FINAL
INVESTIGATION REPORT
PORT OF OLYMPIA BUDD INLET SEDIMENT SITE

Prepared for

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FOREWORD

The information presented in this Investigation Report (Report) describes investigation activities, including field sampling and laboratory analyses and validation, presents the nature and extent of contamination, describes potential ongoing and historical sources of contamination, and describes natural recovery processes based on available data. This Report will provide the basis for evaluations presented in the Identification and Evaluation of Interim Action Alternatives Memorandum (Alternatives Memo), which will develop the conceptual site model (CSM) and cleanup levels used to develop and evaluate potential Interim Action remedial alternatives to address contaminated sediments in the Study Area.

The Port of Olympia (Port; via Anchor QEA, LLC) and the Washington State Department of Ecology (Ecology; via NewFields) both conducted chemometric studies to support identification of potential sources of dioxin/furan contamination to sediments in Budd Inlet in Olympia, Washington. Ecology's chemometric study used a similar Budd Inlet sediment dataset and is available on Ecology's Budd Inlet Site website (NewFields 2015). Both studies found three very similar underlying factors that account for most of the data variance and acknowledge that stormwater is a pathway; however, different interpretive statistical methodologies were used in each study and different conclusions were reached regarding what two of the three underlying factors represent. Ecology will use the results of their study for future decision-making at the Budd Inlet Site. A summary of the interpretation of sources associated with the factor profiles from each study is provided below.

Differences in Interpretation of Factor Profiles by Ecology and the Port

Department of Ecology (NewFields 2015)	Port of Olympia (Appendix D)
Factor 1 – Hog fuel burning	Factor 3 – Hog fuel burning
Factor 2 – Pentachlorophenol • Historical use • Current contamination	Factor 2 – Mixed urban source • Regional sediment profiles • Urban background • Sewage • Nearby catch basins
Factor 3 – PCBs • Historical use at and around the Port peninsula	Factor 1 – Mixed combustion source • Truck diesel, highway • Asphalt • Burn barrels • Medical waste incineration

The Department of Ecology has prepared a Foreword further documenting the differences between the Port of Olympia chemometric analysis and that conducted by Ecology. This Foreword can be found in Appendix D of this Report.

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/kg	micrograms per kilogram
AET	adverse effects threshold
Alternatives Memo	Identification and Evaluation of Interim Action Alternatives Memorandum
AO	Agreed Order
ARI	Analytical Resources Incorporated
ASTM	American Society for Testing and Materials
bgs	below ground surface
City	City of Olympia
cm	centimeter
cm/yr	centimeters per year
COPC	chemicals of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPT	cone penetration test
Cs-137	cesium-137
CSL	cleanup screening level
CSM	conceptual site model
CSO	combined sewer overflow
CU-TX	consolidated-undrained triaxial compression
D/F	dioxin/furan
Delson	Delson Lumber
DMMP	Dredge Material Management Program
Ecology	Washington State Department of Ecology
EDL	estimated detection limit
EISDGM	Existing Information Summary and Data Gaps Memorandum
EMPC	estimated maximum potential concentration
$g/cm^2/yr$	grams per square centimeter per year
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HWA	HWA Geosciences, Inc.
IDW	inverse distance weighting
LAET	lowest adverse effects threshold

2LAET	second lowest adverse effects threshold
LCS	laboratory control sample
LOTT	Lacey-Olympia-Tumwater-Thurston County Clean Water Alliance
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MLLW	mean lower low water
MS	matrix spike
MSD	matrix spike duplicate
MSS	Marine Sampling Services
MTCA	Model Toxics Control Act
ng/kg	nanogram per kilogram
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
Pb-210	lead-210
PCB	polychlorinated biphenyls
PCP	pentachlorophenol
Port	Port of Olympia
PPE	personal protective equipment
PQL	practical quantitation limit
PSEP	Puget Sound Estuary Protocol
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
r^2	Correlation coefficient
RBTC	risk-based threshold concentration
Report	Investigation Report
RI	remedial investigation
RPD	relative percent difference
RSS	Research Support Services
SAP	Sampling and Analysis Plan
SCO	sediment cleanup objective
SCUM II	Sediment Cleanup User Manual II
SMS	Sediment Management Standards
SPT	Standard Penetration Test
SQS	sediment quality standards

SRM	standard reference material
SVOC	semi-volatile organic compounds
SWAC	spatially weighted average concentration
TEF	toxic equivalency factors
TEQ	toxic equivalence or toxic equivalency
TOC	total organic carbon
TS	total solids
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VST	vane shear testing
Work Plan	Budd Inlet Sediment Site Work Plan

1 INTRODUCTION AND BACKGROUND

This Investigation Report (Report) has been prepared as required by an amendment to Agreed Order (AO) No. DE 6083 (Ecology 2008a and 2012) between the Port of Olympia (Port) and the Washington State Department of Ecology (Ecology). The amendment requires that additional investigations be conducted into the nature and extent of contamination and potential sources of contamination to sediments in the vicinity of the Port peninsula in Budd Inlet (Figure 1-1). This Report is a component of Task 3 as described in the Budd Inlet Sediment Site Work Plan (Work Plan; Anchor QEA 2012a) and presents the results of the chemistry and geotechnical sediment investigations completed under the Port's Budd Inlet Sediment Site Sampling and Analysis Plan and Quality Assurance Project Plan (SAP/QAPP; Anchor QEA 2013a). Additional information, such as a summary of the nature and extent of sediment contamination, source evaluations, and natural recovery processes, are also included in this Report. These additional components are based on the new data presented in this Report and the historical data presented in the Existing Information Summary and Data Gaps Memorandum (EISDGM; Anchor QEA 2012b).

1.1 Purpose of Report

The information presented in this Report describes investigation activities, including field sampling and laboratory analyses and validation, presents the nature and extent of contamination, describes potential ongoing and historical sources of contamination, and describes natural recovery processes based on available data. This Report will provide the basis for evaluations presented in the Identification and Evaluation of Interim Action Alternatives Memorandum (Alternatives Memo), which will develop the conceptual site model (CSM) and cleanup levels used to develop and evaluate potential Interim Action remedial alternatives to address contaminated sediments in the Study Area.

1.2 Site Description and Background

The Port is located in the northern portion of the City of Olympia (City) on a peninsula within Budd Inlet, which is a small embayment in southern Puget Sound (Figure 1-1). Budd Inlet is divided into West Bay and East Bay in the southernmost point of Budd Inlet. The filling of tidelands in the late 1800s and early 1900s created the Port peninsula, West Bay and

East Bay of Budd Inlet, and the downtown area of Olympia. The Port peninsula consists of approximately 150 acres; the entire Study Area is approximately 271 acres.

A summary of West Bay, East Bay, and the Study Area are provided below. Detailed background information related to property features, regulatory background, and historical operational uses are presented in the EISDGM (Anchor QEA 2012b).

1.2.1 West Bay

The Olympia Harbor federal navigation channel extends into Budd Inlet's West Bay widens into a turning basin near its southern end, adjacent to the Port's Marine Terminal berthing area (Figure 1-2). The Port manages the harbor area under a Port Management Agreement with the Department of Natural Resources. Along the Marine Terminal, the harbor area is mostly defined as a 54-foot-wide swath that extends from the south end of the Marine Terminal to the north end and beyond (Figure 1-2). This narrow swath extends from the face of the Port's Marine Terminal landward, thus including the under-wharf area of the Marine Terminal. Waterward of the Marine Terminal, the berthing areas coincide with the federal turning basin (Port of Olympia 2008).

The Marine Terminal is approximately 60 acres and provides approximately 2,500 lineal feet of wharf and 76,000 square feet of warehousing. Three modern ships, or a combination of vessels, can be hosted simultaneously at the Marine Terminal. Current upland use immediately adjacent to the berths and turning basin include log storage yards and loading docks (Port of Olympia 2008).

The area south of the Marine Terminal includes a boat basin and waterfront shops and restaurants. West Bay also contains three marinas: Fiddlehead, Martin, and the Olympia Yacht Club. Within West Bay, five contaminated sites under separate AOs with Ecology are located along the western shoreline: Westbay Marina, Hardel Mutual Plywood, Reliable Steel, Solid Wood, Inc., and Industrial Petroleum, Inc. (Figure 1-2).

At the southern end of West Bay, the Deschutes River drains into Capitol Lake. This area was once an estuary where freshwater from the Deschutes River intermingled with salt water from Budd Inlet. The lake was created in 1951 as a reflection pond for the State

Capitol by installing an earthen dam and an approximately 82-foot wide tide gate with spillways across the mouth of the Deschutes River under the 5th Avenue Bridge in Olympia (USGS 2006). The flow of freshwater into West Bay is controlled by gated discharges from Capitol Lake.

1.2.2 East Bay

A second federal navigation channel is authorized from north of the peninsula that extends into Budd Inlet East Bay to elevation –13 feet mean lower low water (MLLW). The primary commercial facilities in East Bay are Swantown Marina and Swantown Boatworks, located on the eastern side of the peninsula (Figure 1-2). The federal navigation channel also extends to the boat launch ramp located just north of Swantown Marina. Swantown Marina has been in operation since 1983 (previously referred to as East Bay Marina prior to 1995) and is owned and operated by the Port and maintains slips for approximately 700 vessels. Swantown Boatworks provides vessel service, haul out, and a vessel storage facility (SAIC 2008).

Two contaminated sites under AOs with Ecology are located on the Port peninsula adjacent to East Bay (Figure 1-2); the Cascade Pole cleanup site is located on the north end of the peninsula that includes a portion of the sediment within East Bay, and East Bay Redevelopment Site is on the southern portion of the peninsula.

Moxlie/Indian Creek, which originates from an artesian spring approximately 1.5 miles south of Budd Inlet, flows into East Bay through a mile-long culvert that discharges at the southern end of East Bay (Anchor QEA 2012b). East Bay was placed on the 1998 303(d) impaired water list for polychlorinated biphenyls (PCBs) based on a single composite sample of mussel tissue collected from the culvert at the mouth of Moxlie/Indian Creek (Ecology 2003 as cited in SAIC 2008).

1.2.3 Study Area Boundary

Figure 1-2 shows the boundaries of the Study Area along with relevant historical and current site features, such as Ecology-listed contaminated sites, historical wood waste burners, and current operators (e.g., marinas and Port). The AO Amendment defines the Study Area

boundary; however, the Interim Action cleanup boundary may extend beyond. The Study Area boundary includes the aquatic areas adjacent to property owned by the Port, which comprises of the Port's berthing areas, under-wharf areas, and log pond in West Bay, and areas adjacent to Port property north of the peninsula and in East Bay, as shown in Figure 1-2. The former Cascade Pole site is excluded from the Study Area since it is being investigated and remediated under a separate AO between the Port and Ecology as shown on Figure 1-2.

1.3 Document Organization

The first part of this Report provides the details of the recent sampling and analyses conducted under the SAP/QAPP (Anchor QEA 2013a) and a presentation of the testing results and data quality. The subsequent sections regarding nature and extent, potential ongoing sources, and natural recovery processes in and around the Study Area are based on the comprehensive dataset (2013 data and historical data). The Report is organized as follows:

- Section 2 – Field Sampling Summary: Provides an overview of the 2013 field sampling components, including any deviations from the SAP/QAPP
- Section 3 – Data Quality: Presents a summary of the 2013 data quality objectives and the results of data validation
- Section 4 – Sample Results: Presents the chemical testing results for the 2013 subsurface sediment, surface grabs, and geotechnical testing
- Section 5 – Nature and Extent of Contamination: Includes an evaluation of the nature and extent of contamination based on the comprehensive dataset compiled from the EISDGM and 2013 studies
- Section 6 – Source Evaluations: Includes source evaluations, fingerprinting, and multivariate statistical analysis of dioxin/furans (D/Fs)
- Section 7 – Natural Recovery Processes: Presents data related to natural recovery processes such as sedimentation and erosion
- Section 8 – Investigation Summary: Provides a concise summary of conclusions presented in this Report
- Section 9 – References: Lists references cited in development of this Report
- Tables, Figures, and Appendices – Contain the field data, laboratory data, data validation reports, and chemometric statistical evaluations

2 FIELD SAMPLING SUMMARY

Section 2 describes the sampling and processing protocols used for the sediment chemistry, geochronology, and geotechnical field tasks and describes any SAP/QAPP deviations. Figure 2-1 shows the sampling locations. Tables 2-1, 2-2, and 2-3 provide field data, including sample coordinates, mudline elevation, sample recovery, testing parameters, and visual observations.

2.1 Sediment Sampling and Processing

2.1.1 Surface Grabs

Surface grabs were collected from the upper 10 centimeters (cm) of sediment to provide information on the nature and extent of contamination in the bioactive zone. Sixty-five surface grab samples were collected as part of the Budd Inlet Characterization Study. Table 2-1 provides a field data summary of all surface grab samples. Most samples were collected using a hydraulic powergrab operated by Marine Sampling Services (MSS) aboard the MSS vessel *Nancy Anne* on March 6, 7, 8, 11, 12, and 13, 2013. Sediment samples from three under-pier locations were collected using an Ekman grab operated by Anchor QEA aboard the Research Support Services (RSS) vessel *Carolyn Dow* on March 11 and 12, 2013. Five supplemental samples were collected using an Ekman grab aboard an Anchor QEA vessel on May 22, 2013. The Anchor QEA vessel was used for the supplemental sampling because the research vessels had already mobilized away from the site for other project work. For all 65 surface sediment grabs, full recovery was obtained and all processing procedures outlined in the SAP/QAPP (Anchor QEA 2013a) were followed with the exception of minor deviations described in Section 2.3. Appendix A-1 presents the field sediment collection forms.

Chemical analyses were conducted by the Ecology accredited laboratory Analytical Resources Incorporated (ARI), in Tukwila, Washington. All surface sediment samples were submitted for the following chemical tests:

- D/Fs by U.S. Environmental Protection Agency (USEPA) method 1613B
- Grain size by Puget Sound Estuary Protocol (PSEP)
- Polycyclic aromatic hydrocarbons (PAHs) by USEPA method 8270D
- Total organic carbon (TOC) by method Plumb, 1981
- Total solids (TS) by method SM2540B

All surface sediment samples were analyzed for D/Fs, as these are the primary chemical of interest for the Budd Inlet Sediment Site Investigation. At the request of Ecology, PAHs were also analyzed at all surface sediment locations. Select samples near potential sources (e.g., outfalls or based on areas with known historical elevated contaminant levels) were additionally analyzed for the following chemical tests:

- Sediment Management Standards (SMS) metals by USEPA methods 6010C and 7471A
- SMS semi-volatile organic compounds (SVOCs) by USEPA method 8270D
- PCB aroclors by USEPA method 8082 following PSEP

Analytical results are discussed in Section 4.2.1.

2.1.2 Subsurface Cores

Subsurface cores were collected to provide data on the vertical extent of elevated concentrations of contaminants. Fifty cores were collected for chemical analysis and four cores were collected for geochronological (i.e., radiochemistry) analysis. All cores were collected using a 4-inch-diameter decontaminated aluminum core tube barrel driven by a hydraulic vibracorer (Figure 2-1). Forty-six cores were collected aboard the MSS vessel Nancy Anne on February 25 and 28, and March 1, 4, 5, and 6, 2013. MSS used 15-foot length core tubes. Eight under-pier locations were collected aboard the RSS vessel Carolyn Dow on March 11 through March 14, 2013. RSS used varying length core tubes (8-, 10-, or 12-foot lengths).

Cores were driven down to the target depth, or until refusal, and then winched up on to the vessel. The percent recovery of each core was calculated based on the recovered length of sediment and the penetration depth. Sediment core tubes were sliced into 5-foot sections and transported upright using a refrigerated truck to the processing facility (ARI) at the end of each collection day. All cores were kept at less than 6 degrees Celsius and processed within 72 hours of collection. Cores were collected, logged, and processed in accordance with the SAP/QAPP (Anchor QEA 2013a) with the exception of minor deviations described in Section 2.3. Tables 2-2 and 2-3 present a summary of the field data and samples collected from each chemistry and geochronology core, respectively.

For the chemistry cores, targeted sample intervals were adjusted based on percent recovery (core drive by recovered length) assuming uniform compaction throughout the core. Appendix A-2 presents the field core collection logs and Appendix A-3 includes the compaction corrected sediment core logs. Select sample intervals from each chemistry core were analyzed for D/Fs, grain size, TOC, and TS. Some samples were also analyzed for SMS parameters (SVOC, PCBs, and metals). The remaining collected samples were frozen at the laboratory for potential future analysis. A tiered approach was used for sample analysis (i.e., deeper intervals were tested based on the chemical concentration of the higher intervals) to determine the depth of elevated chemical concentrations. Analytical results are discussed in Section 4.2.2.

The four geochronology cores were sliced into 2-cm sections throughout the length of the core. Because of volume restrictions and good core collection recoveries (ranging from 91 to 97 percent), sample intervals taken from geochronology cores were not adjusted for compaction. Select samples based on the predicted cesium-137 peak were submitted for analysis at Mass Spec Services in Orangeburg, New York. Geochronology data evaluation, including sedimentation rate determination, is presented in Section 7.1.1.

2.2 Geotechnical Sampling and Processing

Geotechnical explorations consisted of eight hollow-stem auger borings, three cone penetration tests (CPTs), ten vane shear tests, four jet probe transects, and seven debris observation transects (Figure 2-2). To complete the geotechnical sampling design as described in the SAP/QAPP (Anchor QEA 2013a), three separate field efforts were conducted. Upland soil borings were performed at locations SB-1, SB-3, SB-4, and SB-7 and CPTs were performed at locations CPT-1, CPT-2, and CPT-3 between February 25 and 27, 2013. The locations of these explorations are shown on Figure 2-2. In-water soil borings were performed via a barge at locations SB-2, SB-5, SB-6, and SB-8 between March 12 and 14, 2013. All jet probe transects, debris observation transects, and vane shear tests were performed between May 21 and 22, 2013. Details of each exploration method (soil boring, CPT, vane shear, jet probe, and debris observation) are presented in the following subsections. All samples were collected, logged, and processed in accordance with the SAP/QAPP (Anchor QEA 2013a) and delivered to the HWA Geosciences Inc. (HWA)

laboratory located in Bothell, Washington. Minor deviations with respect to sampling locations are described in Section 2.3.

2.2.1 Soil Borings

Soil borings were performed to investigate and characterize the geotechnical properties of sediments and soils to support development and evaluation of potential remedial alternatives. The borings were performed at in-water and upland locations to supplement existing geotechnical exploration data previously collected for other studies, as described in the EISDGM (Anchor QEA 2012b). Upland soil borings at SB-1, SB-3, SB-4, and SB-7 were advanced using a truck-mounted, hollow-stem auger drill rig provided and operated by Holocene Drilling. In-water soil borings SB-2, SB-5, SB-6, and SB-8 were performed in water with a barge using the same truck-mounted drill rig and drill method, which was mobilized onto the marine salvage vessel, the *Seahorse*. The vessel was internally powered and held stationary over the in-water boring location by deploying spud piles on the starboard and port sides of the vessel. Soil boring locations are shown on Figure 2-2. Boring logs for the eight soil borings are included in Appendix A-4.

Samples from soil borings were collected at regular intervals from the ground surface and mudline downward using two methods: split-spoon (American Society of Testing and Materials [ASTM] D1586) and Shelby tube sampling (ASTM D1587). Geotechnical index test samples were collected using a split-spoon sampler to allow Standard Penetration Test (SPT) blow counts to be recorded. SPT sampling was performed using an automatic trip hammer with a hammer efficiency of 6 percent for a 140-pound weight with a 30-inch, free-fall height. Split-spoon samplers had a 2-inch outside diameter with a smooth interior diameter of 1.375 inches. Blow counts were recorded for each 6-inch interval of the sampler that was driven. A total drive length of 18 inches was performed unless refusal was encountered. Refusal is defined as a blow count value of 50 for a drive interval of 6 inches or less and was encountered in borings SB-4 and SB-5 at elevations of -46.0 and -58.6 feet MLLW, respectively.

Geotechnical samples for testing strength, consolidation, bulk density, and dynamic properties were obtained using stainless-steel, thin-walled Shelby tubes. Samplers used had a 3-inch outside diameter and were 30 inches in length. Shelby tubes were advanced into the

soil stratum using hydraulic pressure applied by the drill rig. Samplers were advanced 24 inches and allowed to rest several minutes before extraction. Following extraction from the borehole, samples were classified based on visual observations at the end of the tube and sealed, stored, and handled as described in the SAP/QAPP (Anchor QEA 2013a).

2.2.2 Cone Penetration Test

CPT was performed to investigate and characterize the geotechnical properties of sediments and soils to support development and evaluation of potential remedial alternatives. Three CPTs were performed at upland locations: two near the log pond and one at the approximate middle of the Marine Terminal. The CPTs were performed with porewater pressure readings made during advancement, and seismic shear wave velocity measurements made at approximately 5- to 10-foot intervals. In addition, pore pressure dissipation tests were performed three times for CPT-1 and CPT-2 and four times for CPT-3. The three CPTs were originally proposed to be advanced to a depth of 100 feet below ground surface (bgs). During advancement, a dense gravel layer was encountered at approximately 55 to 60 feet bgs for all CPTs, which resulted in refusal of the cone. CPTs were terminated in the dense gravel layer, and a final pore pressure dissipation test was performed. Logs from the CPT tests are presented in Appendix A-4.

2.2.3 Vane Shear Test

Vane shear testing (VST; ASTM D 2573) was performed to characterize the shear strength of near surface sediments. VST was performed at ten locations around West Bay and East Bay of Budd Inlet. The tests were conducted on May 22, 2013. Tests were performed using RocTest vane borer Model H-60 at depth intervals 1 to 2 feet below the mudline. Both peak and residual undrained strengths were measured. Testing results are presented in Section 4.

2.2.4 Underpier Probing and Debris Observations

A dive team conducted a visual survey of surficial debris and the condition of the riprap slope and its current extents under the pier. The debris and riprap observations were performed by a two-person dive crew to collect the following information: debris type, relative size, location from the pierface, and condition of the riprap slope. The debris observed for each transect is referenced in feet upslope from the pierface on diagrams in

Appendix A-4. Measurements were made using a tape measure referenced to the pierface. Following placement of the measuring tape, the divers started from the pierface and moved up to the exposed riprap slope to observe debris. The video was viewed in the wheelhouse of the dive boat by Anchor QEA field staff, which characterized the debris, recorded respective measurements, and diagrammed the layout of the debris. Anchor QEA field staff and divers communicated using underwater transponders. Results of debris observed at each transect is depicted on figures included in Appendix A-4.

A variety of debris was observed at the seven transects, including the following:

- Loose riprap
- Timber and concrete piles (broken, laying horizontal), estimated to be up to 20 feet in length
- Timber pile stubs (i.e., embedded piles broken off several feet above the mudline)
- Loose or buried cables
- Metal debris piles
- Steel pipes
- Rubber tires

Probing was conducted using a metal rod, rather than jet probing described in the SAP/QAPP (Anchor QEA 2013a). Probing indicated the presence of loose riprap at all locations for a distance of 5 to 11 feet immediately down slope of the exposed riprap slope toe, which resulted in a distance of 40 to 75 feet from the pierface. Sediment thickness above the riprap at the lowest extent of riprap on the slope was measured to be less than 0.5 feet.

2.3 Deviations from Sampling and Analysis Plan and Quality Assurance Project Plan

Deviations from the approved SAP/QAPP were generally determined on site during the field investigation events. Provided is a description of these deviations.

2.3.1 Sediment

- All surface grabs were collected within 2 meters of the target sampling location except for two under-pier locations [SS-10 (16.5 m) and SS-17 (2.1 m)] which were

moved offshore (perpendicular to the pier) due to riprap or debris, and three shoreline locations [SS-3 (4.5 m), SS-39 (7.1 m), and SS-59 (6.3 m)] that were moved slightly offshore due to tidal restrictions or presence of large gravel/riprap.

- Five supplemental surface grab locations were added to further investigate the potential for contaminant sources near outfalls south of the Study Area in West Bay (SS-61, SS-62, SS-63, SS-64, and SS-65).
- Subsurface cores were attempted at the target coordinates. If low recovery or refusal occurred, locations were moved a short distance (within 10 m) of the target coordinates. Locations near the pier were moved parallel to the pier face. All subsurface cores were collected within 10 m of the target sampling coordinates except for four under-pier locations [(SC-11 (16.0 m), SC-12 (15.2 m), SC-17 (10.3 m), and SC-19 (11.3 m)], which were moved offshore (perpendicular to the pier) due to riprap or debris.
- For under-pier locations (subsurface cores and surface grabs), no GPS was accessible. A GPS location was collected at the pier face, and the station coordinates were estimated in CAD based on measured distance beneath the pier.
- Mudline elevations recorded at the following subsurface cores were substantially different (+/- 5 feet) than the elevations from the February 12, 2011, U.S. Army Corps of Engineers (USACE) bathymetric survey: SC-06 (-11 feet), SC-11 (-12.5 feet), SC-12 (-18.4 feet), SC-17 (-17.6 feet), SC-19 (-22.5 feet), SC-20 (-7.3 feet), SC-22 (-7.1 feet), SC-23 (-7.9 feet), SC-47 (+9.8 feet), SC-50 (+5.6 feet), GC-02 (-15.4 feet), GC-04 (+14.2 feet). Most of these locations are underpier at the Port Marine Terminal, where bathymetric measurements are less accurate and small changes in sampling location can affect actual elevation.
- Subsurface cores all achieved the target penetration depths except for SC-18, which had a target penetration of 14 feet and actual penetration 11.9 feet (highest recovery after three attempts).
- Subsurface cores all achieved the target recovery of 75 percent except for 12 cores. Of those 12 cores, 7 had recoveries of 70 percent or greater (SC-20 [73 percent], SC-28 [73 percent], SC-35 [70 percent], SC-36 [74 percent], SC-37 [71 percent], SC-42 [74 percent], and SC-45 [74 percent]). Four cores were under-pier or pier face locations (SC-07 [67 percent], SC-10 [45 percent], SC-15 [61 percent], and SC-22 [66 percent]). SC-05 was located offshore of the pierface and had a best recovery of 55 percent.

Anthropogenic debris, riprap, mussel shells, and wood waste were the primary causes of these low recoveries. The attempt with the highest percent recovery was retained for processing.

- Full penetration and recovery was not obtained at most locations, which resulted in the bottom interval collected from some subsurface cores as being less than the target interval stated in the SAP.
- Sample intervals differed from the SAP for several subsurface cores due to differences in estimated and actual mudline elevations, recovered core lengths, and field observation-based sampling (e.g., as a result of sediment stratigraphy). The following cores had differences: SC-04, SC-06, SC-07, SC-08, SC-09, SC-10, SC-15, SC-18, SC-20, SC-22, SC-23, SC-30, SC-35, SC-46, SC-49, and SC-50.
- As specified in the SAP, a tiered approach was used to determine which intervals from each core should be analyzed for one or more chemical parameters. The following additional samples [stations (with core intervals)] were added to the testing program: SC-02 (1-2, 4-5 feet), SC-04 (11.8-13.5 feet), SC-08 (5.4-6.4, 7.4-8.4 feet), SC-09 (8-9, 9-10 feet), SC-10 (8.2-9.1 feet), SC-11 (8-10 feet), SC-12 (8-10, 10-11.2 feet), SC-13 (9.5-10.4, 10.4-11.4 feet), SC-14 (1-2, 2-3 feet), SC-15 (8.7-9.7, 9.7-10.7 feet), SC-16 (6-7 feet), SC-17 (8-10 feet, 10-11.1 feet), SC-18 (9.7-10.7 feet), SC-19 (8-10, 10-11.2 feet), SC-20 (7.7-8.7 feet), SC-22 (10.6-12.1, 12.1-12.9 feet), SC-25 (1-2 feet), SC-26 (1-2 feet), SC-27 (4-5 feet), SC-28 (1-2 feet), SC-31 (1-2 feet), SC-32 (0-1, 1-2 feet), SC-33 (1-2 feet), SC-34 (0-1 feet), SC-35 (0-1 feet), SC-36 (4-5 feet), SC-37 (1-2 feet), SC-38 (1-2 feet), SC-39 (1-2, 3-4 feet), SC-40 (1-2 feet), SC-41 (1-2, 2-3 feet), SC-42 (1-2 feet), SC-43 (2-3 feet), SC-44 (2-3, 3-4 feet), SC-45 (1-2, 2-3 feet), SC-47 (2-3, 3-4 feet), SC-48 (1-2 feet), SC-49 (2-3, 3-4, 4-6, 6-8, 10.5-11.4 feet), SC-50 (3-4, 4-6, 6-8, 8-9.3, 12.4-13 feet).
- For geochronology cores, lead-210 and cesium-137 were initially analyzed for every third sample within a core. These intervals were selected in order to measure the range of potential historical sediment deposition rates. Additional samples were triggered based on the first round of data results.
- TOC and TS analyses were omitted from the geochronology samples due to insufficient sample volume. These analyses were intended to provide supplemental information and do not impact the data quality objectives of the sedimentation rate determination.

- In core SC-22, samples were collected every recovered 1 foot rather than every 2 feet in situ to allow more resolution for chemical characterization.

2.3.2 Geotechnical

- Soil borings SB-01 and SB-03 were moved approximately 270 feet to the south and 50 feet to the north, respectively, due to an inability to safely extend drilling equipment over the edge of the Marine Terminal. Therefore, SB-01 and SB-03 were performed at the south and north ends of the Marine Terminal, respectively, where drilling could safely be performed.
- CPT explorations were terminated approximately 40 to 45 feet shallower than the proposed depth of 100 feet bgs due to refusal from gravelly soils encountered during advancement.
- Vane shear test VST-1 was moved 122 feet to the west. The test was performed at the new location; however, the presence of granular sediments produced unreliable test results for purposes of estimating the undrained shear strength. The granular nature of the sediments was the only data recorded at this location. Vane shear test VST-6 was moved 270 feet to the north to perform the test in shallower water due to water depth limitations to the testing apparatus. Vane shear tests VST-2, VST-3, VST-4, and VST 10 were moved approximately 240 to 330 feet toward the navigation channel to seek deeper water due to draft requirements of the vessel.
- Jetting using a water pump to advance the probe was unnecessary as the diver crew was able to advance the probe using mechanical means.

2.4 Sample Handling and Shipment

All samples were delivered to the laboratory by Anchor QEA staff within holding time and temperature requirements. Sediment samples were delivered to ARI. Geotechnical samples were delivered to HWA. HWA stored samples in a moisture-controlled environment until testing could be performed. Geochronological samples were submitted for analysis to Mass Spec Services. There are no temperature or holding time requirements for radiochemistry testing.

2.5 Investigative Waste Management

Investigation-derived waste material generated during the sampling event included excess sediment core sample processing materials not used for sample analyses, soil cuttings generated during boring activities, and disposable sampling supplies and personnel protective equipment (PPE) used in sample processing.

Clean sampling supplies and PPE were disposed of in the City's municipal solid waste system. Solids (i.e., sediment and soil) and wastewater (i.e., decontamination and drilling process water) were stored in 55-gallon drums on site until waste characterization was completed. Waste management was facilitated by PSC. Solid waste was picked up on June 20 and 27, 2013 and transported to the Alaska Street Reload and Recycling Facility in Seattle, Washington, under manifest numbers 865207-13 and 869761-13, respectively. Wastewater was treated at Burlington Environmental in Tacoma, Washington, prior to disposal into the City of Tacoma's municipal wastewater system.

3 DATA QUALITY

This section provides a summary of project quality assurance/quality control (QA/QC) objectives for chemical testing data, and provides the findings of data validation activities.

3.1 Testing Labs and Methods

Chemical testing was performed by ARI. ARI is certified by Ecology and the National Environmental Laboratory Accreditation Program (NELAP). Mass Spec Services performed the radiochemistry testing. HWA performed the geotechnical testing.

All analyses conformed to procedures described in the approved SAP/QAPP (Anchor QEA 2013a). Appendix B provides the laboratory data reports and Appendix C provides the data validation reports.

Chemical testing adhered to the QA/QC procedures suggested in SW-846 (USEPA 1986) method, Ecology SMS guidance, and/or Puget Sound Sediment Reference Material guidance (USACE 2013). The data validations of the chemistry results were performed under USEPA National Functional Guidelines for Data Review (2008, 2010, and 2011) and USACE Puget Sound SRM guidance (USACE 2013). External data validation was not conducted for geotechnical and geochronology testing because there is no prescribed validation guidance for these tests. These tests were evaluated internally based on completeness and method QA/QC requirements, if applicable.

3.2 Data Quality Objectives

The SAP/QAPP (Anchor QEA 2013a) was written to ensure that data of acceptable quality were generated to support the sediment investigation. The quality of the laboratory data is assessed by precision, accuracy, representativeness, comparability, and completeness. Applicable quantitative goals for these data quality parameters were listed in Table 7-3 of the SAP/QAPP (Anchor QEA 2013a). Each parameter is discussed below:

- Precision: Laboratory precision was measured with matrix spike (MS)/matrix spike duplicate (MSD) analyses; and laboratory duplicate analyses. Precision goals were

generally met, and in cases where they were not, data were qualified as estimated according to USEPA National Functional Guidelines (2008, 2010, and 2011).

- Accuracy and Bias: Accuracy was measured with laboratory control sample (LCS), standard reference material (SRM), MS, and MSD sample percent recoveries. Accuracy goals were generally met, and in cases where they were not, data were qualified as estimated according to National Functional Guidelines (2008, 2010, and 2011). In these instances, the usability of the data was determined by the extent of the exceedance. The validation reports submitted in Appendix C specify the specific outliers and whether the bias was high or low.
- Representativeness: The list of analytes has been identified to provide a comprehensive assessment of the known and potential contaminants at the sampling sites.
- Comparability: The laboratory used common traceable calibration standards, spiking standards, and regional reference materials. Specific information can be found in the laboratory data packages (Appendix B).
- Completeness: Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. The completeness goal of 95 percent was met.

3.3 Quality Assurance/Quality Control Findings

The overall data QA/QC program for the sediment investigation evaluation followed procedures presented in the SAP/QAPP (Anchor QEA 2013a). Measures were taken to ensure data quality meets the requirements specified by Ecology protocols (Ecology 2015).

3.3.1 Field Quality Assurance/Quality Control

Field QA/QC procedures used for this project included collecting field duplicate samples at a frequency of 1 per 20 samples, and avoiding cross contamination between sample intervals and locations. Field duplicates were prepared by splitting a field sample (grab or core) after compositing/homogenization. Field duplicates were screened against a 50 relative percent difference (RPD) criteria. In general, field duplicate RPDs were well within this criteria indicating that samples were homogenized adequately during sample processing.

3.3.2 Laboratory Quality Assurance/Quality Control

Project-specific action limits based on regional criteria (Ecology 2008b; USACE 2013) were used to assess the precision and accuracy of method blanks, LCS, MS/MSD, SRM, and laboratory replicate samples. The frequencies and control limits of these quality control samples are listed in Tables 7-2 and 7-3 of the SAP/QAPP, respectively (Anchor QEA 2013a). Any quality control results that exceeded these criteria were qualified in the validation process. A summary of all qualified data can be found in the data validation report(s) in Appendix B.

3.3.3 Data Review and Validation

All chemical data submitted in this Report were validated by Laboratory Data Consultants in Carlsbad, California. All results were checked for completeness (correct method, hold times met, results reported for each sample). All analytical results were validated at an USEPA Stage 2A level except D/F results, which were validated at a Stage 4 level according to regional advisory guidance (USACE 2013). The data validations were performed under USEPA National Functional Guidelines for Data Review (2008, 2010, and 2011) and USACE Puget Sound SRM guidance (USACE 2013).

Data validation verified the accuracy and precision of chemical determinations performed during this investigation. Data qualifiers assigned because of the data validation and their definitions are shown on each of the respective analytical results tables. Data may have been qualified as biased or estimated for a particular analysis based on method or technical criteria. Data qualified with a "J" indicates that the associated numerical value is the approximate concentration of the analyte. Data qualified with a "UJ" indicates the approximate reporting limit below which the analyte was not detected. Consequently, these data qualifications are not expected to impact the data quality objectives.

D/F results qualified with the estimated maximum potential concentration (EMPC) data qualifier indicate a response that did not meet all requirements of positive identification, specifically the ion abundance ratio for the quantitation ions. EMPC qualifiers were retained in this dataset. Many samples had one or more EMPC qualifications in the results. The majority of these results were in low level detections or total homolog fractions. Total

homologs were qualified if any congener within the total (210 congeners total) was qualified. Data validation indicated that the method protocols were followed, and the data are usable as qualified.

All sediment investigation data were determined to be useable as reported from the laboratory or as qualified in this Report for the purposes of sediment characterization.

4 SAMPLE RESULTS

This section describes the data reporting procedures used in the Report and presents the laboratory results for the surface and subsurface sediment and geotechnical samples collected in 2013.

4.1 Data Reporting Procedure Summary

The various data reporting procedures used in the data tables are described in the following subsections.

4.1.1 Toxic Equivalency and Chemical Sum Calculations

4.1.1.1 Toxic Equivalency Calculations

D/F congener toxic equivalency (TEQ) is calculated using the World Health Organization consensus toxic equivalency factor (TEF) values (Van den Berg et al. 2006) for mammals as presented in Table 4-1. The TEQ is calculated as the sum of each congener concentration multiplied by the corresponding toxic equivalency factory (TEF) value.

Carcinogenic PAHs (cPAHs) are presented as TEQ sums, calculated by using the TEFs presented in Table 4-2, from Model Toxics Control Act (MTCA) guidance (Ecology 2007).

4.1.1.2 Chemical Sum Calculations

The Sediment Cleanup User Manual II (SCUM II, Ecology 2015) recommends summing rules for calculated totals of grouped chemicals. When all results that are part of a total are detect, the sum is simply the total of the detections. Several summing methods are available when components of the total are non-detect, all of which minimize the bias introduced in the summed result. The more non-detects present in a sample, the more likely a bias could be introduced in the summed result. The results provided in this Report include multiple summation rules to provide a range of bias that may be present in the calculated result as well as accommodate the emerging methods of addressing non-detects and other debatable values (i.e., EMPCs). The following summation rules are used in this Report, when applicable:

- The constituents included in SMS parameter sums (low-molecular-weight polycyclic aromatic hydrocarbon [LPAH], high-molecular-weight polycyclic aromatic hydrocarbon [HPAH], Aroclors, and benzofluoranthenes) follow the summing rules in WAC 173-204-320(2b).
- EMPC values are reported as is (EMPC included) and EMPC = U at the EMPC value (Ecology 2015 - Appendix). EMPC values are only relevant to D/F TEQ sums.
- SMS rules do not provide guidance for TEQ sums (cPAH and D/F). For this dataset TEQs were calculated with non-detect values (U) reported as U=0 and U=1/2 of the method detection limit (MDL), 1/2 of the estimated detection limit (EDL) for D/Fs, or 1/2 of the EMPC for D/Fs with an EMPC qualifier (when using the EMPC = non-detect calculation). Sums presented on figures include the EMPC and use U=0.

4.1.2 Screening Criteria

For the purposes of this Report, SMS chemicals are screened against SMS benthic criteria. Results of D/Fs and cPAHs are also presented in this Report. DFs are screened against a range of arbitrary thresholds (i.e., 0-5, 5-10, 10-20, 20-40, 40-100, 100-500, and greater than 500 nanograms per kilogram [ng/kg]). These results will be further screened in the Alternatives Memo based on practical quantitation limits (PQLs), regional and/or natural background levels, and risk-based threshold concentrations (RBTCs) developed for the protection of human health.

4.1.2.1 Sediment Management Standards Parameters

Sediment results were screened against SMS criteria: the sediment quality standard (SQS) and cleanup screening level (CSL). The SQS corresponds to "a sediment quality that will result in no adverse effects, including no acute or chronic adverse effects on biological resources and no significant health risk to humans" (Ecology 2013). The SQS is specific to benthic criteria. A sediment cleanup objective (SCO) that includes human health criteria will be established in the Alternatives Memo. The CSL is a minor adverse effects level, which is the minimum level to be achieved in all cleanup actions under SMS.

For some chemicals, the SMS criteria are based on organic carbon (OC)-normalized concentrations. If the TOC content of a sediment sample is outside of the recommended

range for marine sediment OC normalization (less than 0.5 percent or greater than 5 percent; Ecology 2015), then dry-weight concentrations were compared with the marine sediment adverse effects threshold (AET) criteria (Ecology 2015). The AETs are defined as the sediment concentration of a contaminant above which statistically significant adverse effects are expected to occur. The AETs are defined on a dry weight basis and were developed for amphipod, oyster, benthic, and microtox thresholds (PTI 1988). The lowest AET (LAET) is functionally equivalent to the SQS, and the second lowest AET (2LAET) is functionally equivalent to the CSL.

4.1.2.2 Dioxins and Furans

D/F results are presented as TEQ sums reported in ng/kg units. No standard numeric criteria for D/Fs are promulgated in SMS for sediment, but concentrations are screened against a range of thresholds in this Report. The lowest screening level (5 ng/kg) is the PQL identified in the SCUM II guidance (Ecology 2015). Additional screening levels will be developed in the Alternatives Memo to use as the TEQ-based cleanup level, based on calculated human health thresholds, background values, and PQL.

4.1.2.3 Carcinogenic Polycyclic Aromatic Hydrocarbons

The results for cPAHs are presented as TEQ sums reported as micrograms per kilogram (µg/kg) units. No standard numeric criteria for cPAHs are promulgated in SMS for sediment. The lowest screening level (9 µg/kg) is the PQL identified in the SCUM II guidance (Ecology 2015). Additional screening levels will be developed in the Alternatives Memo to use as the TEQ-based cleanup level, based on calculated human health thresholds, background values, and PQL.

4.2 Sediment Results

The following subsections provide a brief summary of the results from surface grabs, subsurface cores, and geotechnical borings. In Section 5, this data is used in combination with the historical data presented in the EISDGM (Anchor QEA 2012) to show the nature and extent of surface and subsurface contamination at the site.

4.2.1 Surface Sediment

Surface sediment results are presented in Tables 4-3 and 4-4 and Figure 4-1. Table 4-3 presents the surface grab D/F results, TS, TOC, and grain size. Table 4-4 presents surface grab SMS parameters results. Laboratory data packages and data validation reports are presented in Appendices B and C, respectively.

4.2.1.1 Chemistry

D/F TEQs ranged from 2 ng/kg (location POBI-SS-06 near the Port's A-outfall) to 98 ng/kg (location POBI-SS-59 near East Bay Redevelopment Site and Moxlie Creek outfalls) for all 2013 samples. SMS chemicals exceeded screening criteria at only a few surface sediment locations. These chemicals (and locations) are listed below:

- Samples near outfalls within Study Area
  - POBI-SS-02 – benzoic acid above SQS
  - POBI-SS-06 – benzyl alcohol above SQS
  - POBI-SS-31 – mercury above SQS near outfalls outside Study AreaPOBI-SS-37 – benzo(a)pyrene, benzo(g,h,i)perylene, dibenzo(a,h)anthracene, indeno(1,2,3-c,d)pyrene above SQS
  - POBI-SS-50 – phenol above SQS
  - POBI-SS-61 – benzyl alcohol above CSL, bis(2-ethylhexyl)phthalate above 2LAET, and butylbenzyl phthalate and di-n-butyl phthalate above LAET
- Marine Terminal under-pier samples
  - POBI-SS-13 – acenaphthene above SQS
  - POBI-SS-17 – acenaphthene and butylbenzylphthalate above LAET

All of the surface grab locations with SMS exceedances are adjacent to active outfalls except for POBI-SS-13 and POBI-SS-17, which are under-pier locations near the Marine Terminal. Figure 4-1 shows new and historical surface grab locations along with D/F TEQ concentrations and SMS exceedances.

4.2.1.2 Physical

TOC ranged from 0.67 to 9.4 percent, with an average of 3.65 percent in 2013 samples. Of those samples, 54 were within the 0.5 to 5 percent TOC range typical of Puget Sound sediments, and 11 contained greater than 5 percent TOC. TS ranged from 18.7 to 77.2 percent, with an average of 42.3 percent in 2013 samples.

Surface sediments were predominantly non-plastic silts containing sand, shell fragments, and other organic fragments. Fines content ranged from 7.8 to 98.9 percent, with an average of 63.4 percent in 2013 samples. Three samples contained substantial shell fragments (e.g., greater than 30 percent): near Fiddlehead Marina (POBI-SS-03), Berth 1-2 (POBI-SS-10), and Swantown Marina (POBI-SS-40). Silty Sands were encountered near Berth 1 (POBI-SS-06), north end of Log Pond (POBI-SS-23), two locations along the eastern shore of East Bay (POBI-SS-57, POBI-SS-39), the Swantown Haulout (POBI-SS-53), and along the western edge of the Cascade Pole site (POBI-SS-34). Gravel was encountered at one location along the eastern shore of East Bay (POBI-SS-37). One sample with substantial decomposing wood fragments was collected to the northwest outside of the Study Area (POBI-SS-27).

4.2.2 Subsurface Sediment

4.2.2.1 Chemical

Subsurface sediment results are presented in Tables 4-5 and 4-6 and Figure 4-2. Table 4-5 presents the subsurface D/F results TS, TOC, and grain size. Table 4-6 presents subsurface SMS parameters results. Laboratory data packages and data validation reports are presented in Appendices B and C, respectively.

D/F TEQs varied significantly by depth and location. The highest concentrations of D/Fs are in the southern portion of East Bay and adjacent to the Berth Area. Chemicals that exceed SMS or AET screening levels at one or more location or depth include 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, benzoic acid, 1,2,4-trichlorobenzene, 1,2-dicholorobenzene, 1,4-dichlorobenzene, n-nitrosodiphenylamine, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, dibenzofuran, PAHs, total PCBs, cadmium, mercury, silver, and zinc. Section 5 presents this data in conjunction with the historical dataset to show the nature and extent of contamination in and around the Study Area.

4.2.2.2 Physical

Lithology descriptions were determined and recorded based upon features including density, consistency, moisture content, color, composition, grain size, organic matter content, and other notable characteristics. Budd Inlet sediment was grouped into three stratigraphic units based primarily on density, color, sediment type, and texture. Other information used to identify these units included the presence of anthropogenic material, biota, and dredge events. The three stratigraphic units are:

- Recent: This upper unit consisted predominantly of non- to low-plasticity inorganic silts. The surface fraction of silt often contained up to 10 percent sand. A thin biologically active layer was observed at many locations at the sediment-water interface as evidenced by abundant bivalves (Mytilus sp.) and bivalve shells. Recent materials were characterized by higher moisture content, soft to firm density, and higher visible organic matter and biota compared with underlying materials. Shell fragments, organic fragments (wood), and anthropogenic debris were often present scattered throughout the unit. A hydrogen sulfide-like odor was common.
- Transition: This middle unit formed a transition zone between recent and native units and was characterized as a mix of both sedimentary units. Transition layers were identified predominantly as sandy silts and silts with sand and consisted of varying percentages of silt, sand, and shell fragments. Occasional layers containing poorly sorted gravel were also encountered. Transition layers were characterized by increased density and a higher percentage of sand, shell, and gravel than recent units. Within this matrix, beds and pockets of poorly graded sands and inorganic silts were also present.
- Native: This lower unit contained predominantly two matrices. The shallower native layer was often a poorly graded sand matrix with 5 percent fines and up to 20 percent rounded gravel. The sand matrix consisted of multicolored grains of white, gray, black, red, and orange. In cases where the sand layer was fully penetrated by coring, the matrix typically graded to inorganic Silt of increased density and medium plasticity. Layers of undecomposed wood were sometimes encountered in native matrices.

- Other: Layers with substantial shell fragments were encountered mid-core at locations near the Marine Terminal and Log Pond (from 1 to 8 feet below mudline in POBI-SC-23, 4.6 to 8.7 feet below mudline in POBI-SC-24, and 2.5 to 7.8 feet below mudline in POBI-SC-26). A layer of decomposed woody debris with strong hydrogen sulfide-like odor was encountered from 0.5 to 2 feet below mudline in core POBI-SC-49 (adjacent to East Bay Redevelopment Site). A black silty sand layer with strong hydrocarbon-like odor and sheen was observed from 6.6 to 7.4 feet below mudline in core POBI-SC-19 near Marine Terminal Berth 3 North. Two cores encountered the residuals management sand cover layer placed during the Interim Action in the Berth 2 and 3 Area (POBI-SC-13 from 2 to 3 feet below mudline and POBI-SC-15 from 0.5-2.3 feet below mudline).

4.3 Geotechnical Results

Geotechnical testing is needed for remedial design purposes. This section presents the test results, which will be used for feasibility evaluations of remedial alternatives and remedial design. Geotechnical data results are summarized in Tables 4-7 to 4-10.

Results from index testing, which includes the following, are presented in Table 4-7:

- Moisture content (ASTM D2216)
- Atterberg limits (ASTM D4318)
- Grain size analysis (ASTM D6913)
- Specific gravity (ASTM D854)

Index testing was performed for all soil units described in Section 4.4. Sand and gravel soil units were targeted for grain size analysis while units of predominately silt and clay were subjected to Atterberg limits testing.

Consolidation testing was performed using two test methods: one-dimensional oedometer (ASTM D2435) and constant rate of strain (ASTM D4186). The compressive properties can be estimated from the graphical outputs provided by HWA. The graphical outputs from the laboratory reports are included in Appendix B. Both types of consolidation testing were

performed for the two cohesive units identified at the site: Silt/Organic Silt and Silt/Silty Clay.

Test results for unconsolidated undrained triaxial compression (UU-TX; ASTM D2850) and consolidated-undrained triaxial compression (CU-TX; ASTM D4767) are presented in Table 4-8 and 4-9, respectively. Strength parameters were estimated from graphical outputs and are included in Appendix B. Both types of triaxial compression testing were performed for the two cohesive units identified at the site: Silt/Organic Silt and Silt/Silty Clay.

Results of in-situ vane shear testing are presented in Table 4-10.

4.4 Geotechnical Boring Sample Conditions

General descriptions of the soil units identified from the borings advanced at this site are presented below, in order from the ground surface downward. Further evaluation and characterization of these soil properties will be performed during development and evaluation of remedial alternatives.

Plasticity of each soil unit is included below. Plasticity is defined as the degree a soil can be molded or reworked without rupturing and was determined in the field following the logging methodology outlined in ASTM 2488. Non-plastic sediments cannot be formed or molded into a 1/8-inch thread. Fine-grained soils of increased plasticity (low, medium, high) were determined by their ability to be rolled into a 1/8-inch thread. Soil plasticity was confirmed by the laboratory on a select number of samples for Atterberg limits.

4.4.1 Fill

Fill is identified as loose to medium dense, fine to medium grained sand with silt and variable shell and gravel content. The deposit is generally brownish gray to dark gray with gray and white sand grains and tends to become looser with depth. Fill was observed to be as thick as 20 feet at the upland corner of the log pond (SB-04) and northern end of the port property (SB-07) and to an elevation of approximately -2.0 feet MLLW. Historical documents report that fill exists in the under-pier slope (Figure 2-20 from Anchor QEA 2012b), but the unit was not encountered on explorations performed near the pier (SB-01, SB-02, and SB-03).

4.4.2 Silt and Organic Silt

In-water sediments are generally very soft to soft, sandy silt and vary spatially in organic content. In explorations performed near the pier, the sediments are observed to be very soft to soft, brownish gray to greenish brown, very fine to fine grained sandy silt with abundant shells fragments, low to high plasticity and moderate to high organic content. At explorations performed in and near the log pond, the unit contained little to moderate organic content, was brown to grayish brown, was low to medium plasticity, and contained very fine to fine grained sandy silt. The thickness of this layer ranges from approximately 7.5 to 27 feet. The bottom elevation varies spatially and ranges from -18.1 feet at the north end of the log pond to -46.5 feet MLLW in Berth 2 of the Marine Terminal. The moisture content of this material ranges from 38 to 138 percent.

4.4.3 Silty Sand and Sand with Silt

This unit is loose to medium dense, gray to dark gray, fine to medium grained silty sand and sand with silt, with non-plastic fines and occasional gravel and shells. At in-water locations, the unit ranges in thickness from 12.0 to 28.5 feet thick and has a general bottom elevation ranging from -40.5 feet MLLW near the south end of the pier (SB-01) to -52 feet MLLW near the end of the abandoned wooden pier (SB-06). At the upland corner of the log pond (SB-04), the unit was 24.5 feet thick with a bottom elevation of approximately -34 feet MLLW.

4.4.4 Sand and Gravel with Silt

This unit is medium dense to very dense, primarily gray and multi-colored, medium to coarse grained sand and gravel with non-plastic silt and sub-rounded to sub-angular particles. The unit is 10.5 to 24.0 feet thick. The bottom elevation ranges spatially and does not exhibit a predictable trend. The bottom elevation was deepest at the north end of the pier (SB-03), to -74.0 feet MLLW, and shallowest at the upland corner of the log pond (SB-04), to -54.0 feet MLLW.

4.4.5 Silt and Silty Clay

This unit is stiff to very stiff, light gray to olive gray, silt, and silty clay with very fine grained sand and low to high plasticity. The layer was fully penetrated by borings SB-02, SB-04, SB-06, and SB-08. In these borings, the layer thickness ranges from 4.5 to 9.0 feet. Near the south end of the pier (SB-01), the layer is low plastic silt and at least 15.0 feet thick. The bottom elevation is shallowest at the upland corner (SB-04) and north end of the log pond (SB-08), -63.0 and -64.0 feet MLLW, respectively. The moisture content of this material ranges from 27.0 percent to 40.0 percent.

4.4.6 Silty Sand with Interbedded Silt Layers

This unit primarily consists of medium dense to dense, light gray to gray, fine to medium grain silty sand with little to no plasticity. SB-06 indicated that the unit consists of alternating layers of silty sand and silt. At elevation -95.0 feet MLLW, a silt layer with an approximate thickness of 10.5 feet is underlain by a silty sand layer with a thickness of 11.5 feet. The boring was terminated in a stiff silt layer with a top elevation of -117 feet MLLW.

5 NATURE AND EXTENT OF CONTAMINATION

This section summarizes the historical and recent sediment investigations performed within Budd Inlet between 2003 and 2013 to establish chemicals of potential concern (COPCs) in the Study Area and characterize the nature and extent of contamination. A summary of the investigations reviewed is presented in Table 5-1. Information covered in this section includes the following:

- Chemicals of potential concern
- Surface sediment quality
- Subsurface sediment quality

5.1 Chemicals of Potential Concern

Results from several historical sediment investigations were presented in the EISDGM (Anchor QEA 2012b), which were used to identify data gaps and areas of potential concern. A list of COPCs was defined in the Work Plan (Anchor QEA 2012a), which included D/Fs, acenaphthene, and mercury. The current results presented in Section 4 of this Report are used to further refine the COPC list, which are determined based on the chemicals that exceed SMS criteria. D/Fs are included in the COPC list, as well as PAHs, PCBs, 12 SVOCs, cadmium, mercury, silver, and zinc. The COPCs are summarized in Table 5-2 along with their applicable regulatory criteria and will be further screened in the Alternatives Memo during development of cleanup levels. The nature and extent of the COPCs are discussed in Sections 5.2 and 5.3 (*Surface Sediment Quality* and *Subsurface Sediment Quality*, respectively). COPCs are listed below.

5.1.1 Dioxin and Furan

- Surface sediment concentrations range from 0.65 to 98.9 ng/kg and average 19.5 ng/kg.
- Subsurface sediment concentrations range from 0.004 to 4,206 ng/kg and average 65 ng/kg.

5.1.2 Polycyclic Aromatic Hydrocarbons

- Surface Sediment
  - Acenaphthene exceeded SMS or AET criteria in surface sediments at two locations within the Study Area (POBI-SS-13 and POBI-SS-17)
- Subsurface Sediment
  - All PAHs except acenaphthylene exceeded SMS or AET criteria in one or more subsurface sediment interval within two localized areas within the Study Area, at the northern Berth Area and near the Moxlie/Indian Creek and East Bay Redevelopment Site
- As part of the cleanup level development in the Alternatives Memo, cPAHs will also be evaluated to calculate RBTCs that are protective of human health; cPAHs will be retained as a COPC, pending screening conducted in the Alternatives Memo

5.1.3 Semi-volatile Organic Compounds

- Surface Sediment
  - Benzyl alcohol and butylbenzyl phthalate exceed SMS or LAET criteria in surface sediment at one location each (POBI-SS-06 and POBI-SS-17, respectively)
- Subsurface Sediment
  - 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, benzoic acid, 1,2,4-trichlorobenzene, 1,2-dicholorobenzene, 1,4-dichlorobenzene, n-nitrosodiphenylamine, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, and dibenzofuran exceed SMS or AET criteria in subsurface sediments within two localized areas within the Study Area, at the northern Berth Area and near the Moxlie/Indian Creek and East Bay Redevelopment Site

5.1.4 Polychlorinated Biphenyls

- Surface sediment
  - PCBs did not exceed SMS criteria in surface sediment

- Subsurface sediment
  - PCBs exceed SMS or AET criteria in subsurface sediments within two localized areas within the Study Area, at the northern Berth Area and near the Moxlie/Indian Creek and East Bay Redevelopment Site

5.1.5 Metals

- Surface sediment
  - Mercury exceeded SQS at one location (POBI-SS-31)
- Subsurface sediment
  - Cadmium, mercury, silver, and zinc exceed SMS criteria in subsurface sediments within one localized area within the Study Area at the northern Berth Area; mercury was also slightly above the SQS in one other localized subsurface area near the Moxlie/Indian Creek and East Bay Redevelopment Site

5.2 Surface Sediment Quality

Surface sediment chemical quality was directly measured in and around the Study Area during four studies conducted in years 2006, 2007 to 2010, and 2013. Data collected prior to 2013 was mostly D/Fs (only five samples in the historical dataset had SMS parameters analyzed), while data collected in 2013 included PAHs at all locations and other SMS chemicals at select locations. Historical data that no longer represents the current conditions (i.e. dredged areas) were excluded from the dataset. Summary statistics (e.g., minimum, maximum, mean) on this comprehensive chemical dataset is provided in Table 5-3. As discussed in Section 4.2.1, some chemicals exceed SMS or AET criteria in isolated locations in and around the Study Area, mostly adjacent to active outfalls. Figure 4-1 shows D/F TEQ concentrations and SMS chemical concentrations that are above screening criteria. D/F TEQs (U=0) in the Study Area (Cascade Pole site excluded) ranged between 0.6 ng/kg (POC-S2) and 98.9 ng/kg (POBI-SS-59), and cPAH TEQs (U=0) in the Study Area ranged from 2.5 µg/kg (POBI-SS-21) to 435 µg/kg (POBI-SS-13). TOC in and around the Study Area ranged from 0.57 percent to 9.4 percent with an average concentration of 3.7 percent.

Inverse distance weighting (IDW) is a method used to interpolate concentrations of areas between known data points (where samples were collected). IDW was calculated using the Spatial Analyst tool in ArcGIS data software. Figures 5-1 and 5-2 present interpolated surface sediment D/F TEQ and cPAH TEQ concentrations, respectively.

Spatially weighted average concentrations (SWACs) are based on the IDW and are used to estimate an average concentration across a specified area. The Cascade Pole site is not part of the Budd Inlet Sediment Characterization Study Area; however, sample concentrations from this site were included in SWAC calculations because ecological and human health risks are based on exposure to all sediment in the area, including the Cascade Pole site and the larger Study Area. SWACs were calculated using the Zonal Statistical tool in ArcGIS. The SWAC areas defined for Budd Inlet in this study are described in Chart 1. The SWACs in the Study Area are 16 ng/kg and 82 µg/kg for D/F and cPAHs, respectively.

Chart 1
SWAC Summary

SWAC Area	SWAC Value	
	D/F	cPAH
Study Area as defined in the Agreed Order	16 ng/kg	82 µg/kg
Study Area portion of West Bay	13 ng/kg	72 µg/kg
Study Area portion of East Bay	21 ng/kg	93 µg/kg
Entire West Bay (with northern boundary defined by Study Area extent)	15 ng/kg	87 µg/kg
Entire East Bay (with northern boundary defined by Study Area extent)	21 ng/kg	148 µg/kg

Notes:
µg/kg = microgram per kilogram
cPAH = carcinogenic polycyclic aromatic hydrocarbon
D/F = dioxin/furan
ng/kg = nanogram per kilogram
SWAC = spatially weighted average concentration

5.2.1 West Bay

As seen on Figure 5-1, D/F TEQs range from 0.1 ng/kg (SD18) to 59.8 ng/kg (BI-S7), but are generally between 10 to 20 ng/kg in most of West Bay including the federal navigation channel. The SWAC for all of West Bay (as depicted on Figures 5-1 and 5-2) is 15 ng/kg.

The SWAC for the Study Area portion of West Bay is 13 ng/kg. Lower concentrations are found in the Berth Areas, which range from 2.0 to 21.6 ng/kg and average 10 ng/kg, partly as a result of placement of clean sand cover after the Interim Action[1] dredging in 2009. Underpier concentrations ranged from 0.6 to 44.7 ng/kg and averaged 17.5 ng/kg. Concentrations near the discharge of Capitol Lake tend to have lower concentrations, including in the southwest portion of West Bay, which are consistent with concentrations measured in Capitol Lake in 2008 (SAIC 2008). D/F TEQs were typically higher (20 to 40 ng/kg) outside of the Study Area near the marinas (Fiddlehead, Martin, and Olympia Yacht Club) and near city outfalls located in the same vicinity as the marinas. The highest concentrations of D/Fs in West Bay are outside of the Study Area near the Hardel Mutual Plywood site (59.8 ng/kg).

As seen on Figure 5-2, cPAH TEQs are generally lower than 100 µg/kg in most of West Bay, except for several shoreline areas. The SWAC for all of West Bay is 87 µg/kg. The SWAC for the Study Area portion of West Bay is 72 µg/kg. Lower concentrations are present along the central and southwest portions of West Bay. cPAH TEQs are higher in the Berth Area (71.3 to 668 µg/kg, average of 278 µg/kg), outside of the Study Area near the marinas (164 to 468 µg/kg, average of 242 µg/kg), and near the Hardel Mutual Plywood/Reliable Steel sites (4.3 to 1,489 µg/kg, average of 360 µg/kg).

As described in Section 4.2.1 and Figure 4-1, there were a few exceedances of SMS or AET screening levels in surface sediment. In the West Bay portion of the Study Area, benzyl alcohol was elevated at a location adjacent to the Port's Basin A outfall (POBI-SS-06), acenaphthene was elevated at an under-pier location near Berth 2 (POBI-SS-13), acenaphthene and butylbenzyl phthalate were elevated near Berth 3 North (POBI-SS-17), and mercury was elevated near the northern peninsula Lacey-Olympia-Tumwater-Thurston County Clean Water Alliance (LOTT) outfall (POBI-SS-31). None of the Study Area location concentrations exceed the CSL. Outside of the Study Area, benzoic acid, benzyl alcohol,

[1] Under Ecology's oversight, the Port dredged 9,515 cubic yards of sediments containing elevated levels of D/Fs within a portion of Berths 2 and 3 110 feet wide by 800 feet long. Dredging was conducted to an elevation of -39 feet MLLW over most of the area, but to -40 feet MLLW within 10 feet of the pier face. Dredged areas were covered with an anti-degradation sand cover to provide a clean surface at the end of the project.

bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, and di-n-butyl phthalate were elevated near the Fiddlehead Marina outfalls (POBI-SS-02 and POBI-SS-61).

5.2.2 East Bay

As seen on Figure 5-1, D/F concentrations are generally more elevated in East Bay compared to West Bay. TEQs range from 1.2 ng/kg (CP-19) to 98.9 ng/kg (POBI-SS-59) with most between 20 and 40 ng/kg. The SWAC for all of East Bay (as depicted on Figures 5-1 and 5-2) is 21 ng/kg. The SWAC for the Study Area portion of East Bay is also 21 ng/kg. The highest TEQs are located in the southern portion of East Bay near the Moxlie/Indian Creek outfall and adjacent to East Bay Redevelopment Site, which decreases into the Swantown Marina area to the north. Lower concentrations are present north of the marina and within the Cascade Pole cleanup boundary. Section 6 discusses potential ongoing and historical sources affiliated with these areas. The majority of remaining outfalls in East Bay is on the eastern shoreline and drain residential areas. D/F concentrations near these outfalls are lower than the rest of East Bay (average of 12 ng/kg).

As seen on Figure 5-2, cPAH concentrations are generally more elevated in East Bay compared to West Bay. The cPAH SWAC for all of East Bay is 148 µg/kg, and 93 µg/kg within the Study Area of East Bay. Elevated concentrations generally correlate with elevated D/F concentrations, with higher concentrations near the southern portion of East Bay and decreasing to the north. Outside of the Study Area, location POBI-SS-37 (adjacent to residential outfall) has the highest cPAH TEQ measured (2,688 ng/kg).

Chemicals that slightly exceed the SQS screening level near outfalls on the eastern shoreline include benzo(a)pyrene, benzo(g,h,i)perylene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene at location POBI-SS-37 and phenol at POBI-SS-50 (Figure 4-1, sheet 6 of 7). No samples in East Bay exceeded the CSL.

5.3 Subsurface Sediment Quality

Subsurface sediment chemical quality was directly measured in and around the Study Area during 14 studies conducted in years 2003 to 2011, and 2013. Some cores intervals collected in 2008, prior to the Interim Action dredging were removed as part of that action, but all

intervals shown on Figure 4-2 represent current conditions[2]. Approximately 250 samples were tested for D/Fs with a subset of these having additional SMS parameters analyzed. Summary statistics on this comprehensive chemical dataset are provided in Table 5-4. Figure 4-2 shows sediment core profiles with D/F TEQ concentration ranges and SMS chemical exceedances (when applicable). Figures 5-3a through 5-3l show core profiles along representative cross-sections of key areas in West Bay and East Bay. D/F TEQs and SMS chemical concentrations in the Study Area ranged greatly by location and depth. A description of these elevated concentrations is presented in this section.

The southern portion of the Berth Area was dredged in 2013/2014 by the Port to maintain navigation depths (season 1). The portion adjacent to the pierface was also dredged in early 2015 (season 2). A number of cores are located within the maintenance dredge area, many of which were tested to estimate predicted post-dredge concentrations, as summarized separately for the Dredge Material Management Program (DMMP; Anchor QEA 2013b). All results are included in this section.

5.3.1 West Bay

Elevated concentrations of D/Fs and SMS chemicals in West Bay are described below for the underpier area, Berth Area, and federal navigation channel and for areas outside these areas. TOC in West Bay typically fell within the normal range (0.5 to 5 percent) with some lower TOC values present in deeper intervals and a few higher levels (up to 9.1 percent at POBI-SC-23 and 6 to 8 feet below mudline) in the Berth Area.

5.3.1.1 Underpier Area, Berth Area, and Federal Navigation Channel

D/F concentrations in subsurface sediment are elevated compared to surface concentrations in the Berth Area and underpier areas, just north of the Berth Area and in the federal navigation channel adjacent to the Berth Area. Additionally, some SMS chemicals are also elevated in portions of these areas. Figure 5-3i shows the vertical profiles of cores collected

[2] Chemical concentrations shown in Figure 4-2 are still representative of current conditions; however the mudline elevation changed for a few cores following the Interim Action. The elevations of the subsurface samples are retained in the database and represent current conditions.

in the Berth Area. Figures 5-3c, 5-3d, 5-3e, and 5-3f show the east-west cross section of portions of this area.

Most D/F TEQs range from 20 to 100 ng/kg except for the north end of the Marine Terminal, which has higher concentrations of D/Fs and SMS chemicals. Within this area, both underpier and in the Berth Area, four locations had D/F TEQs greater than 500 ng/kg, with the highest concentration (4,206 ng/kg) in the Study Area at location BI-C5 at 6 to 7 feet below mudline.

SMS chemicals exceed SMS or AET screening levels at one or more interval in cores BI-C5, POBI-SC-12, POBI-SC-17, POBI-SC-19, POBI-SC-22, and POBI-SC-23. The chemicals include 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, benzoic acid, 1,2,4-trichlorobenzene, 1,2-dicholorobenzene, 1,4-dichlorobenzene, n-nitrosodiphenylamine, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, dibenzofuran, PAHs, total PCBs, cadmium, mercury, silver, and zinc. Two cores contained elevated SMS concentrations but no elevated D/Fs at the deepest core interval in the under-pier Berth Area. POBI-SC-12 contained PAHs above SMS criteria at 10 to 11.2 feet, and POBI-SC-17 contained PAHs and dibenzofuran above SMS criteria at 10 to 11.1 feet.

The Berth Area has historically been maintained to elevation -42 feet MLLW, but D/F TEQs greater than 5 ng/kg are present as deep as -47 feet MLLW (BI-C15, POBI-SC-18 and POBI-SC-13). Other cores in this area are generally consistent with the dredge elevation (elevated D/F concentrations are shallower than -42 feet MLLW) with the exception of locations POBI-SC-22 (-46 feet MLLW), POBI-SC-20 (-43 feet MLLW), POBI-SC-10 (-46 feet MLLW), POBI-SC-07 (-45 feet MLLW), POBI-SC-08 (-43 feet MLLW), and POBI-SC-04 (-46 feet MLLW).

Figure 5-3j provides dioxin concentrations for cores in the federal navigation channel. The channel has historically been maintained to elevation -30 feet MLLW, but historical bathymetric surveys indicated elevations as deep as -35 feet MLLW (Anchor QEA 2012a). Consistent with this information, elevated concentrations of D/F (greater than 5 ng/kg) are found at elevations as deep as -36 feet MLLW at locations POBI-SC-05 and POBI-SC-09.

The thickness of sediment with elevated D/F concentrations ranges from 0 to 9 feet and averages 3 feet below mudline for cores in the Navigation Channel outside of the Berth Area.

The 2013 study was designed to delineate the vertical extent of elevated chemical concentrations. The vertical extent of contamination was identified at most sediment cores, except for seven cores in the Berth Area. These cores have elevated concentrations of D/Fs above 5 ng/kg as a conservative screening value or other SMS chemicals in the deepest interval collected. These are described below:

- Berth Area
  - POBI-SC-07 – South Berth Area: D/F TEQ is 60 ng/kg at -45 feet MLLW (13 feet below mudline)
  - POBI-SC-20 – North of Berth Area: D/F TEQ is 113 ng/kg at -43 feet MLLW (8.5 feet below mudline); presence of native gravel was encountered at -45 feet MLLW but not sampled
  - POBI-SC-22 – North of Berth Area: D/F TEQ is 357 ng/kg at -46 feet MLLW (13 feet below mudline); this interval also has elevated mercury, 4-methylphenol, 2,4-dimethylphenol, 1,4-dichlorobenzene, dibenzofuran, PAHs, and PCBs above SQS or CSL
- Underpier Berth Area
  - POBI-SC-11: D/F TEQ is 10 ng/kg at 12 feet below mudline
  - POBI-SC-17: PAHs are elevated above SQS or CSL 11 feet below mudline
  - POBI-SC-19: D/F TEQ is 26 ng/kg and PAHs are elevated above SQS or CSL 11 feet below mudline
  - POBI-SC-23: PAHs and 2,4-dimethylphenol are elevated above SQS or CSL 10 feet below mudline

5.3.1.2 Other Areas

In other areas of West Bay, the upper intervals of the cores contain D/F concentrations that are similar to collocated or nearby surface sediment locations. At these locations, the interval at which concentrations become lower than the surface (less than 10 ng/kg) is encountered around 1 to 2 feet. Two locations outside of the elevated concentration areas

have significantly higher D/F TEQs at depth compared to the surface. Location BI-C2, near the former Solid Wood, Inc. site (now West Bay Park), has a TEQ of 50 ng/kg at 1 to 2 feet compared to the West Bay SWAC of 15 ng/kg. Location POBI-SC-24, near the log pond, is 77 ng/kg at 2 to 3 feet compared to the surface of 20 to 30 ng/kg (Figure 5-3h).

5.3.2 East Bay

East Bay subsurface sediment D/F concentrations are presented in Figure 4-2, sheets 5, 6, and 7, and Figure 5-3l. Cores near the Moxlie/Indian Creek outfall and East Bay Redevelopment Site contain the highest concentrations of D/F and SMS chemicals. Elevated D/Fs are also present in subsurface intervals near the Swantown Marina and Swantown Boatworks Haulout.

5.3.2.1 Area Near Moxlie/Indian Creek Outfall and East Bay Redevelopment Site

Two cores were collected near the Moxlie/Indian Creek outfall and East Bay Redevelopment Site in the 2013 study. One core was in the Study Area (POBI-SC-49) and one was just outside of it (POBI-SC-50). Both locations had generally increasing D/F concentrations with depth. TEQs ranged from 27 to 1,283 ng/kg in POBI-SC-49 and 22 to 225 ng/kg in POBI-SC-50. The highest D/F concentrations in POBI-SC-49 occurred 0 to 4 feet below mudline and 10.5 to 11.4 feet below mudline, with lower concentrations present between these intervals. D/F concentrations were highest in deeper intervals in POBI-SC-50 (4 to 10 feet). TOC was within the normal range (0.5 to 5 percent) except for POBI-SC-49 samples from 0 to 1 feet and 1 to 2 feet below mudline, which had substantial wood waste and high TOC (7.3 and 28.8 percent, respectively). Other chemicals that exceeded SMS screening criteria at these two locations include bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, 1,4-dichlorobenzene, 2,4-dimethylphenol, 4-methylphenol, PCBs, and mercury. Elevated D/Fs and concentrations above SQS or CSL criteria were observed in the deepest interval collected at each of these locations:

- POBI-SC-49: D/F TEQ is 212 ng/kg and mercury was above SQS at 11.5 feet below mudline
- POBI-SC-50: D/F TEQ is 13 ng/kg and 4-methylphenol was above CSL at 13 feet below mudline

5.3.2.2 Swantown Marina and Swantown Boatworks Area

In a sediment characterization study conducted in 2005, cores were collected in East Bay federal navigation channel and adjacent Swantown Boatworks haulout dock to characterize for suitability of open water disposal under DMMP protocols. The top 4 feet of cores within a designated dredge material management unit (DMMU) were composited among two or more cores and submitted for full DMMP chemical analysis. These D/F TEQs ranged from 5 to 52 ng/kg, which tend to be higher than collocated or nearby surface sediment samples. Deeper interval composites at these locations contained TEQs ranging from 26 to 44 ng/kg, with the deepest intervals ranging from 0.3 to 78 ng/kg. Dredging in the area of these DMMP cores has not occurred. A small portion of the Swantown Boatworks haulout area was dredged in 2013/2014 (as part of maintenance dredging), but none of these samples are located in this area.

Cores collected in this area in 2013 include POBI-SC-44, POBI-SC-45, and POBI-SC-46. Core POBI-SC-45 was about 75 feet outside of the federal navigation channel and had a TEQ of 58 ng/kg in the upper 1 to 2 feet. Samples below 2 feet below mudline were less than 5 ng/kg. Core POBI-SC-44 was taken further outside of the federal navigation channel and had lower TEQs than co-located or nearby surface sediment samples (9 to 15 ng/kg in the top 4 feet). POBI-SC-46 was located within the haulout area that was dredged in 2013/2014, and was predicted to expose concentrations less than 5 ng/kg. TOC in these cores were generally within the normal range, except for some deeper intervals that have less than 0.5 percent.

Subsurface sediment in the Swantown Marina area generally contains contamination in the upper 1 to 2 feet of sediment. Presence of contamination tends to correlate with historical dredge elevations in 1982 of -8, -10, and -12 feet MLLW.

Throughout East Bay, D/F concentrations less than or equal to 5 ng/kg were reached in this area with the following exceptions:

- POBI-SC-44: D/F TEQ is 10 ng/kg 4 feet below mudline
- OLYC03/OLYC08/OLYZ03: D/F TEQ is 78 ng/kg at 9 feet below mudline
- OLYC04 /OLYZ04: D/F TEQ is 26 ng/kg at 5 feet below mudline

6 SOURCE EVALUATIONS

Section 6 summarizes historical and potential ongoing sources of sediment contamination based on surface and subsurface sediment concentrations. Planned additional testing of lateral inputs into the Study Area may further refine the discussion of potential ongoing sources of contamination described in this section. As the primary COPC, the main focus of the source evaluation is D/F. Other chemicals exceeded criteria at a few localized shoreline areas and are also discussed (PAHs, SVOCs, and metals). Section 6.1 presents a general summary of sources of surface sediment COPCs, Section 6.2 describes potential ongoing sources based on sediment data, and Section 6.3 presents an overview of source control activities. Site-specific historical sources are discussed in Section 6.4, and D/F congener profiles and chemometric results are described in Sections 6.5.

6.1 Common Sources of Surface Sediment Chemicals of Potential Concern

Section 6.1 describes common sources of COPCs based on elevated concentrations in surface sediment in the Study Area. D/F is a site-wide contaminant, but PAHs, phthalates, and mercury are present only in localized areas near outfalls. PAHs and phthalates tend to be ubiquitous urban contaminants, which tend to be primarily contributed through stormwater and atmospheric deposition (Ecology 2010). Other COPCs with elevated concentrations in subsurface sediment are the result of historical sources, as discussed in Section 6.4.

6.1.1 Dioxin and Furans

Dioxins and furans enter the environment from a variety of sources, and are generally byproducts of chemical manufacturing and combustion or incineration processes involving chlorine compounds. They can also be produced during incineration of wood, oil, and wastes. Major contributors of D/F to the environment include the following:

- Hog-fuel boilers burning salt-laden wood
- Hog-fuel boiler ash
- Vehicle emissions and combustion of gasoline and diesel
- Residential wood burning
- Backyard burning of household waste

- Byproducts and derivatives of chemical production (e.g., pentachlorophenol [PCP], PCBs, 2,4,5-T)
- Incineration of municipal solid waste and medical waste
- Secondary copper smelting
- Forest fires
- Land applications of sewage sludge
- Cement kilns
- Coal-fired power plants
- Chlorine bleaching of wood pulp

D/Fs are present at some level throughout the environment, in air, food, water, soils, and sediments. D/Fs tend to be found in higher concentrations near industrial areas, but are present in various concentrations throughout urban, rural, and even remote wilderness areas. Urban soil and sediment concentrations of D/F commonly represent the combined influences of multiple sources (NewFields et al. 2013).

6.1.2 Polycyclic Aromatic Hydrocarbons

The primary pathways for PAHs are stormwater, atmospheric deposition, and leaching from treated wood products. PAHs are generated from the burning of organic matter, fossil fuels, and charcoal (pyrogenic) and are present in refined petroleum products (petrogenic). PAHs are continually generated and released to Budd Inlet and the atmosphere through petroleum use and combustion. In addition, PAHs were historically released from manufacturing operations, machine shops, and repair and fueling facilities for vehicles, trains, and watercraft. They can continue to be released by most of these sources, but best management practices (BMPs) for controlling spills and leaks have reduced input from these sources. Timber piles in Budd Inlet and utility poles and railroad ties in the watershed have historically been treated with creosote. As these structures degrade, they can deposit PAHs directly into Budd Inlet (such as in localized areas from in-water creosoted structures) or onto impervious surfaces that enter Budd Inlet by stormwater, which tends to occur slowly over time.

6.1.3 Other Semi-volatile Organic Compounds

Benzyl alcohol and butylbenzyl phthalate are present at elevated levels in two samples in the Study Area. The primary pathway for phthalates is stormwater and atmospheric deposition (Ecology 2010). Phthalates are associated with plastics such as polyvinyl chloride (PVC) pipe, vinyl siding, tarps, home windows, automotive surfaces (e.g., bumpers and seals), and wiring sleeves (Floyd|Snider 2007). Phthalates are commonly detected in the Puget Sound region sediment and were regionally evaluated by the Sediment Phthalates Work Group[3], which concluded that phthalates are widespread in urban and other developed environments and are ubiquitous in urban water, soil, sediment, and air (Floyd|Snider 2007).

Benzyl alcohol is often associated with urban runoff, and storm drain and combined sewer outfall discharges (Ecology 2010, King County 2006). Benzyl alcohol, a natural solvent, is commonly found in urban runoff. It occurs in the environment both naturally, in flowers, trees, and wood waste; and anthropogenically, in cosmetic and food products, such as chewing gum and gelatin (King County 2008).

6.1.4 Mercury

Mercury can be generated by industrial practices and be transported via stormwater runoff, wastewater, and/or atmospheric deposition. Elevated dissolved concentrations of metals sometimes discharge from the LOTT outfall at the north end of the Study Area when conductivity is elevated (Butti 2013).

6.2 Ongoing Sources

Potential ongoing sources of contamination to Budd Inlet are described in this section based on the presence of elevated surface sediment chemistry. The primary ongoing source is from stormwater discharges, including Moxlie/Indian Creek and other smaller outfalls.

[3] The Sediment Phthalates Work Group consists of representation from the cities of Tacoma and Seattle, King County, and the U.S. Environmental Protection Agency. The Work Group's goal was to "work together to collaboratively summarize and evaluate existing information on phthalates sediment containment issues, identify data gaps, and provide recommendations to address phthalates sediment contamination to agencies and the community to consider." (Floyd|Snider 2007)

Fifteen outfalls are present along the Port peninsula shoreline within the Study Area, and over 50 are present outside the Study Area. Figure 6-1a shows the stormwater outfall locations. The EISDGM provides details on each of these outfalls (Anchor QEA 2012b). As discussed in Section 5.2 and shown on Figures 5-1 and 5-2, higher concentrations of surface sediment COPCs are concentrated near several of these outfalls, especially outfalls that include stormwater runoff from industrial or large urban drainage basins.

The following four discharge areas correlate with the highest D/F concentrations in lower Budd Inlet:

- As shown on Figure 6-1b, the Moxlie/Indian Creek outfall drains 4.5 square miles of mostly developed areas, including high-density commercial and industrial areas. This 72-inch-diameter outfall also historically discharged the State and Chestnut Street combined sewer overflow (CSO; outfall 003), which has been sealed.
- As shown on Figure 6-1c, the outfall from the East Bay Redevelopment Site drains portions of the City just south of the LOTT facility and along Olympia Avenue NE and Jefferson Street NE.
- As shown on Figure 6-1d, the outfalls adjacent to Hardel Mutual Plywood site drain residential areas, portions of West Bay Drive NW, and portions of the former Hardel site.
- As shown on Figure 6-1e, the outfalls near Fiddlehead Marina drain several city streets and parking lots. LOTT outfall 002 has also historically discharged CSO overflow.

Elevated PAHs were present in surface sediment near these outfalls (based on cPAH concentrations), along with an outfall along the eastern shoreline of East Bay near sample POBI-SS-37, which drains portions of East Bay Drive NE and adjacent residences.

Other COPCs that are elevated near specific outfalls are described as follows:

- Within the Study Area
  - Mercury by the primary LOTT discharge located at the northern end of the Study Area (48 inches in diameter; location POBI-SS-31)
  - Benzyl alcohol near the Port's Basin A outfall (location POBI-SS-06)

  - Butylbenzyl phthalate beneath the northern portion of the marine terminal (location POBI-SS-17)

- Outside the Study Area
  - Benzyl alcohol, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, and di-n-butyl phthalate by an outfall at Fiddlehead Marina (location POBI-SS-61)
  - Benzoic acid near a separate Fiddlehead Marina outfall (location POBI-SS-02)
  - Phenol near a residential outfall on the eastern shoreline of East Bay (East Bay Drive NE drainage; location POBI-SS-50)

Surface sediment concentrations of D/F, PAHs, and other COPCs decrease beyond the immediate vicinity of these outfalls, suggesting that stormwater inputs may be contributing to the elevated concentrations. The Port obtained permission from the City of Olympia to collect samples at several catch basin locations in the vicinity of the Study Area based on the presence of elevated surface concentrations near City stormwater outfalls. This supplemental work was described in an Addendum to the SAP/QAPP (Anchor QEA 2013c). Samples were collected on February 12, 2014, and submitted to ARI for TS, TOC, D/F and PAH analysis. All sampling procedures in the SAP/QAPP Addendum were followed, except where some proposed locations could not be sampled due to insufficient solids accumulation and/or recent cleanings. Results are presented in Table 6-1 and Figures 6-2a through 6-2e. D/F TEQs ranged from 12.5 to 855 ng/kg with an average of 132 ng/kg, and cPAH results ranged from non-detect to 367 µg/kg with an average of 189 µg/kg. These results indicate that catch basin solids are similar to or higher than sediments in the vicinity of the associated outfalls. Section 6.5.1 presents the D/F congener profiles of these catch basin samples for comparison to Budd Inlet surface sediment samples.

The next step is to install sediment traps in the City stormwater system to determine if suspended solids with elevated concentrations of D/F and/or PAHs are entering Budd Inlet from the stormwater system. Data from this study will be reported separately when it is available.

6.3 Source Control Activities

In 2011 and 2013, in compliance with Administrative Order No. 8499, the Port submitted Source Control Monitoring Work Plans (Anchor QEA 2011a, 2013d) to monitor concentrations of D/Fs of solids in specific catch basins that are part of the Port Marine Terminal stormwater system. The Port performs monthly catch basin monitoring of those catch basins to assess if solids have accumulated and if the system needs to be cleaned out. The Port also regularly inspects and cleans the catch basins on the Port Peninsula that lie outside the fenced Marine Terminal. In 2012 and 2013, the Port sampled catch basin solids and stormwater discharge in its A and B Basins for D/F (solids) and 2,3,7,8-TCDD (stormwater). The results of the source control monitoring investigations were presented in two Source Control Investigation Data Reports (Anchor QEA 2012c, 2014) and are summarized in Tables 6-2 and 6-3. The conclusions of the studies indicate the following:

- Solids accumulate very slowly within stormwater basins A and B.
- D/F concentrations in catch basin solids are lower than concentrations present before the Port conducted catch basin cleanouts in 2010 (Figure 6-3), although one location (A02CB) had an increase in concentration between 2012 and 2013. A02CB is located in a low industrial area within the marine terminal, outside of the logyard. The main use of this area since the 2012 sample collection has been truck traffic, primarily associated with the 2013 maintenance dredge event, and ongoing rail traffic. Both of these activities generate D/Fs via exhaust; however, localized studies have not been conducted to determine how much contribution could originate from these sources. The Port expects to continue regular clean-outs of catch basins in stormwater basins A and B.
- No 2,3,7,8-TCDD was detected in trace-level stormwater samples. Results suggest that despite elevated concentrations of D/F in catch basins, stormwater from basins A and B is not a source of 2,3,7,8-TCDD to Budd Inlet.
- Sediment concentrations adjacent to the Port's A and B outfalls (Figures 5-1 and 5-2) are not elevated compared to the rest of lower Budd Inlet, suggesting that higher concentration sediments that were historically present in the catch basins (and subsequently removed during cleaning) were not being deposited in Budd Inlet.

Section 6.5.1 presents the D/F congener profiles of these catch basin samples for comparison to Budd Inlet surface sediment samples. Additional discussion of source control activities

and the potential for recontamination will be included in the Alternatives Memo. Source control programs for the City and LOTT discharges are ongoing.

6.4 Historical Sources

The Port's peninsula has supported industrial activities since its development in the late 1800s. Several sources of D/Fs were present including wood waste burning, wood treating, warehouse/factory fires, emissions from combustion engines, and industrial waste. Several sources of PAHs were also present, including creosote pilings, motor oil runoff from paved areas, and other combustion sources that also generate D/Fs. The potential for several activities to generate D/Fs and other COPCs are discussed in this section.

6.4.1 Atmospheric Deposition

Wood waste burners (i.e., hog-fuel boilers, wigwam burners) have been identified at nine locations near the Study Area, as shown in Figure 1-2 and 6-1a. The presence of these burners was confirmed in various remedial investigation (RI) reports and historical aerial photographs and maps (Figures 6-4a through 6-4f), as detailed below:

- West Bay Marina (Hart Crowser 2011)
- Hardel plywood (Greylock 2007).
- Solid Wood, Inc. (Ecology 2008c), shown in Figure 6-4a (unknown source)
- Delson Lumber, shown in Figure 6-4b (photograph from company website; Delson 2013)
- Washington Veneer, shown in Figure 6-4c (PIONEER 2010b) and Sanborn Map
- East Bay Redevelopment Site (two burners), shown in Figure 6-4d (PIONEER 2010b)
- Cascade Pole, shown in Figure 6-4e (PIONEER 2010b)
- Unknown operator, shown in Figure 6-4f (PIONEER 2010b)

Sediment (surface or subsurface) with higher D/F concentrations in the vicinity of historical wood waste burners is located near Solid Wood, Inc., Hardel Mutual Plywood, Delson Lumber, and East Bay Redevelopment Site. Atmospheric deposition could have deposited on sediments directly, or indirectly, through deposition on nearby soils and paved areas that could be transported back into the water through stormwater runoff or erosion. The predominant wind direction in Olympia is from the south and southwest, suggesting that the

majority of deposition would occur in Budd Inlet, on the Port's peninsula, and on nearby shoreline areas.

PAHs and phthalates are also transported by atmospheric deposition. In addition to the wood waste burners, several industrial emissions (smoke stacks) were present on and along the peninsula as depicted in Figures 6-4a through 6-4f.

6.4.2 Historical Pit

The northern portion of the Berth Area has subsurface concentrations that are significantly higher than other nearby areas. Aerial photographs taken from 1946 and 1960 indicate the presence of an open pit in this vicinity (Figures 6-5a and 6-5b). The date of construction is unknown, and the pit was not present based on aerial photographs from 1970. Activities associated with this pit are unknown, but could have included discharge of wastewater from industrial activities on the peninsula. Elevated subsurface sediment concentrations in this area include:

- D/F (up to 4,206 ng/kg-TEQ)
- Metals (cadmium up to 8 mg/kg, mercury up to 3.17 mg/kg, silver up to 18.1 mg/kg, and zinc up to 449 mg/kg)
- SVOCs (2,4-dimethylphenol up to 270 µg/kg, 2-methylphenol up to 230 µg/kg, 4-methylphenol up to 7,600 µg/kg, benzoic acid up to 1,300 µg/kg, 1,2,4-trichlorobenzene up to 200 µg/kg, 1,2-dicholorobenzene up to 180 µg/kg, 1,4-dichlorobenzene up to 850 µg/kg, n-nitrosodiphenylamine up to 630 µg/kg, bis(2-ethylhexyl)phthalate up to 2,000 µg/kg, butylbenzyl phthalate up to 130 µg/kg, and dibenzofuran up to 22,000 µg/kg)
- PAHs (up to 92,400 µg/kg for HPAH and 160,000 µg/kg for LPAH)
- PCBs (up to 2,400 µg/kg)

A steel sheetpile wall was driven to approximately -10 feet MLLW on the north end of the marine terminal in 1989. Previous to that, a wooden bulkhead had been in place in approximately the same area since the late 1920s. The pit was located waterward of these bulkhead structures and was a source of contaminants to Budd Inlet. Additional

sedimentation could have deposited in this area, resulting in burial of contaminated subsurface sediment.

6.4.3 Stormwater and Combined Sewer Overflow Discharges

Section 6.2 provides information about discharges of stormwater and CSOs to the Study Area. Historical discharges of stormwater are a potential source, including at the Moxlie/Indian Creek outfall. This outfall also discharged CSO overflow from the State and Chestnut Street CSO, which is now sealed. Prior to sealing, this was an active CSO input to East Bay, which may have transported elevated levels of contaminants. Some of the SMS exceedances found in this area in subsurface sediment are typically associated with sewage. 1-4-dichlorobenzene is known to be associated with portable toilet waste since the deodorizing blocks used in the toilets contain 1-4-dichlorobenzene (Windward and Anchor QEA 2013). PAHs and phthalates are ubiquitous in urban areas and are commonly found in stormwater, as described in Sections 6.1.2, and 6.1.3, respectively.

Elevated PCBs are also present in the upper 8 feet of POBI-SC-49 and 2 to 4 feet and 8 to 10 feet below mudline of POBI-SC-50 in cores near this discharge, which may be associated with discharges from this outfall. PCBs are extremely persistent in the environment, are one of the most ubiquitous of all environmental contaminants, and are detected in a variety of matrices (e.g., sediment, soil, dust, tissue, and plants) (Ecology 2010). These PCBs are likely attributed to historical uses, including spills or leaks, as no known ongoing sources are present and no PCBs were measured above SQS in surface sediment during the 2013 study. The latest record of an overflow from this outfall was on January 1, 1990 (LOTT 2011).

Combined sewer overflow discharges were also present at LOTT outfalls 002 and 001 (near Fiddlehead Marina and the northern tip of the peninsula, respectively). In 2007, 9 million gallons of screened, untreated, non-disinfected combined sewer effluent was discharged to outfall 002, and 2.75 million gallons of primary treated, disinfected effluent was discharged at outfall 001. In 2009, 6.3 million gallons of blended, disinfected final effluent was discharged at outfall 002 (LOTT 2011).

6.4.4 Adjacent Cleanup Sites

As described in the EISDGM, activities located on adjacent cleanup sites could have contributed D/Fs and other COPCs to Budd Inlet (Anchor QEA 2012b). The presence of upland contamination has been investigated at each of these sites, but the nature and extent of contamination in sediment has not been thoroughly investigated. Stormwater effluent concentrations to Budd Inlet from each of these sites and elsewhere throughout Budd Inlet are not available. A brief description of results of investigations at each of these sites is described below.

6.4.4.1 Reliable Steel

This site is currently being investigated under an AO with Ecology. It was a former lumber mill until 1941, after which it was used for boat building, welding, and fabrication activities. D/F in surface sediment is as high as 33 ng/kg, but D/F data was not present in any remediation documents.

6.4.4.2 Hardel Mutual Plywood

Upland cleanup is complete and this site has been removed from Ecology's Hazardous Sites List. Three sediment samples collected during the RI in 2007 contained D/F between 18 ng/kg and 41 ng/kg (Greylock 2007). One sediment sample also contained bis(2-thylhexyl)phthalate at a concentration of 94 mg/kg, which is 1.2 times the CSL. Ecology concluded that there have been no documented uses of this site that would have produced phthalates or D/F and these chemicals were not required to be part of the cleanup action plan. However, this site did have a wood waste burner, which could have contributed D/F to both soils and nearby sediment. Additionally, the site facility burned to the ground in 1996, which may have contributed contaminants via air deposition or runoff to Budd Inlet from water used to fight the fire. As seen on Figure 4-1d (page 4 of 7) surface sediment concentrations are as high as 59.8 ng/kg (BI-S7).

6.4.4.3 East Bay Redevelopment Site

This site generated D/Fs from burners at two on-site locations (PIONEER 2010a) and also generated PAHs from a variety of processes, including fuel areas, transformers, and tar dipping tanks. Sediments were not the focus of the site cleanup and the extent to which

upland activities contributed to in-water contamination is unknown. In the Soil-to-Surface Water Empirical Evaluation Report (PIONEER 2011), no complete and significant groundwater exposure pathways were identified for the site. Elevated levels of PCBs, PAHs, phthalates, 1,4-dichlorobenzene, cresol compounds (methylphenols), and mercury were present in subsurface sediments near this site. Based on an undated historical aerial photograph (Figure 6-4f), a pile-supported structure was present in nearshore sediment areas. Elevated levels of PAHs could have been the result of creosote treated wood, which may also be responsible for leached cresol compounds (2,4-dimethylphenol and 2- and 4-methylphenol). Subsurface location POBI-SC-49 is adjacent to the East Bay Redevelopment site and had total PAH (LPAH plus HPAH) concentrations ranging from 447 to 2,502 µg/kg, 2,4-dimethylphenol ranging from non-detect to 17 µg/kg, and 2- and 4- methylphenol ranging from non-detect to 330 µg/kg. Direct inputs to sediment may also have occurred from dumping or other industrial activities that have not been explored in adjacent sediments. Core POBI-SC-49 contained almost 2 feet of decomposing wood (Appendix A-3) with elevated D/F concentrations, and PCB, 1,4-dichlorobenzene, bis(2-ethylhexly)phthalate, and butylbenzylphthalate concentrations above SMS criteria.

6.4.4.4 Cascade Pole

The Cascade Pole site is a cleanup site located at the northern end of the Port peninsula along the shoreline of East Bay of Budd Inlet. This former wood treating facility used creosote and later PCP dissolved in a carrier oil. This site has historical contamination that has resulted in elevated concentrations of PAHs, PCP, and D/Fs in soil, groundwater, sediment, and benthic organisms.

Upland cleanup actions included the installation of a groundwater treatment system for light non-aqueous phase liquid (LNAPL) recovery, dredging and capping of contaminated sediments, and installation of a slurry wall around the site to limit groundwater migration of contaminants to Budd Inlet (SAIC 2008). The site cleanup level for PAHs and PCP in sediment was the SMS CSL, except for D/F which was 80 ng/kg. Groundwater cleanup levels are derived from MTCA Method A (total petroleum hydrocarbons) and Method B (PCP and PAHs). Routine groundwater results indicate that site groundwater is in compliance with the AO (i.e., no COPCs above screening levels outside of the slurry wall) and that the

bentonite slurry wall and hydraulic control system are effectively preventing groundwater contamination from reaching Budd Inlet (Landau 2011).

6.5 Dioxin and Furan Data Analysis

As discussed in Section 6.1, a number of different processes generate D/F, which tend to produce differing distributions, or percent concentrations, of the individual D/F congeners. This section describes two methods to evaluate sources and spatial patterns of D/F congener profiles, which contributes to the understanding of the likelihood of historical inputs and potential for ongoing contributions of D/F in the Study Area.

6.5.1 Dioxin and Furan Fingerprinting

Chemical fingerprinting is a technique used to differentiate potential sources of chemical contaminants. For D/F, congener profiles from site samples can be compared to other site samples to evaluate similarity of groups of samples. Congener profiles from site samples can also be compared to known sources, known as reference profiles. For this evaluation, similarities of congener profiles were evaluated for groups of surface sediment samples in different geographic areas of Budd Inlet. Subsurface sediment D/F congener profiles were also compared to reference profiles. While comparison is provided to reference profiles, it should be noted that urban sediment D/F concentrations commonly represent the combined influences of multiple sources and can be altered by weathering and the lack of detection of specific congeners (Shield et. al. 2006).

Reference profiles that are compared to site samples include hog-fuel boilers, stormwater runoff, diesel and gasoline automobile emissions, pentachlorophenol, and others (Figure 6-6a). Site-specific profiles were also generated. Soil samples from the East Bay Redevelopment Site are presented in Figure 6-6b. These profiles represent stockpile and test pit samples collected during soil excavation. Stockpiles were staged in different zones, which can be correlated to specific industrial work areas within the Site (PIONEER 2010b). Catch basin sample profiles from the City and Port stormwater systems are presented in Figure 6-6c.

All sediment profiles were dominated by octa-chloro dibenzo-p-dioxin (OCDD). In order to examine patterns of sediment profiles, the influence of this dominant congener was

minimized by normalizing each of the 17 congeners to the relative TEQ. For the relative TEQ, the TEF-scaled congener concentration is divided by the total TEQ calculated for that sample. This standardization method takes advantage of the detail provided in the congener specific result. All profiles presented in the figures and discussed in this section are based on relative TEQ rather than percent congener contribution to the sum.

6.5.1.1 Surface Sediment

Figures 6-7a through 6-7h provide congener profiles of sample results from groups of West Bay and East Bay surface sediment samples. These profiles were compared to reference profiles presented in Figure 6-6a, 6-6b, and 6-6c. Few samples were a close match with any of the published reference source profiles (Figure 6-6a). A few samples are similar to select profiles from upland soils from the East Bay Redevelopment Site (Figure 6-6b). Many sediment samples closely resemble profiles of City and Port catch basin samples (Figure 6-6c). In Budd Inlet, surface sediment appears to be comprised of a mixture of several sources due to disturbance and mixing. As seen in Figure 6-7a, the majority of samples collected in 2013 tend to be similar. Many samples may not match published reference profiles well, likely due to more than one source, weathering, and uniqueness of area-specific profiles (i.e., hog fuel air deposition). Patterns between groups of samples can be used to evaluate similarities between individual samples that can be explained by contribution of D/F from a similar source or combination of sources. The underlying signature was similar in most samples; however, a few distinct samples or groups of samples are apparent, which could indicate unique or ongoing source contributions at some locations. Due to the similarity between surface sediment and catch basin samples (Figure 6-6c), it is likely that stormwater inputs are a key contributor of D/F to surface sediment, although similar processes (i.e., erosion and air deposition) may be contributing to both. A summary of the fingerprinting results for groups of similar surface sediment samples are provided below:

- West Bay and East Bay (Figure 6-7a): Similarities are present between West Bay and East Bay samples collected in 2013. A few samples contain different patterns than other samples, which are further described in subsequent bullets.
- Fiddlehead and Martin Marinas (Figure 6-7b): Locations closest to the marinas have a slightly higher contribution of 1,2,3,4,6,7,8- heptachlorodibenzo-p-dioxin (HPCDD)

than the majority of surface samples in Budd Inlet. Location POBI-SS-61, which has the highest TEQ in this area, also has a slightly different signature (higher 1,2,3,4,6,7,8- heptachlorodibenzofuran [HPCDF]) and potentially represents a slightly different mixture of sources.

- Hardel Mutual Plywood and Solid Wood, Inc. (Figure 6-7c): Several locations adjacent to these former sites along the western shoreline have higher contributions of 1,2,3,7,8- pentachlorodibenzo-p-dioxin (PECDD), which tend to be similar to the percent contribution from 1,2,3,4,6,7,8-HPCDD. Several hog-fuel boiler reference profiles (Figure 6-6) show a higher contribution of 1,2,3,7,8-PECDD, suggesting that direct atmospheric deposition from wood waste burning or indirect deposition as a result of atmospheric deposition, erosion, and/or stormwater runoff of upland areas could be the source of D/F in this area. Two historical wood waste burners are present in this vicinity (Figure 1-2). The higher 1,2,3,7,8-PECDD contribution could also be related to the 1996 fire at the Hardel building, which would have a similar profile to other wood burning reference profiles. The City catch basin West Bay profiles (Figure 6-6c) also have similar distributions of 1,2,3,7,8-PECDD and 1,2,3,4,6,7,8-HPCDD.
- Federal Navigation Channel, Berth Area, and West Bay-Other Areas (Figure 6-7d): Samples from the federal navigation channel, in the Berth Area or under pier at the Marine Terminal, and in other portions of West Bay (not including the marinas or samples near Hardel Mutual Plywood and Solid Wood, Inc.) tend to have similar relative TEQ profiles that do not appear to be highly similar to reference profiles, including catch basin profiles from the Port samples, which have higher contribution of 1,2,3,4,6,7,8-HPCDD and all HXCDD congeners than samples near the Berth Area. These samples, which are farther away from outfalls, may represent sediments influenced by multiple sources.
- Swantown Marina (Figure 6-7e): Samples in this area all have similar signatures, which include slightly higher contributions of 1,2,3,4,6,7,8-HPCDD over other congeners. These profiles are similar to those in the federal navigation channel, Berth Area, and West Bay areas.
- Moxlie/Indian Creek near East Bay Redevelopment Site (Figure 6-7f): Surface sediment samples in this area had several different patterns. Sediment samples from near Moxlie Creek are most similar to the profiles found in City catch basin samples

collected near East Bay (Figure 6-6c). All samples resemble one or more stockpile soil samples from the adjacent uplands (Figure 6-6b); however, sample signatures are present in parts of West Bay and East Bay that may not directly represent a source from the East Bay Redevelopment Site.

  - Four samples (BI-C18, POBI-SS-56, POBI-SS-58, and POBI-SS-60) have similar profiles to the Swantown Marina area.
  - Two distinct samples are adjacent to smaller outfalls. POBI-SS-59 has higher contribution of 1,2,3,4,6,7,8-HPCDD, and POBI-SS-53 has higher contribution of 1,2,3,7,8-PECDD.
  - Sample BI-S30, which was collected in 2007, has a very high contribution of 1,2,3,4,6,7,8-HPCDD (almost 50 percent of the TEQ) and looks similar to the pentachlorophenol profile (Figure 6-6a). However, this sample was reoccupied in 2013 with POBI-SS-60, which looks more similar to Swantown Marina samples.

- East Bay-Other Areas (Figure 6-7g): Sample locations along the eastern shoreline outfalls and at the far northeastern edge of the Study Area generally have higher contribution of 1,2,3,7,8-PECDD than other East Bay samples. Several of these samples also have lower TEQs than other East Bay samples. Similar to the Hardel Mutual Plywood site, atmospheric deposition from burners could have impacted the surrounding residential soils (which have less urban development), atmospheric deposition entering the sediment directly or indirectly from erosion and stormwater runoff.
- Cascade Pole (Figure 6-7h): Congener profiles of historical samples collected from the Cascade Pole site indicate a significantly higher contribution of 1,2,3,4,6,7,8-HPCDD in several samples, which is similar to the pentachlorophenol reference profile (Figure 6-6a). Higher 1,2,3,4,6,7,8-HPCDD is found in most samples in the Study Area. However, this contribution is not as high as seen in Cascade Pole samples (greater than 40 percent).

6.5.1.2 Subsurface Sediment and Upland Soils

Fingerprinting of subsurface sediment indicates several unique relative TEQ congener profiles, sometimes within the same core (e.g., different sample intervals), indicating that different sources potentially contributed to elevated D/F concentrations at different

historical time periods at the same location. This section presents a summary of the key findings of the comparison of subsurface sediment profiles to published reference profiles (Figure 6-6a) and nearby soil samples from the East Bay Redevelopment Site (Figures 6-6b). Congener profiles are not presented for each sample interval due to the amount of sample intervals tested. Key subsurface fingerprinting results are presented below:

- Moxlie/Indian Creek and East Bay Redevelopment Site Sediments (Figure 6-8a):
  - POBI-SC-49 has a similar profile through the length of the core. It is similar to the profiles of the adjacent surface grabs (POBI-SS-58 and POBI-SS-56), with higher 1,2,3,4,6,7,8-HPCDD, and to some upland samples from Zones 2 and 4 of East Bay Redevelopment Site excavation.
  - POBI-SC-50 has three distinct profiles through the length of the core. The upper intervals (to 2 feet below mudline) are similar to the surface, with higher 1,2,3,4,6,7,8-HPCDD, but the middle intervals (2 to 10 feet below mudline) have higher contributions of furans, which are similar to several of the historical East Bay Redevelopment Site upland soil samples. The deepest interval (12.4 to 13 feet below mudline) has a unique signature from the rest of the core and consists mostly of 1,2,3,7,8-PECDD, similar to the hog fuel boiler reference profiles (Figure 6-6a).
- Swantown Marina (Figure 6-8b): In all core samples near Swantown Marina, 1,2,3,4,6,7,8-HPCDD is the dominant congener and generally contains more dioxins than furans. This is similar to the surface sediment in this area.
- Solid Wood, Inc. (Figure 6-8c): BI-C2 (1 to 2 feet and 2 to 3 feet below mudline) have similar profiles to the majority of West Bay surface samples, with higher 1,2,3,4,6,7,8-HPCDD. POBI-SC-14 (1 to 2 feet below mudline) has higher contribution of 1,2,3,7,8-PECDD, which matches some of the hog-fuel burner reference profiles.
- Northern Berth Area (Figure 6-8d): Most profiles are similar to nearby surface sediment samples, with higher 1,2,3,4,6,7,8-HPCDD. However, several deeper profiles from the northern Berth Area (including under-pier cores) have higher contributions of 1,2,3,4,7,8- HXCDF (BI-C5 from 6 to 7 feet below mudline) and 1,2,3,4,6,7,8-HPCDF (POBI-SC-19 from 8 to 10 and 10 to 12 feet below mudline) than nearby surface samples. Higher contributions of furans can be associated with several sources including waste incineration and truck diesel (Figure 6-6a).

6.5.2 Chemometric Analysis

Chemometrics, or multivariate statistical analysis of chemical datasets, has been applied to D/F congeners in a variety of systems, including in sediments. The relationship between sources and congener profiles provides the theoretical basis for chemometrics analysis, which identifies underlying patterns in the data and determines the contribution of these patterns (factors) to each sample based on dioxin/furan congener profiles.

The Port conducted a chemometric analysis to support identification of potential sources of dioxin/furan to Budd Inlet sediments (Appendix D). A separate chemometric analysis was also conducted by Ecology using a similar Budd Inlet sediment dataset, which is available on Ecology's Budd Inlet Site website (NewFields 2016). Both studies found three very similar underlying factors that account for most of the data variance and acknowledge stormwater as a pathway; however, different but similar in function interpretive statistical methodologies were used in each study and different conclusions were reached regarding what two of the three underlying factors represent. Ecology will use the results of their study for future decision-making at the Budd Inlet Site. A summary of the interpretation of sources associated with the factor profiles from each study is provided in Chart 2.

Chart 2

Differences in Interpretation of Factor Profiles by Ecology and the Port

Department of Ecology (NewFields 2015)	Port of Olympia (Appendix D)
Factor 1 – Hog fuel burning	Factor 3 – Hog fuel burning
Factor 2 – Pentachlorophenol • Historical use • Current contamination	Factor 2 – Mixed urban source • Regional sediment profiles • Urban background • Sewage • Nearby catch basins
Factor 3 – PCBs • Historical use at and around the Port peninsula	Factor 1 – Mixed combustion source • Truck diesel, highway • Asphalt • Burn barrels • Medical waste incineration

The results of the Port's chemometrics evaluation indicate that multiple sources have contributed D/Fs to sediments in the vicinity of Budd Inlet, with the relative contribution from those sources varying spatially. Three underlying factors were found to account for most of the variance in the data, as follows:

1. Factor 1 - Mixed Combustion Sources. This underlying factor is associated with several elevated furan combustion sources including diesel combustion, highway, asphalt, and burn barrel reference profiles. Factor contributions are strongest in high-concentration subsurface samples along the southwestern shoreline of East Bay and the eastern shoreline of West Bay.
2. Factor 2 - Mixed Urban Sources. The underlying factor is associated with the catch basins, as well as a variety of residential background, sewage, and regional sediment reference profiles. Source contribution is observed in mid-concentration surface and subsurface samples.
3. Factor 3 - Hog Fuel Burning. Strong contributions are seen for this factor in low-concentration subsurface samples, especially from the southern portions of East Bay and West Bay, and also in lower-concentration surface samples.

Spatially distinct areas with differing mixtures of sources were identified, including the following:

1. The eastern shore of East Bay, mid-channel of West Bay, and north of the peninsula, which have lower D/F sum concentrations and strong Factor 3 (hog fuel burning) contributions but low factor contributions for Factors 1 (mixed combustion sources) and 2 (mixed urban sources)
2. The area in West Bay, adjacent to Fiddlehead Marina, with greater Factor 2 contributions (mixed urban sources)
3. The Berthing Area south of Berth 3 North, where samples have very strong Factor 1 contributions (mixed combustion sources) and moderately elevated Factor 2 contributions (mixed urban sources)
4. Along the western shore of West Bay (adjacent to Solid Wood Inc. and Hardel Mutual Plywood), where samples have moderate contributions from Factor 2 (mixed urban sources)

5. Catch basins on the Port marine terminal and along the southern shore of East Bay (City catch basins), with strong Factor 2 contributions (mixed urban sources)
6. City catch basins to the west of West Bay and west of the East Bay Redevelopment Site, with strong Factor 1 contributions (mixed combustion sources)

A small number of elevated-concentration subsurface samples near Berth 3 North (e.g., SC19-6-8, BI-C4-6-7) are consistent with PCP reference source profiles and historical high-concentration Cascade Pole samples. Based on the multivariate statistical techniques used in Appendix D (principal component analysis, hierarchical cluster analysis, and positive matrix factorization analysis), PCP and the high-concentration Cascade Pole samples had weak factor contributions on all three factors, indicating that they are not main underlying or ongoing sources to surface sediment. However, as mentioned in Section 6.4.2, contributions from the historical pit near Berth 3 North was a historical source of PCP, PCB, and cPAH contamination to Budd Inlet since the pit located waterward of bulkhead structures.

In summary, this analysis suggests a consistent mixture of D/F sources to both subsurface and surface sediments. Subsurface samples exhibit spatially and temporally variable contributions from distinct, elevated-concentration sources, and surface samples exhibit a fairly uniform mixture of hog fuel burning, urban, and combustion sources.

7 SEDIMENTATION AND TEMPORAL TRENDS

Natural recovery of aquatic sediments can occur through physical processes, biological processes, and chemical processes. Natural recovery is defined as the effects of natural processes that permanently reduce risks from contaminants in surface sediments (Apitz et al. 2002) and effectively reduce or isolate contaminant toxicity, mobility, or volume. The potential for natural recovery of sediment is determined through multiple lines of evidence including sediment inputs and sedimentation rates. This section summarizes the results of geochronological cores collected as part of the investigation, other studies, and temporal changes in reoccupied surface sediment stations between multiple events.

7.1.1 Net Sedimentation Rates

Sedimentation rate data was collected in Budd Inlet during the 2013 investigation (Anchor QEA 2013a) and as part of studies in 2008 (SAIC 2008) and 1993 (Landau 1993). This consists of an estimate of net sedimentation measured from high-resolution sediment cores. Sedimentation rates are expressed in terms of the thickness of sediment accumulated per unit time or in density per unit time. This section discusses the net sedimentation rate measurements. 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. Table 7-1 provides historical and 2013 estimated net sedimentation rates.

Sedimentation rates are thought to have been affected by the dam that was constructed in 1951 to create Capitol Lake. As part of the 2007 sampling, estimated mass sedimentation rates were calculated in the sediment estimated to have accumulated pre- and post-1951. The mass sedimentation rates calculated in the three cores ranged from 0.24 grams per square centimeter per year ($g/cm^2/yr$) to 0.45 $g/cm^2/yr$ (post-1951). The range of sedimentation rates is equivalent to 0.14 to 0.35 centimeter per year (cm/yr). Rates were higher in the southern areas than the northern areas of the inlet and higher in East Bay than West Bay. Results for this study are discussed in further detail in the Budd Inlet Sediment Characterization Report (SAIC 2008).

An earlier study of sedimentation rates using geochronology techniques was conducted in the Cascade Pole cleanup area (Landau 1993). The samples collected for geochronology

analyses were limited to a small area. Mass sedimentation rates were determined to range from approximately 0.19 g/cm^2/yr to 0.21 g/cm^2/yr in this area based on Cesium-137 (Cs-137) and lead-210 (Pb-210), each of which equate to approximately 0.1 cm/yr. The range of sedimentation rates is equivalent to 0.12 to 0.13 cm/yr.

As part of the 2013 investigation, samples for sedimentation rate analyses were collected from Budd Inlet stations GC-01, GC-02, GC-03, and GC-04 shown in Figure 2-1. Net sedimentation rates were estimated from the radioisotope profile data (Table 7-1). Cesium-137 (Cs-137) and lead-210 (Pb-210) were measured in the four high-resolution sediment cores. Lead-210 profiles from the study are presented in Figure 7-1.

Dating using the Cs-137 core data would be based on both the first appearance of Cs-137 in 1950 and the peak level in 1965. Because the source of Cs-137 was from atmospheric nuclear weapons testing, it is not continuously generated and tends to provide a suitable marker for estimating sedimentation rates. However, Cs-137 was not detected in any of the samples analyzed from cores GC-02 and GC-04. Cesium-137 was detected at very low levels in some of the upper intervals from cores GC-01 and GC-03, but not in deeper intervals. No Cs-137 peaks from the years of maximum deposition were apparent in either core.

The Pb-210 data in 2013 cores exhibited fairly good linearity for each of the cores to varying depths, with the best correlation apparent in core GC-02 (correlation coefficient [r^2] = 0.94), indicating a fairly continuous deposition rate (Figure 7-1). Core GC-04 exhibited the poorest correlation with scattered plots around the linear trendline (r^2 = 0.63), indicating a more irregular deposition rate possibly due to mixing from prop wash and other episodic events. GC-01 exhibited marginally better correlation (r^2 = 0.74), also indicating some disturbance. The results below 50 cm depth were not included in the analysis because the results were not linear below this depth and because more recent deposition trends better estimate current deposition rates. GC-03 exhibited better correlation (r^2 = 0.86), indicating slight disturbances. Disturbances were more evident in the upper 20 cm.

The estimated bulk density used to calculate the mass sedimentation rate (1.60 g/cm^3) was the same used in the Cascade Pole study (Landau 1993). Calculated deposition rates were 1.0 cm/yr for GC-01, located at the southern end of the Study Area in West Bay, 1.1 cm/yr for

GC-02, located at the southern end of the Marine Terminal on the slope, and 0.7 cm/yr for GC-03, at the northwest corner of the Study Area. The calculated deposition rate for core GC-04 in East Bay was 0.9 cm/yr. These results suggest net sedimentation rates are slightly higher in the southern portion of the Study Area (more than 1 cm/yr) than the northern portion of the Study Area (less than 0.7 cm/yr).

7.1.2 Lacey-Olympia-Tumwater-Thurston County Clean Water Alliance Sediment Trap Study

LOTT conducted a sediment trap study in 1996 and 1997 (LOTT 2008), which collected both short-term and long-term sediment trap data over a 13-month period (September 1996 to September 1997). Long-term data was collected at four locations: three along the center line of Budd Inlet and one location in West Bay. Short-term data was collected at two locations within Budd Inlet: one in the approximate center of the inlet and one along the western side of the inlet, near Olympia Shoal (EISDGM, Figure 2-14; Anchor QEA 2013b). Long-term traps were used to determine gross sediment accumulation rates and the short-term traps were used to determine loading of inorganic and organic matter to sediments. The sediment rates ranged from 0.2 to 0.8 cm/yr in central Budd Inlet and 2.0 cm/yr in West Bay (LOTT 2008). Only one long-term sediment trap was located within the Study Area, located in West Bay, which indicated deposition of 2.0 cm/yr. These gross sediment deposition rates do not account for scour from vessel movement or current velocities, which will be further discussed in the Alternatives Memo.

7.1.3 Temporal Surface Sediment Chemical Trends – Reoccupied Stations

Samples were collected as part of the Interim Cleanup Action Pilot Study monitoring events in 2009 and 2010. The results demonstrate temporal trends (over 21 months) in D/F concentrations. Additionally samples were collected in 2013 to reoccupy stations sampled in 2007 (SAIC 2008).

7.1.3.1 Interim Cleanup Action Pilot Study Stations

Surface sediment chemistry was collected in December 2010 by the Port, which was 21 months following the Berths 2 and 3 Interim Cleanup Action Pilot Study (Anchor QEA 2011b). Previous sampling was conducted immediately following placement of a residuals

management sand cover layer and at 3, 9, and 15 months following completion of the Interim Action (Anchor QEA 2009b, 2010a, and 2010b, respectively). Two of these samples were also tested in 2007. Samples were collected from the under-pier area, Berth Area, and ambient area, but residuals management sand cover material was only placed in the Berth Area. A summary of concentrations for Interim Cleanup Action Pilot Study stations are summarized in Table 7-2.

Average TEQ concentrations at reoccupied stations in the Berth Area increased from 0.2 ng/kg following sand cover placement to 5.6 ng/kg at the 21-month monitoring event suggesting concentrations were equilibrating with surrounding areas not included in the Interim Action.

Underpier samples were collected from four locations during all five of the monitoring events and averaged 36 ng/kg to 39 ng/kg during three events in the 9 months following construction. Average concentrations declined to between 15 ng/kg and 17 ng/kg in the 15 and 21 month events, respectively. The declines were likely as a result of a number of Capitol Lake flushing events (Anchor QEA 2009a).

Ambient samples collected away from the pier and outside of the Interim Action remediation area averaged 21.8 ng/kg to 23.8 ng/kg during three sampling events in the 9 months following construction. Two of these samples were tested in 2007, each of which increased during the 2009 sampling. Concentrations declined to an average of 5.5 ng/kg in the 15-month monitoring event as a result of the Capitol Lake flushing. Average concentrations during the 21-month monitoring event were 13.7 ng/kg, indicating concentrations were equilibrating with surrounding areas. One station (AM-50) was re-occupied in 2013, and it was verified that the D/F concentrations in this area have equilibrated.

7.1.3.2 Other Re-occupied Stations

Three additional 2013 sample locations were collected to re-occupy Ecology locations collected in 2007. POBI-SS-01 reoccupied BI-S2 in the southern part of West Bay, POBI-SS-42 reoccupied BI-C10 in the northern part of East Bay, and POBI-SS-60 reoccupied BI-S30 in the southern part of East Bay. D/F results are listed below:

- BI-S2 (2007) = 10.3 ng/kg
- POBI-SS-01 (2013) = 11.8 ng/kg
- BI-C10 (2007)= 30.6 ng/kg
- POBI-SS-42 (2013) = 31.3 ng/kg
- BI-S30 (2007) = 60.3 ng/kg
- POBI-SS-60 (2013) = 19.9 ng/kg

Concentrations were similar for West Bay (POBI-SS-01) and northern East Bay samples (POBI-SS-42) between 2007 and 2013, suggesting consistent concentrations in deposited sediment in these areas. POBI-SS-60 in southern East Bay was lower than the 2007 result. However, other sample results near POBI-SS-60 indicate higher concentrations similar to the 2007 result, suggesting variability in surface sediment conditions.

8 INVESTIGATION SUMMARY

This section provides a concise summary of the results of the Budd Inlet Sediment Investigation, specifically regarding sources of contamination and nature and extent of contamination in the Study Area. A CSM will be developed in the Alternatives Memo.

8.1 Nature and Extent of Contamination

This section summarizes the key observations on the nature and extent of sediment contamination, based on investigations conducted between 2003 and 2013.

8.1.1 Contaminants of Potential Concern in the Study Area

Contaminants of Potential Concern in the Study Area include the following:

- Surface sediment COPCs include D/Fs, PAHs (based on cPAH concentrations), mercury, butylbenzyl phthalate, and benzyl alcohol
- Subsurface sediment COPCs in the Berth Area include 2,4-dimethylphenol, 2- and 4-methylphenol, benzoic acid, 1,2,4-trichlorobenzene, 1,2-dicholorobenzene, 1,4-dichlorobenzene, n-nitrosodiphenylamine, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, dibenzofuran, PAHs, total PCBs, cadmium, mercury, silver, and zinc
- Subsurface sediment COPCs near Moxlie/Indian Creek and the East Bay Redevelopment Site areas include bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, 1,4-dichlorobenzene, 2,4-dimethylphenol, 4-methylphenol, PCBs, and mercury

8.1.2 Surface Sediment

East Bay D/F concentrations tend to be higher than West Bay (SWAC is 15 ng/kg in West Bay and 21 ng/kg in East Bay). East Bay cPAH concentrations are also higher than West Bay (the SWAC is 87 ng/kg in West Bay and 148 ng/kg in East Bay). All other surface sediment COPCs (mercury, butylbenzyl phthalate, acenaphthene (exceeds benthic criteria), and benzyl alcohol) are elevated in localized areas near outfalls.

8.1.2.1 East Bay

- Surface sediment D/F concentrations tend to be highest at the southern end of East Bay (98.9 ng/kg) and tend to decrease farther to the north, with concentrations in the

Swantown Marina area ranging from 27.1 to 39.1 ng/kg and concentrations at the northern end of the Study Area are 27.6 ng/kg or lower.

- Shoreline samples along the eastern shoreline in East Bay tend to have lower D/F concentrations than other parts of East Bay and range from 6.1 to 23.5 ng/kg.
- One location outside of the study area on the north portion of the eastern shoreline (POBI-SS-37) has elevated PAHs.
- D/F Concentrations within the Cascade Pole site boundary range from non-detect to 26.1 ng/kg.

8.1.2.2 West Bay

- Higher surface sediment D/F concentrations in West Bay are located south of the Study Area near outfalls at Fiddlehead Marina (up to 45.9 ng/kg) and near the Reliable Steel (33.2 ng/kg) and Hardel Mutual Plywood (59.8 ng/kg) sites.
- In under-pier, Berth Area, and federal navigation channel areas, D/F concentrations range from 0.6 to 44.7 ng/kg, with most under 25 ng/kg.
- Within the Study Area, one sample is elevated for butylbenzyl phthalate and one for acenapthene in the under-pier sediment.

8.1.3 Subsurface Sediment

8.1.3.1 Berth Area

High concentrations of D/Fs and PAHs are present in subsurface sediment near the northern end of the Marine Terminal, with elevated dioxin elevated beyond 11 feet below mudline. Additionally, elevated levels of 2,4-dimethylphenol, 2- and 4- methylphenol, benzoic acid, 1,2,4-trichlorobenzene, 1,2-dicholorobenzene, 1,4-dichlorobenzene, n-nitrosodiphenylamine, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, dibenzofuran, PAHs, total PCBs, cadmium, mercury, silver, and zinc occur at various depths.

8.1.3.2 West Bay Federal Navigation Channel Sediments

Elevated D/F is generally several feet thick, but extends down to 8 feet below mudline at one core (POBI-SC-09). Depth of contamination tends to correlate with historical navigation

dredge depths, with deeper sediment below the authorized navigation depth having lower concentrations of contaminants.

8.1.3.3 Swantown Marina and Boatworks Haulout

Elevated D/F concentrations are present in the upper 1 to 2 feet in the Swantown Marina, which tends to correlate with historical dredge depths, with deeper sediment below the original dredge depth having lower concentrations of contaminants. In shoaled areas along the shoreline, D/Fs are present up to 9 feet below mudline.

8.1.3.4 Area Near Moxlie/Indian Creek Outfall and East Bay Redevelopment Site

Subsurface sediments in this area contain elevated D/Fs, PAHs, bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, 1,4-dichlorobenzene, 2,4-dimethylphenol, 4-methylphenol, PCBs, and mercury. Elevated concentrations of D/Fs and some other chemicals are present beyond 13 feet below mudline.

8.2 Sources of Contamination

Potential ongoing and historical sources are summarized in this section by COPC based on the results presented in Sections 5 and 6.

Dioxin/Furan

D/F are a site-wide issue. D/F are present at elevated levels in surface and subsurface sediments throughout Budd Inlet. Concentrations are the result of several historical and potential ongoing sources as discussed below:

- Historical Sources:
  - The primary historical source of D/F contamination is atmospheric deposition from wood waste burners in and around the Study Area through direct contributions to the Study Area or indirect contributions via stormwater inputs.
  - Other combustion activities typical of urban and industrial environments may have contributed, including vehicle emissions, incineration, and residential and commercial fires.

  - Historical wood treating activities, including at the Cascade Pole site.
  - Historical activities in the vicinity of the pit near the northern portion of the Marine Terminal may have contributed to elevated D/F concentrations at least during the period of 1946 to 1960. Congener profiles suggest more than one possible source for this subsurface contamination.

- Potential Ongoing Sources:

  - The primary source of ongoing D/F inputs appears to be via stormwater inputs from urban outfalls and Moxlie/Indian Creek. Typical activities contributing to stormwater inputs may include vehicle emissions and other urban combustion activities as well as erosion of soil containing elevated D/F concentrations potentially associated with historical activities, such as wood waste burners.
  - Atmospheric deposition is also likely an ongoing source of D/F, likely associated with urban combustion activities.
  - Elevated surface sediment concentrations near other cleanup sites, such as Reliable Steel and Hardel Mutual Plywood, may suggest potential ongoing sources in the vicinity of those areas.
  - D/F congener profiles do not suggest ongoing contributions of D/F to the Study Area from the Cascade Pole site.

PAHs:

Elevated PAHs are predominantly from historical sources or localized near outfalls. Historical and ongoing sources of PAHs are summarized below:

- Creosote piling is a historical and potential ongoing source for elevated PAHs in the Marine Terminal area.
- In the area near the northern portion of the Marine Terminal, historical sources of PAHs may include creosote piling or direct dumping to the historical pit.
- Elevated PAHs near outfalls tend to be localized and may be the result of stormwater/CSO releases and runoff from motor oil and urban combustion sources.

Mercury:

Mercury is localized near LOTT Outfall 001. One localized surface sediment concentration of mercury is present near the LOTT outfall at the northern end of the Study Area, which is likely the result of discharges of water with elevated dissolved concentrations associated with high conductivity at the LOTT treatment plan (Butti 2013).

Phthalates, Benzoic Acid, and Benzyl Alcohol:

Phthalates, benzoic acid, and benzyl alcohol are associated with ongoing stormwater discharges. Butylbenzyl phthalate and benzyl alcohol are elevated in one surface sediment sample each within the Study area near the Marine Terminal. These elevated concentrations are localized near outfalls. Benzoic acid, di-n-butyl phthalate, and bis(2-ethylhexyl) phthalate are elevated near outfalls at Fiddlehead Marina, but these compounds are not elevated in surface sediment within the Study Area. Historical sources are likely responsible for elevated subsurface concentrations in the northern Berth Area (benzoic acid was elevated in one location [POBI-SC-19] and phthalates in one location [POBI-SC-23]) and near the Moxlie/Indian Creek outfall and East Bay Redevelopment Site (phthalates at one location [POBI-SC-49]).

Other Contaminants:

Other subsurface contamination may result from historical sources as follows:

- The exact source of other SVOCs, PCBs, and other metals in subsurface sediment is unknown, but elevated levels are not present above SMS criteria in surface sediment, suggesting historical sources.
- Elevated concentrations at the northern portion of the Marine Terminal could be associated with dumping into an open pit.
- Elevated concentrations near the Moxlie/Indian Creek outfall and East Bay Redevelopment Site area could be associated with dumping activities or historical stormwater or CSO discharges.
- 2,4-dimethylphenol and 2- and 4- methylphenol present in subsurface sediment near the Marine Terminal and near the Moxlie/Indian Creek outfall and East Bay Redevelopment Site may be the result of historical creosote pilings.

8.3 Sedimentation and Temporal Trends

Calculated deposition rates from 2013 geochronological testing were slightly higher in areas near the southern portion of the Study Area than northern portions. Net deposition for cores GC-01 and GC-02 was estimated to be 1.0 cm/yr. Net deposition was slightly lower for core GC-03, which was located at the northwest corner of the Study Area (0.7 cm/yr). In East Bay, near the southern end of the Study Area, net deposition was 0.9 cm/yr. These results are comparable to previous studies, suggesting net sedimentation rates are slightly higher in the southern portion of the Study Area (1 to 2 cm/yr) than the northern portion of the Study Area (0.1 to 0.7 cm/yr). Additional description of physical processes, including additional evaluations on net sedimentation rates will included in the Alternatives Memo.

Re-occupied surface sediment sample results in West Bay illustrate the influence that the frequency of flushing of Capitol Lake has on sediment concentrations. Samples collected in 2007 had higher D/F concentrations in 2009, but decreased to lower levels in 2010 following several lake flushing events. Stations sampled in 2007 and 2013 indicated that consistent concentrations in sediment is being deposited at the southern end of West Bay and northern end of East Bay. In East Bay, considerable variability is present in results at the southern end, with no trend apparent. Concentrations entering the system from stormwater outfalls, Moxlie/Indian Creek, and Capitol Lake will play a role in predicting recovery.

8.4 Next Steps

The Port is currently working with the City to collect additional source characterization samples at several locations in the vicinity of the Study Area based on the presence of elevated surface concentrations near outfalls, which may include catch basin solids or sediment traps (Anchor QEA 2013c). These data may provide more information regarding the contribution of potential ongoing sources of contamination and will be considered during evaluation of a potential Interim Action for the Study Area. Data from these studies will be reported separately as they become available.

The Port will develop the Alternatives Memo in 2016 to identify and analyze potential remedial alternatives to address contaminated sediments in the Study Area. The Alternatives Memo will identify preliminary cleanup levels and boundaries for the Interim Action based on the nature and extent of contamination in the Study Area presented in this Report.

9 REFERENCES

Anchor QEA (Anchor QEA, LLC), 2009a. *Completion Report- Berths 2 and 3 Interim Cleanup*. Prepared for the Port of Olympia. June 2009.

Anchor QEA, 2009b. *Memorandum Summarizing 3-Month Monitoring Results - Berths 2 and 3 Interim Cleanup Action Pilot Study*. Prepared for the Port of Olympia. September 2009.

Anchor QEA, 2010a. *Memorandum Summarizing 9-Month Monitoring Results - Berths 2 and 3 Interim Cleanup Action Pilot Study*. Prepared for the Port of Olympia. March 2010.

Anchor QEA, 2010b. *Memorandum Summarizing 15-Month Monitoring Results - Berths 2 and 3 Interim Cleanup Action Pilot Study*. Prepared for the Port of Olympia. September 2010.

Anchor QEA, 2011a. *Final Work Plan: Source Control Investigation*. Prepared for the Port of Olympia. August 2011.

Anchor QEA, 2011b. *Memorandum Summarizing 21-Month Monitoring Results - Berths 2 and 3 Interim Cleanup Action Pilot Study*. Prepared for the Port of Olympia. February 2011.

Anchor QEA, 2012a. *Budd Inlet Sediment Site Work Plan*. Prepared by Anchor QEA for Port of Olympia. October 2012.

Anchor QEA, 2012b. *Budd Inlet Sediment Site Existing Information Summary and Data Gaps Memorandum*. Prepared by Anchor QEA for Port of Olympia. October 2012.

Anchor QEA, 2012c. *Data Report. Port of Olympia Source Control Investigations*. Prepared by Anchor QEA for Port of Olympia. June 2012.

Anchor QEA, 2013a. *Sampling Analysis Plan and Quality Assurance Project Plan Budd Inlet Sediment Site*. Prepared by Anchor QEA for Port of Olympia. February 2013.

Anchor QEA, 2013b. *DMMP Memorandum. Port of Olympia Marine Terminal Berth and Swantown Boatworks Maintenance Dredge Sampling Results Summary*. July 5, 2013

Anchor QEA, 2013c. *Budd Inlet Sediment Site Catch Basin Sampling – Addendum 1 to the Sampling Analysis Plan and Quality Assurance Project Plan*. Prepared by Anchor QEA for Port of Olympia. June 19, 2013.

Anchor QEA, 2013d. *Source Control Monitoring Work Plan*. Prepared for the Port of Olympia. January 2013.

Anchor QEA, 2014. *Data Report 2014. Port of Olympia Source Control Investigations*. Prepared by Anchor QEA for Port of Olympia. April 2014.

Apitz, S.E., J.W. Davis, K. Finkelstein, D.L. Hohreiter, R. Hoke, R.H. Jensen, J.M. Jersak, V.J. Kirtay, E.E. Mack, V. Magar, D. Moore, D. Reible, and R. Stahl, 2002. *Critical Issues for Contaminated Sediment Management, MESO-02-TM-01*. Marine Environmental Support Office, United States Navy. Available from: http://meso.spawar.navy.mil/docs/MESO-02-TM-01.pdf. March 2002.

Butti, Ken. 2013. Personal communication on discharge of elevated levels of dissolved metals out of the LOTT outfall. September 26, 2013.

Delson (Delson Lumber Mill), 2013. Website with historical photograph. Available from: http://www.delsonlumber.com/about.html

Ecology (Washington State Department of Ecology), 2003. *Sampling and Analysis Plan Appendix*. Prepared by PTI Environmental Services, Bellevue, Washington, with Revisions by F. Lee, Ecology, Sediment Management Unit, Olympia, Washington. Publication No. 03-09-043. April 2003. Available from: http//www.ecy.wa.gov/biblio/0309043.

Ecology, 2007. *Model Toxics Control Act Statutes and Regulations*. Publication No. 94-06. November 2007.

Ecology, 2008a. Agreed Order No. DE 6083. Washington State Department of Ecology. October 2008.

Ecology, 2008b. *Sediment Sampling and Analysis Plan Appendix. Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards (Chapter 173-204 WAC)*. Ecology Publication No. 03-09-043. Department of Ecology Sediment Management Unit. February 2008.

Ecology, 2008c. *Public Participation Plan for Solid Wood Inc.* Prepared by Washington State Department of Ecology. March 2008.

Ecology, 2010. "Focus on Toxic Chemicals in Puget Sound, Addendum 2, Phase 1 and Phase 2 Toxic Loadings Reports" Technical Memorandum. Olympia, Washington. January 2010.

Ecology, 2011. *Rayonier Mill Off-Property Soil Dioxin Study. Final Project Report, Public Review Draft.* June 2011.

Ecology, 2012. *First Amendment to the Agreed Order No. DE 6083*. Washington State Department of Ecology. February 2012.

Ecology, 2013. *Sediment Management Standards - Chapter 173-204 WAC*. Final Rule. Washington State Department of Ecology. February 22, 2013

Ecology, 2015. Sediment Cleanup Users Manual II. *Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC*. Publication no. 12-09-057. March 2015.

Floyd|Snider, 2007. *Summary of Findings and Recommendations, Sediment Phthalates Work Group* (City of Tacoma, City of Seattle, King County, Washington State Department of Ecology, and U.S. Environmental Protection Agency). September 2007.

Greylock (Greylock Consulting, LLC), 2007. *Former Hardel Plywood Site, Remedial Investigation Report*. Prepared for Hardel Mutual Plywood. December 17, 2007.

Hart Crowser, 2011. *Remedial Investigation Westbay Marina*. Prepared for Washington State Department of Ecology. June 30, 2011.

King County, 2006. *2004 Water Quality Status Report for Marine Water*. King County Department of Natural Resources and Parks. August 2006.

King County, 2008. *King County Sanitary Sewer System - Characterization Sampling for Selected Phthalates and Benzyl Alcohol in the Lower Duwamish Basin – 2003 to 2006. Technical Memorandum*. January 2008.

Landau (Landau Associates), 1993. *Remedial Investigation Report, Sediments Operable Unit, Cascade Pole Company Site*. Prepared for the Washington State Department of Ecology. January 1993.

Landau, 2011. *Groundwater Monitoring Report, February 2010 through May 2011, Cascade Pole Site*. Prepared for Port of Olympia. December 2011.

LOTT (Lacey-Olympia-Tumwater-Thurston County Clean Water Alliance), 2008. *Budd Inlet Scientific Study*. Prepared by LOTT for the Washington State Department of Ecology. August 2008.

LOTT, 2011. Letter to David Dougherty titled 2010 Combined Sewer Overflow Report. May 13, 2011.

NewFields, Infometrix, and G. Glass, 2013. *Port Angeles Harbor Sediment Dioxin Source Study, Port Angeles, WA*. Final Report. Prepared for Washington State Department of Ecology. February 2013.

NewFields, 2016. *Budd Inlet Sediment Dioxin Source Study, Olympia, WA*. Final Report. Prepared for Washington State Department of Ecology. March 2016.

PIONEER (PIONEER Technologies Corporation), 2010a. *Infrastructure Interim Action Report for East Bay Redevelopment Site*. Prepared for the Port of Olympia. June 2010.

PIONEER, 2010b. *Site Boundary Technical Memorandum for East Bay Redevelopment Site*. Prepared for the Port of Olympia. November 2010.

PIONEER, 2011. Letter to Steve Teel, Ecology. Regarding: Final Empirical Evaluation of the Potential for Soil Constituents to Migrate to Surface Water via Groundwater at the East Bay Redevelopment Site. Prepared for the Washington State Department of Ecology on behalf of the Port of Olympia. May 31, 2011.

Port of Olympia, 2008. Interim Action Plan Port of Olympia West Bay Berths 2 and 3. Prepared by Port of Olympia. December 2008

PTI (PTI Environmental Services), 1988. *Sediment Quality Values Refinement: 1988 Update and Evaluation of Puget Sound AET*. Volume 1. September 1988.

SAIC (Science Applications International Corporation), 2008. *Sediment Characterization Study, Budd Inlet*. Final Data Report. Prepared for the Washington State Department of Ecology. March 2008.

Shields, W.J., Y. Tondeur, and L. Benton, 2006. Dioxins and Furans. In *Environmental Forensics: Contaminant Specific Guide*. Edited by Morrison, R. and B. Murphy. Academic Press: San Diego.

USACE (U.S. Army Corp of Engineers), 2013. *Puget Sound Sediment Reference Material: Requesting, Analyzing, Validation and Reporting Data*. March 27, 2013.

USEPA (U.S. Environmental Protection Agency), 1986. *Test Methods for the Evaluation of Solid Waste: Physical/Chemical Methods, 3rd Edition*. EPA SW-846. 1986.

USEPA, 2008. *USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review*. EPA540/08-01. June 2008.

USEPA, 2010. *USEPA Contract Laboratory Program National Functional Guidelines for Superfund Inorganic Methods Data Review*. EPA540-R-10-011. January 2010.

USEPA, 2011. *USEPA Contract Laboratory Program National Functional Guidelines for Dioxins and Furans Methods Data Review*. EPA540-R-11-016. September 2011.

U.S. Geological Survey (USGS), 2006. *Deschutes Estuary Feasibility Study – Hydrodynamics and Sediment Transport Modeling*. Final Report. Available from: http://www.ga.wa.gov/CLAMP/HSTA.pdf.

USGS 2008. *Incorporation of Fine-Grained Sediment Erodibility Measurements into Sediment Transport Modeling, Capitol Lake, Washington*. U.S. Geological Survey Open-File Report 2008-1340, Version 1.0. November 2008. Available from: http://pubs.usgs.gov/of/2008/1340/.

van den Berg, M., L.S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Trischer, J. Tuomisto, M. Tysklind, N. Walker, and R.E. Peterson, 2006. The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicol Sci* 93(2):223–241.

Windward Environmental and Anchor QEA, 2013. *Supplemental Remedial Investigation, East Waterway Operable Unit*. Final. October 2013.

TABLES

FIGURES

APPENDIX A
FIELD DATA

(on DVD)

APPENDIX B
LABORATORY DATA REPORTS

(on DVD)

APPENDIX C
DATA VALIDATION REPORTS

(on DVD)

APPENDIX D
DIOXIN AND FURAN SOURCE EVALUATIONS