential wildlife ROCs were considered for selection from the following four categories:

- **Piscivorous birds** – representing birds that consume primarily fish, including osprey, great blue heron,[14] cormorants, western grebe, and bald eagle[15]
- **Piscivorous/benthivorous birds** – representing birds that consume both fish and benthic invertebrates, including pigeon guillemot and mergansers
- **Benthivorous birds** – representing birds that consume primarily benthic invertebrates, including spotted sandpiper, bufflehead, and goldeneye
- **Piscivorous mammals** – representing mammals that consume primarily fish, including river otter, harbor seal, and sea lion

These categories were considered because representative species are expected to have a higher dietary exposure to chemicals than that of other species that may occur in the EW, because their prey items have a higher trophic status or are more closely associated with sediment.

Other wildlife, such as herbivorous birds (e.g., geese), passerine birds (e.g., pigeons), or omnivorous mammals (e.g., raccoon), are assumed to be less exposed to chemicals in the EW than those listed above because of their foraging behavior and diet. Birds that are primarily herbivorous, such as geese and some diving ducks, may also consume a small amount of benthic invertebrates and may incidentally ingest sediment while foraging, but to a lesser extent than benthivorous birds that feed primarily on benthic invertebrates. Most passerine birds are likely to experience limited exposure to

[14] Great blue heron consume primarily fish, but may also consume benthic invertebrates such as shrimp and crabs.

[15] Bald eagles are primarily piscivorous, but may also be considered carnivores because they may consume a small portion of birds and mammals in their diet.

contaminated sediments in the EW because they primarily use upland habitat. Other mammals, such as raccoons, are expected to have less exposure to sediment-associated chemicals because their food is largely terrestrial in origin, especially when compared to the primarily piscivorous mammals, such as river otter and harbor seal.

Based on the key considerations outlined in Section 4.3, the following four wildlife species were selected as ROCs in the EW:

- Osprey – piscivorous birds
- Pigeon guillemot – piscivorous/benthivorous birds
- River otter – piscivorous semi-aquatic mammals
- Harbor seal – piscivorous marine mammals

An ROC was not selected to represent benthivorous birds because there is very little habitat in the EW to support the birds in this category (spotted sandpiper, bufflehead, and goldeneye). Pigeon guillemot is expected to have higher exposure than benthivorous birds because a higher proportion of their diet is likely to be obtained from the EW, as discussed in more detail in Section 4.3.3.2. The following subsections present the rationale for the selection of each ROC and discuss how these species will serve as representative species for the protection of other species in the EW.

4.3.3.1 Osprey

The osprey (*Pandion haliaetus*) was selected to represent piscivorous birds; osprey was also selected as an ROC for the LDW ERA. Ospreys are generally present in Washington from late March or early April to August or September. Ospreys are known to nest along the EW, with one nest located at T-104 and one at T-18 (Blomberg 2007). Ospreys also nest along the LDW just south of the EW. Ospreys prefer to feed close to the nest during fledgling development. During a survey by the U.S. Fish and Wildlife Service (USFWS) and U.S. Geological Survey (USGS) in April and May 2006, osprey nesting at T-104 and T-18 were observed to capture 67 and 15 percent, respectively, of their prey from the LDW[16] and the remainder from Elliott Bay or Lake Washington (Davis 2007). Ospreys are particularly sensitive to

[16] The survey results did not indicate whether fish captured from the LDW were from within the EW or from locations south of the EW.

pesticides, which cause eggshell thinning. Exposure to pesticides through the mid-1970s resulted in the drastic reduction of osprey populations. In the 1970s, following the reduced use of many pesticides, most populations increased rapidly. Because ospreys nest along the EW, they are exposed to EW chemicals during the sensitive reproductive period, and are thus more susceptible to adverse effects than other piscivorous birds that winter in the area but migrate elsewhere for breeding. Ospreys generate high human interest and are protected under the Migratory Bird Treaty Act.

Osprey was selected as an ROC rather than bald eagle, which also breeds in the area, is susceptible to eggshell thinning, and is listed as a threatened species. Both osprey and bald eagle are exposed during sensitive reproductive stages, but osprey were selected because of their higher incidence in the EW, their smaller foraging range, and their higher ingestion rates normalized for body weight. Thus, risk estimates for osprey should be similar to or higher than those for bald eagles. In addition, information is available on the feeding preferences of osprey nesting at T-104 and T-18 as part of the USFWS and USGS study (Davis 2007). Although bald eagles are listed under ESA as a federally threatened species, all raptors tend to have high human interest and ecological significance.

Other piscivorous birds are less exposed than osprey either because they are not present year-round or because of limited habitat. For example, western grebes are common in the LDW during winter months, but they breed in inland areas east of the Cascades (Canning et al. 1979). Great blue herons forage while wading in shallow water, and there are very few shallow water habitats in the EW. Thus, osprey is expected to be more exposed to EW chemicals than are other piscivorous birds such as western grebe and great blue heron, because a higher proportion of the osprey's diet is likely to be obtained from the EW, particularly during the sensitive reproductive period.

4.3.3.2 Pigeon Guillemot

The pigeon guillemot (*Cepphus columba*) was selected to represent birds that consume both fish and benthic invertebrates or mostly invertebrates. Pigeon guillemot was selected primarily because it is present year-round and breeds along the EW, exposing females during egg development and the young during their most sensitive life stage. In addition, pigeon guillemots dive for prey in deep waters and are, therefore, not limited by the deeper water habitat of the EW. Pigeon guillemots are valued by society as a wildlife species and are protected under the Migratory Bird Treaty Act, as are the other potential ROCs consuming both fish and benthic invertebrates (i.e., mergansers) or primarily benthic invertebrates (i.e., spotted sandpiper, bufflehead, and goldeneye). Species-specific toxicity data are not available to indicate whether one potential ROC is more sensitive to chemical exposures than another. Thus, the primary consideration for selecting pigeon guillemot was the potential for higher exposure because of feeding habits and site use. The remainder of this section describes the rationale for selecting pigeon guillemot rather than mergansers, spotted sandpiper, bufflehead, or goldeneye.

The pigeon guillemot was chosen rather than a merganser species primarily because mergansers use the site less frequently based on presence and foraging habitats. However, the trophic positions of pigeon guillemot and mergansers are similar, with mostly small fish and some crustaceans consumed. Exposure to EW chemicals is expected to be less for mergansers than for pigeon guillemots for the following two reasons:

- Common and red-breasted mergansers are not known to breed along the LDW or the EW, and hooded mergansers may overwinter but have not been reported to nest along the LDW or the EW, whereas pigeon guillemot are present year-round in Puget Sound and have nests along the EW
- Deeper waters of the EW are likely to provide more foraging habitat for pigeon guillemot, which have an optimal diving and foraging efficiency in water 10 to 20 meters deep (Ewins 1993), whereas mergansers prefer shallower water (Mallory and Metz 1999; Dugger et al. 1994; Titman 1999)

Pigeon guillemots are expected to be more exposed than the benthivorous buffleheads and goldeneyes because these diving ducks forage primarily in water depths less than 5 meters (Eadie et al. 2000; Gauthier 1993). Most of the EW is deeper than 5 meters, so it is not likely that these diving ducks obtain much of their prey from the EW. Bufflehead and goldeneye are lower trophic level consumers than pigeon guillemot, consuming primarily invertebrates such as mussels, snails, shrimp, and small crabs; thus, they are less exposed to bioaccumulative chemicals. In addition, buffleheads and goldeneyes do not breed in the vicinity of the EW, so they are not exposed during their most sensitive life stages.

There are more uncertainties regarding the relative exposure of spotted sandpiper than mergansers, buffleheads, and goldeneyes compared to pigeon guillemot because spotted sandpipers may breed in the vicinity of the EW. During a spotted sandpiper site use survey of the LDW (Windward 2004), the closest potential sandpiper nesting habitat to the EW was observed at the T-105 restoration area along the LDW just south of the EW (Map 4-2), although actual nests were not observed. It is unlikely that there are any areas closer to the EW that would be conducive to nesting. Nesting areas are characterized by the presence of shrubs, broad vegetation, slight gradient, and limited human activity. Assuming that spotted sandpipers could forage in intertidal areas up to 1 mile (1.6 km) from a potential nest at T-105 (Norman 2002), there are approximately 16 hectares (ha) of foraging area within the LDW, compared to approximately 1 ha in the EW. Thus, it can be roughly estimated that spotted sandpipers nesting closest to the EW might obtain 6 percent of their diet (1 ha in the EW of the total 17 ha in both the EW and LDW) from intertidal areas within the EW.

Limited data are available to estimate the foraging range of pigeon guillemots; Ewins (1993) cited other reports that document home ranges varying from 0.2 to 7 km from the nest, and Litzow and Piatt (2003) observed that radio-tagged pigeon guillemots foraged only in the area in which they nested, although the size of that area was not defined. Based on this limited information, the percentage of the pigeon guillemot diet obtained from the EW could be less than 10 percent or as much as 100 percent. Even with these uncertainties, it is likely that pigeon guillemot consume a higher percentage of prey in their diet from the EW than do spotted sandpiper.

Other factors that would affect the relative comparison of the dietary exposures of spotted sandpipers and pigeon guillemots are: 1) prey preferences, 2) food ingestion rate normalized for differences in body weight, and 3) sediment ingestion rate as a percentage of the food ingestion rate. Data are not available to compare chemical concentrations in benthic invertebrates from intertidal areas (i.e., sandpiper prey) with those in benthic fish and invertebrates from both intertidal and subtidal areas (i.e., pigeon guillemot prey). Spotted sandpipers have higher food and sediment ingestion rates than do pigeon guillemots. However, based on the paucity of foraging habitat for spotted sandpipers, the spotted sandpiper was not selected as an ROC.

4.3.3.3 River Otter

The river otter (*Lutra canadensis*) was chosen from the three semi-aquatic mammals that use the EW (i.e., river otters, raccoons, and muskrats) because river otters are suspected to be year-round residents that may reproduce and feed in and around the EW. The river otter is susceptible to the biomagnification of chemicals because of its high trophic position and feeding habits, and because it is more likely to feed on fish or other prey from the EW than are raccoons or muskrats. River otters are in the same family as mink, which are known to be highly sensitive to PCBs and other chlorinated organic compounds, and relevant toxicological data are available for mink. River otters also attract a high level of societal interest.

4.3.3.4 Harbor Seal

The harbor seal (*Phoca vituluna*) was chosen from the three marine mammals that may use the EW (i.e., harbor seals, sea lions, and harbor porpoises) to represent piscivorous mammals. All three of these marine mammals are susceptible to the biomagnification of chemicals because of their trophic position and feeding habits. All are suspected to be sensitive to PCBs and other chlorinated organic compounds (Calambokidis et al. 1985; Tanabe et al. 1994), and toxicological data are available for mammals in general, although these data are not specific to marine mammals. In addition, all three species are protected under the Marine Mammal Protection Act and attract a high level of societal interest. There is more anecdotal evidence of the presence of harbor seals in the EW than the other marine mammals, so it is assumed they feed more often in the EW. In addition, the harbor seal was evaluated as an ROC in the LDW RI (Windward 2006c). Therefore, based on the likelihood of higher use of the EW by harbor seals and consistency with the LDW RI, the harbor seal was selected as an ROC for the EW. It is assumed that the harbor seal will act as a surrogate species for other marine mammals, such as sea lions or harbor porpoises. Orcas are not known to inhabit the EW, although they are observed infrequently in Elliott Bay (Traxler 2006). Orcas feed on salmon, which spend a small part of their lives in the LDW or EW and, therefore, have a low exposure to sediment-associated chemicals in the EW.

4.3.4 Summary

In summary, the following species were selected as ROCs to represent the range of organisms exposed to sediment-associated chemicals in the EW:

- Benthic invertebrate community
- Cancrid crab species – higher-trophic-level benthic invertebrate
- Juvenile Chinook salmon – anadromous juvenile salmon
- English sole – benthivorous fish
- Brown rockfish – upper-trophic-level fish
- Osprey – piscivorous bird
- Pigeon guillemot – piscivorous/benthivorous bird
- River otter – piscivorous semi-aquatic mammal
- Harbor seal – piscivorous marine mammal

The key considerations used in selecting each of the above receptors are summarized in Table 4-1.

Table 4-1
Receptors of Concern Selected for the East Waterway and Summary of Rationale for Selection

Receptor of Concern	Exposure Route	Ecological Significance	Societal Significance	Site Use	Exposure Data Availability	Sensitivity
Benthic invertebrate community	Direct contact with sediment; direct or incidental sediment ingestion; ingestion of contaminated prey; direct contact with water	Food source for other invertebrates, fish, birds, mammals; nutrient cycling; sediment oxygenation	Surrogate for the protection of aquatic communities	Present year-round; multiple life stages, diverse phyla	Abundant surface sediment data available	Range of chemical sensitivities represented
Cancrid crab	Direct contact with sediment; incidental sediment ingestion; ingestion of contaminated prey; direct contact with water	Higher-trophic-level benthic invertebrate; food for other invertebrates, fish, birds, and mammals	Recreational and commercial value	Present seasonally; multiple life stages (gravid females, juveniles)	Site-specific tissue data available	Effects data available for decapods; sensitivity relative to other decapods unknown
Brown rockfish	Incidental sediment ingestion; ingestion of contaminated prey; direct contact with water	Higher trophic level fish; important prey item for fish, birds, and mammals	Some commercial (though not in EW) and recreational value	Adults and juveniles present year-round; may spawn in the EW	Site-specific tissue data and prey tissue data available	Effects data available for other fish species; relative sensitivity of rockfish unknown; potential for elevated exposure via bioaccumulation because of trophic position; long-lived
English sole	Direct contact with sediment; incidental sediment ingestion; ingestion of contaminated prey; direct contact with water	Important prey item for fish, birds and mammals; key benthic invertebrate predator	Some commercial and recreational value (though not in EW)	Juveniles present year-round; adults present except during spawning migrations to Puget Sound	Site-specific tissue data available	NMFS data suggest that they are as sensitive as other flatfish species
Juvenile Chinook salmon	Ingestion of contaminated prey; direct contact with water	Important prey item for fish, birds and mammals; seasonally one of the most abundant juvenile salmonids in the EW	T&E species; returning adults important to tribal, commercial, and sport fisheries	Generally present April to July; most estuary-dependent juvenile salmonid	Site-specific tissue data available	Sensitive to a wide range of chemicals
Osprey	Ingestion of contaminated prey and water; incidental sediment ingestion	High trophic level	Highly valued and well-studied bird of prey; protected under the Migratory Bird Treaty Act	Nests along the EW and likely forages in the EW	Site-specific prey tissue data available	Effects data available for other bird species; relative sensitivity of osprey unknown; potential for elevated exposure via bioaccumulation because of trophic position

Receptor of Concern	Exposure Route	Ecological Significance	Societal Significance	Site Use	Exposure Data Availability	Sensitivity
Pigeon guillemot	Ingestion of contaminated prey and water; incidental sediment ingestion	High trophic level	Valued in general as wildlife species; protected under the Migratory Bird Treaty Act	Nests observed along the EW	Site-specific prey tissue data available	Effects data available for other bird species; relative sensitivity of pigeon guillemot unknown; potential for elevated exposure via bioaccumulation because of trophic position
River otter	Ingestion of contaminated prey and water; incidental sediment ingestion	High trophic level	Highly valued by society	Limited data, although anecdotal information indicates year-round presence of a river otter family on Kellogg Island	Site-specific prey tissue data available	Mink are sensitive to some chemicals, such as PCBs although the relative sensitivity of river otter is unknown; potential for elevated exposure via bioaccumulation because of trophic position
Harbor seal	Ingestion of contaminated prey and water; incidental sediment ingestion	High trophic level	Protected under Marine Mammal Protection Act	Occasional use based on a survey in the EW	Site-specific prey tissue data available	Pinnipeds suspected to be sensitive to some chemicals, such as PCBs although the relative sensitivity of harbor seal is unknown; potential for elevated exposure via bioaccumulation because of trophic position

EW – East Waterway
NMFS – National Marine Fisheries Service
PCB – polychlorinated biphenyl
ROC – receptor of concern
T&E – threatened and endangered (species listed under the Endangered Species Act)

4.4 Conceptual Site Model

This section presents the ERA CSM, which is a graphical representation of exposure media, transport mechanisms, exposure pathways, exposure routes, and ROCs. It provides the basis for developing exposure scenarios to be evaluated in the exposure assessment component of the ERA. As specified in the SRI/FS Workplan (Anchor and Windward 2007), the details of specific exposure scenarios will be presented in the ERA Technical Memorandum.

For the purposes of the EW ERA, sediments are the assumed sources of chemicals for all exposures at the site, regardless of the actual exposure medium (e.g., tissue, sediment, surface water). Information on potential chemical sources to sediments will be discussed in the forthcoming Initial Source Screening and Data Gaps Memorandum. The exposure assessment for each ROC will focus on scenarios that include direct or indirect pathways for sediment-associated chemicals. Examples of direct pathways include ingestion of sediment or direct contact with sediment. Indirect pathways include ingestion of aquatic biota that have been exposed to contaminated media. Because of the potential flux of chemicals from sediment to surface water, ecological receptors may also be indirectly exposed to sediment-associated chemicals through ingestion of surface water or contact with surface water.

To understand the potential exposure pathways of a chemical from sediment to biota, including upper-trophic-level ROCs, knowledge of general food web relationships is important. Figure 4 shows a generalized food web diagram for the EW, including uptake from sediment. A more specific food web diagram (Figure 5) shows the interrelationships for the selected ROCs; this figure presents only the ROCs and does not include all prey types of each ROC. The relationship among trophic levels illustrates the pathways for chemical transfer through the ingestion of prey. Figures 4 and 5 are used to further illustrate exposure pathways through the food web; the components of the food web are represented as "biota" in the CSM (as shown in Figures 6 and 7).

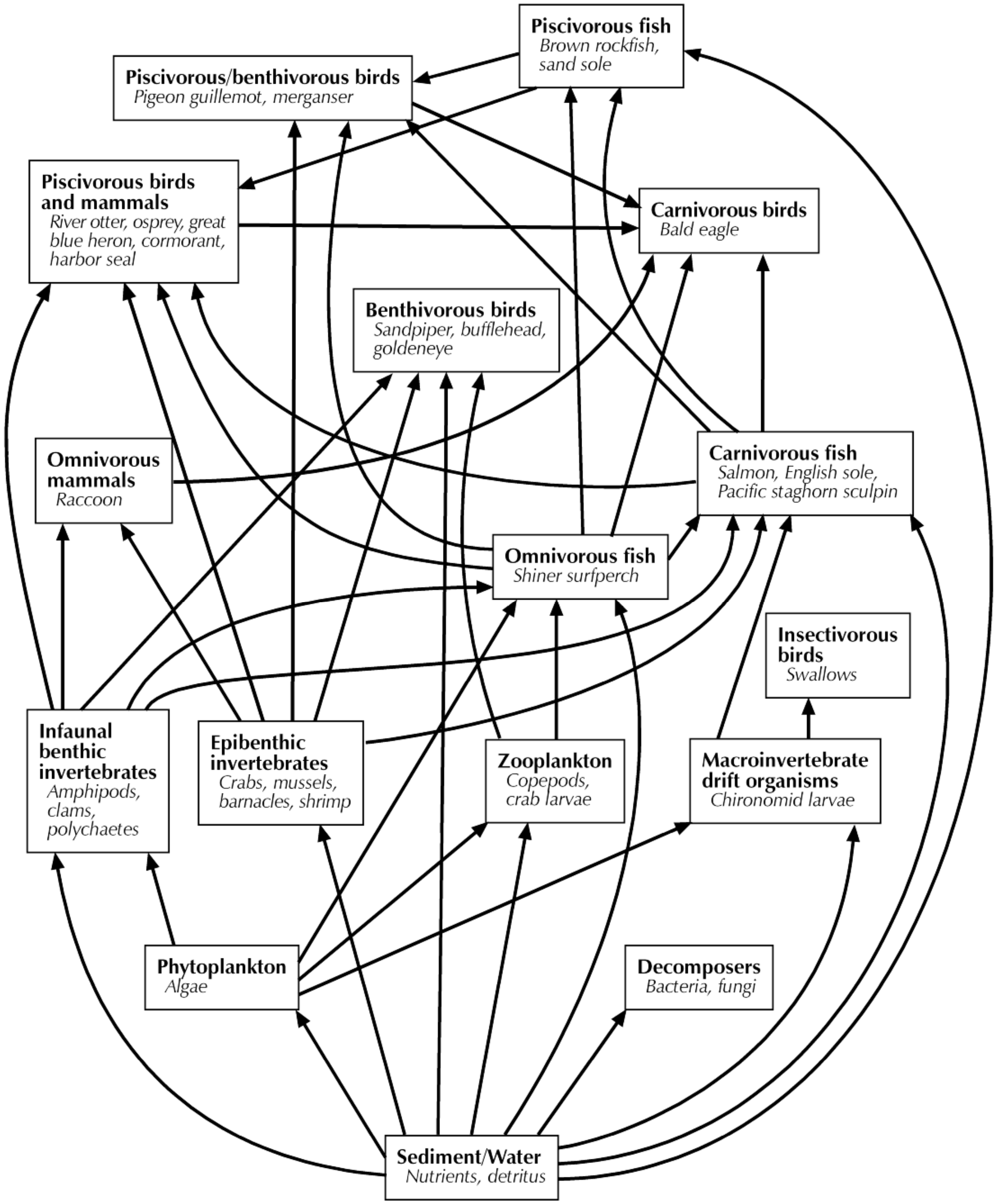
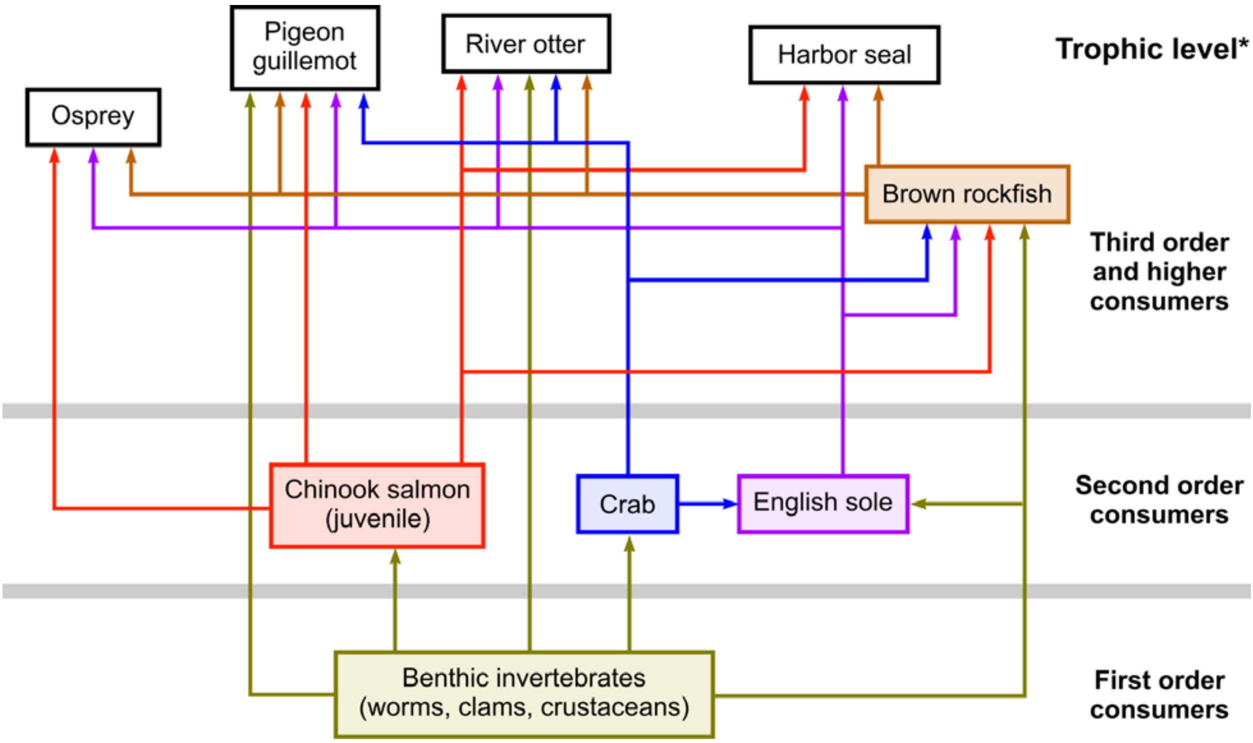


Figure 4 Generalized Food Web Diagram for the East Waterway



* Not all species feed at only one trophic level. In addition, feeding is site-specific and trophic levels tend to increase with the organism's age. Therefore, the trophic level identified for each species is approximate.

Figure 5 Food Web Diagram Illustrating Connections Between Receptors of Concern for East Waterway ERA

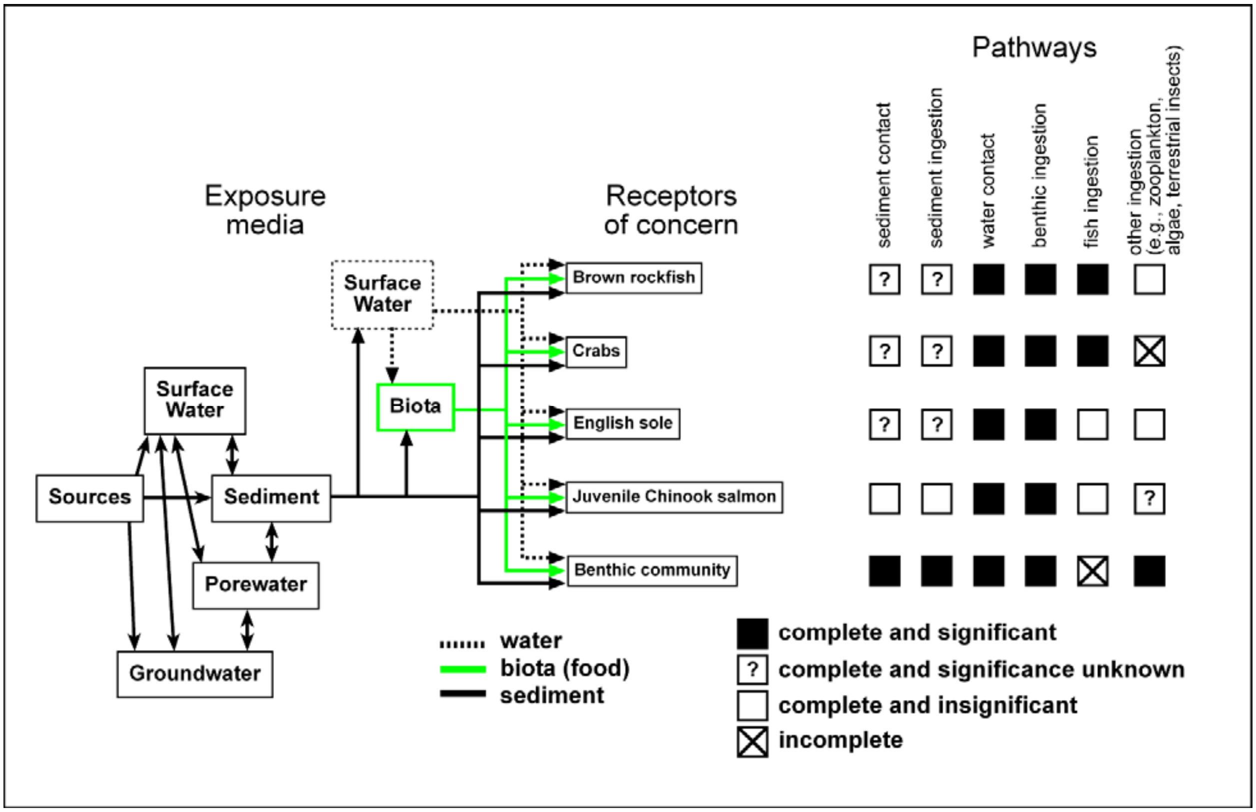


Figure 6 Conceptual Site Model for Fish, the Benthic Invertebrate Community, and Crabs

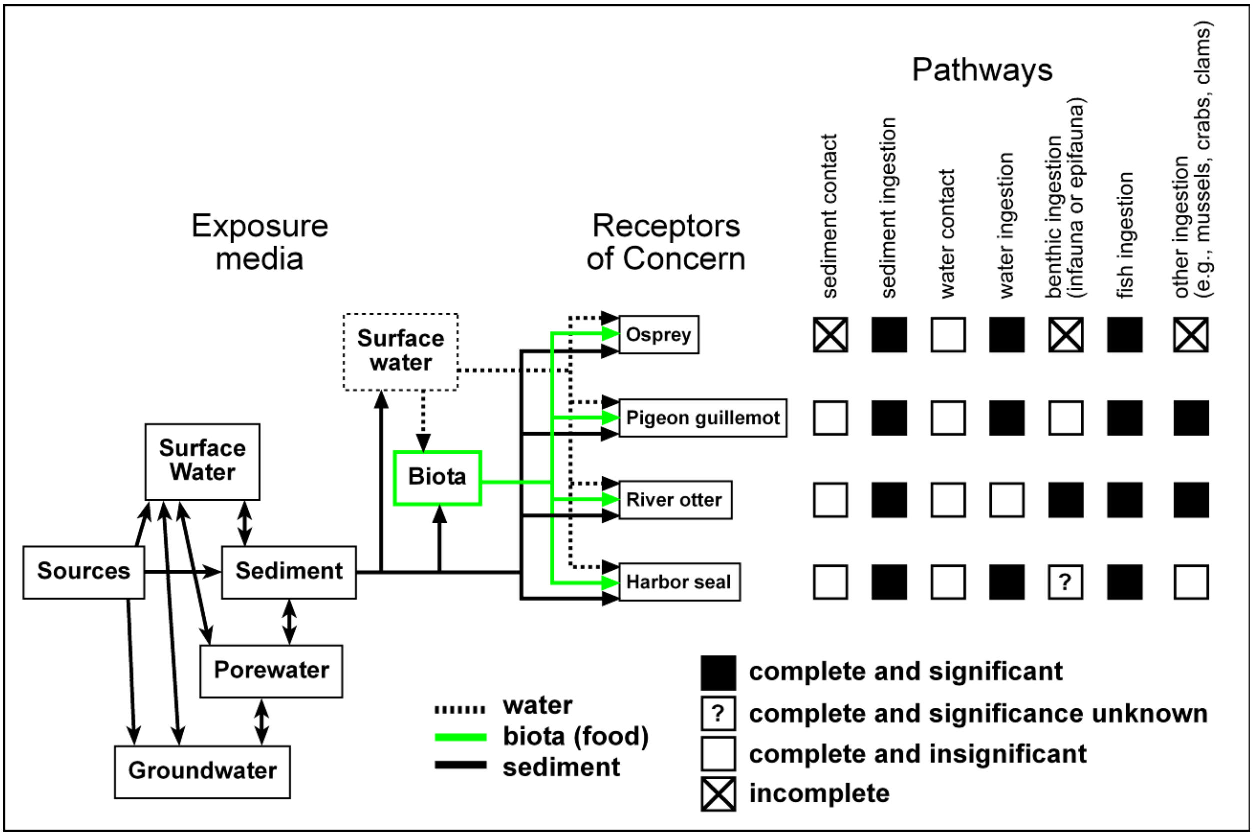


Figure 7 Conceptual Site Model for Wildlife

For chemicals to pose a risk to ROCs, the exposure pathway must be complete. Identifying complete exposure pathways prior to conducting a quantitative evaluation allows for a focused evaluation (EPA 1997a, b). An exposure pathway is considered complete if a chemical can travel from a source to an ecological receptor and the receptor is exposed via one or more exposure routes (EPA 1997a, b). Complete pathways can be of varying importance, so key pathways that reflect maximum exposures of ecological receptors sensitive to a chemical (EPA 1997a, b) are identified as having more importance than pathways that are likely to provide a very low fraction of the total exposure of an ROC to a chemical.

Exposure pathways for ROCs to sediment-associated chemicals in the EW were designated in one of four ways: complete and significant, complete and significance unknown, complete and insignificant, or incomplete. Each of the four designations is defined below. Figures 6 and 7 present the CSMs for fish and the benthic invertebrates and for wildlife, respectively.

- **Complete and significant:** There is a direct link between the ROC and chemical via this pathway, and the specific pathway is considered to be potentially important. Pathways classified as complete and significant will be addressed in greater detail in the exposure and effects assessment of the ERA.
- **Complete and significance unknown:** There is a direct link between the ROC and the chemical via this pathway; however, there are insufficient data available to quantify the significance of the pathway in the overall assessment of exposure. Pathways classified as complete and significance unknown will be discussed qualitatively in the uncertainty analysis section of the ERA.
- **Complete and insignificant:** There is a direct link between the ROC and the chemical via this pathway; however, the significance of this pathway in terms of overall exposure is considered to be very low. Pathways classified as complete and insignificant will not be evaluated in the ERA.
- **Incomplete:** There is no direct pathway between the ROC and the chemical. Pathways classified as incomplete will not be evaluated in the ERA.

For the benthic invertebrate community, complete and significant pathways include sediment contact, sediment ingestion, prey ingestion, and surface water contact (Figure 6).

Three of these pathways will be evaluated in the ERA; exposure of benthic invertebrates to surface water will be addressed via the sediment contact pathway because benthic invertebrates are typically not fully exposed to overlying water. Rather, porewater is the main water exposure and is accounted for both in sediment standards that are protective of benthic invertebrates and in the toxicity testing that will be used in the risk evaluation. In addition, benthic tissue residues will be evaluated for bioaccumulative contaminants and integrate all exposure pathways, including water. For crabs, prey ingestion and surface water contact are complete and significant, but the significance of the sediment ingestion and sediment contact exposure pathways are unknown. However, these pathways, along with the water exposure pathway, will be represented in tissue residue data and, thus, potential risks will be accounted for in the ERA.

For fish, the most important exposure pathway for sediment-associated chemicals in the EW is through prey ingestion (Figure 6). Water contact is also a complete and significant pathway for sediment-associated chemicals released into the surface water. Sediment contact and sediment ingestion are complete pathways for fish; they are insignificant for juvenile Chinook salmon, and the significance is unknown for brown rockfish and English sole.

For wildlife, ingestion of prey, surface water, and sediment are all complete and significant pathways that will be addressed in the ERA (Figure 7). Sediment and water contact are considered complete pathways for all wildlife ROCs, with the exception of sediment contact, which is incomplete for osprey. The complete water and sediment contact pathways are considered insignificant compared to other pathways because the feathers and fur on birds and mammals limits direct exposure of their skin.

4.5 Assessment Endpoints and Measures of Effect and Exposure

An assessment endpoint is an explicit expression of the ecological value that is to be protected (EPA 1992). Ecological values include those roles and processes vital to ecosystem function, those providing critical resources such as habitat and fisheries, and the perception of value by humans (e.g., important to tribal, commercial, and sport fisheries or valued for its beauty or intrinsic value by the general public). An assessment endpoint must define both the valued entity and the attribute of the entity to be protected. Assessment endpoints provide direction for the risk assessment and are the basis for the analyses; they are typically selected for a population of organisms based on organism-level attributes (e.g., survival, growth, or reproduction). In this risk assessment, the populations of receptor organisms are assumed to be those individuals that occur within the boundaries of the EW. For species with home ranges smaller than the EW, all individuals are assumed to reside solely within the EW. For species with home ranges larger than the EW, the individuals present in the EW are assumed to represent a distinct population with regard to chemical exposure, although they are not assumed to forage solely within the EW. For juvenile Chinook salmon, which is a threatened and endangered (T&E) species, risks to individual organisms are important (EPA 1998), although specific guidance is not available. Endpoints selected must be amenable to assessment, using existing data or data that will collected prior to the ERA.

Survival, growth, and reproduction are the endpoints that will be evaluated for all ROCs in this assessment. Reproductive effects considered for juvenile Chinook salmon will be limited to effects associated with the exposure of juvenile salmon because spawning and early life stages do not occur in the EW. Chinook salmon will be limited to reproductive effects occurring from exposure during smolt stage or later juvenile lifestages. Additionally, no data have been identified linking exposure of salmon as juveniles to chemicals such as PCBs, which could later cause reproductive effects in adults. Additionally, adult salmon are exposed to a variety of chemicals in Puget Sound and the Pacific Ocean for much longer periods of time compared to the very limited time spent in the EW. Therefore, the fraction of the total maternal chemical burden in adults accumulated from exposure to EW sources that would be passed on to embryonic life stages is very small compared to the fraction accumulated from other sources (O'Neill et al. 1998).

Biomarker and histological endpoints are not included as assessment endpoints; however, they will be considered for inclusion as measurement endpoints if they can be linked to adverse effects on growth, mortality, or reproduction. Typically, ERAs focus on ecological effects that integrate an overall response by an organism (e.g., survival, growth, or reproduction) rather than indicators of a biochemical response (i.e., biomarkers) that may or may not result in an ecologically relevant effect. For biomarkers to be useful in determining sediment-associated risk, there must be clear dose-response data relating exposure to ecologically significant effects. Biomarkers such as deoxyribonucleic acid (DNA) adducts and Cyp1a induction do not have clearly associated effects data and are thus categorized as a measure of exposure rather than as a measure of effect. Research is ongoing in the area of biomarkers to better understand their significance for potential use in ERAs.

Risk associated with each assessment endpoint is evaluated through measures of exposure and measures of effect, which are defined in EPA (1998) ERA guidelines as follows:

- Measures of exposure – Measures of stressor existence and movement in the environment and their contact or co-occurrence with the assessment endpoint
- Measures of effect – Measurable changes in an attribute of an assessment endpoint or its surrogate in response to a stressor to which it is exposed

Together, each unique combination of assessment endpoint, measure of exposure, and measure of effect constitutes a line of evidence to evaluate risk. Lines of evidence for the EW are presented in Table 4-2.

Table 4-2
Lines of Evidence for Risk Evaluation for the Selected Receptors of Concern

Receptor of Concern	Line of Evidence: Assessment Endpoint	Line of Evidence: Measure of Exposure	Line of Evidence: Measure of Effect	Method of Evaluation
Benthic Community				
Benthic invertebrates (infaunal/ epifaunal)	survival, growth, and reproduction of the benthic invertebrate community in the EW	chemical concentrations in surface sediment	SMS or DMMP criteria for those chemicals without SMS	comparison of measured chemical concentrations in sediment to SMS (or DMMP screening levels)
			site-specific laboratory sediment toxicity tests (10-day amphipod survival, bivalve or echinoderm larval survival and growth, and 28-day polychaete survival and growth)	comparison of amphipod survival in site-collected sediments with reference area amphipod survival
				Comparison of echinoderm or bivalve larval survival in site-collected sediment elutriates with reference area larval survival
				Comparison of echinoderm or bivalve larval growth in site-collected sediment elutriates with reference area larval growth
				comparison of polychaete survival in site-collected sediments with reference area polychaete survival
				comparison of polychaete growth in site-collected sediments with reference area polychaete growth
		Volatile organic chemical concentrations in porewater [a]	WQS and AWQC	comparison of chemical concentrations in porewater to WQS and AWQC
		Bioaccumulative chemical concentrations (i.e., PCBs, mercury, and TBT) in benthic tissue (laboratory-exposed or field-collected)	literature-reported tissue-residue-based TRV	Comparison of tissue burdens to tissue-residue-based TRV
Cancrid crab	survival, growth, and reproduction of crab in the EW	chemical concentrations in crab tissue	literature-reported tissue-residue-based TRV	comparison of chemical concentrations measured in tissue to tissue-residue-based TRVs for crab

Receptor of Concern	Line of Evidence			Method of Evaluation
	Assessment Endpoint	Measure of Exposure	Measure of Effect	
Fish				
Juvenile Chinook salmon	survival and growth of juvenile Chinook salmon in the EW	chemical concentrations in juvenile Chinook salmon whole-body tissue	literature-reported tissue-residue-based TRVs for chemicals evaluated using a critical tissue-residue approach [b]	comparison of chemical concentrations in juvenile Chinook tissue to tissue-residue-based TRVs
		chemical concentrations in benthic invertebrate tissue chemical concentrations in juvenile Chinook salmon stomach contents	dietary-based TRVs for chemicals evaluated using a dietary approach [c]	comparison of chemical concentrations in juvenile Chinook salmon prey, and juvenile Chinook salmon stomach contents to dietary-based TRVs
		chemical concentrations in surface water	WQS and AWQC for chemicals evaluated using a water approach [c]	comparison of chemical concentrations in surface water to WQS, AWQC, and literature TRVs
English sole	survival, growth, and reproduction of English sole in the EW	chemical concentrations in English sole whole-body tissue	tissue-residue-based TRVs for chemicals evaluated using a critical tissue-residue approach [b]	comparison of chemical concentrations in English sole tissue to tissue-residue-based TRVs
		chemical concentrations in benthic invertebrate tissue and surface sediment	dietary-based TRVs for chemicals evaluated using a dietary approach [b]	comparison of chemical concentrations in English sole prey and incidentally ingested sediment collected throughout the EW to dietary-based TRVs for fish
		chemical concentrations in surface water	WQS and AWQC for chemicals evaluated using a water approach [c]	comparison of chemical concentrations in surface water to WQS, AWQC, and literature TRVs
Brown rockfish	survival, growth, and reproduction of brown rockfish in the EW	chemical concentrations in brown rockfish whole-body tissue	tissue-residue-based TRVs for chemicals evaluated using a critical tissue-residue approach [b]	comparison of chemical concentrations in rockfish tissue to tissue-residue-based TRVs for fish
		chemical concentrations in benthic invertebrate tissue, juvenile Chinook salmon, prey fish [d] tissue, and surface sediment	dietary-based TRVs for chemicals evaluated using a dietary approach [c]	comparison of chemical concentrations in brown rockfish prey and incidentally ingested sediment collected throughout the EW to dietary-based TRVs for fish
		chemical concentrations in surface water	WQS and AWQC for chemicals evaluated using a water approach [c]	comparison of chemical concentrations in surface water to WQS, ,AWQC, and literature TRVs

Receptor of Concern	Line of Evidence			Method of Evaluation
	Assessment Endpoint	Measure of Exposure	Measure of Effect	
Wildlife				
Osprey [d]	survival, growth, and reproduction of osprey in the EW	chemical concentrations in fish tissue and water	dietary-based TRVs for birds	comparison of dietary dose calculated from chemical concentrations in fish and water to dietary-based TRVs for birds
Pigeon guillemot	survival, growth, and reproduction of pigeon guillemot in the EW	chemical concentrations in fish tissue, invertebrate tissue (e.g., crabs, shrimp, or mussels), surface sediment, and water	dietary-based TRVs for birds	comparison of dietary dose calculated from chemical concentrations in fish, invertebrates, sediment, and water to dietary-based TRVs for birds
River otter	survival, growth, and reproduction of river otter in the EW	chemical concentrations in fish tissue, invertebrate tissue (e.g., clams, crabs, or mussels), surface sediment, and water	dietary-based TRVs for mammals	comparison of dietary dose calculated from chemical concentrations in fish, invertebrates, sediment, and water to dietary-based TRVs for mammals
Harbor seal	survival, growth, and reproduction of harbor seal in the EW	chemical concentrations in fish tissue, surface sediment, and surface water	dietary-based TRVs for mammals	comparison of dietary dose calculated from chemical concentrations in fish, sediment, and water to dietary-based TRVs for mammals

Note: Surface sediment is defined as the biologically active zone (~10 cm).

a Porewater will be evaluated from intertidal areas adjacent to upland sites with known AWQC/WQS exceedances for VOCs in groundwater.

b A tissue-residue-based approach is preferred for most organic chemicals (excepting PAHs) because tissue concentrations reflect exposures from all pathways and tissue concentrations are more reflective of the concentration at the site of action than concentrations in exposure media.

c An exposure media (i.e., dietary and water) approach is preferred for PAHs and most metals (excepting mercury and butyltins) because fish readily metabolize PAHs and regulate their metals body burdens, thus, tissue concentrations of these chemicals poorly reflect concentrations associated with adverse effects.

d The USGS and USFWS collected osprey eggs from nests near the EW in 2006 and 2007 for chemical analysis (Davis 2007). If these data become available in time to incorporate them into the ERA, they may be compared to TRVs for egg concentrations as an additional line of evidence.

AWQC – Ambient Water Quality Criteria
DMMP – Dredge Material Management Program
ERA – ecological risk assessment
EW – East Waterway
LDW – Lower Duwamish Waterway
PAHs – polycyclic aromatic hydrocarbons
PCBs – polychlorinated biphenyls
QAPP – Quality Assurance Project Plan
ROC – receptor of concern
SMS – Washington State Sediment Management Standards
TBT – tributyltin
TRV – toxicity reference value
USGS – U.S. Geological Survey
USFWS – U.S. Fish and Wildlife Service
VOCs – volatile organic compounds
WQS – Washington State Water Quality Standards

5 DATA GAPS ANALYSIS

This section identifies data gaps associated with the HHRA and ERA CSMs, as well as those associated with describing the nature and extent of the contamination in the SRI and the data gaps for the FS. Data gaps associated with the STE are presented in the STEAM (Anchor and Battelle 2008) and data gaps associated with the SCE will be presented in the Initial Source Screening and Data Gaps Memorandum (upcoming deliverable). The data gaps analysis is based on information presented in the preliminary Physical Processes CSM, HHRA CSM, and ERA CSM in Sections 2, 3, and 4, respectively. Data gaps are also identified based on a review of existing EW data (as presented in the EISR [Anchor and Windward 2008a]). Section 5.1 presents the data gaps analysis for the SRI nature and extent evaluation. The data needs for the HHRA CSM and ERA CSM are identified in Sections 5.2 and 5.3, respectively, and are organized by matrix (sediment and tissue). Data needs for the FS are identified in Section 5.6. Each section in this chapter presents a summary of recommended studies for specific data needs.

5.1 Supplemental Remedial Investigation Nature and Extent Data Gaps

The SRI will include a discussion of the nature and extent of chemical contamination in the EW based on the available sediment, tissue, and water data. This section presents a review and summary of the existing sediment, tissue, and water data to assist in the identification of additional data needed for the SRI. These datasets are presented in detail in the EISR (Anchor and Windward 2008a).

5.1.1 Sediment Data Summary

Sediment data have been collected from the EW during numerous investigations. The existing sediment chemistry data for the EW have been separated into surface sediment samples, which include all samples collected from 0 to 10 cm (0-10cm), and subsurface sediment samples, which consist of core samples. Core samples collected to represent DMMUs were composited over relatively large depth horizons (generally 4 feet or greater) at core locations within the DMMUs, whereas core samples collected for the purpose of characterizing the vertical extent of contamination were sampled at smaller discrete depth intervals (generally in 1-foot intervals) at a particular core location. Surface and subsurface sediment samples collected from areas that were dredged after they had been sampled are not included in this discussion because they do not represent existing conditions in the EW.

The following subsections discuss the spatial distribution of samples throughout the EW and identify samples collected from intertidal and subtidal areas, as well as samples collected under pier structures. Intertidal areas are of particular interest for both the ERA and HHRA because they are important habitat areas for some ecological receptors and can be associated with human access areas for shoreline activities. Pier structures are the dominant shoreline feature in the EW (Section 1.2), and the areas under these structures have not been well characterized. Almost all of the sediment data were collected from subtidal areas in the EW as part of dredge characterization projects.

5.1.1.1 Surface Sediment

A total of 163 surface sediment (0-10cm) samples collected during 14 investigations have been considered suitable for use in the EW SRI/FS dataset (Map 5-1). The data quality of these 163 samples is discussed in Appendix F of the EISR (Anchor and Windward 2008a). Surface sediment samples were collected from many areas within the EW, with the highest density of sampling locations in the southern half of the EW from Station 3600 to Station 5000 (Map 5-1). All data of relevance were collected after 1990 in areas that were either not dredged or that were dredged prior to sample collection.

The majority of the surface sediment samples were collected as post-dredge monitoring samples and, thus, are located in subtidal areas. All surface sediment samples have been collected after 1990 (Anchor and Windward 2007). The numbers of surface sediment samples collected in the intertidal and subtidal areas are provided in Table 5-1. One sediment sample was collected in an intertidal area located under a pier in Slip 36 (Map 5-1). All other underpier surface samples were collected in subtidal areas as follows: Slip 36 (five samples from four locations), the northern end of T-18 (two samples), T-30 (one sample), Slip 27 (one sample), T-25 (one sample), and the southern end of T-18 (one sample).

Table 5-1
Number of Sediment Samples Collected in Subtidal, Intertidal, and Underpier Areas

Sediment Depth Horizon	Subtidal Samples (underpier samples)	Intertidal Samples (underpier samples)
Surface	162 (11)	1 (1)
Subsurface	132 (2)	0

The sediment bioassay data for the EW was presented in Section 3 of the EISR (Anchor and Windward 2008a). Surface sediment bioassays have been conducted at 55 locations throughout the EW (Map 5-1). The greatest density of bioassay samples were collected at the northern and southern ends of the EW with a cluster of six locations in the vicinity of T-25 (Map 5-1). Six surface sediment bioassays have been conducted with sediment samples collected under pier structures. No bioassay data for samples collected in the intertidal areas are available.

The nature and extent evaluation will require the collection of additional surface sediment samples in the subtidal areas that have not been extensively sampled (e.g., the southern end of the EW) and from the intertidal and underpier areas that have not been sampled previously. The assessment of the sufficiency of the bioassay data will be provided in the summary of data needs for the ERA (Section 5.3).

5.1.1.2 Subsurface Sediment

Subsurface core samples were collected over the 0- to 4-foot (0-4ft) interval and at intervals greater than 4 feet (>4ft) for 132 samples collected from 94 locations, as shown on Map 5-2. Most of the samples collected within the 0-4ft depth were composite samples collected for the purpose of dredge material characterization. An additional 14 locations for 0-4ft cores were segmented and analyzed in smaller depth intervals (e.g., four 1-foot depth intervals or three 1-foot depth intervals from 0.5 to 3.5 feet) (Map 5-2).

Fewer samples were collected at depths >4ft (i.e., 23 samples from 20 locations) (Map 5-2). These 20 locations are distributed throughout the EW, with the highest density clustered in the area from Station 5000 to Station 5800 (Map 5-2).

Recent dredging in areas of the EW, including the Stage 1 area (2000), T-30 (2002), Stage 1a area (2005), Phase 1 Removal Action area (2005), and the USCG dredge area (2005), removed the sediment that contained the subsurface sediment samples in those areas (Map 5-2). Finally, no subsurface samples were collected in the southern end of the EW, including the area under the West Seattle and Spokane Street Bridges. No subsurface sediment data are available for intertidal areas, and only two samples were collected from underpier areas (Map 5-2).

The nature and extent evaluation will require the collection of additional subsurface sediment samples from the subtidal areas that have not been extensively sampled (e.g., areas that have been recently dredged) and from intertidal and underpier areas that have not been previously sampled. The majority of the existing subsurface sediment samples are composite samples collected for the purposes of dredge material characterization. Subsurface cores sampled at discrete depth intervals will be needed for the SRI nature and extent evaluation and for the FS.

5.1.2 Tissue Data Summary

Six studies have reported tissue concentrations for fish and shellfish captured throughout the EW. The available tissue data are described in detail in Section 3 of the EISR (Anchor and Windward 2008a). Three English sole fillet composite samples were collected by EVS Environmental Consultants (EVS unpublished); six transplanted mussel samples were sampled and analyzed by King County (1999); and three red rock crab and six striped perch composite samples were collected by Environmental Solutions Group (ESG 1999). Windward collected six juvenile Chinook composite samples (Windward 2002) and then later collected six English sole composite samples, three shiner surfperch composite samples, two individual rock fish samples, and six individual sand sole samples (Windward 2006a). The chemicals that have been analyzed in fish and crab tissue are limited. The Windward 2002 and 2006a samples were analyzed for PCBs and mercury. The ESG 1999 samples were analyzed for PCBs, tributyltin (TBT), and mercury.

The nature and extent evaluation summarize the available tissue data. The adequacy of the available tissue data will be determined by the data requirements for the HHRA and ERA described in Sections 5.2 and 5.3.

5.1.3 Surface Water Data Summary

The surface water chemistry data for the EW are available for three investigations. One event was conducted by King County as part of their CSO water quality assessment (WQA) for the Duwamish River and Elliott Bay (King County 1999); the other two events (SEA 2000; Anchor and Windward 2005) were conducted to monitor water quality during dredging activities.

During the King County WQA (King County 1999), receiving-water samples were collected from three locations along a transect across the EW adjacent to the Hanford Street CSO. These water samples were collected as discrete grab samples at 1 meter below the water's surface and 1 meter above the bottom of the EW. Samples were collected over a 26-week period between October 1996 and June 1997, including sampling for 3 consecutive days following storm events, during which the Hanford CSO often had a discharge event. A large number of samples (approximately 200) were collected and chemically analyzed for this study.

In 2000, water quality monitoring (WQM) was conducted during dredging activities for the Stage 1 dredge event along T-18 (SEA 2000). Water quality field measurements of turbidity, dissolved oxygen, temperature, and salinity were routinely collected, and chemistry samples were collected twice during WQM activities (SEA 2000). Six water samples were also collected from locations 800 feet upstream of dredging operations to determine ambient conditions.

In 2004 and 2005, WQM was conducted during dredging activities for the EW Phase 1 Removal Action (Anchor and Windward 2005). Water quality field measurements of turbidity, dissolved oxygen, temperature, conductivity/salinity, and pH were routinely collected, and chemistry samples were periodically collected as part of WQM activities. Thirty-six water samples were also collected from locations 1,300 feet upstream of the dredging operations to determine ambient conditions.

Additional surface water data will be collected for a complete range of analytes. These data will be used to determine whether or not the historical dataset is representative of current conditions and to provide data for analytes that are not represented in the existing dataset (PAHs and PCBs). The King County WQA (King County 1999) analyzed water for PAHs, but there were no detected results. Water samples collected for the King County WQA were not analyzed for PCBs in the EW. PCBs were analyzed as Aroclors in the water quality monitoring studies and all results were nondetects.

5.1.4 Evaluation of Existing Chemistry Data

The following subsections briefly discuss the range of chemicals analyzed in each matrix and identify chemicals that have been analyzed in relatively few samples infrequently or have not been analyzed in any samples. This discussion will not be used to identify specific data needs, but rather to develop analyte lists for future sampling events. The analyte lists for each sampling event will be provided in the QAPP for that event.

5.1.4.1 Sediment

The complete list of analytes for the surface and subsurface sediment samples is presented in Appendix A (Table A-1). Because the majority of the sediment sampling was conducted for the purpose of dredge material characterization and post-dredge monitoring, chemicals with SMS criteria and DMMP guidelines are those that were most frequently analyzed. The chemicals can be divided into five chemical groups: metals, semivolatile organic compounds (SVOCs), PCBs and dioxins/furans, pesticides, and VOCs. In addition, conventionals, including grain size, sulphides, and TOC, were analyzed for all samples. Very few samples have been analyzed for acid volatile sulfides (AVS) (two surface sediment samples).

5.1.4.1.1 Metals

SMS metals and trace elements were analyzed in approximately 100 of the 163 surface sediment samples, with the greatest number of samples analyzed for mercury (159 samples). Approximately 125 of the 132 subsurface sediment samples were analyzed for metals and trace elements. TBT was analyzed in relatively fewer sediment samples (26 surface sediment samples and 55 subsurface sediment samples).

5.1.4.1.2 SVOCs

SMS SVOCs, including PAHs and phthalates, were analyzed in most of the 163 surface sediment samples, with 136 samples analyzed for PAHs and 123 samples analyzed for phthalates and other SVOCs. For subsurface sediments, SMS SVOCs, including PAHs and phthalates, were analyzed in 122 of the 131 subsurface samples.

5.1.4.1.3 PCBs and Dioxins and Furans

PCBs were analyzed in 160 of the surface sediment samples and 126 of the subsurface sediment samples. PCBs were analyzed as the sum of Aroclors in these samples. No sediment samples were analyzed for PCB congeners or for dioxins and furans.

5.1.4.1.4 Pesticides

Dichloro-diphenyl-trichloroethane (DDT) isomers (4,4′-DDT, 4,4′-DDE, and 4,4′-DDD) have been analyzed in 111 surface sediment samples and 124 subsurface sediment samples. The other organochlorine pesticides, including the 2,4′-DDT isomers, have been analyzed less frequently (18 to 56 surface sediment samples and 12 to 94 subsurface sediment samples).

5.1.4.1.5 VOCs

Most VOCs were analyzed very rarely (one surface sample and four subsurface sediment samples). Because of DMMP requirements, 82 subsurface sediment samples were analyzed for four VOCs (ethylbenzene, tetrachloroethene, trichloroethene, and total xylenes).

5.1.4.2 Tissue

The fish and crab tissue samples were analyzed for a limited number of analytes, including PCBs (as Aroclors), mercury, and TBT. King County (1999) conducted the only study with an extensive analytical list of chemicals, including metals, organometals, SVOCs, PCBs (as Aroclors), and pesticides, which were analyzed in composite mussel tissue samples. No tissue samples have been analyzed for PCB congeners or dioxins and furans.

5.1.4.3 Surface Water

The King County (1999) surface water samples were analyzed for a wide range of analytes such as metals, SVOCs, and conventional parameters (Appendix A). PCBs were not analyzed in any water samples collected from the EW during the King County (1999) study. WQM samples collected during dredging activities were analyzed for TSS, dissolved oxygen, metals (i.e., cadmium, lead, mercury, silver, and zinc), TBT ion, total PCBs (as Aroclors), and organochlorine pesticides. No surface water samples have been analyzed for PCB congeners.

5.1.4.4 Evaluation of Reporting Limits Associated with Non-Detected Results

This section compares the reporting limits (RLs) for non-detected analytes to risk-based analytical concentrations goals (ACGs). This analysis will be useful in determining analytical methods for future sampling work in the EW. The sample-specific RL is based on the lowest point of the calibration curve associated with each analytical batch of samples. The RL is a function of the analytical method used and may greatly overestimate the chemical concentration. The RL can be used as a surrogate for a concentration in cases where the analyte is not detected. However, when the RL is greater than a risk-based ACG, the resulting risk estimate may be highly uncertain.

The risk-based ACGs used for this comparison were developed for the evaluation of sediment RLs in the surface sediment QAPP for the LDW (Windward 2005a). The SMS are criteria developed for the protection of benthic communities and the direct-contact ACGs were based on EPA Region 6 risk-based concentrations (RBCs) for the protection of human health from exposures to soil (EPA 2002a). A more detailed discussion of the basis for the ACGs is presented in Appendix A. The RLs for surface sediment and surface water data are compared to ACGs in the following sections. The assessment of RLs relative to ACGs is not intended to provide a characterization of risk, but has been conducted in order to identify chemicals that may be affected by elevated RL values. No comparison was conducted for subsurface data because the subsurface data will not be used in the risk assessments. If exposure pathways are established for subsurface data, then the RL values will be evaluated. No comparison was conducted for the tissue data because of the extremely limited tissue dataset.

5.1.4.4.1 Surface Sediment Data

RLs for non-detected analytes in surface sediment were compared to ecological ACGs (i.e., SMS criteria and DMMP guidelines), direct-contact ACGs for human health (Appendix A, Table A-3), and to ACGs based on indirect exposure (consumption of tissue) (Appendix A, Table A-3).

Chemicals with RL values above ACGs were divided into six groups: metals (4 chemicals), PAHs (9 chemicals), phthalates (5 chemicals), other SVOCs (22 chemicals), pesticides (7 chemicals), and VOCs (1 chemical). The number of samples with RLs that exceeded ACGs in sediment samples is presented by chemical in Table 5-2.

Table 5-2
Number of Surface Sediment Reporting Limits that Exceeded Analytical Concentration Goals

Chemical	Detection Frequency		No. of RLs > SQS/SL	No. of RLs > CSL/ML	No. of RLs > Human Health Direct-Contact ACG	No. of RLs > Indirect Human Exposure ACG
	Ratio	%				
Metals and Trace Elements						
Antimony	8/49	16	0	0	41	0
Arsenic	75/111	68	1	0	36	36
Cadmium	88/102	86	0	0	0	14
Mercury	157/159	99	0	0	0	2
Selenium	0/14	0	NC	NC	5	0
Thallium	6/13	46	NC	NC	7	0
PAHs						
2-Methylnaphthalene	64/136	47	1	1	NC	1
Acenaphthene	84/136	62	1	1	0	0
Acenaphthylene	69/136	51	2	2	NC	0
Benzo(a)anthracene	127/136	93	0	0	NC	9
Benzo(a)pyrene	127/136	93	0	0	NC	9
Benzo(b)fluoranthene	130/136	96	0	0	NC	6
Benzo(k)fluoranthene	121/136	89	0	0	NC	1
Benzo(g,h,i)perylene	108/136	79	2	2	NC	NC
Dibenzo(a,h)anthracene	73/136	54	8	5	17	NC
Dibenzofuran	64/136	47	3	2	0	2

Chemical	Detection Frequency		No. of RLs > SQS/SL	No. of RLs > CSL/ML	No. of RLs > Human Health Direct-Contact ACG	No. of RLs > Indirect Human Exposure ACG
	Ratio	%				
Fluorene	89/136	65	1	1	0	NC
Indeno(1,2,3-cd)pyrene	109/136	80	2	2	2	27
Naphthalene	80/136	59	1	1	0	0
Phthalates						
Bis(2-ethylhexyl) phthalate	106/123	86	4	2	0	12
Butyl benzyl phthalate	38/122	31	13	2	0	0
Diethyl phthalate	0/123	0	2	1	0	0
Dimethyl phthalate	11/123	9	2	2	0	0
Di-n-octyl phthalate	2/123	2	2	0	0	1
Total PCBs	158/160	99	0	0	0	2
Other SVOCs						
1,2,4-Trichlorobenzene	28/147	19	35	18	0	NC
1,2-Dichlorobenzene	13/147	9	21	21	0	0
1,3-Dichlorobenzene	24/125	19	8	NC	2	NC
1,4-Dichlorobenzene	77/147	52	9	7	1	8
2-Chlorophenol	1/34	3	NC	NC	NC	2
2,4-Dimethylphenol	4/123	3	64	64	0	2
2-Methylphenol	2/123	2	22	22	0	NC
4-Methylphenol	27/123	22	3	3	0	2
2,4,6-Trichlorophenol	0/34	0	NC	NC	4	NC
3,3'-Dichlorobenzidine	0/32	0	NC	NC	2	NC
Benzoic acid	6/114	5	14	14	0	NC
Benzyl alcohol	0/114	0	19	13	0	NC
bis(2-chloroethyl)ether	0/34	0	NC	NC	6	NC
bis(2-chloroisopropyl)ether	0/34	0	NC	NC	1	NC
Carbazole	12/21	57	NC	NC	NC	2
Hexachlorobenzene	0/124	0	43	20	6	NC
Hexachlorobutadiene	0/124	0	15	12	0	26
Hexachloroethane	0/34	0	2	0	0	16
Nitrobenzene	0/34	0	NC	NC	1	NC
n-Nitrosodimethylamine	0/20	0	NC	NC	20	NC
n-Nitrosodiphenylamine	2/123	2	10	10	0	NC
n-Nitroso-di-n-propylamine	0/34	0	NC	NC	21	NC
Pentachlorophenol	8/123	7	23	10	2	NC
Phenol	53/123	43	3	1	0	NC
Pesticides						
DDTs (total calc'd)	12/111	11	58	2	0	99
Aldrin	3/56	5	4	NC	0	53

Chemical	Detection Frequency		No. of RLs > SQS/SL	No. of RLs > CSL/ML	No. of RLs > Human Health Direct-Contact ACG	No. of RLs > Indirect Human Exposure ACG
	Ratio	%				
Dieldrin	0/56	0	25	NC	5	56
gamma-BHC	0/56	0	4	NC	0	54
Heptachlor	2/56	4	4	NC	0	54
Total chlordane (calc'd)	2/51	4	14	NC	0	44
Toxaphene	0/32	0	NC	NC	5	NC
VOCs						
Ethylbenzene	0/1	0	1	0	0	NC

ACG – analytical concentration goals
CSL – cleanup screening level
ML – maximum level
NC – there is no associated criteria for this chemical
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
SL – screening level
SQS – Sediment Quality Standards
SVOC – semivolatile organic compound
VOC – volatile organic compound

The most common reason for elevated RL values is sample extract dilution. For example, elevated RLs for some chemicals in some areas reflect the fact that a greater degree of analytical dilution is required for the quantification of other analytes, such as PCBs. In addition, some analytes are known to be analytically difficult to detect at criteria or risk-based levels.

Metals and Trace Elements

Arsenic was the only metal or trace element with RLs that exceeded the Sediment Quality Standards (SQS) in the entire sediment dataset. Although arsenic was not detected in 32 percent of the surface sediment samples (and 10 percent of subsurface samples), only one non-detected sample had an arsenic RL that exceeded the SQS. Four metals in surface sediment samples had RL values above the direct-contact ACG for human health: antimony, arsenic, selenium, and thallium. In addition, three metals, arsenic, cadmium, and mercury, exceeded the indirect contact ACG for human health (Table 5-2).

PAHs and Phthalates

PAHs and phthalates were detected relatively frequently in surface sediments. Nine PAH compounds and five phthalates had at least one surface sediment sample with an RL above the SQS. RLs for two PAHs in the surface sediment samples exceeded the direct-contact ACG, and RLs for seven PAHs exceeded the indirect contact ACG for those chemicals (Table 5-2). RLs greater than the SQS chemical criteria for PAHs and phthalates primarily resulted from analytical dilution of the sample extracts.

Other SVOCs

The group of compounds labeled as "other SVOCs" includes chemicals that are analytically difficult to quantify at the levels required for comparison to SQS and DMMP chemical criteria and direct-contact ACGs (Table 5-2). Many of these compounds are generally rarely detected (Table 5-2). The specific compounds with elevated RL values tend to have chemical characteristics that differ from those of other analytes being analyzed using the same method. For example, benzoic acid, benzyl alcohol, phenols, and n-nitrosodiphenylamine are all more chemically reactive than are the other SVOCs analyzed by EPA Method 8270. More-reactive compounds can be difficult to extract and often degrade during analysis.

The chemicals with the greatest number of RLs above the SQS were the chlorobenzenes, 2,4 dimethylphenol, hexachlorobenzene, and 2-methyl phenol. The two chemicals with the greatest number of RLs above the direct-contact ACG were n-nitrosodimethylamine and n-nitrosodi-n-propyl amine. Finally, the chemicals with the greatest number of RLs above the indirect contact ACGs were 1,4-dichlorobenzene, hexachlorobutadiene, and hexachloroethane.

Organochlorine Pesticides

Organochlorine pesticides were rarely detected in EW sediments. Total DDTs had the highest detection frequency of all the pesticides and were detected in 11 percent of the 0-10cm sediment samples. RLs for these compounds were compared to the DMMP screening level (SL) value, direct-contact ACGs, and indirect contact ACGs (Table 5-2).

Total DDTs were the analytes with the greatest number of RLs above the DMMP SL and the indirect contact ACG. Dieldrin and toxaphene were the only pesticides with RL values above the direct-contact ACG.

Elevated RL values for organochlorine pesticides generally reflect the presence of probable analytical interference in the analysis because of the presence of PCB congeners. This issue was present in the LDW dataset, and additional analyses confirmed that the elevated RLs associated with pesticides resulted from the presence of PCB congeners (Windward 2005b).

5.1.4.4.2 Surface Water Data

Surface water reporting limits were compared to acute and marine chronic ambient water quality criteria (AWQC) values (EPA 2006b). The AWQC represented the ACGs for water data. The RLs associated with the results from the King County WQA (King County 1999) were all below their corresponding AWQC. For the Striplin Environmental Associates WQM data (SEA 2000), RLs for TBT exceeded the AWQC for five of the six samples. For the Windward WQM study (Anchor and Windward 2005), the RLs for all samples for lead, mercury, silver, TBT, total PCBs, dieldrin, and total DDT exceeded their corresponding AWQC. None of these chemicals were detected in any of the samples. For surface water samples, the RLs are generally determined by the volume of the water sample, with smaller samples resulting in higher RL values.

5.1.4.4.3 Summary

The chemical groups for which elevated RLs are of most concern are those groups of chemicals that are rarely detected and have RL values that are above criteria or risk-based goals. For sediment, organochlorine pesticides and other SVOCs are the chemical groups with the greatest uncertainty resulting from elevated RL values. For surface water samples, the results from the WQM data are less useful because of the elevated RLs associated with small-volume samples.

This analysis will be useful in determining analytical methods for future sampling work in the EW. For some analytes (e.g., pesticides), recently developed analytical methods can be employed to ensure that the RL values associated with non-detected results are below the ACGs. For samples requiring dilutions, the laboratory can be instructed to obtain as much data as possible from the undiluted sample, which should minimize the number of elevated RL values due to sample dilution. However, several analytes remain analytically challenging and available analytical techniques are not sensitive at the levels of the risk-based ACGs (e.g., n-nitrosodiphenylamine, benzyl alcohol, benzoic acid, and toxaphene). For these analytes, there will be uncertainty associated with the assessment of risks for non-detected results.

5.1.4.5 Summary of Chemistry Data Available for COPC Selection

There are insufficient data available for the EW to conduct a formal chemicals of potential concern (COPC) screen. The COPC screening process will be provided in the risk assessment technical memorandum. The screening used for the LDW risk assessments was based on available sediment and tissue data. The available data for each class of chemicals selected as chemicals of interest (COIs) in the LDW ERA and HHRA are summarized in Table 5-3. There are limited tissue data for all analytes. For all analytes except total PCBs, mercury, and TBT, the only samples are six mussel composite samples collected by King County. There are limited sediment data for TBT, dioxins, and furans. The COI list from the LDW RI (Windward 2006c) will be used as a basis for identifying analytes for the EW data collection efforts. Once sufficient data are available, the EW COIs will be selected based on the site-specific sediment and tissue data.

Table 5-3
Data Availability for Chemical Classes Identified as COPCs in the LDW ERA and HHRA

Chemical Class	Surface Sediment Samples	Tissue Data
Metals and Trace Elements		
Aluminum	13	no data
Antimony	49	6 KC mussel samples
Arsenic	111 (no inorganic As)	6 KC mussel samples
Barium	13	no data
Cadmium	102	6 KC mussel samples
Chromuim	108 (9 samples for chromium VI)	6 KC mussel samples
Cobalt	6	3 KC mussel samples
Copper	111	6 KC mussel samples
Iron	13	no data
Lead	111	6 KC mussel samples
Manganese	13	no data

Chemical Class	Surface Sediment Samples	Tissue Data
Mercury	151	all tissue (42 samples)
Molybdenum	5	no data
Nickel	92	6 KC mussel samples
Selenium	14	no data
Silver	102	6 KC mussel samples
Thallium	13	no data
Vanadium	6	no data
Zinc	111	6 KC mussel samples
Organometals (TBT)	23 (TBT)	TBT for 9 fish samples and 6 KC mussel samples
PAHs[a]	136 sediment samples with no alkylated PAH data	6 KC mussel samples, no alkylated PAH data
Phthalates[a]	122-123 sediment samples	6 KC mussel samples,
Other SVOCs[a]	9-147	6 KC mussel samples,
Total PCBs	160 samples (Aroclors) no congener data	all tissue samples (Aroclors) no congener data
Pesticides[a]	DDTs – 110 samples other pesticides – 5-51 samples	6 KC mussel samples
Dioxins and Furans	3 PSAMP samples	no tissue data

a A summary of data by analyte is provided in Appendix A, Table A-1.
KC – King County

5.1.5 Summary of Data Needs for Nature and Extent Evaluation

Data needs for the nature and extent evaluation will include the analysis of additional sediment samples to increase spatial coverage. A summary of the nature and extent data needs is presented in Table 5-4.

Table 5-4
Summary of Nature and Extent Data Needs

Matrix	Data Need	Notes
Sediment	Additional surface sediment sampling	Subtidal and intertidal (including underpier area) samples will be collected to address spatial data gaps. Locations will be identified in the QAPPs for specific sampling events.
	Additional subsurface sediment sampling	Subsurface samples collected from discrete depth intervals are limited.

QAPPs – Quality Assurance Project Plans

5.2 Data Needs for Human Health Risk Assessment Conceptual Site Model

Additional data are needed for the quantification of some of the pathways shown in the EW HHRA CSM (Figure 2). Based on this CSM, the following exposure pathways will be quantified in the risk assessment:

- Dermal sediment contact and incidental sediment ingestion for the occupational exposure scenario (i.e., restoration worker)
- Dermal water contact and incidental water ingestion for the water recreation scenario, which will be assessed using results from the King County (1999) risk assessment and the proposed surface water sampling event
- Fish and shellfish ingestion for the seafood consumption exposure scenario
- Dermal sediment contact and incidental sediment ingestion associated with the collection of fish, crabs, and shellfish (i.e., netfishing and clamming)
- Dermal sediment contact and incidental sediment ingestion for the shore recreation exposure scenario

More knowledge about the presence or absence of clams and the nature and extent of clam habitat (intertidal and subtidal) in the EW will be required to determine seafood consumption rates. The clam survey will provide site-specific information that will help inform the development of input parameters in the HHRA in consultation with EPA and the Tribes.

Uncertainties in sediment exposure in the shore recreation scenario will need to be addressed. Collection of data through a human access survey will be necessary in order to assess the potential for the public to contact intertidal sediment adjacent to the EW for shore recreational activities. Because it has a different focus, the human access survey will be separate from the clam survey. It will identify all potential human access locations to EW beach areas as well as assess the extent of available intertidal habitat with exposed sediment where exposure may occur (Table 5-5). In addition, an assessment of future land use will be used to identify future human uses.

Table 5-5
Data Needs for Human Health Risk Assessment

Type of Data	Proposed Data Use	Rationale for Recommendation
Identification of suitable shore recreation areas	Determine the need for shore recreation scenarios	Limited information is available on the nature and extent of sediment exposed at potential shore recreation areas.
Identification of potential intertidal and subtidal clam habitat	Determine the spatial extent of clamming beaches for the clamming scenarios	Limited information is available on intertidal and subtidal clam habitat in the EW.

Type of Data	Proposed Data Use	Rationale for Recommendation
Surface sediment chemistry	Calculation of exposure from direct sediment contact and incidental sediment ingestion	Based on an evaluation of the potential for clamming and shore recreation activities, additional intertidal sediment data may be needed to characterize those areas. Additional data will be needed to characterize exposure during netfishing.
Surface water data	Evaluate the King County (1999) risk assessment	EPCs in surface water quantified by King County (1999) will be compared to current EPCs from newly collected samples. A numeric risk assessment will be conducted if the EPCs in current water samples exceed those used in the King County risk assessment and result in different risk conclusions. The comparison of EPCs or new risk estimates will be reported in the EW HHRA.
Fish and shellfish tissue chemistry	Calculation of exposure from fish and shellfish ingestion	Existing tissue chemistry data to estimate exposure are limited. Collection of more chemical data would enable the identification of COPCs for fish tissues included in the seafood consumption scenarios (i.e., benthic fish, pelagic fish, and shellfish).[a] Additional data would also be used to calculate EPCs and risk estimates in the HHRA.
Evaluation of clam distribution	Estimation of appropriate clam consumption rates to use for the EW HHRA	Field survey of clam distribution is needed to verify the capacity of the EW, under current and future use scenarios, to support consumption rates derived from a broad region of Puget Sound. In the event that insufficient clam habitat is identified to support clam consumption at the rates specified in the Tribal Framework (EPA 2007), resource switching will be applied in the seafood consumption rates to make up for the percentage of diets usually made up of clams.

a A subset of tissue samples should be analyzed for specific tissue types (e.g., crab hepatopancreas) that reflect fish consumption practices of certain ethnic groups.
COPCs – chemicals of potential concern
EPCs – Exposure Point Concentrations
EW – East Waterway
HHRA – human health risk assessment

Uncertainty in the nature and extent of clam habitat will also need to be addressed. A better understanding of clam habitat will be used to inform the development of a scenario evaluating risks from clamming activity on the EW as well as the clam portion of the seafood ingestion rates. In addition to providing an opportunity to collect clam tissue, a field survey for clams will serve to identify potential clam habitat within the EW, as well as to identify which beach areas are accessible to the public and which may only be accessed by the members of tribes with U&A rights. The spatial extent of intertidal sediments in areas with clam habitat or public access from shore will then be further characterized using bathymetric and tidal elevation data. This information will be used to define the spatial boundaries of the exposure area for the scenario(s) evaluating risks associated with clamming. Details of any clamming scenario(s) developed will be discussed with EPA and the Tribes, and will be presented in the HHRA Technical Memorandum. Information on clamming areas will also be used to determine if additional sediment chemistry data are needed to better characterize particular intertidal regions within the EW.

The collection of additional tissue chemistry data is recommended to reduce uncertainty in the exposure assessment and to supplement the market basket approach.[17] Target species and tissues are summarized in Section 5.4. Analyte lists and collection locations will be developed in coordination with the agencies and other interested parties and presented in a QAPP.

5.3 Data Needs for Ecological Risk Assessment Conceptual Site Model

5.3.1 Benthic Invertebrates

The benthic invertebrate community and cancrid crabs were selected as ROCs to evaluate risk from sediment-associated chemicals to the EW benthic community.

The benthic risk assessment will focus on estimating the potential for effects on survival, growth, and reproduction of benthic ROCs using comparisons of measured COPC concentrations in sediment and tissue, with relevant effects-based standards or toxicological data. A sediment-based approach (e.g., sediment toxicity measured in a laboratory or predicted by an exceedance of the SMS or DMMP screening level, where no standards are available) will be used to estimate risks for all COPCs except for TBT, where a critical tissue-residue-based approach will be used because there is no SMS for this compound. Critical tissue residues will also be evaluated for two bioaccumulative compounds, PCBs and mercury, to supplement the SMS evaluation for these chemicals. Potential data needs associated with the benthic assessment are summarized in Table 5-6.

[17] This approach uses separate human consumption rates for each species, such as English sole, perch, and crab. The chemical intakes associated with each species are then summed to yield an overall chemical intake for risk calculations.

Table 5-6
Data Needs for Benthic Invertebrate Risk Assessment

Type of Data	Proposed Data Use	Rationale for Recommendation
Sediment chemistry from biologically active zone in intertidal and subtidal areas	To evaluate exposure of and effects on the benthic invertebrate community (including crab)	Some analytes have limited data available (e.g., pesticides and dioxins and furans). Additional sediment data are needed to provide spatial coverage for risk assessment purposes. The depth of the biologically active zone must be determined.
Sediment laboratory toxicity tests	To evaluate exposure of and effects on the benthic invertebrate community	The need for additional bioassay samples will be determined following the completion of the surface sediment characterization.
Benthic invertebrate tissue chemistry	To evaluate exposure of the benthic invertebrate community	Limited benthic infaunal bioaccumulation data are available for the EW. Additional data are needed to assess bioaccumulation effects from PCBs, mercury, and TBT to benthic invertebrates.
Crab tissue chemistry	To evaluate exposure of cancrid crabs	Only a few (three) crab composite samples have been analyzed within the EW.

EW – East Waterway
PCBs – Polychlorinated biphenyls
TBT – Tributyltin

Surface sediment chemistry, toxicity, and invertebrate tissue chemistry data are available for the EW (Anchor and Windward 2008a). However, existing data are limited and do not provide the spatial coverage appropriate for a waterway-wide ERA. Thus, it is proposed that additional data be collected to complete the assessment of risks to benthic invertebrates and support the estimation of exposure to higher-order receptors. Additional justification is discussed in Table 5-6.

5.3.2 Fish

Three fish species were selected as ROCs to evaluate risk from sediment-associated chemicals to the EW fish community:

- Juvenile Chinook salmon were selected to represent outmigrating juvenile salmonids
- Brown rockfish were selected to represent piscivorous fish
- English sole were selected to represent all fish not explicitly represented by the above two species

The fish risk assessment will focus on estimating the potential for effects on survival, growth, and reproduction[18] of fish ROCs using comparisons of measured chemical concentrations in sediment, tissue, and water with relevant toxicological data. Depending on the bioaccumulative properties of the chemical, either a critical tissue residue approach or a dietary and water approach will be used to estimate risk. Potential data needs associated with the fish risk assessment are summarized in Table 5-7. Collection of additional surface sediment to increase spatial coverage is proposed, as is the collection of tissue data for the fish ROCs (juvenile Chinook salmon, brown rockfish, and English sole) and the prey species of all three fish ROCs. Surface water data for metals from the King County WQA King County (1999) will be used; additional surface water data for PAHs will be needed because PAHs were not detected in the King County (1999) dataset. Surface water data are not needed for the other analytes because they are being evaluated through the critical tissue residue approach, which incorporates all exposure pathways. Analytes in each media will be determined in coordination with the regulatory agencies and other interested parties, and presented in the appropriate QAPPs.

Table 5-7
Data Needs for Fish Risk Assessment

Type of Data	Proposed Data Use	Rationale for Recommendation
Juvenile Chinook salmon whole-body tissue chemistry	To evaluate exposure of juvenile Chinook salmon	Existing whole-body data were analyzed for only a limited number of analytes (PCBs and mercury); additional data are needed to estimate risks to juvenile Chinook salmon.
English sole whole-body tissue chemistry	To evaluate exposure of English sole	Existing whole-body data are few (six composites of five fish each) and were analyzed for only a limited number of analytes (PCBs and mercury); additional data are needed to estimate risks to English sole.
Brown rockfish whole-body tissue chemistry	To evaluate exposure of brown rockfish	Existing whole-body data are few (two individual fish) and were analyzed for only a limited number of analytes (PCBs and mercury); additional data are needed to estimate risks to brown rockfish.
Juvenile Chinook salmon stomach contents chemistry [a]	To evaluate exposure of juvenile Chinook salmon [b]	Bracket exposure estimates based on benthic invertebrate tissue data because Chinook salmon also prey on pelagic and terrestrial invertebrates; additional data are needed to estimate risks to juvenile Chinook salmon for evaluation of risk from dietary exposure.

[18] The reproductive life stages (i.e., spawning and early development) of Chinook salmon do not occur in the EW, so the reproduction endpoint for juvenile Chinook salmon will be limited to reproductive effects occurring from exposure during smolt stage or later juvenile lifestages.

Type of Data	Proposed Data Use	Rationale for Recommendation
Benthic invertebrate tissue chemistry [b]	To evaluate dietary exposure of all fish ROCs [b]	Limited tissue data are available to assess using the dietary approach.
Shiner surfperch and juvenile Chinook salmon whole-body tissue chemistry [c]	To evaluate dietary exposure of brown rockfish [b]	Limited tissue data (three shiner surfperch) analyzed for only a limited number of analytes (PCBs and mercury).
Surface sediment chemistry	To evaluate dietary exposure of English sole and brown rockfish [b]	Need intertidal sediment data for juvenile Chinook salmon and additional sediment data needed for English sole and brown rockfish fish to characterize incidental ingestion of sediment.
Surface water chemistry	To evaluate water exposure of all fish ROCs [b]	Surface water data for metals (except mercury) and PAHs will be used in conjunction with a dietary approach for fish.

a Stomach content data for other fish ROCs is not necessary because the other fish ROCs consume benthic invertebrates and/or fish exclusively.
b An ambient media (i.e., diet and water) approach is preferred for PAHs and most metals because fish readily metabolize PAHs and regulate their body metals burden, thus, tissue concentrations of these chemicals poorly reflect exposure concentrations associated with adverse effects.
c Other potential prey fish species will be discussed between EWG and EPA.
EPA – U.S. Environmental Protection Agency
EWG – East Waterway Group
PAHs – polycyclic aromatic hydrocarbons
PCBs – polychlorinated biphenyls
ROCs – receptors of concern

5.3.3 Wildlife

Four wildlife species were selected as ROCs for the evaluation of risk from exposure to sediment-associated chemicals in the EW:

- Osprey was selected to represent birds that consume primarily fish
- Pigeon guillemot was selected to represent birds that consume demersal fish and invertebrates
- River otter was selected as a semi-aquatic mammal that consumes primarily fish, and some invertebrates such as crabs, clams, and mussels
- Harbor seal was selected as a marine mammal that consumes primarily fish

The wildlife risk assessment will focus on estimating the potential for effects on survival, growth, and reproduction of avian and mammalian ROCs by using measured chemical concentrations in sediment, tissue, and surface water to calculate an exposure dose. As shown in Table 5-8, collection of whole-body fish and crab samples and bivalves is proposed for the evaluation of the dietary exposure pathway for wildlife ROCs. Collection of additional surface sediment data is also proposed for an evaluation of incidental sediment ingestion by wildlife. Surface water data from the King County

WQA King County (1999) will be used in calculating exposure doses; additional data for PAHs and PCBs will be collected as these analytes were either not detected (PAHs) or not analyzed for (PCBs) during the King County WQA. Numbers and locations of samples and chemicals to be analyzed in each media type will be determined in coordination with the regulatory agencies and other interested parties and presented in the appropriate QAPP.

Table 5-8
Data Needs for Wildlife Risk Assessment

Type of Data	Proposed Data Use	Rationale for Recommendation
Whole-body fish tissue data (English sole, brown rockfish, juvenile Chinook salmon, and shiner surfperch) and invertebrates	To assess dietary exposure of wildlife ROCs	Data exist for only a few whole-body fish samples; these samples were analyzed only for mercury and PCBs.
Whole-body crab tissue data	To assess dietary exposure of pigeon guillemot and river otter	Only three 3-crab composite samples of edible meat have been analyzed.
Surface sediment data	To assess dietary exposure of wildlife ROCs	Existing sediment data do not sufficiently represent all wildlife foraging areas of the EW to characterize incidental ingestion.
Surface water data	To assess dietary exposure of all wildlife ROCs	Existing water data is sufficient for all analytes except PAHs and PCBs.

EW – East Waterway
PAHs – polycyclic aromatic hydrocarbons
PCBs – polychlorinated biphenyls
ROCs – receptors of concern

5.4 Summary of Supplemental Remedial Investigation Data Needs

In summary, the primary data needed for the EW are chemical data for sediment, tissue, and surface water. For sediment, surface and subsurface data are needed for the nature and extent evaluation to characterize areas where historical data are lacking in subtidal, intertidal, and underpier areas (Table 5-9). Surface sediment data from areas where there are few or no existing data are also needed for the ERA, both for comparison to sediment quality guidelines for the benthic community assessment and for the calculation of dietary exposure from incidental ingestion of sediment for fish, birds, and mammals; and for the exposure due to netfishing in the HHRA. Surface sediment data from intertidal areas may also be needed for the HHRA if it is determined that there are complete exposure pathways in areas with insufficient data.

Table 5-9
Sediment Chemistry Data Needs

Data Type	RI Assessment Type	Data Use	Locations
Surface sediment chemistry	Nature and extent of contamination	Additional nature and extent characterization	Data are needed to address spatial gaps in subtidal, intertidal, and underpier areas.
	Human health risk	To characterize exposure from direct contact or incidental sediment ingestion	Data needed in intertidal and subtidal areas where netfishing exposure is likely to occur. Additional intertidal data may be needed for the shore recreation scenario.
	Benthic invertebrate risk	To characterize exposure of and effects on the benthic community (including crab)	Locations will be placed for spatial coverage and will be co-located with toxicity test samples and invertebrate tissue samples.
	Fish, birds, and mammals risk	To characterize dietary exposure resulting from incidental sediment ingestion	Data are needed from both intertidal and subtidal areas where fish, birds, and mammals forage.
Subsurface sediment chemistry	Nature and extent of contamination	Additional nature and extent characterization and FS support	Data are needed to address spatial gaps in subtidal, intertidal, and underpier areas, as well as to characterize specific depth intervals to support the FS.

Note: Data needs for specific chemical analyses will be evaluated and addressed in the surface and subsurface sediment sampling QAPP.
RI – Remedial Investigation
QAPP – Quality Assurance Project Plan

The tissue chemistry data needs were presented in Sections 5.2 and 5.3 according to needs for the HHRA and for each ROC in the ERA. These data needs are summarized for each tissue type in Table 5-10. Data for some of these tissue types will serve data use needs for the HHRA and multiple ROCs in the ERA. For example, shiner surfperch tissue chemistry data will be used to evaluate risk to five ROCs (i.e., brown rockfish, pigeon guillemot, osprey, river otter, and harbor seal) from ingestion of shiner surfperch as prey. Shiner surfperch will also represent pelagic fish as a component of the seafood consumption for humans.

Table 5-10
Tissue Chemistry Data Needs

Tissue Type	Receptor of Concern	Data Use
Benthic invertebrates [a]	Benthic invertebrates	Evaluate exposure of benthic invertebrate community to bioaccumulative contaminants (PCBs, mercury, TBT)
Prey fish	Juvenile Chinook salmon, English sole, and brown rockfish	To evaluate the exposures of these receptors
Crab, whole-body [b]	Crab	Evaluate exposure of crab to chemicals of concern
	Pigeon guillemot and river otter	To evaluate the exposures of these receptors

Tissue Type	Receptor of Concern	Data Use
Crab, edible meat and hepatopancreas	Human shellfish consumers	Calculation of human exposure from crab ingestion
Juvenile Chinook salmon, whole-body	Juvenile Chinook salmon	To evaluate the exposures of this receptor
	Brown rockfish, pigeon guillemot, osprey, river otter, and harbor seal	To evaluate the exposures of these receptors
Juvenile Chinook salmon, stomach contents	Juvenile Chinook salmon	To evaluate the exposures of this receptor
English sole, whole-body	English sole	To evaluate the exposures of this receptor
	Pigeon guillemot, osprey, river otter, harbor seal	To evaluate the exposures of these receptors
English sole, fillets	Human fish consumers	Calculation of human exposure from fish ingestion
Shiner surfperch	Brown rockfish	To evaluate the exposures of this receptor
	Pigeon guillemot, osprey, river otter, harbor seal	To evaluate the exposures of these receptors
	Human consumers	Calculation of human exposure from shiner surfperch ingestion
Clams [c]	Human consumers	Calculation of human exposure from clam ingestion
	River otter	To evaluate the exposures of this receptor
Brown rockfish	Brown rockfish	To evaluate the exposures of this receptor
	Pigeon guillemot, osprey, river otter, harbor seal	To evaluate the exposures of these receptors
	Human consumers	Calculation of human exposure from fish ingestion
Mussels	Human consumers	Calculation of human exposure from mussel ingestion
	River otter	To evaluate the exposure of this receptor

a Epibenthic and infaunal invertebrates will be evaluated as prey for higher order receptors. Tissue residues of three bioaccumulative contaminants will be used to evaluate effects on benthic invertebrates as the receptor of concern.

b Whole-body crab tissues may be calculated from the measured edible tissue and hepatopancreas concentrations.

c Clam tissue data will only be collected if the clam survey indicates sufficient clam habitat for human consumers and river otter

PCBs – polychlorinated biphenyls

TBT – tributyltin

In addition to sediment and tissue chemistry data, three other types of data are needed: surface water chemistry, sediment toxicity tests, a clam survey, and field surveys to characterize human access of the EW (Table 5-11). The sediment toxicity tests will be co-located in a subset of areas where sediment chemistry data will also be collected (the locations are dependent on the results of the sediment chemistry results). Site use surveys of the entire EW will be conducted to evaluate areas with potential habitat for clams and with the potential for shore recreation. The survey will identify existing clam species and habitat present, information that can be used to develop exposure parameters for direct contact and seafood ingestion pathways. The clam survey will provide site-specific information that will help inform the development of input parameters in the HHRA in consultation with EPA and the Tribes.

Table 5-11
Other Data Needs

Data Type	Receptor of Concern	Notes
Surface water data	Fish	Data needed to characterize dietary exposure of fish (PAHs and metals)
	Wildlife	Data needed to characterize exposure
	Human recreation users	Data will be compared with King County dataset
Sediment toxicity tests	Benthic invertebrates	To evaluate toxic effects to benthic invertebrates
Clam survey	Human shellfish consumers	To identify clamming locations and extent to which clams and clam habitat currently exist
Human access survey	Human shoreline recreation users	To identify appropriate exposure scenarios for shoreline recreation users

PAH – polycyclic aromatic hydrocarbons

5.5 Data Needs for Physical Processes Conceptual Site Model

The Physical Processes CSM for the EW will be further refined using additional information on the hydrodynamic and sediment transport processes in each of the three reaches of the EW. The reaches include the Main Body Reach, the Sill Reach, and the Junction Reach. Each of these is subject to different hydrodynamic conditions under the varying tidal and flow regimes of Elliott Bay and the Green River, respectively. The STEAM (Anchor and Battelle 2008) reviews the adequacy of the existing information for use in the STE and identifies any data needs that should be filled with additional sampling in the EW. Following completion of the STE, the sampling results and the model output will be used to update the Physical Processes CSM. Therefore, because the Physical Processes CSM will be refined with information collected and produced as part of the STE, data needs will be presented in the STEAM rather than in this document. The level of data needs in the STEAM is dependent on types of modeling and level of validation for the model.

5.6 Data Needs for Feasibility Study

The following sections present the data gaps analysis for FS-related work. FS data needs were broken down into several categories including structural, utility, slope stability/geotechnical, existing and future site uses, catastrophic events (i.e., seismic), and debris. Sediment transport data gaps are identified separately in the STEAM (Anchor and Battelle 2008).

5.6.1 Structural Information

In general, information is available for most existing structures along the EW. However, some information on adjacent structures is unavailable that may be useful for evaluating remedial alternatives during the FS. The EISR presents a review of available and unavailable record drawings for EW piers and bridges (Table 2-15 and Figure 2-17 of the EISR; Anchor and Windward 2008a). It is anticipated that the unavailable data associated with these structures will not be a significant factor when evaluating remedial alternatives in the FS. However, during development of the FS, if additional field data is needed to develop and evaluate alternatives, further structural inspection may be required. If additional information is required, EWG will communicate this need to EPA.

5.6.2 Utility Information

For the purposes of the FS, there are no data gaps known to be associated with the utilities present in the EW. Specifically, record drawings for outfalls present in the EW are readily available from the Port or the City of Seattle (City). It is anticipated that private utility companies can provide existing utility information without the need to conduct site investigations for FS evaluation purposes.

5.6.3 Slope Stability

As described in the EISR (Anchor and Windward 2008a), multiple geotechnical studies have been performed in and around the EW. Based on a review of these studies, boring logs and soil test data are readily available for the majority of the waterway and are sufficient to evaluate the dredging and capping remedies for the FS, with the exception noted below.

One area, in particular, that requires additional geotechnical information is the mound of soil located offshore of the northwest corner of T-25 in the vicinity of the former rail spur, adjacent to the mouth of Slip 27. In this area, one or more geotechnical borings are proposed to assess the geotechnical properties of the mound and its stability. Samples will be collected and the soil will be characterized and evaluated using laboratory geotechnical tests. Details on the location(s) for proposed exploration, sample collection procedures, and the laboratory testing program will be described in a QAPP developed for this additional data collection.

Other areas requiring additional geotechnical study may be identified during remedial design, but are not needed for FS evaluation purposes.

5.6.4 Existing and Future Site Uses

The EW provides a critical connection for cargo and other materials moving between water and land, as well as routes for cruise ship traffic. Most vessel traffic consists of shipping companies moving container vessels and assorted tugboats into and out of the EW. A discussion of shipping-related activities within the EW is provided in the EISR (Anchor and Windward 2008a). As the Port container volume increases, there may be a need to accommodate larger container vessels in the future, which may require deeper drafts than the current EW depths; specifically, at the south end of the main 750-foot-wide section of the waterway, because it is currently shallower than -51 feet MLLW, and/or by deepening the northern end of the EW.

In addition to shipping-related activities, other known EW uses include commercial netfishing operation by the Muckleshoot Tribe and recreational uses such as boating, fishing, and other water-related recreational activities.

The EWG will coordinate with the Port Seaport Planning Group, the City Department of Planning and Development, King County, USCG, and other stakeholders to conduct an existing and future site use survey, including updated vessel call frequency estimates. The future site use survey will be performed to supplement current known existing site use information and to inform FS elements. The future site use survey will also address potential future structure development to support a potential increase in vessel calls to the EW. Input from other stakeholders concerned with future site use with respect to potential habitat restoration and access to the waterway (e.g., tribes, National Oceanic and Atmospheric Administration [NOAA], and People for Puget Sound) will be focused on specific sites where a significant potential for change in site uses may occur (to restoration or access). This input will be collected through the permitting and design of those sites through the existing established regulatory framework and associated public comment periods.

5.6.5 Catastrophic Events

The EISR describes how regional seismicity is well-understood for the project area (EISR Section 2.2.4.2; Anchor and Windward 2008a). These existing studies provide sufficient basis for performing seismic evaluations at the FS level. Depending on the scope of the selected remedy, more detailed site-specific seismic evaluations may be appropriate during remedial design. If this need arises, the proposed approach for a site-specific seismic evaluation will be presented in a future work plan during the remedial design phase of the project.

5.6.6 Debris

Limited existing data are available to assess the presence or absence of debris in the EW and the presence of debris is not an FS data need, but has been identified as a remedial design data gap. A known area of debris was identified near a timber bulkhead and timber piles present along the southern shoreline of Pier 24. The Port is proposing to remove these piles in addition to a small concrete pier and in-water debris, which currently occupy approximately 2.1 acres of aquatic and shoreline area, for fish and wildlife habitat improvements. This project is expected to be carried out during the 2008-2009 construction season. For other areas of the EW where the presence or absence of debris is unknown, a debris survey will need to be conducted during the remedial design phase.

5.6.7 Background Concentrations

Background concentrations are relevant to setting Preliminary Remediation Goals (PRGs) for risk drivers for the EW OU and are, therefore, a data need for the FS. Natural and anthropogenic background concentrations will be used in the evaluation of cleanup levels as a lower limit below which cleanup levels cannot be achieved. In general, cleanup levels will not be set below natural or anthropogenic (man-made) background concentrations (EPA 1997c, 2005). Natural and anthropogenic background values also must be adequately understood to establish realistic risk-reduction goals (EPA 2002b). Both natural and anthropogenic background concentrations will be evaluated in setting

PRGs. Types of data that may be considered in the background analysis include sediment quality data from locations upstream of the EW and LDW boundaries or from Puget Sound (excluding other cleanup sites), and certain data from non-point sources such as atmospheric deposition or urban run-off.

5.6.8 Sediment Transport Information

Existing information and the current understanding of sediment transport processes were described in the Physical Processes CSM in Section 2. The STEAM (Anchor and Battelle 2008) reviews the suitability of existing data for use in the STE and builds on the Physical Processes CSM to incorporate potential modeling approaches for the EW. The STEAM provides a preferred approach for conducting the STE. Data needs associated with completing the preferred approach are identified and presented in the STEAM.

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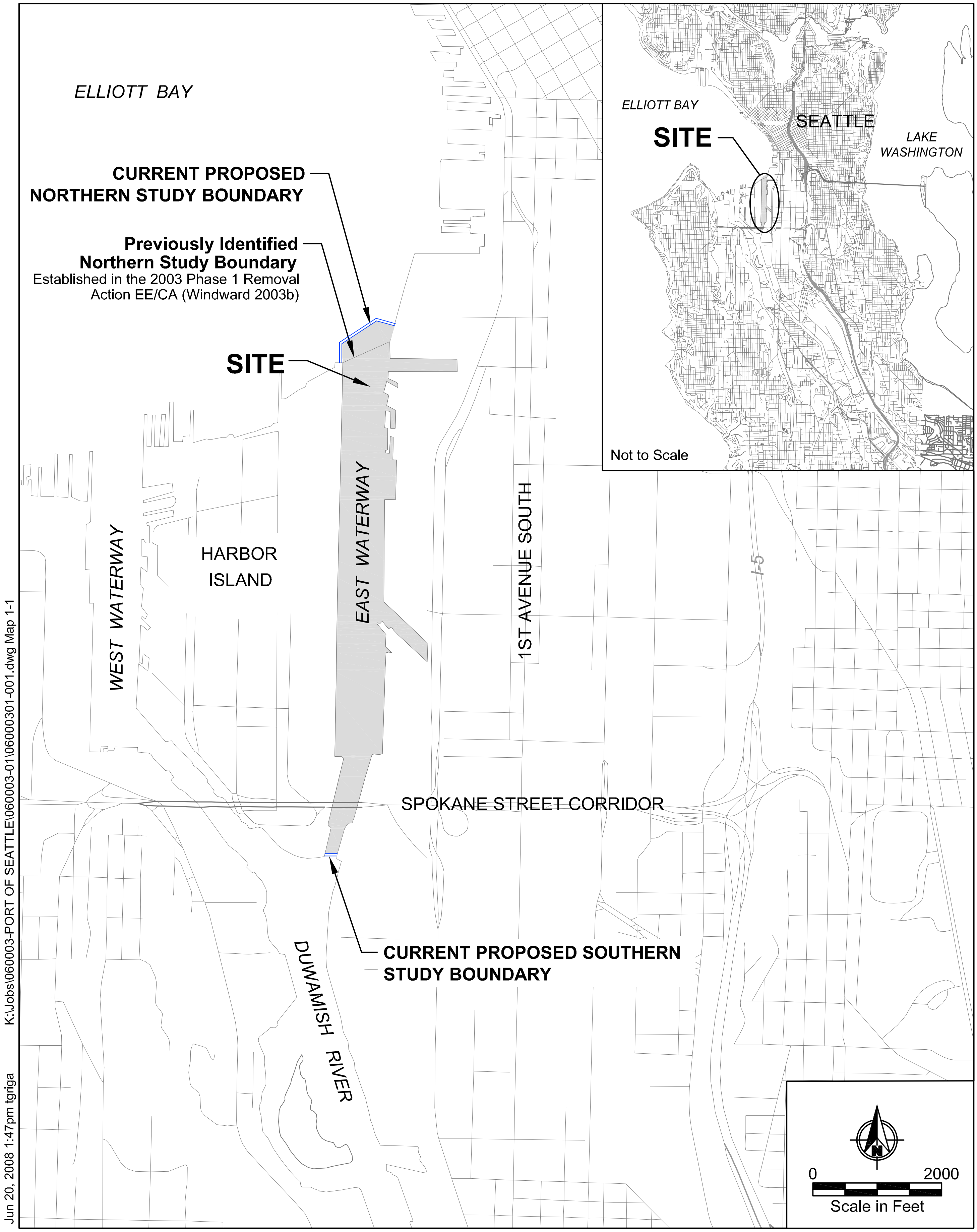
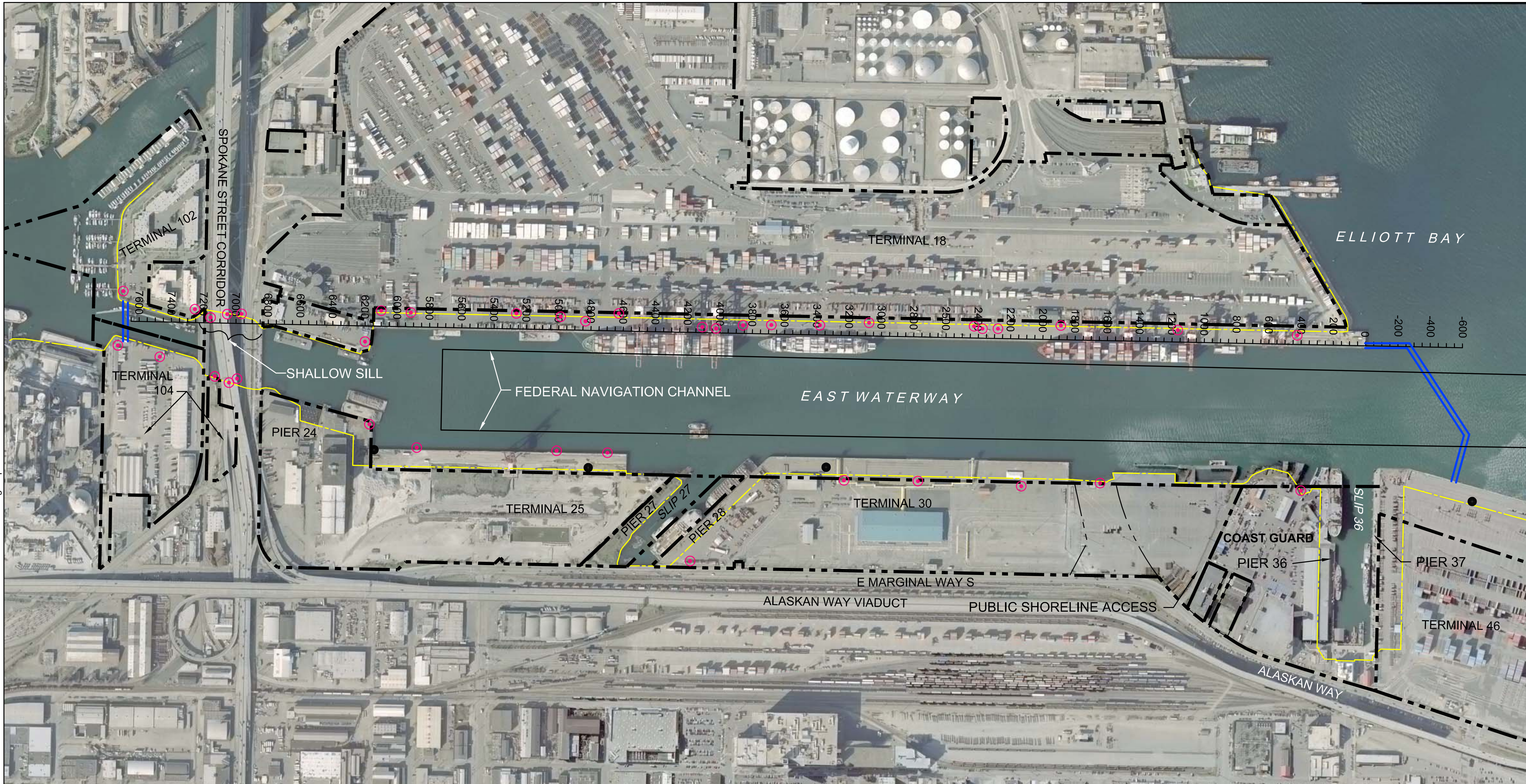
MAPS



Map 1-1
Vicinity Map and Proposed East Waterway Operable Unit Study Boundary
Conceptual Site Model and Data Gaps Analysis Report
East Waterway Operable Unit



LEGEND

- INNER HARBOR LINE/PROPERTY LINE
- PROPOSED EAST WATERWAY OPERABLE UNIT STUDY BOUNDARY
- MHHW LINE
- CSO LOCATION
- APPROXIMATE STORM DRAIN LOCATION

Note: Previously established station locations for the East Waterway are shown along the western shoreline for reference.

K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-017.dwg Map 1-2

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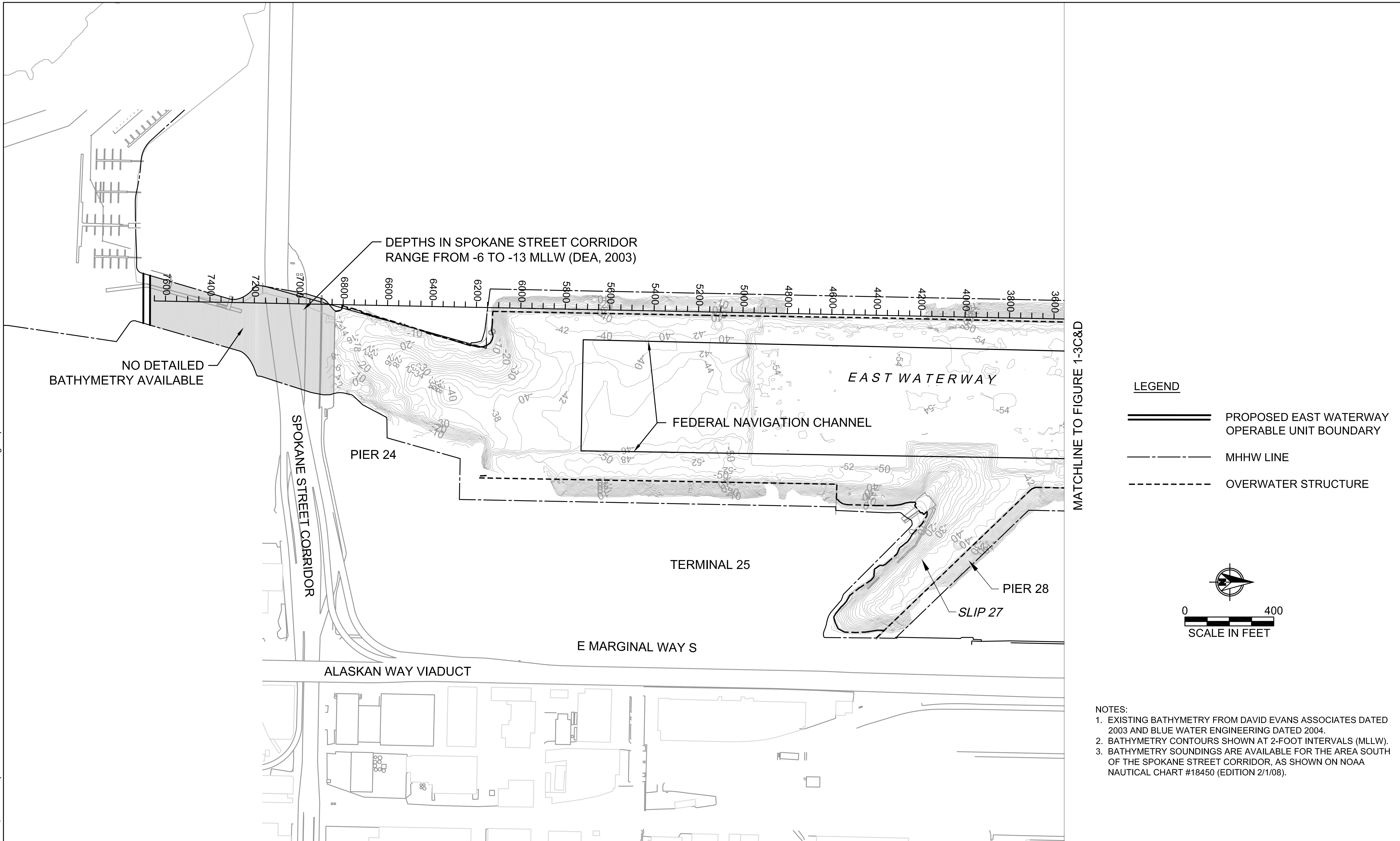
Map 1-2

Major East Waterway Features

Conceptual Site Model and Data Gaps Analysis Report

East Waterway Operable Unit



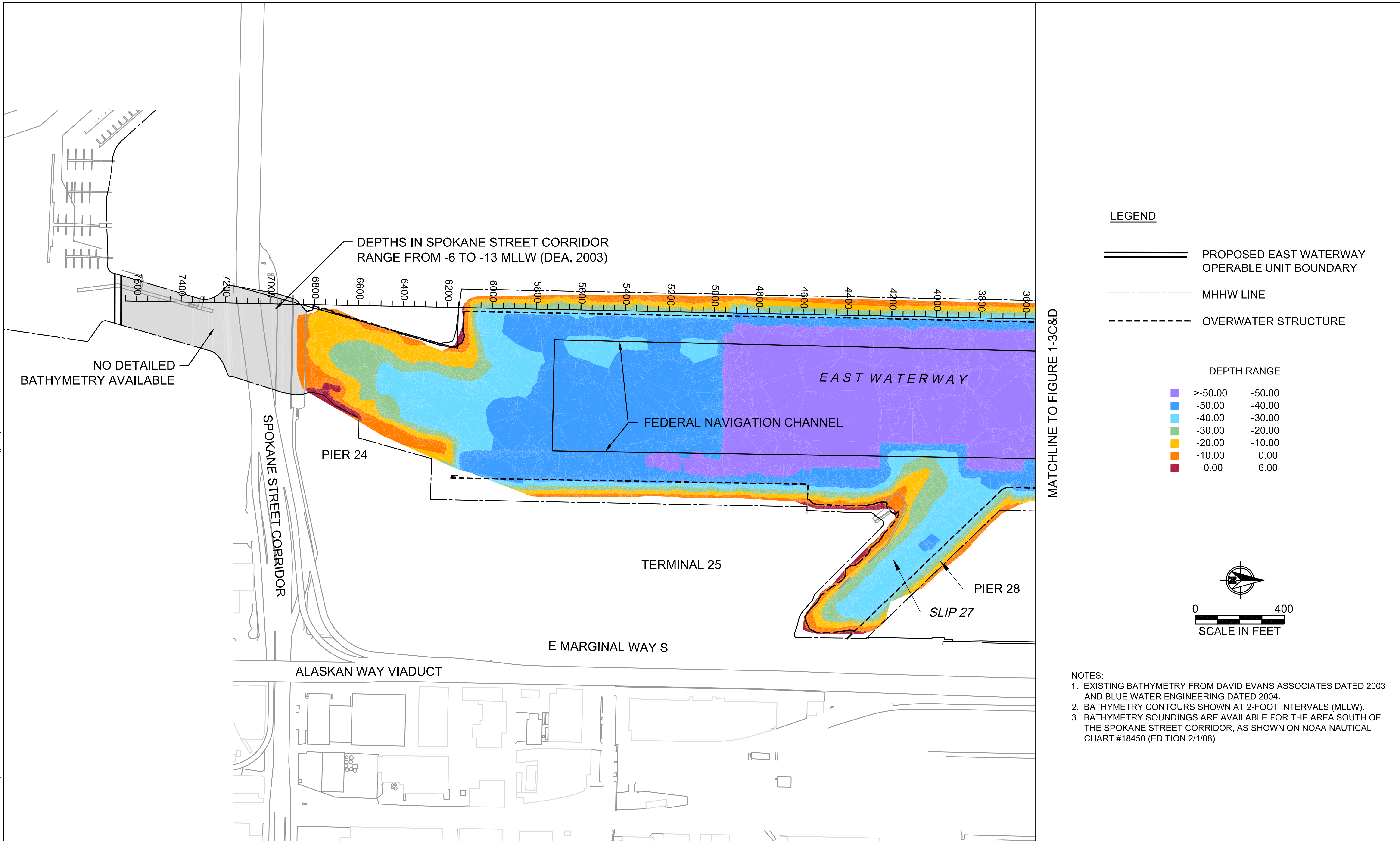
Jun 04, 2008 3:26pm cdavidson K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-018.dwg Map 1-3A

Map 1-3A

Existing Bathymetry

Conceptual Site Model and Data Gaps Analysis Report

East Waterway Operable Unit



NOTES:

1. EXISTING BATHYMETRY FROM DAVID EVANS ASSOCIATES DATED 2003 AND BLUE WATER ENGINEERING DATED 2004.
2. BATHYMETRY CONTOURS SHOWN AT 2-FOOT INTERVALS (MLLW).
3. BATHYMETRY SOUNDINGS ARE AVAILABLE FOR THE AREA SOUTH OF THE SPOKANE STREET CORRIDOR, AS SHOWN ON NOAA NAUTICAL CHART #18450 (EDITION 2/1/08).

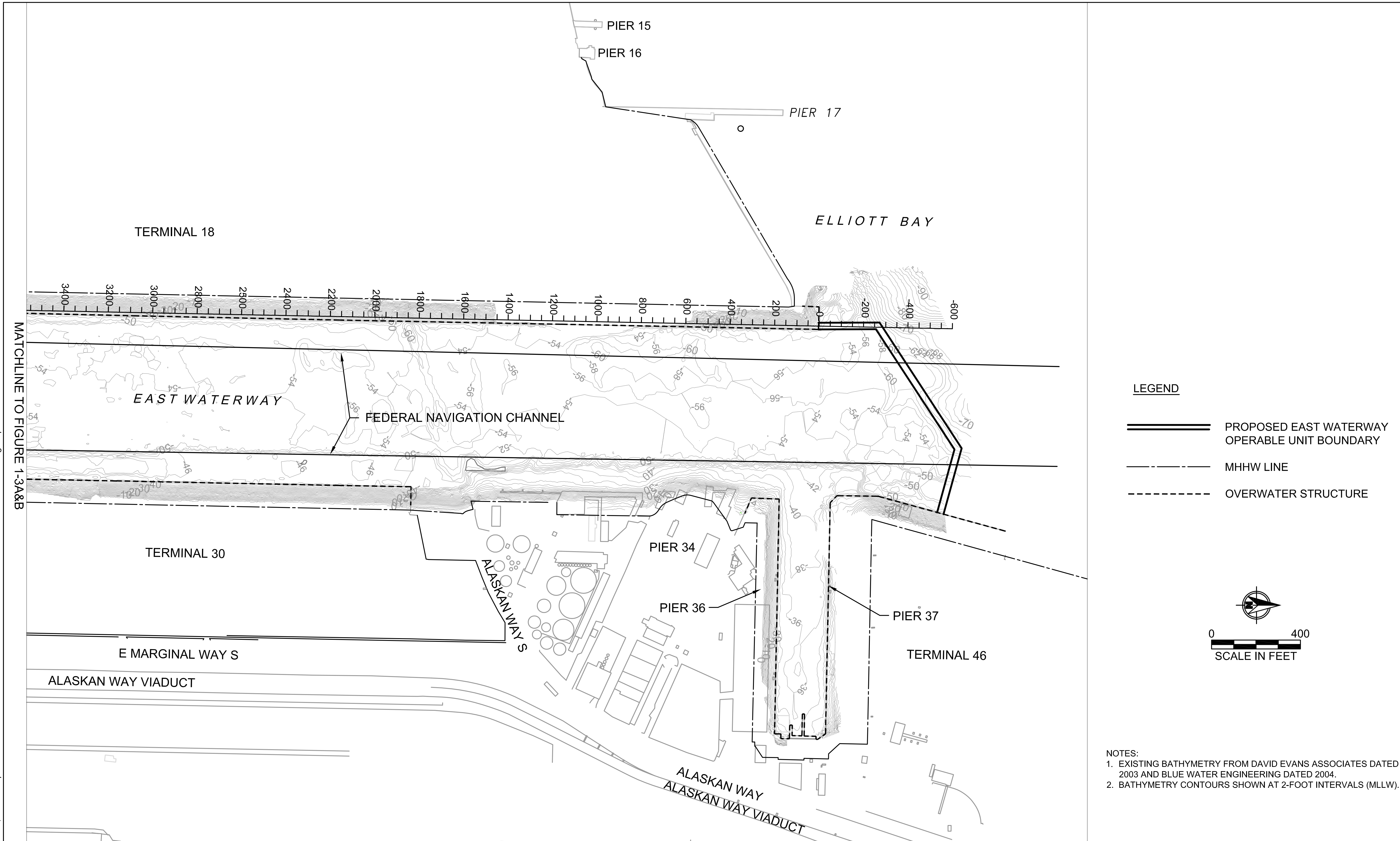
Jun 04, 2008 3:31pm cdavidson K:\Jobs\060003-PORT OF SEATTLE\06000301\06000301-018.dwg Map 1-3B

Map 1-3B

Existing Bathymetry

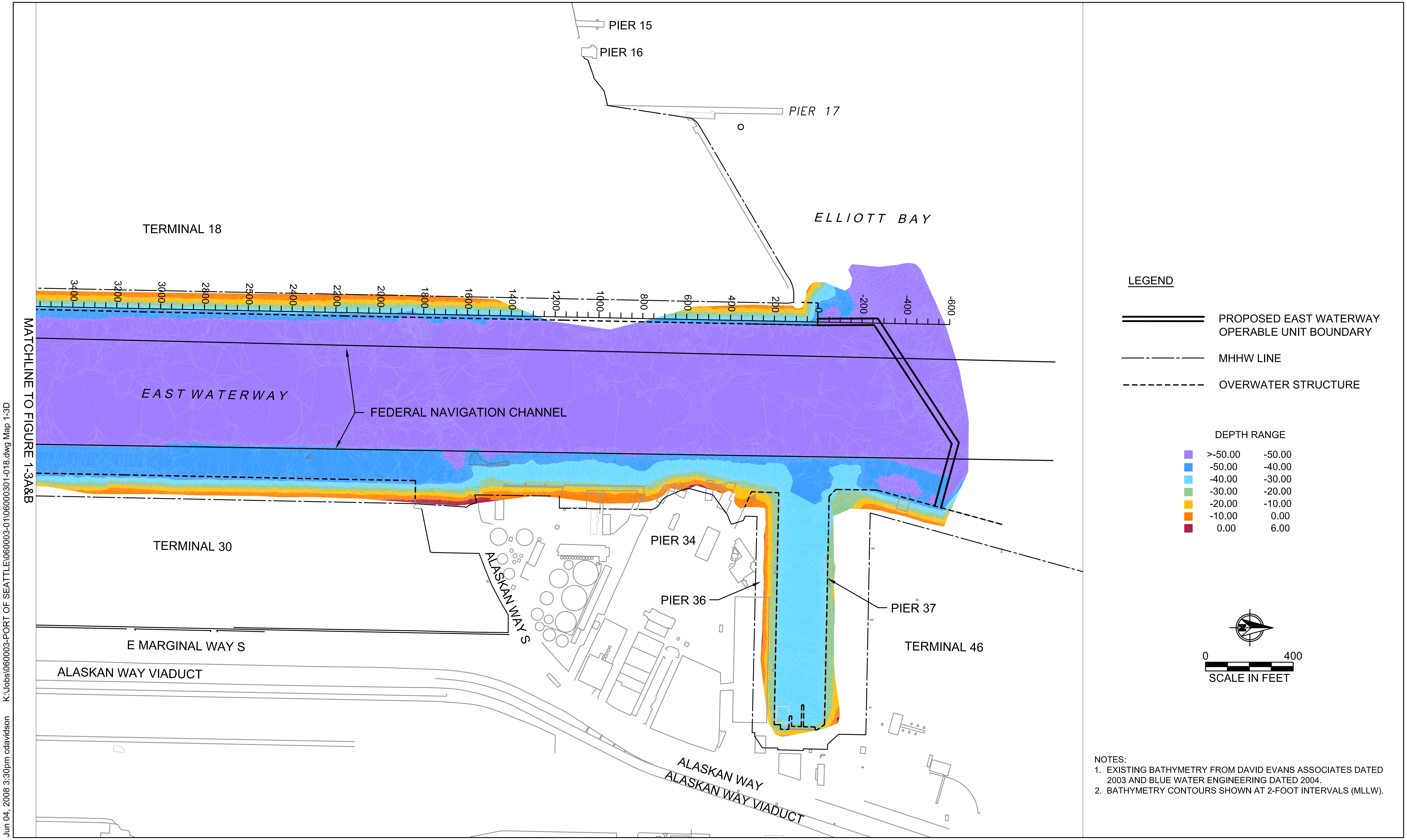
Conceptual Site Model and Data Gaps Analysis Report

East Waterway Operable Unit

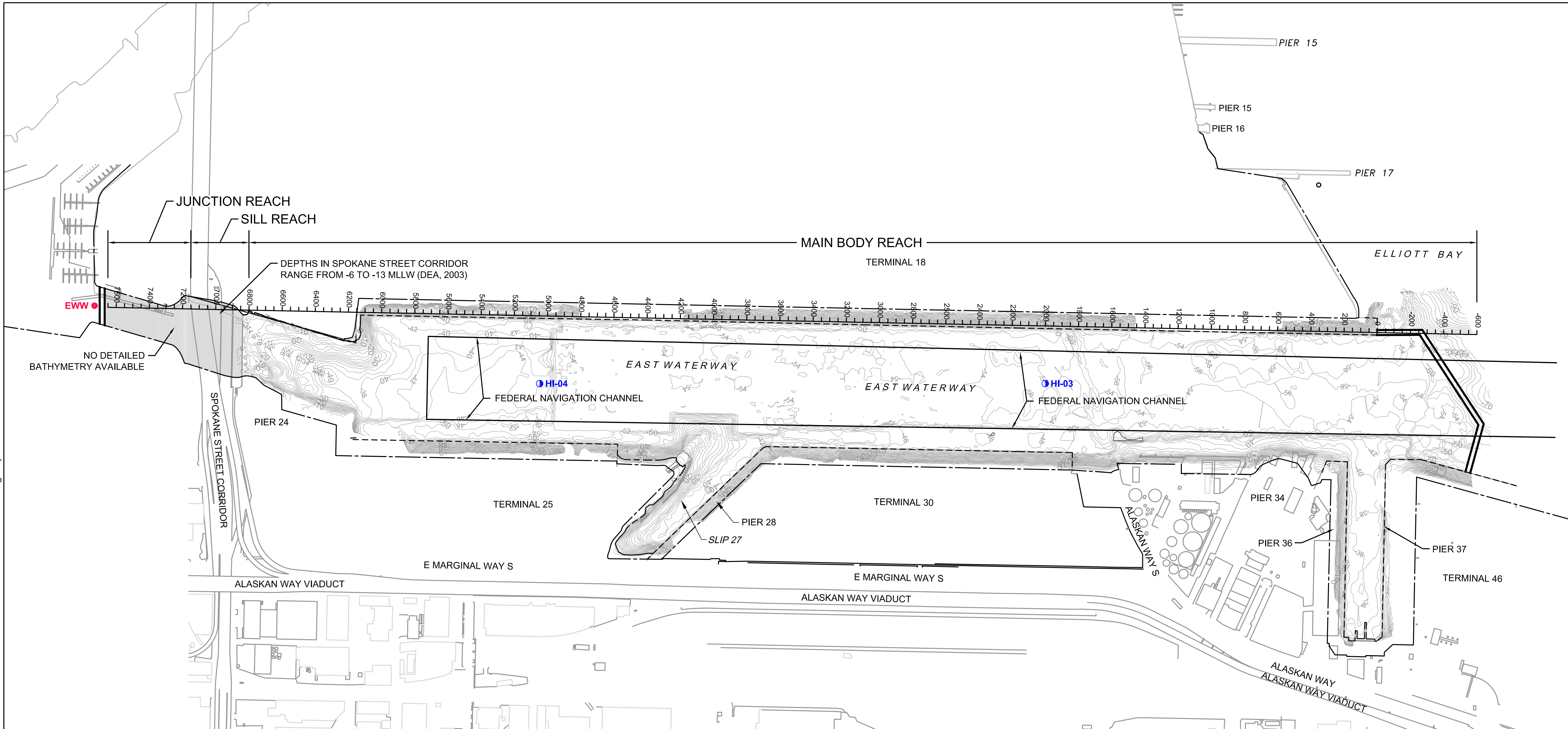


Jun 04, 2008 3:27pm cdavidson K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-018.dwg Map 1-3C

Map 1-3C
Existing Bathymetry
Conceptual Site Model and Data Gaps Analysis Report
East Waterway Operable Unit



Map 1-3D
Existing Bathymetry
Conceptual Site Model and Data Gaps Analysis Report
East Waterway Operable Unit



LEGEND

PROPOSED EAST WATERWAY OPERABLE UNIT BOUNDARY

MHHW LINE

EWW ● KING COUNTY WQA VELOCITY SAMPLE LOCATION

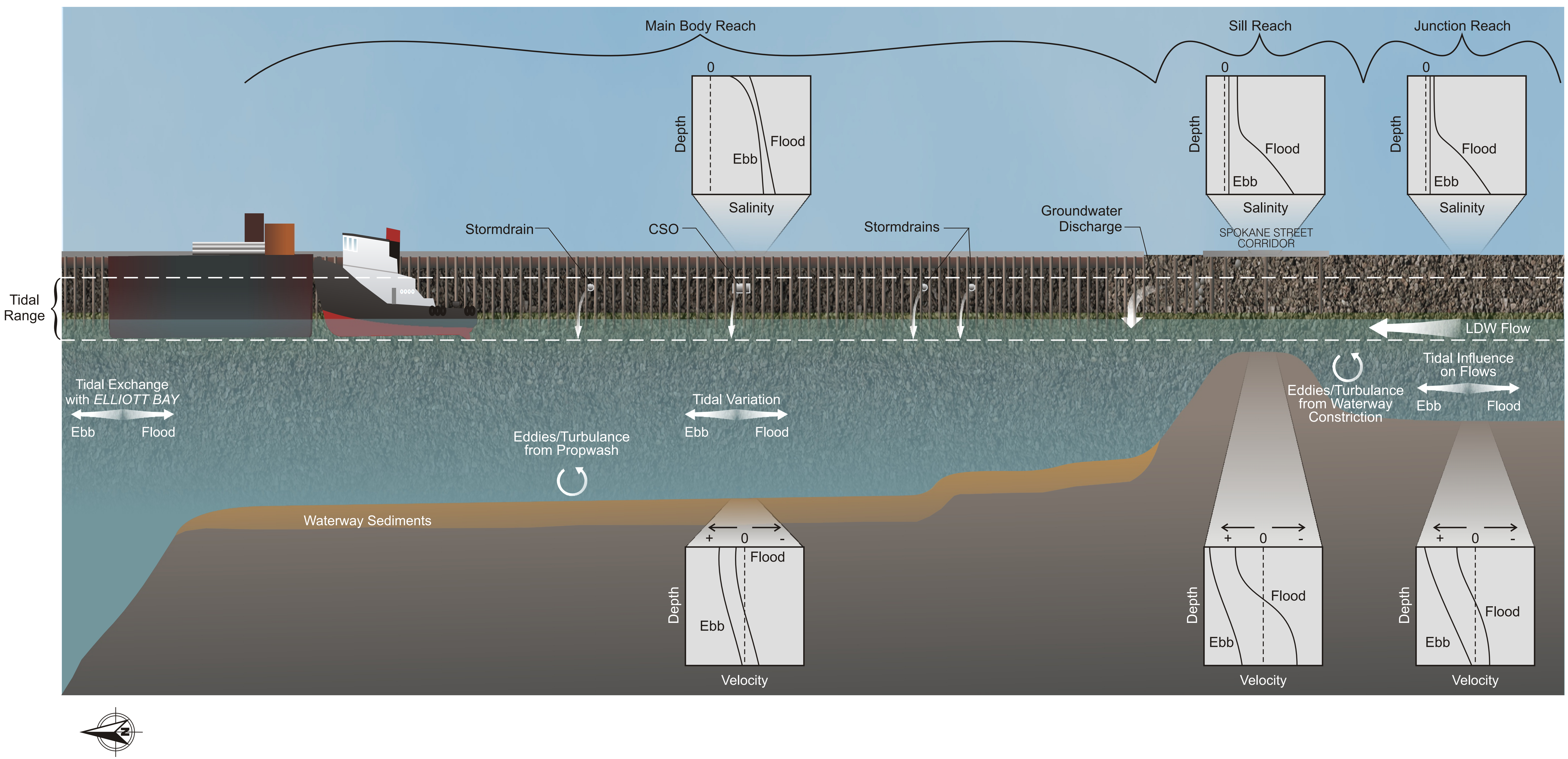
HI-04 ◑ SEDIMENT TRAP AND NEAR-BOTTOM VELOCITY SAMPLE LOCATION

0 600
SCALE IN FEET

NOTES:
1. EXISTING BATHYMETRY FROM DAVID EVANS ASSOCIATES DATED 2003 AND BLUE WATER ENGINEERING DATED 2004.
2. BATHYMETRY CONTOURS SHOWN AT 2-FOOT INTERVALS (MLLW).
3. BATHYMETRY SOUNDINGS ARE AVAILABLE FOR THE AREA SOUTH OF THE SPOKANE STREET CORRIDOR, AS SHOWN ON NOAA NAUTICAL CHART #18450 (EDITION 2/1/08).
4. PREVIOUSLY ESTABLISHED STATION LOCATIONS FOR THE EAST WATERWAY ARE SHOWN ALONG THE WESTERN SHORELINE FOR REFERENCE.
5. CURRENT METERS AND SEDIMENT TRAP DEPLOYED DURING SPRING 1995.
6. KIND COUNTY WQA VELOCITY SAMPLING CONDUCTED IN 1996.

Jun 04, 2008 3:34pm cdavidson K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-018.dwg Map 2-1

Map 2-1
East Waterway Reaches and Existing Hydrodynamic and Sediment Transport Sampling Locations
Conceptual Site Model and Data Gaps Analysis Report
East Waterway Operable Unit

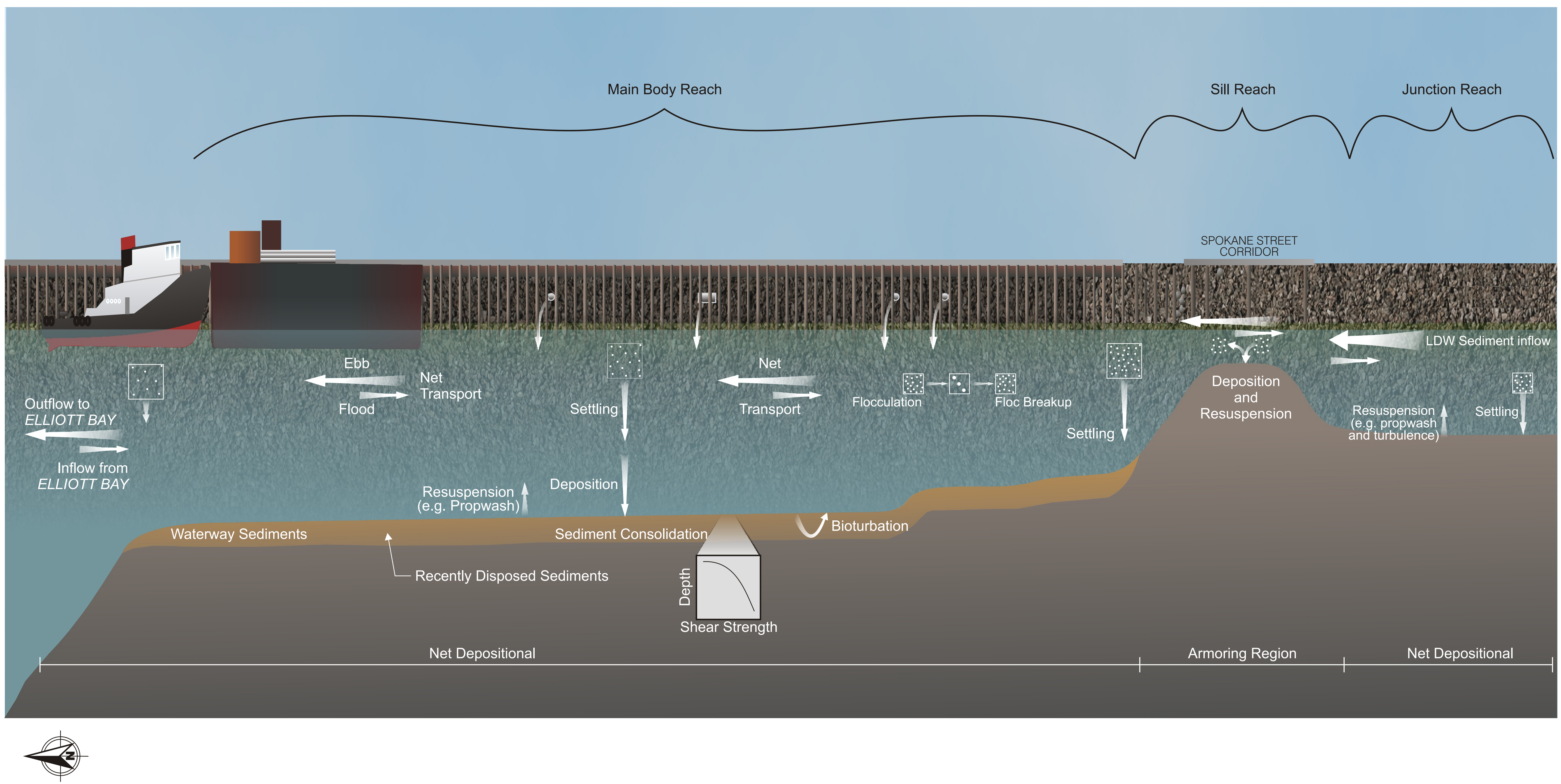


Note: Salinity and velocity profiles shown for each reach are not based on actual data but represent the most likely relationship based on the physical characteristics of the system.

DRAFT

ANCHOR ENVIRONMENTAL, L.L.C.

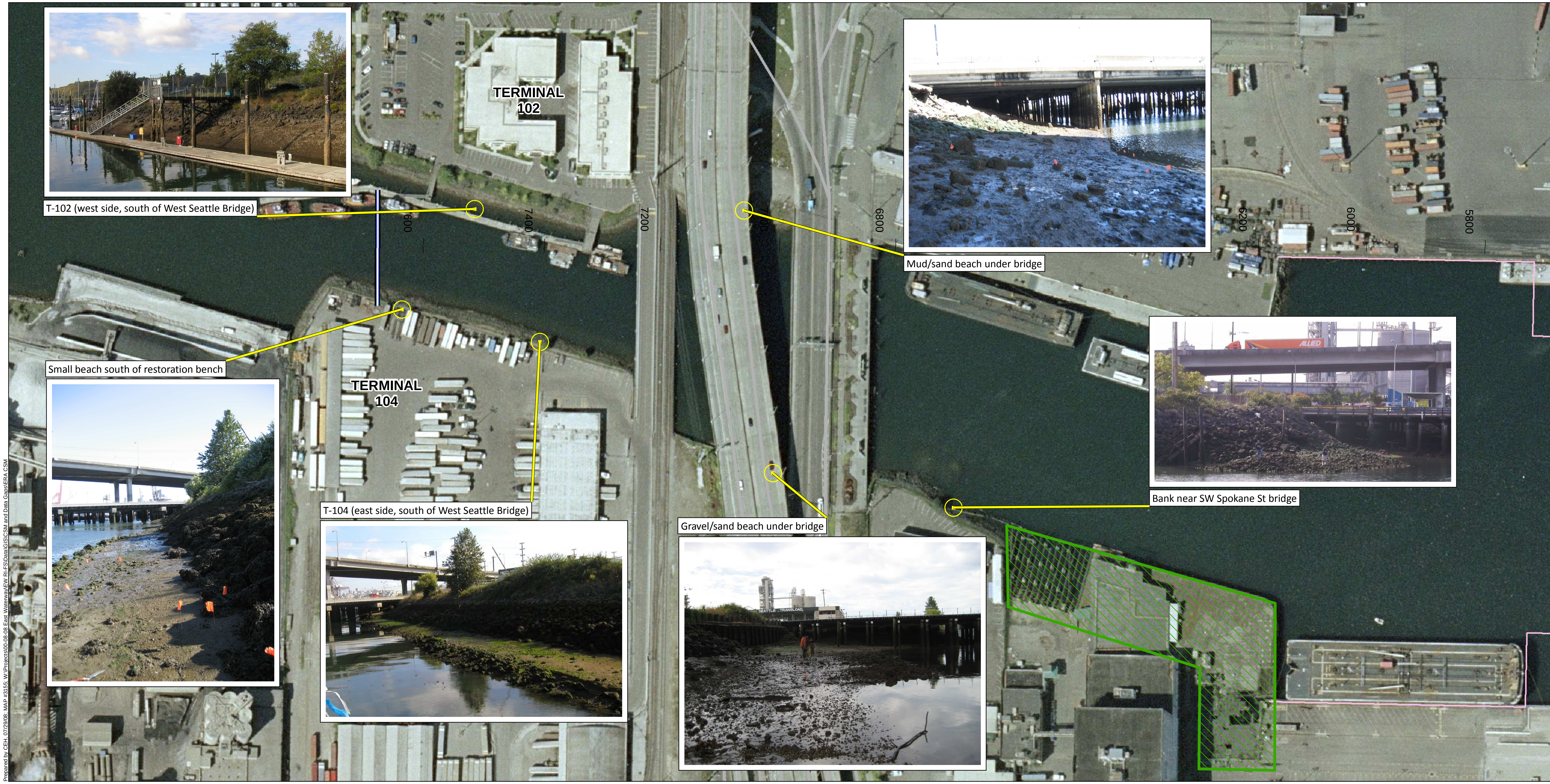
Map 2-2
Physical Hydrodynamic Model
Conceptual Site Model and Data Gaps Analysis Report
East Waterway, Seattle, Washington



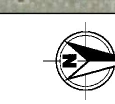
ANCHOR ENVIRONMENTAL, L.L.C.

Map 2-3
Natural Sediment Transport Model
Conceptual Site Model and Data Gaps Analysis Report
East Waterway, Seattle, Washington

06/06/08 dholmer K:\Jobs\060003-PORT OF SEATTLE\060003-01\CoreDRAW figs\Map 2-3.cdr



Prepared by CEH, 07/29/08; MAP #3155; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\CSM and Data Gaps\ERA CSM



0 300
Scale in feet

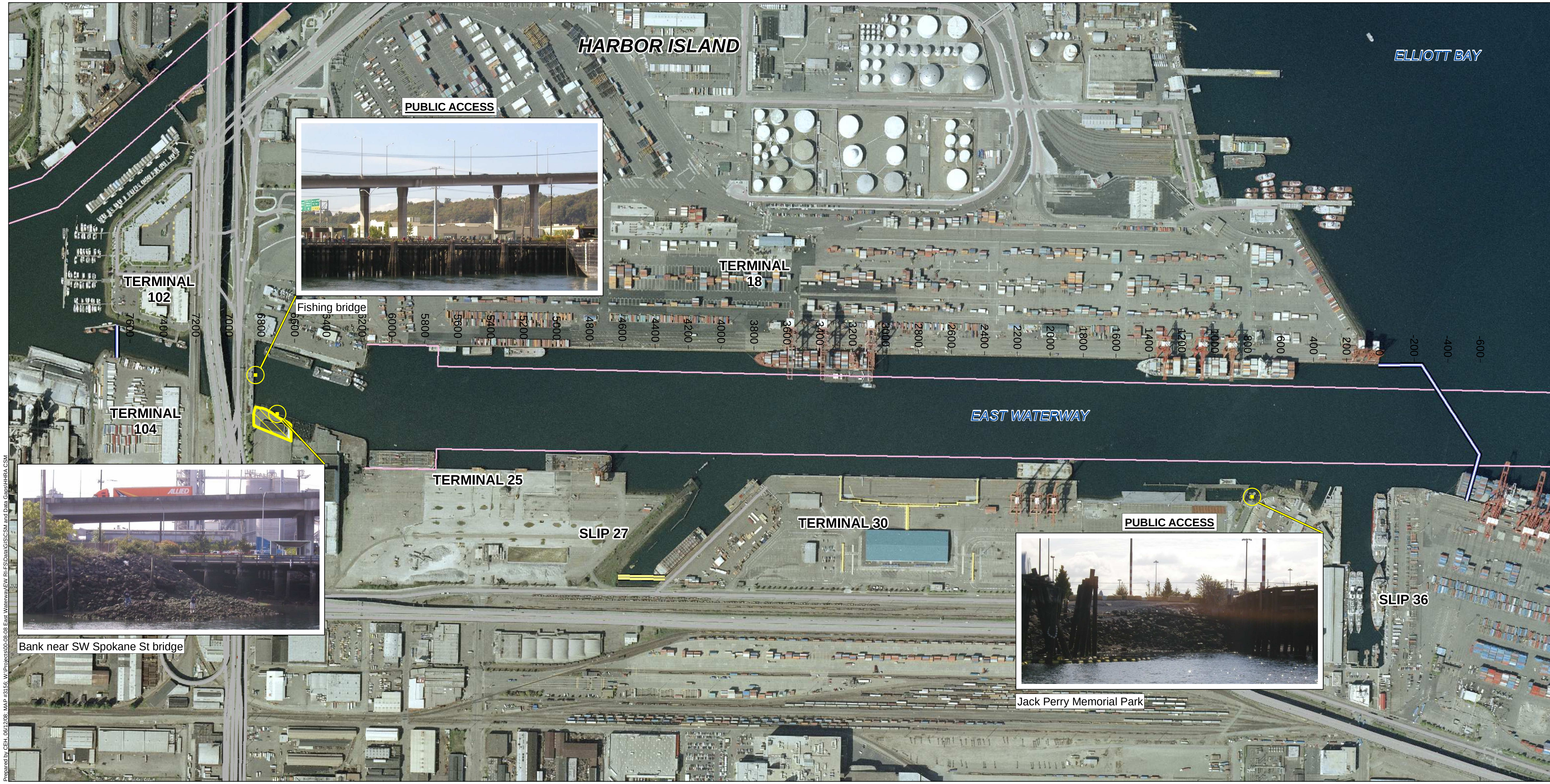
- Photo Locations
- Fish and Wildlife Habitat Enhancement Site
- Navigation Channel
- Slip 27 Bridge
- Proposed East Waterway Operable Unit Boundary

Map 3-1a
Exposed Intertidal Areas Within the East Waterway
Conceptual Site Model and Data Gaps Analysis Report
Proposed East Waterway Operable Unit

0 600
Scale in feet

- Photo Locations
- Navigation Channel
- Slip 27 Bridge
- Proposed East Waterway Operable Unit Boundary

Map 3-1b
Exposed Intertidal Areas Within the East Waterway
Conceptual Site Model and Data Gaps Analysis Report
Proposed East Waterway Operable Unit

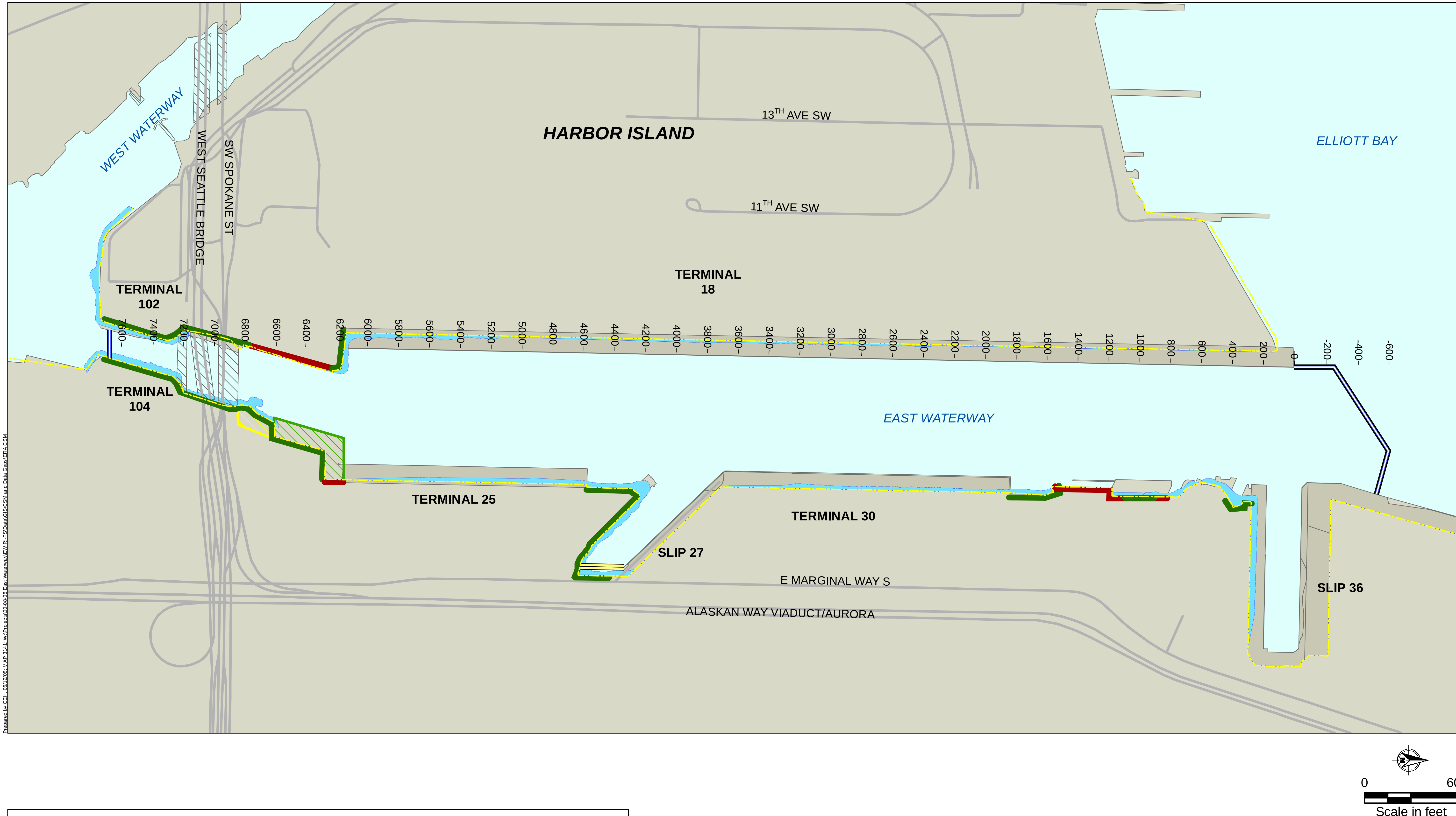


Prepared by CEH, 06/12/08; MAP #3156; W:\Projects\00-08 East Waterway\EW RI-FS\Data\GIS\CSM and Data Gaps\HHRA CSM

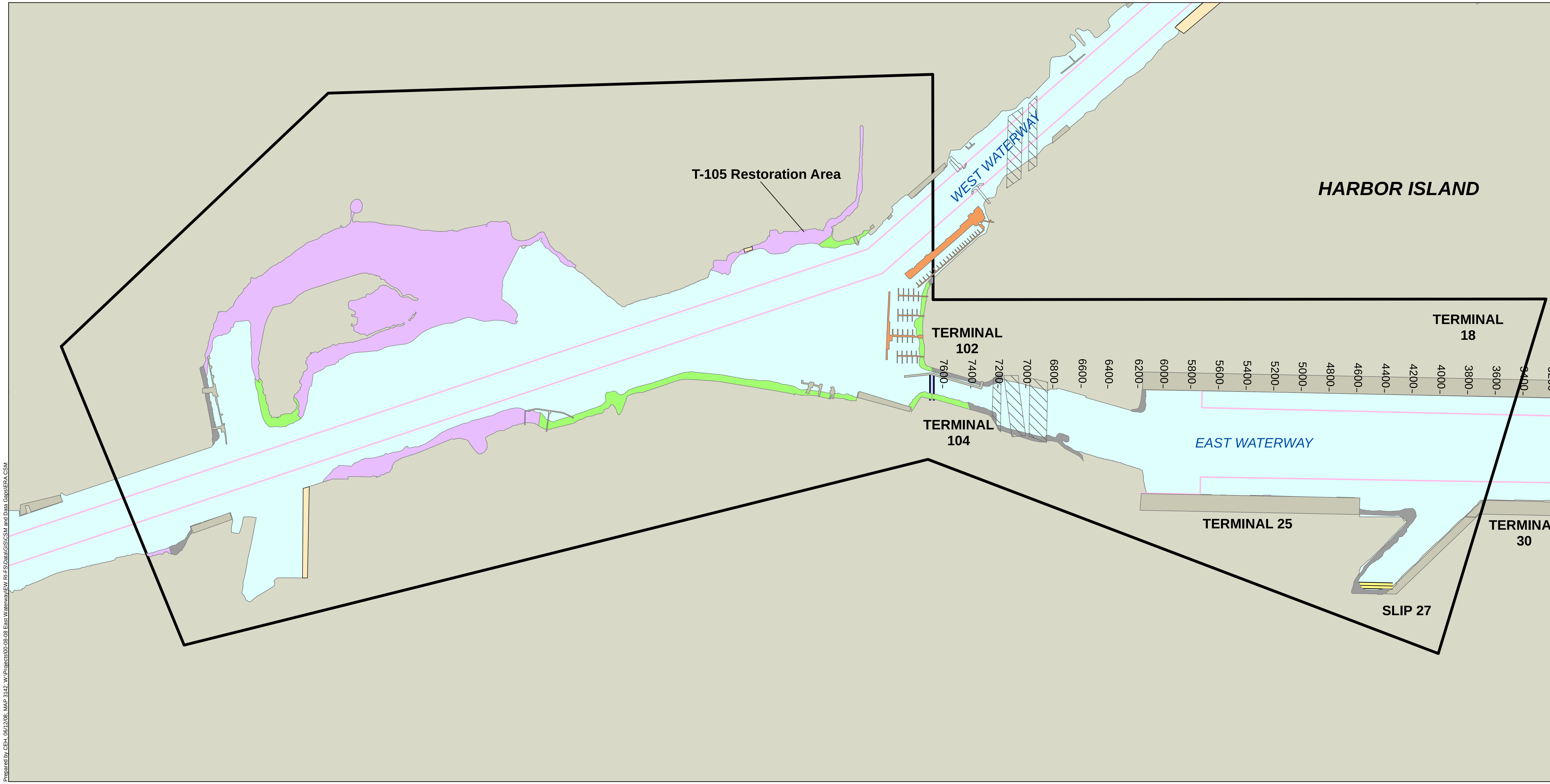
0 600
Scale in feet

- Photo Locations
- Potential Public Shoreline Use Area
- Navigation Channel
- Slip 27 Bridge
- Proposed East Waterway Operable Unit Boundary

Map 3-2
Public Access Locations Within the East Waterway
Conceptual Site Model and Data Gaps Analysis Report
Proposed East Waterway Operable Unit



Map 4-1
Intertidal, Overwater Piers, and Sheetpile Walls in the East Waterway
Conceptual Site Model and Data Gaps Analysis Report
Proposed East Waterway Operable Unit



Prepared by CEH, 06/12/08; MAP 3142; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\CSM and Data Gaps\ERA CSM

Potential Sandpiper Habitat[a]
Surveyed Areas
- High Quality Habitat
- Low Quality Habitat

Non-surveyed Areas
- Unknown Quality

Sandpiper Exposure Area[b]

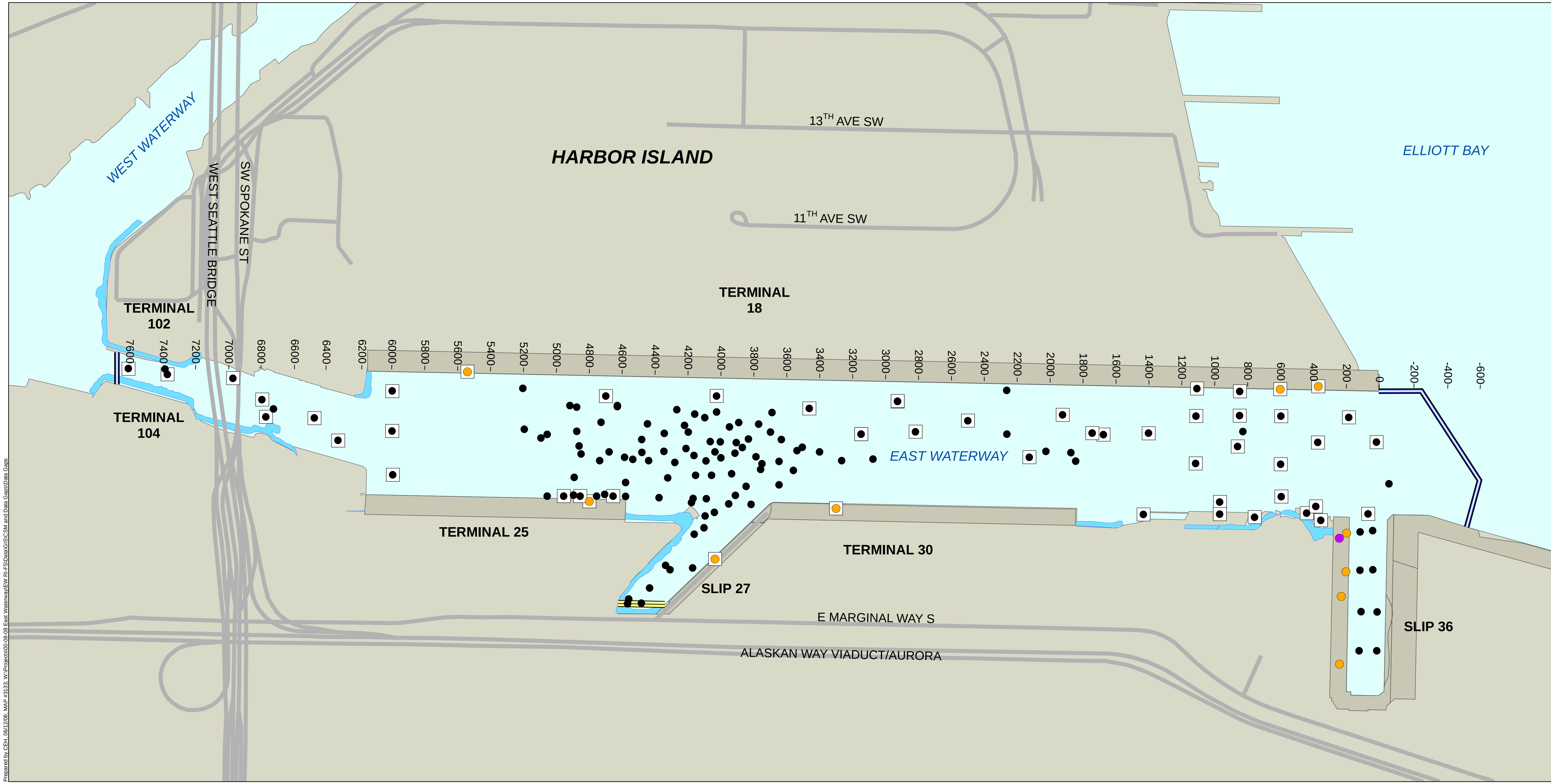
- Bridge
- Building
- Dock/Pier
- Marina
- Navigation channel
- Slip 27 Bridge
- Proposed East Waterway Operable Unit Boundary

0 600
Scale in feet

[a] Habitat was identified by assigning all exposed intertidal areas to one of three categories for habitat quality: high, low, or unknown. Areas of the Lower Duwamish Waterway were surveyed in 2004 as part of the LDW RI (Windward 2004).

[b] Sandpiper exposure area is defined as one mile in either direction from potential nesting habitat at the T-105 Restoration Area.

Map 4-2
Sandpiper Habitat and Exposure Areas in the East Waterway
Conceptual Site Model and Data Gaps Analysis Report
Proposed East Waterway Operable Unit

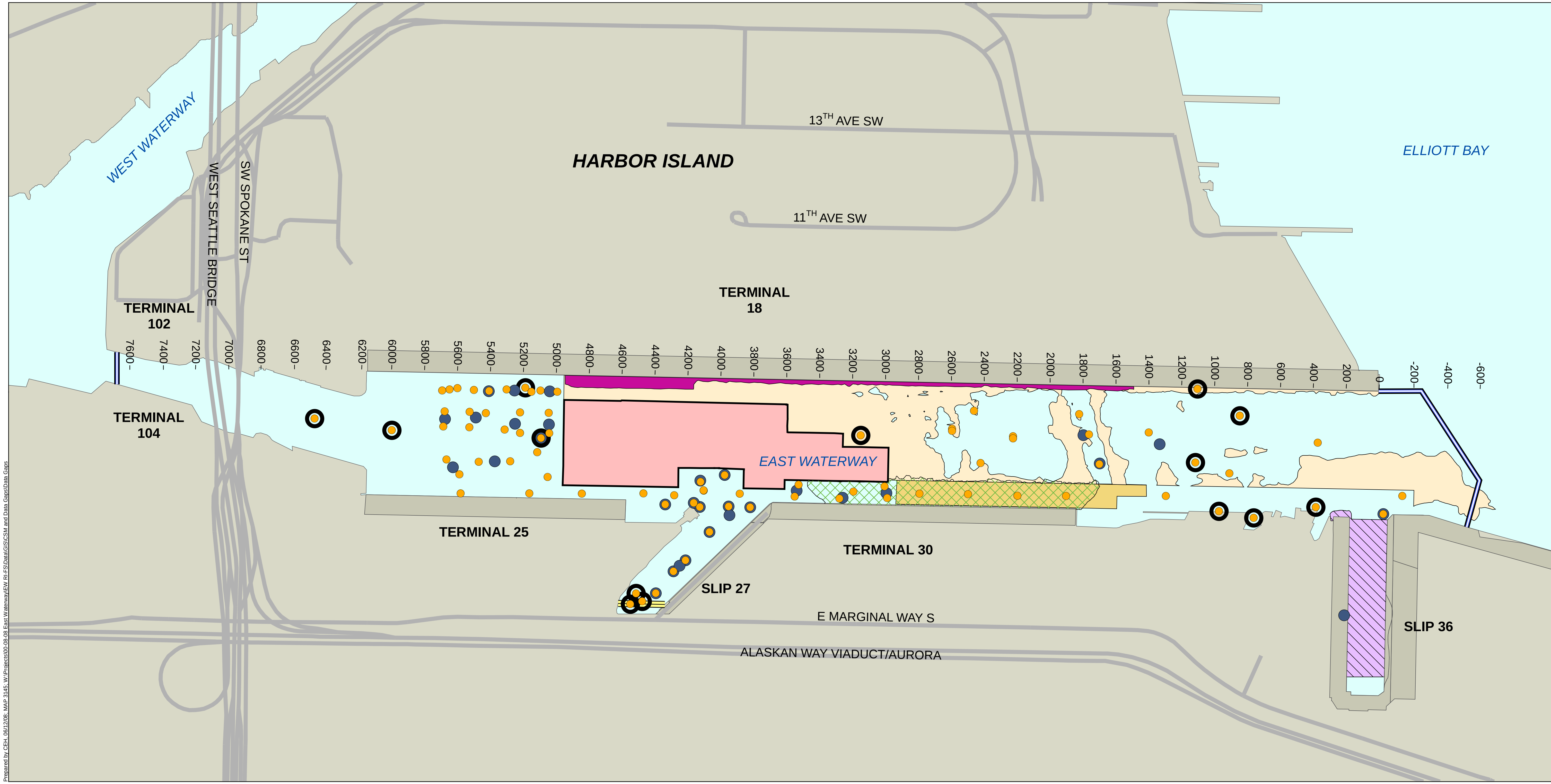


Prepared by CEH, 06/12/08; MAP #3133; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\CSM and Data Gaps\Data Gaps

- Subtidal Surface Sediment Sampling Location
- Subtidal Surface Sediment Sampling Location Under a Pier
- Intertidal Surface Sediment Sampling Location Under a Pier
- Surface Sediment Bioassay Sampling Location
- Dock/Pier
- Intertidal zone
- Slip 27 Bridge
- Proposed East Waterway Operable Unit Boundary

0 600
Scale in feet

Map 5-1
Surface Sediment Sampling Locations in the Intertidal Areas and Under Piers
Conceptual Site Model and Data Gaps Analysis Report
Proposed East Waterway Operable Unit



Prepared by CEH, 06/12/08; MAP 3145; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\CSM and Data Gaps\Data Gaps

Subsurface Location by Depth Horizon

- 0 - 4 ft
- > 4 ft
- 0 - 4 ft Locations Analyzed as Discrete Depth Intervals
- Dock/Pier
- Slip 27 Bridge
- Proposed East Waterway Operable Unit Boundary
- T-30 interim dredge (proposed 2008, -51 MLLW)
- Stage 1a (completed 2006, -51 MLLW)
- Coast Guard dredge, completed 2005
- Phase 1 removal action boundary (completed 2005, -51 MLLW)
- Stage 1 (completed 2000, -51 MLLW)
- T-30 boundary (completed 2002, -51 MLLW)

0 600
Scale in feet

Map 5-2
Subsurface Sediment Sampling Locations by Depth Horizon in the East Waterway
Conceptual Site Model and Data Gaps Analysis Report
Proposed East Waterway Operable Unit

APPENDIX A

SUMMARY OF EXISTING CHEMISTRY DATA

List of Tables

Table A-1
Summary of Chemicals in Sediment

Chemical	Detection Frequency			
	Surface Sediment		Subsurface Sediment	
	Ratio	%	Ratio	%
Metals and Trace Elements				
Aluminum	13 / 13	100	4 / 4	100
Antimony	8 / 49	16	30 / 84	36
Arsenic	75 / 111	68	112 / 125	90
Barium	13 / 13	100	4 / 4	100
Beryllium	7 / 13	54	nd	nd
Cadmium	88 / 102	86	106 / 125	85
Cadmium-SEM	2 / 2	100	nd	nd
Calcium	11 / 11	100	4 / 4	100
Chromium	108 / 108	100	52 / 52	100
Chromium VI	0 / 9	0	nd	nd
Cobalt	6 / 6	100	4 / 4	100
Copper	111 / 111	100	125 / 125	100
Copper-SEM	2 / 2	100	nd	nd
Iron	13 / 13	100	4 / 4	100
Lead	111 / 111	100	121 / 125	97
Magnesium	13 / 13	100	4 / 4	100
Manganese	13 / 13	100	4 / 4	100
Mercury	157 / 159	99	116 / 128	91
Mercury-SEM	0 / 2	0	nd	nd
Molybdenum	0 / 5	0	nd	nd
Nickel	92 / 92	100	123 / 125	98
Nickel-SEM	2 / 2	100	nd	nd
Potassium	13 / 13	100	4 / 4	100
Selenium	0 / 14	0	1 / 22	5
Silver	73 / 102	72	85 / 121	70
Sodium	13 / 13	100	4 / 4	100
Thallium	6 / 13	46	0 / 4	0
Vanadium	6 / 6	100	4 / 4	100
Zinc	111 / 111	100	125 / 125	100
Zinc-SEM	2 / 2	100	nd	nd
Organometals				
Monobutyltin as ion	7 / 9	78	7 / 21	33
Dibutyltin as ion	9 / 10	90	13 / 21	62
Tributyltin as ion	26 / 26	100	34 / 55	62
PAHs				
1-Methylnaphthalene	2 / 7	29	4 / 12	33
2-Chloronaphthalene	0 / 34	0	0 / 16	0
2-Methylnaphthalene	64 / 136	47	53 / 122	43
Acenaphthene	84 / 136	62	78 / 122	64
Acenaphthylene	69 / 136	51	43 / 122	35
Anthracene	119 / 136	88	101 / 122	83

Chemical	Detection Frequency			
	Surface Sediment		Subsurface Sediment	
	Ratio	%	Ratio	%
Benzo(a)anthracene	127 / 136	93	108 / 122	89
Benzo(a)pyrene	127 / 136	93	108 / 122	89
Benzo(b)fluoranthene	130 / 136	96	108 / 122	89
Benzo(g,h,i)perylene	108 / 136	79	102 / 122	84
Benzo(k)fluoranthene	121 / 136	89	108 / 120	90
Benzofluoranthenes (total-calc'd)	130 / 136	96	111 / 122	91
Chrysene	132 / 136	97	109 / 122	89
Dibenzo(a,h)anthracene	73 / 136	54	76 / 122	62
Dibenzofuran	64 / 136	47	70 / 122	57
Fluoranthene	135 / 136	99	114 / 122	93
Fluorene	89 / 136	65	86 / 122	70
Indeno(1,2,3-cd)pyrene	109 / 136	80	100 / 122	82
Naphthalene	80 / 136	59	83 / 122	68
Phenanthrene	132 / 136	97	112 / 122	92
Pyrene	135 / 136	99	117 / 122	96
Total HPAH (calc'd)	135 / 136	99	118 / 122	97
Total LPAH (calc'd)	132 / 136	97	113 / 122	93
Carcinogenic PAHs - Mammal - Half DL	132 / 136	97	111 / 122	91
Total PAH (calc'd)	135 / 136	99	118 / 122	97
Phthalates				
Bis(2-ethylhexyl)phthalate	106 / 123	86	85 / 122	70
Butyl benzyl phthalate	38 / 122	31	31 / 122	25
Diethyl phthalate	0 / 123	0	1 / 122	1
Dimethyl phthalate	11 / 123	9	2 / 122	2
Di-n-butyl phthalate	19 / 123	15	14 / 122	11
Di-n-octyl phthalate	2 / 123	2	1 / 121	1
Other SVOCs				
1,2,4-Trichlorobenzene	28 / 147	19	2 / 123	2
1,2-Dichlorobenzene	13 / 147	9	3 / 123	2
1,2-Diphenylhydrazine	0 / 7	0	nd	nd
1,3-Dichlorobenzene	24 / 125	19	5 / 123	4
1,4-Dichlorobenzene	77 / 147	52	18 / 123	15
2,4,5-Trichlorophenol	0 / 34	0	0 / 16	0
2,4,6-Trichlorophenol	0 / 34	0	0 / 16	0
2,4-Dichlorophenol	0 / 34	0	0 / 16	0
2,4-Dimethylphenol	4 / 123	3	3 / 122	2
2,4-Dinitrophenol	0 / 34	0	0 / 16	0
2,4-Dinitrotoluene	1 / 34	3	0 / 16	0
2,6-Dinitrotoluene	0 / 34	0	0 / 16	0
2-Chlorophenol	1 / 34	3	0 / 16	0
2-Methylphenol	2 / 123	2	1 / 121	1
2-Nitroaniline	0 / 34	0	0 / 16	0
2-Nitrophenol	0 / 34	0	0 / 16	0
3,3'-Dichlorobenzidine	0 / 32	0	0 / 16	0
3-Nitroaniline	0 / 34	0	0 / 16	0

Chemical	Detection Frequency			
	Surface Sediment		Subsurface Sediment	
	Ratio	%	Ratio	%
4,6-Dinitro-o-cresol	0 / 34	0	0 / 16	0
4-Bromophenyl phenyl ether	0 / 34	0	0 / 16	0
4-Chloro-3-methylphenol	1 / 34	3	0 / 16	0
4-Chloroaniline	0 / 32	0	0 / 16	0
4-Chlorophenyl phenyl ether	0 / 34	0	0 / 16	0
4-Methylphenol	27 / 123	22	43 / 122	35
4-Nitroaniline	0 / 34	0	0 / 16	0
4-Nitrophenol	0 / 34	0	0 / 16	0
Aniline	0 / 20	0	0 / 12	0
Benzoic acid	6 / 114	5	0 / 107	0
Benzyl alcohol	0 / 114	0	0 / 118	0
bis(2-chloroethoxy)methane	0 / 34	0	0 / 16	0
bis(2-chloroethyl)ether	0 / 34	0	0 / 16	0
bis(2-chloroisopropyl)ether	0 / 34	0	0 / 16	0
Caffeine	0 / 9	0	0 / 4	0
Carbazole	12 / 21	57	1 / 4	25
Coprostanol	8 / 13	62	0 / 4	0
Hexachlorobenzene	0 / 124	0	1 / 122	1
Hexachlorobutadiene	0 / 124	0	2 / 122	2
Hexachlorocyclopentadiene	0 / 27	0	0 / 16	0
Hexachloroethane	0 / 34	0	1 / 92	1
Isophorone	0 / 34	0	0 / 16	0
Methyl isobutyl ketone	0 / 1	0	0 / 4	0
Nitrobenzene	0 / 34	0	0 / 16	0
N-Nitrosodimethylamine	0 / 20	0	0 / 12	0
N-Nitroso-di-n-propylamine	0 / 34	0	0 / 16	0
N-Nitrosodiphenylamine	2 / 123	2	0 / 122	0
Pentachlorophenol	8 / 123	7	2 / 95	2
Phenol	53 / 123	43	42 / 122	34
Retene	2 / 9	22	1 / 4	25
Polychlorinated Biphenyls				
Aroclor-1016	0 / 160	0	0 / 124	0
Aroclor-1016/1242	nd	nd	0 / 2	0
Aroclor-1221	0 / 160	0	1 / 126	1
Aroclor-1232	0 / 160	0	0 / 126	0
Aroclor-1242	19 / 160	12	21 / 124	17
Aroclor-1248	44 / 160	28	22 / 126	17
Aroclor-1254	109 / 160	68	63 / 126	50
Aroclor-1260	157 / 160	98	106 / 126	84
PCBs (total calc'd)	158 / 160	99	106 / 126	84
Pesticides				
2,4'-DDD	0 / 18	0	0 / 12	0
2,4'-DDE	0 / 18	0	0 / 12	0
2,4'-DDT	0 / 18	0	0 / 12	0
4,4'-DDD	9 / 111	8	26 / 124	21

Chemical	Detection Frequency			
	Surface Sediment		Subsurface Sediment	
	Ratio	%	Ratio	%
4,4'-DDE	5 / 111	5	5 / 123	4
4,4'-DDT	2 / 110	2	5 / 123	4
DDTs (total-calc'd)	12 / 111	11	27 / 124	22
Aldrin	3 / 56	5	4 / 93	4
Dieldrin	0 / 56	0	6 / 94	6
Total aldrin/dieldrin (calc'd)	3 / 56	5	6 / 94	6
alpha-BHC	0 / 50	0	0 / 16	0
beta-BHC	0 / 50	0	0 / 16	0
gamma-BHC	0 / 56	0	0 / 94	0
delta-BHC	0 / 50	0	0 / 16	0
alpha-Chlordane	0 / 51	0	2 / 89	2
gamma-Chlordane	2 / 51	4	2 / 71	3
Chlordane	0 / 5	0	0 / 4	0
alpha-Endosulfan	0 / 50	0	0 / 16	0
beta-Endosulfan	0 / 50	0	0 / 16	0
Endosulfan sulfate	0 / 50	0	0 / 16	0
Endrin	0 / 50	0	0 / 16	0
Endrin aldehyde	0 / 50	0	0 / 16	0
Endrin ketone	0 / 45	0	0 / 16	0
Heptachlor	2 / 56	4	0 / 94	0
Heptachlor epoxide	0 / 50	0	0 / 16	0
Methoxychlor	0 / 50	0	0 / 16	0
Mirex	0 / 18	0	0 / 12	0
Cis-Nonachlor	0 / 18	0	0 / 18	0
Oxychlordane	0 / 18	0	0 / 12	0
Toxaphene	0 / 32	0	0 / 16	0
Trans-Nonachlor	0 / 18	0	0 / 18	0
Total Chlordane (calc'd)	2 / 51	4	4 / 90	4
Volatile Organic Compounds				
1,1,1-Trichloroethane	0 / 1	0	0 / 4	0
1,1,2,2-Tetrachloroethane	0 / 1	0	0 / 4	0
1,1,2-Trichloroethane	0 / 1	0	0 / 4	0
1,1-Dichloroethane	0 / 1	0	0 / 4	0
1,1-Dichloroethene	0 / 1	0	0 / 4	0
1,2-Dichloroethane	0 / 1	0	0 / 4	0
1,2-Dichloroethene (total)	0 / 1	0	0 / 4	0
1,2-Dichloropropane	0 / 1	0	0 / 4	0
2-Hexanone	0 / 1	0	0 / 4	0
Acetone	0 / 1	0	0 / 4	0
Benzene	0 / 1	0	0 / 4	0
Bromodichloromethane	0 / 1	0	0 / 4	0
Bromoform	0 / 1	0	0 / 4	0
Bromomethane	0 / 1	0	0 / 4	0
Carbon disulfide	0 / 1	0	0 / 4	0
Carbon tetrachloride	0 / 1	0	0 / 4	0

Chemical	Detection Frequency			
	Surface Sediment		Subsurface Sediment	
	Ratio	%	Ratio	%
Chlorobenzene	0 / 1	0	0 / 4	0
Chloroethane	0 / 1	0	0 / 4	0
Chloroform	0 / 1	0	0 / 4	0
Chloromethane	0 / 1	0	0 / 4	0
cis-1,3-Dichloropropene	0 / 1	0	0 / 4	0
Dibromochloromethane	0 / 1	0	0 / 4	0
Dichloromethane	0 / 1	0	0 / 4	0
Ethylbenzene	0 / 1	0	9 / 82	11
Methyl ethyl ketone	0 / 1	0	0 / 4	0
Styrene	0 / 1	0	0 / 4	0
Tetrachloroethene	0 / 1	0	0 / 82	0
Toluene	1 / 1	100	4 / 4	100
trans-1,3-Dichloropropene	0 / 1	0	0 / 4	0
Trichloroethene	0 / 1	0	0 / 82	0
Vinyl chloride	0 / 1	0	0 / 4	0
Xylene (ortho)	nd	nd	10 / 58	17
Xylene (meta & para)	nd	nd	5 / 58	9
Total Xylenes	0 / 1	0	11 / 82	13
Petroleum Groups				
Gasoline	0 / 9	0	0 / 4	0
TPH - Diesel #2 Range	2 / 9	22	0 / 4	0
Creosote	nd	nd	1 / 4	25
Lube Oils	5 / 9	56	nd	nd
TPH - Oil and Grease	4 / 5	80	nd	nd
Grain Size				
Fractional % phi >-3 (>8000µm)	nd	nd	3 / 8	38
Fractional % phi >-2 (>4000µm)	6 / 7	86	nd	nd
Fractional % phi >-1 (>2000µm)	77 / 88	88	28 / 29	97
Fractional % phi -3-(-2) (4000-8000µm)	4 / 7	57	4 / 10	40
Fractional % phi -2-(-1) (2000-4000µm)	7 / 7	100	5 / 10	50
Fractional % phi -1-0 (1000-2000µm)	94 / 95	99	37 / 39	95
Fractional % phi 0-1 (500-1000µm)	95 / 95	100	38 / 39	97
Fractional % phi 1-2 (250-500µm)	95 / 95	100	39 / 39	100
Fractional % phi 2-3 (125-250µm)	95 / 95	100	39 / 39	100
Fractional % phi 3-4 (62.5-125µm)	95 / 95	100	39 / 39	100
Fractional % phi 4-5 (31.2-62.5µm)	95 / 95	100	39 / 39	100
Fractional % phi 5-6 (15.6-31.2µm)	95 / 95	100	39 / 39	100
Fractional % phi 6-7 (7.8-15.6µm)	95 / 95	100	39 / 39	100
Fractional % phi 7-8 (3.9-7.8µm)	95 / 95	100	39 / 39	100
Fractional % phi 8-9 (1.95-3.9µm)	95 / 95	100	39 / 39	100
Fractional % phi 9-10 (0.98-1.95µm)	95 / 95	100	39 / 39	100
Fractional % phi 10 (0.98µm)	nd	nd	2 / 2	100
Fractional % phi 10+ (<0.98µm)	95 / 95	100	39 / 39	100
Gravel (total calc'd)	86 / 97	89	82 / 85	96
Sand (total calc'd)	106 / 106	100	89 / 89	100

Chemical	Detection Frequency			
	Surface Sediment		Subsurface Sediment	
	Ratio	%	Ratio	%
Silt (total calc'd)	106 / 106	100	89 / 89	100
Clay (total calc'd)	106 / 106	100	89 / 89	100
Fines (percent silt+clay)	106 / 106	100	92 / 92	100
Conventional Parameters				
Total Organic Carbon (TOC)	202 / 202	100	126 / 126	100
Total solids	151 / 151	100	107 / 107	100
Total solids (preserved)	42 / 42	100	18 / 18	100
Total volatile solids	18 / 18	100	62 / 62	100
Total volatile solids	6 / 6	100	nd	nd
Sulfides (total)	54 / 59	92	76 / 78	97
Acid volatile sulfides	7 / 7	100	nd	nd
Ammonia (total as nitrogen)	50 / 50	100	94 / 94	100
Cyanide	0 / 6	0	4 / 4	100
Moisture	2 / 2	100	nd	nd
Oxidation reduction-field	6 / 6	100	nd	nd
pH	3 / 3	100	nd	nd

nd - no data

ANALYTICAL CONCENTRATION GOALS FOR THE PROTECTION OF BENTHIC INVERTEBRATES

Analytical concentrations goals (ACGs) for the protection of benthic invertebrates are expressed as chemical concentrations in sediment, to which benthic invertebrates are directly exposed. The benthic invertebrate ACGs are derived primarily from the Washington State Department of Ecology's (Ecology's) Sediment Management Standards (SMS). The SMS include numeric chemical standards for 47 chemicals or groups of chemical. The lowest standard is called the Sediment Quality Standard (SQS). The Dredged Material Management Program (DMMP) includes similar criteria. The lowest guideline in that program is called the Screening Level (SL). There are 14 chemicals that have SLs but do not have an SQS value. For these chemicals, the SL is used as the ACG. The SQS and SL values are presented in Table A-2. When sediment TOC exceeds the range of TOC values approved for normalization then dry weight AET values are used in place of SQS. The AETs in Table A-2 for benthic invertebrates are equivalent to the SQS/SL for chemicals with standards expressed on a dry weight basis.

Table A-2
Sediment SMS and Apparent Effects Threshold Criteria

	Benthic ACG					
	SMS Criteria			AET Criteria		
Chemical	Unit	SQS	CSL	Unit	LAET	2LAET
Antimony [a]	mg/kg dw	150	200	na	na	na
Arsenic	mg/kg dw	57	93	na	na	na
Cadmium	mg/kg dw	5.1	6.7	na	na	na
Chromium	mg/kg dw	260	270	na	na	na
Cobalt	nv	nv	nv	nv	nv	nv
Copper	mg/kg dw	390	390	na	na	na
Lead	mg/kg dw	450	530	na	na	na
Mercury	mg/kg dw	0.41	0.59	na	na	na
Molybdenum	nv	nv	nv	nv	nv	nv
Nickel [a]	mg/kg dw	140	370	na	na	na
Selenium	nv	nv	nv	nv	nv	nv
Silver	mg/kg dw	6.1	6.1	na	na	na
Thallium	nv	nv	nv	nv	nv	nv
Vanadium	nv	nv	nv	nv	nv	nv
Zinc	mg/kg dw	410	960	na	na	na
Tributyltin as ion	nv	nv	nv	nv	nv	nv
2-Chloronaphthalene	nv	nv	nv	nv	nv	nv
2-Methylnaphthalene	mg/kg OC	38	64	µg/kg dw	670	1,400

Chemical	Benthic ACG					
	SMS Criteria			AET Criteria		
	Unit	SQS	CSL	Unit	LAET	2LAET
Acenaphthene	mg/kg OC	16	57	µg/kg dw	500	730
Acenaphthylene	mg/kg OC	66	66	µg/kg dw	1,300	1,300
Anthracene	mg/kg OC	220	1,200	µg/kg dw	960	4,400
Benzo(a)anthracene	mg/kg OC	110	270	µg/kg dw	1,300	1,600
Benzo(a)pyrene	mg/kg OC	99	210	µg/kg dw	1,600	3,000
Benzo(b)fluoranthene	nv	nv	nv	nv	nv	nv
Benzo(g,h,i)perylene	mg/kg OC	31	78	µg/kg dw	670	720
Benzo(k)fluoranthene	nv	nv	nv	nv	nv	nv
Benzofluoranthenes (total-calc'd)	mg/kg OC	230	450	µg/kg dw	3,200	3,600
Chrysene	mg/kg OC	110	460	µg/kg dw	1,400	2,800
Dibenzo(a,h)anthracene	mg/kg OC	12	33	µg/kg dw	230	540
Dibenzofuran	mg/kg OC	15	58	µg/kg dw	540	700
Fluoranthene	mg/kg OC	160	1,200	µg/kg dw	1,700	2,500
Fluorene	mg/kg OC	23	79	µg/kg dw	540	1,000
Indeno(1,2,3-cd)pyrene	mg/kg OC	34	88	µg/kg dw	600	690
Naphthalene	mg/kg OC	99	170	µg/kg dw	2,100	2,400
Phenanthrene	mg/kg OC	100	480	µg/kg dw	1,500	5,400
Pyrene	mg/kg OC	1,000	1,400	µg/kg dw	2,600	3,300
Total HPAH	mg/kg OC	960	5,300	µg/kg dw	12,000	17,000
Total LPAH	mg/kg OC	370	780	µg/kg dw	5,200	13,000
bis(2-ethylhexyl)phthalate	mg/kg OC	47	78	µg/kg dw	1,300	1,900
Butyl benzyl phthalate	mg/kg OC	4.9	64	µg/kg dw	63	900
Diethyl phthalate	mg/kg OC	61	110	µg/kg dw	200	1,200
Dimethyl phthalate	mg/kg OC	53	53	µg/kg dw	71	160
Di-n-butyl phthalate	mg/kg OC	220	1,700	µg/kg dw	1,400	5,100
Di-n-octyl phthalate	mg/kg OC	58	4,500	µg/kg dw	6,200	nv
Aroclor-1016	nv	nv	nv	nv	nv	nv
Aroclor-1221	nv	nv	nv	nv	nv	nv
Aroclor-1232	nv	nv	nv	nv	nv	nv
Aroclor-1242	nv	nv	nv	nv	nv	nv
Aroclor-1248	nv	nv	nv	nv	nv	nv
Aroclor-1254	nv	nv	nv	nv	nv	nv
Aroclor-1260	nv	nv	nv	nv	nv	nv
PCBs (total calc'd)	mg/kg OC	12	65	µg/kg dw	130	1,000
1,2,4-Trichlorobenzene	mg/kg OC	0.81	1.8	µg/kg dw	31	51
1,2-Dichlorobenzene	mg/kg OC	2.3	2.3	µg/kg dw	35	50
1,3-Dichlorobenzene [a]	µg/kg dw	170	nv	nv	nv	nv
1,4-Dichlorobenzene	mg/kg OC	3.1	9	µg/kg dw	110	120
2,4,5-Trichlorophenol	nv	nv	nv	nv	nv	nv
2,4,6-Trichlorophenol	nv	nv	nv	nv	nv	nv

Chemical	Benthic ACG					
	SMS Criteria			AET Criteria		
	Unit	SQS	CSL	Unit	LAET	2LAET
2,4-Dichlorophenol	nv	nv	nv	nv	nv	nv
2,4-Dimethylphenol	µg/kg dw	29	29	na	na	na
2,4-Dinitrophenol	nv	nv	nv	nv	nv	nv
2,4-Dinitrotoluene	nv	nv	nv	nv	nv	nv
2,6-Dinitrotoluene	nv	nv	nv	nv	nv	nv
2-Chlorophenol	nv	nv	nv	nv	nv	nv
2-Methylphenol	µg/kg dw	63	63	na	na	na
3,3'-Dichlorobenzidine	nv	nv	nv	nv	nv	nv
4-Chloroaniline	nv	nv	nv	nv	nv	nv
4-Methylphenol	µg/kg dw	670	670	na	na	na
Aniline	nv	nv	nv	nv	nv	nv
Benzoic acid	µg/kg dw	650	650	na	na	na
Benzyl alcohol	µg/kg dw	57	73	na	na	na
bis(2-chloroethyl)ether	nv	nv	nv	nv	nv	nv
bis(2-chloroisopropyl)ether	nv	nv	nv	nv	nv	nv
Hexachlorobenzene	mg/kg OC	0.38	2.3	µg/kg dw	22	70
Hexachlorobutadiene	mg/kg OC	3.9	6.2	µg/kg dw	11	120
Hexachloroethane [a]	µg/kg dw	1,400	14,000	na	na	na
Isophorone	nv	nv	nv	nv	nv	nv
Nitrobenzene	nv	nv	nv	nv	nv	nv
N-Nitrosodimethylamine	nv	nv	nv	nv	nv	nv
N-Nitroso-di-n-propylamine	nv	nv	nv	nv	nv	nv
N-Nitrosodiphenylamine	mg/kg OC	11	11	µg/kg dw	28	40
Pentachlorophenol	µg/kg dw	360	690	na	na	na
Phenol	µg/kg dw	420	1,200	na	na	na
2,4'-DDD	nv	nv	nv	nv	nv	nv
2,4'-DDE	nv	nv	nv	nv	nv	nv
2,4'-DDT	nv	nv	nv	nv	nv	nv
4,4'-DDD	nv	nv	nv	nv	nv	nv
4,4'-DDE	nv	nv	nv	nv	nv	nv
4,4'-DDT	nv	nv	nv	nv	nv	nv
DDTs (total-calc'd) [a]	µg/kg dw	6.9	69	na	na	na
Aldrin [a]	µg/kg dw	10	nv	na	na	na
Dieldrin [a]	µg/kg dw	10	nv	na	na	na
alpha-BHC	nv	nv	nv	nv	nv	nv
beta-BHC	nv	nv	nv	nv	nv	nv
gamma-BHC [a]	µg/kg dw	10	nv	na	na	na
alpha-Endosulfan	nv	nv	nv	nv	nv	nv
beta-Endosulfan	nv	nv	nv	nv	nv	nv
Endosulfan sulfate	nv	nv	nv	nv	nv	nv

Chemical	Benthic ACG					
	SMS Criteria			AET Criteria		
	Unit	SQS	CSL	Unit	LAET	2LAET
Endrin	nv	nv	nv	nv	nv	nv
Heptachlor [a]	µg/kg dw	10	nv	na	na	na
Heptachlor epoxide	nv	nv	nv	nv	nv	nv
Methoxychlor	nv	nv	nv	nv	nv	nv
Mirex	nv	nv	nv	nv	nv	nv
Toxaphene	nv	nv	nv	nv	nv	nv
Total Chlordane (calc'd) [a]	µg/kg dw	10	nv	na	na	na
Ethylbenzene [a]	µg/kg dw	10	50	na	na	na
Tetrachloroethene [a]	µg/kg dw	57	210	na	na	na
Total xylenes [a]	µg/kg dw	40	160	na	na	na
Trichloroethene [a]	µg/kg dw	57	210	na	na	na

a DMMP criteria is presented because SMS criteria is not available for this chemical.
na - not applicable; dry weight SMS or DMMP criteria is used for comparison
nv - there is no criteria available for this chemical

HUMAN HEALTH RISK-BASED ACGs FOR DIRECT CONTACT

ACGs for the protection of humans that may directly contact or incidentally ingest sediment are expressed as chemical concentrations in sediment. Human health guidance documents were reviewed for ACGs for human health. The U.S. Environmental Protection Agency (EPA) Region 10 has not developed sediment risk-based concentrations (RBCs) for the protection of human health, but EPA Regions 6 and 9 have compiled RBCs for the protection of human health from exposures to soil (EPA 2002). The RBCs from Region 6 and Region 9 were compared and the lower of the two values was selected for use as an ACG for direct contact. It should be noted that EPA is revising its approach to computing preliminary remediation goals (PRGs), integrating the approaches of Regions 3, 6, and 9. Quality Assurance Project Plans (QAPPs) prepared subsequent to this Conceptual Site Model (CSM) and Data Gaps Analysis Report will be developed in consultation with EPA and will utilize EPA's new integrated PRG approach.

The Model Toxics Control Act (MTCA; a Washington State statute) also includes RBCs for soil, but they are higher than the EPA RBCs because of different exposure parameters. Consequently, EPA RBCs were used instead of MTCA RBCs because they are more health protective. The soil RBCs represent very conservative ACGs for East Waterway (EW) sediments because they are based on residential soil exposure scenarios at a target HQ of 0.1.

EPA (2002) contains soil RBCs for both industrial and residential scenarios. Residential RBCs were used in this appendix because they are more health protective than the industrial RBCs. RBCs for chemicals with non-carcinogenic effects were decreased by a factor of 10 to account for the target hazard quotients of 0.1 used in screening by EPA Region 10.[1] ACGs can be calculated for chemicals with either carcinogenic or non-carcinogenic endpoints; some chemicals have both types of endpoints. For chemicals with both endpoints, the lower ACG is shown in Table A-3. Indirect sediment exposure pathway RBCs for the indirect sediment exposure pathway (i.e., seafood consumption) require that a relationship be developed between chemical concentrations in tissue and sediment. One commonly used method for evaluating such a relationship for nonpolar organic chemicals that may bioaccumulate is the biota sediment accumulation factor (BSAF). BSAFs can be derived using Equation 1:

$$BSAF = \frac{C_{WB} \div F_L}{C_{sed} \div F_{oc}}$$ **Equation 1**

where:

C_{WB}	=	chemical concentration in whole-body tissue (mg/kg ww)
C_{sed}	=	chemical concentration in sediment (mg/kg dw)
F_L	=	fraction lipid in tissue (kg lipid/kg ww)
F_{oc}	=	fraction organic carbon in sediment (kg OC/kg dw)

A key variable in the BSAF equation is the sediment concentration (C_{sed}). The BSAF equation is based on the assumption that C_{sed} represents the average chemical concentration in sediment to which the organism is exposed. For animals with very small home ranges, such as clams, this assumption may be reasonable if sediment data are collected concurrently with tissue data at the tissue collection locations. For animals with larger home ranges, such as fish, there is greater uncertainty in this assumption because many fish are highly mobile and are not likely to inhabit all areas of their home range with equal frequency. Consequently, fish BSAFs for a given chemical may easily range over at least an order of magnitude (USACE 2003).

[1] EPA Region 10 recommends a target hazard quotient of 0.1; therefore, the EPA Region 9 RBCs (which are based on a target hazard quotient of 1) have been adjusted by dividing by 10 for the ACG.

Equation 1 can be rearranged to solve for C_{sed}, as follows:

$$C_{sed} = \frac{(C_{WB} \div F_L) \times F_{oc}}{BSAF} \qquad \textbf{Equation 2}$$

For this appendix, the C_{WB} based on 98 g/day was used in Equation 2. The BSAFs used to calculate ACGs for sediment (i.e., C_{sed} in Equation 2) were from four sources:

- U.S. Army Corps of Engineers (USACE). 2007. Environmental Residue-Effects Database (ERED). U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Online database: http://el.erdc.usace.army.mil/ered/. Last database update: September 2007.
- Tracey GA, Hansen DJ. 1996. *Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode.* Arch Environ Contam Toxicol 30:467-475.
- EPA. 1997. *The incidence and severity of sediment contamination in surface waters of the United States.* Volume 1: National Sediment Quality Survey. EPA 823-R-97-006. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC.
- Washington State Department of Health. 1995. *Tier I report, development of sediment quality criteria for the protection of human health.* Washington State Department of Health, Olympia, Washington.

The BSAFs cited in these four sources were selected for use as individual values for each analyte. These values will not necessarily be used for any other purpose in the EW Supplemental Remedial Investigation other than developing sediment ACGs in this appendix. BSAFs for bivalve mollusks are most appropriate for the ACG calculation, as described above. However, some fish BSAFs were used in this appendix when bivalve BSAFs were not available (i.e., some semivolatile organic compound [SVOCs] and 2,3,7,8-TCDD).

Table A-3
Direct and Indirect Human Exposure ACGs

Chemical	Unit	Direct Human Exposure ACG	Indirect Human Exposure ACG
Antimony [a]	mg/kg dw	3.1	nv
Arsenic	mg/kg dw	0.39	0.006
Cadmium	mg/kg dw	3.7	0.003

Chemical	Unit	Direct Human Exposure ACG	Indirect Human Exposure ACG
Chromium	mg/kg dw	30	100
Cobalt	mg/kg dw	900	nv
Copper	mg/kg dw	290	1.3
Lead	mg/kg dw	40	nv
Mercury	mg/kg dw	2.3	0.016
Molybdenum	mg/kg dw	39	nv
Nickel [a]	mg/kg dw	160	nv
Selenium	mg/kg dw	39	nv
Silver	mg/kg dw	39	nv
Thallium	mg/kg dw	0.52	nv
Vanadium	mg/kg dw	7.8	nv
Zinc	mg/kg dw	2,300	16
Tributyltin as ion	µg/kg dw	1,800	0.28
2-Chloronaphthalene	µg/kg dw	390,000	nv
2-Methylnaphthalene	nv	nv	1,700
Acenaphthene	µg/kg dw	370,000	540,000
Acenaphthylene	nv	nv	nv
Anthracene	µg/kg dw	2,200,000	900,000
Benzo(a)anthracene	µg/kg dw	150	5.2
Benzo(a)pyrene	µg/kg dw	15	0.76
Benzo(b)fluoranthene	µg/kg dw	150	4.7
Benzo(g,h,i)perylene	nv	nv	nv
Benzo(k)fluoranthene	µg/kg dw	1,500	47
Benzofluoranthenes (total-calc'd)	nv	nv	nv
Chrysene	µg/kg dw	15,000	480
Dibenzo(a,h)anthracene	µg/kg dw	15	nv
Dibenzofuran	µg/kg dw	15,000	560
Fluoranthene	µg/kg dw	230,000	2,100
Fluorene	µg/kg dw	260,000	nv
Indeno(1,2,3-cd)pyrene	µg/kg dw	150	2.9
Naphthalene	µg/kg dw	5,600	4,500
Phenanthrene	nv	nv	nv
Pyrene	µg/kg dw	230,000	8,900
Total HPAH	nv	nv	nv
Total LPAH	nv	nv	nv
bis(2-ethylhexyl)phthalate	µg/kg dw	35,000	120
Butyl benzyl phthalate	µg/kg dw	240,000	30,000
Diethyl phthalate	µg/kg dw	4,900,000	nv
Dimethyl phthalate	µg/kg dw	10,000,000	1,400,000
Di-n-butyl phthalate	µg/kg dw	610,000	14,000
Di-n-octyl phthalate	µg/kg dw	240,000	3,000
Aroclor-1016	µg/kg dw	390	6.1

Chemical	Unit	Direct Human Exposure ACG	Indirect Human Exposure ACG
Aroclor-1221	µg/kg dw	220	0.21
Aroclor-1232	µg/kg dw	220	0.21
Aroclor-1242	µg/kg dw	220	0.21
Aroclor-1248	µg/kg dw	220	0.21
Aroclor-1254	µg/kg dw	220	0.21
Aroclor-1260	µg/kg dw	220	0.21
PCBs (total calc'd)	µg/kg dw	220	0.21
1,2,4-Trichlorobenzene	µg/kg dw	6,200	nv
1,2-Dichlorobenzene	µg/kg dw	28,000	12,000
1,3-Dichlorobenzene [a]	µg/kg dw	1,600	nv
1,4-Dichlorobenzene	µg/kg dw	3,200	73
2,4,5-Trichlorophenol	µg/kg dw	610,000	37,000
2,4,6-Trichlorophenol	µg/kg dw	610	nv
2,4-Dichlorophenol	µg/kg dw	18,000	1,100
2,4-Dimethylphenol	µg/kg dw	120,000	nv
2,4-Dinitrophenol	µg/kg dw	12,000	nv
2,4-Dinitrotoluene	µg/kg dw	12,000	nv
2,6-Dinitrotoluene	µg/kg dw	6,100	nv
2-Chlorophenol	µg/kg dw	6,300	1,800
2-Methylphenol	µg/kg dw	310,000	nv
3,3'-Dichlorobenzidine	µg/kg dw	1,100	nv
4-Chloroaniline	µg/kg dw	24,000	nv
4-Methylphenol	µg/kg dw	31,000	1,800
Aniline	µg/kg dw	85,000	nv
Benzoic acid	µg/kg dw	10,000,000	nv
Benzyl alcohol	µg/kg dw	1,800,000	nv
bis(2-chloroethyl)ether	µg/kg dw	210	nv
bis(2-chloroisopropyl)ether	µg/kg dw	2,900	nv
Carbazole	µg/kg dw	24,000	230
Hexachlorobenzene	µg/kg dw	300	nv
Hexachlorobutadiene	µg/kg dw	6,200	23
Hexachloroethane [a]	µg/kg dw	35,000	120
Isophorone	µg/kg dw	510,000	nv
Nitrobenzene	µg/kg dw	2,000	nv
N-Nitrosodimethylamine	µg/kg dw	2	nv
N-Nitroso-di-n-propylamine	µg/kg dw	69	nv
N-Nitrosodiphenylamine	µg/kg dw	99,000	nv
Pentachlorophenol	µg/kg dw	3,000	nv
Phenol	µg/kg dw	1,800,000	210,000
2,4'-DDD	µg/kg dw	1,700	8.3
2,4'-DDE	µg/kg dw	1,700	2.6
2,4'-DDT	µg/kg dw	1,700	0.92

Chemical	Unit	Direct Human Exposure ACG	Indirect Human Exposure ACG
4,4'-DDD	µg/kg dw	1,700	8.3
4,4'-DDE	µg/kg dw	1,700	2.6
4,4'-DDT	µg/kg dw	1,700	0.92
DDTs (total-calc'd) [a]	µg/kg dw	1,700	0.92
Aldrin [a]	µg/kg dw	29	0.063
Dieldrin [a]	µg/kg dw	30	0.033
alpha-BHC	µg/kg dw	90	nv
beta-BHC	µg/kg dw	320	0.63
gamma-BHC [a]	µg/kg dw	440	0.83
alpha-Endosulfan	µg/kg dw	37,000	500
beta-Endosulfan	µg/kg dw	37,000	500
Endosulfan sulfate	µg/kg dw	37,000	500
Endrin	µg/kg dw	1,800	27
Heptachlor [a]	µg/kg dw	110	0.25
Heptachlor epoxide	µg/kg dw	53	nv
Methoxychlor	µg/kg dw	31,000	440
Mirex	µg/kg dw	270	nv
Toxaphene	µg/kg dw	440	nv
Total Chlordane (calc'd) [a]	µg/kg dw	1,600	1.7
Ethylbenzene [a]	µg/kg dw	1,700	nv
Tetrachloroethene [a]	µg/kg dw	1,700	nv
Total xylenes [a]	µg/kg dw	1,700	nv
Trichloroethene [a]	µg/kg dw	1,700	nv

a DMMP criteria is presented because SMS criteria is not available for this chemical.
na - not applicable; dry weight SMS or DMMP criteria is used for comparison
nv - there is no criteria available for this chemical

Table A-4
Summary of Metals RLs for Sediment Samples Compared to Direct Human Exposure ACGs for Chemicals With At Least One RL > ACG
(mg/kg dw)

Chemical	Detection Frequency (DF)	DF (%)	Minimum RL	Maximum RL	ACG Direct Human Exposure	Count RLs > ACG
Surface Sediment						
Antimony	8 / 49	16	7	37.5	3.1	41
Arsenic	75 / 111	68	7	62.5	0.39	36
Selenium	0 / 14	0	0.7	62.5	39	5
Thallium	6 / 13	46	112	250	0.52	7
Subsurface Sediment						
Antimony	30 / 84	36	0.5	10	3.1	13
Arsenic	112 / 125	90	6	7	0.39	13

Table A-5
Summary of PAHs and Phthalates with RL Values above Benthic ACGs
(mg/kg OC)

Chemical	Detection Frequency (DF)	DF %	Minimum RL	Maximum RL	Count RLs > SQS	Count RLs > CSL
Surface Sediment						
PAHs						
2-Methylnaphthalene	64 / 136	47	0.51	200	1	1
Acenaphthene	84 / 136	62	0.51	200	1	1
Acenaphthylene	69 / 136	51	0.51	200	2	2
Benzo(g,h,i)perylene	108 / 136	79	0.51	200	2	2
Dibenzo(a,h)anthracene	73 / 136	54	0.51	200	8	5
Dibenzofuran	64 / 136	47	0.51	200	3	2
Fluorene	89 / 136	65	0.51	95	1	1
Indeno(1,2,3-cd)pyrene	109 / 136	80	0.51	200	2	2
Naphthalene	80 / 136	59	0.51	200	1	1
Phthalates						
Bis(2-ethylhexyl)phthalate	106 / 123	86	0.51	110	4	2
Butyl benzyl phthalate	38 / 122	31	0.50	200	13	2
Diethyl phthalate	0 / 123	0	0.50	200	2	1
Dimethyl phthalate	11 / 123	9	0.23	200	2	2
Di-n-octyl phthalate	2 / 123	2	0.50	200	2	0
Subsurface Sediment						
PAHs						
2-Methylnaphthalene	53 / 122	43	0.56	13	1	0
Dibenzo(a,h)anthracene	76 / 122	62	0.70	13	5	1
Dibenzofuran	70 / 122	57	0.70	25	1	0
Phthalates						
Bis(2-ethylhexyl)phthalate	85 / 122	70	1.4	110	4	2
Butyl benzyl phthalate	31 / 122	25	0.35	13	13	0
Diethyl phthalate	1 / 122	1	0.56	13	7	0
Dimethyl phthalate	2 / 122	2	0.35	13	11	8

Table A-6
Summary of PAH RLs for Sediment Samples Compared to Direct Human Exposure ACGs for Chemicals With At Least One RL > ACG
(µg/kg dw)

Chemical	Detection Frequency (DF)	DF (%)	Minimum RL	Maximum RL	ACG Direct Human Exposure	Count RLs > ACG
Surface Sediment						
Benzo(a)pyrene	127 / 136	93	19	53	15	9
Dibenzo(a,h)anthracene	73 / 136	54	18	4,100	15	63
Indeno(1,2,3-cd)pyrene	109 / 136	80	19	4,100	150	4
Subsurface Sediment						
Benzo(a)pyrene	108 / 122	89	19	130	15	14
Dibenzo(a,h)anthracene	76 / 122	62	9.2	780	15	45
Indeno(1,2,3-cd)pyrene	100 / 122	82	19	390	150	1

Note: Phthalate RLs did not exceed human health ACGs.

Table A-7
Summary of SVOCs with RL Values Above SMS Criteria

Chemical	Detection Frequency (DF)	DF %	Units	Minimum RL	Maximum RL	Count RLs > SQS/SL	Count RLs > CSL/ML
Surface Sediment							
1,2,4-Trichlorobenzene	28 / 147	19	mg/kg OC	0.21	200	35	18
1,2-Dichlorobenzene	13 / 147	9	mg/kg OC	0.043	200	21	21
1,3-Dichlorobenzene [a]	24 / 125	19	µg/kg dw	0.90	4,100	8	n/a
1,4-Dichlorobenzene	77 / 147	52	mg/kg OC	0.056	200	9	7
2,4-Dimethylphenol	4 / 123	3	µg/kg dw	6.1	4,100	64	64
2-Methylphenol	2 / 123	2	µg/kg dw	6.1	4,100	22	22
4-Methylphenol	27 / 123	22	µg/kg dw	9.8	4,100	3	3
Benzoic acid	6 / 114	5	µg/kg dw	160	2,000	14	14
Benzyl alcohol	0 / 114	0	µg/kg dw	9.8	190	19	13
Hexachlorobenzene	0 / 124	0	mg/kg OC	0.028	200	43	20
Hexachlorobutadiene	0 / 124	0	mg/kg OC	0.030	200	15	12
Hexachloroethane	0 / 34	0	µg/kg dw	20	4,100	2	0
N-Nitrosodiphenylamine	2 / 123	2	mg/kg OC	0.24	200	10	10
Pentachlorophenol	8 / 123	7	µg/kg dw	58	10,000	23	10
Phenol	53 / 123	43	µg/kg dw	18	2,000	3	1
Subsurface Sediment							
1,2,4-Trichlorobenzene	2 / 123	2	mg/kg OC	0.18	13	33	21
1,2-Dichlorobenzene	3 / 123	2	mg/kg OC	0.035	13	18	18
1,3-Dichlorobenzene	5 / 123	4	µg/kg dw	0.90	780	10	n/a
1,4-Dichlorobenzene	18 / 123	15	mg/kg OC	0.035	13	13	10
2,4-Dimethylphenol	3 / 122	2	µg/kg dw	9.1	780	29	29
2-Methylphenol	1 / 121	1	µg/kg dw	9.1	780	16	16
Benzoic acid	0 / 107	0	µg/kg dw	97	7,800	18	18
Benzyl alcohol	0 / 118	0	µg/kg dw	12	780	22	20
Hexachlorobenzene	1 / 122	1	mg/kg OC	0.028	13	69	10
Hexachlorobutadiene	2 / 122	2	mg/kg OC	0.026	13	11	3
N-Nitrosodiphenylamine	0 / 122	0	mg/kg OC	0.27	13	16	14
Pentachlorophenol	2 / 95	2	µg/kg dw	20	3,900	12	10
Phenol	42 / 122	34	µg/kg dw	18	780	2	0

a There is no SMS criteria for this chemical. RLs were compared to DMMP SL and ML.
n/a - not applicable

Table A-8
Summary of SVOC RLs for Sediment Samples Compared to Direct Human Exposure ACGs for Chemicals With At Least One RL > ACG
(µg/kg dw)

Chemical	Detection Frequency (DF)	DF (%)	Minimum RL	Maximum RL	ACG Direct Human Exposure	Count RLs > ACG
Surface Sediment						
1,3-Dichlorobenzene	24 / 125	19	0.90	4,100	1,600	2
1,4-Dichlorobenzene	77 / 147	52	0.9	4,100	3,200	1
2,4,6-Trichlorophenol	0 / 34	0	97	4,100	610	4
3,3'-Dichlorobenzidine	0 / 32	0	97	4,100	1,100	2
bis(2-chloroethyl)ether	0 / 34	0	20	4,100	210	6
bis(2-chloroisopropyl)ether	0 / 34	0	20	4,100	2,900	1
Hexachlorobenzene	0 / 124	0	0.82	4,100	300	6
Nitrobenzene	0 / 34	0	20	4,100	2,000	1
N-Nitrosodimethylamine	0 / 20	0	30	400	2	20
N-Nitroso-di-n-propylamine	0 / 34	0	30	4,100	69	21
Pentachlorophenol	8 / 123	7	58	10,000	3,000	2
Subsurface Sediment						
N-Nitrosodimethylamine	0 / 12	0	30	31	2	12
N-Nitroso-di-n-propylamine	0 / 16	0	46	160	69	10
Pentachlorophenol	2 / 95	2	20	3,900	3,000	1

Table A-9
Summary of Pesticide RLs Compared to DMMP Criteria
(µg/kg dw)

Chemical	Detection Frequency (DF)	DF %	Minimum RL	Maximum RL	Count RLs > SL	Count RLs > ML
Surface Sediment						
DDTs (total-calc'd)	12 / 111	11	1.1	100	58	2
Aldrin	3 / 56	5	0.53	20	4	n/a
Dieldrin	0 / 56	0	1.1	51	25	n/a
gamma-BHC	0 / 56	0	0.53	20	4	n/a
Heptachlor	2 / 56	4	0.82	20	4	n/a
Total Chlordane (calc'd)	2 / 51	4	0.96	190	14	n/a
Subsurface Sediment						
DDTs (total-calc'd)	27 / 124	22	0.61	210	46	6
Aldrin	4 / 93	4	0.30	42	12	n/a
Dieldrin	6 / 94	6	0.61	120	23	n/a
Heptachlor	0 / 94	0	0.30	42	9	n/a
Total Chlordane (calc'd)	4 / 90	4	0.87	200	27	n/a

n/a - not applicable

Table A-10
Summary of Pesticide RLs for Sediment Samples Compared to Direct Human Exposure ACGs for Chemicals With At Least One RL > ACG
(µg/kg dw)

Chemical	Detection Frequency (DF)	DF (%)	Minimum RL	Maximum RL	ACG Direct Human Exposure	Count RLs > ACG
Surface Sediment						
Dieldrin	0 / 56	0	1.1	51	30	5
Toxaphene	0 / 32	0	11	1,500	440	5
Subsurface Sediment						
Aldrin	4 / 93	4	0.3	42	29	2
Dieldrin	6 / 94	6	0.61	120	30	8
Toxaphene	0 / 16	0	6.1	990	440	4

Table A-11
Summary of RLs for Surface Sediment Samples Compared to Indirect Human Exposure ACGs for Chemicals With At Least One RL > ACG
(µg/kg dw)

Chemical	Unit	Detection Frequency (DF)	DF (%)	Minimum RL	Maximum RL	ACG Indirect Human Exposure	# RLs > ACG
Metals and trace elements							
Arsenic	mg/kg dw	75 / 111	58	7	62.5	0.006	36
Cadmium	mg/kg dw	88 / 102	86	0.3	1	0.003	14
Mercury	mg/kg dw	157 / 159	99	0.05	0.07	0.016	2
PAHs							
2-Methylnaphthalene	µg/kg dw	64 / 136	47	9.8	4,100	1,700	1
Benzo(a)anthracene	µg/kg dw	127 / 136	93	19	53	5.2	9
Benzo(a)pyrene	µg/kg dw	127 / 136	93	19	53	0.76	9
Benzo(b)fluoranthene	µg/kg dw	130 / 136	96	19	53	4.7	6
Benzo(k)fluoranthene	µg/kg dw	121 / 136	89	19	53	47	1
Dibenzofuran	µg/kg dw	64 / 136	47	18	4,100	560	2
Indeno(1,2,3-cd)pyrene	µg/kg dw	109 / 136	80	19	4,100	2.9	27
Phthalates							
Bis(2-ethylhexyl)phthalate	µg/kg dw	106 / 123	86	19	1,800	120	12
Di-n-octyl phthalate	µg/kg dw	2 / 123	2	9.8	4,100	3,000	1
Other SVOCs							
1,4-Dichlorobenzene	µg/kg dw	77 / 147	52	0.9	4,100	73	8
2,4-Dichlorophenol	µg/kg dw	0 / 34	0	97	4,100	1,100	2
2-Chlorophenol	µg/kg dw	1 / 34	3	20	4,100	1,800	2
4-Methylphenol	µg/kg dw	27 / 123	22	9.8	4,100	1,800	2
Carbazole	µg/kg dw	12 / 21	57	121	4,100	230	2
Hexachlorobutadiene	µg/kg dw	0 / 124	0	0.87	4,100	23	26
Hexachloroethane	µg/kg dw	0 / 34	0	20	4,100	120	16
Polychlorinated biphenyls							
Aroclor-1016	µg/kg dw	0 / 160	0	5.3	970	6.1	159
Aroclor-1221	µg/kg dw	0 / 160	0	5.3	970	0.21	160
Aroclor-1232	µg/kg dw	0 / 160	0	5.3	970	0.21	160
Aroclor-1242	µg/kg dw	19 / 160	12	5.3	970	0.21	141
Aroclor-1248	µg/kg dw	44 / 160	28	16	1,100	0.21	116
Aroclor-1254	µg/kg dw	109 / 160	68	18	1,900	0.21	51
Aroclor-1260	µg/kg dw	157 / 160	98	18	160	0.21	3
PCBs (total calc'd)	µg/kg dw	158 / 160	99	19	35	0.21	2
Pesticides							
2,4'-DDD	µg/kg dw	0 / 18	0	1.9	29	8.3	5
2,4'-DDE	µg/kg dw	0 / 18	0	1.9	29	2.6	16
2,4'-DDT	µg/kg dw	0 / 18	0	1.9	29	0.92	18
4,4'-DDD	µg/kg dw	9 / 111	8	1.1	40	8.3	32
4,4'-DDE	µg/kg dw	5 / 111	5	1.1	46	2.6	72
4,4'-DDT	µg/kg dw	2 / 110	2	1.1	100	0.92	108
DDTs (total-calc'd)	µg/kg dw	12 / 111	11	1.1	100	0.92	99
Aldrin	µg/kg dw	3 / 56	5	0.53	20	0.063	53
Dieldrin	µg/kg dw	0 / 56	0	1.1	51	0.033	56

Chemical	Unit	Detection Frequency (DF)	DF (%)	Minimum RL	Maximum RL	ACG Indirect Human Exposure	# RLs > ACG
beta-BHC	µg/kg dw	0 / 50	0	0.53	19	0.63	49
gamma-BHC	µg/kg dw	0 / 56	0	0.53	20	0.83	54
Endrin	µg/kg dw	0 / 50	0	1.1	38	27	3
Heptachlor	µg/kg dw	2 / 56	4	0.82	20	0.25	54
Total Chlordane (calc'd)	µg/kg dw	2 / 51	4	0.96	190	1.7	44

Surface Water RLs Compared to Washington State Water Quality Criteria

The reporting limits for the EW surface water data were compared to Washington State marine water quality criteria (WQC). The reporting limits for the King County WQA (King County 1999) were all below the corresponding WQC. The reporting limits associated with lead, mercury, silver, total polychlorinated biphenyls (PCBs), dieldrin, total DDT, and tributyltin (TBT) exceeded corresponding criteria in the Windward Environmental, LLC water quality monitoring data (Table A-12). Reporting limits for total DDT and TBT exceeded WQC in the Striplin Environmental Associates water quality monitoring data (Table A-13).

Table A-12
Summary of RLs for Chemicals that Exceed WA WQC Analyzed from Ambient Locations During Windward Water Quality Monitoring (Phase 1 and Phase 2)
(µg/L)

Chemical	Detection Frequency (DF)	DF %	Minimum RL	Maximum RL	Acute marine WA WQC	Chronic marine WA WQC	Count RL > Acute WA WQC	Count RL > Chronic WA WQC
Metals								
Lead	0 / 36	0	10	11	210	8.1	0	36
Mercury	0 / 36	0	0.1	0.1	1.8	0.025	0	36
Silver	0 / 36	0	2.0	5.0	1.9	n/a	36	n/a
Total PCBs [a]	0 / 36	0	0.040	0.60	10	0.03	0	36
Pesticides								
Dieldrin	0 / 36	0	0.10	0.11	0.71	0.002	0	36
Total DDT	0 / 36	0	0.10	0.11	0.13	0.001	0	36
Organometals								
TBT ion	0 / 36	0	0.022	0.022	0.42	0.0074	0	36

a Total PCBs are the sum of Aroclors

n/a – not applicable

Table A-13
Summary of RLs for Chemicals that Exceed WA WQC Analyzed from Ambient Locations During Striplin Water Quality Monitoring
(µg/L)

Chemical	Detection Frequency (DF)	DF %	Minimum RL	Maximum RL	Acute marine WA WQC	Chronic marine WA WQC	Count RL > Acute WA WQC	Count RL > Chronic WA WQC
Pesticides								
Total DDT	0 / 6	0	0.0015	0.0017	0.13	0.001	0	6
Organometals								
TBT ion	1 / 6	17	0.020	0.022	0.42	0.0074	0	5

DF – detection frequency
RL – reporting limit
WA WQC – Washington water quality criteria

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