11.0 SUMMARY AND CONCLUSIONS

This summary and conclusions section provides an overview of Sections 1 through 10 of the RI report and lists the major findings of this investigation and next steps in the remedial investigation and feasibility study (RI/FS) process. The objective of the subsection-by-subsection summaries is to describe the content and key elements of each section. A summary of the key findings of the RI is presented in Section 11.11.

This Draft RI report provides adequate data and data analysis to move forward with the FS and is consistent with the National Contingency Plan. Upon final approval by U.S. Environmental Protection Agency (EPA), this RI will fulfill the Administrative Order on Consent and statement of work (SOW) requirements for an RI, as agreed to by EPA and the Lower Willamette Group (LWG) in 2001 and as subsequently directed by EPA.

11.1 INTRODUCTION

The LWG is performing the RI/FS for the Site pursuant to an EPA Administrative Settlement Agreement and Order on Consent (AOC; EPA 2001a, 2003b, 2006a). The LWG includes 12 private property owners along the Willamette River, the Port of Portland, and the City of Portland and represents a small subset of the potentially responsible parties (PRPs) identified by EPA.

As a Superfund site identified under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Portland Harbor has been the focus of a phased RI conducted by the LWG, as well as numerous environmental investigations completed by the individual LWG members, other private entities, and various governmental organizations since 2001. RI data collected by the LWG were used to characterize the physical system of the lower Willamette River (LWR) and assess the nature and extent of contamination in sediment, surface water, transition zone water (TZW), stormwater, and biota (including fish, clams, and crayfish).

11.1.1 Objectives of the RI/FS

Consistent with the SOW to the AOC, the objectives of the Portland Harbor RI/FS are as follows:

- Investigate the nature and extent of chemical contamination for the in-water portion of the Site
- Assess potential risk to human health and the environment, including identifying chemicals of concern (COCs)
- Evaluate the loading, fate, and transport of bounding indicator chemicals (ICs) selected from the list of COCs

- Identify sources of contamination that contribute, or have contributed, to unacceptable risk in the in-water portion of the Site[1] and describe the status of source control activities
- Develop and evaluate potential remedial alternatives to reduce risks to acceptable levels.

This RI Report addresses the first four objectives and includes the baseline human health and ecological risk assessments (BHHRA, BERA) as appendices. The final objective will be addressed in the FS. The FS will also identify potential upland sources of COCs to the river. Management of these sources will be referred to the Oregon Department of Environmental Quality (DEQ).

11.1.2 Area of Study

Following the RI/FS sampling investigations and a preliminary summary of results in the Round 2 Report (Integral et al. 2007), EPA defined the Study Area to include river mile (RM) 1.9 to 11.8[2] (Map 1.2-1). This Study Area and previously defined study areas do not define the Portland Harbor Superfund Site, the boundaries of which will be determined by EPA upon issuance of a record of decision (ROD).

11.1.3 Site Background

Portland Harbor is a heavily industrialized reach of the LWR located immediately downstream of downtown Portland, Oregon and extending almost to the confluence with the Columbia River (Map 1.2-1). The harbor has been the site of manufacturing, shipbuilding, petroleum storage and distribution, metals salvaging, electrical power generation, and municipal development for over a century. The harbor has been extensively modified by wetland draining, channelization, and dredging. Some riverbank areas and adjacent parcels include naturally vegetated areas and beaches.

11.2 ENVIRONMENTAL DATA SETS

Environmental data have been collected from the Portland Harbor Study Area during numerous LWG sampling events since 2001. These data, along with data from historical and concurrent studies by other parties in the LWR, constitute the Portland Harbor Sediment Characterization and Risk Assessment (SCRA) database. All data included in the SCRA have undergone rigorous data quality review and quality assurance and quality control (QA/QC) checks made throughout the data management process, in accordance with EPA approved quality assurance project plans.

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[1] Upland source control efforts, including site-specific upland source control studies and implementation of source control measures, are performed under the oversight of Oregon Department of Environmental Quality and are not within the scope of the AOC and SOW for the in-water portion of the Site.

[2] As part of the RI, the LWG also sampled contiguous areas adjacent to the RI Study Area downstream to RM 0.8, in the upstream portion of Multnomah Channel, and upstream to RM 12.2. This sampling was conducted to support the Site boundary definition and assess potential contaminant migration in these adjacent areas. A discontiguous upriver reach from RM 15.3 to 26.6 was also sampled by the LWG to characterize background conditions (see Section 7).

Chemistry data were collected by the LWG between 2002 and 2008 for biota, sediment traps, surface and subsurface sediments, stormwater, surface water, and TZW. Chemical and biological data from other parties were obtained primarily from individual LWG members, EPA, DEQ, U.S. Geological Survey, and U.S. Army Corps of Engineers. In addition to the chemistry data, the LWG collected data on sediment toxicity and physical characteristics, habitat types and their distribution, species occurrence, hydrodynamic/sediment transport processes, upland sources and pathways, and cultural resources. Table 11.2-1 summarizes the LWG data and select non-LWG data used in the RI data set. Map 11.2-1 provides an overview of sampling locations for the major media. Tables 2.0-1 and 2.2-1 through 2.2-9 summarize the investigations and chemistry data used in the RI. Maps 2.2-1a–y through 2.2-14 display the sampling locations of the various media. Appendix A1 provides a summary of the data from other parties included in the RI data set.

11.3 CURRENT ENVIRONMENTAL SETTING

An understanding of the natural and human-altered environmental setting of Portland Harbor, including land use, regional geology and hydrogeology, surface water hydrology, the in-water physical system, habitat, and human use, informs the site-wide conceptual site model (CSM), facilitates interpretation of the results of the RI, and provides context for the FS. Over the past 100 years, major physical alterations have modified the river hydrodynamics and changed the configuration of the river. Although urbanization of the LWR has been extensive, there are remnant natural areas that support habitat for aquatic and terrestrial wildlife.

11.3.1 Current Land and Harbor Use

Portland Harbor is a heavily industrialized reach of the LWR and is located within a broader region characterized by commercial, residential, recreational, municipal, and agricultural uses. Current uses of the land and water in Portland Harbor include industrial and commercial operations, marine activities, surface transportation (railroads and roadways), recreational use (including parks, boating and fishing), and cultural activities. Maps 3.1-2a–e illustrate current land use zoning within the LWR and upper Multnomah Channel and sites located within Study Area drainage basins.

The shoreline has had significant physical modifications including structures built to stabilize portions of the riverbanks for development. Riprap is the most common bank-stabilization measure, although upland bulkheads and rubble piles are also used. Seawalls are constructed primarily of treated timbers or concrete to control periodic flooding. The current overwater structures such as wharfs, piers, floating docks, and pilings were built largely to accommodate or support shipping traffic. These shoreline modifications and structures are clearly visible in the aerial photographs provided in Maps 3.1-3a–t. Overwater structures related to former industrial operations have been removed in some areas leaving remnant pilings that are visible in nearshore areas. In addition, numerous public and private outfalls, including storm drains and combined sewer overflows, enter both shores of Portland Harbor.

11.3.2 Hydrogeology and Hydrology

The Willamette River drains the Willamette Basin, which lies between the Cascade Range and the Coast Range and extends from headwater streams in the mountains southwest of Eugene, Oregon, to the confluence with the Columbia River at Columbia RM 103. The section of the river from Willamette Falls to the Columbia River is considered the LWR (see Map 1.2-1), a portion of which includes the Study Area (RM 1.9 to 11.8). Portland Harbor is defined by the -40 ft Columbia River Datum (CRD) authorized federal navigation channel, which extends from the RM 0 (Columbia River) upstream to RM 11.7 (Broadway Bridge). Multnomah Channel is a channel of the LWR that begins at RM 3.1 and flows approximately 21 miles to its confluence with the Columbia River.

The Study Area is located along the southwestern edge of a large geologic structure known as the Portland Basin, a bowl-like structure bounded by folded and faulted uplands. The basin has been filled with up to 1,400 ft of alluvial and glacio-fluvial flood deposits since the middle Miocene (approximately 12 million years ago). Generally, groundwater flow adjacent to the Study Area is toward the river. Discharge from the shallow-water-table groundwater system tends to be focused at or below the river/shore interface.

River stage and currents in the Study Area are influenced by hydrologic conditions in both the Willamette and Columbia rivers, and are further affected by the operations of federal and non-federal dams along these two rivers, as well as tidal stages of the Pacific Ocean. The seasonal cycle of discharge rates on the Willamette River is illustrated in Figure 3.3-2. Annual low flows occur during the regional dry season from August to November, while winter (November to March) flows are relatively high but variable due to short-term changes in precipitation levels in the Willamette Basin. A distinct and persistent period of relatively high Willamette River stage occurs from late May through June when discharge to the Columbia is slowed by high flows on the Columbia during the spring freshet, as a result of snowmelt in the much larger Columbia River watershed. Finally, under certain river stages, flows, and tidal conditions, typically in the late summer and fall, the influence of the Columbia River estuary causes periodic flow reversals in the lower portion of the Willamette River.

Average annual mean discharge in the Willamette River during the water years 1973 through 2007 was approximately 33,000 cfs at the Morrison Bridge (near RM 12.8) in Portland. The two highest peaks in the daily mean discharge record occurred in the winters of 1996 and 1997, when peak flows reached 420,000 cfs on February 9, 1996 and 293,000 cfs on January 2, 1997.

11.3.3 Riverbed Characteristics/Dynamics and Sediment Transport Regimes

Channel morphology in the Study Area is largely a result of dredging to maintain the federally authorized navigation channel at -40 ft CRD; the 40-ft federal channel extends

from RM 0 (Columbia River) to 11.7 (Broadway Bridge). Approximately 60 percent of the riverbed in the Study Area lies within the federal navigation channel. The nearshore areas between the riverbank and the channel edge are often narrow and steep sloped along much of the main stem of the river. Larger, more gently sloping off-channel areas include embayments (e.g., Willamette Cove, Willbridge Terminal), Swan Island Lagoon, and slips (e.g., Terminal 4 and International Slip).

Sediment deposition or scouring in the Study Area has been revealed by periodic bathymetric surveys conducted from 2002 to 2009. Map 3.5-1 illustrates areas of shoaling and deepening during this period. Channel profiles demonstrate the relative steepness of the channel sides. The river is depositional in most areas with substantial sediment accrual in the left (west) side of the channel between RM 8.5 and 10 and on the right (east) side of the channel between RM 1.5 and 3.

Areas of sediment net deposition in the channel roughly correspond with relatively high percentages of fine-grained material in the surface sediments. Conversely, areas with no net change in depth generally correspond with a relatively high composition of coarser-grained material. Map 3.5-3 shows side-by-side comparisons of sediment grain size and bathymetric change in the Study Area. Also shown in Map 3.5-3 is a map of modeled maximum erosion, a product of the numerical hydrodynamic and sediment transport (HST) model developed in order to predict the potential impact of extreme (flood) events on site sediments, particularly the potential for buried contaminated sediments to be re-exposed. The RI HST model predicts the highest rates of episodic erosion to occur in the narrowest portions of the Study Area, particularly upstream of RM 10 and in the reach from RM 5 to 7.

11.3.4 Habitat

As noted above, the majority of the Study Area shoreline is industrialized, with modified shoreline and nearshore areas. Shallow water areas, gently sloped beaches, localized small wood accumulations, and less-developed shoreline areas provide some habitat for a suite of local flora and fauna (see Appendix G, Figures 2-1 through 2-6).

Although shallow-water habitats were predominant in the Study Area prior to human development, the Study Area is currently dominated by open-water habitat (i.e., representing upwards of 80 percent of all aquatic habitat). Shallow-water habitats are largely limited to the narrow strip (median width of approximately 300 ft, ranging from 0 to 1,200 ft) between the shoreline and the navigation channel. Remaining pockets of shallow-water habitat include areas such as Willamette Cove, Swan Island Lagoon, the mouth and channel of Multnomah Channel, and the Sauvie Island shoreline.

Benthic habitats in the open waters of the Study Area are generally limited to unconsolidated sediments (sands and silts) in both the deeper water (greater than approximately -20 ft CRD) of the navigation channel and lower channel slopes and shallow water depths (less than -20 ft CRD) in gently sloping nearshore areas (e.g., beaches and benches) and on the upper channel slopes. Although there are no extensive

areas of aquatic macrophytes in the Study Area, overwater structures, pilings, submerged riprap, and other physical objects provide structural complexity that increases habitat (e.g., attachment sites and refuges) in some nearshore areas.

11.3.5 Human Access and Use

Humans interact with the riverine environments in a number of ways, although direct contact with Study Area water and sediments appears to be limited. Worker activities are minimal in the shoreline areas at industrial and commercial facilities in the Study Area due to the sparse beach areas and high docks associated with most of the facilities. However, there are a number of natural areas and recreational opportunities, both within the river itself and along the riverbanks. Within the Study Area, Cathedral Park, located under the St. Johns Bridge, includes a sandy beach area and a public boat ramp and is used for water skiing, occasional swimming, and waterfront recreation. Recreational beach use also may occur within Willamette Cove, which is a riverfront natural area; in Swan Island Lagoon; and on the southern end of Sauvie Island, which is within the Study Area. Swan Island Lagoon includes a public boat ramp. Diving activity appears to be minimal throughout the Study Area, and is generally limited to commercial diving.

Non-commercial fishing is conducted throughout the LWR basin and within the Study Area, both by boaters and from locations along the banks. The most commonly consumed species are carp, brown bullhead (a catfish), crappie, and smallmouth bass (Agency for Toxic Substances and Disease Registry; ATSDR 2002a). There is also an active recreational fishery for salmon, steelhead, and sturgeon in the LWR.

Other sources (Columbia River Inter-Tribal Fish Commission; CRITFC 1994) suggest that Native Americans fish in the Willamette River. The LWR provides a ceremonial and subsistence fishery for Pacific lamprey (particularly at Willamette Falls) and spring Chinook salmon for Native American tribes. Many areas in the LWR are also important for cultural and spiritual uses by local Native Americans.

No reports of commercial fisheries for anadromous salmonids on the Willamette River have been found. According to the Oregon Department of Fish and Wildlife, a commercial crayfish fishery exists in the LWR, although no commercial crayfish landings were reported for the portion of the Willamette River within Multnomah County for the most recent period of record (2005–2007).

11.4 IDENTIFICATION OF SOURCES

The Study Area is adjacent to Portland's principle industrial area at the downstream end of the Willamette River Basin. Consequently, it has a long history of industrial, municipal, and agricultural source inputs. Understanding both point and non-point sources of contamination is essential to a useful CSM for this site. Understanding and appreciating the significance of various historical inputs, as well as current inputs, is

necessary for characterization, and ultimately for effective source control efforts within the Study Area.

11.4.1 Upland Sources Adjacent to the Study Area

The development of Portland Harbor is presented in Section 4 in terms of land use, shoreline operations, fill placement, and overwater operations by river segments. The LWG compiled an extensive data and information base for upland sites identified in DEQ's Oregon Environmental Cleanup Site Inventory (ECSI) database with the development of site summaries. The site summaries were the primary tool for identifying chemicals used in industrial operations at ECSI sites or generated in waste streams and for assessing contaminant migration pathways to the river, including stormwater/wastewater discharge, overland runoff, groundwater infiltration, riverbank erosion, and overwater releases. Releases and discharges from these migration pathways include a variety of chemicals such as heavy metals, PCBs, pesticides, petroleum hydrocarbons, and phthalates.

Historical point and non-point sources likely account for the majority of the observed chemical distribution in sediments within the Study Area; however, quantification and timing of historical releases is often difficult to ascertain. Current sources, where identified, are typically undergoing controls and monitoring. While available information on current sources varies in detail because of differences in quantitative investigations, the current pathways and chemicals are generally well identified. However, it is acknowledged that additional sources may yet be identified.

Appendix C2 and Section 4 provide a detailed discussion of the methods and results of the Groundwater Pathway Assessment (see summary of results below in Section 11.5.4). This quantitative assessment was conducted offshore of nine sites where groundwater was suspected of potentially impacting sediment and pore water quality.

11.4.2 Sources Upriver and Downriver of the Study Area

Upriver of the Study Area, the river's chemical burden is elevated to levels above predevelopment conditions as a result of agricultural runoff, inputs from industries and cities (including downtown Portland) upstream, and contributions from atmospheric deposition in the watershed to stormwater runoff. More than 750 permitted discharges enter the Willamette River upstream of Willamette Falls, including 10 municipal sewage treatment plants and several pulp, paper, lumber, and fiberboard manufacturers. Hundreds of facilities also have general permits for discharge of noncontact cooling water and filter backwash, gravel mining waste streams, and tank cleaning fluids. The primary issues associated with nonpoint sources from forestry and agricultural activities include accelerated sediment transport, nutrient enrichment, and pesticide inputs from both current and historical applications and practices.

For the purposes of this RI, the LWR upriver of the Study Area is divided into the downtown reach, which extends from RM 11.8 through downtown Portland to RM 15.3 (upper end of Ross Island), and the upriver (background) reach from RM 15.3 to 28.4

(above Willamette Falls). Sediment quality in the downtown reach is influenced by local sources in this highly urbanized corridor, as well as former industrial sites that are unrelated to Study Area sources. Examples of contaminated sediment sites in the downtown reach include the Zidell Waterfront Property, which is scheduled for remediation in the near future, and two historical sediment cleanup sites, Portland General Electric Company (PGE) Station L and Ross Island Lagoon, which have been remediated (capped).

11.4.3 Existing Source Control Measures

Upland source control is necessary to allow cleanup of the river to proceed without the risk of recontamination. Under the 2001 MOU, DEQ is responsible for identifying and controlling upland sources of contamination, and EPA for overseeing the investigation and cleanup of the in-water portion of the Study Area. Together, these two agencies developed the Portland Harbor Joint Source Control Strategy (JSCS) in 2004, with the goals of identifying, evaluating, and controlling sources of contamination that may affect the LWR.

Currently, DEQ is investigating or directing source control work at over 80 upland sites in Portland Harbor, the progress of which is tracked in annual Milestone reports. Maps 4.6-1a–e display the source control status, as of April 2009, for each of the major pathways of a particular site: riverbank erosion, groundwater, overland transport, overwater activities, and stormwater/wastewater. Additionally, DEQ and the City (under an Intergovernmental Agreement) are jointly working together to identify and control upland sources draining to the Study Area through City outfalls.

Source control measures are implemented at a given site to address ongoing sources of contamination, whether or not the source is a result of a historical or current release. These measures can be a combination of tools, including technical assistance, stormwater programs, hazardous waste management and pollution prevention programs, inspection and maintenance programs, water quality compliance and spill response programs, administrative actions and enforcement, and other regulatory programs, in an effort to control sources of contamination. Approximately 22 sites currently have source control decisions with approved plans for interim or final remediation.

11.5 IN-RIVER DISTRIBUTION OF INDICATOR CHEMICALS

Numerous chemical and physical parameters have been analyzed for in the following media from the Study Area: sediments, in-river sediment traps, surface water, TZW, and biota. Chemicals or ancillary parameters that were detected in these analyses are referred to as chemicals of interest, or COIs (Table 5.0-1). From the list of COIs, several risk screening steps and a review of upland COI information were used to select ICs mapped and discussed in the RI report (Table 5.0-2).

Four ICs—total PCBs, total PCDD/Fs (as both total dioxins/furans and dioxin/furan TCDD TEQ[3]), total DDx[4], and total PAHs—were identified as "bounding" ICs. These four chemical groups are considered "bounding" because their distribution is believed to encompass the spatial extent of potentially unacceptable risks associated with all COCs identified in the baseline risk assessments. This is not intended to imply that other COCs will not be evaluated in the FS. The discussions of the nature and extent of ICs in sampled media from the Study Area focus on these four ICs.

11.5.1 Indicator Chemicals in Sediment

Surface and subsurface sediment samples were collected and analyzed for a full range of COIs and conventional parameters over three rounds of sampling between 2002 and 2007 in the LWR (see Section 5.1 for details). Sediment samples were collected throughout the Study Area—but focused on areas of known or suspected contamination based on existing information—as well as upstream and downstream of the Study Area. In addition to sediment chemistry analyses, toxicity testing (sediment bioassays) was conducted on over 200 surface sediment samples collected by the LWG (see Section 11.9 and Appendix G). Summary statistics for ICs in Study Area sediments are presented in Table 11.5-1 (also see Tables 5.1-1 and 5.1-2; the full data set is provided in Appendix D1.2).

Section 5.6 compares sediment data from the Study Area to sediment data from areas outside the Study Area: the upriver reach (RM 15.3–28.4), the downtown reach (RM 11.8–15.3), the downstream reach (RM 0–1.9), and Multnomah Channel. Summary statistics for the upstream and downstream reaches for all ICs in surface and subsurface sediments are provided in Tables 5.6-1 through 5.6-12. Section 5.6 data is summarized here in Section 11.5.1 in juxtaposition to the Study Area data.

Total PCBs: When congener data were available, the reported total PCB value was based on the congener results. Otherwise, the total PCB value reported was based on Aroclors. PCBs were detected in 79 percent of surface sediment samples and 65 percent of subsurface sediment samples (Table 11.5-1). Total PCB concentrations in sediments varied widely across the Study Area (Figures 5.1-1 and 5.1-2; Maps 5.1-1 and 5.1-2a–m). In general, surface and subsurface sediment concentrations were typically less than 100 µg/kg within the spatial limits of the navigation channel, whereas many areas in the nearshore zones contained concentrations greater than 100 µg/kg. Concentrations greater than 1,000 µg/kg occurred in several nearshore areas, and surface and subsurface total PCB concentrations greater than 1,000 µg/kg generally occurred in similar locations. The highest surface and subsurface sediment

[3] The tetrachlorodibenzo-p-dioxin toxic equivalent concentration (TCDD TEQ) was calculated for detected values only using WHO 2005 toxicity equivalency factors (TEF) and does not include dioxin-like PCB congeners. See Sections 8 and 9 of the RI report for descriptions of methods for assessing risks from PCBs and dioxins/furans and resulting risk estimates. TEQ concentrations are discussed in Section 5 of the RI report.

[4] Total of 2,4′- and 4,4′-DDD (dichloro-diphenyl-dichloroethane), -DDE (dichloro-diphenyl-dichloroethene), -DDT (dichloro-diphenyl-trichloroethane).

PCB concentrations occurred in the western nearshore zone near RM 8.8 (35,400 µg/kg in surface sediment and 36,800 µg/kg in subsurface sediment).

Total PCB concentrations were higher in subsurface sediments within the Study Area as a whole (see Map 5.1-2; Figure 5.1-33), indicating predominantly historical total PCB sources.

Overall, surface sediment PCB concentrations in the Study Area were greater than those in the upriver (upstream of Ross Island) and downstream (main stem of the LWR downstream of RM 1.9 and Multnomah Channel) reaches (Table 5.6-13; Figure 5.6-3).

Total PCDD/Fs and TCDD TEQ: Total PCDD/F and TCDD TEQ were detected in almost all surface and subsurface sediment samples analyzed (Table 11.5-1). Total PCDD/F and TCDD TEQ concentrations varied along the length of the Study Area (Figures 5.1-7 through 5.1-10; Maps 5.1-3 through 5.1-6a–m). The concentration peak in the data occurred in the western nearshore between approximately RM 6.8 and 7.3. The highest relative total PCDD/F concentrations (i.e., greater than 2,000 pg/g) in surface and subsurface sediment were generally found at similar locations.

Except for a few localized areas with highly elevated concentrations, surface sediment TCDD TEQ concentrations in the Study Area were similar to those in the upstream and downstream reaches (Table 5.6-13; Figure 5.6-4).

Total DDx: DDx compounds were detected in 89 percent of surface sediment samples and 81 percent of subsurface sediment samples (Table 11.5-1). The relative concentrations of DDD, DDE, and DDT isomers varied widely among samples. Areas of total DDx concentrations greater than 1,000 µg/kg occurred at several locations along the nearshore and channel margins. The areas of highest total DDx concentrations (greater than 1,000 µg/kg) in surface sediment occurred along the western shoreline between RM 6.5 and 7.5 and at RM 8.9 (Figures 5.1-11 and 5.1-12; Maps 5.1-7 and 5.1-8a–m). Samples from the navigation channel were typically less than 100 µg/kg total DDx. Total DDx concentrations were generally higher in the subsurface than in the surface layer (Map 5.1-8; Figure 5.1-42), indicating predominantly historical DDx sources.

The concentrations of total DDx in Study Area surface sediments were greater than those in the upriver, downtown, Multnomah Channel, and downstream reaches (Table 5.6-13; Figure 5.6-5).

Total PAHs: PAHs were detected in 99 percent of surface sediment samples and 95 percent of subsurface sediment samples (Table 11.5-1). PAH concentrations were highly variable across the Study Area, with peak concentrations around RM 6 (Figures 5.1-13 and 5.1-14). Except for limited areas of relatively higher concentrations, total PAH levels were generally 1,000 µg/kg or less. The highest concentrations (>30,000 µg/kg) were found in the eastern and western nearshore zones between approximately RM 3 and 7.5 (Figures 5.1-13 and 5.1-14; Maps 5.1-9 and

5.1-10a–m). With few exceptions, total PAH concentrations were generally higher in subsurface than in surface sediments (Map 5.1-10; Figure 5.1-45). One exception occurred at RM 5–6, where the mean channel surface concentration was markedly higher than the mean subsurface concentration, due to several relatively high concentration surface-only samples in the channel.

The mean PAH concentration for Study Area surface sediments was markedly greater than the mean value in the upriver, downtown, Multnomah Channel, and downstream reaches, and the range of values was much wider (Table 5.6-13; Figure 5.6-6).

Additional ICs in Sediments: Areas of high concentrations of the other ICs detailed in Section 5.1 were limited and located in localized nearshore areas. Bis(2-ethylhexyl)phthalate (BEHP), total chlordanes, aldrin, dieldrin, and tributyltin (TBT) were detected more frequently in the surface sediments than in subsurface sediments, and the median concentrations of these chemicals was generally higher in the surface sediments; however, the maximum concentrations generally occurred in subsurface sediments. The median concentrations and detection frequencies of the metals in surface and subsurface sediments were similar.

Upstream Depositional Cores: Sediment cores were collected in long-term depositional areas at the upstream end of the Study Area that are expected to act as natural sediment traps. The core samples were analyzed for both radioisotopes and conventional/contaminant chemistry at regular intervals with depth from the mudline to the bottom of the 300+ cm cores. The objective of this sampling and analysis was to determine the rate of deposition and chemical quality of sediments accumulating in the upper Study Area. Two of the three stations sampled were situated in formerly excavated borrow pits (at RM 10.9 and 10.5) with mudline depths well below the authorized channel depth of -40 ft CRD. The third station at RM 9.6 was located in the main channel on the large shoal that occurs along the western half of the channel there (Figure 5.6-13).

The 300+ cm cores were collected at each location and sectioned at 2-cm intervals for radioisotope analyses and 30-cm intervals for contaminant/conventional chemistry. Evaluation of the radioisotope data from these cores did not support the assignment of a timeline to the sediment profiles due to the heterogeneous origins of the sediments in the deposits (e.g., mix of suspended and bedload sediments from a variety of lateral, upstream, and atmospheric sources). However, empirical data on the 30-year history of the borrow pits, as well as the shorter-term LWG time-series bathymetric data, indicate long-term net sedimentation rates of 30 cm/yr or greater in the borrow pits that accumulate sediments.

The concentrations with depth of the bounding ICs measured in these three depositional cores showed relatively low concentrations for all chemicals and minimal gradients with depth within each core (see Figures 5.6-9 through 5.6-12). For total PCBs, total DDx, and total PAHs, the average concentration for all sediment-depth horizons

(surface and subsurface) in the three depositional cores combined from the upper end of the Study Area (RM 9.5 to 10.9) were slightly higher than chemical concentrations measured in surface sediments in the upriver reach (RM 16) and lower than the mean in the downtown reach (see Table 5.6-13). TCDD TEQ concentrations in these depositional cores were similar to the upriver reach (above RM 16). These data indicate that sediments accumulating in these upstream depositional portions of the Study Area have chemical concentrations that are comparable to chemical concentrations measured in sediments in the upriver reach.

11.5.2 Indicator Chemicals in Sediment Traps

Sediment trap samples were collected quarterly at 16 locations in the LWR (RM 2 to 16) and in the Multnomah Channel from late 2006 through late 2007 to measure the concentrations of chemicals bound to suspended sediments upstream, within the Study Area near potential sources, and downstream of the Study Area. Summary statistics for ICs in the sediment trap samples are presented in Tables 5.2-1 through 5.2-4.

Total PCBs: PCBs (as congeners) were detected in all 52 sediment trap samples analyzed. Total PCB congener concentrations from sediment traps in the Study Area were all higher than the average PCB concentrations from the upriver location (RM 16). Increasing concentrations generally occurred with each successive sampling period (i.e., from winter through the following fall) at the majority of sampling locations, possibly reflecting seasonal changes in river flow and sediment transport. PCB concentrations were generally higher in sediment traps located between RM 6.7 and 11.3 compared to other locations (Figure 5.2-5). Aside from large differences in PCB concentrations between ST007 (RM 11.3E) and its paired location ST008 (RM 11.5W), there was little relative difference in PCB concentrations between other cross-river sample pairs.

Total PCDD/Fs and TCDD TEQ: PCDD/Fs were detected in all 48 sediment trap samples analyzed. Study Area samples had an overall median total PCDD/F concentration approximately 40 percent higher than the overall median of the upriver samples. There were no apparent spatial or seasonal trends in total PCDD/F homolog concentrations (Figure 5.2-10). TCDD TEQ concentrations tracked total PCDD/F homolog concentrations, both geographically and seasonally.

Total DDx: DDx compounds were detected in 98 percent of the sediment trap samples. Total DDx concentrations in Study Area samples were generally higher than those from upriver locations. At most locations, total DDx concentrations were highest during Quarter 4 (August–November 2007), and the fourth quarter samples collected from sediment traps from RM 6 to 11.3 generally had the highest total DDx concentrations. Downstream of RM 6, total DDx concentrations appeared to be similar within quarters. Cross-river sample pairs had similar concentrations in the first and second quarters; however, differences were noted at RM 6 and 11.5 in the fourth quarter samples.

Total PAHs: PAHs were detected in all 49 samples analyzed. Most samples from Study Area locations had total PAH concentrations exceeding average upriver

concentrations during concurrent sampling periods. The highest PAH concentrations within stations tended to occur during Quarters 3 (May–August 2007) and 4, but additional seasonal differences among stations was not apparent. Spatially, total PAH concentrations were higher at locations between RM 3 and 6, including Multnomah Channel, relative to the rest of the Study Area. Total PAH concentrations were consistently higher in samples from the sediment trap at RM 6W compared to its cross-river counterpart at RM 6E. Other cross-river sample pairs generally did not exhibit substantial differences in total PAH concentrations.

Additional Indicator Chemicals in Sediment Traps: Concentrations of BEHP, total chlordanes, and TBT in sediment traps located within the Study Area were generally higher than in traps located upstream of the Study Area. The concentrations of arsenic, chromium, copper, and zinc in sediment traps from within the Study Area were generally similar to or slightly above that of the upriver traps. Relatively high concentrations of BEHP and TBT were observed in Swan Island Lagoon. Aldrin and dieldrin concentrations were variable, and there was a low frequency of detection for these chemicals, making geographical trends unclear.

11.5.3 Indicator Chemicals in Surface Water

The objectives of the surface water investigation were to assess water quality under various flow conditions, support the BERA and BHHRA (including the food-web model), support the fate and transport evaluation, assist in the characterization of background conditions and identification of sources, and to support refinement of the CSM.

The surface water investigation consisted of seven field collection events that occurred between November 2004 and March 2007 and targeted seasonal flow events: low-flow (<50,000 cfs), high-flow (>50,000 cfs), and stormwater-influenced flow (active runoff in the Study Area). Samples were collected at six transect stations and 26 single-point stations, located from RM 2 to 16, utilizing peristaltic pump and high-volume XAD sampling methods. Transect samples were spatially integrated across the width and depth of the river or spatially integrated vertically at multiple locations across the river (RM 11 and RM 2), while the single-point samples were collected near the river bottom or simultaneously at near-bottom and near-surface locations.

Summary statistics for ICs in the surface water samples are presented in Tables 5.3-2 through 5.3-7. Overall, concentrations of the bounding ICs in surface water were generally lower during the stormwater-influenced event than under low-flow or non-storm high-flow conditions. Results for low-flow and non-storm high-flow conditions are discussed below.

Total PCBs: Total PCBs as the sum of congeners in surface water were detected in all (100 percent) XAD samples for all flow conditions. Total PCB concentrations for both single-point samples and transect samples tended to decrease with increasing flow rates, for example, from a range of 375 pg/L to 12,000 pg/L during low-flow conditions to a

range of 110 pg/L to 749 pg/L during high-flow conditions for single-point samples (Tables 5.3-2 through 5.3-5). The highest total PCB concentration (12,000 pg/L) was found at RM 6.7E, within Willamette Cove, during low-flow conditions (Figure 5.3-15). Total PCB concentrations across all flow conditions were lower in the transect samples (range = 41.9 pg/L to 950 pg/L) than in the single-point samples (range = 110 pg/L to 12,000 pg/L). PCB concentrations from samples within the Study Area, including the downstream end at RM 2, were greater than upstream concentrations.

Total PCDD/Fs and TCDD TEQ: The detection frequency for PCDD/Fs was 100 percent during all flow conditions; however, no relationship between PCDD/F concentrations and flow conditions was observed. Total PCDD/Fs ranged from 24.7 pg/L to 163 pg/L in single-point samples and from 5.36 pg/L to 51.6 pg/L in transect samples (Tables 5.3-2 through 5.3-5). TCDD TEQ ranged from 0.110 pg/L to 0.917 pg/L in single-point samples and from 0.0181 pg/L to 0.327 pg/L in transect samples.

The highest total PCDD/F concentration (163 pg/L) was found at RM 6.7E, within Willamette Cove, during low-flow conditions (Figure 5.3-30). The distributions of total PCDD/F concentrations were relatively consistent throughout the Study Area and upstream to RM 16, with the exceptions of the five highest concentrations. Total PCDD/F concentrations tended to be lower in the transect samples than in the single-point samples.

Total DDx: DDx compounds were detected in all XAD samples collected. Total DDx concentrations ranged from 49.2 pg/L to 9,760 pg/L in single-point XAD samples and from 42.8 pg/L to 618 pg/L in XAD transect samples (Tables 5.3-2 through 5.3-5).

Concentrations of total DDx measured in high-flow samples were generally higher than those associated with the low-flow and stormwater-influenced samples. However, the single highest total DDx concentration (9,760 pg/L) was found at RM 7.2W and was detected during low-flow conditions. Excluding the highest concentrations, the observed concentrations across the Study Area and upstream to RM 16 were consistently detected. At the downstream end of the Study Area, total DDx concentration ranges decreased relative to ranges observed within the central portion of the Study Area for all flow event types (Figures 5.3-42, 5.3-43, 5.3-45, and 5.3-46).

Total PAHs: PAHs were detected in all XAD samples collected, with concentrations ranging from 10,400 pg/L to 231,000 pg/L in single-point XAD samples and from 3,970 pg/L to 66,000 pg/L in XAD transect samples (Tables 5.3-2 through 5.3-5).

The highest total PAH concentration was found at RM 6.9, near the west end of the Railroad Bridge during low-flow conditions. Total PAH concentrations measured at RM 11 and 16 tended to be lower than those within the Study Area. Total PAH concentrations tended to vary within a flow condition rather than over the range of flow conditions sampled; however, the highest concentrations were found in low-flow conditions.

Additional Indicator Chemicals in Surface Waters: Concentrations of total chlordanes and dieldrin in surface water were generally higher in samples collected under high-flow conditions; however, the highest total chlordane concentration was observed under low-flow conditions at RM 6.9. Concentrations of aldrin were generally similar between flow conditions. The concentrations of arsenic, copper, and zinc were generally consistent across the Study Area and between flow events; however, a relatively high zinc concentration was observed at RM 9.7 under low-flow conditions.

11.5.4 Indicator Chemicals in Transition Zone Water and Groundwater Seeps

Samples of TZW were collected offshore of nine sites (Map 2.2-6) with known upland groundwater plumes and with a confirmed or reasonable likelihood for discharge of COIs to Portland Harbor surface water. Samples were collected from both shallow (0 to 30 cm below mudline [bml]) and deep (90 to 150 cm bml) pore water. The ICs for TZW were defined by the COIs found in upland groundwater plumes and therefore differ from the ICs for other media (Table 5.0-2). Of the four bounding ICs for other media, only two, DDx and PAHs, were analyzed in TZW.

Summary statistics for TZW are provided in Appendix D4, Tables D4-1 and D4-2.

Total DDx: DDx components were identified as upland groundwater COIs at the Arkema site and were found in the TZW samples collected offshore of this area (RM 7.2 to 7.5). In addition, a sample offshore of the distal groundwater plume downgradient of the Rhone Poulenc site (RM 6.7 to 6.8) was analyzed for DDx compounds. Filtered DDx concentrations ranged from undetected to 0.179 µg/L, and unfiltered DDx concentrations ranged from 0.0075 µg/L to 5.73 µg/L.

The concentrations of the DDx compounds were consistently higher in unfiltered samples than filtered and peeper samples, indicating the DDx compounds are at least partly associated with solids in the transition zone. As stated in Appendix C2, the possibility is not ruled out that hydrophobic DDx compounds may be transported to the transition zone to a small degree via the groundwater pathway; however, the finding that detectable DDx in TZW appears to be largely an artifact of particulates introduced during sampling suggests that other potential pathways are more significant.

Total PAHs: PAHs were identified as upland groundwater COIs at six of the nine sampled sites: Kinder Morgan Linnton Terminal (RM 4.1 to 4.2), ARCO Terminal 22T (RM 4.7 to 4.9), ExxonMobil Oil Terminal (RM 4.8 to 5.1), Gasco (RM 6.1 to 6.5), Siltronic (RM 6.3 to 6.5), and Willbridge Terminal (RM 7.6 to 7.8). PAHs were detected in TZW samples offshore of all six sites. Filtered sample total PAH concentrations ranged from undetected to 1,200 µg/L, and unfiltered total PAH concentrations ranged from undetected to 15,100 µg/L. The highest filtered total PAH concentration occurred in a sample collected at the downstream end of the Gasco site, and the four highest unfiltered total PAH concentrations occurred in samples collected roughly offshore of the property line between the Gasco and Siltronic sites.

The concentrations of total PAHs was higher in unfiltered samples than filtered samples collected from the same locations, indicating the PAHs are sorbed to solids in TZW. Unfiltered deep samples consistently exhibited higher concentrations than collocated shallow samples; however, the three filtered deep/shallow sample pairs did not exhibit this trend. Acenaphthene was the dominant PAH component of the majority of the samples; however, the very mobile PAH naphthalene was the dominant component at sample locations with total PAH concentrations greater than ~1,000 µg/L.

Additional Indicator Chemicals in TZW:

Total Petroleum Hydrocarbons (TPH) in TZW: TPH (including diesel-range hydrocarbons [DRH], residual-range hydrocarbons [RRH], and gasoline-range hydrocarbons [GRH]) was identified as an upland groundwater COI for six of the nine TZW study sites: Kinder Morgan, ARCO, ExxonMobil, Gasco, Siltronic, and Willbridge Terminal. TPH was detected in TZW samples at all six of the studied sites. Filtered sample TPH concentrations ranged from undetected to 4.1 mg/L, and unfiltered TPH concentrations ranged from undetected to 11.3 mg/L. The highest concentrations of TPH in TZW were observed offshore of the Gasco and Siltronic sites. Deep unfiltered concentrations tended to be higher than shallow unfiltered results. Furthermore, comparison of DRH and RRH showed that filtration consistently decreased observed concentrations (per sampling protocols for volatile organic compounds [VOCs], filtered samples of GRH were not collected).

Review of the fractional components (DRH, RRH, and GRH) showed a composition shift toward GRH in the offshore discharge zone at the Siltronic site; however, patterns elsewhere were generally weak and more difficult to interpret when TPH concentration changes were also considered.

Finally, in addition to the select ICs and TPH, Silvex was sampled in TZW offshore of Rhone Poulenc; cyanide in TZW offshore of the Gasco and Siltronic sites; perchlorate offshore of Arkema; and metals (arsenic, barium, cadmium, copper, lead, manganese, nickel, and zinc), VOCs (chlorobenzene, chloroethane, 1,2-dichloroethane, 1,1,2-trichloroethane, vinyl chloride, cis-1,2-dichloroethene, trichloroethene, chloroform, and methylene chloride, benzene, toluene, ethylbenzene, xylenes, carbon disulfide), and 1,2-dichlorobenzene were sampled offshore of all nine TZW sites. 1,2,4-trimethylbenzene was sampled offshore of the Siltronic site from RM 6.3 to 6.5 only. Concentration trends of these chemicals varied by chemical and area (see Section 5.4.7 for details).

Groundwater Seeps: Groundwater seeps were evaluated for the BHHRA due to the potential for humans to come into contact with seep water. Thirty-seven seeps were identified between RM 2 and 10.5, and water quality data were collected at six of these (Figure 5.4-5). Only one seep, associated with groundwater infiltrating into Outfall 22B, is relevant for use in the BHHRA, based on data quality and seep discharge to a human-use beach. For most analytes evaluated, the seep concentrations were near or

below detection limits. The groundwater seep data are limited and do not allow for definitive conclusions.

11.5.5 Indicator Chemicals in Biota

Fish and invertebrate samples were used to evaluate the nature and extent of chemical concentrations in biota from the Study Area and from adjacent areas, including those immediately upstream and downstream of the Study Area, from Multnomah Channel near its divergence from the LWR, and from the upriver reach (RM 15.3–28.4) and above Willamette Falls. These tissue data were also used extensively in the BHHRA and BERA to evaluate potential risks at the Site. Data for 11 fish species, four benthic invertebrate species, epibenthic communities, and fish stomach contents were collected and evaluated. With the exception of sturgeon, fish tissue samples were composites of individual fish. All invertebrate samples were composites.

Summary statistics for biota samples are presented in Tables 5.5-1 through 5.5-5.

Total PCBs: PCBs were detected in all fish samples from the Study Area and most fish samples from above the Study Area. PCBs were detected in all invertebrate samples from the Study Area that were analyzed for PCB congeners. PCB concentrations varied between and within species by several orders of magnitude. The maximum whole-body (25,100 µg/kg) and fillet concentrations (19,700 µg/kg) occurred in carp composite samples from RM 4 to 8. The highest average total PCB concentrations in fish species from within the Study Area were at least an order of magnitude higher than concentrations in the upriver reaches.

Within the Study Area average total PCB concentrations in fish samples ranged from 24.1 µg/kg-wet (black crappie fillet) to 2,760 µg/kg-wet (whole-body carp). Average total PCB concentrations from fish samples from the upriver reach and above-falls areas ranged from 14.5 µg/kg-wet (whole-body juvenile Chinook) to 238 µg/kg-wet (whole-body smallmouth bass).

Average invertebrate sample PCB concentrations ranged from 10.6 µg/kg-wet (sturgeon stomach contents) to 514 µg/kg-wet (laboratory-exposed worms). In invertebrate samples from the upriver reach, total PCBs (as congeners) were only analyzed in juvenile Chinook stomach contents (average concentration of 10.6 µg/kg-wet) and laboratory-exposed clams and worms (average concentrations of 16.6 µg/kg-wet and 6.86 µg/kg-wet, respectively).

Total PCDD/Fs and TCDD TEQ: PCDD/Fs were detected in all fish and invertebrate samples analyzed. The highest average whole-body fish tissue concentrations of PCDD/Fs in the Study Area and the upriver reaches were similar despite the maximum Study Area concentration (388 pg/g, whole-body sculpin composite from RM 7W) being an order of magnitude greater than that of the upriver reach maximum concentration (63 pg/g in juvenile lamprey composite collected near RM 18.9).

The highest average invertebrate total PCDD/F concentration (360 pg/g) in the Study Area was measured in worms exposed in the laboratory to sediment. PCDD/Fs were not analyzed in invertebrate samples from above the Study Area.

The highest average whole-body TCDD TEQ (4.77 pg/g) was measured in smallmouth bass composite tissue, and the highest average fillet TCDD TEQ (2.83 pg/g) was measured in carp composite fillet tissue. The highest average invertebrate TCDD TEQ occurred in a worm sample (16.5 pg/g) exposed in the laboratory to sediments.

Total DDx: DDx compounds were detected in all fish and invertebrate samples analyzed. The highest average total DDx concentrations within the Study Area were at least an order of magnitude higher than in the upriver reaches.

Within the Study Area the maximum total whole-body fish sample DDx concentration (3,060 µg/kg) occurred in a sculpin composite from RM 7.3W. The maximum fillet concentration (494 µg/kg) was measured in a carp composite sample from RM 4 to 8.

The average total DDx concentration in fish tissue samples from the Study Area ranged from 11.4 µg/kg (black crappie fillet) to 322 µg/kg (whole-body northern pikeminnow). In fish samples from the upriver reach and above Willamette Falls, average total DDx concentrations ranged from 8.5 µg/kg (whole-body juvenile Chinook) to 94 µg/kg (whole-body smallmouth bass).

Average total DDx concentrations for each invertebrate species from the Study Area ranged from 2.47 µg/kg (mussel) to 114 µg/kg (laboratory-exposed worm).

Total PAHs: PAHs are a biota IC only for clam tissue, and were detected in all clam samples from the Study Area. The average clam tissue concentration from the Study Area was at least an order of magnitude higher than the one upriver sample.

Average total PAH concentrations for clam tissue from the Study Area ranged from 76 µg/kg (depurated clam tissue) to 478 µg/kg (undepurated clam tissue), with the highest concentration found in undepurated clam tissue from RM 6.4W (4,980 µg/kg).

PAH data were available for only one clam sample that represents exposures upriver of the Study Area. The total PAH concentration in this laboratory-exposed clam tissue was 29.7 µg/kg.

Additional Indicator Chemicals in Tissue: BEHP, total chlordanes, aldrin, dieldrin, arsenic, chromium, copper, zinc, TBT, and percent lipids were also analyzed in biota samples. BEHP and TBT were the only ICs not found across the entire Study Area. These chemicals were found Study Area-wide in clam and laboratory-exposed worm samples but only in localized areas in fish tissues. Tissue concentrations of total chlordanes, aldrin, dieldrin, arsenic, and copper within the Study Area were generally higher than those found in the upriver reaches.

11.6 LOADING, FATE, AND TRANSPORT FOR SELECT INDICATOR CHEMICALS

An assessment of chemical loading to the surface water and surface sediment of the Study Area from external sources, along with an evaluation of chemical fate and transport mechanisms within the Study Area, was conducted under this RI. This loading assessment provides information that can be used to better understand processes influencing the nature and extent of select ICs within the Study Area, support development of the CSM (Section 10), and provide information that will be needed for the evaluation of remedial alternatives in the FS.

11.6.1 External Loading

Loading terms/pathways evaluated in the RI include upstream loading (via surface water and sediment bedload), stormwater runoff, non-stormwater point source permitted discharges, upland groundwater plumes migrating to the Study Area, atmospheric deposition to the river surface, mobilization of sediment contaminants via groundwater advection, direct upland soil and riverbank erosion, and overwater releases. A simplified conceptualization of the external loading terms and internal transport processes within the Study Area is presented in Figure 6.1-1.

Chemical loading estimates developed for the RI illustrate the general extent and variability in chemical loads to the Study Area under "typical" conditions, i.e., in an average water year. The estimation approach for each loading term varied from qualitative to quantitative, depending on the degree to which available data and information support generation of numerical estimates. Table 6.1-1 summarizes the load estimate quantification level and calculation approach for each loading term, and Table 6.1-14 summarizes the central load estimate results for pathways and ICs. Details of the calculations can be found in the supporting Appendix E.

The current loading terms and transport mechanisms evaluated include the following:

- Upstream surface water
- Stormwater runoff
- Permitted non-stormwater point source discharges
- Atmospheric deposition
- Upland groundwater plumes
- Sediment advective loading
- Upland soil and riverbank erosion.

11.6.2 Fate and Transport

Several physical, chemical, and biological processes influence the fate and transport of chemicals within the in-water portion of the Study Area. These processes are generally described qualitatively in the RI and will be assessed further in the context of the FS and related modeling efforts.

For highly hydrophobic ICs (i.e., PCBs, PCDD/Fs, pesticides including DDx compounds, and HPAH compounds), movement of sediments and suspended sediment particles, especially silts and clays, is the dominant physical transport mechanism in the Study Area. Other, more soluble ICs (e.g., LPAHs, BEHP, and some metals) may occur at appreciable aqueous-phase concentrations in surface water and/or pore water, where they are subject to physical transport via advection and dispersive mixing.

Chemical and biological processes can result in the transport, transfer, transformation, and/or degradation of ICs in abiotic media (water, suspended solids, sediment, and air) within the Study Area. These processes include sorption, precipitation, volatilization, abiotic degradation (chemical reaction or photolysis), and biodegradation.

Finally, a number of biological processes govern how organisms living in the LWR may become exposed to chemicals and how chemicals are transformed, excreted, or stored in tissue. Organisms take up chemicals through physically, chemically, and biologically mediated processes, including transfer of waterborne chemicals across gill structures or other tissues, consumption of prey, or ingestion of sediment. Organisms can modify the chemical burden in their tissues through growth, reproduction, excretion, metabolic transformation, or sequestration.

11.7 DETERMINATION OF BACKGROUND CONCENTRATIONS FOR INDICATOR CHEMICALS

The broad goal of a background evaluation in the context of an RI/FS is to estimate the levels of chemicals that would exist in environmental media at the site in the absence of CERCLA-related hazardous chemical releases. For the Portland Harbor RI/FS, a background evaluation was performed for both bedded sediment and surface water. For the Portland Harbor Site, a range of potential uses of background information have been identified, such as providing context for interpretation of risk estimates and support for delineation of areas of potential concern (AOPCs) and evaluation of potential remedies in the FS.

11.7.1 Background Evaluation Summary

The background evaluation involved the selection of background ICs, identification of an appropriate reference area for background conditions, and compilation of background data sets. Chemicals included in the background analysis, i.e., background ICs, are presented in Tables 7.2-1 and 7.2-2.

Establishing an appropriate background reference area in the context of Portland Harbor differs from settings in which an appropriate background data set is intended to represent "pristine" conditions. In developed settings like Portland Harbor and the Willamette Basin, reference areas may be influenced by local point sources (e.g., shoreline industrial facilities, municipal sources, and overwater structures), as well as by diverse non-point sources of chemicals (e.g., atmospheric deposition and storm runoff from a range of land use types, including industrial, agricultural, and municipal uses).

For bedded sediment, the upriver reach of the LWR, extending from RM 15.3 to 28.4, was selected, by EPA, as the reference area for determining background concentrations. This reach was chosen because it is considered broadly representative of a nonindustrialized land use area with relatively high sediment quality, and its location is upstream and uninfluenced by releases from the Study Area. The downtown reach between RM 15.3 and the Study Area contains general inputs associated with urbanization, as a well as several historical industrial sites. Additional context to background bedded sediment was provided by related data sets, including in-river sediment traps, surface water suspended sediment, and sediment cores from borrow pits and shoaling areas.

For surface water, samples collected from transects at RM 11 and RM 16 formed the basis of the background data set.

11.7.2 Surface Sediment Background Concentrations

Background bounding IC concentrations in upriver surface sediments with primary outliers removed are summarized in Tables 7.3-3 and 7.3-5b (dry-weight basis) and 7.3-4 and 7.3-7b (OC-normalized). Background concentrations were not calculated for total PAHs[5]; the table below provides the central tendency (UCL; 95th percentile upper confidence limit on the mean) and upper threshold (UPL; 95th percentile upper prediction limit) statistics for the other three bounding ICs.

IC	UCL (dry-weight)	UPL (dry-weight)	UCL (OC-normalized)	UPL (OC-normalized)
Total PCBs (µg/kg)	6.9	17	690	1600
TCDD TEQ (pg/g)	1.3	2.2	360	545
Total DDx (µg/kg)	1.9	3.6	170	260

[5] Background analyses were only performed for analytes that exceeded screening levels based on the BERA and BHHRA. Total PAHs did not exceed these screening levels and, hence, were excluded from the background analysis.

11.7.3 Surface Water Background Concentrations

Summary statistics for background IC concentrations in surface water with primary outliers removed can be found in Tables 7.4-2a and 7.4-4a. Background concentrations were not calculated for total PAHs;[6] the table below summarizes the UCL and UPL for the other three bounding ICs.

IC	UCL	UPL
Total PCBs (congeners only; pg/L)	236	389
TCDD TEQ (pg/L)	0.066	0.098
Total DDx (pg/L)	430	590

11.8 BASELINE HUMAN HEATH RISK ASSESSMENT

The BHHRA was conducted to identify chemicals and exposure scenarios (i.e., combinations of media, exposure pathways, and human subpopulations) that may result in potentially unacceptable risks and to inform risk management decisions for the Site. The sources of data used in the BHHRA, data uses, and an evaluation of data for purposes of the BHHRA are described in Appendix F, Section 2 and Attachment F2.

11.8.1 BHHRA Exposure Scenarios

The BHHRA evaluated the following exposure scenarios, as provided in the approved Programmatic Work Plan and subsequent agreements with or directives from EPA:

- **Dockside Worker** – Direct exposure to (i.e., ingestion of and dermal contact with) beach sediment
- **In-water Worker** – Direct exposure to in-water sediment
- **Adult and Child Recreational Beach User** – Direct exposure to beach sediment and surface water
- **Transient** – Direct exposure to beach sediment, surface water, and groundwater seep
- **Diver** – Direct exposure to in-water sediment and surface water
- **Tribal Fisher** – Direct exposure to beach sediment or in-water sediment and fish consumption
- **Fisher** – Direct exposure to beach sediment or in-water sediment, fish consumption, and shellfish consumption.

[6] See footnote 5.

There is no information documenting whether shellfish consumption actually occurs on an ongoing basis within the Study Area. Similarly, an exposure scenario for future residential use of LWR water was also included to evaluate hypothetical domestic use of untreated surface water (ingestion and dermal contact), even though there are no current plans for future use of the LWR within Portland Harbor as a domestic water source.

The human health risk assessment CSM presented in Figure 8.2-1 of the RI report illustrates the pathways that chemicals may follow from exposure media to the potential receptor populations.

11.8.2 BHHRA Exposure and Toxicity Assessments

The exposure assessment followed the reasonable maximum exposure (RME) methods recommended by EPA and also incorporated central tendency values, which represent average exposures, for certain exposure assumptions. However, for some exposure scenarios, such as fish consumption, the exposure assumptions were based on upper-bound (i.e., 90th, 95th, and 99th) percentiles only.

Exposure point concentrations for sediment, surface water, groundwater seeps, and tissue were calculated for individual exposure areas and on a Study Area-wide basis. Assumptions about each population evaluated in the BHHRA were used to select exposure parameters to calculate the pathway-specific chemical intakes. Site-specific values were not available for all populations and pathways, so default values were used in those cases. Where default values were not available, best professional judgment based on knowledge of human uses of the Study Area or directives from EPA were used to quantify exposure parameters. Because many of the exposure scenarios that were evaluated in the BHHRA do not have standard default exposure factors, the assumptions made to quantify exposure parameters are conservative and health-protective. The resulting uncertainties are anticipated to result overestimation of risk.

Toxicity values for carcinogenic and noncarcinogenic endpoints provide a quantitative estimate of the potential for adverse effects resulting from exposure to a chemical. Toxicity values used in the BHHRA are presented in Section 4 of Appendix F. As described in Section 8.3 and Appendix F of this RI report, some toxicity values are based on exposure to chemical mixtures and not to individual chemicals. Because toxicity values used in the BHHRA are often extrapolated from the results of animal studies and include safety factors of 100 to 1,000 multipliers, actual risks within the Study Area are likely lower than the risk estimates calculated in the BHHRA.

11.8.3 Summary of Risks and Uncertainties

Noncarcinogenic and carcinogenic effects were evaluated separately in the BHHRA. To characterize potential noncarcinogenic effects, comparisons were made between projected intakes of substances and toxicity values using a hazard quotient (HQ) approach. The HQs with common toxicological endpoints were then summed to yield hazard indices (HIs) for each individual exposure area and for the entire Study Area.

To characterize potential carcinogenic effects, projected intakes and chemical-specific, dose-response data were used to estimate the probability that an individual will develop cancer over a lifetime of exposure to the potential carcinogen.

The results of the risk characterization are presented in Section 8.4.2 and Appendix F of this RI report. The following presents the major findings of the BHHRA:

- Risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment, surface water, or seeps. Risks from fish and shellfish consumption are within or above the cumulative cancer risk range of 10^{-6} to 10^{-4} and exceed a HI of 1. With the exception of two half-mile river segments on the west side of the Study Area near RM 6 and near RM 7 for the tribal fisher scenario, direct contact with sediment, surface water, and seeps results in risks within or below the EPA target cancer risk range of 10^{-6} to 10^{-4} and below the target noncancer HI of 1.

- For the fish consumption scenario, PCBs are the primary risk driver, and dioxins/furans are a secondary risk driver. Total PCBs were found to account for 90 percent of the risk for fish ingestion. Together, PCBs and dioxins/furans contribute approximately 98 percent of the cumulative cancer risk for fish ingestion. Risks from PCBs based on consumption of fish within the Study Area exceed the EPA target risk range of 10^{-6} to 10^{-4}, with a maximum estimated risk of 6×10^{-2}.

- The impact of uncertainties associated with the tissue consumption scenarios will be considered when using the results of the BHHRA in risk management decisions. For example, the fish tissue consumption risks in the BHHRA incorporate assumptions that may underestimate, or more likely overestimate, the actual risks.

- On a regional basis, risks from exposure to bioaccumulative compounds in tissue exceed EPA target risk levels. For example, the PCB concentrations detected in resident fish from the Willamette and Columbia rivers are approximately 20 to 100 times higher than the EPA target fish tissue concentration, which is based on a target risk level of 10^{-6} (EPA 2000c).

- The contribution of background sources of COCs is an important consideration in risk management decisions. For example, it was found that approximately 50 percent of the highest risk to tribal fishers from exposure to beach sediment is associated with arsenic concentrations that are at or below the background arsenic concentration of 7 mg/kg (DEQ 2007b).

The BHHRA identifies numerous uncertainties related to exposure assumptions and toxicity information that are inherent in conducting risk assessments (see Section 7 of Appendix F). The cumulative effect of these uncertainties could be significant to the

conclusions of the BHHRA; these uncertainties should be considered when making risk management decisions.

The results of the BHHRA will be used to support the development of remedial action objectives and to inform risk management decisions for the Site.

11.9 BASELINE ECOLOGICAL RISK ASSESSMENT

The general objectives of the BERA prepared for the RI/FS are:

- Identify the risks posed by chemical contaminants to aquatic and aquatic-dependent ecological receptors in the Portland Harbor Study Area
- In the event that unacceptable ecological risks are found and require remedial actions in the Study Area, provide information that risk managers can use to set cleanup levels protective of ecological receptors.

Data from all LWG sampling rounds, as well as other relevant and acceptable sources (see Table 4-1 of Appendix G), combined with a series of exposure assumptions and effects thresholds, formed the basis of the risk estimates in the draft BERA.

11.9.1 Ecological Setting of the BERA

Within the Study Area, the LWR is typical of an industrialized urban river corridor, with a highly developed shoreline and channel modified for marine uses, manufacturing, and navigation. Some ecological habitats with plant and animal communities remain in the Study Area, despite extensive anthropogenic uses that limit the area of existing wetlands in shallow-water and riparian areas (see Map 2-2 of Appendix G). The invertebrates, fishes, birds, mammals, amphibians, reptiles, and aquatic plants in the LWR include native species, as well as non-native species that are important in the food web (e.g., centrarchid fish; see Tables 2-3 through 2-9 of Appendix G). Each group makes an important contribution to the ecological function of the river based on its trophic level, abundance, and interaction with the physical environment. Details on the ecological habitat types and species present in the Study Area are presented in Section 3.6 of the RI and in Appendix G.

11.9.2 BERA Problem Formulation

The problem formulation for the BERA includes the refinement of preliminary contaminants of ecological concern (i.e., COPCs), selection of assessment and measurement endpoints, development of a CSM and risk questions, and development of an analysis plan (see Attachment 2 of Appendix G). The ecological receptors selected for this assessment include:

- **Benthic invertebrate community** – Benthic macroinvertebrate community as a whole, clams, and crayfish

- **Fish populations –** Various species in different trophic guilds (i.e., omnivores, invertivores, piscivores, and detritivores)
- **Bird populations** – Sediment-probing invertivore (spotted sandpiper), omnivore (hooded merganser), and piscivores (osprey and bald eagle)
- **Mammal populations** – Aquatic-dependent carnivores **(**mink and river otter)
- **Amphibian and reptile populations**
- **Aquatic plant community**.

The assessment endpoints for all receptors are based on the protection and maintenance of their populations and the communities, with the exception that protection of individual organisms was designated by EPA as the assessment endpoint for juvenile Chinook salmon, Pacific lamprey ammocoetes, and bald eagle. Table 3-1 of the BERA summarizes assessment and measurement endpoints along with lines of evidence.

The ecological CSM presented in Figure 9-1 of the RI report illustrates the pathways that chemicals may follow from exposure media to the ecological receptors.

11.9.3 Overall Ecological Risk Conclusions

The results of the BERA will be used to produce risk-based preliminary remediation goals (PRGs) and identify AOPCs, and potentially to support development of practical risk management objectives during the course of the FS. Key findings of the draft BERA are discussed below (see also Table 11-2 of Appendix G).

The risk conclusions of the BERA are as follows:

- In total, 31 COCs (as individual chemicals, sums, or totals) were identified for the Study Area. The majority of COCs identified in the draft BERA were determined to pose no unacceptable risks to ecological populations or communities.

- Potentially unacceptable ecological risks are primarily from four COCs: total PCBs, total dioxins and furans, total DDx, and total PAHs.

- Bioaccumulation of PCBs by receptors and their prey poses the most significant ecological risks of all COCs evaluated. Mink and otter were identified as the ecological receptors at greatest risk and as having the largest spatial extent of risk (see Figure 8-5 of Appendix G). Most unacceptable ecological risks from other COC-receptor pairs are spatially collocated with mink PCB risks. Hence, the potentially unacceptable ecological risks for other COC-receptor pairs likely would be reduced or eliminated as a result of remedies in areas of elevated PCBs.

- Other areas of potentially unacceptable risk were identified for the benthic invertebrate community based on exceedances of sediment quality guidelines (SQGs) for PAHs and DDx, primarily in portions of the middle reach of the Study

Area (RM 5 to 8). Approximately 5 percent of the Study Area poses potentially unacceptable risk to the benthic community.

- Surface water and TZW results do not identify any additional ecological risk areas.
- Exposure to mercury concentrations in fish was found to pose potentially unacceptable risk to individual bald eagles; however, mercury contamination is a greater Willamette River issue requiring watershed-scale risk management.
- Background levels of chemicals are an important factor, in addition to site-specific releases, contributing to unacceptable ecological risk in the Study Area.

The draft BERA identified uncertainties associated with the risk conclusions. Following the methods of EPA's Problem Formulation, the identification of COCs was conducted using conservative methods and assumptions, with the consequence that not all COCs pose unacceptable ecological risk. The most important conservative assumption in the draft BERA's COC selection process was the assumption that effects on organisms translate into effects on ecological populations and communities. Populations compensate for individual losses through a variety of ecological processes, so individual-level risks do not necessarily imply population-level risks.

11.10 CONCEPTUAL SITE MODEL

The CSM (Section 10) synthesizes the information gathered through extensive physical, chemical, and biological characterizations of the Portland Harbor Study Area to provide a coherent picture of the history of the Study Area, current site conditions, risks posed, historical releases and ongoing sources. The CSM will also be used in the identification and evaluation of remedial alternatives in the FS. The CSM will be revised during the FS.

11.10.1 Physical Setting

The Study Area is a relatively low-energy depositional reach of the LWR and the entire Willamette River Watershed. The reaches upstream (from approximately RM 11 to the Willamette Falls at RM 26) and downstream of the Study Area (RM 1.9 to the Columbia River) are narrower than the Study Area, and the Multnomah Channel exits the LWR at RM 3, considerably reducing the LWR discharge downstream of this point. This physical configuration and the associated hydrodynamic interactions generally result in the deposition and accumulation of sediments in much of the Study Area, with prominent channel shoals from RM 2 to 3 and RM 8 to 10. Conversely, some channel segments (e.g., RM 5 to 7) are more dynamic. Nearshore and off-channel (e.g., Swan Island Lagoon) areas are generally depositional but some of these areas are subject to anthropogenic disturbance and sediment resuspension (e.g., boat propwash).

11.10.2 Sources

Historical industrial activities and facilities in the Study Area and upriver areas date back to the late 1800s and include shipbuilding, repair, and dismantling; wood treatment operations and lumber mills; bulk fuel facilities and manufactured gas plants; chemical plants; steel mills; metal recycling; rail yards; electricity generation and distribution; and other urban and industrial activities. Chemicals used in these operations or generated as waste, as well as chemicals from municipal and agricultural sources, have reached the river through public and private conveyances, overland flow, overwater releases and spills, bank erosion, and through groundwater transport. Contaminants from regional sources have also reached the Study Area via upstream surface water and sediment inputs and atmospheric deposition to the river surface and local stormwater drainage. A wide range of chemicals, including metals, PCBs, PCDD/Fs, pesticides, petroleum and other hydrocarbons, and phthalates have been released to the river over the decades.

Historical sources are likely the primary source of the observed chemical distributions in sediments, reflected in the extent and degree of subsurface sediment contamination observed in the Study Area. While some chemicals continue to enter the river from lateral and upstream sources, loading to the river has been reduced over time due to ceased operations, much improved management practices, and source control.

For PCBs, the main external ongoing sources quantified in the RI are upstream surface water inputs encompassing all upstream watershed sources, and in the Study Area, local stormwater, and atmospheric deposition. Some unquantified terms, e.g., bank erosion, may also be important in localized areas. These ongoing inputs may account for the low levels (that are comparable to upriver levels) seen across much of the Study Area, but the distribution of elevated PCB concentrations in sediments in many nearshore portions of the Study Area appears to reflect more significant historical localized lateral inputs. The spatial correlation between elevated levels of PCBs in tissues with elevated concentrations in sediments suggests that bottom sediments are an ongoing source of PCB contamination to biota.

Currently known and likely sources and pathways for specific ICs are documented in Panels 10.2-1 through 10.2-13 and Tables 10.2-1 through 10.2-13 on a chemical-by-chemical basis. These include, but are not limited to, bulk fuel storage, ship building at one site, ship repair, automobile scrapping, recycling, steel manufacturing, cement manufacturing, electrical transformer reconditioning and repair, electrical substations, and many smaller industrial operations. Additional sources may yet be identified, and the CSM will be updated as necessary during the FS and subsequent pre-remedial design studies and investigations.

11.10.3 Risk

Total PCBs were found to account for 90 percent of the risk posed to human health, primarily via fish consumption. Together, PCBs and dioxins/furans contribute

approximately 98 percent of the cumulative cancer risk for fish ingestion. However, even regional tissue concentrations of PCBs pose potentially unacceptable human health risk through fish consumption under the conservative, health-protective assumptions made in the BHHRA to calculate risks.

For direct contact with sediment, surface water and seeps, there are two half-river-mile segments on the west side near RM 6 and near RM 7 that exceed the EPA target cancer risk range of 10^{-6} to 10^{-4} or the target noncancer HI of 1 for either RME or central tendency scenarios. The remaining areas that compose the Study Area do not pose unacceptable risk from exposure to these media.

PCBs are also the most significant contributor to ecological risk, and the highest estimated risk from PCB exposure through the dietary pathway was found for mink. Only PCBs were identified as a COC for all six ecological receptor groups (benthic invertebrates, fish, birds, mammals, amphibians, and aquatic plants) and represented potentially unacceptable risks in all reaches of the Study Area for certain receptors (e.g., mink and river otter). Other COCs were spatially limited in their distribution and are unlikely to pose unacceptable risks to fish and wildlife populations at the levels of exposure occurring in the Study Area. Mercury was found to pose an unacceptable risk to individual bald eagles, but mercury contamination of fish and resulting risks to the bald eagle are a regional issue unrelated to sources within the Study Area. PCBs, PAHs, and/or DDx pose a potentially unacceptable risk to the benthic invertebrate community or populations on a station-by-station basis for approximately 5 percent of the Study Area.

11.10.4 Chemical Distribution, Current Chemical Loading, Fate and Transport, and Future Risk

Elevated concentrations of ICs in the Study Area are generally located in nearshore areas adjacent to known or likely historical or current sources (see Panels 10.2-1 through 10.2-4), and higher levels of multiple ICs are often collocated in these areas. An exception to this pattern is elevated levels of some IC (e.g., PAHs, PCBs) in the higher energy portion of the channel in the middle of the Study Area (RM 5–7); this may reflect past or current dispersal of material away from nearshore source areas. Throughout the Study Area, IC concentrations are generally higher in subsurface sediments than in surface sediments, indicating both higher historical inputs and improving sediment quality over time.

Areas with elevated IC concentrations in surface sediments generally correspond to areas of elevated subsurface sediment IC concentrations. Areas where only surface or subsurface sediments exhibited elevated concentrations of ICs point to spatially and temporally variable inputs and sources, or to different influences from sediment transport mechanisms. The PCB homolog distributions in areas of elevated PCB concentrations are generally distinct from those in surrounding areas of lower PCB concentrations. Within areas of elevated PCB concentrations, the PCB homolog patterns in surface and subsurface sediment, sediment traps, and in the particulate

portion of the surface water samples are often similar. A similar pattern and similar composition across media was observed to a lesser degree for PAHs, but was less apparent for PCDD/Fs or DDx compounds.

Localized exceptions to the pattern of higher subsurface sediment concentrations exist in a few areas for some ICs, likely reflecting more recent releases or disturbances of bedded sediments.

The principal current external loads of most ICs to the Study Area are upstream surface water inputs, which include all upstream watershed sources of ICs (including stormwater) and stormwater inputs in the Study Area. Within the Study Area, atmospheric deposition directly to the river surface may also be an important current loading term for some ICs (e.g., DDx). Subsurface advective loading is the largest current estimated loading term for two ICs, total PAHs and TBT. Other external loads, such as bank erosion, may be important in localized areas but were not quantified in the RI.

While the RI catalogues or estimates historical and current sources of ICs to the Study Area, not all sources have been identified. Current inputs of ICs to the Study Area from upstream surface waters may explain the widespread, relatively low concentrations of many ICs within the Study Area away from nearshore sources areas and in known sediment accumulation areas (e.g., in the borrow areas at the upstream end of the Study Area, see Section 5.6). However, the distribution of elevated IC concentrations in nearshore sediments appears to indicate higher historical and, in some cases, current inputs from known or likely local sources. The general spatial correlation of higher levels of bioaccumulative ICs in tissues with the higher concentrations of these ICs in sediments indicates that surface sediments are an ongoing source of contamination to biota. The bioaccumulation modeling and the FS fate and transport modeling efforts are ongoing, and quantitative statements about the relative contribution of sediment versus other sources to tissue residues cannot yet be made.

Based on bedded sediment concentration gradients downstream of areas with elevated sediment concentrations, limited downstream dispersal of some ICs in sediments is suggested, although much larger historical direct discharges rather than post-depositional downstream dispersal could have produced some of the observed patterns (e.g., elevated levels in subsurface sediments downstream of the source areas). Neverthelesss, most areas of elevated IC concentration in bedded sediment are located in stable nearshore areas, and large-scale downstream migration/disperal of concentrated contaminants from these areas is not indicated by the bedded sediment data. Sediment transport modeling using simulated flood conditions suggests that significant erosion deeper than 30 cm is likely to occur only in the navigation channel in the sand-dominated upstream (above RM 10) and mid-Study Area (RM 5–7) reaches. Sediments below 30 cm in these areas generally do not have high concentrations of ICs, indicating that the risk of re-exposure of buried contaminants and large-scale downstream dispersal of contamination is low on a harbor-wide scale.

Finally, the loading estimates presented in this RI suggest that the current mass flux of many ICs exiting the downstream end of the Study Area in surface water and suspended sediments is greater than the estimated flux entering the Study Area from upstream. Although there is uncertainty in the quantified loading estimates, this suggests that Study Area sources influence the quality of surface water and suspended sediments that move through the harbor. These sources likely include external inputs, such as stormwater and atmospheric deposition, as well as internal inputs, such as the mass transfer of chemicals from bedded sediments to the water column through sediment resuspension.

11.11 CONCLUSIONS AND NEXT STEPS

Conclusions and next steps are presented below.

11.11.1 Conclusions

The key findings of the Draft RI include the following:

Extent of Contamination

- Sediments in Portland Harbor reflect the industrial, marine, commercial, and municipal practices for over 100 years in this active industrial, urban, and trade corridor, as well as agricultural activities in the Willamette Basin.
- Higher concentrations of contaminants in sediments occur in nearshore and off-channel areas that are generally associated with known or likely historical or current sources.
- Chemical concentrations in sediment are generally higher at depth than in the surface layer, indicating that past chemical inputs were greater than current inputs, and that surface sediment quality has improved over time. The few exceptions include areas where higher surface sediment concentrations appear to be associated with ongoing local sources, low rates of sediment deposition, and physical sediment disturbance (e.g., from boat scour).
- Except for the nearshore areas of relatively high chemical concentrations, concentrations of many chemicals in the remainder of the Study Area, including much of the navigation channel, are similar to levels measured in sediments in the upriver or background reach from Ross Island to the Willamette Falls, an area unaffected by Portland Harbor sources.

Estimates of Risk

- PCBs, and to a lesser extent dioxins/furans, PAHs, and DDx, account for almost all of the estimated human health risk. PCBs are the most significant contributors to human health risk, with ingestion of fish representing the primary exposure pathway and the highest estimated risk. Consumption of fish and shellfish from the Study Area may pose health risks to humans that are greater

than the EPA target risk range for human health (greater than one in a million [10^{-6}] to one in ten thousand [10^{-4}] excess risk of cancer).

- PCBs are also the most significant contributor to the estimated ecological risks, with the mink population being the receptor most at risk from PCB exposure. PCB risk to spotted sandpiper and bald eagle are elevated, but not as high as for mink. Along with PCBs, other chemicals (e.g., PAHs and DDx) were associated with toxicity to benthic invertebrates in several areas constituting approximately 5 percent of the Study Area. The estimated risks to fish from PCBs and other site-related chemicals are negligible.
- To be protective of humans, fish, and wildlife, conservative risk assessment methods were used to minimize the chance of underestimating exposure and risk. As a result, the cumulative effects of the numerous conservative health protective assumptions made during the evaluation of this exposure pathway result in risk estimates that may be higher than actual risks within the Study Area.
- PCBs are a highly persistent compound found in fish on a regional (i.e., watershed-wide) and global level. Fish caught in the Willamette and Columbia rivers, outside of the Study Area, also contain PCBs that pose potentially unacceptable risk.

Sources of Chemical Contamination

- Much of the sediment contamination in the Study Area is from historical sources and practices that have been controlled. Historical activities in the harbor include or have included ship building, dismantling and repair; gas and chemical manufacturing; steel production; wood treatment operations; metal recycling; fuel storage and transfer operations; electrical production and distribution; and rail yards.
- Municipal/commercial activities along the harbor include or have included ship terminals, an airport, and wastewater and stormwater outfalls, as well as general runoff.
- A comparison of the relative mass of contaminants in bedded sediment with the current loading rates indicates that past releases of chemicals related to historical upland and overwater activities likely account for most of the exisitng contamination in the Study Area.
- Chemicals still reach the Study Area in stormwater, permitted industrial discharges, atmospheric deposition, bank erosion, groundwater, and incidental releases within the Study Area, as well as in surface water and sediment inflows from upstream.
- Based on loading estimates, the current mass of most contaminants entering the Study Area from upstream river flows (in surface water and suspended sediments) per year exceeds the current mass from upland sources within the

Study Area. This is due to the very large relative volume of water and sediments that enter the Study Area from upstream.

- Chemical concentrations in lateral external loads that enter the Study Area (such as stormwater) are generally greater than concentrations in the upstream external loads (upriver surface water and sediments). Consequently, discharges of contaminants through stormwater outfalls and other pathways, depending on the specific release locations, may cause localized areas of elevated chemical concentrations in bottom sediment.
- Stormwater input is the most important current source pathway within the Study Area (i.e., excluding upstream sources) for many chemicals, including PCBs and DDx.
- Contributions of contaminants to the Study Area via groundwater are currently known to be limited to only a few upland plumes.

Potential for Contaminant Transport within and Downstream of the Study Area

- Most of the sediments with elevated chemical concentrations that pose risk are in relatively stable, nearshore areas.
- The spatial distribution of chemicals and sediment transport dynamics suggest that some downstream migration of contaminants has occurred from past large releases and/or periodically occurs within the Study Area from locations with highly elevated sediment concentrations. This will be further evaluated in the FS fate and transport modeling effort.
- Most nearshore areas and much of the navigation channel are stable, depositional environments. Two well-defined portions of the channel (i.e., RM 5 to 7 and upstream of RM 10) are more dynamic and potentially subject to erosion during flood events. Deep sediments (>30 cm sediment depth) in these areas are generally not highly contaminated, so the risk of re-exposure of buried contaminants and large-scale downstream dispersal of contaminants is limited in spatial extent on a harbor-wide scale.
- There is little evidence from concentration gradients in bedded surface sediment data of significant migration of chemicals immediately downstream of the Study Area in either the Willamette River main stem or Multnomah Channel.
- These key findings provide the framework for evaluating alternatives to remediate areas of unacceptable risk to humans and/or ecological receptors.

11.11.2 Next Steps

The key RI findings described above were developed specifically to inform the framework for identifying, analyzing, and comparing alternatives to remediate areas of elevated risk to humans and/or ecological receptors in the FS. The next major milestone of the Portland Harbor RI/FS will be the preparation of a draft FS that will

identify appropriate cleanup strategies and methods. The results of the RI/FS will be used by EPA to identify specific areas of the Site that will require cleanup.

Consistent with EPA RI/FS guidance, the Portland Harbor RI and FS are interactive efforts. The Draft RI provides an extensive library of information, including the following: Study Area physical, chemical, and biological characteristics; source identification; contaminant loading; a site-wide CSM; and risk assessment results sufficient to conduct a comprehensive FS. No additional sampling data are anticipated to be needed to complete the FS; however, new data may be incorporated as they become available.

To support the FS, some tasks begun under the RI will be completed as part of the FS:

- **Fate and transport modeling** – Fate and transport models will support the evaluation of the effectiveness of remedial alternatives in the FS. They will also be used to assess the potential for recontamination of the Site from upland or upstream sources after implementation of potential remedies. The HST model developed for the RI will be refined and coupled to chemical fate and transport models to achieve these objectives. In addition, the relative contribution of chemicals in sediment and surface water to chemicals in fish and wildlife resulting from sediment versus surface water contamination will be evaluated using the fate and transport and bioaccumulation models developed for the RI/FS.
- **Ongoing source inventory update** – Additional source information, including appropriate data collected by others, will be compiled in the FS to develop an updated inventory of ongoing sources for each potential in-water cleanup area. This information will be used to address the potential for unacceptable levels of recontamination or the need for DEQ to undertake upland source controls.
- **Refinement of the Conceptual Site Model** – The CSM provided in the Draft RI will be refined as necessary and focused on individual sediment management areas identified in the FS.

To expedite development of the FS, EPA and the LWG have started to discuss PRGs and AOPCs. Early PRGs and AOPCs will be refined following EPA's review of the Draft BHHRA and Draft BERA. The refined PRGs and AOPCs will be incorporated into the FS. The LWG is currently proceeding with initial development and screening of remedial alternatives. Following EPA's review of the alternatives screening effort, the LWG will proceed with a detailed evaluation and comparative analysis of the remedial alternatives in accordance with EPA's evaluation criteria, culminating in development and submittal of the Draft FS report.