APPENDIX B

REVISED DRAFT WORK PLAN ENGINEERING EVALUATION/COST ANALYSIS, ARKEMA REMOVAL ACTION (INTEGRAL 2006)

Revised Draft

WORK PLAN

ENGINEERING EVALUATION/COST ANALYSIS
ARKEMA REMOVAL ACTION

PORTLAND, OREGON

Prepared for

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This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part.

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ACRONYMS AND ABBREVIATIONS

AHPA	Archaeological and Historical Preservation Act
AOC	Administrative Order on Consent
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
ATT	aquatic toxicity test
BA	biological assessment
BEDS	biological effects database for sediments
bgs	below ground surface
BNAs	base-neutral acid extractables
BNSF	Burlington Northern Santa Fe
BPA	Bonneville Power Administration
BSAF	biota-sediment accumulation factor
BTEX	benzene, toluene, ethylbenzene, xylenes
CAD	confined aquatic disposal
CAS	Columbia Analytical Services, Inc.
CCWQ	Certification and Compliance with Water Quality
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	chemical of concern
COI	chemical of interest
CPD	City of Portland Datum
CRD	Columbia River Datum
CFR	Code of Federal Regulations
CSF	cancer slope factor
C/S-F	concentration/screening factor
CSM	conceptual site model
CST	column settling test
CU	consolidated, undrained
CWA	Clean Water Act
cVOC	chlorinated volatile organic compound
DCHH	direct contact human health
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-dichloroethene
DDT	dichloro-diphenyl-trichloroethane
DDx	total 2,4′- and 4,4′-DDD, DDE, DDT
DEA	David Evans and Associates
DEQ	Oregon Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid

DOC	dissolved organic carbon
DRET	dredging elutriate test
DSL	Oregon Department of State Lands
ECSI	environmental cleanup site information
EE/CA	engineering evaluation/cost analysis
EET	effluent elutriate test
EFH	essential fish habitat
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ER-L	effects range low
ER-M	effects range median
ESA	Endangered Species Act
FCR	field change record
FER	Fugitive Emissions Requirements
FS	feasibility study
FSP	field sampling plan
GUS	Gregory undisturbed sampler
HASP	health and safety plan
HHRA	human health risk assessment
IGPO	Indian Graves and Protected Objects
IRM	interim remedial measure
ISA	initial study area
LL	liquid limit
LSS	Legacy Site Services LLC
LWG	Lower Willamette Group
LWR	lower Willamette River
LWRMP	Lower Willamette River Management Plan
JSCS	Joint Source Control Strategy
MCB	monochlorobenzene
MCL	maximum contaminant level
MPR	manufacturing process residue
NA	natural attenuation
NAGPR	Native American Graves Protection and Repatriation Act
NAPL	non-aqueous phase liquid
NAVD	North American Vertical Datum
NAS	Northwest Aquatic Services, Inc.
NCP	National Contingency Plan
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRWQC	National Recommended Water Quality Criteria

NTCRA	non-time critical removal action
OAR	Oregon Administrative Rules
OCTF	Old Caustic Tank Farm
ODFW	Oregon Department of Fish and Wildlife
PAH	polycyclic aromatic hydrocarbon
PBT	persistent bioaccumulative toxins
PCB	polychlorinated biphenyls
PCDD/F	polychlorinated dibenzo-*p*-dioxin and furan
PCP	pentachlorophenol
PEC	probable effects concentration
PEL	probable effect level
PI	plasticity index
PID	photoionization detector
PL	plastic limit
PRD	Portland River Datum
PRE	preliminary risk evaluation
PRG	preliminary remediation goal
PTSV	principal threat screening values
QA/QC	quality assurance and quality control
QAPP	quality assurance project plan
RA	removal action
RAA	removal action area
RAO	removal action objectives
RCRA	Resource Conservation and Recovery Act
RFD	reference dose
RFLR	Removal Fill Laws and Regulations
RI	remedial investigation
RME	reasonable maximum exposure
ROD	record of decision
RPD	relative percent difference
SAP	sampling and analysis plan
SBLT	sequential batch leaching test
SCR	site characterization report
SDWA	Safe Drinking Water Act
SLML	Submerged Land Management Laws
SLV	screening level value
SOW	statement of work
SPT	standard penetration test
SQV	sediment quality value
STA	sediment trend analysis
SWMA	Solid Waste Management Act

SWPCP	storm water pollution control plan
SVOC	semivolatile organic compound
TAL	target analyte list
TBC	to be considered
TBT	tributyltin
TCDD	tetrachorodibenzo-*p*-dioxin
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TEC	threshold effects concentration
TEL	threshold effects level
TIR	thermal infrared imaging
TLC	thin layer chromatography
TLP	thin-layer placement
TOC	total organic carbon
TPH-D	total petroleum hydrocarbons-diesel range
TPH-G	total petroleum hydrocarbons-gasoline range
TSCA	Toxic Substances Control Act
TSS	total suspended solids
TTF	trophic transfer factor
TZW	transition-zone water
UU	unconsolidated, undrained
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VES	vapor extraction system
VOC	volatile organic compound
WDFW	Washington Department of Fish and Wildlife
WQC	water quality criteria
WQL	Water Quality Law

1 INTRODUCTION

This work plan is for an engineering evaluation/cost analysis (EE/CA) in support of a non-time critical removal action (NTCRA) for the Arkema Inc. facility in Portland, Oregon (Figure 1-1). The primary objective of the NTCRA is to address, at a minimum, the principal threat contamination extending from the top of the riverbank on the Arkema site into the Willamette River, including unsubmerged and submerged lands. The purpose of this EE/CA work plan is to summarize and analyze existing information and data for the Arkema site, develop a conceptual model of the fate and transport of chemicals of interest (COIs) related to historical site operations, evaluate data gaps where additional data may be needed, and propose a scope of work and sampling plan to complete the EE/CA for the Arkema Removal Action (RA).

Integral Consulting Inc. is conducting this work under contract with Legacy Site Services LLC (LSS)[1]. The Arkema proposed action meets the criteria for initiating a removal action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This work plan has been prepared in accordance with an Administrative Order on Consent (AOC) for Removal Action and Statement of Work (SOW) signed by Arkema and the U.S. Environmental Protection Agency (EPA) with an effective date of June 27, 2005 (Docket No. CERCLA 10-2005-0191), and with EPA EE/CA guidance (USEPA 1993a).

An early and essential step in the NTCRA process is the completion of an EE/CA to address chemicals in sediments and on the riverbank that are considered principal threat areas. During the EE/CA, a removal action area (RAA) is defined, and a focused list of removal actions for the site is evaluated. At the end of the EE/CA process, a preferred removal action alternative is selected to address the principal threat in the RAA.

This work plan incorporates several attachments. Altogether, these documents are referred to as the EE/CA work plan for the Arkema RA:

- ***Field Sampling Plan* [FSP], *EE/CA Arkema Removal Action, Portland, Oregon* (Attachment 1).** The FSP provides specific guidance for field methodology and quality assurance procedures that will be followed by Integral and its subcontractors.
- ***Quality Assurance Project Plan* [QAPP], *EE/CA Arkema Removal Action, Portland, Oregon* (Attachment 2).** The QAPP describes laboratory methodology

[1] LSS is Arkema's agent for all environmental matters at the Portland site.

and quality assurance/quality control (QA/QC) procedures that will be used to complete the EE/CA for the Arkema In-Water RA.

- ***Project Health and Safety Plan* [HASP], *EE/CA Arkema Removal Action, Portland, Oregon* (Attachment 3).** The HASP has been prepared in conformance with Integral's Health and Safety Plan guidelines and in accordance with Occupational Safety and Health Administration regulations (29 CFR 1910.120) and project requirements. The HASP addresses those activities associated with work to be performed on the Arkema site.
- ***Integral Standard Operating Procedures* [SOPs].** The SOPs provide specific, detailed information on conducting routine, repetitive field techniques (e.g., split-spoon sampling from a drill rig). These documents are found in Appendix A of the FSP.

1.1 PROJECT BACKGROUND

The Arkema property is located on the southwest bank of the Lower Willamette River (LWR) between river mile (RM) 6.9 and 7.6, immediately upstream of the Burlington Northern Santa Fe (BNSF) Railroad Bridge (Figure 1-1). The property is located within Portland Harbor, which was designated a federal Superfund site by EPA in 2000 based on sediment contamination. The initial study area (ISA) of the Portland Harbor Superfund site encompasses about 5.7 miles of the Willamette River from approximately the southern tip of Sauvie Island at RM 3.5 to the southern end of Swan Island at RM 9.2. The ISA does not define the Superfund Site; the boundaries of the Site will be determined upon issuance of a Record of Decision (ROD; Integral et al. 2004b). The Lower Willamette Group (LWG), a consortium including the Port of Portland, the City of Portland, and private industry, has been working to complete a remedial investigation (RI) of the LWR including the ISA and areas both upstream and downstream of the ISA.

Inorganic chemicals were manufactured at the Arkema site from 1941 until 2001, when the facility was closed and chemical manufacturing discontinued. For most of the site's history, the chemical activities involved electrolytic decomposition of brine solutions to manufacture inorganic chemicals, including sodium chlorate, chlorine, sodium hydroxide, hydrogen, and hydrochloric acid. Other chemical manufacturing processes during the site's operational history included the production of dichloro-diphenyl-trichloroethane (DDT) from 1947 to 1954, and ammonium perchlorate from 1958 to 1962 (ERM 2005d).

Arkema (also formerly known as ATOFINA Chemicals, Inc., Elf Atochem North America, Inc., and Pennwalt) has conducted investigations and several interim remedial measures (IRMs) in the upland portion of the site since 1994. In 1995, Arkema (then known as Elf Atochem) submitted an intent to participate in the Oregon Department of Environmental

Quality (DEQ) Voluntary Cleanup Program, an agreement which was later signed with DEQ in 1996. In 1998, Arkema signed a voluntary agreement with DEQ to complete a remedial investigation and feasibility study (RI/FS) of the former DDT manufacturing area. The RI/FS was later expanded to include other areas and chemicals at the site (e.g., hexavalent chromium and perchlorate). For the RI, Arkema completed two phases of in-river investigation to assess the extent of chemicals from the former DDT manufacturing process in nearshore Willamette River sediments and groundwater. Data collected for the Portland Harbor RI/FS, for the site-wide Arkema RI, and for other relevant investigations are also available and will be evaluated and used in the EE/CA.

Arkema has implemented significant IRMs and source control actions at the site to address contaminated soil and groundwater. In 2000 and 2001, Arkema completed two phases of excavation and disposal to remove surface and subsurface soil with elevated DDT concentrations from the former manufacturing process residue pond and trench. Arkema has also conducted vapor extraction and air sparging in the upland portion of the site to address chlorobenzene that is present in groundwater in both dissolved and non-aqueous phases. Full-scale implementation of groundwater treatments for hexavalent chromium, chlorobenzene, and DDT are ongoing. Studies of *in situ* treatments for perchlorate in groundwater have been completed, and preparations are underway to begin field treatability studies. Additional descriptions of IRMs and source control actions are provided in Section 4.1.5 and Section 9.2.

Portland Harbor is a heavily industrialized reach of the LWR and has been the site of numerous manufacturing, shipbuilding, petroleum storage and distribution, metals salvaging, and electrical power generation activities for over a century. Other current and historical industrial sites have an impact on the Arkema RAA. Neighboring industrial facilities and their primary COIs that are potentially contributing to the RAA include the following:

- **CertainTeed Roof Product Manufacturing:** petroleum-related volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs)

- **Willbridge Bulk Fuel Storage Terminal:** petroleum hydrocarbon-related chemicals, VOCs, polycyclic aromatic hydrocarbons (PAHs), and metals

- **Bayer CropScience, LP (formerly Rhône-Poulenc) Fertilizer, Herbicide, and Pesticide Manufacturer:** VOCs, SVOCs, phenolics, herbicides, pesticides (including DDT), PCDD/Fs, and metals.

Neighboring facilities are described in more detail in Section 2.2.2. In addition to these nearby facilities, the RAA is subject to contributions of contamination from contaminant sources along the Willamette River upgradient of the property.

1.2 REMOVAL ACTION OBJECTIVES

The following removal action objectives (RAOs) for the Arkema RA are noted in the SOW of the AOC, dated June 27, 2005:

1. Reduce human health risks to acceptable levels from direct contact with and incidental ingestion of chemicals of concern (COCs) in sediments and riverbank within the RAA.
2. Reduce COC concentrations in sediments and riverbank within the RAA to levels that will result in acceptable risks to humans that eat fish and shellfish from the Willamette River.
3. Reduce human health risks to acceptable levels from direct contact with and incidental ingestion of water with COCs within the RAA.
4. Reduce ecological risks from contact with and ingestion of COCs in sediments or riverbank material or prey within the RAA to acceptable levels.
5. Reduce ecological risks to acceptable levels from contact with and ingestion of water with COCs within the RAA.
6. Eliminate the potential for migration of contaminants at unacceptable levels from the RAA to the Willamette River.
7. Reduce contaminant flux from uplands, riverbank, and sediments so that recontamination of any sediment or riverbank caps put in place does not occur.

In accordance with EE/CA guidance, the RAOs are intended to address the principal threat area of the site in the intertidal area and submerged lands on and adjacent to the Arkema site. This EE/CA work plan summarizes existing information and data for the Arkema site and includes an evaluation of data gaps where additional data may be needed to complete the evaluation of remedial alternatives in the EE/CA. The selected remedial alternative(s) for the Arkema RA must achieve these RAOs.

1.3 REGULATORY FRAMEWORK

The NTCRA for the Arkema site will be conducted under CERCLA, 42 U.S.C. §§ 9601 *et seq*. (as amended). CERCLA Section 121 (d) and requires that a cleanup: 1) be protective and, 2) if any hazardous substance will remain on the site, attain a level of cleanup that

complies with any legally applicable or relevant and appropriate requirement (ARAR). A preliminary list of statutes and regulations that may be considered ARARs for the project is included in Table 1-1. These and other potential ARARs can be generally categorized as chemical-specific, action-specific, or location-specific. ARARs for each of these categories will be finalized and selected in consultation with EPA during preparation of the EE/CA.

Table 1-1. Preliminary Project ARARs.

ARAR and Citation	Description	Applicability
Federal		
Federal Water Pollution Control Act/Clean Water Act (CWA) [33 USC Sections 1313, 1314, 1341 and 1344; 40 CFR Parts 131, 230]	The CWA establishes the basic structure for regulation of discharges of pollutants into the water of the United States. Section 404 (33 USC §1344) regulates the discharge of dredged material or fill into navigable waters. Section 401(33 USC §1341) requires state certification that a discharge will not violate state water quality standards.	The implementing regulations of the CWA are applicable to potential sediment dredging and capping actions.
Rivers and Harbors Appropriations Act [33 USC Section 403; 33 CFR Parts 230, 322]	The Rivers and Harbors Act prohibits unauthorized activities that obstruct or alter a navigable waterway. It controls the alteration of navigable waters (i.e., waters subject to ebb and flow of the tide shoreward to the mean high water mark). Activities controlled include construction of structures such as piers, berms, and installation of pilings. Section 10 may be applicable for any action that may obstruct or alter a navigable waterway.	The Rivers and Harbors Act regulations are applicable to potential remedial activities in the river including, sediment dredging and capping actions.
Resource Conservation and Recovery Act (RCRA) [42 USC Section 6921; 40 CFR Parts 260, 261]	RCRA provides standards for the identification and management of solid and hazardous waste.	These regulations are applicable because dredged/excavated material that contains a listed or characteristic waste could be subject to RCRA requirements for storage, treatment, and disposal.
The Endangered Species Act (ESA) [16 USC Section 1536; 50 CFR Part 402]	The ESA requires an evaluation of a federal agency's action's impacts on listed (or proposed for listing) species of fish, wildlife, or plants.	The ESA regulations are applicable because a removal action has the potential to impact listed species in the Willamette River.

Table 1-1. Preliminary Project ARARs.

ARAR and Citation	Description	Applicability
Floodplain Management and Wetlands Protection [40 CFR Part 6 App. A and Executive Order 11988 and 11990]	Floodplain Management and Wetlands Protection requires federal agencies to conduct their activities to avoid, if possible, adverse impacts associated with the destruction or modification of wetlands and occupation or modification of floodplains. Executive Order 11988 requires federal projects to avoid adverse effects associated with construction in floodplains.	This regulation is applicable because any removal action construction could at least in part be within a floodplain.
Magnuson-Stevens Fishery Conservation and Management Act [16 USC Section 1855(b); 50 CFR Part 600, subparts J-K]	Section 305(b) of the Magnuson-Stevens Act requires federal agencies to evaluate impacts to essential fish habitat (EFH) for activities that may adversely affect EFH.	This regulation is applicable because implementation of a removal action has the potential to impact EFH in the Willamette River.
Marine Mammal Protection Act [16 USC Section 1372]	EPA must ensure that the actions do not involve the unauthorized taking of marine mammals.	This regulation is unlikely to be applicable because marine species do not inhabit the lower Willamette River.
Hazardous Materials Transportation Act [49 USC Section 15101 *et seq.*; 49 CFR Section 171-177]	Regulations provide for packaging, documentation, and transportation of hazardous waste (some RCRA requirements also apply).	This regulation is applicable if any material dredged as part of the removal action is identified as hazardous waste and requires shipment for treatment or disposal.
National Historic Preservation Act (NHPA) [16 USC Sections 470h-2]	The NHPA requires EPA to consider the effects of remedial actions on historic properties.	This regulation is unlikely to be applicable because this site is not an historic property.
Archaeological and Historical Preservation Act (AHPA) [16 USC Sections 4699a-1]	In the event that significant scientific, prehistoric, or archaeological data are present on site, the AHPA requires EPA to approve the remedial activities so that such data are preserved.	This regulation is unlikely to be applicable because the site has not been shown to be an archaeological resource.
Native American Graves Protection and Repatriation Act (NAGPR) [25 USC Section 3001 *et seq.*]	The NAGPR act requires federal agencies and museums with possession or control over Native American human remains and associated funerary objects to compile an inventory of such items. It requires federal agencies and museums with possession or control over Native American non-associated funerary objects, sacred	This regulation is only applicable if Native American remains or funerary objects are at the site, which, based on current information, is considered very unlikely.

Table 1-1. Preliminary Project ARARs.

ARAR and Citation	Description	Applicability
	objects, or objects of cultural patrimony to provide a written summary of such objects. It prescribes when a federal agency or museum must return Native American cultural items.	
Safe Drinking Water Act (SWDA) [42 USC 300f *et seq.*]	The SDWA establishes maximum contaminant level (MCL) standards for the protection of drinking water sources.	This regulation is not applicable because the site is not impacting a drinking water source; however, the MCL standards are to be considered (TBC) in selecting a removal action for the site.
State		
Oregon Water Quality Law (WQL) [ORS 468b.005 – 468b.095 (surface water) and ORS 468B.150-190 (groundwater); Oregon Water Quality Standards and Criteria, OAR Chapter 340, Divisions 40 and 41]	The WQL designates beneficial uses of water bodies and water quality standards and criteria necessary to protect those uses. In particular, OAR 340-041-0340 provides the beneficial water uses that shall be protected in the Willamette Basin. OAR 340-041-0442 through 340-041-0445 provide water quality standards for the State of Oregon. With respect to groundwater, OAR 340-0404-020 and 340-0404-0303(3)(b) define an "antidegradation policy to emphasize the prevention of groundwater pollution and to control waste discharges to groundwater so that the highest possible water quality is maintained."	This regulation is applicable because the beneficial use of groundwater and the Willamette River must be protected. Water quality standards may apply to groundwater and the Willamette River.
Oregon Solid Waste Management Act (SWMA) [ORS 459.005 *et* seq.; OAR 340-094-0040]	The SWMA provides standards for the management and handling of solid wastes in Oregon.	This regulation is potentially applicable because disposal of nonhazardous materials may be disposed of at a Subtitle D landfill.
Hazardous Waste Regulations [ORS 466.005-466.225; OAR Chapter 340-101-0033]	Hazardous waste regulations provide standards for the identification and management of hazardous wastes in Oregon.	This regulation is applicable if any material dredged as part of the removal action is identified as hazardous waste and requires shipment for treatment or disposal in Oregon.

Table 1-1. Preliminary Project ARARs.

ARAR and Citation	Description	Applicability
Cleanup Standards [OAR 340-122-0040(2)(a), (4) and (6]	The cleanup standards provide hazardous substance remedial action levels and requirements.	This regulation is applicable to the establishment of cleanup levels and other requirements for the removal action.
Indian Graves and Protected Objects (IGPO) [ORS 97.740 *et seq.*]	The IGPO protects human remains, funerary objects, sacred objects, and objects of cultural patrimony.	This regulation is only applicable if Native American remains or funerary objects are at the site, which, based on current information, is considered very unlikely.
Archaeological Objects Site [ORS 358.905 *et seq.*]	The archaeological objects laws protect archaeological objects and sites; requires notice upon discovery of artifacts.	This regulation is unlikely to be applicable because the site has not been shown to be an archaeological resource.
Air Quality [OAR 340-226-0100]	The air quality laws provide general emission standards for fugitive emissions of air contaminants and require the highest and best practicable treatment of control of such emissions.	This regulation is only applicable if a removal action generates fugitive emissions of air contaminants, which is considered unlikely.
Visible Air Contaminant Limitations [OAR 340-208-0110]	The visible air contaminant limitations prohibit the emission of any air contaminant from a new source for a period or periods aggregating more than 3 minutes in any 1 hour that is equal to or greater than 20% opacity. These rules are for “special control areas” including Multnomah County.	This regulation is only applicable if a removal action generates visible air emissions of air contaminants, which is considered unlikely.
Fugitive Emission Requirements (FER) [OAR 340-208-0200, 0210]	The FER prohibits any handling, transporting, or storage of materials, or use of a road, or any equipment to be operated, without taking reasonable precautions to prevent particulate matter from becoming airborne. These rules are for “special control areas” including Multnomah County.	This regulation is potentially applicable only if dredged removal action material had very low water content and requires shipment, which is considered very unlikely.
Lower Willamette River Management Plan (LWRMP) [ORS 273.045; OAR Chapter 141 Division 80]	The LWRMP provides policy direction and guidance to the Department of State Lands’ (DSL) regulatory and proprietary interests of the lower 17.5 miles of the Willamette River.	This regulation is potentially applicable because a large portion of the removal action area is located on DSL property.

Table 1-1. Preliminary Project ARARs.

ARAR and Citation	Description	Applicability
Removal Fill Laws and Regulations (RFLR) [ORS 196.795 through 196.990; OAR Chapter 141, Division 85]	The RFLR define the requirements for dredging and filling activities and coordination of the permit requirements with federal regulations.	This regulation is potentially applicable to a removal action that includes dredging and/or capping in the Willamette River.
Submerged Land Management Laws and Regulations (SLML) [ORS Chapter 274; OAR Chapter 141, Division 82	The SLML laws and regulations govern the management of state-owned submerged land for commercial and non-commercial uses and structures	This regulation is potentially applicable because a large portion of the removal action area is located on DSL property.
Certification of Compliance with Water Quality Requirements and Standards (CCWQ) [ORS 468b.035 OAR Chapter 340, Division 48]	The CCWQ requirements describe procedures for processing applications for certification pursuant to Section 401 of the Clean Water Act.	This regulation is potentially applicable because a water quality monitoring program and performance standards will be required for the preferred removal action alternative.

1.4 WORK PLAN ORGANIZATION

The remaining sections and appendices of this work plan include the following:

- **Section 2, Removal Action Area Characteristics** — describes the physical and ecological setting, site history, facility operations, and cultural resources.
- **Section 3, Review of Existing Data** — summarizes the previous investigations at the site and presents geologic, hydrogeologic, and physical data. This section also summarizes the habitat characteristics of the in-water portion of the site.
- **Section 4, Preliminary Conceptual Site Model** — describes and synthesizes available information on sources, transport pathways, potential receptor populations, and potential exposure pathways for COIs in river sediments, riverbank soils, groundwater discharging into the Willamette River, surface water, and transition-zone water.
- **Section 5, Comparison to Joint Source Control Strategy (JSCS) and Other Criteria**—describes the JSCS criteria by media and presents criteria in data tables. Summary data tables with associated statistics and electronic copies of the detailed data tables are provided in Appendix C of the work plan.
- **Section 6, EE/CA Data Screening**—summarizes the results of data screening in accordance with the AOC requirements. This section also describes the screening level value (SLV) exceedances, which ultimately led to the identification of principal threat areas. The text is accompanied by screening tables in Appendix D.

- **Section 7, Removal Action Evaluation Approach**—summarizes the process and approach to complete the removal action evaluation for the site.
- **Section 8, Data Gaps and Removal Action Characterization Activities**—identifies the data gaps that will need to be filled as part of the EE/CA and describes the scope of work that has been developed to fill the data gaps for sediment quality, water quality, engineering, biological, hydrological, and recontamination source characterization.
- **Section 9, Project Schedule**—presents the proposed NTCRA project schedule and upland source control measures, in accordance with the AOC, and includes assumptions about agency and trustee review of project deliverables.
- **Section 10, Project Team and Responsibilities**—summarizes the project team and their roles and responsibilities on the project.
- **Section 11, References**—lists documents cited in the work plan.
- **Appendix A, Supplemental Figures**
- **Appendix B, Exposure Factors and Parameters Used to Develop Sediment Screening Values for Humans**
- **Appendix C, Detailed and Summary Joint Source Control Strategy Comparison Tables**
- **Appendix D, Detailed and Summary Engineering Evaluation/Cost Analysis Data Comparison Tables**
- **Appendix E, Upland Remedial Investigation Reports, Lots 3 & 4 and Tract A –Revision 1**
- **Appendix F, Portland Harbor RI/FS Conceptual Site Model, Volume II, Appendix A-2, Arkema, Inc.**
- **Appendix G, NPDES Permit #100752**
- **Appendix H, Arkema Database Reference Table**
- **Appendix I, Draft EE/CA Work Plan Comment and Response Summary.**

The SOW to the AOC specifies several required elements for the work plan (Appendix B, Section II.1 of the AOC). Table 1-2 summarizes the specific SOW requirements along with the location in the work plan where each element is addressed.

Table 1-2. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Respondent shall submit an EE/CA Work Plan that will include a summary of existing information, a project work plan, a Sampling and Analysis Plan (SAP) and a Health and Safety Plan (HASP).	This document is the EE/CA work plan. The FSP, QAPP, and HASP will be submitted as separate appendices in accordance with a pending scheduled date.
Introduction/Purpose	The introdction and purpose are provided in Section 1.
Brief description of Arkema Removal Action Area characteristics, including ecological and physical characteristics;	A brief description of the RAA is provided in Section 2.1 with additional details in Section 4, Preliminary Conceptual Site Model.
Identification of historic and ongoing sources of contamination to the Arkema Removal Action Area, including past and present operations, drainage, discharges, groundwater seeps, or other releases;	Historical operations that are potential sources of contamination to the RAA are identified in Section 2.2.3.
Summary of existing information on upstream and upland contamination sources that have the potential to contaminate the Removal Action Area, including a description of environmental investigations, environmental cleanups and planned upland source control measures that will be conducted under agreements with DEQ as the lead agency. The summary of upland source control measures being conducted must contain a schedule for implementation to be completed prior to the EE/CA;	A summary of previous investigations is provided in Section 3. Upland source control measure summaries are provided in Section 4.1.5. The proposed schedule for upland source control is provided in Section 9.
Arkema historical information including dredging history and identification of past and present property owners, operators, and major tenants as well as owners and operators of all immediately adjacent upland properties;	A dredge and fill history is presented in Section 2.2.4. Past and current property owners/operators are identified in Section 2.2.1. Adjacent property owners are identified in Section 2.2.2.

Table 1-2. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Summary of current facility operations and potential access or operational constraints on Work Plan implementation;	Current facility operations are summarized in Section 2.3.
Description of the nature and extent of contamination in the Arkema Removal Action Area, to the extent known, including a summary of existing sediment quality data with a comparison to:	The JSCS sediment and water screening values are summarized in Sections 5.1 and 5.2, respectively. The results of the JSCS screening, supported by tables, are presented in Appendix C.
Existing ecological sediment quality guidelines that represent a range of levels including, but not limited to, low or no effects (e.g., Threshold Effects Concentrations [TECs], Threshold Effects Levels [TELs], Effects Range Low [ERLs]), as well as levels at which some effects are expected (e.g., Probable Effects Concentrations [PECs], Effects Range Medium [ERMs]). Existing chemistry data will be reviewed to establish Category 1 and Category 2 data categories in accordance with the Portland Harbor RI/FS protocols; *Estimated risk-based sediment cleanup values for persistent bioaccumulative toxins (PBTs) that are protective of humans and wildlife that consume aquatic biota from the Willamette River; and* *Sediment cleanup values that are protective of humans from direct contact with, and incidental ingestion of, chemicals of concern in sediments, riverbank and water. Existing sediment data should be plotted on site maps. Locations with sediment concentrations above the risk based levels in (1) , (2), and (3) above should be indicated on these maps;*	The EE/CA screening values for sediment and water are summarized in Sections 6.1 and 6.2, respectively. The nature and extent of contamination within the preliminary RAA is described in Section 6.3 with screening results in Appendix D and figure presentations in the map folio.
Summary of results from sediment toxicity testing conducted to date;	A summary of the results of fish tissue and sediment toxicity data are presented in Sections 3.1.7 and 3.1.12, respectively.
A process for developing a cultural resources survey, and a process for developing procedures to protect and address such cultural resources;	Cultural resource surveys have been conducted on behalf of the LWG for this reach of the Willamette River. The survey incorporates information for the Arkema site. A summary of the cultural resources in the area is presented in Section 2.4.

Table 1-2. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Identification of Removal Action Objectives (RAOs), potential Applicable or Relevant and Appropriate Requirements (ARARs), and To Be Considered (TBCs) for the Arkema Removal Action Area;	RAOs are summarized in Section 1.2. A preliminary list of ARARs for the Arkema RAA is also presented in this section. A final list of ARARs will be developed though the EE/CA process and in consultation with EPA.
A description of the analysis to be conducted to determine disposal facility or containment options for contaminated sediment;	Tests that will be conducted to evaluate potential disposal options are summarized in Section 7.3.3. The rationale and process for evaluating dredging options is summarized in Section 8.1.
A detailed conceptual site model that shows the relationship of the contaminant plumes including, but not limited to: pH variations, hexavalent chrome, perchlorate, monochlorobenzene, DDT and salinity gradients, starting in the uplands and continuing through the riverbank, and into sediment in the river, to the full extent of the data available at the time of submittal; and	The preliminary conceptual site model is presented in Section 4.
Other information (including maps and figures) necessary to gain a general understanding of the Arkema Removal Action Area.	This document contains more than 300 figures that support the interpretation, planning, and presentation.
Respondent shall also identify data gaps that will be filled by the collection and analysis of field data. Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate the following:	Section 8 presents a summary of the data gaps and the evaluation process that is addressed by the data collection activities detailed in Section 8.
Nature, extent, and volume of riverbank and sediment contamination including the degree to which riverbank and sediments will need to be removed that represent the principal threat of contamination, an ongoing source of contaminants to the river, and which may represent a recontamination risk to any cap put in place;	Proposed data collection efforts in support of the analysis of the nature and extent of the principal threat area are summarized in Section 8.2. Section 6 includes the EE/CA data screening and preliminary evaluation of the nature and extent of contamination. Supporting data tables and associated COI figures are presented in Appendix D and the map folio, respectively. Recontamination analysis requirements are presented in Section 8.1.9.

Table 1-2. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Potential human health and ecological risks resulting from sediment and surface water contamination;	Proposed data collection efforts in support of the analysis of potential human health and ecological risks are summarized in Section 8.2.2.
Engineering characteristics of the Removal Action Area including sediment consistency, dredgeability, potential slope stability issues related to dredging, and potential sediment consolidation issues associated with capping;	Proposed data collection efforts in support of the analysis of engineering characteristics and requirements are summarized in Section 8.2.3.
Potential water quality effects associated with dredging, piling removal, sheet pile installation, capping, or disposal technologies;	Proposed data collection efforts in support of dredged material characteristics and potential debris are summarized in Sections 8.2.4 and 8.2.5.
Technologies for sediment remediation including capping, dredging, treatment, including any necessary treatability testing, and disposal (on-site and off-site);	Technologies under consideration and the process for the EE/CA evaluation are discussed in Sections 7 and 8, respectively.
Identification of upland sources and remedial technologies for source control that Respondent anticipates implementing including a schedule for implementation to be completed prior to the EE/CA;	Sources are presented Section 4.1. Source control evaluation documentation and schedules are presented in Section 9.
Assessment of hydraulic control measures, including a sheet pile wall keyed into bedrock across the site, should these be necessary to ensure recontamination risk to in water work (riverbank and sediment cleanup) is eliminated; and	The evaluation of source control measures is incorporated in the data collection efforts outlined in the physical and engineering characteristics data collection efforts in Sections 7 and 8.1.
Potential impacts to threatened or endangered species, other biological receptors, and the potential habitat benefits and impacts of the removal action.	The proposed data collection efforts in support of the analysis of ecological receptors are summarized in Section 8.2.2.

Table 1-2. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
The procedures Respondent plans to implement when conducting all field activities will be detailed in the SAP for the specific field activity. The initial SAP will be included in the EE/CA Work Plan. The SAP for any field activity will ensure that sample collection and analytical activities are conducted in accordance with technically acceptable protocols that data meet data quality objectives. A SAP provides a mechanism for planning field activities and consists of a Field Sampling Plan (FSP) and a Quality Assurance Project Plan (QAPP). Details are provided in section II of this SOW.	An FSP and QAPP, which make up the SAP, will be submitted as appendices of this work plan at yet-to-be-determined dates.
Respondent shall also prepare HASP that is designed to protect personnel from physical, chemical and other hazards posed by field sampling efforts. Details are set forth in Section III of this SOW.	The HASP will be submitted as an appendix to this work plan at a later date.
Upon request by EPA, Respondent shall also submit copies of previous studies or sampling efforts conducted independently or under local, state or other federal authorities or agreements that are determined by EPA to relate to remedy selection under this Order.	Copies of selected historical data reports were requested and provided to EPA prior to submittal of this work plan.

Table 1-2. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Additionally, Respondent shall continue to work under DEQ supervision on upland source control actions related to the Arkema Site and that are threatening to be released to the Willamette River, which may include source identification, source prioritization, documentation and tracking of source control plans and completed source control actions, evaluating and documenting effectiveness of source control measures, and providing input to EPA's and DEQ's decision as to effectiveness of source control in order to implement the Removal Action. The goal is for significant upland sources to be controlled to the greatest extent practicable before or during Removal Action implementation such that significant post Removal Action recontamination is not predicted. The EE/CA work plan shall contain a process and schedule for evaluation of the upland source control program. As a result of the evaluation, should it be determined that sources are not being controlled sufficiently to achieve the RAOs, this SOW requires, upon notice by EPA, Arkema to conduct evaluation of hydraulic control measures in the EE/CA, including, but not limited to, installation of a sheet pile wall, such that this Removal Action may occur without the expectation of recontamination. A schedule for such evaluation will be included in the EE/CA work plan.	Arkema is actively working with DEQ on source control measures. The schedule for source control measure evaluation is provided in Section 9.

2 REMOVAL ACTION AREA CHARACTERISTICS

This section describes the physical and ecological setting, site history, facility operations, and cultural resources for the Arkema project.

2.1 PHYSICAL AND ECOLOGICAL SETTING

The Arkema facility is located at 6400 N.W. Front Avenue in Portland, Oregon, on the southwest bank of the LWR between approximately RM 6.9 and 7.6 (Figure 1-1). The Arkema property encompasses approximately 54 acres of land and is often discussed in terms of four lots and one tract along the Willamette River. Lots 1 and 2 are an undeveloped portion on the north end of the site that is covered by a mixture of grasses, bare soil, and disturbed scrub/shrub vegetation. Lots 3 and 4 are the developed portion of the site where the majority of chemical manufacturing and processing occurred. Tract A along the river is steeply sloping and in some areas is covered with rubble used for bank stabilization; a limited amount of vegetation grows among the bank-armoring material.

The facility is located in the Guild's Lake Industrial Sanctuary (formerly the Northwest Portland Industrial Sanctuary). The site is zoned and designated "IH" for heavy industrial use, which means that there are strict restrictions associated with non-industrial uses (Portland Development Commission 2004). The site is restricted to industrial use, which is currently undergoing upland remedial activities. The industrial sanctuary is bounded by U.S. Highway 30 and the Portland Hills west of the site. On the east, the Willamette River has historically been a commercial, industrial, and recreational waterway. Industrial processes and associated contamination of adjacent facilities are discussed in Section 2.2.2.

The in-water portion of the site is defined as the land below mean high water (approximately 12 ft NAVD88)[2]. In-water access to the Arkema facility was historically provided from three docks—from upstream to downstream—the Salt Dock, Dock 1, and Dock 2. The site is bounded to the south (upstream) by the CertainTeed roofing products facility and the Willbridge petroleum storage terminal (consisting of Kinder Morgan, Chevron, and ConocoPhillips). To the north (downstream), the site is bounded by a City of Portland sewer right-of-way that includes a discharge pipe from the groundwater remediation system located on the former Rhône Poulenc site. The City of Portland right-of-way is located immediately south of the BNSF Railroad Bridge (Figure 1-1).

[2] The in-water portion of the site below mean low water is leased from the Oregon Department of State Lands (DSL).

The Willamette River is a diverse ecological system, and the shoreline and in-water portions of the site represent habitat for several species of fish as well as aquatic birds, mammals, and amphibians (see Section 3.4, Habitat Characteristics). The Arkema property is secured, with limited walking access to the shoreline, which is not accessible to recreational users. However, evidence of trespassers has been observed, which has warranted the inclusion of transients as a potential human receptor in the in-water preliminary conceptual site model (see Section 6).

The initial RAA has been approximately defined in the AOC as the nearshore in-water area extending from the Salt Dock to downstream of Dock 2. The initial RAA includes the nearshore beaches and shallow river-bottom bench, and the western river-bottom slope that defines the edge of the river channel near the docks.

2.1.1 Regional Datums

The bathymetric data discussed as a part of this EE/CA work plan are presented relative to the North American Vertical Datum of 1988 (NAVD88). NAVD88 supercedes the National Geodetic Vertical Datum of 1929 through the Pacific Northwest Supplemental Adjustment of 1947 (NGVD29/47), a fixed datum adopted and adjusted in 1947 as a national standard geodetic reference for heights prior to June 23, 1993. The Columbia River Datum (CRD) is used as the chart datum for the LWR. CRD is a reference plane established by the U.S Army Corps of Engineers (USACE) in 1912 by observing low water elevations at numerous points along the Columbia and Willamette rivers (USACE 1966). The CRD is not a fixed/level datum, but slopes upward moving upstream.

The relationships or conversion factors between these datums are shown in Table 2-1 for the LWR to about RM 16 (Ross Island). On the Willamette River along the Arkema facility, elevations reported relative to the CRD are approximately 5.2 ft less than NAVD88 elevations. Water level data measured by the Morrison Bridge U.S. Geological Survey (USGS) gauge (#14211720) at RM 12.8, which is the nearest gauge to the Arkema facility, are recorded as the Portland River Datum (PRD) and are 1.55 ft above NGVD29/47 (USACE 1991). The CRD is 1.85 ft above NFVD29/47 at the Morrison Bridge. On December 27, 2001, David Evans and Associates (DEA) confirmed the relationship between this gauge and the CRD (DEA 2002). This survey confirmed that the Morrison Bridge staff gauge is 0.30 ft lower than the CRD, as defined by the USACE (1991).

Table 2-1. Portland Harbor Vertical Datum Conversion Table.

River Mile	NAVD88 Elev.	NGVD29/47 Elev.	CRD Elev.
0.4	10.0’ 0.0’ -10.0’	6.8’ -3.2’ -13.2’	5.4’ -4.6’ -14.6’
1.3	10.0’ 0.0’ -10.0’	6.8’ -3.2’ -13.2’	5.4’ -4.7’ -14.7’
5	10.0’ 0.0’ -10.0’	6.7’ -3.3’ -13.3’	4.9’ -5.1’ -15.1’
9.8	10.0’ 0.0’ -10.0’	6.5’ -3.3’ -13.5’	4.7’ -5.3’ -15.3’
12.8	10.0’ 0.0’ -10.0’	6.5’ -3.5’ -13.5’	4.6’ -5.4’ -15.4’
15.6	10.0’ 0.0’ -10.0’	6.5’ -3.5’ -13.5’	4.6’ -5.4’ -15.4’

2.1.2 Willamette River Stages

A major tributary to the Columbia River, the Willamette River merges with the Columbia at RM 103. A detailed discussion on Willamette River stages and seasonal fluctuations is presented in Integral (2004b). Figure 2-1 is a cross-section of the Willamette River within the Arkema facility boundary, and depicts the ordinary high water (OHW) level, mean high water (MHW), mean low water (MLW), and mean February and mean September river heights between RM 7 to 8. The MHW and MLW elevations of 12 feet and 9 feet, respectively, are based on an average of daily high water level from January 1972 through December 2005. The mean February and September river heights are from monthly averages for a 16-year period from October 1987 to June 2002.

2.1.3 Willamette River Flows

Figure 2-2 presents historical daily mean flows recorded from the USGS gauge located on the Morrison Bridge. Data after September 1994 are based on estimated flows by the USGS. Average flow ranges from 58,000 cubic feet per second (cfs) in winter to 9,000 cfs in late summer. Major flood events can trigger flows in excess of 150,000 cfs, with maximum flow over 400,000 cfs (1996 winter flood). A more detailed description of LWR flow regimes is discussed in Integral (2004b).

2.1.4 Bathymetry

A series of multibeam bathymetric surveys were conducted on the LWR from the confluence with the Columbia River to RM 15.6. The initial bathymetric survey was conducted by DEA during a high-flow event between December 13, 2001 and January 14, 2002. A bathymetric report detailing the methods used and the survey results has been provided to EPA under separate cover (DEA 2002). Higher resolution maps are provided in DEA (2002). A second bathymetric survey was conducted in the summer of 2002 (DEA 2003), the results of which are presented and discussed in Integral (2004b). Figure 2-3 provides a summary of bathymetric survey results and shows LWR bed elevations in the vicinity of the Arkema site as of February 2004 (Integral and DEA 2004).

During the winter of 2004, DEA conducted a bank-to-bank multibeam bathymetric survey. The primary goal of this survey was to create a data set containing riverbed elevations for 2004 following a high river flow event that could be directly compared to prior surveys to determine areas of sediment erosion and accretion within the study area (Integral and DEA 2004). These results are presented and discussed in Integral and DEA (2004).

2.2 SITE HISTORY

A history of Arkema site ownership, adjacent site ownership, manufacturing, and dredge and fill operations is presented below. Unless otherwise noted, this information was reported in the *Upland Remedial Investigation Reports, Lots 3 & 4 and Tract A –Revision 1* (Upland RI, ERM 2005d).

2.2.1 Arkema Site Ownership History

The facility manufactured inorganic chemicals from 1941 to 2001. It was constructed and operated by Pennsylvania Salt Manufacturing, which later became known as Pennwalt Corporation (Pennwalt). Purchased by Societe Nationale Elf Aquitaine (ELF) in 1989, Pennwalt was combined with two other companies in 1990 to form Elf Atochem North America, Inc. In 2000, ELF merged with TOTALFINA to form TOTALFINA ELF and Elf Atochem became ATOFINA Chemicals, Inc. (ATOFINA). In 2004, ATOFINA changed its name to Arkema Inc. In April 2006, the management of Arkema Inc.'s environmental work for the Portland property was transferred to LSS, the sole agent for Arkema.

2.2.2 Current Adjacent Site Ownership

The site is bordered on the east by the Willamette River and to the south by CertainTeed (GS Roofing Products; DEQ's Environmental Cleanup Site Information [ECSI] database site 117). The Willbridge Bulk Fuel Area (ECSI 1549) and Kinder Morgan (ECSI 2104) sites are located immediately south of CertainTeed. Front Avenue borders the site to the north and west. Six sites are located to the west of Front Avenue, upgradient of the site. These sites include Bayer CropScience, LP (Rhône-Poulenc; ECSI 155), Gould Industries, Doane

Lake (ECSI 36), and Kinder Morgan (ECSI 2104). The Siltronics Inc. site (ECSI 183) is located immediately north of Front Avenue. Descriptions of these facilities, including associated processes and COIs, are presented in Table 2-2. Additional details on the adjacent properties can be found in DEQ's ECSI database (also refer to Figure 2-4).

Table 2-2. Adjacent Sites and Associated COIs.

Facility	ECSI	Processes/Activities[a]	COIs
CertainTeed (formerly GS Roofing Products)[b]	117	Asphalt roof products manufacturing	TPH-G[f]G[b]; petroleum-related VOCs (e.g., BTEX); SVOCs
Doane Lake[c]	36	Past dumping to lake (1900s-1980s)	VOCs; petroleum-related VOCs (e.g., BTEX); SVOCs; phenolics; PAHs; herbicides; metals; pH (pH 5.7)
Gould Electronics, Inc.[d]	49	Battery breaking; lead oxide production; lead smelting and refinishing; zinc alloying and casting	Herbicides; pesticides; VOCs; phthalates; phenolics; PDCC/Fs; metals
Siltronics, Inc.[e]	183	Fuel storage and dispensing; waste-containing fill accepted historically; manufactured gas production	VOCs (e.g., BTEX); chlorinated VOCs (cVOCs); SVOCs; PAHs; TPH-G[f]; TPD-D[g,c]; petroleum-related VOCs (e.g., BTEX, MTBE); metals; cyanide
Bayer CropScience, LP (formerly Rhône-Poulenc)[e]	155	Production of fertilizers, herbicides, and pesticides	TPH-D[g]; VOCs; cVOCs; SVOCs; PAHs; phenolics; PCBs; herbicides; pesticides; PCDD/Fs (e.g., 2,3,7,8-TCDD); metals
ESCO Corp.-Willbridge Landfill	397	Landfill that received non-recyclable wastes from ESCO's foundry operations.	Lead, zirconium sand.
Schnitzer Investment-Doane Lake (Air Liquide America Corp.)	395	Acetylene manufacturing	Calcium hydroxide, metals, petroleum hydrocarbons, PCBs, chlorinated solvents, acetone, methyl ethyl ketone.
Willbridge Bulk Fuel Area (includes ConocoPhilips and Chevron)[e]	1549	Bulk petroleum storage	TPH-D[g]; TPH-G[f]; petroleum-related VOCs (e.g., BTEX); PAHs; metals; DDT.
Willbridge Bulk Fuel Area (Kinder Morgan)[e]	2104	Bulk petroleum storage	TPH-D[g]; TPH-G[f]; petroleum-related VOCs (e.g., BTEX); PAHs; Dibenzofuran; metals

Notes:
[a] May include current and historically relevant activities.
[b] Integral and GSI (2005a).
[c] DEQ (2006b). Chemicals are presented as 'contaminating substances' in the ECSI database rather than COIs.
[d] Integral and GSI (2005b).
[e] Integral and GSI (2004a).
[f] Total petroleum hydrocarbons - as gasoline.
[g] Total petroleum hydrocarbons - as diesel.

2.2.3 Arkema Site Operational History

The Arkema site operated as a chlor-alkali plant throughout most of its history from 1941 until 2001, when the entire facility was shut down due to escalating electricity costs. The facility used electrolytic cells to reduce concentrated sodium chloride brine to produce chlorine, caustic soda, hydrogen, hydrochloric acid, and sodium chlorate (CH2M Hill 1997).

Other chemicals that have been produced historically at the facility include the following: potassium chlorate, DDT, sodium hydroxide, sodium orthosilicate, magnesium chloride hexahydrate, ammonia, ammonium perchlorate, and sodium perchlorate. These processes are summarized below. A more detailed description of these activities is presented in the Preliminary Assessment for Elf Atochem North America (Elf Atochem 1999) and the Phase II Preliminary Assessment for Elf Atochem North America (Elf Atochem 2000), which are provided in the Upland RI Report (ERM 2005d). Information related to the manufacture of chlorine was provided in a letter from LSS to DEQ dated May 18, 2006 (LSS 2006, per. comm). Historical site features and uses are presented in Figure 2-4.

2.2.3.1 Acid Plant Area

A detailed summary of the processes used to manufacture DDT, magnesium chloride hexahydrate, ammonium perchlorate, solid sodium hydroxide, a grass defoliant, sodium orthosilicate, and hydrochloric acid in the Acid Plant area is presented in the following sections. Acid plant area features are presented in Figure 2-4 and additional details are provided in Upland RI report (Figure 1-4, ERM 2005c; Appendix E).

DDT Manufacturing (1947 – 1954)

The pesticide DDT was manufactured in the Acid Plant area between 1947 and 1954. The raw materials used to manufacture DDT included chloral (trichloroacetaldehyde), chlorobenzene (also known as monochlorobenzene [MCB]), and oleum-104 percent (fuming sulfuric acid).

DDT was manufactured inside the former DDT process building (Figure 2-4; see Figure 1-4 of the Upland RI Report [ERM 2005c], Appendix E). During initial startup, residues of the manufacturing process were reportedly discharged to a floor drain apparently connected to a pipe terminating in the river. The manufacturing process residue (MPR) discharge pipe was located in the vicinity of borehole WB-9 on the northern side of Dock 1 (Integral 2003; Appendix A, Figure 1). (Note: As part of the EE/CA, the locations of old and existing discharge pipes will be evaluated within the RAA.) From 1948 to 1950, process residues were discharged directly to an MPR pond located northeast of the process building (Figure 2-4). From 1950 until DDT manufacturing ceased completely in

1954, the residue was piped to an MCB recovery system and then east into the shallow MPR pond. The MCB recovery system consisted of a steam stripper in which chlorobenzene was removed from the MPR and returned to the DDT manufacturing process. The entire system was located on a curbed concrete slab. In approximately 1951 or 1952, a trench was reportedly constructed, extending north about 285 ft from the northeastern corner of the former MPR pond (Figure 2-4).

The raw materials chlorobenzene and oleum were purchased from outside sources and stored in aboveground tanks located immediately adjacent to the eastern side of the process building. Chloral was formulated from the chlorination of ethanol onsite and stored in an aboveground tank on a concrete floor located inside the process building. Chemical reactions to form DDT occurred inside the process building, where portable metal pans several feet square were filled with hot DDT. When cooled, the material in the pans was broken with a jackhammer to form large fragments of crystalline material. The crystalline DDT was temporarily stored on an asphalt slab located in the Acid Plant Area.

The DDT on the storage slab was transferred to the southwest corner of Warehouse 2 for milling and grinding inside the warehouse. Dry-processed DDT was loaded into bags and transported from the plant by railcar. The railcar loading area was located on the northern side of Warehouse 2. A small amount of material was dissolved in diesel fuel and loaded into trucks, and possibly railcars, as a liquid for DDT application. The aboveground dissolving tanks were located immediately adjacent to the western side of the DDT process building. This building was extended to the west after DDT operations ceased.

Magnesium Chloride Hexahydrate Manufacturing (1952 – 1962)

From approximately 1952 to 1962, a sodium chlorate-based cotton defoliant material was manufactured. Magnesium chloride was delivered to the plant and hydrated to form magnesium chloride hexahydrate in the former Warehouse 1. The magnesium chloride hexahydrate was taken to the northern end of the sodium chlorate process area, where it was ground and mixed with sodium chlorate. The blended material was bagged and sold.

Ammonium Perchlorate Manufacturing (1958 – 1962)

From approximately 1958 to 1962, ammonium perchlorate was manufactured in the former DDT process building. During this period, sodium perchlorate was produced inside the chlorate cell room near the south end of the property, and then converted to ammonium perchlorate by using ammonium chloride in the Acid Plant area. This material was sold as a solid rocket propellant. Some ammonium perchlorate handling took place in Warehouse 3, adjacent to the Acid Plant area to the southeast.

Solid Sodium Hydroxide (early 1950s – 1980s)

In the early 1950s, a process was installed to produce solid (100%) sodium hydroxide. Large pots were filled with sodium hydroxide solution, and the caustic was boiled using fuel oil to fire the pots. This operation took place in the south side of the No. 1 Warehouse (Figure 2-4). The operation was terminated in the early 1980s (Elf Atochem 1999).

Grass Defoliant (early 1950s)

For only a few months in the early 1950s, Pennwalt Corporation attempted to produce a grass defoliant material for use in the agricultural industry. The operation consisted of chlorinating acetone with chlorine gas. The operation took place inside the old DDT process building. It is not known if an acetone storage tank ever existed for this short-lived operation (Elf Atochem 1999).

Sodium Orthosilicate (1950 – 1980)

Sodium orthosilicate operations started in 1950 and were terminated in 1980. Silica sand and soda ash were mixed with sodium hydroxide to produce granular cleaners. Other ingredients occasionally used in some of the orthosilicate products included trisodium phosphate, soap, paraffin oil, and bentonite clay. This operation occurred in the No. 1 Warehouse.

Hydrochloric Acid Manufacturing (1966 – 2001)

From 1966 to 2001, hydrochloric acid was produced in the general area where DDT had been manufactured (Integral 2004a). This area became known as the Acid Plant area (Figure 2-4). Chlorine and hydrogen were burned together in aboveground towers to form hydrogen chloride vapor. The vapor was absorbed in water to form hydrochloric acid. The acid was stored in two aboveground storage tanks in the Acid Plant area. The acid was loaded from the storage tanks into tanker trucks or was piped to either a storage tank near the chlorine cell room or to a storage tank adjacent to Track #6 (see Figure 5-2 of Appendix D of the Upland RI report [ERM 2005d; Appendix E]).

2.2.3.2 Chlorate Plant Area

A summary of the processes used to manufacture sodium chlorate and potassium chlorate in the Chlorate Plant area is presented in the following sections. This section also includes a description of the boiler room, part of which is located in the Chlorate Plant area (Figure 2-4).

Sodium Chlorate Manufacturing (1941 – 2001)

Sodium chlorate manufacturing started in 1941 in the Chlorate Plant area. Chlorate was produced by electrolysis of a sodium chloride solution. As part of the overall process, sodium bichromate was added to inhibit corrosion and to improve the electrical efficiency of the process. Historically, the bichromate arrived at the plant in dry form in sealed bags

and was stored inside the chlorate department. The bags were opened inside the chlorate cell room, and the contents were dissolved in tanks with water. The solution was fed into the circulating liquor in the chlorate cell room.

Beginning in the early 1990s, sodium bichromate was received in 30-gallon metal drums. The drums were also stored inside the chlorate department. The bichromate was dissolved in the 30-gallon drums and then siphoned into tanks for incorporation into the circulating liquor.

Historically, the liquid sodium chlorate product contained the sodium bichromate. After completion of a chlorate plant modernization project in 1990, the sodium bichromate was separated from the chlorate solution and returned to the circulating liquor, with very little sodium bichromate remaining in the final chlorate product.

Chlorate solutions were shipped by either truck or barge (ERM 2005d). Trucks were loaded on the southern side of the Chlorate Plant area. Barges were loaded at Dock 2 (Figure 2-4). An aboveground pipeline was used to transport sodium chlorate from the Chlorate Plant area to Dock 2 (Figure 2-4). There were no known releases from this pipeline.

Potassium Chlorate Manufacturing (1941 – 1978)

Potassium chlorate manufacturing also started in the Chlorate Plant area in 1941. Operations were similar to those of sodium chlorate, except that the salt source was potassium chloride rather than sodium chloride. This manufacturing operation terminated in approximately 1978.

Boiler Room (Steam Plant)

Operation of the boiler room/steam plant started in 1941. The boiler room operated at the same location throughout the operation history of the facility (Figure 2-4). Fuels used in the boiler room included natural gas, hydrogen, No. 6 fuel oil, and propane (Elf Atochem 1999).

2.2.3.3 Chlorine Manufacturing Area

Chlorine manufacturing started in 1946 using cells equipped with graphite anodes (LSS 2006, per. comm). These cells were operated in an area of the plant that later became the Maintenance Shop (Figure 2-4). These chlorine cells were operated until 1971, when they were shut down and replaced by a new chlorine cell room located north of the old cell room. Arkema's newer chlorine cell room was initially started in 1962 and expanded over the years until plant shutdown in the spring of 2001. The new cell room used cells equipped with metal (titanium) anodes.

Approximately once each year the chlorine cells with graphite anodes needed to be rebuilt. The process involved dismantling the cell and placing the spent cell components into open metal containers. The metal containers were transported to the bank area along the river where the contents of the containers were used as fill material. The components consisted of spent graphite anodes, spent concrete cell heads, various steel parts, and possibly asbestos materials. Wash water used during the cell dismantling process was discharged through a pipe to the Willamette River just north of the Dock 1 (Figure 2-4). Asbestos from the older graphite anode chlorine cells was placed into the disposal trenches on Lots 1 and 2 that were subsequently excavated (Section 2.2.3.5).

Chlorine condensate from the old chlorine cell room flowed through an acid stripper where hydrochloric acid was used to strip chlorine from the liquid condensate. The condensate was then discharged to the river through the outfall pipe immediately north of Dock 1.

Chlorine condensate from the new chlorine cell room was also treated in an acid stripper located on the south side of the new cell room. The stripper used hydrochloric acid to remove the chlorine from the condensate, and the chlorine was fed back into the main chlorine header. The stripped condensate was conveyed to a tank-based wastewater treatment system for neutralization of pH and any remaining chlorine residual. Final effluent from the waste water was conveyed to the river through current Outfall 004 or another former outfall in the same area.

Liquefied chlorine was shipped by railcar, by a barge moored at the Dock 2, and occasionally by truck. The plant also used to package liquefied chlorine into 1-ton containers and small 150- to 200-pound cylinders. The packaging occurred inside the chlorine finishing area (Elf Atochem 2000).

2.2.3.4 Salt Pads

Salt was the primary raw material used at the site throughout its operational history (1941-2001). The Arkema plant historically received salt (sodium chloride) by ship. The salt was transferred onto asphalt-lined salt pads in the southeastern corner of the site (Figure 2-4). The salt was dissolved in water while on the salt pads to produce brine for plant manufacturing operations (ERM 2005d).

As the salt dissolved, small quantities of sand that accumulated with the salt was left on the pads. Over a period of years, the sand that accumulated was removed. From the mid-1980s until the plant was shut down, the sand was hauled to a local permitted landfill. Prior to the mid-1980s, the sand was disposed of on the plant's northern property. Some salt would have been mixed with the sand (Elf Atochem 1999). After the plant was shut down in 2001, the remaining salt was sold to a facility in Vancouver, Canada.

2.2.3.5 Asbestos Ponds and Trenches

The asbestos diaphragm chlorine cells were rebuilt annually. Starting in approximately 1990, the removal of used asbestos diaphragms took place in a controlled maintenance room, and the asbestos was drummed and sent to a DEQ-approved landfill (Elf Atochem 1999). Prior to 1990, the diaphragm chlorine cells were rebuilt using the disposal practices described below.

Asbestos diaphragm material was removed from the chlorine cells by washing with water. The slurry entered two earthen impoundments near the chlorine plant (Figure 2-4). A pipe was installed between these ponds to keep the water level somewhat equal. A manually controlled pump was available in one of the ponds to transfer the slurry to a third surface impoundment. Occasionally, the asbestos was excavated from the ponds and was disposed of in trenches on the northern portion of the site (Figure 2-4; Elf Atochem 1999).

Scrubber waste from the Sodium Orthosilicate Plant was also discharged into the asbestos pond nearest the river for an unknown period of time. The scrubber water was used to control particulate dust and did not contain any hazardous substances. The dust would have consisted of silica sands and bentonite clay particles (Elf Atochem 1999).

Approximately 12 trenches were filled with asbestos-containing residue from the diaphragm chlorine cells. In order to make the property useful for potential future development, and to meet conditions in its renewed air permit, Elf Atochem undertook a project to decommission the ponds and to voluntarily excavate the trenches containing asbestos residue. The asbestos removal work was conducted under a work plan approved by DEQ and under DEQ's oversight (Patterson 1992, pers. comm.). The asbestos removal work was completed in 1992 (Elf Atochem 1999).

2.2.3.6 Former Brine Mud Pond

The origin of the salt that was brought into the plant as a raw material was from either the Pacific Ocean or Utah. The salt contained crystals of calcium and magnesium that needed to be removed prior to use in the electrolytic cells. With the addition of sodium carbonate and sodium hydroxide, the calcium and magnesium were precipitated in the form of calcium carbonate or magnesium hydroxide (referred to as dolomite/brine mud) in the later years of plant operation. Historically, brine mud was stored on soil in a diked area and in a pond located in the northern area of the property (Figure 2-4). These accumulations of brine mud were excavated in the early 1990s, and the material was hauled to a permitted landfill (Elf Atochem 1999). In the later years of plant operation, this material was dewatered in a filter press and was transported to a local landfill. Brine mud is not a hazardous substance.

2.2.3.7 Old Caustic Tank Farm (1946 – 1996)

The Old Caustic Tank Farm (OCTF), sometimes referred to as the Former Caustic Tank Farm, is located just south of the Acid Plant area (Figure 2-4). Tanks within the OCTF were used to store sodium hydroxide from 1946-1996. Over the years, tanks were added to the OCTF as production of sodium hydroxide increased. The aboveground tanks were situated on soil. Heavy petroleum compounds were injected beneath the tanks to prevent external corrosion of the tank bottoms. A sump was located within the OCTF to catch rain water. Originally, this rainwater entered the plant's industrial sewer system. In the early 1970s, a pump was installed to convey drainage from the OCTF to the plant's wastewater treatment system. In 1988, a concrete containment wall was constructed around the perimeter of the OCTF.

The OCTF was in use until 1996. The idle tanks were removed from the OCTF during the demolition activities in the spring of 2002 (ERM 2005d).

2.2.3.8 Ammonia Plant (mid-1950s – 1990)

Ammonia production operations commenced in the mid-1950s and lasted until approximately January 1990. Nitrogen was stripped from air and combined with hydrogen that was produced in the chlor-alkali process. The combined gases were compressed and cooled to form anhydrous ammonia. A portion of the ammonia was mixed with water to produce aqueous ammonia. These products were shipped by truck and railcar. The operation was located in what is known as the New Caustic Tank Farm Area (Figure 2-4).

2.2.3.9 Transformer Pads

Electrical transformers were historically installed at various locations throughout the Arkema facility (see Figure 1-5 of the Upland RI report [ERM 2005d]; Appendix E). Arkema maintained a master list of transformers, their status, locations, fluid capacity, and results of testing for PCBs. Over time, many of these transformers were drained or properly disposed. During facility demolition, all transformers were removed. The pads on which the transformers were located were tested for the presence of PCB and managed or disposed of in accordance with DEQ oversight (Patterson 2003, pers. comm.; McClincy 2003, pers. comm.; Patterson 2004, pers. comm.). The scope and results of that investigation are summarized in the Upland RI report (ERM 2005d).

2.2.3.10 Bonneville Power Administration Substation

The Bonneville Power Administration (BPA) owned and operated an electrical substation on the site. As shown on Figure 2-4, the substation, which is divided into the main substation (also referred to as the Pennwalt Substation) and a substation annex to the north, occupied a total area of 1.28 acres of the facility. The property on which the main substation and substation annex were located is owned by Arkema. Arkema was the sole

user of electricity from the substation, and due to the closure of the facility, the substation was decommissioned and the associated equipment was removed from the property during 2002 (ERM 2005d).

Thirteen transformers and five oil-filled power circuit breakers were located in the main substation, and one transformer was located in the substation annex. These transformers and circuit breakers contained, or were assumed to contain, PCBs. In November 2001, an environmental assessment was performed for the BPA at the main substation. The scope and results of the investigation are included as Appendix E to the Upland RI report (ERM 2005d; Appendix E).

2.2.3.11 Stormwater Drain System

The layout of the plant's stormwater system is shown in Appendix E, Figure 1-6 of the Upland RI report (ERM 2005d). Many of these sewers have been in place since at least the mid-1950s and were designed to carry large volumes of cooling water. Many were also designed to drain building basements and process sumps, and are therefore deep (approximately 12 ft below ground surface in certain locations).

The plant's stormwater drain system is separated into four smaller drainage systems. Each drainage system is connected to a separate, large, concrete Parshall flume and discharge pipe (identified as Outfalls 001 through 004) located on the riverbank (Figure 2-4). Parshall flumes for Outfalls 001, 002, and 003 are located between the southernmost dock (the Salt Dock) and the northernmost dock (Dock 2), whereas Outfall 004 is located north of the Dock 2. Discharge pipes and diffusers extend out into the river from each Parshall flume.

The facility was issued a National Pollutant Discharge Elimination System (NPDES) permit on January 28, 1993, which authorized the discharge of process waste water, cooling water, and stormwater runoff. The permit allowed a discharge flow of up to 37million gallons per day, most of which was cooling water. In January 2004, a new NPDES permit was issued to Arkema solely for the discharge of stormwater.

Additional details on the stormwater drain system are presented in the Stormwater IRM work plan (Integral 2006j).

2.2.4 Dredge and Fill History

Known and potential dredge and fill activities at Arkema are summarized in Table 2-3. Dredging permit files dating back to 1971 were obtained from the USACE through a Freedom of Information Act request. Information obtained from the USACE included the 1977, 1984, 1993, and 1999 dredging permit applications. Information related to dredge activity for 1956 and some of the information related to the 1977 and 1984 dredge

activities were provided by Arkema. Additional information was obtained from the Expanded Preliminary Assessment (Elf Atochem 2000) and the Upland RI Report (ERM 2005d). In addition to these data sources, former plant employees have reported that periods of dredging were necessary off of the Salt Dock and Dock 1 to maintain sufficient depth for the ship that delivered salt.

Figure 2-4 shows the areas assumed to be dredged in 1956, 1977, 1984, and 1993, and the approximate location of the fill material placed in the vicinity of the Salt Dock.

Table 2-3. Chronology of Fill and Dredge Events at Arkema.

Year	Location	Description
1953	Northern vacant portion of the property	In 1953, the Port of Portland in cooperation with the USACE disposed of dredged materials from the Willamette River onto what is currently Lots 1 and 2 (Elf Atochem 2000).
After 1953	Along riverbank	Fill was placed in the Acid Plant area bordering the Willamette River after DDT manufacturing ceased. It appears that the bank adjacent to the Acid Plant area has been filled out toward the Willamette River approximately 200 ft since the 1950s (CH2M Hill 1997). Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 ft along the riverbank (Integral 2004a). The sources of the fill material included the City of Portland, private excavation contractors, and Elf Atochem (ERM 2005d). Fill materials included clean soil, asphalt, concrete, metal piping, and miscellaneous materials from spent chlorine cells (ERM 2005d).
1956	Salt Dock	Two areas were dredged to accommodate dock construction. The dredged material was placed behind an earthen berm, which extended from Dock 1 to the upstream end of the property, to form the base of the eastern half of the current salt pads.[a] Some dredged materials from the navigation channel may have also been placed on the property by others (Elf Atochem 2000).
1977	Dock 1 and Salt Dock[b]	Three areas were apparently dredged. A letter from Pennwalt Corporation to USACE requested permission to complete the dredging with a clamshell to an elevation of -30 ft (datum unknown). The permit application (No. 2607) indicates that the dredging was to be conducted between May 15 and June 15, 1977. According to a letter from Pennwalt to the USACE, dated April 19, 1977, approximately 1,000 cy of material was supposed to be dredged by clamshell derrick, loaded onto flat-decked barges, and removed from the site for disposal behind a protective berm that is located above the high water mark at the Brand S disposal site (Pennwalt 1977). There is no documentation or confirmation that dredging took place.

Table 2-3. Chronology of Fill and Dredge Events at Arkema.

Year	Location	Description
1984	Dock 1 and Salt Dock[b]	Joint permit application No. 5565 to USACE and Oregon DSL to repeat dredging apparently conducted in 1977. This permit application was approved in a letter from the USACE to Pennwalt Corporation dated September 15, 1984 (USACE 1984). Dredging was to be completed to elevation -30 ft MSL and application was for 500 cubic yards (cy). There is no confirmation that dredging was initiated and completed, but application states that the dredging was to be conducted from September 17-20, 1984.
1993	Dock 1 and Salt Dock[b]	Dredging permit application No. 93-54 was granted in a letter from the USACE on January 19, 1994 (USACE 1994). The application was for maintenance dredging of 500 cy of sand and silt. The dredging spoils were to be disposed of in the Ross Island Lagoon. This permit application was submitted because of the company name change from Pennwalt Corporation to Elf Atochem North America. The estimated start date on the application was June 1993; the completion date was listed as "ongoing." There is no confirmation that dredging was initiated or completed.
1999	Dock 1 and Salt Dock	Dredging permit application No. 99-651 was denied in 1999 due to concerns about pesticide contamination. On February 6, 2002, the permit was withdrawn by ATOFINA Chemicals, Inc. because the Portland plant was shut down.

Notes:

[a] 1956: Approximate dredge areas were as follows: an area 175 ft x 1200 ft was dredged to -35 ft, extending from Dock 1 to the south end of the current No. 3 Salt Pad (the southernmost pad). A second area within the channel, 575 ft x 1225 ft , was dredged to -50 ft (datum unknown) [Source: Arkema].

[b] 1977, 1984, and 1993: Proposed dredge areas: (1) area 200 ft long and 30 ft wide at northern end of Dock 1; (2) area 150 ft long and 25 ft wide towards the middle of Dock 1; (3) area 150 ft long and 25 ft wide along the Salt Dock (Figure 2-1) [Source: USACE permit applications].

2.3 CURRENT AND FUTURE FACILITY OPERATIONS

Chemical manufacturing operations at the facility ceased in 2001. Decommissioning and removal of the manufacturing infrastructure were completed in early 2005. The only structure remaining is the office building at the site entrance on Front Street and some concrete floor slabs left in place as environmental caps. Arkema maintains leases from the Oregon DSL for the docks in the Willamette River, but the docks are not currently in use. Upland remedial activities to address environmental impacts are ongoing.

There is no known access or operational constraints on EE/CA work plan implementation, although the timing of in-water work must be coordinated with the Oregon Department of Fish and Wildlife (ODFW) fish window. Therefore, in-water work will be restricted to established 'preferred work periods' for the LWR (mouth to Willamette Falls), which are July 1 to October 31 and December 1 to January 31. These guidelines were developed to

minimize the impacts to fish during times when they may be most vulnerable such as during migration and spawning (http://www.fs.fed.us/r6/water/oregon_404.pdf).

Future use of the facility is unknown but will continue to be limited to heavy industrial. Currently, the site activities are upland IRMs. The EE/CA activities will be coordinated with the upland IRMs and the activities associated with the LWG Portland Harbor RI/FS, including data collection exercises. LWG Round 3 activities are currently being negotiated, and LSS believes that it is important for appropriate LWG data (e.g., data collected from samples offshore and adjacent to the site) to be used for the EE/CA as the data become available. Round 3 activities and approximate timelines are presented below.

Round 3A activities have been preliminarily approved by EPA. LWG is determining the scope of work for the following sampling activities:

- **Sediment Traps** – The draft FSP has been submitted and is expected to be finalized within the next two months. Traps will be deployed on a quarterly basis starting in late summer or early fall of 2006. The data set for the first quarter will likely be available in March 2007 or earlier.
- **Surface Water** – The draft FSP is currently in preparation. A low-flow event (< 20,000 cfs) will likely occur in August or September of 2006. Data would be available following a 120-day turnaround time. This low-flow event is designed to coordinate the Round 2 with the Round 3 data. A fall stormwater event will likely occur in October 2006 (which will be flow-dependent) and a high-flow event (> 50,000 cfs) will likely occur in December 2006 or January or February 2007, depending upon seasonal water flow in the river.

The following Round 3B activities are under discussion between LWG and EPA and have not been approved:

- **Crayfish/Sculpin Study** – A sampling event for the collection and analysis of crayfish and sculpin tissue may occur during the summer of 2006.
- **Adult Lamprey/Juvenile Sturgeon and Lamprey** – This event will likely occur during late summer early fall of 2006 if approved.
- **Transition-Zone Water** – A transition-zone water (TZW) event may occur during fall 2006, but likely will be delayed to fall 2007. Fall represents the preferred time to sample because the best TZW signal can be obtained when there is a significant temperature difference between river surface water and groundwater.

2.4 CULTURAL RESOURCES

A comprehensive cultural resource analysis was conducted for the LWG as part of the RI/FS for the Portland Harbor site and completed in 2005 (AINW 2005). The Arkema property is designated in the *Cutural Resource Analysis Report for the Portland Harbor Superfund Site* as a low-probability area. A follow-up study is proposed in this work plan (see Section 8.1.2), and the results of the study will be reported in the EE/CA report.

3 REVIEW OF EXISTING DATA

This section presents a summary of previous environmental investigations for the Arkema property, including studies conducted in the Willamette River and riverbank adjacent to the site. This section also presents our current understanding of site geology, hydrogeology, engineering, and habitat characteristics at the Arkema facility.

3.1 SUMMARY OF PREVIOUS INVESTIGATIONS

Monitoring data were first collected at the site in 1996. A number of sampling efforts have been conducted in the Willamette River and riverbanks adjacent to the Arkema site since 1996, as listed in Table 3-1. Historical sample station locations are shown on Figures 3-1 through 3-4. A summary of the field methods and number of samples analyzed for each investigation is presented chronologically in the following sections. The comprehensive data sets are discussed and presented in Sections 4, 5, and 6.

Table 3-1. Summary of Previous Investigations.[a]

Investigation (report reference)	Year[b]	No. of Stations	Media Sampled, Measured, Remediated, or Tested
Studies Completed for the Arkema RI/FS			
Monitoring Well Installation Adjacent to River (ERM 2005d, 2005a)	1996-2005	35[c]	Soil and Upland Groundwater
Riverbank Sediment Sampling (Exponent 1999)	1998	6	Sediment
Offshore Sediment Sampling (Exponent 1999)	1999	6	Sediment
Riverbank Soil Sampling (ERM 2005d)	2000	6	Sediment
Phase I Soil Removal IRM (ERM 2001b)	2000	NA	Soil
Phase II Soil Removal IRM (ERM 2002)	2001	NA	Soil
Stage 1 & 2 Groundwater and Sediment Investigation (Integral 2003)	2002-2003	25	Sediment, Sediment Groundwater[d]
MCB Recovery Unit Area Soil Vapor Extraction System (ERM 2003 and monthly progress reports)	2000-2003	Installation of VES system; 8 hand auger borings; 24 direct push vapor monitoring points; 15 confirmation soil borings	Soil

Table 3-1. Summary of Previous Investigations.[a]

Investigation (report reference)	Year[b]	No. of Stations	Media Sampled, Measured, Remediated, or Tested
In Situ Sodium Persulfate Pilot Study and Full Scale IRM (ERM 2001a, 2005c)	2001-present	NA	Groundwater
DNAPL Remediation Pilot Study and Full Scale IRM (ERM 2004a,b)	2004-present	NA	Soil and Groundwater
Hexavalent Chromium Reduction Pilot Study and Full Scale IRM (ERM 2004c, 2005b)	2004-present	NA	Groundwater
Perchlorate Remediation Bench Study (ATOFINA 2003)	2003-present	NA	Groundwater
Studies Completed for the Portland Harbor RI/FS			
Portland Harbor Sediment Investigation (Weston 1998)	1997	13	Sediment
Seep Reconnaissance Survey (GSI 2003)	2002	Arkema Riverbank	Groundwater Seeps Along Riverbank
Round 1 Sediment Investigation (SEA et al. 2003; Integral 2004c)	2002	5	Sediment
Sediment Stake Erosion/Accretion Monitoring Study (Anchor 2003, 2004)	2002-2004	1 Transect	Mudline Elevations
Round 2 Beach and Surface Sediment Investigation (Integral 2005c,d)	2004	21	Sediment
Round 2 Subsurface Sediment Investigation (Integral and Anchor 2005; Integral 2005c)	2004	11	Sediment
Round 2A Sediment Toxicity Testing Investigation (Windward 2005b)	2004	14	Sediment Toxicity Tests
Monitored Natural Recovery Report (Anchor 2005a)	2004	1	Sediment
Round 2 Groundwater Pathway Pilot Study (Integral 2005a)	2004-2005	11 Transects	Sediment, Sediment Groundwater[d], Porewater, Vapor Diffusion Gas
Round 2 Sampling of Invertebrates Using Multiplate Samplers, Field Sampling Report (Windward 2005c)	2005	2	Tissue
Round 2 Sampling of Benthic Invertebrate Tissue Field Sampling Report (Windward and Integral 2006)	2005	3	Tissue, sediment
PCB Congeners in Archived Round 2A Surface Sediment Data Report (Integral 2006c)	2004	7	Sediment

Table 3-1. Summary of Previous Investigations.[a]

Investigation (report reference)	Year[b]	No. of Stations	Media Sampled, Measured, Remediated, or Tested
Round 2 Subyearling Chinook Tissue Data Report (Integral and Windward 2006b)	2005	1	Tissue
Round 2A Archived Core Sediment Data Report (Integral 2006d)	2004	9	Sediment
Round 2B Subsurface Sediment Data Report (Integral 2006g)	2005	2	Sediment
Round 2 Groundwater Pathway Assessment, Transition Zone Water Sampling Field Sampling Report (Integral 2006b)	2005	28 (17 sample stations, 11 discharge stations)	Transition-Zone Water[d]
Round 2A Surface Water Site Characterization Summary Report (Integral 2006f)	2004-2005	3	Surface Water
Round 3 January 2006 High-Flow Surface Water Field Sampling Report (Integral 2006h)	2006	3[e]	Surface Water
Round 2 Hydrodynamic/Sediment Transport Modeling Data Collection (Integral 2006e)	2005-2006	1	Sediment

Notes:
[a] Arkema and Portland Harbor Superfund studies met Category 1 data requirements.
[b] Years the field work was conducted.
[c] Includes monitoring wells adjacent to the river installed through July 2005.
[d] Some groundwater samples were collected using a Geoprobe® or similar method, which can generate turbid water samples. Reported pesticide and metal concentrations using these sampling methods may not be representative of actual dissolved groundwater concentrations.
[e] None of the stations was adjacent to the Arkema site.

3.1.1 Monitoring Well Installation Adjacent to the River (ERM 2005d)

From 1996 to 2005, 70 borings were completed for the installation of monitoring wells (including replacement wells MWA-6r and MWA-15r), which included 40 shallow-zone, 25 intermediate-zone, 4 deep-zone, and 1 basalt-zone monitoring well borings. Thirty-five of these wells (MWA series) were installed along the Willamette River near the top of the riverbank (Figures 3-1 and 3-3). Monitoring well borings were advanced using hollow-stem auger, sonic, or cable tool drilling methods to depths ranging from 26 to 70 ft below ground surface (bgs). Where monitoring well borings were advanced through low-permeability silt zones, the borings were cased off to prevent direct vertical hydraulic connection between water-bearing zones.

Soil samples from monitoring well borings were visually inspected and logged for lithology using the Unified Soil Classification System (USCS). In addition, soil samples

were collected from discrete depth intervals and many were field-screened after collection. Screening methods applied included thin-layer chromatography (TLC), Sudan IV® hydrophobic dye, photoionization detector (PID), or visual inspection. Selected soil samples were collected for analysis of VOCs, organochlorine pesticides, total petroleum hydrocarbons-diesel range (TPH-D), total petroleum hydrocarbons-gasoline range (TPH-G), and selected soil physical properties.

Groundwater samples collected from the monitoring wells were analyzed for one or more of the following constituents: VOCs, SVOCs, PAHs, organochlorine pesticides, TPH-D, metals, perchlorate, carbonate/bicarbonate, alkalinity, ammonia-nitrogen, nitrate, nitrite, sulfate, chloride, total organic carbon (TOC), chloral hydrate, *p*-chlorobenzene sulfonic acid, and dissolved methane.[3]

An overview of the geology and hydrogeology of the upland portion of the site through the transition zone[4] is presented in Sections 3.2.1 and 3.2.2, respectively. Additional details on the upland portion of the site, including the COI distribution and data tables, are provided in the Upland RI Report (ERM 2005d). Detailed cross-sections extending from the upland source areas to the in-water portion of the site including selected COI data are provided in the accompanying map folio.

3.1.2 Portland Harbor Sediment Investigation (Weston 1998)

In September and October 1997, sediment samples[5] were collected from 13 stations in the vicinity of the Arkema site (SD- series; Figures 3-1 and 3-2). Sediment samples were collected from either 0 to 10 cm (~0.3 ft) or 0 to 90 cm (~3 ft) below mudline (except for one sample collected from 90 cm [~3 ft] to 150 cm [~5 ft]), with a modified 0.1-m^2 van Veen grab sampler (surface sediment samples) or a 3-in-diameter gravity corer configured with a 5-ft core barrel and a 700-lb weight stand. Each sediment sample was analyzed for organochlorine pesticides, base-neutral-acid (BNAs) SVOCs, TOC, EPA Target Analyte List (TAL) metals, and grain size. Selected samples were also analyzed for polychlorinated biphenyls (PCBs) and herbicides, and one sample was analyzed for titanium.

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[3] Selected groundwater sample results are presented in this report. The RI report presents a comprehensive summary of groundwater results (ERM 2005d).

[4] The groundwater/surface water transition zone (transition zone) is the interval where both groundwater and surface water comprise some percentage of the water occupying pore space in the sediments. The physical and biochemical properties of water within the transition zone reflect the effects of mixing between groundwater and surface water that occurs within the sediments (Integral 2004b).

[5] Sediment samples described in this section and throughout the document are bulk samples that include porewater.

3.1.3 Beach Sediment Sampling (Exponent 1999)

In November 1998, beach sediment samples were collected from exposed river sediments at six stations (RB-1 through RB-6) during a relatively low river stage (Figures 3-1 and 3-2). Surface samples were collected using a stainless-steel spoon from the depth interval of 0-10 cm (0-0.4 ft) at each sample station. Sediment coring at depths greater than 10 cm was achieved using a titanium drive corer. The maximum penetration depth was less than 35 cm (1.1 ft), except at station RB-6, where penetration reached 90 cm (3 ft).

Surface sediments and sediment core samples were submitted for the analysis of SVOCs, VOCs, pesticides, TOC, and grain size. Each sediment increment was also field-screened using a PID for the presence of VOCs, DDT using TLC, and non-aqueous phase liquid (NAPL) using Sudan IV® hydrophobic dye.

3.1.4 Offshore Sediment Sampling (Exponent 1999)

In January 1999, sediment samples were collected from six offshore stations (OSS series; Figures 3-1 and 3-2). Samples were collected from the surface (0–10 cm) and at subsequent 20-cm increments to a total depth of 90 cm (3 ft). The surface sediment and one or more deeper intervals from each core were submitted for analysis of SVOCs, VOCs, pesticides, TOC, and grain size. Each subsurface sediment increment was also field-screened using a PID, TLC, and Sudan IV® hydrophobic dye.

3.1.5 Riverbank Soil Sampling (ERM 2005d)

In August 2000, surface (0 to 15 cm [0.5 ft]) soil samples were collected from six riverbank[6] sampling locations (RB-7 through RB-12) and analyzed for organochlorine pesticides, SVOCs, and four metals (cadmium, total chromium, lead, and zinc). One duplicate sample was collected and analyzed for the same suite of analytes. Samples were collected from three paired locations with one sample location near the top of the slope and the second downslope from the first sample location (Figures 3-1 and 3-2). The sample stations were located between Docks 1 and 2.

3.1.6 Seep Reconnaissance Survey (GSI 2003)

In October 2002, a reconnaissance groundwater seep survey was conducted for the Portland Harbor RI/FS. Its objective was to inventory readily identifiable groundwater seeps present between RM 2 and RM 10.5 for the human health risk assessment and

[6] The riverbank (i.e., considered soil) is defined in this work plan as the area between the mean high water and ordinary high water. The riparian zone is the area between mean high water and the top of the bank. The beach (i.e., considered sediment) is defined as the area between mean low water and mean high water.

groundwater conceptual model (GSI 2003). The survey was conducted in an outboard motor-powered launch by cruising close to the shoreline at low speed while observing the banks for signs of groundwater seepage. The reconnaissance survey was conducted during a low stage period on the Willamette River after a drier than normal summer and fall. More bank and beach areas were exposed during this low stage, which increased the likelihood of observing seeps. Seeps were not observed during the October 2002 reconnaissance survey.

3.1.7 Round 1 Site Characterization Summary and Round 1 Field Sampling Reports (SEA et al. 2003, Integral 2004c)

In 2002, surface sediment samples were collected during Round 1 studies from two stations (07R003 and 07R006) in the river adjacent to the Arkema site (Figures 3-1 and 3-4). Surface sediments were collected from 0 to 15 cm (0.5 ft) using either a 0.1-m^2 van Veen grab sampler or a 0.3-m^2 hydraulic power grab sampler. The surface sediment sampling stations were located with a differential GPS navigation system and collocated with tissue (sculpin, crayfish, and clams) sampling locations.

Beach sediments were collected from one station (07B024) using a stainless-steel hand corer at a minimum of three locations, depending on the total length of the beach. Each beach was subdivided into three transects parallel to the shoreline. The river waterline was defined as the lower beach transect (transect 1). The vegetation line became the upper beach transect (transect 3), and halfway between transects 1 and 3 became transect 2. A pre-determined, randomly selected transect (1, 2, or 3) was then sampled for station 07B024 (Integral 2004c).

Surface and beach sediments were analyzed for metals, organochlorine pesticides, PCB Aroclors, chlorinated herbicides, SVOCs, TOC, grain size, and total solids. Collocated surface sediment samples were additionally analyzed for PCB congeners, polychlorinated dibenzo-*p*-dioxins and furans (PCDD/Fs), butyltins, and VOCs (Integral 2004c).

Biological tissue sampling of ecological risk assessment (ERA) target species included the collection of clam, crayfish, and sculpin tissue from the onsite stations 07R003 and 07R006. The tissue samples from each station were composited and assembled by weight (>150 g per composite) rather than by numbers of individual samples. Sculpin tissue samples were collected using a variety of sampling techniques, including backpack electroshocker, boat electroshocker, and trotlines. The field manager determined which method would be the most effective based upon field observations of suitable sculpin habitat (SEA et al. 2003). Crayfish were sampled using standard minnow traps within 100 ft of the shoreline at marked sculpin stations. Clam tissue was collected using a 0.1-m^2 single van Veen grab sampler.

The tissue samples collected adjacent to the Arkema facility, 07R003 and 07R006, were analyzed for organochlorine pesticides, PCB Aroclors, metals, lipids and total solids (SEA et al. 2003). At station 07R006, crayfish and sculpin tissue were also analyzed for SVOCs. At station 07R006, clam tissue was also analyzed for butyltins but not for SVOCs, PCB congeners, and PCDD/Fs. Tissue sample analyte lists are presented in the Round 1 Site Characterization Summary Report (Integral 2004c).

Biological tissue sampling of human health risk assessment (HHRA) target species included the collection of carp, smallmouth bass, and crayfish from onsite stations 07R009 and FZ0609. Tissue samples for smallmouth bass and carp were predominantly caught by electroshocker and crayfish by standard minnow traps.

The HHRA target species caught adjacent to the Arkema facility were located at stations 07R009 and FZ0609. Compositing of HHRA target species is discussed in detail in the Fish Tissue Compositing and Shipping SOP (SEA et al. 2002a). The tissue samples were analyzed for organochlorine pesticides, PCB Aroclors, metals, lipids, and total solids. The laboratory that performed the chemical analyses retained an aliquot of homogenized tissue for analyses of PCDD/Fs and PCB congeners on whole-body samples for HHRA species only. Tissue sample analyte lists are presented in the Round 1 Site Characterization Summary Report (Integral 2004c).

3.1.8 Sediment Stake Erosion/Accretion Monitoring Study (Anchor 2003, 2004)

A transect of stakes was deployed at the Arkema site in July 2002 and monitored periodically until January 2004 to assess sediment deposition or erosion rates (Figures 3-1 and 3-2). The sediment stake report indicated that the stakes were “missing” or “disappeared” toward the end of the monitoring sequence. Three stakes were placed along a transect perpendicular to the shoreline near the downstream portion of Dock 2. The stakes were placed at the 10th percentile (low stakes), 50th percentile (median stakes) and 90th percentile (high stakes) of the river stage. Changes in bathymetry between September 2002 and May 2003 were also examined to assess the changes in sediment depth.

A discussion of the bathymetric survey data collected from 2002 to 2004 is presented in Section 3.2.1.2.

3.1.9 Stage 1 & 2 Groundwater and Sediment Investigation (Integral 2003)

The Phase II Stage 1 and Stage 2 investigations were conducted in June 2002 and February through March 2003, respectively. For Stage 1, seven borehole pairs (WB-1 through WB-7)

were advanced using direct-push techniques (standard Geoprobe® push-probe rig, a smaller Geoprobe® push-probe unit attached to the bed of a standard pickup truck, or a portable tripod Geoprobe® unit) from Docks 1 and 2. For Stage 2, 18 borehole pairs (WB-8 through WB-25) were advanced using a Geoprobe® push-probe rig mounted on a barge. Figures 3-1 through 3-3 show the station locations.

Borehole pairs were advanced through conductor casing using direct-push techniques to refusal (generally basalt). Sediment samples were continuously collected for logging, field screening, and potential analysis through the first conductor casing. Where possible, sediments were composited over approximate 2-ft intervals and screened in the field for VOCs, NAPL, and DDT. The constituent that was targeted for the NAPL screening was MCB. Selected Stage 2 sediment samples were analyzed for pesticides. Groundwater samples were collected from the second conductor casing through a 4-ft stainless-steel temporary Geoprobe® screen at one or more discrete intervals from each borehole (with the exception of boreholes WB-6 and WB-17) and were analyzed for VOCs and organochlorine pesticides. Selected groundwater samples were analyzed for cations (calcium, magnesium, potassium, sodium) and anions (bicarbonate, sulfate, alkalinity, and chloride). Stage 2 groundwater samples were also analyzed for perchlorate.

The sediment and groundwater samples collected during the Phase II Stage 1 and 2 investigations were not analyzed for all site COIs.

3.1.10 Round 2 Beach and Surface Sediment Investigation (Integral 2005c,d)

In August and September 2004, grab surface sediment samples were collected from 30 stations (i.e., G300 series) in the river adjacent to the Arkema site (Figures 3-1 and 3-2). Six of these stations (i.e., G328, G337, G349, G357, G361, and G365) are located in the Willamette River channel adjacent to the Arkema site, but are beyond the area covered by the figures. The samples were collected using a 0.3-m^2 hydraulic power grab sampler. The target sampling interval was 0-30 cm below the sediment-water interface, with a minimum acceptable penetration depth of 20 cm. All samples were analyzed for grain size, SVOCs, pesticides, metals, and TOC. Selected samples were analyzed for ammonia, hexavalent chromium, TPH-D, TPH-G, PCDD/Fs, herbicides, PCB Aroclors, VOCs, pentachlorophenol, total sulfides, Atterberg limits, specific gravity (10 percent of samples based on grain-size analysis), and bioassays.

3.1.11 Round 2 Subsurface Sediment Investigation (Integral 2005d; Integral and Anchor 2005)

In October and November 2004, sediment cores were collected from 16 stations (i.e., C300 series) in the river adjacent to the Arkema site (Figure 3-2) during Round 2 activities. One

of these stations (i.e., C357) is located in the Willamette River channel adjacent to the Arkema site, but is beyond the area covered by the figure. Subsurface cores were collected over water using a vessel-deployed vibracore equipped with either a 14-ft or 20-ft aluminum core tube (4-in. diameter). At each core station, a single core was driven to the maximum core tube length (13 ft for the 14-ft core tubes and 19 ft for the 20-ft core tubes) or refusal depth.

At the onshore core processing lab, the majority of the cores were opened using a table saw. After the sediment in each core segment was exposed, the subsurface sample intervals were determined, based primarily on lithology (USCS visual classification) and the minimum (1 ft) and maximum (approximately 4 ft) thickness criteria as stated in the Round 2 FSP (Integral and Windward 2005a).

A total of 75 sediment samples (including field replicates) were collected from the 16 stations adjacent to the Arkema site. Forty-seven of these samples were analyzed for selected analytes, including grain size, Atterberg limits, specific gravity, SVOCs, pesticides, PCBs, metals, total solids, TOC, hexavalent chromium, TPH-D, TPH-G, VOCs, PCDDs/Fs, herbicides, and pentachlorophenol. Of the sediment samples collected, 28 were archived at the laboratory and not analyzed.

3.1.12 Round 2A Sediment Toxicity Testing (Windward 2005b)

From July through October 2004, 14 grab surface (0-30 cm) sediment samples were collected in the river adjacent to the Arkema site (G300 series; Figure 3-5). The samples were collocated with surface chemistry samples (Integral 2005c,d) using a power grab sampler deployed from a sampling vessel. Each sample underwent 10-day *Chironomus tentans* and 28-day *Hyalella azteca* sediment toxicity tests. The toxicity tests were also conducted on negative control sediments, collected from a well-established area free of contaminants. The toxicity test results for each test sediment sample were compared against the negative control samples for each batch.

3.1.13 Monitored Natural Recovery Report (Anchor 2005a)

In October 2004, subsurface cores were collected from four stations within the Portland Harbor Superfund study area. Dredging records, bathymetry, site use, and hydrodynamic conditions within the study area were reviewed to identify sediment core locations that showed the potential for net sedimentation and various degrees of natural attenuation processes. A single core (NA-3) was collected at Willbridge Terminal, immediately upstream of the Arkema site. Samples were collected from the mudline elevation to a depth of 94 cm (3.1 ft) below the mudline elevation. Radioisotopes beryllium-7, cesium-137, and lead-210 were analyzed from selected depth intervals for sediment-dating purposes. Beryllium-7 has a relatively short half-life of 53 days and is useful in

measuring the biological mixing zone in sediments. Lead-210 and cesium-137 have longer half-lives (22 years and 30 years, respectively) and can provide information on net deposition rates for a location. Bulk metals, PCBs, PAHs, and DDT were also analyzed in selected samples.

3.1.14 Groundwater Pathway Assessment Pilot Study (Integral 2005a)

The groundwater pilot study was conducted by the LWG at the Arkema site between November 2004 and February 2005. The objective of the pilot study was to evaluate groundwater discharge mapping tools and TZW sampling methods under realistic field conditions for the Willamette River (Integral 2005a). Three groundwater discharge mapping tools were evaluated during the pilot study: thermal infrared imaging, the Trident Probe, and the UltraSeep® system. Five TZW sampling tools were evaluated during the pilot study: the Trident Probe, the UltraSeep® system, large- and small-volume peepers, vapor diffusion samplers, and power grab sampling, followed by centrifugation.

The groundwater discharge mapping tools and TZW sampling tools were utilized in five transects in the Acid Plant area and six transects in the Chlorate Plant area (Figure 3-3). The groundwater pilot study data are presented in Appendix B of the Round 2 Groundwater Pathway Assessment Sampling and Analysis Plan (Integral 2005a). An evaluation of the effectiveness of the TZW sampling methods tested during the pilot study is presented in Addendum 1 (Field Sampling Plan – Transition Zone Water Sampling; Integral 2006c) to Attachment 2 of the Round 2 Groundwater SAP (Integral 2006b). Pilot study results at the Arkema site are summarized in Section 3.2 (physical results) and Sections 5 and 6 (analytical results).

3.1.15 Round 2 Groundwater Pathway Assessment SAP (Integral 2005a)

The Round 2 Groundwater Pathway SAP was initiated to address data gaps needed to perform the ERA and HHRA for the Portland Harbor RI/FS. Activities that pertained to the Arkema site are summarized below.

3.1.15.1 Groundwater Discharge Mapping

The initial phase of work conducted under the Round 2 Groundwater Pathway SAP (Attachment 1; Integral 2005b) consisted of groundwater discharge mapping activities to assess risk to human health associated with exposure to groundwater-related COIs in surface seeps via incidental ingestion and dermal contact, and to identify target areas for TZW sampling activities. Vertical groundwater gradient information was collected for the Arkema site using time-series water level data loggers over a 72-hour period. In addition, groundwater discharge verification measurements were collected using seepage

meters at 11 locations offshore of the Arkema site in August 2005 (Figure 3-3). Results of the groundwater discharge mapping activities are presented in Attachment 2, Addendum 1 of the Round 2 Groundwater Pathway SAP (Integral 2006a). A discussion of the groundwater discharge results is presented in Section 3.2.2.1.

3.1.15.2 Transition-Zone Water Sampling

TZW samples were collected to estimate exposure-point concentrations for chemicals in TZW that may not adequately reflect bulk sediment chemistry and bioassay toxicity data. Based on findings of the pilot study, two complementary sampling methods were used for the collection of Round 2 TZW samples: the Trident Probe, and small-volume peepers. The Trident Probe was used to collect TZW samples in coarse-grained sediments. When the presence of fine-grained sediments precluded the use of the Trident Probe (due to low water production rates), small-volume peeper sampling devices were used to collect the TZW samples. A total of 25 TZW samples were collected at 17 distinct locations along the shoreline of the Arkema site (Figure 3-3). Of these 25 samples, 18 samples were collected using the Trident Probe method, and the remaining 7 samples were collected using small-volume peepers. Field sampling activities have been documented in the Round 2 Groundwater Pathway Assessment Transition Zone Water Sampling Field Sampling Report (Integral 2006b).

3.1.16 Arkema Stormwater Characterization (Integral 2006j)

The Arkema site was issued an NPDES stormwater discharge permit by DEQ on January 22, 2004. As a condition of the permit, Arkema was required to conduct a stormwater characterization for legacy and 303(d) constituents for a 1-year period. Stormwater characterization sampling consisted of monthly sampling of all four stormwater outfalls (Figure 3-1a) from March 2004 through February 2005. Stormwater samples were analyzed for total dissolved solids, iron, manganese, mercury, hexavalent chromium, DDT and metabolites DDD and DDE (DDx), PAHs, PCBs, chlorobenzene, pentachlorophenol, perchlorate, and chloride.

On May 18, 2005, Arkema submitted a Stormwater Characterization Report (SCR) to DEQ in compliance with its permit (Arkema 2005). Subsequent to submitting the SCR, analytical results from the SCR were screened against SLVs set forth by DEQ and EPA in the JSCS (DEQ and USEPA 2005). The results of this screening are presented in Appendix A of the Stormwater IRM Work Plan – Final (Integral 2006j) submitted to DEQ on June 9, 2006. The stormwater IRM work plan was prepared to identify the approach designed to address COIs detected in stormwater at the site, which include perchlorate, manganese, hexavalent chromium, and DDx. Method detection limits for data collected as part of the SCR for PCBs, PAHs, and pentachlorophenol did not achieve the JSCS screening values or achievable method reporting limits for water. Therefore, analysis of stormwater and catch basin sediments identified in the work plan will include these additional analytes.

Furthermore, analysis of catch basin sediment samples identified in the work plan will also include phthalates (Integral 2006j; Appendix A, Figure 1).

3.1.17 Subyearling Chinook Tissue Collection (Integral and Windward 2005b, 2006)

In the spring of 2005, juvenile Chinook salmon were collected by the LWG for tissue analysis, in order to fill in data gaps for the harborwide RI and risk assessments and to begin collection for the FS. Of the four stations sampled on the river, one station (T02) was sampled within the Arkema facility's boundary in the vicinity of the City of Portland and Rhône Poulenc's outfalls, between RM 6 and 7 (Figure 3-1 and 3-4). Juvenile Chinook salmon were collected using a 100-foot-long pole seine for beach seining. The target length was between 50-80 mm. All juvenile Chinook tissue collection and processing followed the procedures in the Chinook Tissue FSP and associated QAPP and QAPP addenda (Integral and Windward 2005b).

Both whole-body tissue and stomach content chemical analyses were conducted from fish caught at station T02. Chemical analyses conducted on whole-body fish tissue included percent lipids, percent moisture, total metals, butyltin compounds, organochlorine pesticides, PAHs, SVOCs, PCDD/Fs, and PCB congeners. Stomach contents of five to eight fish per composite were removed for taxonomic identification of prey species, and the remaining contents were analyzed for PAHs, PCB congeners, and organochlorine pesticides.

3.1.18 Round 2 Sampling of Invertebrates Using Multiplate Samplers (Windward 2005c)

Multiplate samplers were deployed for the Portland Harbor ERA at 10 stations between RM 2 and RM 11 from July 26 to 28, 2005, to collect invertebrates to assess chemical loading. Two of the stations, MIT005 (located at RM 6.8) and MIT006 (located at RM 7.4), were located adjacent to the Arkema site. At each station, four arrays of six multiplate samplers (total of 24 multiplate samplers per station) were deployed based on field determination of the most suitable locations for each array. Factors included in the suitability evaluation included water depth (at least 5 m to ensure adequate water depth later in the summer), existence of a tie-up point for the rope connected to the array, avoidance of high traffic and prop-wash areas, and avoidance of the dredge operation near GASCO.

Two of the sampler arrays at station MIT005 were reported damaged near the Rhône Poulenc outfall diffuser. The damaged arrays were retrieved and new sampler arrays were constructed and deployed. The multiplate samplers were retrieved approximately 6 weeks after deployment.

The samplers were processed and the invertebrate tissue was frozen until analyzed. Details on processing the tissue are presented in the field sampling report for the Round 2 sampling of invertebrates using multiplate samplers (Windward 2005c). Because of the limited number of tissue samples, samples from several stations were combined to achieve sufficient mass for chemical analysis, including tissue from stations MIT003 (GASCO), MIT005 (Rhône Poulenc), and MIT006 (Arkema). The combined tissue sample was analyzed for PCBs, DDTs, lipids, PAHs, and moisture content.

3.1.19 Round 2 Sampling of Benthic Invertebrate Tissue Sampling (Windward and Integral 2006)

The benthic invertebrate tissue sampling effort was conducted to measure constituents in benthic invertebrate prey organisms within the study area for use in the ERA dietary exposure models, and to calculate a site-specific biota-sediment accumulation factor using data obtained from field-collected organisms and laboratory bioaccumulation tests. The sampling effort included a series of two sampling events, where samples were collected at 33 locations between RM 2 and RM 10. The first event consisted of the field collection of clams (*Corbicula* sp.), followed by the collection of sediment in the same vicinity one week later. One composite sample was prepared for each area for both clam tissue and sediments. Of the 33 locations sampled, three sampling areas (BT017, BT018, and BT020) were located near the Arkema site (Figures 3-1 and 3-4).

Clams were collected for chemical analysis, while sediments were collected for both chemical analysis and bioaccumulation testing with two organisms, the clam *Corbicula fluminea* and the worm *Lumbriculus variegatus*. Site-collected clam tissue as well as tissue samples obtained from bioaccumulation testing were targeted for the following analysis (if adequate biomass was collected): percent moisture, lipid content, phthalate esters and SVOCs, PAHs, organochlorine pesticides, PCB congeners, PCDD/Fs, butyltin compounds, mercury, and other metals. Sediment samples were analyzed for conventional parameters, SVOCs, petroleum hydrocarbons, VOCs, oganochlorine pesticides, herbicides, PCB Aroclors and congeners, PCDD/Fs, butyltin compounds, mercury, and other metals. Data associated with these analyses were not available at the time this work plan was written.

3.1.20 PCB Congeners in Archived Round 2A Surface Sediments (Integral 2006c)

The Round 2 sediment sampling was performed by the LWG during multiple field efforts in the fall/winter of 2004 and the spring/summer/fall of 2005. Surface and subsurface sediments were collected at numerous stations between RM 2 and RM 11, as well as at several upstream locations between RM 16 and RM 25, and were analyzed for a full suite

of chemicals, including PCBs as Aroclors. A portion of each of the sediment samples was archived for possible future analysis.

EPA, in their comments on the Round 2 FSP for Sediment Sampling and Benthic Toxicity Testing (Integral and Windward 2005a), requested that a subset of Round 2 archived surface sediment samples be analyzed for PCB congeners for comparison and correlation with PCB Aroclor totals, for human health and ecological risk assessment of coplanar PCB congeners, and for use in the food web model. The rationale and selection of archived surface sediment samples are documented in the Round 2 Surface Sediment PCB Congeners Sample Selection Memo (Kennedy/Jenks and Integral 2005).

Seven surface sediment samples (stations G339, G351, G353-1, G355, G358, G360, and G371; Figures 3-1 and 3-2) collected from stations adjacent to the Arkema site were analyzed for PCB congeners.

3.1.21 Round 2A Archived Core Sediment Data (Integral 2006d)

The Round 2A sediment sampling was performed by the LWG during multiple field efforts in the summer and fall of 2004. Subsurface core sediment samples were collected at numerous stations between RM 2 and RM 11, as well as at several upstream locations between RM 16 and RM 25, and analyzed for a full suite of chemicals. A portion of each of the core sediment samples was frozen and archived for possible future analyses.

After a review of the spatial vertical trends of the Round 2A analytical results for subsurface sediment, gaps were noted for several "indicator chemicals" in the data set. A decision process was enacted to select archived subsurface samples for analysis to supplement the data set. A total of 13 archived samples were selected for analysis from nine sediment cores (stations C334, C335, C348, C349, C356, C361, C366, C371, and C377; Figures 3-1 and 3-2) adjacent to the Arkema site.

Each sample was analyzed for a subset of 16 of the 27 chemicals mapped in the Round 2 data summary report. The 16 chemicals included those that can be analyzed in a frozen archived samples (i.e., VOCs were not included) and encompassed the major "archive-able" compound groups (metals, SVOCs, PCBs, pesticides, and PCDD/Fs). When possible, the summed parameters for a compound group (e.g., total PCBs) were included as the screened chemicals rather than the individual chemicals (e.g., Aroclor 1260) to capture broad trends in contaminant nature and extent.

3.1.22 Round 2B Subsurface Sediment Data (Integral 2006g)

Round 2B subsurface sediment samples were collected to fill in data gaps for the Portland Harbor RI, risk assessments, and the FS. Subsurface sediment cores were collected at 42

locations within the LWR from approximately RM 3.5 to RM 10 during the October 18-28, 2005 sampling event. These locations were sampled to support site nature and extent characterization efforts; however, 14 locations also supported FS purposes, and 7 locations also supported the assessment of potential groundwater impacts.

Two of the 42 subsurface sediment cores (C358 and C360) were located within 200 feet of the southeast side of Arkema's Dock 1 (Figures 3-1 and 3-2). Subsurface core C358 was separated into four depth intervals for chemical analyses as follows: 0 to 30 cm – hexavalent chromium and VOCs; and 30 to 152 cm, 152 to 248 cm, and 248 to 303 cm – conventional parameters, Atterberg limits, SVOCs, chlorinated pesticides, PCB Aroclors, VOCs, mercury and other metals, and hexavalent chromium. Two sample intervals were collected from subsurface core C360: 90 to 213 cm – conventional parameters, Atterberg limits, SVOCs, chlorinated pesticides, PCB Aroclors, VOCs, mercury and other metals, and hexavalent chromium; and 448 to 572 cm – hexavalent chromium and VOCs.

The subsurface sediment data generated from this effort will be evaluated in conjunction with the surface sediment and beach sediment data collected in 2004, and will be reported in the Round 2 Comprehensive Site Characterization Report later in 2007.

3.1.23 Round 2A Surface Water Site Characterization Summary (Integral 2006f)

The Round 2A surface water sampling was performed by the LWG during the fall of 2004 (November 8–December 2, 2004), the winter of 2005 (March 1–17, 2005), and the summer of 2005 (July 5–20, 2005). The purpose of the Round 2A sampling was to collect surface water data for the RI and risk assessments, and to initiate data collection for the FS. The fall 2004 event was selected as the mid-to-late fall/early rainy season event. The schedule for the winter 2005 event was selected to coincide with the release of amphibian egg masses. The summer 2005 event was chosen to be representative of typical low-flow conditions.

Three surface water stations were located adjacent to the Arkema site (stations W015, W016, W017; Figures 3-1a and 3-3). A field replicate was collected from station W016 during each sampling event. Surface water samples for standard chemical and conventional analyses were collected from all three stations using a peristaltic pump with an extended Teflon™ sampling tube lowered to the desired depth. The sample was composited and mixed as described in the Round 2A Surface Water Site Characterization Summary Report (Integral 2006f).

Surface water samples requiring ultra-low detection limits were collected from stations W015 and W016 using the high-volume XAD sampling method. This method eliminates the need to collect, store, and transport large volumes of water. Large volumes of water

were pumped through Teflon™-lined polypropylene tubing, a 140-μm stainless-steel pre-filter, 0.5-μm glass fiber filter cartridges, and XAD-2 resin beads packed inside stainless-steel canisters using an Infiltrex 300 pump system. Organic compounds associated with the particulate phase were collected with 0.5-μm glass fiber filters, and the dissolved particulate and colloidal organic compounds less than 0.5 μm were adsorbed onto XAD resin columns. The columns and filters were analyzed individually to determine, respectively, the dissolved and particulate concentrations of analytes in the samples. A total volume of approximately 1,000 liters of water was pumped at each high-volume sample station at a flow rate of approximately 1.25 liters per minute.

Surface water samples collected from each of the three stations were analyzed for TSS, total dissolved solids (TDS), TOC, dissolved organic carbon (DOC), unfiltered metals, filtered metals and hardness, tributyl tin (TBT), herbicides, and SVOCs with standard detection limits. Selected surface water samples were also analyzed for hexavalent chromium, perchlorate, PCB Aroclors, and pesticides with standard detection limits. Selected XAD resin and filter samples from stations W015 and W016 were also analyzed for PCDD/Fs, PCB congeners, phthalate esters, pesticides, and PAHs with ultra-low detection limits. In addition to surface water sample collection, general water quality parameters (temperature, pH, dissolved oxygen, oxidation-reduction potential [ORP], conductivity, and depth) were measured *in situ* at all sampling stations.

3.1.24 Round 3 January 2006 High-Flow Surface Water Sampling Event (Integral 2006h)

The first sampling event of the Round 3 surface water sampling program was performed by the LWG from January 19–21, 2006. The purpose of the Round 3 sampling was to collect surface water samples during the January 2006 high-flow event on the LWR. Surface water sampling was conducted using two methods, the peristaltic pump method, and high-volume sampling with XAD-2 columns.

The target stations sampled were W005, W023, and W024 located at RM 4, RM 11, and RM 16, respectively. None of the stations was located adjacent to the Arkema site. The surface water samples were collected from a single point, approximately one-third below the water surface, at a mid-channel location. The surface water samples were collected with a peristaltic pump and using an Infiltrex 300 system connected to XAD-2 resin columns to collect hydrophobic organic compounds for analysis by ultra-low analytical methods. The sample collection methods utilized in the Round 3 surface water sampling were the same as those described above in the Round 2A surface water sample collection. One station (W023) was occupied twice to generate a field replicate for the peristaltic sampling method. A field replicate was not collected for the XAD method. A total volume of approximately 400 liters of water was pumped at each high-volume sample station at a flow rate of approximately 1.25 liters per minute.

Each surface water sample was analyzed for metals, SVOCs, butyltin compounds, TDS, TSS, TOC, and DOC. Water quality parameters (temperature, dissolved oxygen, specific conductance, pH, turbidity, and ORP) were also measured at all stations; however, due to problems with calibration, DO and conductivity data were not collected at stations W005 and W023. XAD resin and filter samples were collected at each of stations for analysis of PCDD/Fs, PCB congeners, pesticides, and PAHs with ultra-low detection limits.

3.1.25 Round 2 Hydrodynamic/Sediment Transport Modeling Data Collection (Integral 2006e)

The overall goal of the hydrodynamic/sediment transport modeling of the LWR is to provide information on sediment stability/erodibility over time and over a range of potential hydrologic conditions. The hydrodynamic/sediment transport modeling effort was initiated in 2004, and two modeling efforts were anticipated. The Phase 1 effort included model setup, an analysis of modeling sensitivity, initial model calibration and validation runs for both hydrodynamics and sediment transport, and a discussion of the results (Integral 2006e).

The EPA, in its comments on the Phase 1 modeling report and the hydrodmodeling FSP, also recommended the collection of several types of site-specific measurements to enhance model performance. The critical data needs identified in the review process for Phase I model results included the collection of TSS measurements upstream and in the study area over a range of flow conditions, physical bed properties in the study area, and short-term (i.e., days) response of the river bed to a relatively high flow (>100,000 cfs) event.

Vertically integrated TSS samples were collected along four transects in the study area, RMs 11, 6.3, 2, and the Multnomah Channel, on April 3 and 4, 2006, with river flows of less than 30,000 cfs. Three vertically integrated samples (west side, mid-channel, and east side) were collected along each transect. During this sampling effort, two sets of TSS samples were collected over one tidal cycle, one at mid-flood and one at mid-ebb. None of the sample stations was adjacent to the Arkema site. A total of 10 upstream TSS samples were collected at time intervals triggered by changes in river flow from November 22, 2005 to April 5, 2006.

Suspended sediment measurements were collected using a laser *in situ* scattering transmissometer (LISST)-100 system from April 3 and 4, 2006. The LISST-100 was deployed from a vessel and measured *in situ* suspended sediment grain-size distributions over depth and time at five target locations. Four stations were located in the study area between RM 2 and RM 11 and were distributed in the mid-channel as well as along both the east and west banks. The fifth station was located in a narrow portion of the river

upstream of Ross Island at approximately RM 18. None of the stations was adjacent to the Arkema site.

Surface sediment bed properties were estimated at 17 stations throughout the study area, including one station adjacent to the Arkema site (HMC12). At each station, a rectangular acrylic Sedflume core and a pair of collocated plastic cylindrical cores were collected by divers. The cores were processed at an onshore lab. Erosion measurements were made at 5-cm intervals to a maximum depth of 30 cm below mudline in each Sedflume core, and small aliquots of sediment from each interval were collected for particle-size measurements (laser-detector) and bulk density. The collocated cylindrical cores were logged by a geologist, and core intervals to a depth of 30 cm were analyzed for grain size, specific gravity, and TOC. Core intervals below a depth of 30 cm were archived.

The data from this investigation were not available at the time this work plan was prepared.

3.1.26 Upland Pilot Studies and IRMs (ERM 2001a,b, 2002, 2003, 2004a,b,c, 2005a,b,c,d; ATOFINA 2003)

The upland pilot studies and IRMs are discussed in Sections 4.1.5 and 9.2. These studies and IRMs are also summarized in the Upland RI report (ERM 2005d), and additional details are provided in the individual IRM and bench study reports (ERM 2001a,b; 2002; 2003; 2004a,b,c; 2005c,d; ATOFINA 2003).

3.1.27 Riverbank Soil Sampling (Integral 2006i)

Nine riverbank composite soil samples will be collected and analyzed in support of the upland ecological risk assessment for the Arkema site (Integral 2006i). The composites will be collected from five locations mid-bank and four locations top of bank along the Arkema waterfront. Each composite sample will be composed of five discrete samples collected to a depth of 1 foot bgs. This sampling is planned for late summer 2006.

3.2 GEOLOGIC AND HYDROGEOLOGIC DATA

This section summarizes the physical characteristics of the in-water and upland geology and hydrogeology at the site. Specific physical parameters and engineering characteristics are presented in Section 3.3.

3.2.1 Geologic Data

The following sections summarize the in-water and upland geology of the site.

3.2.1.1 In-water Geology

Detailed cross-sections that link the upland source areas to the in-water portion of the site are provided in Figures 3-6 through 3-9. Additional cross-sections that focus on the in-water portion of the site in the vicinity of Docks 1 and 2 are provided in Appendix A (Figures 4a, 5a, 6a, and 7a, Integral 2003). A cross-section location map is also provided in Appendix A (Figure 1; Integral 2003). With increasing distance from the shoreline (eastward), sediments overlying the basalt become finer-grained, thickness of the sediment layer diminishes, and sand horizons become more limited in vertical extent. The increased thickness of sediments on the landward side of the docks is likely due to several factors, including increased deposition because of the sheltering effect of the docks, natural sedimentation, dredging, and filling activities in the vicinity of the docks. In general, the sediments represent a fining upward sequence (i.e., coarser sediments at the bottom and finer sediments at the top of the sequence) and become thinner toward the east.

Thin layers (i.e., less than 1 ft thick) of sand and silt were observed in a number of the boreholes and are shown on the cross-sections. Although available data suggest that many of these layers are discontinuous, some of these horizons may nonetheless serve as important controls on the migration of COIs (Integral 2003). Some of these layers appear to dip to the east, consistent with the slope of the basalt surface.

During the Stage 1 and 2 in-water investigation (Integral 2003), the top of the underlying basalt surface was encountered in 20 of 25 boreholes at elevations ranging from -14.3 ft (WB-2) to -43.1 ft (WB-21) City of Portland Datum (CPD) (Integral 2003). A basalt surface contour map is provided in Appendix A (Figure 3, Integral 2003). The basalt surface generally slopes to the east. There is an apparent high spot (i.e., mound) on the basalt surface around borehole WB-2. There are also two apparent troughs in the basalt surface, one trough centered on Dock 1 and the other just south of Dock 2, near borehole WB-14 (Figure 3, Integral 2003; Appendix A).

Historically, fill materials were used to extend the ground surface out into the Willamette River. A discussion of the filling activities is presented in Section 3.2.1.3.

3.2.1.2 Sedimentation Rates

Sediment accretion and erosion rates based on various studies at the Arkema site are described in the following sections.

Bathymetric Surveys

Five bathymetric surveys were conducted in the Willamette River adjacent to the Arkema site between 1999 and 2004 (Exponent 1999; SEA and DEA 2003; Anchor 2003; LWG 2004). The surveys were conducted in February 1999, January 2002, September 2002, May 2003,

and February – March 2004. Three bathymetric survey difference maps have been generated for the data; the one covering the longest time interval between surveys covers 25 months (January 2002 to February – March 2004; LWG 2004). The bathymetric survey difference maps are provided in Appendix A. Figure 2-3 provides the bathymetric surface in the vicinity of the Arkema site in 2004.

The winter 2002 to winter 2004 map indicates sediment erosion between Docks 1 and 2 of 0.25 to 2 ft between January 2002 and February 2004. Downstream of Dock 2, there was also generally 0.25 to 2 ft of erosion. Between Dock 1 and the Salt Dock, there was both sediment erosion and accretion. Immediately downstream of the Salt Dock there was 0.25 to 1 ft of erosion; upstream of Dock 1 there was 0.25 to 2 ft of accretion. The winter 2004 bathymetric survey was conducted immediately following a relatively high flow event on the LWR (LWG 2004).

The spring 2003 to winter 2004 bathymetric survey difference map indicates generally no change in bathymetry in the vicinity of Dock 1 and the Salt Dock, with some small areas of accretion (0.25 to 1 ft) around the docks and some very small localized areas of nearshore erosion (0.25 to 1 ft). The area in the vicinity of Dock 2 generally showed erosion of 0.25 to 5 ft, except for the upstream tip of the dock that had 0.25 to 1 ft of accretion.

The September 2002 to May 2003 bathymetric survey difference map indicates sediment erosion of 0.25 to 1 ft in the vicinity of Docks 1 and 2 between September 2002 and May 2003. Between the docks, however, there was some localized accretion of 0.25 to 1 ft. The Salt Dock had both erosion (0.25 to 1 ft, downstream portion of the dock) and accretion (0.25 to 1 ft, upstream portion of the dock).

Sediment Stake Survey

The results of the sediment stake study referenced in Section 3.1.8 (Anchor 2003, 2004) indicated the mudline elevation at the low stake on the Arkema site fluctuated between ±2 cm of the initial elevation through July 2003. The final measurement, collected in November 2003, recorded 7 cm of sediment accretion. The mudline elevation at the median stake showed approximately 10 cm of sediment accretion in October 2002, but only 2 cm during the final measurement in March 2003. The mudline elevation at the high stake showed a small (up to 3 cm) sediment accretion over time (the final measurement was collected in December 2002). The high stakes were probably not inundated by the river during most of the study period because the investigation included the seasonal period when river stage is typically at its minimum and least likely to reach the 90th percentile elevation.

The sediment stake study on the downstream side of Dock 2 indicated 7 cm of accretion between July 2002 and November 2003 at the low stake, an accretion rate of 5.3 cm per year. Less accretion (2 cm) was measured at the median stake between July 2002 and March 2003, which represents approximately 3 cm per year. Sedimentation rates were not estimated for the high stake because the survey occurred when the river stage was least likely to reach the high stake.

Bathymetric changes between September 2002 and May 2003 at the sediment stakes adjacent to the Arkema site indicate accretion of 7.5 to 15 cm.

Radioisotope Study

As discussed in Section 3.1.13, a single core (NA-3) was collected at Willbridge Terminal, immediately upstream of the Arkema site (Anchor 2005a). Based on results of the radioisotope dating, the sediments at this station appear to be well-mixed over the entire core depth. Calculation of a net sedimentation rate was not possible. The sediment mixing could be due to active ship movements and propeller wash in the area.

Dredging History

As described in Section 2.2.4, permission was obtained from the USACE to dredge the areas around Dock 1 and the Salt Dock in 1977. In addition, a joint application to the USACE and the Oregon DSL was submitted in 1984 and 1993 to repeat the dredging that was completed in 1977. However, there is no documentation to confirm that the dredging actually occurred.

Discussion

Bathymetric surveys (LWG 2004) generally indicated sediment erosion downstream of and between Docks 1 and 2 over the two years of study. Both deposition and erosion occurred between Dock 1 and the Salt Dock over the same period. The sediment stake survey indicated a small amount of sediment accretion at both the low and median stakes after 8 to 16 months of monitoring. The radioisotope study results were generally inconclusive for the core collected at the Willbridge Terminal.

The above-referenced studies examined sedimentation rates over relatively short periods of time. Accretion and erosion rates tend to fluctuate with the river stage and velocity, but over time reveal either net accretion or erosion. The only long-term (e.g., 20 years) data available are qualitative. This information, in the form of dredging history, indicates there may have been sufficient accretion adjacent to Dock 1 and the Salt Dock to have required dredging at least three times between 1956 (when the Salt Dock was built) and 1993. However, as previously noted, there is no documentation to confirm that the latest dredging actually occurred. Although the sedimentation rate cannot be quantified, the data appear to indicate there is a net long-term sediment accretion in these areas.

Sediment trap studies proposed by the LWG will provide additional information on the sedimentation rates in the vicinity of the Arkema site (see Section 2.3)

3.2.1.3 Upland Geology

Results of the Arkema RI indicated the following regarding upland site geology (ERM 2005a; Integral 2004a):

- The surficial geology at the site is characterized by fill and alluvial deposits of the Willamette River.
- The eastern portion of the upland site, generally between Docks 1 and 2, has been filled with debris consisting of asphalt, concrete, pipe, soil, and fill from other sources (e.g., City of Portland). These materials occur from the surface to depths of approximately 25 ft bgs. The area from the Dock 1 to the upstream end of the property was filled primarily with materials dredged to accommodate the Salt Dock. Figure 2-4 shows the approximate extent of fill adjacent at the site.
- The native soil profile is generally characterized by laterally discontinuous, alternating layers of dark gray-brown sand with various amounts of silt and thinner silt layers with various amounts of fine sand. The layers vary from massive to finely laminated.
- Underlying the deepest silt layer, at a depth of approximately 35 ft bgs[7], is a sand layer with black sands adjacent to the river in the Acid Plant area and dark gray-brown sands toward the southern end of the plant.
- Columbia River Basalt is present below the fill and alluvium at the upland portion of the site at depths of 49 to 55 ft bgs.

Detailed cross-sections that link the upland source areas to the in-water portion of the site are provided in Figures 3-6 through 3-9. Cross-sections that include the eastern upland portion of the site and extend into the Willamette River are provided in the Upland RI Report (ERM 2005d; Appendix E).

Fill materials occur from the surface to depths of approximately 25 ft bgs and consist of brown clayey silt to silty sand with occasional wood, brick, concrete, metal piping, asphalt, and miscellaneous materials from spent chlorine cells. Historically, fill materials were used to extend the ground surface out into the Willamette River. Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 ft along the riverbank. In some areas of the site, the ground surface has been extended into

[7] The deepest silt layer is continuous throughout the Acid Plant area and somewhat discontinuous in the Chlorate Plant area toward the river.

the river by as much as 200 ft (Figure 2-4). The majority of the filling activities were conducted after DDT operations ceased in the Acid Plant area in 1954. In 1956, two areas were dredged to accommodate the construction of the Salt Dock. The dredge material was placed behind an earthen berm, which extended from the Dock 1 to the upstream end of the property to form the base of the eastern half of the current salt pad (Figure 2-4).

3.2.2 Hydrogeologic Data

Physical hydrogeologic data are presented in the following sections for the in-water and upland portions of the site. Chemical hydrogeologic data are presented in Sections 5 and 6.

3.2.2.1 Sediment Groundwater

Sediment groundwater is groundwater that is located in-river below the mean high water line. Sediment groundwater was studied at the Arkema site during three investigations, the Phase II Stage 1 & 2 in-water sediment and groundwater investigation (Integral 2003), the Groundwater Pathway Assessment Pilot Study (Integral 2005a), and the Round 2 Groundwater Pathway Assessment (Integral 2006a). The pilot study and Round 2 assessment focused on shallow sediment groundwater in the transition zone, and the Stage 1 and 2 investigation focused on deeper sediment groundwater[8].

Groundwater and TZW analytical results are presented in Sections 5 and 6. Detailed cross-sections with selected COIs plotted on them are provided in the map folio.

Transition-Zone Water

Groundwater discharge was evaluated in the river adjacent to the Arkema site during the groundwater pilot study (Integral 2005a) using thermal infrared imaging (TIR), the Trident Probe, and the UltraSeep® system. Pressure transducers were deployed in upland wells in the Chlorate Plant area (MWA-32i) and the Acid Plant area (MWA-10i) to collect measurements during the UltraSeep® investigation. Groundwater discharge was evaluated during the Round 2 Groundwater Pathway Assessment using the UltraSeep® system (Integral 2006a).

TIR Survey - TIR imaging is a distributed groundwater mapping technique that relies on a temperature difference between surface water and groundwater (Integral 2005a). The images produced by the survey have a high resolution, with a ground surface pixel size of 1.5 m^2 and temperature differential increments of 0.2°C.

[8] Some groundwater samples were collected using a Geoprobe® or similar method, which can generate turbid water samples. Reported pesticide and metal concentrations using these sampling methods may not be representative of actual dissolved groundwater concentrations.

The TIR survey was conducted in November 2004 when the temperature difference between Willamette River water and groundwater at the Arkema site was approximately 6.9°C. The TIR survey did not positively identify any groundwater discharge areas at the Arkema site or any other areas surveyed, but it did identify a number of point sources (i.e., known outfalls). The utility of the TIR survey in identifying groundwater seepage areas was limited; the primary but not sole confounding factor was thermal stratification of the river.

Trident Probe Survey - The Trident Probe is a direct-push system equipped with temperature, conductivity, and water sampling probes (Integral 2005a). The Trident Probe operates as a point measurement system that evaluates the contrast in temperature and conductivity between surface water and TZW. Multiple point measurements are combined to develop a qualitative map of groundwater discharge zones. Interpretation of the Trident temperature results requires consideration of tidal influences, sediment texture, and stratigraphy. Because of tidal influences on the system, flux at the sediment-water interface can alternate between positive and negative over the course of each tidal cycle (Integral 2005b).

In November 2004, the Trident Probe was employed to collect temperature and conductivity measurements in river water and shallow sediments along 11 transects (five in the Acid Plant area and six in the Chlorate Plant area). Each transect had three or four individual measurement stations. Station locations in the Acid Plant and Chlorate Plant areas are provided on Figure 3-3 and in Appendix A (Figures 2-4 and 2-6).

Temperature differences between surface water and sediments 60 cm below mudline generally increased with distance from the shore. In addition, silty sediments generally displayed greater temperature differences than sandy sediments, likely because tidal mixing effects are reduced in zones of lower hydraulic conductivity. A strong conductivity signal was observed at the site. The high conductivity readings may be associated with groundwater discharge (Integral 2005b).

The single events measured in the Trident study may not represent long-term groundwater seepage, cannot provide data on seasonal variations, and cannot capture alterations between positive and negative flux due to the tidal cycle.

UltraSeep® Survey - The UltraSeep® is an automated seepage meter that uses an ultrasonic flow meter to measure flux as a function of time over the period of deployment. It produces direct quantitative measurements, even at very low seepage rates. The UltraSeep® system can also be fitted with various water quality probes. The unit rests on the sediment surface, requiring diver deployment and retrieval.

Pilot Study

The UltraSeep® system was deployed at three locations at the Arkema site during the pilot study (Figure 3-3): two in the former Acid Plant area (AP04B and AP04D; Figure 2-4 [Integral 2005b; Appendix A]) and one in the former Chlorate Plant area (CP07B; Figure 2-6 [Integral 2005b; Appendix A]). Prior to each deployment, the UltraSeep® system was programmed to collect flow records every 5 to 12 minutes (depending on station) for approximately 24 hours. Fifteen-minute groundwater level data were also collected by pressure transducers deployed in two nearshore wells at the site during deployments of the UltraSeep®.

The flow record (specific discharge) from each deployment is presented in Appendix A (Figure 2-11, Integral 2005b), plotted with tidal height and groundwater level readings from the nearshore groundwater wells. The UltraSeep® discharge signals recorded at all three locations show evidence of a periodic semidiurnal wave, indicative of the tidal influence (Integral 2005a). A negative correlation between tidal stage and seepage rate is generally expected due to the tidal influences (i.e., fluctuations in the river water column height [head]) on seepage rates. However, a clear negative correlation between tidal stage and seepage rate was not observed, likely indicating a phase lag between groundwater response in the nearshore area and the resulting effect of changing gradient on the seepage rate (Integral 2005d). Note that the groundwater response preceding the river stage response is likely a result of the river stage data being collected at the USGS station at the Morrison Bridge several miles upstream of the Arkema site.

A comparison of the tidal and groundwater level data shows a clear groundwater-surface water connection, consistent with the tidal influence study at the site in 1999 (ERM 2005d). Furthermore, groundwater head data show asymmetry, with the rise in hydraulic head being more rapid than the subsequent decline. A similar groundwater response has been observed in other discharge studies (Integral 2005b), and has been attributed to the boundary condition along the sloping beach face that acts as a nonlinear filter (Paulsen et al. 2004). It is not known why the groundwater response curves are steeper than the river stage response curves (Integral 2005b).

At all three UltraSeep® locations, both positive and negative seepage rates were observed. The scale of specific discharge, as measured in all three deployments, indicates low seepage rates, on the order of a few cm/day. The magnitude of both the peak positive and negative seepage rates can be related to sediment texture at each deployment location. The location with the highest discharge (maximum reading 6.11 cm/day) was station CP07B, a sandy area. Station AP04B, a sandy silt area, exhibited the second highest specific discharge (maximum reading 1.97 cm/day). Finally, the lowest discharge (maximum reading 0.47 cm/day; an overall negative value, though many of the

measurements were near the limits of detection for the meter) was observed at station AP04D, a fine silt location.

Round 2 Groundwater Pathway Assessment

The UltraSeep® system was deployed at 11 locations at the Arkema site during the Round 2 Groundwater Pathway Assessment: six in the former Acid Plant area (APSEEP 1 through APSEEP6; Figure 5-5 [Integral 2005a; Appendix A]), and five in the former Chlorate Plant area (CPSEEP 7 through CPSEEP 11; Figure 5-5 [Integral 2005a; Appendix A]). Pressure transducers were not deployed in nearshore wells to collect water level data during the Round 2 investigation.

The flow record from each deployment is presented in Appendix A (Figure 5-7a-c, Integral 2005a), plotted with tidal height. Near the shoreline, sandy and silty-sand locations APSEEP 1, APSEEP 5, CPSEEP 10, and CPSEEP 11 displayed high discharge rates relative to other locations, with average specific discharge rates of 4.0, 3.1, 7.0, and 2.1 cm/day, respectively (Integral 2006a). The maximum specific discharge rates recorded at these locations were 16.0, 17.4, 31.5, and 3.1 cm/day, respectively. The average specific discharge rate at the remaining locations was low (<0.5 cm/day). In general, the nearshore sand and silty-sand sediments were found to have higher relative discharge rates, consistent with site stratigraphy and the conceptual model of shallow groundwater flow (Integral 2006c). The most offshore seepage meters (APSEEP 3, APSEEP 6, and CPSEEP 9), located slightly offshore of the dock structures, showed near-zero average discharge rates (ranging from 0.5 to –1.2 cm/day).

The results of the Ultraseep® surveys indicate that although the specific discharge rates fluctuate between positive and negative values (i.e., groundwater discharge and recharge, respectively), the magnitude of specific discharge was generally small. Groundwater has, however, been shown to discharge from the site. Transition-zone water has detectable concentrations of certain COIs (see Sections 5 and 6). In general, the nearshore sand and silty-sand sediments were found to have higher relative discharge rates than the sediments farther from the shore. This might be a result of steeper hydraulic gradients in sediments that are close to the shore. Because the UltraSeep® data were collected over a short time (i.e., approximately 24 hours per station) at a limited number of stations, the data may not represent long-term seepage rates and provide little information on seasonal variations.

Deep Sediment Groundwater

During the Stage 1 and 2 investigations, groundwater samples were collected from depths ranging to 37.8 ft below mudline. Relative surface water and groundwater level measurements were collected at each screened interval prior to groundwater sample collection. The results indicate that the potentiometric surface of groundwater in

sediments is generally higher than the river level (typical head difference ranged between 0.1 and 1.0 ft). Some of the measurements, however, indicated a potentiometric surface of groundwater in sediments lower than the river level. The surface water potentiometric surface differences should be interpreted with caution, because the groundwater levels were measured from temporary monitoring points and water levels may not represent a static equilibrated groundwater surface (Integral 2003). In addition, tidal stages were not correlated with the water levels measured during the Stage 1 and 2 investigations.

Detailed cross-sections that show selected COIs in deep sediment groundwater are provided in the map folio[9].

3.2.2.2 Groundwater Seeps

As discussed in Section 3.1.6, a reconnaissance groundwater seep survey was conducted in October 2002 for the Portland Harbor RI/FS. No seeps were observed at the Arkema site during the reconnaissance survey. Seeps were not observed during the reconnaissance survey.

3.2.2.3 Upland Groundwater

Groundwater occurs in fill materials and in four distinct groundwater zones beneath the site. In general, the depth to groundwater increased from west to east across the site (from Front Avenue toward the Willamette River). Table 3-2 provides a summary of the four groundwater zones and their characteristics (Integral 2004a).

[9] Some groundwater samples were collected using a Geoprobe® or similar method, which can generate turbid water samples. Reported pesticide and metal concentrations using these sampling methods may not be representative of actual dissolved groundwater concentrations.

Table 3-2. Upland Groundwater Zones and Characteristics.

Shallow Unconfined Alluvial Aquifer	
No. of Monitoring Wells	>50 (includes wells installed for monitoring of pilot studies)
Depth of Aquifer	Unconfined – ground surface to 32 ft bgs
Depth to First Groundwater	6 to 12 ft on the western portion of the site; 14 to 32 ft on the eastern portion of the site (adjacent to the river)
Saturated Thickness	~20 ft on the western portion of the site; ~10 to 15 ft adjacent to the river
Groundwater Flow Direction	East-northeast in the Acid Plant area; east-southeast in the Chlorate Plant area
Hydraulic Gradient	0.0024 to 0.0069 ft/ft
Hydraulic Conductivity	5.9 to 34 ft/day (17 ft/day average)
Intermediate Confined or Semi-Confined Alluvial Aquifer	
No. of Monitoring Wells	11
Depth of Aquifer	36 to 46 ft bgs in the Acid Plant and Chlorate Plant areas
Saturated Thickness	5 to 10 ft
Groundwater Flow Direction	East-northeast in the Acid Plant area; east-southeast in the Chlorate Plant area
Hydraulic Gradient	0.0038 to 0.0069 ft/ft
Hydraulic Conductivity	0.04 ft/day to 21 ft/day (5.8 ft/day average)
Deep Confined Alluvial Aquifer	
No. of Monitoring Wells	1
Depth of Aquifer	40 to 45 ft bgs
Saturated Thickness	Unknown
Groundwater Flow Direction	Assumed to be east-northeast
Hydraulic Gradient	Unknown
Hydraulic Conductivity	0.3 ft/day
Basalt Bedrock Aquifer	
No. of Monitoring Wells	1
Depth of Aquifer	45 to >76 ft bgs (maximum depth explored)
Saturated Thickness	Unknown
Groundwater Flow Direction	Assumed to be northeast
Hydraulic Gradient	Unknown
Hydraulic Conductivity	Unknown

Conceptual models of groundwater in the Acid Plant and Chlorate Plant areas are shown in the Upland RI report (Figures 4-1 and 4-2, respectively, ERM 2005d). Detailed cross-sections that show selected COIs in groundwater are provided in the map folio. Potentiometric surface maps for the shallow and intermediate groundwater zones are provided in the Upland RI report (ERM 2005d).

A 24 to 60 inch diameter concrete sewer pipe owned by the City of Portland (Outfall 22B Storm Sewer) is located upgradient of the site beneath Front Avenue and terminates near the Willamette River just north of the LSS property (AMEC 2004, pers. comm.; Appendix

A, Figure 1). Previous investigations of the Outfall 22B Storm Sewer have indicated that groundwater infiltrates into the pipe. This is based on several lines of evidence including shallow groundwater and storm sewer pipe elevation data, a camera survey of the Outfall 22B storm sewer, and continuous discharge from Outfall 22B during dry weather (AMEC 2004, pers. comm.).

On the upland portion of the site, vertical hydraulic gradients between groundwater zones are primarily downward, with occasional upward gradients observed for well pairs near the Willamette River. Shallow groundwater at the site is likely recharged by precipitation that infiltrates at and to the west of the site.

The silt horizons (aquitards) separating the groundwater zones vary in thickness from approximately several inches to 5 ft. The distinct groundwater zones have been observed in most parts of the site, with the exception of the southeastern portion. In that area, downgradient of the Chlorate Plant area, the silt aquitard tends to become discontinuous, and the shallow and intermediate groundwater zones tend to coalesce. The intermediate groundwater zone aquifer is confined or semi-confined beneath the four uppermost alternating sand and silt layers (ERM 2005d). The deep groundwater zone aquifer is confined.

The shallow groundwater surface fluctuates seasonally, rising during periods of high rainfall and infiltration and decreasing during mid-to-late summer and low rainfall periods. Shallow groundwater in close proximity to the Willamette River rises in direct response to large increases in Willamette River stage (e.g., during a flood). In general, these short-term perturbations do not affect shallow groundwater flow directions, with the exception of short-term groundwater flow reversals in very close proximity to the river (i.e., the transition zone).

A tidal influence study conducted at the site in February 1999 provided a general understanding of the effects that tidal and river stage fluctuations in the Willamette River have on the groundwater flow system at the site (ERM 2005d). The shallow-zone groundwater levels were not affected by the fluctuations in the river, whereas intermediate- and deep-zone groundwater levels exhibited some influence from the Willamette River tidal fluctuations up to 300 ft from the river. Results of the tidal influence monitoring suggest that Willamette River fluctuations are propagated inland as pressure waves through the intermediate and deep groundwater zones, but do not significantly alter the groundwater flow system at the site.

Additional information on the upland hydrogeology and groundwater chemistry is presented in the Upland RI Report (ERM 2005d). Groundwater plumes and the migration of contaminants at the site are discussed in Section 4.1.2.3.

3.3 ENGINEERING AND PHYSICAL PARAMETERS

Arkema site engineering characteristics are summarized below and are based on information available from previous investigations at the facility (refer to references in Section 3.1). The information includes engineering characteristics of both the upland and the sediment conditions at the Arkema site.

The following list of engineering and physical characteristics were considered in the review of previous investigations:

- Density/consistency
- Liquid limit (LL), plastic limit (PL), and plasticity index (PI)
- Percent moisture
- Organic content
- Gradation
- Porosity
- Consolidation characteristics
- Shear strength and stiffness
- Dynamic (seismic) characteristics.

Data available from previous investigations and data obtained from additional characterization as described in this EE/CA work plan will be used to evaluate the conceptual design of the removal action alternatives and to compare the removal action alternatives.

3.3.1 Available Information

From 1997 to 2004, multiple investigations occurred at the Arkema facility both upland and in-water (refer to Section 3.1). Of the data collected, there is limited information regarding the geotechnical properties of the soil and sediment for an engineering evaluation. The primary sources for this information are geotechnical borings (direct-push borings and upland monitoring well installations) and sediment investigations (in-water and beach cores and surface grabs). Table 3-3 presents the physical parameter data collected at the Arkema facility and vicinity for upland soils and in-water sediments.

Table 3-3. Summary of Physical Parameters Collected in Upland Soils and In-water Sediments.

Physical Parameter	Number of Samples Collected for Analysis	
	Sediment/Bank	Soil
Grain Size[a]	120	14
Specific Gravity[b]	70	3
Percent Moisture[c]	77	11
Bulk Density	0	3
Hydraulic Conductivity	0	3
Liquid Limit	5	9
Plastic Limit	5	9
Plasticity Index	5	9

Notes:
[a] 120 samples from 73 sample locations.
[b] 70 samples from 41 sample locations.
[c] 77 samples from 48 sample locations.

3.3.2 Upland Soil Physical Properties

A number of borings and monitoring wells have been installed at the site, as discussed in Section 3.1. Of these, physical property data are available from six locations. The results are presented below in Table 3-4. No data have been collected for upland shear strength or dynamic properties.

Table 3-4. Upland Soil Physical Properties.

Station ID	Sample Interval (ft bgs)	Percent Moisture (%)	Specific Gravity	Bulk Density (lb/ft^3)	Dry Density (lb/ft^3)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	USCS Soil Class	Hydraulic Cond. (ft/day)
MWA-8i	36.5-37.8	43	--	--	--	38	31	7	ML	--
MWA-8i	48-49	35	--	--	--	NP	NP	NP	SM	--
MWA-9i	30-32	34	--	--	--	NP	NP	NP	SM	--
MWA-9i	38-40	45	--	--	--	43	31	12	ML	--
MWA-10i	30-32	48	--	--	--	39	30	9	ML	--
MWA-10i	36-38	54	--	--	--	42	32	11	ML	--
MWA-10i	44-46	37	--	--	--	37	36	11	ML	--
MWA-10i	45.3-46.8	34.2	2.7	120	96.6	31	25	6	ML	0.0028
MWA-11i	39-40.25	37.2	2.7	119	86.9	41	24	17	CL	0.0007
MWA-12i	48-50	35	--	--	--	41	22	19	CL	--
MWA-13d	48-50	45	2.7	112	76.5	38	39	9	ML	0.0071

Notes:
Bulk density is dry mass/wet volume.
NP = not plastic.
-- not analyzed.
Data in table obtained from Upland RI Lots 3 & 4 and Tract A (ERM 2005d).

Of the above wells, MWA-8i through MWA 10i and MWA-13d are located just upland from the top of the riverbank between Docks 1 and 2. Due to their proximity to the bank, it is important to consider the physical parameter data that are available. Based on boring logs, the first 25 ft is fill material followed by a mix of silt and sand layers. The Atterberg limits indicate low (MWA-10i: 45.3-46.8) to medium compressibility/plasticity properties for these soils. The bulk density and specific gravity results indicate the analyzed samples are comprised of mostly silts and clays when compared to typical ranges for each of the soil types.

3.3.3 Sediment Physical Properties

Data for physical properties were collected during previous investigations of surface and subsurface sediments. Sediments collected from 1997 to 1998 were analyzed for grain size only (Weston 1998). All sediments collected offshore of the Arkema facility during Portland Harbor RI/FS activities were analyzed for grain size and percent moisture[10] (Integral 2004b, 2005a,b). Of these, 70 samples (41 sample locations) were analyzed for specific gravity and 5 samples (5 locations) were analyzed for LL, PL, and PI. Table 3-5 presents the physical data for the above five sample locations with the most physical data available.

Table 3-5. Physical Data for In-water Sediments.

Station ID	Sample Interval (ft)	Percent Moisture (%)[1]	Specific Gravity	Bulk Density (lb/ft^3)	Dry Density (lb/ft^3)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Hydraulic Conductivity (ft/day)
LW2-C341	0.984-4.43	49.3	1.45	--	--	--	NP	--	--
LW2-C356-B	0.984-4.46	50.9	1.43	--	--	36.7	31.4	5.3	--
LW2-G349	0-0.919	48	1.46	--	--	59.1	28.4	30.7	--
LW2-G350	0-0.95	49.9	1.45 T	--	--	--	NP	--	--
LW2-G368	0-0.853	59.4	1.44	--	--	38.2	29.9	8.3	--

Notes:
Sample interval is in feet below mudline.
-- not analyzed.
NP = non-plastic.
T = The associated numerical number was mathematically derived (e.g., from summing multiple analyte results or calculating the average of multiple results for a single analyte). Also indicates that all results that are selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods) for Round 2 data.
[1] Percent moisture data is an average value and is from unvalidated data.
Data in table obtained from Round 2A Sediment Site Characterization Report (Integral 2005c).

Atterberg limits indicate a medium to high (G349) compressibility/plasticity. The average percent moisture of all sediment samples collected offshore of Arkema is 36.5 percent

[10] Percent moisture was determined by the laboratories as other analyses were completed on the sample.

(*n*=77). Grain-size data for most sediment samples were described as silty sands (SM) and sandy silts (ML) (Integral 2004a).

The sediment physical property data collected to date are shallow (i.e., up to 4.5 ft below mudline).

3.4 HABITAT CHARACTERISTICS

No specific studies on the habitat conditions have been conducted at the Arkema facility. The Portland Harbor RI/FS Programmatic Work Plan, Appendix B: Ecological Risk Assessment Approach (Integral et al. 2004b) that was approved by EPA includes a description of the habitat types in the LWR. A summary of the habitat types follows.

Within the Portland Harbor study area, the river is characterized by a maintained navigation channel and shoreline that has been modified for industrial and commercial uses. Two general habitat types are present in the LWR, open-water, and bank and riparian, as described in Table 3-6.

Table 3-6. Habitat Characteristics in the Lower Willamette River.

Habitat Type	Location	Habitats	Impacts to Habitats	Communities Present
Open-water	Main navigation channel (deeper >20 CRD) and lower channel slopes (<20 CRD)	Unconsolidated sediments (sands and silts)	Seasonal and annual variability, navigation impacts, sediment deposition, erosion, bedload transport, and periodic dredging	Stable and unstable environments of heterogeneous infaunal communities controlled by physical regime
	Nearshore (beaches and benches) and upper channel slopes	Unconsolidated sediments (sands and silts)	Less temporal variability, influenced by local riverbank morphologies	Well-developed infaunal invertebrate communities
	Developed shoreline	Rock riprap, sheet piles, bulkheads	Limited benthic communities controlled by physical disturbances	More likely epibenthic communities
Bank and Riparian	Bank and upland	Bank is river beach and unclassified fill, upland is industrial	Industrial activities/ human disturbances (transients)	Shorebird foraging areas on beach, uplands are limited by industrial activities

Notes:
Arkema beach sample collected as part of Round 2 surface sediment and beach sampling. Area was identified as available to shorebirds and a shorebird foraging area (Integral 2005d).

The in-water areas (< 20 ft deep) adjacent to the site were characterized in the Programmatic Work Plan (see Figures 2-6 through 2-10, Integral et al. 2004b) as being optimum fish habitat for species including common carp, juvenile Chinook, largescale sucker, Pacific lamprey, and smallmouth bass. These areas were also determined to be habitat for crayfish, sculpin, and hooded mergansers. The beaches along the site

represent habitat for the spotted sandpiper as well as mink, which also use the riverbanks. The more vegetated northern portion of the site represents amphibian habitat (Integral et al. 2004b).

From RM 9.7 to RM 7, the Willamette River is classified as a deposition zone 1. Specifically, the river is depositional as it widens and cross-sectional areas increase, the river flow velocities decrease, and the ability of the river to entrain and transport sediment decreases, resulting in the deposition of bedload sediment and possibly sediments in suspension. Bottom sediments are organic, methanogenic silts with deep apparent redox potential discontinuities that have been thickened by deposition of oxidized, fine-grained sediment (Integral et al. 2004b).

4 CONCEPTUAL SITE MODEL

The conceptual site model (CSM) presents a detailed description of site conditions. Integral developed the CSM from the extensive information presented in Section 3, general knowledge of site conditions and chemical transport behavior (Integral 2004a), and from information in the Upland RI Report (ERM 2005d). The Upland RI Report contains text and figures for developing an understanding of the upland site hydrogeology.

Development of a CSM early in the EE/CA process helps identify data gaps and guides collection of data appropriate for assessing risks and remedial actions. The CSM will be refined throughout the project as additional data are collected and site conditions are clarified. The CSM, illustrated in Figures 4-1 and 4-2 and described in the following sections, includes sources of chemicals (primary, secondary, and tertiary), transport pathways, and uptake routes for potential exposure of human and ecological receptors to chemicals of interest at the site.

4.1 SOURCES

This section presents information describing how various activities and operations that took place at the Arkema facility may have been sources (primary and secondary) of chemicals to the Willamette River. Primary COIs in environmental media at the site as identified in the AOC and SOW are associated with residues of the site manufacturing processes, including DDT and its degradation products[11] DDD and DDE (DDx), monochlorobenzene (MCB, or chlorobenzene), perchlorate, and hexavalent chromium (Integral 2005)[12]. Secondary or additional COIs are identified in the data screening described below in Section 5 and Section 6. For many of these secondary COIs, there is little evidence of historical use or releases at the Arkema site. Descriptions of these secondary COIs are provided in Section 4.1.3, Additional Site COIs.

4.1.1 Primary Sources

The following list of the primary sources of COIs from the Arkema site was summarized from historical site records and previous upland investigations. The draft CSM for the Arkema facility developed for the LWG (Integral 2004a, with comments from USEPA

[11] DDD and DDE are also by-products of the manufacturing process (ATSDR 2002).

[12] pH variations and salinity gradients in sediments and groundwater are also of interest as described in the AOC SOW.

2005) was used as a supplemental resource for source information at the site. The primary sources are presented on a base map in Figure 2-4. Because the site has undergone extensive remediation and demolition to date, including interim remedial source control measures, these areas may no longer function as sources of COIs to the in-water portion of the site. The upland areas listed below are combined as "Manufacturing Process Residue/Manufacturing Chemicals" under the "Primary Source" heading in the EE/CA CSM Figures 4-1 and 4-2:

- **Former Stormwater Outfall**—In 1947, at the initiation of DDT manufacturing, MPR was discharged to floor drains connected to a stormwater-system that drained into the Willamette River. This stormwater outfall is referred to as the former process discharge pipe on site figures (Figures 2-4) and was also used to discharge cooling water from upland production processes. The outfall that is suspected to have received the MPR is located between Docks 1 and 2, near boring location WB-9 (Figure 2-4). The exact position of the pipe is unknown but the approximate location is indicated on the aforementioned figures. The conventional practice at the plant was to abandon outfalls and discharge pipes in place by filling the upper end at manholes with concrete. Therefore, it is assumed that this particular structure was decommissioned and abandoned employing traditional plant techniques.
- **Former MPR Pond**—A shallow unlined pond was constructed in 1948 northeast of the manufacturing building, and MPR that formerly went to the floor drain was redirected to the pond. The pond was used until about 1954 when DDT manufacturing operations ceased. Major portions of the former MPR pond soils were removed during a soil IRM in 2000 to a depth of 12 ft bgs.
- **Former MPR Trench**—In 1951 or 1952, a trench 8 ft wide by 285 ft long was constructed north of the MPR pond to increase its capacity. Use of the MPR trench ceased in about 1954 when DDT operations ended. Elevated concentrations of MCB and DDT were found in this area prior to soil removal. A two-phased soil removal and source control IRM was implemented in 2000 and 2001. Soils in the trench were removed to depths of up to 8 ft bgs.
- **Former DDT Process Building**—The pesticide DDT was manufactured in the former DDT process building from 1947 to 1954. Chemical base stocks used in the DDT manufacturing process included MCB, chloral, and sulfuric acid. Some DDT handling took place in Warehouse No. 2, in the northwest corner of the Acid Plant area. From 1958 to 1962, after DDT manufacturing ceased, ammonium perchlorate operations were conducted in the former DDT process building. During this period, sodium perchlorate was produced inside the chlorate cell room. Sodium perchlorate was transferred to the Acid Plant area where it was converted to ammonium perchlorate by using ammonium chloride to form a solid propellant

for guided missiles. The production of sodium perchlorate and ammonium perchlorate ceased in 1962.

- **Sodium Chlorate Manufacturing**—Sodium chlorate manufacturing started in the Chlorate Plant area in 1941. Chlorate solutions were shipped by truck or barge. Trucks were loaded on the southern side of the Chlorate Plant area. Barges were loaded at Dock 2. The production of sodium perchlorate in the chlorate plant is assumed to be the source of the main perchlorate plume. There were no disposal ponds or trenches associated with the Chlorate Plant. Wastes from this area were discharged under a general state water pollution control facilities (WPCF) permit to the Willamette River via the stormwater sewer system until the mid 1970s. Subsequently, wastewaters were reused in Chlorate Plant processes or evaporated in this area. The upland RI report (Appendix E) contains additional details regarding perchlorate at the site, including relevant figures (Figures 5-31 and 5-32 present perchlorate groundwater data, and Figure 5-33 through 5-35 are cross-sectional views of the site with associated groundwater data for perchlorate) (ERM 2005d).
- **Lot No. 1 Former DDT Trench**—Historical construction activities in the Acid Plant area generated soils with DDT residues that were reportedly disposed of in a defined trench on Lot No. 1 of the site. Arkema discovered and excavated the trench on Lot 1 that contained DDT MPR in 1994. Confirmation samples indicated concentrations of DDT, DDD, and DDE, below DEQ industrial soil cleanup levels, are present in shallow soil in a discrete area between 3 and 14 ft bgs along the perimeter of the former trench. None of the 33 confirmation samples contained constituent pesticides greater than the USEPA Region 9 Preliminary Remediation Goal (PRG) for industrial soil. Arkema has a DEQ-approved soil management plan to ensure proper management of these soils.
- **Historical Spills**—Chemical spills that occurred when the plant was operational included a 1,200-gallon ammonium hydroxide leak to the sewer system in 1986, a sodium chlorate release of unknown quantity to the sewer system in 1987, and other smaller spills (Integral and GSI 2004b).
- **Contaminant Deposition from Upstream Sources**— Sediment particle-associated contaminants (e.g., contaminated sediments) may be transported from upstream locations and subsequently deposited in the river adjacent to the site via fluvial processes. Preliminary data screening of sediments identified additional COIs. However, historical information regarding the production and/or release of these chemicals from the site is nonexistent. Therefore, the source of these COIs is likely attributable to deposition from upstream locations. Upriver sources have been included as a primary source in the EE/CA CSM that may directly impact the sediment, surface water, and biota within the in-water portion of the Arkema site.

4.1.2 Secondary and Tertiary Sources

Secondary sources of COIs at the Arkema facility include upland surface and subsurface soils, where discharges from historical manufacturing processes occurred. COIs contained in upland soil then may be transported to tertiary sources. Tertiary sources of COIs include riverbank soil and groundwater, which receive COIs via overland runoff from upland surface soil or via leaching, percolation, and infiltration from subsurface soil. Sediments impacted by historical upland discharges, as well as resuspended COI-containing sediments represent potential sources and also are mechanisms of chemical movement to and within the in-water site. Sediments are characterized as an exposure medium to human and ecological receptors in this CSM. Sedimentation and resuspension are presented as release mechanisms (discussed further in Section 4.2). Secondary and tertiary sources are discussed in more detail within the following text.

4.1.2.1 Upland Soil

The nature and extent of COIs in soil are described in detail in the upland RI report (ERM 2005a). As noted by ERM (2005d), historical discharges of chemicals from primary source area soils may be transported via overland runoff to other portions of the site. In addition, COIs in primary source area soils may percolate, leach, or otherwise infiltrate subsurface soils with rainfall.

Upland soils are presented as potential secondary sources of COIs in Figures 4-1 and 4-2 to demonstrate their potential contribution to in-water sources. COIs present in upland surface and subsurface soil currently are being addressed by the upland RI/FS for the Arkema site.

4.1.2.2 Riverbank Soil

Fill was placed in the Acid Plant area bordering the Willamette River after DDT manufacturing ceased. The bank adjacent to the Acid Plant area has widened with fill toward the Willamette River approximately 200 ft since the 1950s (CH2M Hill 1997). Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 ft along the riverbank (Integral and GSI 2004b). DDT residuals have been measured in some portions of the fill. In areas where DDT residuals have been addressed as part of the ongoing upland IRMs, they are no longer a seconday or tertiary souce.

4.1.2.3 Groundwater

Groundwater is considered a tertiary source of COIs to the in-water portion of the site via laminar flow and dispersion to transition zone water. Groundwater surface elevations and flow directions in the shallow, intermediate, and deep zones are presented in the upland RI report (ERM 2005d) (Figure 4-6 [Acid Plant Area Shallow-Zone Groundwater Elevation Map]; Figure 4-7 [Acid Plant Area Intermediate-Zone Groundwater Elevation Map]; Figure 4-14 [Chlorate Plant Area Shallow-Zone Groundwater Elevation Map];

Figure 4-15 [Chlorate Plant Area Intermediate-Zone Groundwater Elevation Map]; and Figure 4-17 [Deep-Zone Potentiometric Surface Map]). Dissolved groundwater plumes at the site are relatively stable and well-documented (Integral and GSI 2004b). Figure 4-3 presents a conceptual interpretation of the current approximate configuration of groundwater plumes originating from the upland portion of the site and entering into river sediments. Acute water quality criteria were generally used to define the approximate limits of each of the primary COI plumes at the site in Figure 4-3 (see Sections 5 and 6).

In the Acid Plant area, residual MCB DNAPL has been observed, and a focused investigation has documented the nature and extent of DNAPL in the upland subsurface. DNAPL exists in residual form and is not readily mobile. Several phases of the upland RI focused on DNAPL presence and mobility (ERM 2005d). The upland RI report presents the extent of DNAPL in the subsurface at the site (see Figures 5-12 through 5-14 in ERM 2005a). The extent of DNAPL has also been confirmed in the Draft Acid Plan Area DNAPL Sampling Summary Report (ERM 2006). Several monitoring wells were installed in the Acid Plant area and screened in the DNAPL zone. MCB DNAPL was detected in only one well for a short period of time following well installation and development. Because DNAPL cannot be recovered from wells, there is no information available on the physical properties of the residual MCB DNAPL observed in the Acid Plant area. To date, DNAPL has not been detected in any other monitoring wells and, therefore, is considered immobile. However, DNAPL likely contributes to the continued presence of dissolved-phase MCB in groundwater observed in upland soils and sediments (Figure 4-3)[13].

DDT is also present in the Acid Plant area. The DDT and MCB groundwater plumes are generally collocated because of the common primary source (i.e., the MPR pond and trench) for these two COIs. The upland RI report presents the groundwater data associated with DDx, as well as MCB (DDT, DDD, and DDE concentrations in groundwater are presented in Figures 5-15 through 5-18; Figures 5-15 and 5-16 present concentrations of these chemicals in the shallow and intermediate groundwater zones, respectively; Figures 5-17 and 5-18 are cross-sectional views of the site with associated concentrations of DDx in groundwater; MCB concentrations in groundwater are presented in Figures 5-19 through 5-22; Figures 5-19 and 5-20 present MCB concentrations in the shallow and intermediate groundwater zones, respectively; and Figures 5-21 and 5-22 are cross-sections with associated MCB concentrations in groundwater) (ERM 2005d).

In the Chlorate Plant area, two separate groundwater plumes, one of hexavalent chromium and the other of perchlorate, have been identified and are contained in both the

[13] DNAPL has been observed on a continuous silt layer in the Acid Plant area of the site.

shallow and intermediate groundwater zones (Figure 4-3). Both plumes extend from the former chlorate cell room building to the east toward the river. The plumes overlap but are not identical in their nature or extent. The hexavalent chromium plume is likely related to the use of sodium bichromate as a corrosion inhibitor and to enhance electrical efficiency in the sodium chlorate manufacturing process. The upland RI report presents groundwater data for chromium (Figures 5-26 through 5-30 present chromium concentrations in groundwater; and Figures 5-28 through 5-30 are cross-sections with associated chromium concentrations in groundwater [ERM 2005d; Appendix E]). The most recent hexavalent chromium data is presented in the February 2006 progress report (Arkema 2006). The perchlorate plume is likely related to the manufacture of sodium perchlorate in the chlorate cell room building during a brief period between about 1958 and 1962.

On the eastern edge of the former Salt Pads, chloride is found in groundwater. This area is immediately downgradient of the former Salt Pads, where salt was historically stockpiled and where salt brine was produced for the production of chlorine, hydrogen gas, sodium hydroxide, and sodium chlorate from 1941 to 2001. Even though chloride is a naturally occurring chemical, chloride concentrations are found in groundwater beneath the eastern edge of the salt pads and in groundwater beneath sediments in the Salt Dock area. The highest groundwater chloride concentrations are in the intermediate groundwater zone sampled from monitoring well MWA-30 (191,000 mg/L) in the upland portion of the site and at CP08D-1, a transition zone water station (89,700 mg/L) in the in-water portion of the site (Figures 3-3 and 4-3).

The minimum and maximum concentrations of selected COIs and corresponding sample stations in groundwater and transition-zone water are presented in Table 4-1.

Table 4-1. Detections of Selected COIs in Groundwater and Transition-Zone Water[a].

		Analyte	Value (µg/L)		Location	SampleDate
TZW	min	2,4'-DDD	0.0033	UJ	R2AP01PR	11/14/2005
	max	2,4'-DDD	1.1	J	AP02DTR	10/10/2005
	min	2,4'-DDE	0.0023	U	AP02ATR	10/10/2005
	max	2,4'-DDE	0.79	U	AP02DTR	10/10/2005
	min	2,4'-DDT	0.00089	UJ	R2AP01PR	11/14/2005
	max	2,4'-DDT	0.47		AP03ATR	10/10/2005
GW	min	4,4'-DDD	0.00103	U	MWA-8i	9/15/2005
	max	4,4'-DDD	710		WB-10	3/5/2003
	min	4,4'-DDD (dissolved)	0.04	J	MWA-6	4/29/1999
	max	4,4'-DDD (dissolved)	9	J	MWA-9i	1/28/1999
TZW	min	4,4'-DDD	0.0015	U	AP03B-2	1/12/2005
	max	4,4'-DDD	1.8	J	R2AP02TR	10/11/2005

Table 4-1. Detections of Selected COIs in Groundwater and Transition-Zone Water[a].

		Analyte	Value (µg/L)		Location	SampleDate
GW	min	4,4'-DDE	0.00367	U	MWA-2	9/15/2005
	max	4,4'-DDE	26.5		MWA-62	8/2/2005
	min	4,4'-DDE (dissolved)	0.04	J	MWA-8i	1/27/1999
	max	4,4'-DDE (dissolved)	1.3		MWA-6	1/27/1999
TZW	min	4,4'-DDE	0.0012	U	AP04B	1/11/2005
	max	4,4'-DDE	0.93	U	AP02DTR	10/10/2005
GW	min	4,4'-DDT	0.005	U	MWA-27	11/15/2001
	max	4,4'-DDT	2040		MWA-62	8/2/2005
	min	4,4'-DDT (dissolved)	0.04	U	MWA-10i	1/28/1999
	max	4,4'-DDT (dissolved)	11		MWA-15	8/26/1999
TZW	min	4,4'-DDT	0.0042	U	AP04B	11/19/2004
	max	4,4'-DDT	2.7		AP03ATR	10/10/2005
GW	min	Chloride	0.057	U	MWA-27	9/9/2005
	max	Chloride	191000		MWA-30	4/12/2002
TZW	min	Chloride	1.6		AP04CPR	11/14/2005
	max	Chloride	89700		CP08D-1	11/20/2004
GW	min	Chlorobenzene	0.04	U	NMP-4D	3/30/2006
	max	Chlorobenzene	370000	J	GA-GW04	11/3/1994
TZW	min	Chlorobenzene	0.14	U	CP09DPR	11/14/2005
	max	Chlorobenzene	30000		AP03DTR	10/11/2005
GW	min	Chromium hexavalent	0.0005	J	MWA-18	12/8/2005
	max	Chromium hexavalent	14.9		MWA-36	12/3/2003
GW	min	Perchlorate	0.5	U	RP-02	3/11/2005
	max	Perchlorate	367000		WB-23	2/18/2003
TZW	min	Perchlorate	0.4	U	AP04CPR	11/14/2005
	max	Perchlorate	210000		CP07DTR	10/12/2005
GW	min	Total of 2,4' and 4,4'-DDD	0.005	UJT	MWA-25	11/15/2001
	max	Total of 2,4' and 4,4'-DDD	710	T	WB-10	3/5/2003
	min	Total of 2,4' and 4,4'-DDD (dissolved)	0.04	JT	MWA-6	4/29/1999
	max	Total of 2,4' and 4,4'-DDD (dissolved)	9	JT	MWA-9i	1/28/1999
TZW	min	Total of 2,4' and 4,4'-DDD	0.0015	UT	AP03B-2	1/12/2005
	max	Total of 2,4' and 4,4'-DDD	2.46	JT	R2AP02TR	10/11/2005
GW	min	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	0.005	UT	MWA-27	11/15/2001
	max	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	2620	JT	WB-10	3/5/2003
	min	Total of 2,4' and 4,4'-DDD, -DDE, -DDT (dissolved)	0.04	JT	MWA-8i	8/24/1999
	max	Total of 2,4' and 4,4'-DDD, -DDE, -DDT (dissolved)	17.3	JT	MWA-9i	1/28/1999
TZW	min	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	0.0042	UT	AP04B	11/19/2004
	max	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	5.73	JT	AP03ATR	10/10/2005
GW	min	Total of 2,4' and 4,4'-DDE	0.005	UJT	MWA-25	11/15/2001
	max	Total of 2,4' and 4,4'-DDE	13	T	WB-10	3/5/2003
	min	Total of 2,4' and 4,4'-DDE (dissolved)	0.04	JT	MWA-8i	1/27/1999
	max	Total of 2,4' and 4,4'-DDE (dissolved)	1.3	T	MWA-6	1/27/1999

Table 4-1. Detections of Selected COIs in Groundwater and Transition-Zone Water[a].

		Analyte	Value (µg/L)		Location	SampleDate
TZW	min	Total of 2,4' and 4,4'-DDE	0.0012	UT	AP04B	1/11/2005
	max	Total of 2,4' and 4,4'-DDE	0.93	UT	AP02DTR	10/10/2005
GW	min	Total of 2,4' and 4,4'-DDT	0.005	UT	MWA-27	11/15/2001
	max	Total of 2,4' and 4,4'-DDT	1900	T	WB-10	3/5/2003
	min	Total of 2,4' and 4,4'-DDT (dissolved)	0.04	UJT	MWA-1	1/29/1999
	max	Total of 2,4' and 4,4'-DDT (dissolved)	11	T	MWA-15	8/26/1999
TZW	min	Total of 2,4' and 4,4'-DDT	0.0042	UT	AP04B	11/19/2004
	max	Total of 2,4' and 4,4'-DDT	3.17	T	AP03ATR	10/10/2005
GW	min	Total of 4,4'-DDD, -DDE, -DDT	0.005	UT	MWA-27	11/15/2001
	max	Total of 4,4'-DDD, -DDE, -DDT	2620	T	WB-10	3/5/2003
	min	Total of 4,4'-DDD, -DDE, -DDT (dissolved)	0.04	JT	MWA-8i	8/24/1999
	max	Total of 4,4'-DDD, -DDE, -DDT (dissolved)	17.3	JT	MWA-9i	1/28/1999
TZW	min	Total of 4,4'-DDD, -DDE, -DDT	0.0042	UT	AP04B	11/19/2004
	max	Total of 4,4'-DDD, -DDE, -DDT	4.59	JT	AP03ATR	10/10/2005

Notes:

[a] Some groundwater samples were collected using a Geoprobe® or similar method, which can generate turbid water samples. Reported pesticide and metal concentrations using these sampling methods may not be representative of actual dissolved groundwater concentrations.

U - The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

T - The associated numerical value was mathematically derived (e.g., from summing multiple analyte results such as Aroclors, or calculating the average of multiple results for a single analyte). Also indicates all results that are selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods) for the Round 2 data.

J - The associated numerical value is an estimated quantity.

4.1.3 Sources and Release Mechanisms for Additional Site COIs

Sources and possible release mechanisms of COIs beyond the primary source list, which were identified during the data screening, are described below. Information regarding the possible sources of these chemicals to the in-water portion of the site is provided where available. COI-containing matrices being evaluated for the EE/CA include riverbank soil, in-water sediment, groundwater, transition zone water, and surface water.

Metals including aluminum, cadmium, chromium, copper, lead, manganese, selenium, silver, and zinc are present in site soils. There is no indication that cadmium, manganese, and selenium were ever used as raw materials or process ingredients during plant operations. Aluminum and copper were components of the bus bars used in the electrolytic cell rooms. A bus bar is a "physical electrical interface where many devices share the same electric connection" (http://en.wikipedia.org/wiki/Electrical_bus). The aluminum bus bar was implemented in the chlorate plant in 1990 during infrastructure modernization. Copper was used in the bus bars connected to the chlorine and chlorate cells, as well as in electrical wires throughout the plant.

Silver was never used as a raw material or a process ingredient at the site. However, limited quantities may have been used for reagent purposes in laboratory chemical analyses. Zinc was used as a biocide to inhibit biological growth in the cooling towers at the Chlorate Plant and the Chlorine Plant. Non-contact cooling tower waters were discharged by permit through industrial sewers to the river. There may have been small quantities of lead used in some of the older chlorine cell components. Some of these decommissioned chlorine cells containing lead may have been used as fill along the riverbank between Docks 1 and 2.

The chlorinated dioxin 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is a COI at the site. PCDD/Fs were never used as a raw material or process ingredient; however, PCDD/Fs may be associated with chlorine production from some cells equipped with graphite anodes. In 1946, the plant began using graphite anodes during chlorine production. The graphite anodes were replaced with titanium anodes. The convernsion to titanium anodes was completed in 1971. A letter from LSS to DEQ, dated May 18, 2006, addresses the potential generation of PCDD/Fs during production processes at the site (LSS 2006, per. comm). Cells were dismantled and washed approximately once per year, and the associated wash water was discharged to the river. This may represent a source of PCDD/Fs to the in-water portion of the site. However, the transport of combustion-derived chemicals such as dioxins from upstream sources should also be noted as a potential source.

Halogenated compounds including hexachlorobenzene and hexachlorbutadiene were detected at elevated concentrations at the site. Neither of these COIs were ever used as a raw material or process ingredient at the Arkema facility.

Polycyclic aromatic hydrocarbons (PAHs) including benz[a]anthracene, benzo[a]pyrene, and naphthalene are individual chemicals of significance at the site. Total PAHs, which include the previous three chemicals, as well as 2-methylnaphthalene, acenaphthylene, anthracene, benzo[ghi]perylene, benzo[k]fluoranthene, chrysene, dibenz[a]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, phenanthrene, and pyrene, have been carried through as site COIs. PAHs were never used as a raw material or process ingredient during plant operations. However, asphalt paving, a PAH-containing material, was a common component of riverbank fill. Private contractors and the City of Portland transported the material to the site during road maintenance projects. Other potential sources of PAHs include atmospheric deposition from offsite locations, road runoff, and the transport and deposition of upstream particulate.

PCB-containing transformers were used at the site (see Figure 1-5 of ERM 2005d) and the concrete pads supporting them were sampled following transformer decommissioning

and removal (ERM 2005d). Furthermore, the BPA operated an electrical substation on the property for a number of years.

Pesticides including aldrin, dieldrin, endrin, beta-endosulfan, gamma-hexachlorohexane, and heptachlor epoxide were not manufactured at the site; however, none were used as a raw material or process ingredient. Many of these pesticides were handled by the upgradient Rhône Poulenc facility. DDT was the sole pesticide that was manufactured and handled at the Arkema facility.

Phenols were not used at the site. Phenolic COIs include phenol, 2-chlorophenol, and pentachlorophenol. It is possible that railroad ties and utility poles used on site may have been impregnated with wood preservatives such as pentachlorophenol.

VOCs that represent COIs at the site include carbon disulfide, carbon tetrachloride, chloroform, methylene chloride, trichloroethane, tetrachloroethene (PCE), toluene, *m,p*-xylene, and monochlorobenzene (MCB). Carbon disulfide, carbon tetrachloride, chloroform, trichloroethene, and PCE were not used at the site. Carbon disulfide may have been a constituent of the asphalt used as fill along the riverbank. Chloroform (trichloromethane) may have been produced from alkaline reactions with chloral. Methylene chloride was used in the auto shop (near the Front Office) and in the ammonia plant for parts cleaning and a degreaser, respectively. It appears that methylene chloride was seldom used at the plant, and the auto shop dip tank contents were manifested off the site shortly after 1990.

Toluene and xylenes are constituents of gasoline, which was contained in an underground storage tank located at the west end of the old caustic tank farm (Figure 2-4). Records indicate that this tank was removed and replaced with an aboveground tank near the Front Office. These chemicals are also constituents of paint thinners, which were used at the plant. Annecdotal information suggests that in the early years thinner residue periodically was blended with used sandblast material and then incorporated into riverbank fill material between Docks 1 and 2. Spent paint thinners later were manifested offsite for incineration.

4.1.5 Source Control

Since 1989, Arkema has conducted several source control measures to improve soil, stormwater, groundwater, and sediment quality at the site. Several groundwater source control measures are ongoing, and other source control measures are presently under development. A chronological summary of source control measures that have been completed or that are ongoing at the site is provided below. A comprehensive description of the IRMs conducted on the upland portion of the site is provided in the Upland RI Report (Section 7 and associated figures, ERM 2005d).

Brine Residue Pile and Pond—The brine residue pile and pond were located on Lots 1 and 2. Brine residue, which was composed of calcium carbonate and magnesium hydroxide, was historically disposed of in either the brine residue pile or pond. The brine residue pile was completely removed from the site in February 1989, and the pond was completely removed in August 1992 (Integral and GSI 2004b). The material was transported to Hillsboro Landfill and beneficially used as a soil amendment in the final landfill cap.

Asbestos-Containing Residue Removal—In 1992, ATOFINA completed the decommissioning of three surface impoundments containing asbestos. The decommissioning included the excavation of trenches with asbestos-containing residue. The removal action was approved and overseen by DEQ (Integral and GSI 2004b). Periodic inspections were conducted throughout the project, including a final inspection for closing the project on February 12, 1992.

DDT Removal—In 1994, a trench on Lot 1 that contained DDT residues was excavated, disposed of, and backfilled with clean material. Approximately, 1,700 tons of soil with DDT residues was excavated and disposed of at the Waste Management Subtitle C landfill in Arlington, Oregon. Although Arkema initially proposed to finalize a soil management plan for the DDT source removal project on Lot 1, it was later decided to incorporate both Lots 1 and 2 into Arkema's upland risk assessment.

Phase I and II Soil Removal IRMs—Soil removals were carried out in 2000 and 2001 to address soil containing high concentrations of DDT and chlorobenzene in the Acid Plant area. The Phase I soil removal IRM was performed at the site between September and November 2000. During the Phase I removal, approximately 3,800 tons of soil was excavated from the former MPR pond and trench. These soils were disposed of at the Waste Management Subtitle C landfill in Arlington, Oregon. In addition, a temporary surface cover (Visqueen plastic between two layers of geotextile beneath approximately 2 in. of gravel) was constructed in the unpaved fill area east of the Acid Plant area, where unpaved surface soil samples had been collected.

The Phase II soil removal IRM was completed in November 2001 in the area north of the Acid Plant area and south of No. 2 Warehouse. A total of 915 tons of shallow soil (up to 1 ft bgs) was removed from throughout the Acid Plant area and disposed of at the Subtitle C landfill in Arlington, Oregon. Exposed surfaces were paved to provide a temporary cover system to minimize the contamination from stormwater runoff. In addition, a storm drain was installed west of the former Acid Plant control house. The Phase I and II IRMs provided effective measures for removing significant amounts of DDT- and

chlorobenzene-containing soil, subsequently reducing the potential for migration transport in shallow soils (ERM 2005a).

Soil Vapor Extraction System—A soil VES was installed in December 2000 to extract chlorobenzene mass from subsurface soils. The primary goal of this operation was to reduce the chlorobenzene mass in the shallow soils. The PRG for chlorobenzene is 2,000 mg/kg, which was 20 times the hazardous waste toxicity characteristic of 100 mg/L (ERM 2005a). The system was expanded over 2-1/2 years of operation and included five horizontal extraction wells. Approximately 2,500 pounds of MCB was removed by the end of operation. This system was shut down in 2003.

Stormwater System Improvements—Phase I efforts included the cleanout of stormwater catch basins and subsurface lines, emplacement of filter bags in catch basins, and the removal of some surface soil and placement of a temporary cap over a large, unpaved area (USEPA 2005). Upon completion of the Phase I and Phase II removal activities, asphalt was placed over the area to divert stormwater directly to surface drains. A temporary impermeable cover was also placed on a fill area on the eastern boundary of the Acid Plant area to divert stormwater runoff directly to surface drains.

Groundwater Cleanup/Source Control—Pilot studies were conducted in the following areas to develop remedial strategies for cleanup/source control: *in situ* persulfate injection, DNAPL remediation, and hexavalent chromium reduction. Perchlorate bioremediation treatability studies are also ongoing. Based on the observations of the DNAPL remediation pilot study, a full-scale air sparging/vapor extraction system was installed and began operating in December 2004. The full-scale persulfate injection chemical oxidation program was also initiated in September 2005, but is temporarily on hold. The hexavalent chromium reduction study was successful, and two phases of calcium polysulfide injections were completed in July 2005 and November 2005. Figures 19-21 in Appendix A (Arkema 2006) displays the most recent data of the hexavalent chromium plume in groundwater.

Results from the perchlorate bioremediation study are still pending. Two potential pilot test options are currently being evaluated, including active recirculation and passive biobarrier for groundwater treatment (GeoSyntec 2006). Data collection activities are being conducted at the site to determine the most suitable biotreatability option to employ. Pre-design characterization activities include the assessment of vadose zone perchlorate distribution and hydraulic testing.

4.2 TRANSPORT PATHWAYS

Potential COI transport pathways or release mechanisms depicted on Figures 4-1 and 4-2 include the following:

- Groundwater migration via advection and hydrodynamic dispersion
- Leaching from soil to groundwater
- Stormwater discharge via outfalls
- Stormwater discharge via overland (sheet) flow from the riverbank soils
- Erosion of bank soils
- Resuspension and translocation of sediment
- Resuspension of wind-blown dust and vapor emission from soil (airborne transport).

COI transport pathways are discussed in the following sections in terms of their relevance to the in-water EE/CA and other ongoing investigations at the Arkema site.

4.2.1 Groundwater Migration

Groundwater occurs in fill materials and four distinct zones beneath the site (shallow, intermediate, deep, and basalt zones) (Integral 2004a). The general direction of groundwater flow for all zones is towards the river, with discharge to the river. Upward vertical hydraulic gradients were observed in the sediment and groundwater investigations conducted in the river, in the vicinity of Docks 1 and 2 (Integral 2004a).

Upland and in-river investigations indicate that upland groundwater discharges to the river, and historical discharges from a former process discharge pipe located just north of Dock 1 are the primary source of DDT in sediments. The current dissolved-phase transport of DDT to the river is low relative to the historical deposits. Chlorobenzene and DDT are both present in groundwater in the Acid Plant area. At higher concentrations, chlorobenzene can be a cosolvent for DDT; however, the existing data indicate that even considering cosolvency, the current flux of DDT in groundwater is small compared to the historical deposits. Perchlorate and chromium plumes may also be potential continuing sources via the groundwater to surface water pathway (Integral 2004a); however, IRMs which will reduce the concentration and flux of these chemicals in groundwater are ongoing. Hydraulic control measures will be evaluated, if necessary, in the EE/CA as a means to prevent recontamination following in-water remedial activities such as dredging or capping (see Section 7).

4.2.2 Leaching from Soil to Groundwater

The majority of the site surfaces are covered with concrete and temporary cover systems such as asphalt pavement. Because these impervious surfaces impede infiltration and downward movement of rainwater and subsequent leaching of COIs in soil to groundwater, leaching of COIs to groundwater is not considered a significant transport pathway.

The northern portion of the site is heavily vegetated and COI concentrations are low, and therefore do not represent a significant source for the contamination of groundwater via leaching. There is no evidence to suggest that leaching of soils to groundwater is a complete pathway.

4.2.3 Stormwater Discharge—Outfalls

Stormwater from Arkema is discharged through four outfalls under NPDES Permit No. 100752 (Appendix G), none of which have discharged process waste water since the plant closed in 2001. Prior to 2001, wastewater from Arkema was discharged pursuant to NPDES permits through these four outfalls. Noncontact cooling water from the Acid Plant was discharged through Outfall 002. Combustion chamber cooling water from the Acid Plant was pumped to a wastewater treatment system for pH neutralization before discharging through Outfall 004. Cooling water from caustic evaporators was conveyed to Outfall 002. Cooling water from the chlorine cell room was conveyed to Outfalls 003 and 004, and from the chlorine finishing process to Outfall 001.

Although these outfalls historically discharged these cooling waters into the Willamette River, only stormwater runoff has been discharged since the plant shut down in 2001. Since reissuance of the stormwater NPDES permit in January 2004, all permit limits have been met. As stipulated in the permit, quarterly monitoring has been conducted for the following analytes: TSS (130 mg/L); oil and grease sheen (no visible sheen via visual inspection); oil and grease (10 mg/L); pH (5.5–9.0); copper (0.1 mg/L); lead (0.4 mg/L); and zinc (0.6 mg/L). As required by the permit, oil and grease sheen and floating solids are monitored more frequently on a monthly basis. The associated concentrations are benchmarks representing guideline concentrations, not limitations. The benchmarks are provided to determine the efficacy of the storm water pollution control plan (SWPCP).

Stormwater was sampled for the RI during four separate sampling events from 1999 to 2001 (Integral and GSI 2004b; USEPA 2005, per. comm..). Stormwater samples were collected in the Acid Plant area from a storm drain system, prior to mixing with noncontact cooling water. Total DDT and its metabolites were detected, suggesting that some material containing very low levels of DDT was present in the stormwater that discharges into the Willamette River. However, significant reductions of these

constituents in stormwater were observed after the Phase I soil removal IRM was completed (ERM 2005d).

Comprehensive stormwater monitoring was conducted monthly in 2004–2005 as a requirement for the renewal of an NPDES permit for the facility (Integral 2006j). Stormwater samples were collected between March 2004 through March 2005 (except for months when there was no precipitation) and analyzed for selected legacy and 303(d) constituents. Analytical parameters included the following: TDS; iron, manganese, and mercury; hexavalent chromium; DDT, DDD, and DDE; PAHs; PCBs; chlorobenzene; pentachlorophenol (PCP); perchlorate; and chloride. DDT and metabolites were detected in site stormwater. Permit limits were not established for these additional analytes because they were of general interest to DEQ to support the stormwater characterization and not inclusive of the permit requirements.

Groundwater elevations in the Chlorate Plant area and the Acid Plant area are consistently below the invert elevations of the stormwater system (ERM 2005d). Therefore, groundwater contribution to stormwater does not appear to be a complete pathway at the site. Refer to Sections 5.9 and 6.2.8 and Figure 1-6 of the Upland RI Report (ERM 2005a; Appendix E) for a detailed description of site stormwater.

4.2.4 Stormwater Discharge—Overland Flow

With the exception of some erosion of bank soils, little overland transport of chemicals is expected via stormwater runoff. The northern third of the property consists of open fields of brush and healthy vegetation. The southern two-thirds of the property, where chemical manufacturing activities took place, is almost entirely covered by pavement, gravel, or a temporary cover system (e.g., asphalt pavement). This area of the property is served by a storm sewer system that conveys stormwater directly to the Willamette River. Overland sheet runoff to the river is not a complete pathway.

4.2.5 Erosion of Bank Soils

The riverbank in the vicinity of Arkema is partially river beach and steep slopes covered with bank stabilization material that includes large chunks of concrete, asphalt, and other impervious material (Integral 2004a). There is no evidence of large-scale bank erosion, although there was minor sloughing of the bank between Docks 1 and 2 during the 1996 flood (Integral 2004a). Monitoring of sediment stakes placed at low, mid, and high bank elevations indicated relatively small-scale erosion and accretion between July 2002 and January 2004 (Anchor 2004). Nevertheless, erosion of riverbank soils and sediments during high water flooding or rain events may represent a potential source of COIs to sediments and surface water.

COIs in bank soils are evaluated under the upland RI/FS process; however, COIs present in sediment and surface water that may be a result of erosion of bank soil are evaluated as potential exposure media for the in-water EE/CA.

4.2.6 Resuspension and Translocation of Sediment

The in-water area offshore of the Arkema facility lies within the downstream end of a main channel depositional zone in the Willamette River (Integral and GSI 2004a). Bathymetry data collected between January 2002 and February 2004 indicated that net sediment accretion and erosion rates were essentially equal (approximately 1 ft) (Integral and GSI 2004a). Approximately 1 ft of sediment is lost downstream annually, but replaced by approximately by 1 ft of sediment from upstream. Therefore, the resuspension of sediments containing site COIs could potentially represent a pathway to surface water.

4.2.7 Airborne Transport

COIs in soil may be transported to areas of the site as wind-blown dust and vapors. Volatile COIs released from soil will disperse readily except in the immediate area of release. Known areas of volatile COIs in shallow soils are confined to portions of the Acid Plant area (i.e., near the MCB recovery unit). In addition, non-volatile COIs found in surface soil may adhere to particles in fugitive dust dispersed by wind and vehicular traffic. Wind-blown dust is minimized in areas where there is groundcover (e.g., gravel, grass, and pavement). Wind transport of COIs in upland and riverbank soil is addressed in the upland RI/FS process and is considered an insignificant transport pathway for the in-water EE/CA.

4.3 EXPOSURE PATHWAYS AND POTENTIAL RECEPTOR POPULATIONS

The primary and secondary sources and release mechanisms described above have led to COIs in both abiotic and biotic exposure media at the site (Figures 4-1 and 4-2). Abiotic exposure media are air, surface water, transition zone water, riverbank sediments, riparian soils, and in-water sediments. Transition zone water is not an exposure medium in the human receptor conceptual site model. However, the contribution from laminar flow and dispersion from transition zone water to fish and shellfish is being evaluated in this particular model. Biotic exposure media are fish and shellfish that have potentially bioaccumulated COIs via exposure to surface water, transition zone water, riverbank sediments, and in-water sediments.

Although air and riparian soils are identified as potential but insignificant exposure media for the Arkema site, these media will not be evaluated further for in-water actions.

COIs in riparian soil, wind-blown particulates, and vapors in air are being investigated through the upland RI/FS process. In addition, a beneficial water use survey (ERM 2005a) found that groundwater in the locality of the facility has not been a source, nor will it likely be a source in the future, for drinking water at the site (CH2M Hill 1997; ERM 2005d, Appendix G; Woodward-Clyde 1997).

4.3.1 Human Receptors

Human receptors that may come into contact with site-related COIs are onsite workers, dockside workers, in-water workers, transient trespassers, divers, and fishers (recreational, Native American, and non-tribal) (Figure 4-1). Residents do not currently reside on or adjacent to the site, and future land use precludes construction of residences on the site. Recreational users also are not considered relevant because the site is fenced and locked, upland and beach access to the Arkema site is not permitted, and on-water recreational users are more conservatively represented by fishers.

Onsite workers are generally restricted to upland activities and therefore would most likely be exposed to upland and riparian soils, which extend to the top of the bank. Onsite workers include general outdoor or maintenance workers, excavation or trench workers, construction workers, and indoor office workers. Potential exposures of onsite workers to upland and riparian soils via incidental ingestion, dermal contact, and inhalation are evaluated in the upland RI/FS and are not considered further in this EE/CA. There may be a potential for contact with in-water sediment and surface water, particularly during in-water activities such as dredging, although it is assumed that potential exposure of onsite workers to in-water media would be represented by the dockside and in-water worker scenarios.

Dockside workers may be exposed to COIs via incidental ingestion or dermal contact with riverbank and in-water sediments, surface water, and to a lesser extent, riparian soils. These exposures may occur while loading or unloading vessels or performing dock or shoreline maintenance but are expected to be infrequent. Inhalation of particulates and vapors transported via the wind to dock areas is a complete but insignificant exposure route.

In-water workers are involved in in-water removal actions such as dredging, capping, or other excavations. These activities may require workers to be on the water full-time throughout the construction period, but the project duration is expected to be shorter than a typical onsite or dockside worker employment duration. In-water workers may be exposed to COIs via incidental ingestion of or dermal contact with surface water, riverbank and in-water sediment, and to a lesser extent, riparian soils. As with dockside workers, repeated contact with in-water media will not be associated with routine job

functions. Inhalation of particulates and vapors from upland soils is a complete but likely insignificant exposure pathway.

Although current access to the site is limited and will remain limited under future industrial uses, transients are included as potential receptors for the Arkema site. Transients gaining temporary site access may be exposed to COIs in upland and riparian soil via incidental ingestion, dermal contact, and inhalation of particulates and vapors. These exposure pathways are evaluated under the upland RI/FS process.

Transients also may contact riverbank sediments and surface water via incidental ingestion or dermal contact. These pathways are considered complete but are expected to be limited in duration and frequency because transients are not permitted to reside on site. If transients gain access to the site, they may ingest locally caught fish or shellfish. Contact with site-related COIs in biotic and/or abiotic exposure media is expected to be much less than that of onsite or in-water workers and fishers. Unlike EPA's conceptual site model for Portland Harbor, seeps do not represent an exposure medium to transients or other receptors at the Arkema site because these features are not present. Seeps were not identified along the riverbank at the site during an in-water survey conducted from a boat.

Divers would only be involved in remedial investigations, such as surface water and in-water sediment sampling. Therefore, exposure media for divers are limited to surface water and in-water sediments. Dermal contact with surface water is considered to be a complete exposure pathway, while incidental ingestion and dermal contact with sediment are potentially complete but not likely to be significant exposure routes. Divers in the Willamette River are expected to wear climate-appropriate wet or dry suits that cover the entire body and head. The suit and face mask would limit the potential for skin contact, and the surface water would wash away sediment adhering to the suit while diving.

Fishers, whether they are recreational, Native American, or non-tribal, are evaluated as on-water fishers. Their access to site surface water is restricted to boat travel because access to the riverbank is not permitted. Therefore, exposure media of concern would be surface water and fish or shellfish. Fishers that gain access as pedestrians to the riverbank are considered transients or trespassers, as discussed above.

4.3.2 Ecological Receptors

The CSM for ecological receptors is based on the general model recommended by EPA for the Portland Harbor and is presented in Figure 4-2. Ecological receptors of concern are represented by six higher taxonomic categories: plants, invertebrates, fish, amphibians, birds, and mammals. These categories are further broken down into different guilds of organisms based on their habitat or feeding preferences. Representative receptors that occur within the Portland Harbor ecosystem are identified for the macrofaunal

invertebrates and all of the vertebrate foraging guilds. Potential routes of exposure for these receptors are as follows:

- **Inhalation**—limited to amphibians, birds, and mammals
- **Direct contact via dermal or respiratory tissues**—limited to invertebrates and fishes
- **Ingestion of abiotic media**—sediments or water
- **Ingestion of food**—defined as tissue consumed by an organism within a particular exposure medium.

The ingestion route of exposure also includes indirect exposure via trophic transfer through the food chain.

4.3.2.1 Departures from EPA Ecological Conceptual Site Model

This section discusses the departures from the EPA's ecological conceptual site model for the Portland Harbor. The conceptual site model developed for the EE/CA at Arkema is site-specific and therefore has some site specific distinctions, which are described below.

Seeps are not connected to a source release mechanism and therefore do not represent an exposure medium to ecological receptors because these features are not present at the site. Seeps were not identified along the riverbank at the site during an in-water survey of the shoreline (see Section 3).

Phytoplankton exposure to sediments via the direct contact route is extremely difficult to quantify. There does not appear to be the potential for actual exposure of phytoplankton to COIs in river sediment. By definition, phytoplankton reside in the water column and are highly transitory. Consequently, this pathway has been assigned an "incomplete" designation, which is not consistent with EPA's model that presents this pathway as being complete but insignificant. Potential exposure of sediment-dwelling (i.e., edaphic) unicellular algae is covered by the periphyton guild and is not changed from that described in the EPA CSM.

Zooplankton also dwell in the water column and therefore are unlikely to be exposed directly to sediments. However, resuspended sediments and organic matter may be present in the water column near the sediment–water interface. Consequently, zooplankton dietary exposure via river sediment is designated as a complete but insignificant route. Zoobenthic microfauna (e.g., some harpacticoid copepods) that may transiently enter the water column at the sediment–water interface are treated as members of the epifaunal guild, which is not changed from that described in the EPA CSM.

The dietary exposure route of infauna and epifauna via surface water and transition zone water was considered complete, but with unknown significance. It is extremely difficult to quantify this dietary route as well as determine the significance of this pathway. EPA's model indicated that dietary pathway was complete for both receptors but insignificant for infauna and significant for epifauna. Modification of these functional designations does not affect the screening evaluation described in Sections 5 and 6. Infauna and epifauna are usually evaluated directly via comparisons of relevant SLVs (e.g., benthic TEC, PEC). Their relative contribution to exposure to higher trophic level organisms is usually assessed through food chain models, which are being developed by LWG in collaboration with the government team, and is beyond the scope of the screening level evaluation conducted herein.

The direct contact route of exposure via Willamette River sediments to adult Chinook salmon is considered incomplete in this evaluation. EPA's CSM characterized this exposure route as complete and significance unknown. However, upstream migrating adult salmon are highly transitory and remain in the water column where their exposure would be via direct contact with surface water primarily through respiration. Nor is direct contact with sediments likely during spawning. Adult Chinook salmon spawn in coarse gravel in the upper reaches of the Willamette River or in its tributaries, which are above Portland Harbor.

Direct contact with Willamette River sediments by juvenile salmon is also considered to be an incomplete pathway. Juvenile salmon dwell in the water column where their exposure would be via direct contact with surface water primarily through respiration. Juvenile salmon are pelagic foragers of the zoobenthos and therefore may be exposed to sediments via the ingestion and dietary routes, both of which are complete pathways and in agreement with EPA's CSM.

Amphibians are likely exposed to Willamette River surface water at the Arkema site. The dermal exposure to organisms such as frogs or salamanders, which have mucosal skin glands may be both complete and significant. This is contrary to EPA's model that assigned an incomplete pathway label to this class of receptors.

The dietary route of exposure to birds and mammals (mink) to transition zone water also departs from EPA's CSM. Osprey and bald eagle forage over wide areas that may range from 3 to 20 km depending on species, nest location and availability of food (USEPA 1993a). Both birds are opportunistic foragers whose prey may include bottom-dwelling fish. Dietary exposure to transition zone water for osprey and bald eagle is considered to be complete and significance unknown, because the foraging range of theses species is much greater than the area of the site and because the areal extent of near-surface transition zone water is also unknown. Mink and diving carnivores such as the hooded merganser may forage in a limited area on small bottom-dwelling fishes that are directly

exposed to transition zone water at the sediment-water interface. Dietary exposure to transition zone water for mink and the hooded merganser is also considered to be complete and significance unknown, because the areal extent of near-surface transition water is also unknown. The spotted sandpiper forages in nearshore areas by probing sediments and shallow surface water, but is unlikely to be exposed to transition zone water. Consequently, dietary exposure of spotted sandpiper to transition zone water is considered as an incomplete pathway.

5 COMPARISON TO JOINT SOURCE CONTROL STRATEGY CRITERIA AND OTHER SLVS

This section of the work plan describes the approach used to compare all of the data in the Arkema EE/CA project database to the JSCS criteria and other SLVs provided by EPA in order to identify COIs for the site.

Data that are relevant to the Arkema site (data between shoreline and thalweg[14] and Arkema's south and north property lines) were pooled into a comprehensive data set that includes sediment, riverbank soils, surface water, groundwater (upland groundwater along the riverbank and groundwater in sediments below TZW), TZW, and tissue data.[15] Each individual data point from the comprehensive data set was compared to each SLV, by medium, to determine whether the data point was greater than or less than the SLV. The result of this data comparison is a list of chemicals that had one or more data values that were greater than one or more SLVs. These chemicals are identified as COIs and are tabulated and summarized by media in Table 5-1.

In addition to chemical detections, some of the chemicals analyzed at the site had detection limits that were greater than some of the SLVs used in the JSCS data comparisons. A second list of COIs is presented for chemicals that were not detected, but for which more than 10 percent of the detection limits for that chemical exceeded their respective SLVs. COIs that were identified solely on the basis of a detection limit value (i.e., not detected above an SLV) are summarized in Table 5-2. Detected COIs are carried forward into the site-specific EE/CA data screening that is presented in Section 6.

The remainder of this section summarizes the SLV used, by medium, for comparison of the comprehensive data set and provides the tabular results of the comparisons.

[14] Defined as the longitudinal line that connects the deepest points of the channel.

[15] See Section 3.1 of the work plan for a full list of data sources and data stations that are included in the comprehensive Arkema data set.

Table 5-1. Chemicals of Interest based on Detected Chemicals.

Analyte	Exceeded Aqueous Criteria	Exceeded Solid Phase Criteria
Key COIs		
4,4'-DDD	X	X
4,4'-DDD (dissolved)		X
4,4'-DDE	X	X
4,4'-DDE (dissolved)		X
4,4'-DDT	X	X
4,4'-DDT (dissolved)		X
Chlorobenzene		X
Chromium (dissolved)		X
Chromium (total)	X	X
Chromium hexavalent		X
Perchlorate	X	X
Total of 2,4' and 4,4'-DDD	X	X
Total of 2,4' and 4,4'-DDD (dissolved)		X
Total of 2,4' and 4,4'-DDD, -DDE, -DDT	X	X
Total of 2,4' and 4,4'-DDD, -DDE, -DDT (dissolved)		X
Total of 2,4' and 4,4'-DDE	X	X
Total of 2,4' and 4,4'-DDE (dissolved)		X
Total of 2,4' and 4,4'-DDT	X	X
Total of 2,4' and 4,4'-DDT (dissolved)		X
Total of 4,4'-DDD, -DDE, -DDT	X	X
Total of 4,4'-DDD, -DDE, -DDT (dissolved)		X
VOCs		
1,1,2,2-Tetrachloroethane		X
1,1,2-Trichloroethane		X
1,1-Dichloroethane		X
1,2,3-Trichloropropane		X
1,2,4-Trimethylbenzene		X
1,2-Dichloroethane		X
1,2-Dichloropropane		X
1,4-Dichlorobenzene		X
2-Butanone		X
Acetone		X
Benzene		X
Bromodichloromethane		X
Bromoform		X
Bromomethane		X
Carbon disulfide		X
Carbon tetrachloride		X
Chloroethane		X
Chloroform		X

Table 5-1. Chemicals of Interest based on Detected Chemicals.

Analyte	Exceeded Aqueous Criteria	Exceeded Solid Phase Criteria
Chloromethane		X
cis-1,2-Dichloroethene		X
Ethylbenzene		X
m,p-Xylene		X
Methylene chloride		X
Tetrachloroethene		X
Toluene		X
trans-1,2-Dichloroethene		X
Trichloroethene		X
Vinyl chloride		X
PAHs		
2-Methylnaphthalene	X	
Acenaphthene	X	X
Acenaphthylene	X	
Anthracene	X	
Benz(a)anthracene	X	X
Benzo(a)pyrene	X	X
Benzo(b)fluoranthene	X	X
Benzo(g,h,i)perylene	X	
Benzo(k)fluoranthene	X	X
Chrysene	X	X
Dibenz(a,h)anthracene	X	
Fluoranthene	X	X
Fluorene	X	X
Indeno(1,2,3-cd)pyrene	X	X
Naphthalene	X	X
Phenanthrene	X	X
Polycyclic Aromatic Hydrocarbons	X	
Pyrene	X	X
SVOCs		
1,2-Dichlorobenzene		X
2,4,6-Trichlorophenol		X
2-Chlorophenol		X
Bis(2-ethylhexyl) phthalate	X	X
Carbazole	X	
Dibutyl phthalate	X	
Pentachlorophenol	X	X
Phenol	X	
PCBs		
Aroclor 1242	X	
Aroclor 1248	X	

Table 5-1. Chemicals of Interest based on Detected Chemicals.

Analyte	Exceeded Aqueous Criteria	Exceeded Solid Phase Criteria
Aroclor 1254	X	
Aroclors	X	X
Polychlorinated biphenyls	X	X
Pesticides		
Aldrin	X	X
alpha-Hexachlorocyclohexane		X
alpha-Hexachlorocyclohexane (dissolved)		X
beta-Endosulfan		X
beta-Hexachlorocyclohexane		X
beta-Hexachlorocyclohexane (dissolved)		X
Chlordane (cis & trans)	X	X
delta-Hexachlorocyclohexane		X
Dieldrin	X	X
Dieldrin (dissolved)		X
Endrin	X	X
Endrin aldehyde	X	
Endrin ketone	X	
gamma-Hexachlorocyclohexane	X	X
gamma-Hexachlorocyclohexane (dissolved)		X
Heptachlor		X
Heptachlor epoxide	X	X
Hexachlorobenzene	X	X
Hexachlorobutadiene	X	X
Hexachloroethane		X
Methoxychlor		X
Total Chlordanes	X	X
Total Endosulfan		X
Dioxin/Furans		
2,3,7,8-Tetrachlorodibenzo-p-dioxin	X	X
Dioxin/furan TCDD toxicity equivalent	X	X
Dioxin-like PCB congener TCDD toxicity equivalent	X	X
Total TCDD toxicity equivalent	X	X
Metals		
Aluminum (dissolved)		X
Aluminum (total)		X
Antimony (dissolved)		X
Antimony (total)		X
Arsenic (dissolved)		X
Arsenic (total)	X	X
Barium (dissolved)		X
Barium (total)		X

Table 5-1. Chemicals of Interest based on Detected Chemicals.

Analyte	Exceeded Aqueous Criteria	Exceeded Solid Phase Criteria
Beryllium (dissolved)		X
Cadmium (dissolved)		X
Cadmium (total)	X	X
Chloride		X
Copper (dissolved)		X
Copper (total)	X	X
Iron (dissolved)		X
Iron (total)	X	X
Lead (dissolved)		X
Lead (total)	X	X
Manganese (dissolved)		X
Manganese (total)		X
Mercury (dissolved)		X
Mercury (total)	X	X
Nickel (dissolved)		X
Nickel (total)	X	X
Selenium (dissolved)		X
Selenium (total)	X	X
Silver (dissolved)		X
Silver (total)		X
Thallium (dissolved)		X
Thallium (total)	X	X
Vanadium (total)	X	
Zinc (dissolved)		X
Zinc (total)	X	X

Table 5-2. Chemicals of Interest based on Non-detected Chemicals.

Analyte	Exceeded Aqueous Criteria	Exceeded Solid Phase Criteria
VOCs		
1,1,1,2-Tetrachloroethane		X
1,1,1-Trichloroethane		X
1,1,2,2-Tetrachloroethane		X
1,1-Dichloroethane		X
1,1-Dichloroethene		X
1,2,4-Trichlorobenzene		X
1,2-Dibromo-3-chloropropane		X
1,3,5-Trimethylbenzene		X

Table 5-2. Chemicals of Interest based on Non-detected Chemicals.

Analyte	Exceeded Aqueous Criteria	Exceeded Solid Phase Criteria
1,3-Dichlorobenzene		X
1,3-Dichloropropane		X
2-Chlorotoluene		X
2-Hexanone		X
4-Methyl-2-pentanone		X
Acrolein		X
Acrylonitrile		X
Bromobenzene		X
Chlorodibromomethane		X
cis-1,3-Dichloropropene		X
Dibromomethane		X
Dichlorodifluoromethane		X
Ethylene dibromide		X
Isopropylbenzene		X
Methyl tert-butyl ether		X
n-Butylbenzene		X
n-Propylbenzene		X
o-Xylene		X
Sec-butylbenzene		X
tert-Butylbenzene		X
Total xylenes		X
trans-1,3-Dichloropropene		X
SVOCs		
2,4-Dinitrophenol		X
2,4-Dinitrotoluene		X
2,6-Dinitrotoluene		X
2-Nitroaniline		X
3,3'-Dichlorobenzidine		X
3-Nitroaniline		X
4,6-Dinitro-2-methylphenol		X
4-Nitroaniline		X
Aniline		X
Benzyl alcohol		X
Bis(2-chloroethyl) ether		X
Butylbenzyl phthalate		X
Dibenzofuran		X
Diethyl phthalate		X
Dimethyl phthalate		X
Di-n-octyl phthalate		X
Hexachlorocyclopentadiene	X	X
Nitrobenzene		X
N-Nitrosodimethylamine	X	X

Table 5-2. Chemicals of Interest based on Non-detected Chemicals.

Analyte	Exceeded Aqueous Criteria	Exceeded Solid Phase Criteria
N-Nitrosodiphenylamine		X
N-Nitrosodipropylamine	X	X
Pesticides/Herbicides		
Aldrin (dissolved)		X
alpha-Endosulfan		X
alpha-Endosulfan (dissolved)		X
beta-Endosulfan (dissolved)		X
Chlordane (cis & trans) (dissolved)		X
delta-Hexachlorocyclohexane (dissolved)		X
Endrin (dissolved)		X
Endrin aldehyde (dissolved)		X
Endrin ketone (dissolved)		X
Heptachlor (dissolved)		X
Heptachlor epoxide (dissolved)		X
MCPA		X
MCPP		X
Methoxychlor (dissolved)		X
Total Endosulfan (dissolved)		X
Toxaphene	X	X
Toxaphene (dissolved)		X

5.1 SOLID-PHASE MEDIA

Sediment and riverbank soil data are the solid-phase media that were compiled and tabulated for the JSCS and other SLV data comparison. The SLV and procedures used for data comparison are provided in this section along with tabulated summaries of the results.

5.1.1 Sediments

Analytical data from 134 sediment stations were compared to the JSCS and other SLV criteria. Sediment data were compared to the following JSCS criteria:

- Probable effects concentrations (PECs) or other screening values for toxicity from Table 3-1 of the JSCS[16] [identified in tables as Toxicity PEC]
- DEQ's 2001 Bioaccumulative Sediment SLVs from Table 3-1[17], except for ecological SLVs for fish consumption for DDD, DDE, and DDT, which were taken from Poulsen and Peterson (DEQ 2006a) [identified in tables as HH DEQ 2001].

The following additional SLVs also were used for sediment data comparisons:

- Threshold effects concentrations (TECs) from MacDonald et al. (2000) [identified in tables as Toxicity TEC]
- Human health SLVs for fish consumption for DDD, DDE, and DDT from Poulsen and Peterson (DEQ 2006a) [identified in tables as HH P&P 2006]
- Region 9 PRGs for Industrial Soils, Direct Contact [identified in tables as HH EPA Reg 9 Ind]. For chemicals with a noncancer endpoint, the PRG values were recalculated using a hazard quotient of 0.1 [identified in tables as HH EPA Reg 9 Ind HQ 0.1].

A sediment data comparison summary is provided in Table C-1 of Appendix C. The data comparison summary table provides summary statistics, by analyte, including the number of samples analyzed, range of detected and nondetected results, location of the maximum concentration, percentage of results that were not detected at the detection limit, and summary sample statistics for each SLV (Toxicity PEC and TEC, HH DEQ 2001, HH P&P 2006, and HH EPA Reg 9 Ind, HH EPA Reg 9 Ind 0.1).

The results of the sediment sample comparison are presented in a detailed data comparison table (Table C-2 of Appendix C). For each sediment sample in the detailed comparison table, any detected chemical value that is greater than an SLV is highlighted.

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[16] Toxicity values for some of the organic chemicals listed in Table 3-1 of the JSCS document (December 2005) are different from the values reported in the original source documents. The JSCS SLV comparison for PECs and other SLVs in Table 3-1 was made to corrected values based on the original source document reference.

[17] The bioaccumulative SLVs for 2,3,7,8-TCDD and DDD, DDD, and DDT listed in Table 3-1 of the JSCS document (December 2005) are different from the values reported in the original source document. The JSCS SLV comparison for DEQ's 2001 bioaccumulative SLVs in Table 3-1 was made to corrected values based on the original source document reference.

5.1.2 Riverbank Soils

Analytical data from 12 riverbank soil stations were compared to the JSCS criteria and other SLVs. The data comparison SLVs for riverbank soils are the same as for sediments presented in Section 5.1.1.

A riverbank soil data screening summary is provided in Table C-3 of Appendix C. The data comparison summary table provides summary statistics, by analyte, including the number of samples analyzed, range of detected and non-detected results, location of the maximum concentration, percentage of results that were not detected at the detection limit, and summary sample statistics for each SLV (Toxicity PEC and TEC, HH DEQ 2001, HH P&P 2006, and HH EPA Reg 9 Ind, HH EPA Reg 9 Ind 0.1).

The results of the riverbank soil sample comparison are presented in the detailed data comparison table (Table C-4 of Appendix C). For each riverbank soil sample in the detailed comparison table, any detected chemical value that is greater than an SLV is highlighted. Table C-4 (Appendix C) includes all of the Arkema site riverbank soil sample data from the comprehensive database.

5.2 AQUEOUS-PHASE MEDIA

Groundwater, TZW, and surface water data are the aqueous-phase media that were compiled and tabulated for the JSCS and other SLV data comparison. The SLV criteria and procedure used for data comparison are provided in this section along with tabulated summaries of the results.

5.2.1 Groundwater

Analytical data from 59 groundwater stations, including 36 riverbank wells, 1 riverbank borehole, and 22 in-river boreholes[18], were compared to the JSCS criteria and other SLVs. Groundwater data were compared to the following JSCS SLV criteria:

- Human health SLVs from EPA's 2004 NRWQC and DEQ's 2004 AWQC (17.5 g/day fish consumption rate) from Table 3-1 of the JSCS [identified in tables as Fish]
- EPA's maximum contaminant levels (MCL) [DW MCL] and EPA Region 9 Tapwater PRGs [DW PRG] from the JSCS Table 3-1[19] [SLV Drinking Water]

[18] These groundwater samples were collected using a Geoprobe® or similar method, which can generate turbid water samples. Reported pesticide and metal concentrations using these sampling methods may not be representative of actual dissolved groundwater concentrations

- EPA's 2004 NRWQC (chronic), DEQ's 2004 AWQC (chronic), or Oak Ridge National Laboratory's Tier II SCV from the JSCS Table 3-1[20] [Eco]
- A monochlorobenzene value of 1,100 µg/L, Oak Ridge National Laboratory's Tier II SAV [Eco].

The SLVs were compared using the hierarchy presented in the JSCS document (DEQ 2005).

The following additional SLVs also were used for groundwater data comparisons:

- A perchlorate drinking water level equivalent of 24.5 µg/L [DW SCAT].
- For chemicals with noncancer endpoints, EPA Region 9 Tapwater PRGs with a hazard quotient of 0.1 [SLV DW PRG HQ 0.1].

A groundwater data screening summary is provided in Table C-5 of Appendix C. The data comparison summary table provides summary statistics, by analyte, including the number of samples analyzed, range of detected and nondetected results, location of the maximum concentration, percentage of results that were not detected at the detection limit, and summary sample statistics for each SLV (Fish, DW MCL, DW PRG, Eco, DW SCAT, and DW PRG HQ 0.1).

The results of the groundwater sample comparison are presented in the detailed data comparison table (Table C-6 of Appendix C). For each groundwater sample in the detailed comparison table, any detected chemical value that is greater than an SLV is highlighted. Table C-6 (Appendix C) includes all of the Arkema site groundwater sample data from the comprehensive database.

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[19] Tap water PRGs for MCPP and *trans*-1,2-dichloroethene listed in Table 3-1 of the JSCS document (December 2005) are different from the values reported in the original source document. The JSCS SLV comparison for tap water PRGs in Table 3-1 was made to corrected values based on the original source document reference.

[20] DEQ's 2004 AWQC for 2,3,7,8-TCDD listed in Table 3-1 of the JSCS document (December 2005) is different from the value reported in the original source document. The JSCS SLV comparison for AWQC in Table 3-1 was made to corrected values based on the original source document reference. SLVs for specific metals were adjusted for hardness using in-river calcium and magnesium concentrations.

5.2.2 Transition-Zone Water

Analytical data from 25 TZW stations were compared to the JSCS criteria and other SLVs. The data comparison criteria for TZW data are the same as those for groundwater presented in Section 5.2.1.

A TZW data comparison summary is provided in Table C-7 of Appendix C. The data comparison summary table provides summary statistics, by analyte, including the number of samples analyzed, range of detected and nondetected results, location of the maximum concentration, percentage of results that were not detected at the detection limit, and summary sample statistics for each SLV (Fish, DW MCL, DW PRG, Eco, DW SCAT, and DW PRG HQ 0.1).

The results of the TZW sample comparison are presented in the detailed data comparison table (Table C-8 of Appendix C). For each TZW sample in the detailed comparison table, any detected chemical value that is greater than an SLV is highlighted. Table C-8 (Appendix C) includes all of the Arkema site TZW sample data from the comprehensive database.

5.2.3 Surface Water

Analytical data from four surface water stations were compared to the JSCS criteria and other SLVs. The data comparison criteria for surface water data are the same as those for groundwater presented in Section 5.2.1, except that human health SLVs from EPA's 2004 NRWQC and DEQ's 2004 AWQC use the fish consumption rate of 175 g/day from Table 3-1 of the JSCS.

A surface water data comparison summary is provided in Table C-9 of Appendix C. The data comparison summary table provides summary statistics, by analyte, including the number of samples analyzed, range of detected and nondetected results, location of the maximum concentration, percentage of results that were not detected at the detection limit, and summary sample statistics for each SLV (Fish, DW MCL, DW PRG, Eco, DW SCAT, and DW PRG HQ 0.1).

The results of the surface water sample comparison are presented in the detailed data comparison table (Table C-10 of Appendix C). For each surface water sample in the detailed comparison table, any detected chemical value that is greater than an SLV is highlighted. Table C-10 (Appendix C) includes all of the Arkema site surface water sample data from the comprehensive database.

6 EE/CA DATA SCREENING

This section of the work plan describes the modified EE/CA data screening process and the screening results, which were used to assist in delineating the preliminary RAA boundary and to further characterize the site in support of the EE/CA. The initial step in the EE/CA screening procedure was to compare existing site data that exceeds the JSCS SLVs to appropriate screening level values that would identify a level or degree of a principal threat. Existing site data include all of the data in the Arkema EE/CA project database as described in Section 5 (Comparison to JSCS Criteria and Other SLVs). Chemicals identified as preliminary COIs were carried forward from the JSCS screening (Section 5) to the EE/CA data comparison. The preliminary COIs will be analyzed for media that require further evaluation at the site during the EE/CA process.

The COIs were evaluated to determine if upland sources were contributing to in-water contamination and to address IRMs for effective upland control. Identified COIs are summarized and supporting figures are presented in the map folio showing the areal and vertical distribution of each COI compared to screening benchmarks including probable adverse effect (e.g., PEC and acute water quality) and no- or low-adverse effect values (e.g., TEC and chronic water quality).

Sources and descriptions of the screening values for solid-phase and aqueous-phase media are provided in Sections 6.1 and 6.2, respectively, and results of the screening for these media are provided in Section 6.3. A summary of the tissue results are presented in Section 6.4. A revised RAA boundary is proposed in Section 6.5 based on the results of this screening.

6.1 SOLID-PHASE MEDIA

Solid-phase media include in-water river sediment and riverbank soil data. These data were evaluated to identify exceedances of the SLVs described below. This section presents the SLV and screening procedure. The EE/CA data screening summary tables are also provided in this section. SLVs used include:

- Benthic Community Sediment Quality Values including MacDonald et al. PECs or for chemicals without a corresponding PEC value, other probable effects values including Probable Effects Levels (PELs) or Upper Effects Threshold (UET) levels (refer to Section 5.1.1). The PECs or other toxicity screening values were multiplied by a factor of 10 and 100 to establish a sediment concentration range that can be used to define a principal threat boundary.

- Wildlife Sediment Quality Values x Multiplier. The DEQ (2001, 2006a) bioaccumulative screening values were multiplied by a factor of 1,000 to establish a sediment concentration range that can be used to define a principal threat boundary (refer to Section 6.1.1).
- Human Health Screening Values for Direct Exposure (dockside worker and transient scenarios; based on a 1×10^{-5} cancer endpoint or 1.0 HQ noncancer endpoint) (refer to Section 6.1.2)
- Human Health Screening Values for Indirect Exposure x Multiplier. The DEQ (2006) bioaccumulative screening values for DDx were multiplied by a factor of 1,000 to establish a sediment concentration range that can be used to define a principal threat boundary (refer to Section 6.1.2).

The SLVs and screening procedure are further described in the following subsections.

6.1.1 Wildlife Sediment Quality Values

6.1.1.1 Site-Specific Wildlife SLVs

EPA has identified 12 priority chemicals or compound groups that are persistent, bioaccumulative, and toxic (PBT) (http://www.epa.gov/pbt/background.htm). These are alkyl-lead, mercury and its compounds, benzo[a]pyrene, PCDD/Fs, hexachlorobenzene, octachlorostyrene, PCBs, aldrin/dieldrin, chlordane, mirex, toxaphene, and DDT and its metabolites.

Published screening level criteria are available for selected wildlife species for a few of these substances through the U.S. Department of Energy's Oak Ridge National Laboratory (http://risk.lsd.ornl.gov/index.shtml). However, these values are typically based on receptors, complex food web models, and exposure assumptions that are specific to the regions in which they were generated and may not be applicable to either Portland Harbor or the Arkema site.

The general procedure for estimating sediment-related dose and therefore sediment screening levels appropriate to semiaquatic birds and mammals is well known and has been incorporated into the Portland Harbor RI/FS Programmatic Work Plan (Windward 2004). However, the preliminary risk evaluation (PRE) (Windward 2005a) for Portland Harbor is under revision, and assumptions concerning wildlife exposure to sediments have not been finalized. Wildlife modeling and BSAF values needed to estimate PRGs in support of the Round 2 Comprehensive Report and the ecological risk assessment are still in the developmental stages. Because of these limitations, DEQ's (2001, 2006a) wildlife SLVs for sediment were used to evaluate the nature and extent of COIs within sediments at the Arkema site. These SLVs are based on the sediment-biota-predator exposure pathway and account for wildlife exposure to sediment indirectly via consumption of

food. With the exception of DDx, the DEQ (2001) SLVs were used for this evaluation. For DDx, wildlife SLVs are those provided by DEQ (2006a). Both sets of criteria were multiplied by a factor of 1,000 and used to define a principal threat boundary.

6.1.1.2 DEQ Bioaccumulative Sediment SLVs

In the absence of site-specific wildlife screening values, DEQ (2001, 2006a) bioaccumulation sediment screening levels were used to evaluate the nature and extent of COIs within sediments at the Arkema site. Ecological and human health effects SLVs for evaluating bioaccumulation of DDx were developed by DEQ (2006a). For other COIs, the 2001 SLVs were used for this evaluation. Both sets of criteria were multiplied by a factor of 1,000 and used to define a principal threat boundary.

6.1.2 Human Health Screening Values

The AOC requests identification of sediment screening values that would be protective of human health via several pathways:

- Direct exposure via contact or incidental consumption of riverbank soils or sediments
- Indirect exposure via contact or incidental consumption of surface water or aquatic organisms

An overview of the methods or limitations to each is provided below.

6.1.2.1 Direct Exposure to Riverbank Soils or Sediments

As an initial health-protective approach, the most current EPA Region 9 PRGs for soil have been proposed as the basis for screening values for beach sediments for Portland Harbor (Kennedy/Jenks 2004c). Although conservative, these screening values do not represent either the sediment and riverbank exposure matrices or the specific exposure scenarios selected to manage Portland Harbor sediments. Consequently, in-water sediment and riverbank screening values developed for this EE/CA are based on initial Portland Harbor-specific site assumptions and exposure models described in the programmatic work plan and its supporting documentation (Kennedy/Jenks 2004a,c).

Using the reasonable maximum exposure (RME) assumptions and exposure equations provided by Kennedy/Jenks (2004c), sediment screening levels were calculated for the dockside worker and transient scenarios only. The screening levels are based on exposures to sediment via incidental ingestion and skin contact. Typical onsite worker scenarios are dominated by contact with upland exposure media and will be evaluated quantitatively in the Arkema upland RI/FS process but not the in-water EE/CA.

While divers and in-water workers also are considered relevant receptors for the Arkema site, sediment screening levels for these scenarios were not developed. Exposures to the dockside workers are expected to occur over a longer duration and greater frequency, so it was assumed that screening levels calculated for dockside workers are protective of exposures to divers and in-water workers. As discussed in Section 4, recreational beach users that may be present in various portions of Portland Harbor are not relevant to the Arkema site.

Screening values were calculated separately for carcinogens and noncarcinogens. For carcinogens, screening values for the combined ingestion and skin contact routes were determined using the following equation (Kennedy/Jenks 2004a):

$$SSV_c = \frac{RL_c \times BW \times AT}{CSF \times EF \times ED \times CF \times (SIR + SA \times AF \times ABS)}$$

where:

SSV_c = Sediment screening value for carcinogens (mg/kg dry weight)

RL_c = Assumed cancer risk level (10^{-5}) (unitless)

BW = Body weight (kg)

AT = Averaging time (days)

CSF = Cancer slope factor (mg/kg BW-day)$^{-1}$

EF = Exposure frequency (days)

ED = Exposure duration (years)

CF = Conversion factor (kg/mg)

SIR = Sediment ingestion rate (mg/day)

SA = Skin surface area (cm^2/day)

AF = Skin adherence factor (mg/cm^2)

ABS = Skin absorption factor (unitless)

For noncarcinogens, screening values for the combined ingestion and skin contact routes were determined using the following equation (Kennedy/Jenks 2004a):

$$SSV_{nc} = \frac{HL_{nc} \times RfD \times BW \times AT}{EF \times ED \times CF \times (SIR + SA \times AF \times ABS)}$$

where:

SSV_{nc}= Sediment screening concentration for noncarcinogens (mg/kg dry weight)

HL_{nc} = Assumed noncancer hazard quotient (1)

RfD = Reference dose (mg/kg BW-day)

The CSF and RfD values in the above expressions are the same as those summarized by Kennedy/Jenks (2004a). Upper-bound levels for cancer risks (10^{-5}) and noncancer hazard quotients (1) were assumed to calculate principal threat screening values (PTSVs) for sediments. These risk levels were assumed rather than *de minimis* values because principal threat levels are identified at or above the high end of the risk range that would result in a risk management action (USEPA 1991; DOE 1997a,b).

Based on the assumptions provided by Kennedy/Jenks (2004c), the lowest sediment screening values for carcinogenic and noncarcinogenic COIs are those representing the dockside worker and transient, respectively (Appendix B). The lower of the screening values for the dockside worker or the transient scenarios was selected for identification of the RAA for the EE/CA (Table 6-1).

Table 6-1. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Noncancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
Butyltin	78763-54-9	Butyltin ion	--	-- [1]	2971	183	183
Butyltin	14488-53-0	Dibutyltin ion	--	--	2971	183	183
Butyltin	1461-25-2	Tetrabutyltin	--	--	178	11	11
Butyltin	36643-28-4	Tributyltin ion	--	--	178	11	11
Dioxin		Total Dioxin TEQ	4.3E-04	6.5E-05	--	--	4.3E-04
Metal	7429-90-5	Aluminum	--	--	594,186	36,649	36,649
Metal	7440-36-0	Antimony	--	--	238	15	15
Metal	7440-38-2	Arsenic	43	65	697	84	43
Metal	7440-43-9	Cadmium	--	--	2,547	347	347
Metal	16065-83-1	Chromium, trivalent	--	--	891,279	54,974	54,974
Metal	18540-29-9	Chromium, hexavalent	--	--	1,783	110	110
Metal	7440-50-8	Copper	--	--	23,767	1,466	1,466
Metal	7439-92-1	Lead	--	--	--	--	--
Metal	7439-96-5	Manganese	--	--	83,186	5,131	5,131
Metal	7439-97-6	Mercury (tissue)	--	--	59	4	4
Metal	7439-97-6	Mercury (sediment)	--	--	178	11	11
Metal	7440-02-0	Nickel	--	--	11,884	733	733
Metal	7782-49-2	Selenium	--	--	2,971	183	183
Metal	7440-22-4	Silver	--	--	2,971	183	183
Metal	7440-28-0	Thallium	--	--	39	2	2
Metal	7440-66-6	Zinc	--	--	178,256	10,995	10,995
PAH	91-57-6	2-Methylnaphthalene	--	--	7,152	663	663
PAH	83-32-9	Acenaphthene	--	--	107,278	9,946	9,946
PAH	208-96-8	Acenaphthylene	--	--	107,278	9,946	9,946
PAH	120-12-7	Anthracene	--	--	536,389	49,728	49,728

Table 6-1. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Noncancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
PAH	56-55-3	Benz[a]anthracene	69	79	--	--	69
PAH	50-32-8	Benzo[a]pyrene	6.858	7.947	--	--	6.858
PAH	205-99-2	Benzo[b]fluoranthene	69	79	--	--	69
PAH	191-24-2	Benzo[ghi]perylene	--	--	53,639	4,973	4,973
PAH	207-08-9	Benzo[k]fluoranthene	686	795	--	--	686
PAH	218-01-9	Chrysene	6,858	7,947	--	--	6,858
PAH	53-70-3	Dibenz[a,h]anthracene	6.858	7.947	--	--	6.858
PAH	206-44-0	Fluoranthene	--	--	71,519	6,630	6,630
PAH	86-73-7	Fluorene	--	--	71,519	6,630	6,630
PAH	193-39-5	Indeno[1,2,3-cd]pyrene	69	79	--	--	69
PAH	91-20-3	Naphthalene	--	--	35,759	3,315	3,315
PAH	85-01-8	Phenanthrene	--	--	53,639	4,973	4,973
PAH	129-00-0	Pyrene	--	--	53,639	4,973	4,973
PCBs	1336-36-3	Total PCB Aroclors	24	28	35	3	3
PCBs		Total PCB Congeners	--	--	35	3	3
PCBs		Total PCB Congeners, adjusted	24	28	--	--	3
PCBs		Total PCB TEQ	3.3E-04	3.7E-04	--	--	3.3E-04
Pesticide	309-00-2	Aldrin	0.979	0.755	18	1	0.755
Pesticide	319-84-6	alpha-Hexachlorocyclohexane	2.641	2.036	4,753	293	2.036
Pesticide	319-85-7	beta-Hexachlorocyclohexane	9.243	7.126	357	22	7.126
Pesticide	319-86-8	delta-Hexachlorcyclohexane	--	--	--	--	--
Pesticide	60-57-1	Dieldrin	1.040	0.802	30	2	0.802
Pesticide	72-20-8	Endrin	--	--	178	11	11
Pesticide	7421-93-4	Endrin aldehyde	--	--	178	11	11
Pesticide	53494-70-5	Endrin ketone	--	--	178	11	11

Table 6-1. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Noncancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
Pesticide	58-89-9	gamma-Hexachlorocyclohexane	49	70	677	78	49
Pesticide	76-44-8	Heptachlor	3.697	2.850	297	18	2.850
Pesticide	1024-57-3	Heptachlor epoxide	1.828	1.410	8	0.476	0.476
Pesticide	72-43-5	Methoxychlor	--	--	2971	183	183
Pesticide	8001-35-2	Toxaphene	15	12	594	37	12
Pest - Chlor	5103-71-9	alpha-Chlordane	--	--	--	--	--
Pest - Chlor	27304-13-8	Oxychlordane	--	--	--	--	--
Pest - Chlor	12789-03-6	Total Chlordane	181	261	1,129	130	130
Pest - Chlor	5103-74-2	trans-Chlordane	--	--	--	--	--
Pest - Chlor	39765-80-5	trans-Nonachlor	--	--	--	--	--
Pest - DDD	53-19-0	2,4'-DDD	--	--	--	--	--
Pest - DDD	72-54-8	4,4'-DDD	--	--	--	--	--
Pest - DDD		Total DDD	271	406	1162	139	139
Pest - DDE	72-55-9	4,4'-DDE	--	--	--	--	--
Pest - DDE		Total DDE	191	287	1162	139	139
Pest - DDT	789-02-6	2,4'-DDT	--	--	--	--	--
Pest - DDT	50-29-3	4,4'-DDT	--	--	--	--	--
Pest - DDT		Total DDT	191	287	1,162	139	139
Pest -	959-98-8	alpha-Endosulfan	--	--	--	--	--

Table 6-1. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Noncancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
Endo							
Pest - Endo	33213-65-9	beta-Endosulfan	--	--	--	--	--
Pest - Endo	1031-07-8	Endosulfan sulfate	--	--	--	--	--
Pest - Endo	115-29-7	Total Endosulfan	--	--	3,565	220	220
Phenol	106-44-5	4-Methylphenol	--	--	29,709	1,832	1,832
Phenol	87-86-5	Pentachlorophenol	327	325	42,000	3,347	325
Phenol	108-95-2	Phenol	--	--	178,256	10,995	10,995
Phthalate	117-81-7	Bis(2-ethylhexyl) phthalate	1,188	916	11,884	733	733
Phthalate	85-68-7	Butylbenzyl phthalate	--	--	118,837	7,330	7,330
Phthalate	84-66-2	Diethyl phthalate	--	--	475,349	29,319	29,319
Phthalate	84-74-2	Dibutyl phthalate	--	--	59,419	3,665	3,665
Phthalate	117-84-0	Di-n-octyl phthalate	--	--	23,767	1,466	1,466
SVOC	86-74-8	Carbazole	2,689	3,302	--	--	2,689
SVOC	132-64-9	Dibenzofuran	13,447	16,509	--	--	13,447
SVOC	118-74-1	Hexachlorobenzene	34	41	1,537	151	34
SVOC	87-68-3	Hexachlorobutadiene	690	847	384	38	38
SVOC	67-72-1	Hexachloroethane	3,842	4,717	1,921	189	189

[1]-- Data not available (Kennedy/Jenks 2004a).

6.1.2.2 Indirect Exposure to Sediments via Water and Aquatic Organisms

Sediment screening values do not reflect indirect exposure to sediment through contact with surface water and ingestion of aquatic organisms. Indirect exposure to sediments via incidental ingestion of or dermal contact with surface water is not evaluated because the site-related content of sediment particulate matter or sediment porewater in surface water is not known and cannot be predicted with reasonable certainty from the exposure models and scenarios developed for Portland Harbor.

Indirect exposure to sediments via consumption of fish and shellfish is not evaluated in the risk-based screening process. A survey of chemical concentrations in fish and shellfish tissues has been conducted to assess exposure point concentrations for various species site-wide, by river mile, and within fishing zones (Kennedy/Jenks 2004b). Section 8 provides an evaluation of data for tissue collected in the vicinity of the Arkema site. However, quantitative relationships[21] between chemical concentrations in fish or shellfish and sediments are in the draft stage of development for Portland Harbor and have not been finalized or published in a citable form. Such relationships are important because they provide a means of relating sediment management decisions directly to affected fish and shellfish and indirectly to their human and nonhuman consumers.

Once these relationships have been established for the harbor-wide evaluation, they will provide a basis for development of risk-based screening criteria for sediments at the Arkema site. It is therefore recommended that selection of sediment screening values protective of indirect human exposure via consumption of aquatic organisms be completed after collection of additional data for the EE/CA. It is anticipated that a harbor-wide approach will have been established and approved by EPA for calculation of sediment screening levels in time that it can be used in the Arkema EE/CA. A separate memorandum evaluating sediment chemistry data based on comparison to these levels may be necessary.

In the interim, DEQ's (2006a) sediment screening levels for DDx will be used to evaluate human health effects based on bioaccumulation. The SLVs were multiplied by 1,000 to evaluate a principal threat boundary.

6.2 AQUEOUS-PHASE MEDIA

Surface water, TZW, and groundwater data were subjected to the EE/CA screening approach developed for the water matrix. Freshwater acute water quality values from the

[21] Statistically based correlations and linear regression models supplemented by mechanistic modeling or empirical biota-sediment accumulation factors (Kennedy/Jenks 2004b).

following sources, in the order presented, were compared as available for each chemical in water (Table 6-2):

1. National Recommended Water Quality Criteria (NRWQC) (USEPA 2006)
2. Ambient Water Quality Criteria (AWQC) Table 33A (DEQ 2004)
3. AWQC Table 33B (DEQ 2004)
4. Tier II Secondary Acute Values (Suter and Tsao 1996)
5. AWQC Table 33C (DEQ 2004).

The acute water quality values were selected as PTSVs. USEPA (1991) defines principal threat wastes as source materials that are highly toxic or highly mobile and which cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. USEPA (1991) does not establish threshold levels of toxicity that equate to a principal threat. However, USEPA (1991) indicates[22] that principal threat levels are identified at or above the high end of the risk range that would result in a risk management action. This general guidance is consistent with development of preliminary remediation goals and the implementation of NTCRAs, which seek to identify principal threat chemicals for migration pathways that should be removed, or intervention measures needed to prevent existing or imminent threats to the environment (DOE 1997a,b).

Two chemicals, perchlorate and MCB, do not have readily available water quality values. For perchlorate, a concentration of 20 mg/L was used for the EE/CA screen, which is the criterion maximum concentration (CMC) for the protection of aquatic life developed recently by Dean et al. (2004). For MCB, a concentration of 1.1 mg/L was used, which is a Tier II, Secondary Acute Value that was developed by Suter and Tsao (1996) for use by the Oak Ridge National Laboratory. Tier II values are surrogate aquatic benchmarks for AWQC recommended in EPA's (1993b) Proposed Water Quality Guidance for the Great Lakes System.

COIs were also screened against associated maximum contaminant levels (MCL) multiplied by 10 and JSCS fish consumption values (17.5 g/day for TZW and groundwater data and 175 g/day for surface water data) by 10,000 for those chemicals that have these criteria. These data were primarily used for figure presentation purposes and to assist in defining the RAA boundary.

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[22] USEPA (1991) states that treatment alternatives should be evaluated for source materials with combined mobility and toxicity that result in 10^{-3} or greater cancer risk for human health.

Table 6-2. Screening Level Values for Site COIs in Water.

Chemical	CAS Number	Acute (mg/L)	Chronic (mg/L)
Inorganics			
Aluminum	7429-90-5	0.75	0.087
Arsenic	7440-38-2	0.34	0.15
Cadmium	7440-43-9	0.00058 [a]	0.00010 [a]
Chromium, total	7440-47-3	-	-
Chromium, hexavalent	18540299	0.016	0.011
Chromium, trivalent	16065-83-1	0.20 [a]	0.026 [a]
Copper	7440-50-8	0.0040 [a]	0.0030 [a]
Lead	7439-92-1	0.016 [a]	0.00061 [a]
Manganese	7436-96-5	2.3	0.12
Mercury	7439-97-6	0.0014	0.00077
Nickel	7440-02-0	0.16 [a]	0.018 [a]
Selenium	7782-49-2	0.014	0.0050
Silver	7440-22-4	0.00036 [a]	0.00010 [a]
Zinc	7440-66-6	0.040 [a]	0.040 [a]
Chloride	16887-00-6	860	230
Perchlorate	14797-73-0	20.0	0.025
Pesticides			
Aldrin	309-00-2	0.0030	-
cis-Chlordane	5103-71-9	0.0024	0.0000043
trans-Chlordane	5103-74-2	0.0024	0.0000043
DDD (4,4' only)	72-54-8	0.00019	0.000011
DDE (4,4' only)	3547-04-4	1.1	-
DDT (4,4' only)	50-29-3	0.0011	0.0000010
Total of 4,4' DDD-DDE-DDT		0.0011	0.0000010
Dieldrin	60-57-1	0.00024	0.000056
beta-Endosulfan	33213-65-9	0.00022	0.000056
Endrin	72-20-8	0.000086	0.000036
Eldrin aldehyde	7421-93-4	-	-
Heptachlor Epoxide	1024-57-3	0.00052	0.0000038
alpha-Hexachlorocyclohexane	319-84-6	0.039	0.0022
beta-Hexachlorocyclohexane	319-85-7	0.039	0.0022
gamma-Hexachlorocyclohexane	58-89-9	0.00095	0.000080
PCBs			
Aroclor 1242	53469-21-9	0.0012	0.000053
Aroclor 1248	12672-29-6	0.0014	0.000081
Aroclor 1254	27323-18-8	0.00060	0.000033
Aroclor 1260	11096-82-5	1.7	0.094

Table 6-2. Screening Level Values for Site COIs in Water.

Chemical	CAS Number	Acute (mg/L)	Chronic (mg/L)
Total PCBs (Aroclors)	-	0.0020	0.000014
Phenols			
2-Chlorophenol	95-57-8	4.4	2.0
Phenol	108-95-2	10.2	2.6
Pentachlorophenol	87-86-5	0.019 [b]	0.010 [b]
Polycyclic Aromatic Hydrocarbons (PAH)			
Benz(a)anthracene	56-55-3	0.00049	0.000027
Benzo(a)pyrene	50-32-8	0.00024	0.000014
Benzo(b)fluoranthene	205-99-2	-	-
Benzo(k)fluoranthene	207-08-9	-	-
Chrysene	218-01-9	-	-
Indeno(1,2,3-cd)pyrene	193-39-5	-	-
Naphthalene	91-20-3	0.19	0.012
Total PAHs	-	-	-
Phthalates			
Bis(2-ethylhexyl)phthalate	-	0.027	0.0030
Dibutyl phthalate	84-74-2	0.19	0.035
Organonitrogen Compounds			
Carbazole	86-74-8	-	-
Halogenated Compounds			
Hexachlorobenzene	118-74-1	-	-
Hexachlorobutadiene	87-68-3	0.090	0.0093
Hexachloroethane	67-72-1	0.21	0.012
VOCs			
1,2-Dichloroethane	107-06-2	8.8	0.91
1,1,2,2-Tetrachloroethane	79-34-5	2.1	0.61
1,1,2-Trichloroethane	79-00-5	5.2	1.2
1,1-Dichloroethane	75-34-3	0.83	0.047
1,2-Dichloropropane	78-87-5	23.0	5.7
Benzene	71-43-2	2.3	0.13
Carbon disulfide	75-15-0	0.017	0.00092
Carbon tetrachloride	56-23-5	0.18	0.0098
Chloroform	67-66-3	0.49	0.028
Tetrachloroethene	127-18-4	0.83	0.098
Toluene	108-88-3	0.12	0.0098
Trichloroethene	79-01-6	0.44	0.047
Methylene chloride	75-09-2	26.0	2.2
MCB (chlorobenzene)	108-90-7	1.1	0.064
Vinyl Chloride	75-01-4	-	-
m,p-Xylene	1330-20-7	0.0032	0.0018

Table 6-2. Screening Level Values for Site COIs in Water.

Chemical	CAS Number	Acute (mg/L)	Chronic (mg/L)
Dioxins/Furans			
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	0.000010	0.000000038

Notes:
- No screening level value available.
[a] Screening level value calculated based on the average site-specific hardness (27.9 mg/L) for Round 2 surface waters sample collected in vicinity of Arkema site.
[b] Screening level value calculated based on the average site-specific pH (7.43) for Round 2 surface water samples collected in vicinity of Arkema site.

6.3 DATA SCREENING

This section summarizes the degree to which detected concentrations exceed the thresholds presented in Sections 6.1 and 6.2 for each medium. Results of the data screening are summarized in Appendix D, Tables D-1 for sediments, D-3 for riverbank soils, D-5 for surface water, D-7 for transition zone water, and D-9 for groundwater. Within each of these appendix tables, the following summary statistics are presented for each analyte:

- Minimum and maximum for all detected and nondetected results
- Sample identification for the maximum value of all detected and nondetected results
- Minimum and maximum for detected values only
- Maximum nondetected value
- Mean and median for all data assuming that nondetected values are present at their full detection limit
- The total number of samples
- The number of samples in which the analyte was detected
- The percentage of samples where the analyte was not detected.

Each table also presents the various screening values identified in Sections 6.1 and Section 6.2 and provides the following comparisons with the summary data:

- The number of detected results that exceed the SLV
- The frequency of detected results that exceed the SLV
- The number of nondetected results that exceed the SLV

- The percentage of nondetected values that exceed the SLV.

A complete list of all chemicals above screening levels for each medium are presented in Appendix D. A comparison of selected COIs to screening levels is also presented graphically on maps and cross-sections in the map folio. Please note that the 2,4′ isomer of DDD, DDE and DDT was not analyzed ina all soil and sediment samples and was not analyzed in any of the aqueous samples.

The following subsections provide an overview of the results of the comparisons with screening levels and a discussion on general locations and spatial patterns of SLV exceedances for each matrix.

6.3.1 Sediment

Analytical data from 134 sediment stations were compared to the EE/CA SLVs (Sections 6.1 above). In-water sediment samples exceeded SLV for 34 chemicals in eight chemical classes (Table 6-3). Patterns of SLV exceedances for these chemicals and compound classes are discussed for each of the major receptor categories for which SLVs are available.

Table 6-3. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Sediments.

		Screening Level Parameters Used for Comparisons with Site Data									
		Sediment Quality - Benthic Community				Bioaccumulation - Wildlife				Bioaccumulation - Human	
Chemical Class	**Analyte**	**TEC**	**PEC**	**PEC x10**	**PEC x100**	**Bio_ECO**	**Bio_ECO x1000**	**JSCS_Bio**	**JSCS_BIO x1000**	**Bio_HH**	**Bio_HH x1000**
Aroclors	Aroclors	20%	2%	0%	0%	--	--	--	--	--	--
Dioxins_Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin	--	9%	3%	0%	--	--	31%	0%	--	--
Metals	Aluminum (total)	--	--	--	--	--	--	--	--	--	--
	Cadmium (total)	1%	0%	0%	0%	--	--	100%	0%	--	--
	Chromium (total)	15%	1%	0%	0%	--	--	0%	0%	--	--
	Copper (total)	70%	1%	0%	0%	--	--	100%	0%	--	--
	Lead (total)	17%	3%	1%	0%	--	--	3%	0%	--	--
	Nickel (total)	63%	4%	1%	0%	--	--	1%	0%	--	--
	Selenium (total)	--	14%	0%	0%	--	--	35%	0%	--	--
	Zinc (total)	36%	0%	0%	0%	--	--	100%	0%	--	--
PAHs	Benz(a)anthracene	41%	5%	1%	0%	--	--	--	--	--	--
	Benzo(a)pyrene	26%	3%	0%	0%	--	--	--	--	--	--
	Naphthalene	3%	2%	0%	0%	--	--	--	--	--	--
	Polycyclic Aromatic Hydrocarbons	39%	--	--	--	--	--	--	--	--	--
Pesticides	Aldrin	--	3%	1%	0%	--	--	--	--	--	--
	Chlordane (cis & trans)	15%	6%	1%	0%	--	--	--	--	--	--
	cis-Chlordane	7%	3%	0%	0%	--	--	--	--	--	--
	Dieldrin	4%	0%	0%	0%	--	--	--	--	--	--
	Endrin	6%	0%	0%	0%	--	--	--	--	--	--
	gamma-Hexachlorocyclohexane	8%	6%	1%	0%	--	--	--	--	--	--
	Heptachlor epoxide	3%	2%	0%	0%	--	--	--	--	--	--
	Total Chlordanes	40%	17%	4%	0%	--	--	--	--	--	--
	Total of 2,4' and 4,4'-DDD	86%	68%	37%	14%	94%	63%	--	--	94%	63%
	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	92%	--	--	--	--	--	97%	57%	--	--

Table 6-3. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Sediments.

		Screening Level Parameters Used for Comparisons with Site Data									
		Sediment Quality - Benthic Community				Bioaccumulation - Wildlife				Bioaccumulation - Human	
Chemical Class	**Analyte**	**TEC**	**PEC**	**PEC x10**	**PEC x100**	**Bio_ECO**	**Bio_ECO x1000**	**JSCS_Bio**	**JSCS_BIO x1000**	**Bio_HH**	**Bio_HH x1000**
	Total of 2,4' and 4,4'-DDE	71%	38%	13%	1%	79%	36%	--	--	79%	69%
	Total of 2,4' and 4,4'-DDT	83%	64%	35%	15%	94%	70%	--	--	94%	65%
	trans-Chlordane	8%	3%	1%	0%	--	--	--	--	--	--
Phenols	Pentachlorophenol	--	1%	1%	1%	--	--	--	--	--	--
	Phenol	--	10%	0%	0%	--	--	--	--	--	--
Phthalates	Bis(2-ethylhexyl) phthalate	--	4%	0%	0%	--	--	13%	0%	--	--
	Dibutyl phthalate	--	7%	1%	0%	--	--	--	--	--	--
SVOCs	Carbazole	--	3%	1%	0%	--	--	--	--	--	--
	Hexachlorobenzene	--	4%	1%	1%	--	--	--	--	--	--
	Hexachlorobutadiene	--	1%	1%	0%	--	--	--	--	--	--

Notes:

-- Stands for either nonexistent SLV value, or for any statistical value which is not available because of a nonexistent SLV value, or for any other value which is not available (e.g. "--" would appear in column 'Maximum Detected Value' or '# Detected Results Exceeding SLV' if there are no detected values throughout the whole data set).

All compounds are "total".

DL = Detection Limit

SLV = Screening Level Value

COI - Chemical of Interest

Only result values > SLV have been screened out.

All SLV units are the same as chemical units given in column C.

Column 'SLVs exceeded to define chemical as COI' lists those SLV sets which were exceeded by **a detected result**, or by a non-detected result provided **non-detected results** in ≥ 10 % of all samples are above an SLV.

Data have been screened against all criteria separately without applying any hierarchy.

No averaging of samples has been performed. Each sample and each replicate sample were screened individually.

Table 6-3. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Sediments.

Tier Trigger I: at least one detected value exceeds one or more SLVs.

Tier Trigger II: only non-detected results in ≥ 10% of the samples exceed one or more SLVs.

Column 'Sample IDs showing Max Result' can display up to 255 characters. If Sample ID's list forms a longer string, it is truncated to 255 characters.

SLV (Bio_ECO) - Poulsen and Peterson (2006) Ecological Bioaccumulative Sediment SLVs for DDx.

SLV (Bio_HH) - Poulsen and Peterson (2006) SLV.

DCHH - EE/CA Human Health Direct Contact SLV

SLV (JSCS_Bio) - DEQ (2001) Bioaccumulative Sediment SLV.

SLV (PEC) - MacDonald PEC or other SQV.

SLV (TEC) - TEC SLV.

6.3.1.1 Benthic Community

Sediment concentrations exceeded TEC or PEC values for 34 chemicals (Table 6-3). COI that exceed the PEC in more than 10 percent of the samples are selenium (14%), total chlordanes (17%), total[23] DDD (68%), total DDE (38%), and total DDT (64%). The spatial distributions of these SLV exceedances in surface and shallow subsurface sediments are presented in the map folio (M-319 and M-320 for selenium, M-272 and M-273 for chlordanes, M-16 and M-17 for total DDD, M-30 and M-31 for total DDE, and M-2 and M-3 for total DDT). Few (< 5%) of the selenium and chlordanes values exceed the PEC X 10 or PEC X 100 benchmarks and there is no known source of these chemicals from the Arkema site (see Section 4.1). However, DDx compounds exceed the PEC X 10 benchmark in 13 to 35 percent of the samples, and exceed the PEC X 100 benchmark in 1 to 15 percent of the samples. The majority of these exceedances were associated with samples collected in nearshore water located within the navigation channel line and from the Salt Dock downstream to Outfall 004, and near the bridge at the northern end of the site. For 2,4'- and 4,4'-DDT, the PEC X 100 exceedances in deeper subsurface sediments were mostly limited to samples between and adjacent to Docks 1 and 2.

6.3.1.2 Wildlife Exposure via Food Chain Bioaccumulation

Sediment concentrations exceeded wildlife bioaccumulation SLVs for 11 chemicals (Table 6-3). Of these, all but two (lead and nickel) exceeded SLVs in 10 percent or more of the samples. Only the DDx compounds individually and collectively exceeded the Bio_Eco X 1,000 or the JSCS_Eco X 1,000 benchmarks. Areas where bioaccumulation values exceeded these benchmarks were nearshore sediments within the channel line and extending from the Salt Dock downstream to the railroad bridge (see figures in map folio).

6.3.1.3 Human Exposure via Food Chain Bioaccumulation

Sediment concentrations exceeded human health bioaccumulation SLVs for total DDD, total DDE, and total DDT in over 79 percent of the samples (Table 6-3). Benchmarks set at 1,000 X the SLV were exceeded in over 63 percent of the samples. With the exception of DDE, spatial patterns for areas that exceeded these benchmarks are similar to those described above for wildlife and are in the nearshore sediments extending from the Salt Dock downstream to the railroad bridge (see figures in map folio). The bioaccumulation SLV for DDE is much lower than that for either DDT or DDD. Consequently, sediments throughout the sampling area exceed the DDE bioaccumulation SLV for human health (M-30 through M-33). Sediment concentrations of all other substances for which SLVs were available were below their respective screening values.

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[23] Total refers to the sum of the 2,4'- and the 4,4' isomers for the various DDx compounds.

6.3.2 Riverbank Soil

Analytical data from 12 riverbank soil stations were compared to the EE/CA SLVs (Sections 6.1). Riverbank soil samples exceeded SLV for 24 chemicals in six chemical classes (Table 6-4). Patterns of SLV exceedances for these chemicals and compound classes are discussed below for each of the major receptor categories for which SLVs are available.

Table 6-4. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Riverbank Soils.

		Screening Level Parameters Used for Comparisons with Site Data										
		Sediment Quality - Benthic Community				Bioaccumulation - Wildlife				Bioaccumulation - Human		Human Direct Contact
Chemical Class	**Analyte**	**TEC**	**PEC**	**PEC x10**	**PEC x100**	**Bio_ ECO**	**Bio_ ECO x1000**	**JSCS_ Bio**	**JSCS_ BIO x1000**	**Bio_ HH**	**Bio_HH x1000**	**DCHH**
Metals	Cadmium (total)	29%	0%	0%	0%	--	--	29%	0%	--	--	0%
	Lead (total)	100%	14%	14%	0%	--	--	14%	0%	--	--	--
	Zinc (total)	29%	0%	0%	0%	--	--	100%	0%	--	--	0%
PAHs	Benz(a)anthracene	10%	5%	0%	0%	--	--	--	--	--	--	0%
	Benzo(a)pyrene	10%	0%	0%	0%	--	--	--	--	--	--	0%
	Naphthalene	0%	0%	0%	0%	--	--	--	--	--	--	0%
	Polycyclic Aromatic Hydrocarbons	10%	--	--	--	--	--	--	--	--	--	--
Pesticides	Aldrin	--	0%	0%	0%	--	--	--	--	--	--	0%
	Chlordane (cis & trans)	0%	0%	0%	0%	--	--	--	--	--	--	--
	cis-Chlordane	0%	0%	0%	0%	--	--	--	--	--	--	--
	Dieldrin	0%	0%	0%	0%	--	--	--	--	--	--	0%
	Endrin	0%	0%	0%	0%	--	--	--	--	--	--	0%
	gamma-Hexachlorocyclohexane	0%	0%	0%	0%	--	--	--	--	--	--	0%
	Heptachlor epoxide	0%	0%	0%	0%	--	--	--	--	--	--	0%
	Total of 2,4' and 4,4'-DDD	81%	67%	29%	0%	81%	62%	--	--	81%	62%	0%
	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	100%	--	--	--	--	--	100%	81%	--	--	--
	Total of 2,4' and 4,4'-DDE	100%	86%	33%	5%	100%	81%	--	--	100%	100%	0%
	Total of 2,4' and 4,4'-DDT	100%	90%	57%	24%	100%	95%	--	--	100%	90%	0%
	trans-Chlordane	0%	0%	0%	0%	--	--	--	--	--	--	--
Phenols	Pentachlorophenol	--	0%	0%	0%	--	--	--	--	--	--	0%
	Phenol	--	0%	0%	0%	--	--	--	--	--	--	0%
Phthalates	Bis(2-ethylhexyl) phthalate	--	5%	0%	0%	--	--	14%	0%	--	--	0%
	Dibutyl phthalate	--	0%	0%	0%	--	--	--	--	--	--	0%

Table 6-4. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Riverbank Soils.

		Screening Level Parameters Used for Comparisons with Site Data										
		Sediment Quality - Benthic Community				Bioaccumulation - Wildlife				Bioaccumulation - Human		Human Direct Contact
Chemical Class	**Analyte**	**TEC**	**PEC**	**PEC x10**	**PEC x100**	**Bio_ ECO**	**Bio_ ECO x1000**	**JSCS_ Bio**	**JSCS_ BIO x1000**	**Bio_ HH**	**Bio_HH x1000**	**DCHH**
SVOCs	Hexachlorobenzene	--	0%	0%	0%	--	--	--	--	--	--	0%

Notes:

-- Stands for either nonexistent SLV value, or for any statistical value which is not available because of a nonexistent SLV value, or for any other value which is not available (e.g. "--" would appear in column 'Maximum Detected Value' or '# Detected Results Exceeding SLV' if there are no detected values throughout the whole data set).

All compounds are "total".

DL = Detection Limit

SLV = Screening Level Value

COI - Chemical of Interest

Only result values > SLV have been screened out.

All SLV units are the same as chemical units given in column C.
Column 'SLVs exceeded to define chemical as COI' lists those SLV sets which were exceeded by **a detected result**, or by a non-detected result provided **non-detected results** in ≥ 10 % of all samples are above an SLV.

Data have been screened against all criteria separately without applying any hierarchy.

No averaging of samples has been performed. Each sample and each replicate sample were screened individually.

Tier Trigger I: at least one detected value exceeds one or more SLVs.

Tier Trigger II: only non-detected results in ≥ 10% of the samples exceed one or more SLVs.

Column 'Sample IDs showing Max Result' can display up to 255 characters. If Sample ID's list forms a longer string, it is truncated to 255 characters.

SLV (Bio_ECO) - Poulsen and Peterson (2006) Ecological Bioaccumulative Sediment SLVs for DDx.

SLV (Bio_HH) - Poulsen and Peterson (2006) SLV.

DCHH - EE/CA Human Health Direct Contact SLV

SLV (JSCS_Bio) - DEQ (2001) Bioaccumulative Sediment SLV.

SLV (PEC) - MacDonald PEC or other SQV.

SLV (TEC) - TEC SLV.

6.3.2.1 Benthic Community

Sediment concentrations exceeded TEC or PEC values for eight individual chemicals plus two additional aggregate compound categories (PAH and total-DDx) (Table 6-4). COIs that exceed the PEC in more than 10 percent of the samples are lead (14%), total DDD (67%), total DDE (86%), and total DDT (90%). The spatial distributions of these SLV exceedances in riverbank soils are presented in the map folio (M-301 and M-302 for lead, M-16 and M-17 for total DDD, M-30 and M-31 for total DDE, and M-2 and M-3 for total DDT). The concentrations of these chemicals were highest between Docks 1 and 2 where the PEC X 100 screening value for 2,4'- and 4,4'-DDT was exceeded in several samples.

6.3.2.2 Wildlife Exposure via Food Chain Bioaccumulation

Riverbank concentrations exceeded wildlife bioaccumulation SLVs for eight chemicals (Table 6-4), all of which exceeded SLVs in 10 percent or more of the samples. Only the DDx compounds individually and collectively exceeded the Bio_Eco X 1,000 or the JSCS_Eco X 1,000 benchmarks. Areas where bioaccumulation values exceeded these benchmarks in riverbank soils extend from the Salt Dock downstream to the railroad bridge (see map folio).

6.3.2.3 Human Exposure via Bioaccumulation and Direct Contact

Riverbank soil concentrations exceeded human health bioaccumulation SLVs for total DDD, total DDE, and total DDT in over 80 percent of the samples (Table 6-4). Benchmarks set at 1,000 X the SLV were exceeded in over 60 percent of the samples. Spatial patterns for areas that exceeded these benchmarks are similar to those for wildlife bioaccumulation and extend from the Salt Dock downstream to the railroad bridge (see map folio). Riverbank soil concentrations were below direct contact SLVs for all substances for which benchmarks were available.

6.3.3 Surface Water

Analytical data from three surface water stations were compared to aqueous-phase EE/CA SLVs (Section 6.2). Surface water samples exceeded SLV for 18 chemicals in seven chemical classes (Table 6-5). Patterns of SLV exceedances for these chemicals and compound classes are discussed below for each of the major receptor categories for which SLVs are available.

Table 6-5. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Surface Water.

		Screening Level Parameters Used for Comparisons with Site Data				
		Ecological - Water Quality		Human Exposure		
				Fish Consumption		Water Ingestion
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
Aroclors	Aroclors	0%	0%	86%	0%	0%
Dioxins_Furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin	0%	0%	17%	0%	--
Metals	Aluminum (total)	100%	0%	--	--	0%
	Arsenic (dissolved)	0%	0%	100%	0%	--
	Arsenic (total)	0%	0%	100%	0%	--
	Chromium hexavalent	0%	0%	--	--	--
	Mercury (dissolved)	0%	0%	0%	0%	--
	Mercury (total)	0%	0%	0%	0%	--
PAHs	Benz(a)anthracene	0%	0%	18%	0%	0%
	Benzo(a)pyrene	0%	0%	14%	0%	0%
Pesticides	4,4'-DDD	0%	0%	80%	0%	--
	4,4'-DDE	--	0%	80%	0%	--
	4,4'-DDT	20%	0%	80%	0%	--
	Aldrin	--	0%	7%	0%	--
	alpha-Hexachlorocyclohexane	0%	0%	0%	0%	--
	Chlordane (cis & trans)	0%	0%	7%	0%	--
	Dieldrin	0%	0%	53%	0%	--
	Heptachlor epoxide	0%	0%	33%	0%	0%
	Total Chlordanes	0%	0%	7%	0%	--
	Total of 2,4' and 4,4'-DDD	--	0%	80%	0%	--
	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	60%	0%	87%	0%	--
	Total of 2,4' and 4,4'-DDE	--	0%	80%	0%	--
	Total of 2,4' and 4,4'-DDT	27%	0%	80%	0%	--
	Total of 4,4'-DDD, -DDE, -DDT	60%	0%	--	--	--

Table 6-5. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Surface Water.

		Screening Level Parameters Used for Comparisons with Site Data				
		Ecological - Water Quality		Human Exposure		
				Fish Consumption		Water Ingestion
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
Phthalates	Bis(2-ethylhexyl) phthalate	0%	0%	9%	0%	0%
SVOCs	Hexachlorobenzene	--	--	36%	0%	0%

Notes:

-- Stands for either nonexistent SLV value, or for any statistical value which is not available because of a nonexistent SLV value, or for any other value which is not available (e.g. "--" would appear in column 'Maximum Detected Value' or '# Detected Results Exceeding SLV' if there are no detected values throughout the whole data set).

Compounds that are not labeled as "dissolved" are "total".

DL = Detection Limit

SLV = Screening Level Value

COI - Chemical of Interest

Only result values > SLV have been screened out.

All SLV units are the same as chemical units given in column C.

Column 'SLVs exceeded to define chemical as COI' lists those SLV sets which were exceeded by **a detected result**, or by a non-detected result provided **non-detected results** in ≥ 10 % of all samples are above an SLV.

Data have been screened according to the EE/CA hierarchy, with the exception of the Human Health Fish Consumption SLVs and MCLs (see main text).

No averaging of samples has been performed. Each sample and each replicate sample were screened individually.

Tier Trigger I: at least one detected value exceeds one or more SLVs.

Tier Trigger II: only non-detected results in ≥ 10% of the samples exceed one or more SLVs.

Column 'Sample IDs showing Max Result' can display up to 255 characters. If Sample ID's list forms a longer string, it is truncated to 255 characters.

Acute SLV - See main text for a description of the selected EE/CA acute SLVs.

Chronic SLV - See main text for a description of the selected EE/CA chronic SLVs.
SLV (Fish) –Portland Harbor specific fish consumption rat @ 175 g/day SLV.
SLV (Fishx10,000) –Portland Harbor specific fish consumption rate @ 175 g/day x10,000 SLV.

SLV (MCLx10) - Drinking Water MCL SLV x 10.

6.3.3.1 Ecological Aquatic Life Exposure

Aluminum, the sole metal exceeding freshwater screening values, was detected at concentrations exceeding the chronic screening value in surface water samples collected from W015 (northern boundary), W016 (between Docks 1 and 2), and W017 (southern boundary) (map folio M-282). DDT and total-DDx exceeded chronic SLVs in 20 to 60 percent of the samples. DDT exceeded the chronic screening value in one sample collected near the southern end of Dock 2 (W016). In addition, the total of DDx compounds exceeded the chronic SLV in W016 and the sample from station W015 at the northern boundary of the site. There were no acute exceedances of any of the COI in surface water samples for which benchmarks were available.

6.3.3.2 Human Exposure via Fish Consumption and Ingestion of Surface Water

Fifteen chemicals exceeded human health SLVs based on consumption of fish (Table 6-5). Total Aroclors, arsenic, dieldrin, DDT, DDD, DDE, and total-DDx exceeded their respective SLVs in 80 percent or more of the samples. However, none of these exceeded the Fish X 10,000 benchmark. None of the chemicals for which MCLs were available exceeded the MCL X 10 benchmark.

6.3.4 Transition-Zone Water

Analytical data from 25 TZW stations were compared to aqueous-phase EE/CA SLVs (Section 6.2). TZW samples exceeded SLV for 34 chemicals in six chemical classes (Table 6-6). Patterns of SLV exceedances for these chemicals and compound classes are discussed below for each of the major receptor categories for which SLVs are available.

For the Arkema site, groundwater has been identified as a secondary source of chemicals that may be transported into near-surface transition-zone water and result in direct exposure to benthic organisms or entrainment into near-bottom surface water and subsequent exposure to other receptors. All of the samples screened were from the Portland Harbor groundwater pathway assessment pilot study (Integral 2005a). During this study a number of different sampling techniques were evaluated at the same stations. As a result, many of the chemicals above acute screening values are from samples collected from the same location using different sampling methods. The different sampling methods employed during the pilot study had varying degrees of reliability (see Section 3.2.2).

Table 6-6. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Transition Zone Water.

		Screening Level Parameters Used for Comparisons with Site Data				
		Ecological - Water Quality		Human Exposure		
				Fish Consumption		Water Ingestion
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
Conventionals	Chloride	90%	90%	--	--	--
Metals	Aluminum (dissolved)	10%	0%	--	--	0%
	Aluminum (total)	50%	42%	--	--	46%
	Arsenic (dissolved)	0%	0%	50%	0%	--
	Arsenic (total)	0%	0%	79%	0%	--
	Cadmium (dissolved)	30%	0%	--	--	0%
	Cadmium (total)	38%	17%	--	--	0%
	Chromium (dissolved)	19%	0%	--	--	0%
	Chromium (total)	15%	0%	--	--	0%
	Copper (total)	14%	14%	--	--	0%
	Lead (total)	63%	17%	--	--	0%
	Manganese (dissolved)	95%	50%	95%	0%	75%
	Manganese (total)	97%	59%	97%	0%	79%
	Mercury (dissolved)	0%	0%	10%	0%	--
	Mercury (total)	0%	0%	25%	0%	--
	Nickel (dissolved)	10%	0%	0%	0%	--
	Nickel (total)	38%	0%	0%	0%	--
	Perchlorate	53%	33%	--	--	--
	Silver (total)	17%	13%	--	--	0%
	Zinc (total)	21%	21%	0%	0%	0%
PAHs	Naphthalene	6%	0%	--	--	9%
Pesticides	4,4'-DDD	41%	26%	41%	0%	--
	4,4'-DDE	--	0%	33%	0%	--
	4,4'-DDT	37%	11%	37%	4%	--
	Total of 2,4' and 4,4'-DDD	--	30%	52%	0%	--

Table 6-6. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Transition Zone Water.

		Screening Level Parameters Used for Comparisons with Site Data				
		Ecological - Water Quality		**Human Exposure**		
				Fish Consumption		**Water Ingestion**
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	67%	30%	67%	19%	--
	Total of 2,4' and 4,4'-DDE	--	0%	33%	0%	--
	Total of 2,4' and 4,4'-DDT	37%	11%	37%	4%	--
	Total of 4,4'-DDD, -DDE, -DDT	56%	30%	--	--	--
SVOCs	Hexachlorobutadiene	0%	0%	0%	0%	--
VOCs	1,1,2,2-Tetrachloroethane	0%	0%	3%	0%	--
	1,1,2-Trichloroethane	0%	0%	6%	0%	--
	1,1-Dichloroethane	6%	0%	--	--	--
	1,2-Dichloroethane	0%	0%	9%	0%	--
	1,2-Dichloropropane	0%	0%	3%	0%	--
	Benzene	3%	0%	3%	0%	--
	Carbon disulfide	0%	0%	--	--	--
	Carbon tetrachloride	0%	0%	0%	0%	0%
	Chlorobenzene	27%	9%	9%	0%	9%
	Chloroform	36%	18%	18%	0%	--
	m,p-Xylene	6%	6%	--	--	--
	Methylene chloride	9%	9%	12%	0%	--
	Tetrachloroethene	9%	6%	21%	0%	9%
	Toluene	12%	0%	0%	0%	0%
	Trichloroethene	12%	6%	15%	0%	9%

Table 6-6. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Transition Zone Water.

Notes:

-- Stands for either nonexistent SLV value, or for any statistical value which is not available because of a nonexistent SLV value, or for any other value which is not available (e.g. "--" would appear in column 'Maximum Detected Value' or '# Detected Results Exceeding SLV' if there are no detected values throughout the whole data set).

Compounds that are not labeled as "dissolved" are "total".

DL = Detection Limit

SLV = Screening Level Value

COI - Chemical of Interest

TZW - Transition Zone Water

Only result values > SLV have been screened out.

All SLV units are the same as chemical units given in column C.

Column 'SLVs exceeded to define chemical as COI' lists those SLV sets which were exceeded by **a detected result**, or by a non-detected result provided **non-detected results** in ≥ 10 % of all samples are above an SLV.

Data have been screened according to the EE/CA hierarchy, with the exception of the Human Health Fish Consumption SLVs and MCLs (see main text).

No averaging of samples has been performed. Each sample and each replicate sample were screened individually.

Tier Trigger I: at least one detected value exceeds one or more SLVs.

Tier Trigger II: only non-detected results in ≥ 10% of the samples exceed one or more SLVs.

Column 'Sample IDs showing Max Result' can display up to 255 characters. If Sample ID's list forms a longer string, it is truncated to 255 characters.

Acute SLV - See main text for a description of the selected EE/CA acute SLVs.

Chronic SLV - See main text for a description of the selected EE/CA chronic SLVs.

SLV (Fish) - EPA's (2004) NRWQC (organism only; fish consumption @ 17.5 g/day) SLV, or DEQ's (2004) AWQC (organism only; fish consumption @ 17.5 g/day) SLV if the first is not available.

SLV (Fishx10,000) - EPA's (2004) NRWQC (organism only; fish consumption @ 17.5 g/day) SLV, or DEQ's (2004) AWQC (organism only; fish consumption @ 17.5 g/day) SLV if the first is not available x 10,000.

SLV (MCLx10) - Drinking Water MCL SLV x 10.

6.3.4.1 Ecological Aquatic Life Exposure

Eleven conventional substances and trace metals exceeded chronic SLVs. Of these, nine exceeded their respective acute SLVs. Chloride exceeded the acute screening value in the majority of TZW stations (M-102). The presence of elevated chloride concentrations in riverbank monitoring well groundwater samples is consistent with this distribution. Chloride handling at the site likely contributed to the release to groundwater and subsequent transport to the river. Samples collected from stations between Dock 1 and the Salt Dock exceeded the acute screening value for perchlorate (Figured M-89). These exceedances are consistent with a groundwater acute exceedance just upgradient on the riverbank (see Section 6.3.5 below).

Manganese emerged as the metal with the greatest number of acute exceedances in TZW samples. These exceedances were associated with 16 of the 22 sampling stations located from the north side of the Salt Dock downstream to Dock 2 (Figure M-306). This metal was not detected in the riverbank monitoring well stations so the source in transition-zone water is undetermined. Aluminum, cadmium, copper, lead, silver, and zinc also exceeded acute SLVs in 13 to 42 percent of the sampling stations located inside the 20-ft water depth contour and among the docks.

Among the PAH, naphthalene was the only compound that exceeded chronic SLVs in 6 percent of the samples, and was below the acute SLV in all samples and locations.

DDT exceeded its chronic SLV at four locations and its acute SLV at one station located between Docks 1 and 2 (map folio M-1). Samples collected farther towards the channel did not yield DDT at detectable levels. Concentrations of DDD that exceeded the acute screening value were also limited to a portion of the stations located between Docks 1 and 2 (M-15). DDE was not detected in any of the aqueous samples included in the EE/CA data screening.

Nine VOCs exceeded chronic or acute SLVs. Dichloroethane, benzene, and toluene exceeded their respective chronic SLVs at a low frequency (≤ 6 percent of the samples) and were all below their acute SLVs. MCB in transition-zone water exceeded its chronic SLV at four locations and its acute SLV at two locations in the area around Docks 1 and 2 (M-57). Other VOCs including chloroform, m,p-xylene, methylene chloride, tetrachloroethene, and trichloroethene exceeded acute SLVs at one to three stations (depending upon the chemical) between Docks 1 and 2. These stations are positioned in a linear path perpendicular to the river, downgradient from groundwater stations (e.g., MWA-17i, MWA-9i) with elevated VOC concentrations. There is also a cluster of stations between Dock 1 and the Salt Dock that exceeded the chronic SLV for chloroform.

6.3.4.2 Human Exposure via Fish Consumption and Ingestion of Transition-Zone Water

Three trace metals, DDx, and 10 VOCs exceeded fish consumption SLVs in transition-zone water (Table 6-6). Arsenic and manganese exceeded the fish consumption SLV in the majority of samples. Mercury exceeded the fish consumption SLV in 10 percent (dissolved analysis) to 25 percent of the samples (total analysis). None of the trace metals exceeded the Fish X 10,000 benchmark for fish consumption.

DDT, DDD, DDE and total-DDx exceeded their respective SLVs for fish consumption in 33 to 67 percent of the samples. The Fish X 10,000 benchmark was exceeded at one location for DDT between Dock 1 and Dock 2 (M-1) and at five locations for total-DDx (M-43).

The MCL X 10 SLV for ingestion of water was exceeded for two trace metals (aluminum and manganese), one PAH (naphthalene), and three VOCs (monochlorobenzene, tetrachloroethene, and trichloroethene). Aluminum and manganese exceedances occurred with a relatively high frequency (45 to 79 percent) and were associated with many of the sampling stations located inside the 20-ft water depth contour and among the docks. Naphthalene and the three VOCs were above their respective MCL X 10 SLVs in fewer than 10 percent of the samples, which represent stations clustered between Dock 1 and Outfall 002.

6.3.5 Groundwater

Analytical data from 59 groundwater stations, including 36 riverbank monitoring wells, 1 riverbank borehole, and 22 in-river boreholes, were compared to the aqueous-phase EE/CA SLVs (Section 6.2). Groundwater samples exceeded SLV for 37 chemicals in seven chemical classes (Table 6-7). Patterns of SLV exceedances for these chemicals and compound classes are discussed below for each of the major receptor categories for which SLVs are available.

Table 6-7. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Ground Water.

		Screening Level Parameters Used for Comparisons with Site Data				
		Ecological - Water Quality		Human Exposure		
				Fish Consumption		Water Ingestion
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
Conventionals	Chloride	78%	63%	--	--	--
Metals	Arsenic (dissolved)	11%	9%	58%	0%	--
	Arsenic (total)	0%	0%	100%	0%	--
	Cadmium (dissolved)	45%	35%	--	--	0%
	Cadmium (total)	50%	0%	--	--	0%
	Chromium (dissolved)	34%	5%	--	--	1%
	Chromium (total)	57%	26%	--	--	13%
	Chromium hexavalent	55%	47%	--	--	--
	Copper (dissolved)	74%	71%	--	--	0%
	Copper (total)	25%	25%	--	--	0%
	Lead (dissolved)	69%	14%	--	--	3%
	Lead (total)	25%	25%	--	--	0%
	Manganese (dissolved)	72%	22%	77%	0%	40%
	Mercury (dissolved)	3%	3%	9%	0%	--
	Nickel (dissolved)	82%	35%	0%	0%	--
	Nickel (total)	75%	50%	25%	0%	--
	Perchlorate	33%	7%	--	--	--
	Selenium (dissolved)	8%	2%	0%	0%	0%
	Selenium (total)	25%	0%	0%	0%	0%
	Silver (dissolved)	17%	12%	--	--	0%
	Silver (total)	0%	0%	--	--	0%
	Zinc (dissolved)	45%	45%	0%	0%	0%
	Zinc (total)	25%	25%	0%	0%	0%
PAHs	Benz(a)anthracene	7%	0%	7%	0%	0%
	Benzo(a)pyrene	1%	0%	1%	0%	0%

Table 6-7. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Ground Water.

		Screening Level Parameters Used for Comparisons with Site Data				
		Ecological - Water Quality		Human Exposure		
				Fish Consumption		Water Ingestion
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
	Naphthalene	0.8%	0.4%	--	--	2%
Pesticides	4,4'-DDD (dissolved)	44%	28%	44%	3%	--
	4,4'-DDD	60%	40%	61%	16%	--
	4,4'-DDE (dissolved)	--	0%	18%	0%	--
	4,4'-DDE	--	0%	24%	1%	--
	4,4'-DDT (dissolved)	38%	5%	38%	3%	--
	4,4'-DDT	49%	13%	49%	9%	--
	Aldrin (dissolved)	--	0%	0%	0%	--
	Aldrin	--	0%	3%	0%	--
	alpha-Hexachlorocyclohexane (dissolved)	0%	0%	3%	0%	--
	alpha-Hexachlorocyclohexane	0.8%	0%	2%	0%	--
	beta-Endosulfan (dissolved)	0%	0%	0%	0%	--
	beta-Endosulfan	2%	0.8%	0%	0%	--
	beta-Hexachlorocyclohexane (dissolved)	0%	0%	5%	0%	--
	beta-Hexachlorocyclohexane	0%	0%	3%	0%	--
	Chlordane (cis & trans) (dissolved)	0%	0%	0%	0%	--
	Chlordane (cis & trans)	4%	0%	4%	0%	--
	Dieldrin (dissolved)	3%	3%	3%	3%	--
	Dieldrin	1%	0.8%	1%	0.4%	--
	Endrin (dissolved)	0%	0%	0%	0%	0%
	Endrin	0.4%	0%	0.4%	0%	0%
	gamma-Hexachlorocyclohexane (dissolved)	3%	0%	0%	0%	--
	gamma-Hexachlorocyclohexane	12%	0%	0%	0%	--
	Heptachlor epoxide (dissolved)	0%	0%	0%	0%	0%
	Heptachlor epoxide	2%	0%	2%	0.4%	0%

Table 6-7. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Ground Water.

		Screening Level Parameters Used for Comparisons with Site Data				
		Ecological - Water Quality		Human Exposure		
				Fish Consumption		Water Ingestion
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
	Total of 2,4' and 4,4'-DDD (dissolved)	--	28%	44%	3%	--
	Total of 2,4' and 4,4'-DDD	--	42%	68%	19%	--
	Total of 2,4' and 4,4'-DDD, -DDE, -DDT (dissolved)	51%	23%	51%	13%	--
	Total of 2,4' and 4,4'-DDD, -DDE, -DDT	78%	30%	78%	23%	--
	Total of 2,4' and 4,4'-DDE (dissolved)	--	0%	18%	0%	--
	Total of 2,4' and 4,4'-DDE	--	0%	29%	2%	--
	Total of 2,4' and 4,4'-DDT (dissolved)	38%	5%	38%	3%	--
	Total of 2,4' and 4,4'-DDT	51%	14%	51%	10%	--
	Total of 4,4'-DDD, -DDE, -DDT (dissolved)	51%	23%	--	--	--
	Total of 4,4'-DDD, -DDE, -DDT	75%	28%	--	--	--
Phenols	2-Chlorophenol	0%	0%	2%	0%	--
	Pentachlorophenol	2%	0%	2%	0%	2%
Phthalates	Bis(2-ethylhexyl) phthalate	0%	0%	0%	0%	0%
SVOCs	Hexachlorobenzene	--	--	1%	0%	0%
	Hexachlorobutadiene	0.8%	0%	0.8%	0%	--
	Hexachloroethane	1%	0%	2%	0%	--
VOCs	1,1,2,2-Tetrachloroethane	0%	0%	0%	0%	--
	1,1,2-Trichloroethane	0%	0%	0%	0%	--
	1,1-Dichloroethane	0%	0%	--	--	--
	1,2-Dichloroethane	0%	0%	0.4%	0%	--
	1,2-Dichloropropane	0%	0%	0%	0%	--
	Benzene	0%	0%	0.4%	0%	--
	Carbon disulfide	2%	0%	--	--	--
	Carbon tetrachloride	5%	2%	6%	0%	4%
	Chlorobenzene	61%	43%	39%	0%	44%

Table 6-7. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Ground Water.

		Screening Level Parameters Used for Comparisons with Site Data				
				Human Exposure		
		Ecological - Water Quality		Fish Consumption		Water Ingestion
Chemical Class	**Analyte**	**Chronic SLV**	**Acute SLV**	**Fish**	**Fishx10,000**	**MCLx10**
	Chloroform	29%	7%	8%	0%	--
	m,p-Xylene	0%	0%	--	--	--
	Tetrachloroethene	6%	2%	36%	0%	8%
	Toluene	1%	1%	0%	0%	0%
	Trichloroethene	2%	0%	3%	0%	2%

Notes:

-- Stands for either nonexistent SLV value, or for any statistical value which is not available because of a nonexistent SLV value, or for any other value which is not available (e.g. "--" would appear in column 'Maximum Detected Value' or '# Detected Results Exceeding SLV' if there are no detected values throughout the whole dataset).

Compounds that are not labeled as "dissolved" are "total".

DL = Detection Limit

SLV = Screening Level Value

COI - Chemical of Interest

Only result values > SLV have been screened out.

All SLV units are the same as chemical units given in column C.

Column 'SLVs exceeded to define chemical as COI' lists those SLV sets which were exceeded by **a detected result**, or by a non-detected result provided **non-detected results** in ≥ 10 % of all samples are above an SLV.

Data have been screened according to the EE/CA hierarchy, with the exception of the Human Health Fish Consumption SLVs and MCLs (see main text).

No averaging of samples has been performed. Each sample and each replicate sample were screened individually.

Tier Trigger I: at least one detected value exceeds one or more SLVs.

Tier Trigger II: only non-detected results in ≥ 10% of the samples exceed one or more SLVs.

Column 'Sample IDs showing Max Result' can display up to 255 characters. If Sample ID's list forms a longer string, it is truncated to 255 characters.

Acute SLV - See main text for a description of the selected EE/CA acute SLVs.

Chronic SLV - See main text for a description of the selected EE/CA chronic SLVs.

Table 6-7. Summary of COI and the Frequency at which Detected Values Exceed Screening Level Values in Ground Water.

SLV (Fish) - EPA's (2004) NRWQC (organism only; fish consumption @ 17.5 g/day) SLV, or DEQ's (2004) AWQC (organism only; fish consumption @ 17.5 g/day) SLV if the first is not available.
SLV (Fishx10,000) - EPA's (2004) NRWQC (organism only; fish consumption @ 17.5 g/day) SLV, or DEQ's (2004) AWQC (organism only; fish consumption @ 17.5 g/day) SLV if the first is not available x 10,000.

SLV (MCLx10) - Drinking Water MCL SLV x 10.

6.3.5.1 Ecological Aquatic Life Exposure

Samples from the majority of riverbank monitoring wells exceeded the acute screening value for chloride. These stations are located along the top of the riverbank from the Salt Dock in the south to Dock 2 to the north. Perchlorate exceeded the chronic value at 14 locations along the riverbank, but exceeded the acute SLV at one station along the riverbank adjacent to the Salt Dock and two stations near Dock 1 within the river.

Virtually all of the metals exceeded their chronic and acute SLVs in groundwater. Cadmium (dissolved), hexavalent chromium, copper (dissolved), nickel (dissolved and total), and zinc (dissolved) exceeded their SLVs most frequently in 35 to 71 percent of the samples. Total chromium exceeded chronic SLVs in 93 samples and exceeded acute SLVs in 42 samples collected from over 20 locations along the riverbank (see map folio). Hexavalent chromium exceeded the chronic SLV in 48 samples and exceeded the acute SLV in 46 samples collected from 16 locations along the riverbank (M-70).

Pentachlorophenol exceeded the acute value in one groundwater sample collected from a riverbank monitoring well located adjacent to Dock 1. This compound was not included as a chemical analyte in transition-zone water and riverbank and in-river borehole groundwater samples.

DDT, DDD, total-DDx, and gamma-HCH were the only pesticides that exceeded chronic SLVs in more than 5 percent of the samples. Gamma-HCH exceeded chronic, but not acute, SLVs at riverbank locations between Dock 1 and Dock 2. Acute exceedances for DDT, DDD, and total DDx in groundwater collected from the riverbank monitoring wells are also distributed between the Salt Dock and Dock 2. Locations that exceeded the SLVs for DDT, DDD, and total-DDx were distributed shoreward of the 20-ft water depth contour, with the exception of one station located in the river close to the navigation channel off of Dock 1.

MCB exceeded its chronic SLV in 61 percent of the samples and exceeded its acute SLV in 43 percent of the samples. The acute exceedances are generally collocated with elevated DDx concentrations because this VOC represented a DDT-production ingredient. There is also a cluster of MCB chronic screening value exceedances in riverbank borehole station samples collected beyond the river channel line. Another VOC, chloroform, exceeded the acute value in a few samples from riverbank monitoring wells between Docks 1 and 2, as well as stations located just northwest of the Salt Dock. Another cluster of chloroform chronic exceedances occurs around Dock 1. Tetrachloroethene exceeded the acute value in one sample from a riverbank monitoring well closest to Dock 1.

6.3.5.2 Human Exposure via Fish Consumption and Ingestion of Surface Water

Four trace metals (arsenic, manganese, mercury and nickel) exceeded their fish consumption SLVs in groundwater (Table 6-7). Of these, arsenic and manganese were most often detected above their SLVs in 77 to 100 percent of the samples. However, none of the trace metals exceeded the Fish X 10,000 benchmark.

Two PAH compounds (benz[a]anthracene and benzo[a]pyrene) were detected above SLVs in a few samples located along the riverbank between Dock 1 and Dock 2. Neither compound exceeded the Fish X 10,000 benchmark.

Eleven pesticides or aggregate pesticide groups exceeded the fish consumption SLV. However, most were infrequently detected (≤ 5 percent) above their fish consumption SLVs. Pesticides that were detected above their fish consumption SLV in more than 5 percent of the samples were DDD, DDE, DDT, and total-DDx. The Fish X 10,000 benchmark was exceeded for these compounds in a number of samples located principally between Dock 1 and Dock 2 (see map folio, M-1, M-15, M-29, M-43).

The MCL X 10 SLV for ingestion of water was exceeded for three trace metals (chromium, lead, and manganese), one PAH (naphthalene), one SVOC (pentachlorophenol), and four VOCs (carbon tetrachloride, monochlorobenzene, tetrachloroethene, and trichloroethene). Total chromium and manganese exceedances occurred with a relatively high frequency (13 to 40 percent). Monochlorobenzene exceeded its MCL X 10 SLV in 44 percent of the samples located principally between Dock 1 and Dock 2. The three remaining VOCs were above their respective MCL X 10 SLVs in fewer than 10 percent of the samples, which represent stations clustered between Dock 1 and Dock 2.

6.4 TISSUE DATA SUMMARY

The results of the bioaccumulation tissue data of ERA and HHRA species are presented in (Tables D-11 and D-12 of Appendix D) and the locations of these stations are presented in Figure 3-3. Figures included in the map folio present surface sediment and tissue chemistry results for ERA and HHRA target species.

6.4.1 ERA Species

For the ERA species (juvenile Chinook, sculpin, crayfish, and clams), the following COIs were detected in samples along the Arkema waterfront (Table D-11):

- DDx

- Metals (aluminum, chromium, copper, cadmium, lead, manganese, mercury, nickel, silver, and zinc)
- PCB Aroclors and congeners
- PCDD/Fs
- PAHs
- Other chlorinated pesticides and hydrocarbons (e.g., chlordanes, dieldrin, heptachlor epoxide, hexachlorobenzene).

The highest concentrations of DDx in tissue samples were found at station 07R006 located between Docks 1 and 2. This was also the area with the highest concentrations of DDx in sediment. Concentrations of DDx found in sculpin, crayfish, and clam tissue were generally lower at station 07R003 located in the vicinity of the Salt Dock.

Metals concentrations were the highest in crayfish and clam tissue from both site locations. PCB Aroclors were detected in all tissue samples, with the highest levels observed in juvenile Chinook and sculpin (total PCB Aroclors of 430 μg/kg at 07R006).

Clam tissue samples contained the highest PAH concentrations (268 μg/kg at 07R006). PCDD/Fs were only analyzed in the juvenile Chinook (T02) and crayfish and sculpin from station 07R006 with the highest TCDD toxicity equivalent in the sculpin tissue sample. Other chlorinated hydrocarbons and pesticides were detected at low levels in one or more of the samples.

6.4.2 HHRA Species

For the HHRA species (carp fillet/whole body and smallmouth bass whole body), the following COIs were detected in samples thatincluded the Arkema waterfront (Table D-12):

- DDx
- Metals (aluminum, chromium, copper, cadmium, lead, manganese, mercury, nickel, silver, and zinc)
- PCB Aroclors and congeners
- PCDD/Fs
- PAHs
- cis-Chlordane
- Hexachlorobenzene.

The highest concentrations of DDx in tissue samples were found in the smallmouth bass collected from station 07R009. Metals concentrations were the highest in carp tissue from both locations 07R009 and FZ0609. PCB Aroclors were detected in all tissue samples with the highest levels observed in carp fillets from both composite stations (total PCB Aroclors of 1,200 μg/kg).

Smallmouth bass tissue samples contained the highest PAH concentrations (308 μg/kg at 07R006). PCDD/Fs were detected in both smallmouth bass whole body and carp fillets at both composite locations. Hexachlorobenzene and cis-chlordane were detected at low levels in one or more of the samples.

6.5 RAA BOUNDARY

The preliminary RAA boundary presented in the AOC was modified based on the results of the EE/CA screening and distribution of COIs in site media, as shown on maps in the map folio. In general, the revised RAA boundary follows the PEC x 10 contour line delineated for DDx in sediments (refer to Figure 6-1). The proposed RAA includes the following delineation:

- The proposed upstream boundary is delineated along the Salt Dock based on chemical exceedances of PECx10 for DDx in sediments.
- The proposed offshore boundary is the navigation channel line, a physical demarcation from the Arkema site based on water depth and sediment type and chemical exceedances of PEC x 10 for DDx in sediments and acute water quality SLVs for several COIs (i.e., DDx, MCB, perchlorate, chloride, manganese).
- The proposed downstream boundary is located approximately 200 ft downstream from Outfall 4 and is represented by the PEC x 10 contour line delineated for DDD and DDT in surface sediments.
- The designated onshore boundary is the MHW line at an elevation of 12 ft NAVD88 as described in the AOC. Where appropriate, the preliminary RAA may extend to the top of the bank, such as in the area between Docks 1 and 2.

The proposed RAA boundary represents an area of approximately 472,000 ft^2 (~11 acres). A final RAA boundary will be delineated once the RA characterization is completed in support of the EE/CA.

7 REMOVAL ACTION EVALUATION APPROACH

The purpose of the NTCRA for the Arkema site is to conduct a removal action that addresses the principal threat contamination extending from the top of the riverbank on the site into the Willamette River, including unsubmerged and submerged lands. RAOs described in the AOC and presented in Section 2.1 were developed for the Arkema removal action to meet this goal. The purpose of the EE/CA is to analyze the effectiveness, implementability, and cost of remedial alternatives that may satisfy these objectives (USEPA 1993a). The consideration and selection of remedial alternatives will also be dependent upon mandated land use restrictions and potential land use activities. Only the most qualified technologies that apply to the medium or source of contamination will be addressed in the EE/CA. A preliminary list of qualified technologies includes the following:

- *In situ* capping
  - Isolation capping
  - Thin-layer enhancement capping
- Dredging and onsite disposal
  - Nearshore confined disposal facility (CDF) (including in-water sheet pile wall)
- Dredging and offsite disposal
  - Subtitle C/D Landfill
  - Nearshore CDF
  - Confined aquatic disposal (CAD)
- Monitored natural recovery
- Treatment
- A combination of the above.

Source control measures are being designed and implemented to effectively reduce any principal threats and/or the potential for recontamination before or during implementation of the in-water RA. However, hydraulic containment may be required within the upland portions of the site. Construction of a sheet pile wall along the shoreline or in-water, or other hydraulic or *in situ* source control measures will be evaluated in the EE/CA. In addition, upland hydraulic controls will be evaluated to address potential recontamination concerns for these remedial technologies..

The EE/CA will evaluate each of these technologies (and possibly others) against three broad criteria: effectiveness, implementability, and cost. Subcriteria to be evaluated under each broad criterion are generally described in USEPA (1993a) guidance (with specific screening criteria summarized below. After the technologies have been evaluated relative to these criteria and subcriteria, a comparative analysis will be conducted to evaluate and rate the relative performance of each alternative or technology. The result of this comparative analysis is a recommended removal action alterative for the site. A summary of the technologies to be considered in the EE/CA, along with key engineering and design considerations that will be evaluated as part of the screening process, is described in the following sections.

7.1 CAPPING TECHNOLOGIES

Capping technologies involve the placement of a covering or cap over an *in situ* deposit of problem sediment. The cap may be constructed of clean sediments, sand, and gravel, or may involve a more complex design with geotextiles, liners, organoclay, carbon-activated material (e.g., granular activated carbon), or other materials in multiple layers. Capping may be used to enhance natural recovery of the sediments or isolate the contaminated sediments. Capping technogies include:

- **Thin-Layer Placement**—Thin-layer placement (TLP) can be constructed by slowly and gently distributing a thin layer (e.g., 6 to 12 in.) of clean, sandy material on top of existing problem sediments. The design must account for potential bioturbation of the TLP by aquatic organisms, sedimentation, and erosional processes.
- **Isolation**—Isolation caps are typically constructed by placing at least one layer of clean sediment of required thickness over existing problem sediments. As a viable alternative, the design must account for potential bioturbation of the cap by aquatic organisms; consolidation of the capping material and underlying sediment; erosion due to river currents, waves, tides, storms, and vessel propeller scour; operational concerns including placement inaccuracies; and contaminant isolation. The effect of cap placement on slope stability also needs to be evaluated with an isolation cap.

The screening criteria that will be used to evaluate the effectiveness, implementability, and cost of capping technologies for the removal action will include the following:

- **Physical Isolation Component**
  - Strength and compressibility of cap material and underlying problem sediments

  - depth of effective sediment mixing due to bioturbation and/or frequent sediment disturbance

- **Stabilization/Erosion Protection Component (including Operation Conditions)**
  - Stability of sediment slopes to be capped
  - Impacts to water quality during cap placement
  - Engineering controls (e.g., silt curtain, coffer dam) to limit the implementation risk during capping activities
  - The presence of underwater debris
  - Potential interference of the cap with navigation
  - The presence of piers, piles, stormwater pipes, and under-pier areas to be capped
  - Periodic external loads on the cap, including seismic forces, erosion, propeller wash, and ice, as appropriate
- **Chemical Isolation Component**
  - Evaluation of partition coefficients of COIs
  - Migration of dissolved contaminants by diffusion (movement across a concentration gradient) and advection (flow of groundwater or porewater)
  - Sorptive capacity of cap material
  - Hydraulic conductivity of cap materials, underlying problem sediment and clean sediment.
- **Capping Costs.**

Analytical and numerical models are available to predict movement of contaminants into and through caps (USACE 1998; USEPA 1998). These models examine both the short-term transport of chemicals caused by consolidation, and the longer-term transport of chemicals caused by groundwater advection and diffusion processes. The modeling of contaminant transport through a cap will be conducted in preparation of the EE/CA if capping presents itself as a viable remedial technology.

Following this screening, a short list of capping technologies will be developed and will serve as the basis for developing remedial action alternatives. Sediment removal and capping design will be guided by temporal considerations such as whether the remedial action is temporary or permanent. The capping technology screening will also include an assessment of how future dredging may affect the cap if the docks are not removed.

7.2 DREDGING TECHNOLOGIES

Mechanical (land-based or barge-mounted) and hydraulic dredging technologies will be evaluated in portions of the removal action where removal of contaminated sediment may be appropriate. Mechanical dredges apply mechanical forces to dislodge the sediment at or near in-place densities. The most common mechanical dredge consists of a crane, derrick, or excavator, mounted on a floating barge that removes sediment with a clam-shell bucket or similar device (e.g., cable arm environmental bucket). By contrast, the hydraulic cutterhead dredge cuts into the river bed, pumps the sediment through a pipe, and discharges it as a solids and slurry mixture directly to a disposal site. If dredging becomes a preferred alternative, the equipment selected may be determined by considerations such as dredge volume requirements, entrainment of water, sediment resuspension, water quality impacts, equipment availability, and disposal options.

The key engineering and design considerations that will be used to evaluate the effectiveness, implementability, and cost of dredging technologies for the removal action include the following:

- Resuspension of sediment and water quality impacts during dredging (e.g., contaminant release control and containment)
- Dredging accuracy (vertical and horizontal)
- Operating production rate
- Dredging depth
- Volume and characteristics of water generated from dredging operations
- Equipment availability
- Dredging support equipment requirements
- Positioning control and ability to handle underwater obstructions, piers, riprap, and other debris
- Site constraints; slopes, including water depths; underwater pilings (cut piles); and presence of piers
- Engineering controls (e.g., coffer dam, silt curtain) to limit the implementation risk during dredging activities
- Residual sediment management requirements
- Dredge material transport options and disposal locations
- Dredging cost.

Following this screening, a short list of dredging technologies will be developed and will serve as the basis for developing removal action alternatives. Possible water quality impacts will be considered during dredging activities, and appropriate containment and engineering controls will be evaluated in the EE/CA. The modeling of contaminant transport (e.g., DREDGE, SSFATE) during dredging activities will be conducted in preparation of the EE/CA if dredging becomes a viable remedial technology for the site.

7.3 DREDGED MATERIAL HANDLING TECHNOLOGIES

This section presents a summary of the technologies likely to be considered for the handling, treatment, and disposal of dredged sediment.

7.3.1 Dredged Material Transport Technologies

The EE/CA will discuss the various alternatives for dredged material handling and transport and their applicability to the removal action. The first stage of the transport process is to move the dredged material to the disposal, staging, or rehandling site. Sediment may then be transported for dewatering, treatment (of sediment, water, or both), or disposal (USEPA 1994). Transport methods such as pipelines, barges, and transfer to truck and rail will be reviewed in the EE/CA. The key design considerations that will be used to evaluate the effectiveness, implementability, and cost of transport technologies for the removal action may include the following:

- Dredging methods
- Sediment physical properties that may affect sediment handling and pumping characteristics (specific gravity, gradation, water content, plasticity)
- Sediment chemical properties and leaching potential
- Dredged material effluent water quality
- Distance to disposal or temporary handling facilities
- Physical constraints that may preclude transport by barge or pipelines
- Location and availability of truck and train transloading facilities
- Availability of upland area and resources for storage, handling, and processing of dredged material
- Availability of required equipment and contractor expertise.
- Transport cost.

7.3.2 Dredged Material Treatment Technologies

The treatment of contaminated sediment may involve a combination of processes, including pre-treatment, operational treatment, effluent treatment, and residuals handling. Treatment technologies for sediment are generally classified as biological, chemical, extraction or washing, immobilization (solidification/stabilization), and thermal (destruction or desorption). In some cases, particle-size separation is also considered a treatment technology. The key design considerations that will be used to evaluate the treatment technologies may include the following:

- Chemical characterization of proposed dredged sediments (integral to choice of treatment technology)
- Ability of treatment method to effectively destroy site chemicals of concern (or reduce volume of contaminated sediment)
- Ability of treatment method to accommodate the expected variation in chemical and physical properties of site sediments
- Estimated quantity and characteristics of contaminated residuals generated from treatment process (solids, water, air emissions), and associated secondary treatment or disposal requirements
- Demonstrated (full-scale) success of treatment method at similar sites (i.e., similar sediment chemicals, physical, and volume characteristics)
- Permitting requirements
- Treatment cost.

7.3.3 Dredged Material Disposal Options

The range of disposal options considered for the in-water removal action may include upland disposal into an appropriate landfill, disposal in a nearshore CDF (constructed along the Willamette shoreline), and CAD. Each of these technologies will be evaluated for the removal action and may include the following design considerations:

- Requirement for dewatering or stabilization before disposal
- Hazardous waste characterization (TCLP, Oregon Aquatic Toxicity Test)
- Short-term releases (e.g., effluent, surface runoff)
- Long-term releases (e.g., groundwater seepage, water column)
- Availability
- Permitting
- Disposal cost.

Sediments may require treatment before disposal at a CDF. If required, treatment will be considered when assessing disposal at a CDF.

Following this screening, a short list of dredged material handling technologies will be developed to serve as the basis for developing remedial action alternatives.

7.4 MONITORED NATURAL RECOVERY

This technology depends on natural processes (e.g., natural sediment accumulation, mixing, chemical degradation and diffusion, benthic community succession) to achieve RAOs. Long-term monitoring to confirm recovery is an important component of this alternative. The following types of information and conditions will be required to support monitored natural recovery as an effective remedial technology for the site:

- Control of significant ongoing chemical sources
- An understanding of the nature and extent of chemicals at the site
- An understanding of natural processes affecting sediment and chemicals at the site (e.g., sedimentation and erosion processes)
- Evaluation of ongoing risks during the recovery period and exposure source control (period to be determined)
- Monitoring of natural processes, concentrations of chemicals in sediment, and toxicity to biota to determine whether recovery is occurring at the expected rate
- Predicting effects of natural processes in the future.

An important consideration in assessing whether monitored natural recovery is a viable alternative is to show that observed reductions in sediment and biological risks can reasonably be expected to continue into the future. Simple one-dimensional models (e.g., SEDCAM) can be useful tools for predicting these conditions in the future and may be included in evaluating this technology for development of remedial action alternatives. A form of this modeling may be conducted in preparation of the EE/CA for the site.

7.5 HYDRAULIC CONTAINMENT

LSS is currently evaluating the success of several upland IRMs in eliminating or significantly reducing the potential migration of contaminants to the river. If the upland IRMs do not effectively treat or contain contaminated groundwater prior to or during implementation of the sediment remedial actions, other measures such as hydraulic containment (e.g., sheet pile wall) may be required. Accordingly, LSS plans to evaluate

other upland source control technologies and alternatives as part of this EE/CA. For feasibility planning purposes, it is assumed that a containment system would be comprised of a vertical barrier (e.g., sheet pile or slurry wall), and/or pumping and treatment of groundwater to control hydraulic gradients. The following types of information and conditions will be required to evaluate the feasibility of hydraulic containment technologies at the site:

- Likelihood of success of upland IRMs
- Schedule for completion of upland IRMs
- Topography along wall alignment
- Lithology and hydraulic conductivity along proposed barrier wall alignment
- Possible obstructions (e.g. stormwater outfalls, buried structures)
- Sediment/soil physical properties that may affect excavation or pile driving characteristics (e.g., gradation, density, water content, specific gravity, plasticity)
- Nature and extent of contaminated groundwater plume (e.g., area and depth of contaminants to be contained)
- Groundwater chemical properties and leaching potential (hydrogeologic model such as MODFLOW to estimate long-term contaminant releases and to evaluate chemical compatibility with containment wall materials)
- Groundwater flow regime
- Depth and tie-in to basalt
- Bedrock quality (i.e., strength, weathering characteristics)
- Availability of required equipment and contractor expertise
- Potentially applicable hydraulic containment methods (e.g., slurry wall, sheet pile wall, extraction wells/trench)
- Hydraulic containment cost.

8 DATA GAPS AND PROPOSED REMEDIAL ACTION CHARACTERIZATION ACTIVITIES

This section presents the approach in evaluating data gaps for selected removal action technologies and alternatives to meet the RAOs for the Arkema in-water site. The data gap evaluation process begins with a summary of potential removal action technologies and alternatives as described in Section 7, including sampling and analysis "tools," which will be considered in the EE/CA. Specific data gaps are then evaluated based on a review of existing data (Section 3.1) and locations of site concentrations that exceed PTSVs (Section 6) that may pose a principal threat to the environment and human health or pose a threat of recontamination. A preliminary RAA boundary has been proposed based on the SQV evaluation (refer to Section 6.5). Although this supersedes the preliminary RAA boundary as shown in the AOC, the final RAA boundary will be determined later in the EE/CA process.

The following data gap evaluation focuses on the COIs in sediments and riverbank soils in order to define the principal threat boundary. In addition, surface water, transition-zone water, and groundwater will also be evaluated in order to evaluate the potential that these media have to recontaminate sediments in riverbank soils post removal action. In general, the following data gaps have been identified within the preliminary RAA boundary for the site:

- **Sediment Chemical Quality Characteristics**—Additional evaluation is required over a large area offshore of the Arkema property from upstream of the Salt Dock to downstream of Dock 2, including immediately offshore of Lots 1 and 2.
- **Water Quality Characteristics**—Additional sampling and testing of transition-zone water and groundwater are required to provide baseline information on water quality characteristics within and surrounding the preliminary RAA boundary.
- **Tissue Bioaccumulation Data**—Additional sampling and testing of selected in-water species are required to provide baseline information in support of ERA and HHRA characteristics within and surrounding the preliminary RAA boundary.
- **Sediment Physical and Engineering Characteristics**—Additional evaluation is required for the in-water portion of the site located within and surrounding the preliminary RAA boundary.
- **Water Quality/Chemical Mobility Testing**—Evaluation is required of in-water areas that could be dredged such as between Dock 1 and Dock 2.

A summary of proposed characterization activities to fill data gaps identified for the site is also provided in this section. The additional characterization of the site is planned before completion of the EE/CA. Detail descriptions of proposed sampling and analytical testing procedures are presented in the accompanying SAP and QAPP, respectively.

8.1 DATA GAPS

8.1.1 Removal Action Technologies and Alternatives

Removal action technologies and alternatives will be evaluated to address the RAOs listed in Section 2.1. Only the most suitable technologies that apply to the medium or source of contamination will be considered for the development, comparative evaluation, and selection of removal action technologies and alternatives (USEPA 1993a). Table 8-1 presents the sampling and analysis tools that will be considered for each potential remedial action technology for the site. Table 8-2 presents the sampling and analysis tools that may be considered for each potential disposal alternative but initiated by the owner of each site (e.g., Port of Portland's Terminal 4 CDF). A checkmark indicates sufficient data are available and no additional data are needed for the sampling or analysis tool. An "X" indicates that insufficient data are available and additional data are needed for the sampling or analysis tool.

These tools are discussed in more detail in the following sections and the accompanying FSP and QAPP. Details on specific data quality objectives for the EE/CA are also presented in the accompanying QAPP.

Table 8-1. Sampling/Analysis Tools – Potential Remedial Action Technologies.[a]

Sampling/Analysis Tools	Monitored Natural Recovery	Thin-Layer Placement	Isolation Cap	Sediment Dredging/Disposal – Characterization	Hydraulic Containment
Sediment Surface Grab Samples					
Chemical Analyses (COIs, Conventionals[b])	X	X	X	X	--
Physical Analyses (grain size)	X	X	X	X	--
Bioassays	X	X	X	X	--
Sediment Borings (In-Water and Bank)					
Chemical Analyses (COIs, TOC)	--	--	X	X	--
Geotechnical Analyses					
Grain Size	--	--	X	X	X
Standard Penetration Test	--	--	X	X	X
Atterberg Limits	--	--	X	X	X
Specific Gravity	--	--	X	X	X
Moisture/Bulk Density	--	--	X	X	X
Consolidation	--	--	X	X	X
Shear Strength[c]	--	--	X	X	X
Water Quality					
DRET[d]	--	--	X	X	--
EET[d]	--	--	--	X	--
SBLT[d]	--	--	--	X	--
TCLP[d]	--	--	--	X	--
Oregon ATT[e]	--	--	--	X	--
Column Settling	--	--	--	X	--
Tissue Sampling (Baseline and Recontamination Evaluations)					
Chemical Analyses	X	X	X	X	X
Conventional Analyses (e.g., lipid content)	X	X	X	X	X
Surface Water Sampling (Baseline and Recontamination Evaluations)					
Chemical Analyses	✓	✓	✓	✓	✓

Table 8-1. Sampling/Analysis Tools – Potential Remedial Action Technologies.[a]

Sampling/Analysis Tools	Monitored Natural Recovery	Thin-Layer Placement	Isolation Cap	Sediment Dredging/Disposal – Characterization	Hydraulic Containment
Conventional Analyses (TOC, Anions/Cations)	✓	✓	✓	✓	✓
Surface Water Sampling (Water Quality Testing Related to Dredging and Disposal)					
Chemical Analyses	--	--	--	X	--
Conventional Analyses (TOC, Anions/Cations)	--	--	--	X	--
TZW Sampling (Baseline and Recontamination Evaluations)					
Seepage Velocity	✓	✓	✓	✓	✓
Chemical Analyses	X	X	X	X	X
Conventional Analyses (TOC, Anions/Cations)	X	X	X	X	X
Groundwater Sampling (Baseline and Recontamination Evaluations)					
Seepage Velocity	✓	✓	✓	✓	✓
Chemical Analyses	X	X	X	X	X
Conventional Analyses (TOC, Anions/Cations)	✓	✓	✓	✓	✓
Stormwater Sampling (Baseline and Recontamination Evaluations)					
Flow Rates	✓	✓	✓	✓	✓
Chemical Analyses (COIs)	✓	✓	✓	✓	✓
Bathymetry/Topography	✓	✓	✓	✓	✓
Sedimentation Rates[†]	✓	✓	✓	✓	✓
Erosion/Stability Analysis					
Willamette River	X	X	X	X	X
Prop Wash	X	X	X	X	X
Bank/slope	--	--	X	X	X
Seismic	--	--	X	X	X

Notes:
✓ Sufficient data are available and no additional data and evaluation are needed for the sampling or analysis tool.
X Insufficient data are available and additional data and evaluation are needed for the sampling or analysis tool.
-- Data not required for the EE/CA.

Table 8-1. Sampling/Analysis Tools – Potential Remedial Action Technologies.[a]

[a] Once the final principal threat boundary is established, several factors pertaining to the area will be examined in the EE/CA report, including constructability, short-term impact, recontamination potential, permanence of the removal action, and proposed institutional controls to further assess the RAA boundary and final selection of remedial action(s).
[b] Conventional analytes for bioassays include total solids, total sulfides, ammonia and TOC.
[c] May include *in situ* vane shear, cone penetrometer testing, and/or laboratory shear strength testing.
[d] Suite of conventional and chemical analyses including anions/cations, TOC, COIs.
[e] The Aquatic Toxicity Test (ATT) is required by Oregon for all pesticide wastes in determining its acceptability into a Subtitle D Landfill.
[f] Tools for evaluating sedimentation analyses include radioisotope dating, sedimentation stakes, sediment traps, comparison of bathymetry surveys, and hydrodynamic modeling.

Table 8-2. Sampling/Analysis Methods – Potential Disposal Alternatives[a,b]

Sampling/Analysis Tools	Onsite Disposal	Offsite Disposal	
	Nearshore CDF	Nearshore CDF (Terminal 4)	Subtitle C/D Landfill
Sediment/Soil Borings			
Chemical Analyses (COIs, TOC)	X	[c]	X
Index Parameters			
Grain Size	X	[b]	X
SPT	X	[c]	X
Atterberg Limits	X	[c]	X
Specific Gravity	X	[c]	X
Moisture/Bulk Density	X	[c]	X
Geotechnical			
Consolidation	X	[c]	--
Shear Strength[d]	X	[c]	--
Permeability	X	[c]	--
Groundwater Sampling			
Seepage Velocity	✓	[c]	--
Chemical Analyses (COIs)	✓	[c]	--
Conventional Analyses (TOC, Anions/Cations)	✓	[c]	--
Bathymetry/Topography	✓	[c]	--
Sedimentation Rates[e]	✓	[c]	--
Erosion/Stability Analysis			
Willamette River	X	[c]	--
Prop Wash	X	[c]	--
Bank/slope	X	[c]	--
Seismic	X	[c]	--

Notes:

✓ Adequate data available for this sampling/analysis tool.

X Additional data required for this sampling/analysis tool.

\- Data not required for the EE/CA.

[a] Once the final principal threat boundary is established, several factors pertaining to the area will be examined in the EE/CA report including constructability, short-term impact, recontamination potential, permanence of the removal action, and proposed institutional controls to further assess the RAA boundary and final selection of remedial action(s).

[b] Chemical analyses that include an evaluation of the leachability of sediment will be conducted on representative composite samples prior to disposal.

[c] Arkema assumes sampling and analysis requirements will be available for the Terminal 4 or other offsite nearshore CDF.

[d] Includes *in situ* vane shear, cone penetrometer testing, and/or laboratory shear strength testing.

[e] Tools for evaluating sedimentation analyses include radioisotope dating, sedimentation stakes, sediment traps, comparison of bathymetry surveys, and hydrodynamic modeling.

8.1.2 History, Cultural Resources, and Land Use

There are no data gaps that have been identified with respect to historical site operations. The Arkema site operational history is sufficiently understood to evaluate for purposes of the EE/CA how operations have influenced the nature and extent of contamination within the current RAA boundary. No additional data collection regarding the history of the Arkema site is proposed, but if additional data become available, the data will be incorporated into the overall data set.

LSS will conduct a follow-up study on the designation of archaeological probability areas detailed in the *Cultural Resource Analysis Report for the Portland Harbor Superfund Site*, prepared by Archaeological Investigations Northwest, Inc. (AINW 2005) in conjunction with the participating tribes pursuant to the Administrative Order on Consent for the Portland Harbor Superfund Site RI/FS, U.S. EPA Order No. CERCLA 10-2001-0240, effective September 28, 2001 (as amended) (RI/FS AOC). LSS proposes that David Ellis of AINW conduct a records review and a site reconnaissance survey of the Arkema RAA to determine if there are any native soil exposures or physical evidence of archaeological or historical resources. AINW will prepare a technical memorandum that presents the results of its inquiry. If archaeological or historical resources are identified or considered likely within the RAA, the technical memorandum will include recommendations for further actions to comply with relevant state and federal requirements.

No data gaps exist in the understanding of current land uses. Currently, the site is inactive, except for ongoing upland remediation operations. Future land uses at the Arkema site will remain heavy industrial. River-based access could remain a component of any future use.

8.1.3 Hydrodynamic Characteristics of the River

Recent studies for the Portland Harbor RI/FS have evaluated bathymetry, erosion and deposition rates, and other hydrodynamic conditions within all or portions of the Arkema in-water site (see Section 3.2).

Bathymetric surveys that cover most of the Arkema in-water site were performed for the Portland Harbor RI in 1999, 2002, 2003 and 2004. These surveys were used to generate bathymetric surface base maps of the Willamette River (LWG 2004). The current information for the site is adequate to evaluate the feasibility of remedial alternatives (i.e., capping, dredging, hydraulic containment) as part of the EE/CA. A more detailed bathymetric survey of the in-water portions of the site and a topographic survey of the banks may be required in support of the remedial design.

Sedimentation rates have been determined by various methods in the vicinity of the site, including bathymetry difference maps, hydrodynamic modeling, and sediment stakes (refer to Section 3.2). These data and the requirement for periodic dredging indicate that over long time frames there is net deposition of sediments to most areas of the Arkema in-water site. Because of the short-term fluctuations in accretion versus deposition at the site and the short duration of the Portland Harbor sedimentation studies, there is some uncertainty in the actual long-term sedimentation rate for the site. However, the sediment stake data, which were collected downstream of Dock 2, indicate a predicted sedimentation rate of 3 to 5 cm per year. This current Portland Harbor information and data from sediment traps planned for three locations in the vicinity of the Arkema waterfront (upstream, within Docks 1 and 2, and downstream near the railroad bridge[24]) will be adequate to support the EE/CA.

8.1.4 Nature and Extent of Contamination and Human Health and Ecological Risk Characteristics

A "multiple lines of evidence" approach will be used to define the final RAA sediment boundary. The multiple lines of evidence approach includes comparisons to sediment screening values (as described in Section 6), sediment bioaccumulation, and toxicity[25]. Comparisons will be made to existing data compiled from historical sediment studies at the site and to additional data collected as identified in the data gap analysis. Extensive sediment, soil, surface water, transition-zone water, groundwater, tissue, and stormwater sampling has been completed over portions of the site, especially between Docks 1 and 2 (Figure 3-1 to Figure 3-5). However, additional sediment and water quality data, and tissue data are required to complete the EE/CA for the site. The following sections describe the data gaps for each data set that support the evaluation of nature and extent of contamination at the site and human health and ecological risk characteristics.

8.1.4.1 Sediment Quality Characteristics

Extensive surface and subsurface sediment quality data have been collected within the central waterfront area of the Arkema site. However, additional data are required for the following areas (beginning upstream of the Arkema site) to complete the EE/CA (see Figures 3-1 and 3-2):

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[24] LSS has proposed additional sediment traps along the Arkema waterfront to support the EE/CA. This information will be used to provide additional information on sedimentation rates in the area of the site and baseline information on source control. Sediment traps are planned for deployment by the LWG in later summer or early fall 2006 (refer to Section 8.1.9).

[25] The multiple lines approach focuses on COIs in sediments to define the boundary of the principal threat area.

- Surface (0 to 1 ft)[26] sediment chemistry and bioassay[27] data to address ecological risk in nearshore sediments associated with groundwater transport of chloride. The areas offshore of the salt pads and in the vicinity of the Salt Dock require additional evaluation.
- Surface sediment chemistry and bioassay data to further evaluate ecological and human health characteristics in nearshore sediments associated with groundwater transport of chromium. The areas requiring additional evaluation includes the area between the Salt Dock and Dock 1 and immediately offshore of these docks.
- Surface sediment chemistry and bioassay data to further evaluate ecological and human health characteristics in nearshore sediments associated with groundwater transport of perchlorate. Additional sampling and testing is required between the Salt Dock and Dock 1.
- Surface sediment chemistry and bioassay data to further evaluate ecological and human health characteristics in nearshore sediments associated with sediment DDx and MCB concentrations. Additional sampling and testing is required offshore of Docks 1 and 2 and downstream of Dock 2.
- Subsurface sediment borings to further delineate the extent of total chromium and perchlorate in sediments between the Salt Dock and Dock 1, specifically near Station C366 (see Figure 3-2).
- Subsurface sediment borings to further delineate the extent of DDx and MCB contamination in sediments for the following areas:
  - Dock 1—Upstream in the vicinity of stations C359 and WB-23 and along the dock face near station C356. The additional borings will be used to further delineate the upstream RAA boundary for DDx and MCB in sediments (Figure 3-2).
  - Between Docks 1 and 2—The area closer to Dock 2 to further delineate the depth of DDx near stations WB-13 and WB-14 (Figure 3-2).
  - Downstream of Dock 2 in the vicinity of Stations C348, SD84, SD83, and SD80—The additional borings will be used to further delineate the nature and extent of DDx and MCB in sediments (Figures 3-2).
- Surface and subsurface sediment borings for the analysis of PCDD/Fs in sediments in the vicinity of Docks 1 and 2.

[26] Surface sediments are defined for the Portland Harbor Superfund Site as 0–1 ft. For consistency, Arkema has defined surface sediments at the same depth.

[27] Sediment bioassays may be tested concurrently with chemical analyses or required based on chemicals above SQVs (tiered approach).

Riverbank surface soil samples are planned for late summer 2006 in support of the upland ecological risk assessment (Integral 2006i, refer to Section 3.1.27). This information should fill a data gap for riverbank soils along the Arkema waterfront.

8.1.4.2 Water Quality Characteristics

Surface water, transition-zone water, and groundwater sampling has been conducted within the in-water portion of the Arkema site. Extensive groundwater sampling and testing is ongoing in support of the upland remedial measures (ERM 2001a, b; 2002; 2003; 2004a,b,c; 2005c, 2005b,c; ATOFINA 2003). However, additional water quality data are required to provide a baseline for transition-zone water within and outside the preliminary RAA boundary; in particular, upstream and offshore of Dock 1 and the Salt Dock and downstream of Dock 2. There are data gaps in the nature and extent of several COIs (e.g., chloride, perchlorate, DDx, MCB, manganese, zinc) that exceeded acute SLVs in one or more TZW samples collected previously from these areas of the site. There is also a lack of PCDD/Fs data for transition-zone water and groundwater in upland wells. Specifically, the following data are required for the following areas to complete the EE/CA:

- TZW samples upstream of the Salt Dock to evaluate the nature and extent of chloride in sediments
- Extension of four transects offshore of the Salt Dock and Dock 1 for transition-zone water to further evaluate the extent of COIs (e.g., chloride, perchlorate, manganese, zinc, MCB, and DDx) in near-surface groundwater in this area of the site
- Extension of one transect offshore of Dock 2 for transition-zone water to further evaluate the extent of COIs (e.g., DDx, MCB, perchlorate, chloride) in this area of the site
- TZW samples downstream of Dock 2 to further evaluate the extent of COIs
- Groundwater sampling of upland wells (MWA-2, MWA-4, MWA-6r, MWA-15R, MWA-30, MWA-46, MWA-63, MWA-67si, MWA16i, and MWA-32i) for the analysis of COIs, including PCDD/Fs.

8.1.4.3 Tissue Bioaccumulation Data

ERA Target Species

Bioaccumulation tissue data for sculpin, crayfish, clams, and out-migrating juvenile Chinook were available from the Portland Harbor study and included in the Arkema database. Sculpin, crayfish, and clam samples were collected during the Round 1 site characterization in 2001. The juvenile Chinook sampling effort in 2006 was intended to

supplement data related to potential exposure of juvenile Chinook salmon to COIs in the Portland Harbor area. The existing bioaccumulation data for juvenile Chinook, a migratory species, provides adequate baseline data with respect to the Arkema facility. Juvenile Chinook salmon forage in the water column and occur transiently in the area for a short time during their migration to the sea. However, there is a data gap in the available tissue data collected for sculpin and crayfish[28]. These species have restricted or localized home ranges, and dwell and forage on the bottom. Additional tissue data to support baseline conditions are required between the Salt Dock and Dock 1, and downstream of Dock 2.

HHRA Target Species

USEPA (2000c) provides guidance for identification of fishing sites that may be contaminated and may present a risk to human health. To characterize potential chemical bioaccumulation by fish or shellfish, USEPA (2000c) recommends sampling and analysis of one bottom feeder and one predator target fish species. At the Arkema site, bioaccumulation tissue data exist on three HHRA target species: smallmouth bass, carp, and crayfish. This data set includes the minimum of two trophic levels of fish recommended by USEPA (2000c). Smallmouth bass are a predator (trophic level IV species) and carp are a bottom feeder (trophic level II species) (FishBase 2006). Crayfish are omnivorous scavengers that forage on detritus, plant matter, and animals including other crayfish.

Tissue data representing predator and bottom feeder as well as a scavenger allow for adequate characterization of bioaccumulation in fish and shellfish at multiple trophic levels. Collection of replicate composite samples of each target species, as conducted for the Portland Harbor Round I field effort, is one of three preferred sample collection options recommended by USEPA (2000c) for human health screening of potentially contaminated fishing sites. Because multiple composite samples collected in the vicinity of the Arkema site are available for each target species, variability in tissue concentrations and resulting health risks can be evaluated.

The composite sampling strategy for smallmouth bass and carp included fish from the site as well as fish from other nearby locations, which is assumed to be consistent with typical fishing practices. Fishers off the Arkema site are likely to catch fish from a wide area,

[28] Although clams were collected at the Arkema site in 2001, this target species for the ecological risk assessment was not found in great enough numbers at many Portland Harbor stations locations. Consequently, the freshwater clam is not currently considered a target species for river-wide study and therefore not considered for further evaluation at the Arkema site.

rather than limit themselves to fishing within the facility boundary. This sampling strategy is adequate for baseline characterization at the Arkema site.

Additional collection of fish adjacent to the Arkema facility will not be necessary partly because the home ranges of carp and smallmouth bass are larger than the waterfront area represented by the Arkema facility boundaries on the Willamette River and also because existing bioaccumulation data provide adequate information on tissue concentrations of these target species at the site. In addition, adequate representation of extremes in bioaccumulation exists (scavenger, bottom feeder, and predator) as well as replicate samples for evaluation of variability in tissue concentrations.

As discussed above, tissue data for crayfish between the Salt Dock and Dock 1, and downstream of Dock 2, are not available. Samples collected from these areas will complete the characterization of the Arkema shoreline for potential consumption of crayfish by humans.

8.1.4.4 Stormwater Data

Stormwater data collected from Outfalls 1–4 in 2004/2005 provide a reasonable baseline for understanding the levels of COIs and flow from stormwater discharges offsite (Integral 2006j). With the proposed additional sampling of the outfalls and catch basins in the fall of 2006, and the proposed analysis of COIs, no data gaps have been identified for this pathway (also refer to Section 8.1.9 on recontamination evaluation).

8.1.5 Sediment Physical and Engineering Characteristics

A suite of physical tests is proposed to evaluate sediment properties pertinent to dredging and capping technologies, dredged material transport and placement, dredged material behavior in a disposal site, potential short-term impacts at the dredge and disposal sites, capacity of existing sediments to provide foundation support for capping material, and the viability of sheet pile wall construction or other technology for nearshore containment (refer to Table 8-1 and 8-2). The following tests will be required to evaluate these technologies.

8.1.5.1 Index Parameters

Grain Size

Grain size provides information on site geologic character and engineering properties of sediment proposed for capping or dredging. Sediment grain-size information is available for most surface sediments previously collected from the site. However, there is limited quantitative grain-size data available for the subsurface sediments within the preliminary RAA boundary.

Atterberg Limits

Atterberg limits, which include the liquid limit, plastic limit, and the plasticity index, are used to define plasticity characteristics of cohesive sediments and are a useful index parameter for sediment strength correlations. There are only limited data available on Atterberg limits from historical studies within the current RAA boundary. Selected fine-grained surface and subsurface sediments collected for grain size will also be analyzed for Atterberg limits.

Specific Gravity

The specific gravity of sediment samples is used to determine the dispersal and settling characteristics of the sediment during dredging and disposal. Limited data are available for specific gravity in sediments between the docks and nearshore (Portland Harbor RI sampling locations only). There are also limited data available for upland soils.

Moisture/Bulk Density

Moisture content is used to determine the initial *in situ* void ratio of the sediment and to estimate the short-term bulking (or increase in volume) during dredging activities, and for correlation with other geotechnical parameters. There have been no direct measurements in site sediments for moisture content or bulk density. Selected samples will be analyzed in support of the remedial alternative selection.

8.1.5.2 Evaluation of Cap Integrity

Cap design involves the evaluation of long-term stability and integrity based upon physical and chemical parameters expected at the site. Parameters to evaluate in the design of a cap include chemical isolation, cap thickness, cap materials, cap armoring, strength of underlying sediments, bioturbation, cap erosion and scour, vessel prop wash, slope stability, and settlement/consolidation (USACE 1998; USEPA 1998). The tests required to support a cap design are described below. None of these tests has been conducted previously on in-water site sediments.

Shear Testing

In situ and laboratory shear tests are used to determine bearing capacity and slope stability design parameters for cap placement (Holtz and Kovacs 1981). *In situ* shear testing can be evaluated either by vane shear or cone penetrometer. Both *in situ* tests can be performed from a barge during drilling operations (i.e., collocated with sediment quality testing). The cone penetrometer is preferred over the vane shear in cohesionless sediments, most likely found at the Arkema site. The laboratory shear testing is used to evaluate foundation capacity of a cap and for dredge equipment selection and production rates. Short-term critical loading may occur immediately following cap placement, and also can occur as a result of seismic activities. The appropriate shear test to model short-term critical loads is the unconsolidated, undrained (UU) triaxial shear test. Long-term

critical loading is best modeled by the consolidated, undrained (CU) triaxial test with pore pressure measurements.

Consolidation Testing

Consolidation tests are performed to determine the potential consolidation of sediment deposits under loading conditions associated with capping materials. An understanding of the consolidation of underlying sediment is important in evaluating the effective (or minimum) thickness of a cap (USACE 1998). The effective thickness of a cap is reduced by the consolidation in the underlying sediment. Standard vertical loads are reduced to include the equivalent varied thickness of a cap (modified EM-1110-2-5027 for lower loads).

8.1.6 Water Quality/Chemical Mobility Testing during Dredging and Disposal

None of these tests has been conducted previously on in-water site sediments. Representative sediment from areas that could be dredged will be collected for this testing (refer to Table 8-1).

8.1.6.1 Elutriate Testing

Elutriate testing is required on representative dredged material to provide an assessment of contaminant mobility during dredging and disposal operations. The dredging elutriate test (DRET) and effluent elutriate test (EET) are used to predict the potential short-term contaminant release. The tests are generally conducted in accordance with USACE Engineering Research and Development Center (ERDC)-recommended procedures (USACE 2003; USEPA/USACE 1998; DiGiano et al. 1995; Palermo 1986).

Dredging Elutriate Test

The DRET method is commonly used for examining potential short-term impacts at the point of dredging or capping. The results of the DRET are compared to water quality SLVs, and any chemicals exceeding the SLVs are carried forward and modeled (i.e., DREDGE and SSFATE) to predict the concentrations and subsequent impacts of these chemicals over a wider area surrounding the dredging or capping operations.

Recently, the use of the DRET and subsequent modeling were called into question based on the results from a recent dredging project for NW Natural's Gasco site on the Willamette River (Anchor 2006). For this particular project, dredging of a tar body in the nearshore surface sediments was required by EPA as part of a time-critical removal action. Prior to dredging, the DRET was conducted and a simple analytical model developed by Kuo and Hayes (1991) was used to predict the distribution of chemicals in the water column at varying distances from the dredging operations. Specifically, the Kuo and Hayes model predicts the suspended sediment concentrations at varying

distances. Using simple mass balance equations, the suspended sediment concentrations from the Kuo and Hayes model and chemical concentrations observed in the bulk sediments (from the DRET) were used to predict the concentrations present in the water column during dredging. These additional calculations are similar to the mass calculations contained in the USACE's DREDGE model (Hayes and Je 2000), also developed by Dr. Don Hayes. Although the models are similar, the Kuo and Hayes model allows for the incorporation of more site-specific characteristics, in addition to the DRET results, in the evaluation of contaminant transport in the water column during dredging operations.

DRET results for sediments from the Gasco site exceeded water quality values for several chemicals (Anchor 2006). Although the resulting modeling analysis predicted no water quality exceedances at distances greater than 300 ft from the dredge area, several water quality exceedances did occur throughout the dredging operations at the Gasco site, despite the use of environmental controls (i.e., outer bed load baffle curtain, inner silt curtain, and multiple layers of sorbent oil booms throughout). Reportedly, several openings in the silt curtain were observed during operations. There are several factors that contributed to the inability of the DRET/Kuo and Hayes model analyses being predictive of water column concentrations during dredging of the Gasco site. These factors are described in detail in the *Final Removal Action Completion Report – NW Natural "Gasco" Site Removal Action* (Anchor 2006) and are summarized below:

- Bulk sediment used for DRET was not representative of the wide range of tar consistency observed in the field and dredged from the site.
- The standard sampling and modeling tools applied were not designed for "free-product" levels of contaminants, which were found within the tar body.
- Environmental control measures may have been compromised by the use of a "bubble curtain" to deter fish from entering the dredge area.
- Environmental control measures may not have been adequate.

Considering the water quality impacts at the Gasco site, the DRET, combined with an appropriate model, can still be a useful and appropriate tool for predicting chemical concentrations in the water column as a result of dredging or capping operations at the Arkema site. First, sediments proposed for dredging or capping nearshore of the Arkema site do not contain "free-product," such as LNAPL or DNAPL, that would significantly change the physical nature of the sediment matrix and how it behaves when disturbed. DNAPL has been observed in portions of the upland Arkema site, but not within the in-water area. In addition, environmental controls such as a silt curtain may not be effective for dredging operations in a river system. Other environmental controls (e.g., sheet pile wall) will be considered in limiting contaminant movement during these operations.

Effluent Elutriate Test

The EET is used to predict the quality of effluent from the filling of an upland or nearshore CDF or dewatering facility using hydraulic dredging. A combination of the EET and modeling (e.g., EFQUAL, EFFLUENT) will be conducted to predict the quality of effluent from various disposal sites.

8.1.6.2 Column Settling Test

The column settling test is used to model the settling behavior of sediments (USACE 1993). The objective of the test is to predict the gravity settling rate and behavior of dredged material upon placement into a nearshore CDF disposal site. Results of the testing are used to select an appropriate placement method, predict potential water quality effects in or near the disposal area, and design the disposal site area.

8.1.7 Potential Leaching to Groundwater (Nearshore CDF, Landfill, or CAD Site)

The sequential batch leaching test (SBLT) is used to evaluate possible leachate quality from dredged materials placed in a nearshore or upland CDF. It is recommended that upland groundwater be used to run the SBLT, preferably groundwater located upgradient of the proposed disposal site. Alternatively, distilled water can be used. The design recommendations for the SBLT apparatus are described by Myers et al. (1992) and Brannon et al. (1994).

The toxicity characteristic leaching procedure (TCLP) test is used to evaluate possible leachate quality when dredged sediments are disposed of into a landfill. Other evaluation criteria may include hazardous waste determination, data on the generation and loss of free liquid, and other landfill-specific acceptance criteria.

Oregon requires the Aquatic Toxicity Test (ATT) for wastes containing pesticide active ingredients listed in 40 CFR 261.33(e) and (f). A representative sample must exhibit a 96-hour aquatic toxicity LC50 equal to or less than 250 mg/L to be acceptable in a state Subtitle D Landfill (OAR 340-109-0001).

8.1.8 Hydrogeologic Characteristics

Groundwater characteristics have been evaluated for site upland soils and in-water sediments including the transition zone between sediments and overlying water (Integral 2004a, 2005d). Upland groundwater zones and their characteristics (including hydraulic gradient and conductivity measurements) are summarized in Section 3.2.2.3. Transition zone groundwater seepage rates were measured as part of the recent Portland Harbor RI groundwater study, as described in Section 3.2.2.1. The information from these studies will be used in calculations and modeling to estimate long-term contaminant release or

loss associated with placement of an isolation cap and to assist in the evaluation of hydraulic containment technologies. An understanding of groundwater advection in the sediments is important in evaluating the effective (or minimum) thickness of a cap. This information will also be beneficial in evaluating hydraulic containment alternatives for the site, if necessary.

Data gaps have been identified for evaluating the nature and extent of COIs in transition-zone water and groundwater at the Arkema site (see Section 8.1.4.2). Additional information is also needed to understand the depth to basalt within the in-water portion of the site (see Section 8.1.4.1). No other hydrogeologic data are required in support of the EE/CA.

8.1.9 Recontamination Source Characterization

Secondary sources of COIs to the sediments include groundwater and stormwater discharges from the upland portion of the site. An important aspect of identifying the effectiveness of source control measures is establishing a sufficient baseline with which to compare future monitoring activities. This section explores whether sufficient data exist for establishing site baseline conditions, identifying data gaps, and how to address those gaps.

Upland source control actions are being conducted and scheduled for completion during 2009, before implementation of the in-water removal action. Groundwater monitoring will continue in order to verify the effectiveness of the planned upland treatments. In addition to the upland groundwater monitoring, the Portland Harbor groundwater site work and monitoring during the Stage 1 and 2 investigations provide a sufficient baseline for most COIs in groundwater from the Arkema site (refer to Section 8.1.4.2). However, there is a lack of PCDD/F data for site groundwater to evaluate adequate baseline conditions. Groundwater wells along the shore will be sampled to provide baseline information on PCDD/F concentrations (Section 8.1.4.2).

In addition to the upland groundwater monitoring, additional transition-zone water sampling is required for COIs that sorb onto sediments (i.e., DDx, trivalent chromium). While several TZW samples have been collected along the shoreline as part of the Portland Harbor study (Integral 2006b), several areas have been identified where additional data would be useful in establishing baseline conditions for the site. Specifically, new sampling transects will be added upstream of the Salt Dock and downstream of Dock 2. In addition, stations will be added along selected pre-existing transects offshore toward the navigation channel, in order to better define the outer boundary of site-related impacts to TZW. Samples collected from the new baseline locations would be analyzed for the full suite of COIs, including PCDD/Fs on selected samples. The details of the monitoring are summarized in Section 8.2 with more detail

presented in the accompanying FSP. The proposed sample collection method is the Trident Probe which has been shown to be one of the most reliable and effective methods in measuring transition-zone water (Integral 2005d).

Surface water has been collected from three stations in the vicinity of the Arkema site (refer to Section 3.1.23). Samples were collected by standard peristaltic and high-volume methods. Surface water will also be collected from these locations as part of the proposed Round 3 Portland Harbor work (refer to Section 3.1.24)[29]. The combination of data provides an adequate baseline of surface water quality conditions at the Arkema site.

Stormwater discharges from the site have been controlled by removal of contaminated soils and placement of permanent and/or temporary soil cover systems (see Section 4.1.5). In 2004/2005, Arkema collected and analyzed representative stormwater samples from Outfalls 001 through 004. Additional stormwater and catch basin sediment sampling are planned for the site to provide further information on the effectiveness of the upland surface soil control measures and to monitor potential COIs entering the Willamette River through the stormwater discharge points (Outfalls 001–004). The 2004/2005 data and the planned 2006 sampling effort is considered adequate baseline information on stormwater discharges to evaluate recontamination potential at the site.

Sediment traps are proposed to evaluate recontamination potential for three locations along the Arkema waterfront in support of the Portland Harbor FS (refer to Section 8.1.3)[30]. The traps will be deployed in late summer to early fall 2006. The results of this study will provide adequate baseline information for the Arkema site.

A riverbank seep survey was conducted by GSI for the Portland Harbor study and included the Arkema waterfront (refer to Section 3.1). Seeps were not observed along the Arkema shoreline. However, seep reconnaissances should be conducted during any future proposed field activities in support of the RA characterization. If active seeps are observed, sampling may be required in support of the EE/CA.

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[29] The actual locations of the surface water samples have not been determined as of this writing. LSS, as a participating member of the LWG, has recommended additional surface water collection events at stations W015, W016, and W017. Samples will be collected using the high-volume method and analyzed for COIs.

[30] The actual locations of sediment traps have not been determined as of this writing. LSS has recommended sediment traps be positioned at locations upstream of the Salt Dock, between Dock 1 and 2, and downstream of Dock 2 near the railroad bridge.

8.2 REMOVAL ACTION CHARACTERIZATION ACTIVITIES

This section provides the rationale for additional removal characterization activities proposed for the Arkema site before completion of the EE/CA.

8.2.1 Nature and Extent of Contamination

This section presents the sampling design and rationale for supplementary evaluation of sediment and water quality characteristics at the Arkema site. Additional information on sediment and water quality characteristics is required to evaluate the nature and extent of contamination within and outside the preliminary RAA boundary and to support the ecological and human health risk screening. These additional data will be used to delineate the final RAA boundary in the EE/CA and provide necessary information in support of achieving RAOs 1-5.

8.2.1.1 Sediment Quality Characteristics

Rationale

The primary goal of sediment sampling is to define the vertical and lateral extent of COIs that exceed the principal threat level, and to further define the final RAA boundary and associated removal action subareas[31]. The sampling pattern will focus on refining sediment COIs boundaries that could be considered principal threats in areas identified in previous investigations (e.g., Arkema's Stage 1 and 2 studies and Portland Harbor RI studies). As described in Section 8.1, additional sediment borings are required upstream of and near Dock 1, and upstream and downstream of Dock 2.

Sampling Strategy

A total of 33 borings will be drilled to basalt (or refusal) to evaluate the extent of COI contamination within the preliminary RAA boundary. The borings will be positioned in the following locations (see Figure 8-1):

- A cluster of four borings to confirm the extent of total chromium and perchlorate in sediments near station C366. The borings will be within 50–75 ft of this station (proposed boring locations WB-26 to WB-29).
- A transect of two borings beginning approximately 50 ft offshore of the high water line, and located 75–100 ft upstream of Stations C359 and WB-23 (upstream of Dock 1). Additional borings will assist in understanding the extent of DDx, MCB,

[31] The RAA boundary may be subdivided into multiple subareas, based on variation of COIs and applicable remedial technologies.

total chromium, and perchlorate in sediments upstream of these locations (WB-30 to WB-31).

- A single boring shoreward of WB-23 and downstream towards Dock 1. Sediment borings have not been collected in this area of the site to determine the vertical extent of DDx and MCB in sediments near the bank. Samples collected from this boring will also be analyzed for total chromium, perchlorate, and other COIs (WB-32).
- A single boring offshore of C359. Station C359 showed DDx concentrations above the PEC to a depth of 12 ft below mudline. An additional boring offshore of this location will assist in understanding the lateral extent of problem sediment in this area of the site. Samples collected from this boring will be analyzed for DDx, MCB, total chromium, perchlorate, and other COIs (WB-33).
- A cluster of three borings within 50–75 ft of station C356 located at the face of Dock 1. Station C356 showed DDx concentrations above the PEC to a depth of approximately 8.5 ft below mudline. The cluster of proposed borings will assist in delineating the extent of DDx and MCB in sediments in the vicinity of Station C356. Samples collected from these borings will also be analyzed for total chromium, perchlorate, and other COIs (WB-34 to WB-36).
- A transect of three borings beginning within approximately 100 ft of the high water line and positioned between station WB-13 and WB-14 and the upstream edge of Dock 2. Sediment borings have not been collected in this area of the site to determine the extent of DDx and MCB in sediments. Information obtained from these borings will assist in evaluating the downstream boundary of the principal threat area (WB-37 to WB-39).
- A line of two borings between the face of Docks 1 and 2, one located approximately 75 ft offshore of WB-14, the other located approximately 75 ft downstream of WB-7. Information obtained from these borings will assist in evaluating the channel side boundary of DDx and MCB in the principal threat area (WB-40 to WB-41).
- Three transects of three borings downstream of Dock 2 evenly spaced between the downstream edge of Dock 2 and Station C348. One boring is positioned offshore of Station WB-19. Sediment borings have not been collected in this area of the site to determine the extent of DDx and MCB in sediments. Information obtained from these borings will assist in evaluating the downstream boundary of the principal threat area (WB-42 to WB-50).
- A transect of two borings located approximately 75–100 ft downstream of Station C348. Station C348 showed DDx concentration above the PEC to a depth of approximately 8 ft below mudline. Additional borings downstream of this

location will assist in evaluating the downstream boundary of the principal threat area (WB-51 to WB-52).

- A transect of two sediment borings in line with SD84 at approximate water elevations of –15 and 0 ft (WB-62 to WB-63) to determine the lateral and vertical extent of DDx in sediments downstream of Dock 2.
- A transect of two borings in line with SD83 at approximate water elevations of –20 and 0 ft (WB-64 to WB-65) to determine the lateral and vertical extent of DDx in sediments downstream of Dock 2.
- A transect of two borings in line with SD80 at approximate water elevations of –20 and 0 ft (WB-66 to WB-67) to determine the lateral and vertical extent of DDx in sediments downstream of Dock 2.

Several of these borings will be collocated with borings proposed for geotechnical, physical, and water quality testing (i.e., CST, EET, DRET, SBLT, TCLP, ATT) described below. More than one boring will be required at several of these locations for the collection of undisturbed samples and to provide enough sediment for the proposed tests.

A hollow-stem auger (or equivalent) advanced to basalt (or refusal) with a drill rig positioned on a barge will be used to complete the borings. Samples will be collected continuously at 2-ft intervals using a Gregory Undisturbed Sampler (GUS) or Osterberg Sampler and stainless-steel Shelby tube. A large-volume split-spoon sampler may also be used for sampling (refer to FSP).

Analytical Strategy

Sediment samples will be collected continuously in each boring at 2-ft intervals for the entire length of each boring. Field observations will guide the preliminary selection of individual samples for the following analyses of COIs:

- Total metals by EPA Method SW846-6010B/7000 Series
- Perchlorate by EPA Method 314.0 (modified for sediments)
- Chlorinated pesticides by EPA Method SW846-8081A
- PCBs by EPA Method SW846-8082A
- VOCs by EPA Method SW846-8260B
- SVOCs by EPA Method SW846-8270C
- TOC by EPA Method SW846-9060A (modified for sediments).

Subsurface samples from borings within the preliminary RAA (WB-27, WB-33, WB-34 WB-36, WB-40 to WB-43, WB-45, and WB-51) will also be analyzed for PCDD/Fs by EPA Method 1613.

Up to three samples will be selected initially for analysis from each boring for a total of 99 samples plus quality control samples (e.g., field duplicates). The selection of samples in a core will initially be based on field observations, including visual contamination (e.g., sheen), odor, and presence of volatile chemicals (e.g., PID), etc. A portion of all samples will be archived for possible future analyses. Archive of samples will allow flexibility in the testing program with additional analysis (if necessary) to confirm the nature and extent of contamination at a specific location. Table 8-3 presents the proposed sampling and testing of the sediment borings. The actual sample(s) selected for analysis from each boring will be dependent on field observations. All sediment borings that are logged for lithology will also be examined for bioturbation.

Table 8-3. Proposed Subsurface Sampling and Chemical Testing in Support of EE/CA.

Station	Northing	Easting	Total Depth[a]	Sample Depths[a]	TOC	Total Metals	Perchlorate	Chlorinated Pesticides/ PCBs	VOCs	SVOCs	PCDD/Fs
WB-08			20	TBD	--	--	--	--	--	--	--
WB-09			20	TBD	--	--	--	--	--	--	--
WB-11			20	TBD	--	--	--	--	--	--	--
WB-23			20	TBD	--	--	--	--	--	--	--
WB-26			10	0-2, 4-6, 8-10	3	3	3	3	3	3	--
WB-27			30	2-4, 4-6, 8-10, TBD	4	4	4	4	4	4	4
WB-28			40	0-2, 4-6, 8-10, TBD	4	4	4	4	4	4	--
WB-29			30	2-4, 4-6, 8-10, TBD	4	4	4	4	4	4	--
WB-30			10	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-31			40	2-4, 4-6, 8-10, TBD	4	4	4	4	4	4	--
WB-32			40	2-4, 4-6, 8-10, TBD	4	4	4	4	4	4	--
WB-33			<10	2-4, 4-6	2	2	2	2	2	2	2
WB-34			15	2-4, 4-6, 8-10	3	3	3	3	3	3	3
WB-35			<10	2-4, 4-6	2	2	2	2	2	2	--
WB-36			<15	2-4, 4-6, 8-10	3	3	3	3	3	3	3

Table 8-3. Proposed Subsurface Sampling and Chemical Testing in Support of EE/CA.

Station	Northing	Easting	Total Depth[a]	Sample Depths[a]	TOC	Total Metals	Perchlorate	Chlorinated Pesticides/ PCBs	VOCs	SVOCs	PCDD/Fs
WB-37			<5	2-4	1	1	1	1	1	1	--
WB-38			20	0-2, 4-6, 8-10	3	3	3	3	3	3	--
WB-39			20	0-2, 4-6, 8-10	3	3	3	3	3	3	--
WB-40			<10	2-4, 4-6	2	2	2	2	2	2	2
WB-41			<15	2-4, 4-6, 8-10	3	3	3	3	3	3	3
WB-42			<5	2-4	1	1	1	1	1	1	1
WB-43			15	0-2, 4-6, 8-10	3	3	3	3	3	3	3
WB-44			20	0-2, 4-6, 8-10	3	3	3	3	3	3	--
WB-45			<10	2-4, 4-6	2	2	2	2	2	2	2
WB-46			20	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-47			25	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-48			20	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-49			25	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-50			30	2-4, 4-6, 8-10, TBD	4	4	4	4	4	4	--
WB-51			20	2-4, 4-6, 8-10	3	3	3	3	3	3	3
WB-52			25	2-4, 4-6, 8-10	3	3	3	3	3	3	--

Table 8-3. Proposed Subsurface Sampling and Chemical Testing in Support of EE/CA.

Station	Northing	Easting	Total Depth[a]	Sample Depths[a]	TOC	Total Metals	Perchlorate	Chlorinated Pesticides/ PCBs	VOCs	SVOCs	PCDD/Fs
WB-53			20	TBD	--	--	--	--	--	--	--
WB-54			20	TBD	--			--	--	--	--
WB-62			20	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-63			25	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-64			10	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-65			30	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-66			10	2-4, 4-6, 8-10	3	3	3	3	3	3	--
WB-67			20	2-4, 4-6, 8-10	3	3	3	3	3	3	--
TOTAL					97[b]	97[b]	97[b]	97[b]	97[b]	97[b]	26[b]

Notes:
[a] Estimated in feet to basalt based on previous sampling in the area. Total depth and sample selection may change based on field observations.
[b] Does not include field and laboratory quality control sample analysis. Number of samples analyzed may change based on field observations.
TBD – To be determined in the field.

8.2.1.2 Water Quality Characteristics

Rationale

The primary goals of water sampling are to provide a baseline for COI concentrations in water and to identify which COIs have the potential for recontamination once the removal action is completed, in accordance with RAOs 6 and 7. The approach to water quality sampling is to sample along the groundwater flow path from upland sources to their ultimate point of discharge. Water quality sampling at an intermediate flowpath point (riverbank monitoring well samples) and at the point of discharge (TZW samples) will be conducted to establish water quality characteristics along these flowpaths. The sampling pattern will focus on refining water quality issues within the principal threats areas identified in previous investigations (e.g., Portland Harbor RI studies). As described in Section 8.1, additional TZW samples are required upstream and offshore of the Salt Dock, offshore of Docks 1 and 2, and downstream of Dock 2. Additional groundwater sampling is required for wells along the Arkema bank to provide information on all COIs (including PCDD/Fs).

Sampling Strategy

Transition-zone water samples will be collected from 13 stations using the Trident Probe. This method was shown to be the most effective in sampling representative transition-zone water samples during the recent Portland Harbor groundwater study (Integral 2006a). The sampling is proposed at the following locations (see Figure 8-2):

- A transect of two stations upstream of the Salt Dock to further evaluate the nature and extent of chloride in TZW (TZW-1 and -2)
- A transect of two stations offshore of the Salt Dock and Station CP10A to further evaluate the extent of chloride in TZW (TZW-3 and -4)
- A transect of two stations offshore of the Salt Dock and Station CP08D to further evaluate the extent of chloride, perchlorate, and chromium concentrations in TZW (TZW-5 and -6)
- A single station (TZW-7) offshore of the Salt Dock and Station CP07D to further delineate the extent of COIs in TZW
- A transect of two stations offshore of the Salt Dock and Station CP06C to further delineate the extent of COIs in TZW (TZW-8 and -9)
- A single station (TZW-10) offshore of Dock 2 and Station AP02D to further delineate the extent of COIs in TZW
- A transect of three stations downstream of the Salt Dock to further delineate the extent of COIs in TZW (TZW-11, -12, and -13).

Groundwater will be collected from the following upland wells in support of the EE/CA:

- Groundwater sampling of well cluster MWA-30, MWA-32i, and MWA-46 near the chloride plume for additional baseline data including PCDD/Fs
- Groundwater sampling of well cluster MWA-6r and MWA-16i near the perchlorate, chromium, DDx, and MCB plumes for additional baseline data including PCDD/Fs
- Groundwater sampling of wells (MWA-2, MWA-4, MWA-15R, MWA-63, MWA-67si) near the MCB and DDx plumes for additional baseline data including PCDD/Fs.

Analytical Strategy

Water samples will be collected, centrifuged, and analyzed for COIs using the following methods:

- Total metals by EPA Method SW846-6000/7000 Series
- Hexavalent chromium by EPA Method SW846-6010B
- Chloride by EPA Method 300.0
- Perchlorate by EPA Method 314.0
- Chlorinated pesticides by EPA Method SW846-8081A
- PCBs by EPA Method SW846-8082A
- VOCs by EPA Method SW846-8260B
- SVOCs by EPA Method SW846-8270C
- TOC by EPA Method SW846-9060A
- TSS by EPA Method 160.2
- Anions by EPA Method 300.0
- Cations by EPA Method SW-846-6000 Series.

Selected transition-zone water samples (TZW-5, 8, 10, 12) and groundwater wells will also be analyzed for PCDD/Fs by EPA Method 1613.

Table 8-4 presents the proposed sampling and testing of the transition-zone and groundwater samples. One sampling event is planned for the collection and analysis of these samples.

Table 8-4. Proposed TZW and Groundwater Sampling and Chemical Testing in Support of EE/CA

Station	Northing	Easting	Anions/ Cations/ Conventionals	Total Metals	Chlorinated Pesticides/ PCBs	Perchlorate	Chloride	VOCs	SVOCs	PCDD/Fs
Upstream of Salt Dock										
TZW-1			1	1	1	1	1	1	1	--
TZW-2			1	1	1	1	1	1	1	--
TZW-3			1	1	1	1	1	1	1	--
TZW-4			1	1	1	1	1	1	1	--
Offshore of Dock 1 and Salt Dock										
TZW-5			1	1	1	1	1	1	1	1
TZW-6			1	1	1	1	1	1	1	--
TZW-7			1	1	1	1	1	1	1	--
TZW-8			1	1	1	1	1	1	1	1
TZW-9			1	1	1	1	1	1	1	--
Offshore of Dock 2										
TZW-10			1	1	1	1	1	1	1	1
Downstream of Dock 2										
TZW-11			1	1	1	1	1	1	1	--
TZW-12			1	1	1	1	1	1	1	1
TZW-13			1	1	1	1	1	1	1	--
Arkema Groundwater Wells										
MWA-30			1	1	1	1	1	1	1	1
MWA-32i			1	1	1	1	1	1	1	1
MWA-6r			1	1	1	1	1	1	1	1
MWA-16i			1	1	1	1	1	1	1	1
MWA-46			1	1	1	1	1	1	1	1
MWA-67si			1	1	1	1	1	1	1	1
MWA-15r			1	1	1	1	1	1	1	1
MWA-2			1	1	1	1	1	1	1	1
MWA-4			1	1	1	1	1	1	1	1
MWA-63			1	1	1	1	1	1	1	1
TOTAL			20	20	20	20	20	20	20	14

8.2.2 Ecological and Human Health Risks

As stated in Section 8.1.4, additional surface sediments and tissue samples are required to support the evaluation of human health and ecological risk characteristics for the Arkema site. These additional data will also be used to delineate the final RAA boundary in the EE/CA and provide necessary information in support of achieving RAOs 1-5.

8.2.2.1 Surface Sediments

Rationale

In addition to defining the spatial extent of sediment COIs within the site boundary, surface sediment samples will be used to evaluate the potential risks to human health and the environment, including benthic community and wildlife receptors. A tiered approach of sediment chemistry and bioassay testing is proposed. The locations of planned surface samples are provided below, followed by the analytical strategy and proposed approach for interpreting the data in support of the EE/CA.

Sampling Strategy

Thirty-five surface sediment (0–1 ft) samples are proposed for collection in support of the EE/CA[32]. The sampling pattern will focus on bounding areas of elevated COIs in sediments identified in previous investigations (e.g., Portland Harbor Round 2 study) that could be considered within or near the principal threat areas. Many of the stations will be collocated with sediment borings proposed in Section 8.2.1. As described in Section 8.1, additional surface sediment samples are required in four areas onsite (plus reference locations) including (Figure 8-1):

- Salt Dock and upstream of this area (WS-56 to WS-61)
- Between Dock 1 and the Salt Dock (WS-23, WS-27, WS-29 to WS-32)
- Offshore of Docks 1 and 2 (WS-33 to WS-37, WS-40 to WS-42, WS-45, WS-48, WS-55)
- Downstream of Dock 2 (WS-46, WS-47, WS-49 to WS-52, WS-62 to WS-67)

[32] The total number does not include reference samples collected from an upstream (upgradient) location to be determined.

- Ambient upstream locations on the Willamette River[33] (number and location to be determined based on physical characteristics of site sediments).

Analytical Strategy

All surface samples will be analyzed for COIs using the following methods:

- Conventional analytes (TOC, total sulfides, ammonia)[34]
- Chloride by EPA Method 300.0
- Total metals by EPA Method SW846-6000/7000 Series
- Perchlorate by EPA Method 314.0 (modified for sediments)
- Chlorinated pesticides by EPA Method SW846-8081A
- PCBs by EPA Method SW846-8082
- VOCs by EPA Method SW846-8260B
- SVOCs by EPA Method SW846-8270C.

Sediment samples (WS-27, WS-33, WS-36, WS-40, WS-45, WS-51) within the preliminary RAA will also be analyzed for PCDD/Fs by EPA Method 1613.

Table 8-5 presents the proposed sampling and testing of the surface sediment samples. One sampling event is planned for the collection and analysis of these samples.

Solid Phase (Bulk Sediment) Toxicity Tests—For sediments where COI concentrations exceed corresponding PEC values, sediment toxicity will be tested using for the following EPA-recommended bioassays:

- 10-day growth and survival in the midge *Chironomus tentans*—USEPA (2000b) Test Method 100.2.
- 28-day growth and survival in the amphipod *Hyalella azteca*—USEPA (2000b) Test Method 100.4.

[33] Ambient upstream stations LW2-U1C through LW2-U6C are between RM 15 and RM 26 on the Willamette River. Selection of upstream ambient locatins will be done in consultation with the government team.

[34] TOC by EPA Method SW846-9060A modified for sediments, total sulfides by EPA Method SW846-9034, and ammonia by Plumb (1981).

Toxicity testing will follow procedures recommended for the harbor-wide investigation of risks to benthic organisms (Windward et al. 2005) and described in the accompanying QAPP. These solid-phase growth and survival tests were selected as measurement endpoints to help predict the potential for benthic community effects and to define principal threats associated with COIs for the site. However, some of the COIs are total dissolved solids or salts of common compounds that are mildly toxic, highly soluble, have a low affinity for the solid phase sediment matrix, and are not routinely managed pursuant to CERCLA. Consequently, additional sediment toxicity testing using purged samples and porewater techniques is proposed to segregate the effects of these COIs and identify their relative importance as they contribute to principal threats at the site.

Purged Sediment Tests—Selected sediment samples collected upstream of Dock 1 and in the vicinity of the Salt Dock will be evaluated for possible biological effects concurrently with chemical testing (Table 8-5). Sodium and potassium salts of perchlorate and chloride have been shown to be associated with groundwater discharging into river sediments from upland sources (Integral 2003). These chemicals may cause sediment toxicity as a component (porewater) of the bulk sediment sample but are not expected to adsorb onto sediments as they pass through the sediments into the overlying water. Therefore, toxicity test methods conducted on selected sediment samples in the vicinity of the Salt Dock will be tested with and without purging steps. Selected samples will be modified in order to reduce the effects of these chemicals found in the porewater. Overlying water in the test containers will be replaced or "purged" twice daily to reduce their concentration levels before introducing the organisms. The purging technique will be adapted from that recommended by Barton (2002) for reducing ammonia levels in sediment porewater. The process will continue until TDS concentration, conductivity, or pH in the porewater is reduced to ambient or tolerant levels[35], as defined in the QAPP. Selected samples will also be tested concurrently without purging for confirmation purposes and to assist in interpreting the chemical and toxicity testing results (see Co-Occurrence Analysis below). Testing methodology is discussed further in the QAPP.

Porewater Sediment Tests—Porewater testing will be conducted to characterize toxicity associated with the TDS content of transition-zone water. Although porewater toxicity tests have their inherent limitations,[36] they nevertheless can be a useful supplement to understanding causes of toxicity in bulk-sediment tests. Consequently, porewater testing as a complement to the suite of solid-phase and purge tests described above will be used to further elucidate possible causes of toxicity in cases where the non-purged bulk sediments are toxic and purged sediments are not toxic, as illustrated in Figure 8-3.

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[35] As much as 5–10 days of purging may be required before test initiation.

[36] See the SETAC publication (Carr and Nipper 2003) entitled *Porewater Toxicity Testing: Biological, Chemical, and Ecological Considerations.*

Depending on the results of the purged-sediment bioassays (see Figure 8-3) porewater testing will be conducted with either the amphipod *Hyalella azteca* or the midge *Chironomus tentans,* as recommended by Scroggins et al. (2003). The porewater toxicity testing procedure for each of these test species will be modified from their respective reference toxicant methods described by and USEPA (2000b). Details of the toxicity testing methods and performance standards are provided in the FSP and QAPP.

Table 8-5 presents the proposed sampling and testing of the surface sediment samples.

Table 8-5. Proposed Surface Sampling and Chemical Testing in Support of EE/CA.

Station	Northing	Easting	Depth (ft)	Conventional Testing	Total Metals	Chlorinated Pesticides/ PCBs	Perchlorate	Chloride	VOCs	SVOCs	Dioxins	Bioassays[a]
Upstream of Salt Dock												
WS-56			0-1	1	1	1	1	1	1	1	--	1
WS-57			0-1	1	1	1	1	1	1	1	--	1
WS-58			0-1	1	1	1	1	1	1	1	--	1
WS-59			0-1	1	1	1	1	1	1	1	--	1
WS-60			0-1	1	1	1	1	1	1	1	--	1
WS-61			0-1	1	1	1	1	1	1	1	--	1
Dock 1 to Salt Dock												
WS-23			0-1	1	1	1	1	1	1	1	--	1
WS-27			0-1	1	1	1	1	1	1	1	1	1
WS-29			0-1	1	1	1	1	1	1	1	--	1
WS-30			0-1	1	1	1	1	1	1	1	--	1
WS-31			0-1	1	1	1	1	1	1	1	--	1
WS-32			0-1	1	1	1	1	1	1	1	--	1
WS-33			0-1	1	1	1	1	1	1	1	1	1
WS-34			0-1	1	1	1	1	1	1	1	--	1
WS-35			0-1	1	1	1	1	1	1	1	--	--
WS-36			0-1	1	1	1	1	1	1	1	1	--
WS-55			0-1	1	1	1	1	1	1	1	--	--
Offshore of Docks 1 and 2												
WS-37			0-1	1	1	1	1	1	1	1	--	--
WS-40			0-1	1	1	1	1	1	1	1	1	--
WS-41			0-1	1	1	1	1	1	1	1	--	--
WS-42			0-1	1	1	1	1	1	1	1	--	--
Downstream of Dock 2												
WS-45			0-1	1	1	1	1	1	1	1	1	--
WS-46			0-1	1	1	1	1	1	1	1	--	--
WS-47			0-1	1	1	1	1	1	1	1	--	--
WS-48			0-1	1	1	1	1	1	1	1	--	--
WS-49			0-1	1	1	1	1	1	1	1	--	--

Table 8-5. Proposed Surface Sampling and Chemical Testing in Support of EE/CA.

Station	**Northing**	**Easting**	**Depth (ft)**	**Conventional Testing**	**Total Metals**	**Chlorinated Pesticides/ PCBs**	**Perchlorate**	**Chloride**	**VOCs**	SVOCs	Dioxins	**Bioassays[a]**
WS-50			0-1	1	1	1	1	1	1	1	--	--
WS-51			0-1	1	1	1	1	1	1	1	1	--
WS-52			0-1	1	1	1	1	1	1	1	--	--
WS-62			0-1	1	1	1	1	1	1	1	--	--
WS-63			0-1	1	1	1	1	1	1	1	--	--
WS-64			0-1	1	1	1	1	1	1	1	--	--
WS-65			0-1	1	1	1	1	1	1	1	--	--
WS-66			0-1	1	1	1	1	1	1	1	--	--
WS-67			0-1	1	1	1	1	1	1	1	--	--
TOTAL				35[b]	35[b]	35[b]	35[b]	35[b]	35[b]	35[b]	6[b]	14[b]

[a] Additional stations may be tested for bioassays pending the chemical results.
[b] Does not include field and laboratory quality control sample analysis or reference sediments.

8.2.2.2 Tissue Samples

Rationale

Tissue samples are required to further evaluate the potential risks to the environment including wildlife receptors. ERA target species include crayfish and sculpin[37]. The locations of planned tissue sample collections are provided below, followed by the analytical strategy and proposed approach for interpreting the data in support of the EE/CA (Table 8-6).

Sampling Strategy

The riverfront adjacent to the Arkema facility will be divided into five sections for sampling (Figure 8-4). Sampling sections will include the area upstream of the Salt Dock, between the Salt Dock and Dock 1, between Docks 1 and 2, and two areas downstream of Dock 2. The areas upstream of the Salt Dock and between Docks 1 and 2 are within the same areas as LWG tissue sample stations 07R003 and 07R006 (Figure 8-4).

The sampling techniques that proved most effective during the LWG Round 1 sampling effort are proposed for sampling in support of the EE/CA. Depending upon site conditions and river habitat characteristics, the field manager will make a decision on which sampling technique to employ. A brief description of each proposed technique is provided below. Detailed descriptions of each sampling method are provided in the FSP (SEA et al. 2003; SEA 2002a,b).

Crayfish Traps—The most efficient method in catching crayfish was with minnow traps with long bodies (approximately 30 in.) and long entry cones (SEA et al. 2003). The most effective bait was frozen smelt. Crayfish preferred sandier over muddier substrates and were noted to be of larger size in deeper water (30–40 ft) than closer to shore. Crayfish traps will be deployed within 100 ft of the shoreline at marked sculpin stations.

Backpack Electrofishing—Primarily due to safety concerns, backpack electrofishing works well in shallow water, shallow sloped banks and where subsurface structures, such as rip rap, pilings, big boulders, are not present. Backpack electrofishing will be used only under the optimum conditions to ensure the safety of field staff and to improve the chances of success in capturing sculpin.

[37] Opportunistic collection of HHRA target species will also be included as part of this sampling and testing plan. If successful, the additional data would strengthen the baseline data for the site.

Boat Electrofishing—Boat electrofishing is appropriate in areas that are too deep for backpack electrofishing. Based upon previous observations, it was only effective in water up to 10 ft deep (SEA et al. 2003). As the water deepens, it may become more difficult to visually detect sculpin and scoop them out of the water with a net. Areas with large gaps between stones and riprap also may prove difficult to capture sculpin because of the likelihood of them sinking into the crevices.

Trotlines—Trotlines are long fishing lines with many short lines with hooks attached to it. Trotlines used in support of the Portland Harbor study were 150 ft long and were either strung between pilings or anchored by buoys. Trotlines proved efficient in catching sculpin at locations where electrofishing was not effective.

As conducted during the Portland Harbor study (SEA et al. 2002), a minimum of 150 g of tissue will be collected for both sculpin and crayfish. This quantity equates to about 10 sculpin and 5 crayfish per composite sample. These weights are based on the average weights from the 2002 catch records (SEA et al. 2003). Each station will be sampled systematically until three composite samples at each proposed station are collected. Fish specimen sample handling and processing procedures will follow guidelines outlined in SEA (2002a,b) and SEA et al. (2003). Details are provided in the FSP. The minimum required detection limit for COIs will be based on screening values used to judge risk characteristics for the Arkema site. Performance standards are provided in guidance documents (SEA 2002b; USEPA 2000b).

Analytical Strategy

All tissue samples collected will be analyzed for conventional, inorganic, and organic parameters in accordance with the procedures detailed in the project QAPP. A summary of the analytical parameters and methods of analyses are provided below:

- Percent moisture (gravimetric using drying ovens at 50°C or freeze drying)
- Lipid content (Bligh and Dyer 1959; or comparable method)
- Aluminum, antimony, arsenic, cadmium, copper, lead, manganese, nickel, silver, thallium, and zinc by EPA Method SW846-6020
- Chromium by EPA Method SW846-6010B
- Mercury by EPA Method SW846-7471A
- Selenium by EPA Method SW846-7740
- SVOCs by EPA Method SW846-8270C with selective ion monitoring option (SIM) for low-level analyses
- Organochlorine pesticides and selected SVOCs by EPA Method SW846-8081A

- PCBs Aroclors by EPA Method SW846-8082
- Chlorinated PCDD/Fs by EPA Method 1613B.

Table 8-6 presents the proposed testing of tissue composite samples at the Arkema site. At least 150 grams of tissue or approximately 10 individual crayfish or sculpin are required for chemical analysis. It may be necessary to modify the above-referenced analytical procedures in order to conserve sample volume, minimize dilutions required, and reduce co-elution interferences. These modifications are discussed below.

SVOCs – A silica fractionation cleanup will be necessary to remove lipids prior to analyzing the extracts for SVOCs. The silica fractionation procedure also results in the removal of several compounds in addition to removing lipids. In order to quantify these compounds, additional analysis of the un-cleaned extracts will be analyzed by GC/MS-SIM.

Organochlorine Pesticides and PCB Aroclors – In order to minimize the need for excessive sample dilution and to conserve sample volume, the lab will perform a screening level extraction and analysis for organochlorine pesticides and PCBs to determine the appropriate mass of sample to use for extraction. This procedure will involve extracting a small portion of the tissue sample in hexane and injecting an aliquot of the extract into the GC column.

Evidence of potential interference in the organochlorine pesticide analyses from the presence of PCBs was evident in tissue samples analyzed as part of LWG's Round 1 Site Characterization (Integral 2004c). If this is evident in the Arkema EE/CA tissue samples, the affected samples will be reanalyzed by GC/MS using a mass spectrometer equipped with an ion trap (Method 8270C), which will increase the sensitivity of the instrument. This method was developed during the analysis of the LWG Round 1 tissue samples (Integral 2004) and was proven to be effective.

PCB Congeners – In order to conserve sample volume, screening results generated for the PCB Aroclor analysis will be provided to the laboratory conducting the PCB congener analysis to help assist them in determining the appropriate sample volume for extraction. In addition, it may be necessary to analyze a split of the extracts on a carbon column to allow for better separation of selected congeners from other congeners and interferences. This is modification is allowed in the referenced method (EPA Method 1668A).

Table 8-6. Proposed Tissue Sampling and Chemical Testing in Support of the EE/CA

Station	Northing	Easting	Moisture	Lipid Content	Metals	Chlorinated Pesticides/ PCBs	SVOCs	PCDD/Fs
Bio-1			2	2	2	2	2	2
Bio-2			2	2	2	2	2	--
Bio-3			2	2	2	2	2	2
Bio-4			2	2	2	2	2	--
Bio-5			2	2	2	2	2	2
Total			10	10	10	10	10	6

8.2.2.3 Multiple-Lines-of-Evidence Approach to Evaluate Ecological Risk Characteristics

Sediment chemistry, bioaccumulation, and toxicity testing results will be evaluated using multiple lines of evidence in a tiered approach to evaluate ecological risk characteristics and assist in delineating the final RAA boundary. The lines of evidence will be evaluated in the following sequence:

- Statistical significance of the test results—Do individual locations exceed *de minimis* levels of concern?
- Biological effects thresholds—Do individual stations and endpoints exceed biological effects thresholds for sediment toxicity or wildlife bioaccumulation?
- Geo-spatial characterization—Are there areas of contiguous stations that exceed biological effects thresholds?
- Co-occurrence and relative concentration of COIs in sediments—Are observed levels of bioaccumulation and toxicity explained by the presence and concentrations of COIs in sediments for the site?

Statistical Significance

Sediment chemistry, bioaccumulation, and toxicity will be compared statistically to that in ambient upstream reference sediments. The harbor-wide sediment toxicity testing program (Windward et al. 2005, 2006) has adopted statistical comparisons to negative control sediments to increase test sensitivity and reliability of empirically derived sediment quality values. However, site-specific testing typically relies on comparisons to reference conditions in order to isolate chemical toxicity from other environmental stressors associated with benthic habitat conditions such as sediment grain size and organic carbon content. Consequently, for the determination of an area of principal threats, the upstream reference stations established for the harbor-wide program (Windward et al. 2005) will be used to identify reference locations for comparisons to site sediments. Only those ambient stations that were not toxic in comparison with laboratory controls will be selected as reference locations for comparison and evaluation of the RAA.

Results of the Round 2A data report on toxicity testing (Windward 2005a) indicate that four of the six upstream locations (U1C, U2C, U3C, U5Q) did not have substantive effects on either toxicity or growth in amphipod or midge tests. Consequently, these locations are proposed as candidate reference stations for further toxicity testing of sediments in the vicinity of the Arkema facility. Final selection of reference locations will be developed in consultation with the government team pursuant to the analysis of sediment toxicity and proposed sediment quality values in the draft benthic interpretive report (Windward et al. 2006).

Following appropriate transformations[38], sediment chemistry, bioaccumulation, and toxicity data will be evaluated for normality and for homogeneity of variances to determine whether parametric or nonparametric statistics will be used. Data that satisfy assumptions or normality and homogeneity of variances will be evaluated using a one-tailed[39] parametric Student's *t*-test with alpha of 0.1. Data that do not satisfy assumptions of normality and homogeneity will be evaluated using a one-tailed nonparametric procedure such as the Mann-Whitney U-test. Selection of the alpha level, statistical power, and the importance of Type I and Type II errors will be discussed in an evaluation of uncertainty.

Site stations that are not significantly different from the reference stations will be judged unaffected (i.e., are below any *de minimis* adverse effects level) and will not be evaluated further. Site sediments that are significantly different from the reference sediments will be evaluated for biological effects as described below.

Biological Effects

Toxicity Testing—Site stations that have significantly lower rates of survival or growth than reference stations in bulk sediment tests will be evaluated for possible biological effects using numeric thresholds for each test and endpoint. Effects thresholds will be those developed in the Washington State Department of Ecology's (Ecology 2002) review of the toxicity testing information available for the two test species (ASTM 2000; USEPA 2000b). The thresholds developed by Ecology (2002) represent levels above which minor or potentially significant effects[40] are expected to occur. Each threshold level is based on either the absolute or relative difference in the observed response to site sediments in comparison with reference sediment (Table 8-7):

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[38] For example, the arcsine square root transformation will be used for data expressed as percentages.

[39] The alternative hypothesis in a one-tailed test will be that the response (i.e., survival or growth) in the site sediments is less than that in the reference sediment.

[40] Ecology (2002) uses regulatory nomenclature for Washington State in describing minor effects (SQS) and significant effects (CSL) thresholds.

- Amphipod and midge percent mortality
  - No effect where S – R (i.e., mortality in site sediments minus mortality in reference sediments) ≤ 10%
  - Minor threshold where 10% < S – R ≤ 25%
  - Significant threshold where S – R>25%.
- Amphipod growth
  - No effect where S/R (i.e., growth in the site sediment divided by that in the reference sediment) ≥ 0.75
  - Minor effect where 0.6 ≤ S/R < 0.75
  - Significant effect where S/R < 0.6.
- Midge growth
  - No effect S/R ≥ 0.8
  - Minor effect where 0.7 ≤ S/R < 0.8
  - Significant effect where S/R < 0.7.

Stations that exceed two minor effects thresholds or one significant effect threshold will be designated as stations of concern. These stations of concern will be the focus of further geo-spatial evaluation as described in the following section.

In addition to the foregoing bulk-sediment evaluations, site stations that are located in areas with high concentrations of perchlorate or sodium chloride in transition-zone water will be evaluated for potential contributory effects of these and other highly water soluble substances in interstitial porewater. As indicated above in Section 8.8.2.3 and Figure 8-3, sediments with high concentrations of perchlorate or sodium chloride will be tested for solid phase toxicity. Concurrently, aliquots of the sediments from these locations will be treated by purging or extraction of porewater for further testing pending results of the bulk phase tests. Bulk phase tests that are significantly toxic in comparison to reference samples will trigger additional testing on purged samples. Purged sediments that are toxic will provide confirmation of toxicity in the bulk phase for the designation of minor and major effects levels as described above. Purged sediments that are not toxic would indicate that toxicity is associated with either the porewater phase or with substances that are very weakly affiliated with the solid phase. This result would trigger porewater testing as indicated in Figure 8-3. Porewater that is not toxic will indicate that toxicity is weakly affiliated with the solid-phase, was very labile, and was essentially lost during the purging protocol. These results will be interpreted as confirmation of toxicity in the bulk phase and the designation of minor and major effects levels as described above. However, porewater that is toxic will be interpreted in support of the conclusion that

toxicity is attributed to highly soluble substances in the aqueous phase, which may not be easily controlled or mitigated by a sediment management strategy.

Table 8-7. Biological Effects Thresholds for Interpretation of Sediment Toxicity Tests.

Hyalella azteca Mortality[1]	*Hyalella azteca* Growth[2]	*Chironomus tentans* Mortality[1]	*Chironomus tentans* Growth[2]
No effect S-R ≤ 10%	No effect S/R ≥ 0.75	No effect S-R ≤ 10%	No effect S/R ≥ 0.8
Minor effect threshold S-R >10% to ≤ 25%	Minor effect threshold S/R < 0.75	Minor effect threshold S-R >10%	Minor effect threshold S/R < 0.8
Major effect threshold S-R > 25%	Major effect threshold S/R < 0.6	Major effect threshold S-R > 25%	Major effect threshold S/R < 0.7

[1] Expressed as the absolute difference of the result for the site sediment minus the result for the reference sediment (S-R).
[2] Expressed as the relative difference of the results for the site sediment divided by the result for the reference sediment (S/R).
Reference: Adapted from Ecology (2002).

Bioaccumulation—Following the statistical comparisons described above, bioaccumulation data will be evaluated in two steps. First, tissue levels will be compared directly with critical tissue concentrations that are associated with effects in higher trophic level receptors based on harbor-wide risk assessment, tissue data, and food chain modeling being developed by the LWG in consultation with the government team. Second, for those substances that exceed risk-based critical tissue concentrations, biota-sediment accumulation factors (BSAFs) or trophic transfer factors (TTFs) will be used to estimate corresponding concentrations in sediments that can facilitate judgments concerning the RAA boundary. The BSAFs and TTFs are being developed collaboratively by the LWG and the government team and should be available by the time the site characterization data are validated. Where BSAF or TTF values have not been developed, they may be determined empirically for the Arkema site pending review and acceptance by the government team. Arkema recognizes that BSAFs or TTFs may not be available or technically acceptable by either of these methods. In such circumstances, the bioaccumulation data will be assessed indirectly using simple comparisons of sediment chemistry to wildlife sediment SLVs as described above in Section 5 and Section 6, and by further comparisons using geo-spatial techniques and correlation analysis, as described below, to identify areas of concern based on concentrations and distributional patterns that appear elevated in comparisons with reference areas.

Geo-spatial Evaluation

Geo-spatial techniques (e.g., Goff 2003) will be used to identify areas where average sediment toxicity results exceed two minor or one significant effect threshold for sediment toxicity, or where chemical concentrations in tissues of sculpin or crayfish exceed risk-based levels of concern for wildlife receptors as described above (see **Bioaccumulation**). The geo-spatial characterization will be viewed in context with the other lines of evidence

on statistical significance, biological effects (toxicity and bioaccumulation), and co-occurrence with chemicals of concern. Our intent is to align bioassay and bioaccumulation testing results with sediment chemistry to identify areas where we can achieve a reduction in both concentration (sediment and tissue) and toxicity that is protective of the environment. These areas will define the principal threat zone for sediment toxicity and wildlife food chain exposure and will be the focus of sediment remediation strategies for the EE/CA.

Co-occurrence of Chemicals of Interest

Multivariate statistical analysis will be undertaken to determine whether there is a relationship between observed levels of sediment toxicity or tissue bioaccumulation and sediment concentrations of COIs for the site. Results of the multivariate analysis will be used in conjunction with the geo-spatial characterization described above for both bulk sediments and purged samples to qualitatively characterize the principal threat zone for biological effects and determine whether remediation of any single substance or group of substances will effectively reduce sediment toxicity. Where sediment toxicity or bioaccumulation and food chain exposure cannot be explained by the presence of COIs in sediments, sediment management strategies based on reduction in sediment toxicity or bioaccumulation alone rather than on sediment chemistry will be explored.

8.2.2.4 Multiple-Lines-of-Evidence to Evaluate Human Health Risk Characteristics

Sediment chemistry and bioaccumulation results will be evaluated to assist in delineating the final RAA boundary (Table 8-8). Data will be evaluated through a statistical comparison of site data with reference concentrations followed by screening against risk-based values.

Sediment chemistry and bioaccumulation data in site sediments will be compared statistically to reference site sediment and tissue data. The statistical evaluation will be conducted as described in Section 8.8.2.4. Data points that are not significantly different from the reference stations will be judged unaffected (i.e., are below any *de minimis* adverse effects level) and will not be evaluated further. Site sediments that are significantly different from the reference sediments will be evaluated for potential human health risks.

Sediment chemistry stations determined to be above *de minimis* levels will be compared to two sets of screening values: SLVs protective of direct contact via incidental ingestion and dermal contact and SLVs protective of indirect contact via consumption of fish and shellfish. SLVs for direct contact pathways are described in Section 6.1 and Appendix B and will be used to define the preliminary principal threat area(s) for riverbank and in-water sediments. Once SLVs for fish consumption are developed and approved by EPA, this additional level of screening will be used to refine the principal threat zone(s) for the

site. The resulting area encompassing sediments with COI concentrations that pose a potential threat to humans via direct and indirect exposures will be the focus for remediation strategies.

Table 8-8. Multiple Lines of Evidence for Judging Principal Threat to Sediments in the Vicinity of the Arkema Site.

1	2	3	4	5	6
	Biological Effects at Individual Station Locations				
Statistical Comparisons (*De Minimis* Threshold)	Sediment Toxicity Thresholds	Wildlife Bioaccumulation Thresholds	Human Health PRGs	Geo-spatial Patterns	Chemicals of Interest
• Site vs. ambient	• Bulk sediment toxicity – 2 minor thresholds exceeded – 1 significant threshold exceeded • Purged sediment toxicity • Porewater toxicity	• Risk-based critical tissue levels • BSAFs/TTF estimates for sediments • Sediment SLV comparisons	• Direct contact – Dermal • Direct contact – Ingestion • Indirect contact – Fish consumption	• Solitary station • Multiple stations	• Present • Elevated above reference • Correlations – Toxicity – Bioaccumulation

8.2.2.5 Evaluation within the Final RAA Boundary

Once the RAA boundary is established based on the multiple-lines-of evidence approach, several factors pertaining to the area will be examined in the EE/CA report, including constructability, short-term impact, recontamination potential, permanence of the removal action, and proposed institutional controls. Collectively, this evaluation will determine the final RAA boundary for the site.

8.2.3 Physical and Engineering Characteristics

8.2.3.1 Rationale

A testing program will be performed to determine the sediment index properties and geotechnical engineering parameters within the preliminary RAA boundary. The physical characteristics of sediments are important in the evaluation of dredging and capping technologies, dredged material transport and disposal, dredged material behavior in a disposal site, potential short-term impacts at the dredge and disposal sites, and capacity of existing sediments to provide foundation support for capping material. The justification for each test as it relates to the EE/CA is discussed in Section 5.5.

8.2.3.2 Sampling Strategy

Nineteen borings will be drilled to basalt (or refusal) to evaluate geotechnical properties and conditions within the preliminary RAA boundary. Most of these 19 borings are collocated with the borings for chemical analysis (described in Section 8.2.1.1). The borings will be distributed over the in-water site as follows (Figure 8-1):

- A line of four borings approximately 50 ft east the dock face, including one location between the Salt Dock and Dock 1, another location east of Dock 1, another location between Docks 1 and 2, and the fourth location east of Dock 2 (WB-26, WB-36, WB-41, WB-53).
- A cluster of three borings located upstream of Dock 1, with 1 boring located within 50 ft of the high water line and two others farther offshore (WB-23, WB-30, WB-32).
- A cluster of four borings positioned downstream of Dock 1, with two borings located within 50 ft of the high water line and two others 100 ft away. The borings will be placed in the vicinity of the former discharge pipe located downstream of Dock 1 (WB-8, WB-9, WB-11, WB-54).
- A cluster of four borings upstream and just downstream of Dock 2, with two borings located within 50 ft of the high water line and two others 100 ft farther toward the channel (WB-38, WB-39, WB-43, WB-44).

- A cluster of four borings located downstream of Dock 2, with two borings located within 75–100 ft of the high water line and two others 50 ft east and downstream of Dock 2 (WB-45, WB-47, WB-48, WB-50).

Borings will be positioned approximately 100–125 ft apart, except those located outside the dock face, which will be spaced at greater distances. Borings proposed for geotechnical and physical testing will be collocated with borings used to characterize sediment and water quality testing (i.e., CST, EET, DRET, SBLT, TCLP, ATT). More than one boring will be required at several of these locations for the collection of undisturbed samples and to provide enough sediment for all proposed tests.

A hollow-stem auger (or equivalent) advanced with a drill rig positioned on a barge will be used to complete the borings. Samples will be collected continuously at 2-ft intervals using a GUS or Osterberg Sampler and stainless-steel Shelby tube. A large-volume split-spoon sampler may also be used for sampling (refer to FSP). All sediment borings that are logged for lithology will also be examined for bioturbation.

8.2.3.3 Analytical Strategy

The following tests will be performed on the 0- to 2-ft, 4- to 6-ft, and 8- to 10-ft samples[41] from borings within the preliminary RAA boundary (Table 8-9).

- Grain-size analysis by ASTM-D422 with hydrometer
- Atterberg limits by ASTM-D4318
- Specific gravity by ASTM-D854
- Moisture content/density by ASTM-D2216/D2937
- Organic content by ASTM-D2974.

Grain-size and Atterberg limits will also be performed on selected samples collected within each boring. In addition, the following tests will be performed on selected relatively undisturbed samples from the borings:

- Consolidation by EM-1110-2-5027 Appendix D, modified for low loads
- UU triaxial shear stress by ASTM-D2850
- CU triaxial shear stress by ASTM-D4767.

[41] The number of samples analyzed and selection of sample depths may change based on visual observations (e.g., grain size, color, debris) in each boring.

Selected sediment samples will be collected and analyzed for physical and geotechnical parameters listed in Table 8-9. The actual number of tests performed will be based on field observations.

Table 8-9. Proposed Borings for Engineering and Water Quality Evaluation.

Station	Northing	Easting	Depth	Index Parameters	Consolidation	Laboratory Shear Strength, Permeability	*In situ* Shear Strength	Elutriate Testing, SBLT	Column Settling Testing	TCLP, ATT
Offshore of Docks	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-26								--	--	--
WB-36								--	--	--
WB-41								--	--	--
WB-53								--	--	--
Upstream of Dock 1	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-23								--	--	--
WB-30								--	--	--
WB-32								--	--	--
Downstream of Dock 1	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-8								X	X	X
WB-9								X	X	X
WB-11								X	X	X
WB-54								X	X	X
Dock 2										
WB-38								--	--	--
WB-39								--	--	--
WB-43								--	--	--
WB-44								--	--	--
Downstream of Dock 2	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-45								--	--	--
WB-47								--	--	--
WB-48								--	--	--
WB-50								--	--	--

8.2.4 Dredged Material Characterization (Water Quality)

8.2.4.1 Rationale

Representative large-volume samples are required for evaluation of dredging and disposal design requirements (USEPA/USACE 1998).

Potential water quality impacts during dredging will be evaluated using the DRET, CST, EET, and SBLT data to assess disposal in a CDF or other disposal facility. The assessment of offsite disposal in a Subtitle D landfill will be performed with landfill-specific acceptance criteria including hazardous waste determination, TCLP tests, and the DEQ ATT.

8.2.4.2 Sampling Strategy

Large-volume samples will be composited from borings located between Dock 1 and mid-way between Docks 1 and 2 (WB-08, WB-09, WB-11, WB-54). This area is near the former outfall through which DDT manufacturing process residue was discharged during a portion of the first year of DDT production. This area has been shown to have the highest DDx concentrations in sediments within the preliminary RAA boundary. Figure 8-1 presents the proposed boring location for each composite sample.

The compositing scheme for each large-volume sample at depths of 0-4 ft, 4-8 ft, and >8 ft, will consider the estimated volume of sediments containing the most elevated concentrations of DDx from this area of the river. At a minimum, sediment will be collected from each location over each depth range to provide a sufficient amount of representative material for all tests.

8.2.4.3 Analytical Strategy

The following tests will be conducted on each composite sediment sample representative of the four areas described above:

- DRET (DiGiano et al. 1995)
- EET (USACE 2003)
- CST (USEPA/USACE 1998)
- SBLT (Myers et al. 1992)
- TCLP (EPA SW-846 Methods)
- DEQ ATT (OAR 340-109-0001).

A representative sample of the composite sediment used in each elutriate and SBLT test will be analyzed for the following.

- Perchlorate by EPA Method 314.0
- Chlorinated pesticides by EPA Method SW846-8081A
- PCBs by EPA Method SW-846-8082
- SVOCs by EPA Method SW846-8270C
- VOCs by EPA Method SW846-8260B
- PCDD/Fs by EPA Method 1613
- Metals by EPA Methods SW846-6020, -7471A
- TOC by EPA Method SW846-9060A (modified for sediments).

Baseline water testing and water samples generated from the elutriate and SBLT testing will also be analyzed for the following:

- Perchlorate by EPA Method 314.0
- Chlorinated pesticides by EPA Method SW846-8081A
- PCBs by EPA Method SW-846-8082
- SVOCs by EPA Method SW846-8270C
- VOCs by EPA Method SW846-8260B
- PCDD/Fs by EPA Method 1613
- Metals by EPA Methods SW846-6020, -7471A
- TOC by EPA Method 415.1
- TSS by EPA Method 160.2.

Table 8-9 presents the proposed sampling and testing for water quality samples.

8.2.5 Debris Survey (Dredging) and Dock Encumbrances

The nature and extent of debris within the project site RAA will need to be considered in development and evaluation of sediment capping, dredging, and hydraulic containment technologies. Accordingly, a reconnaissance survey of the project area will be conducted to estimate the quantity and nature of surface debris. In addition, boring logs will be reviewed to identify subsurface debris encountered during both historical and the proposed site investigations. This information will be compiled for consideration during

the EE/CA and will also be useful for inclusion in the final design documents and remedial construction contract.

There are three large docks at the site, which have been out of service since 2001. The docks are primarily timber construction (but include four large concrete dolphins), supported by a dense network of timber, steel, and concrete pilings. Four stormwater outfall structures extend into the preliminary RAA boundary. The dock and outfall structures may impact the feasibility of sediment capping or dredging. The site characterization program will include a survey of these structures to verify their condition and catalogue the type and quantity of construction materials. Surveying may expand to include additional structures once the RAA has been established. It is anticipated that one or more of the docks may be removed as part of the removal action. If dredging becomes a viable option for the site, additional investigation of debris may be warranted during design or as part or condition of the construction specifications. A historical review will be conducted to determine the extent of building and demolition debris in the area currently occupied by the docks and outfalls. This information may assist in further characterizing the sediments in this area.

8.2.6 Recontamination Source Characterization

Remedial measures for upland source control should be evaluated and considered effective before implementation of the removal action for those COIs that could recontaminate sediments. Upland source control work is under way and is being evaluated through an ongoing monitoring program. A groundwater monitoring program is an integral element of each of the upland remedial measures. Monitoring plans to establish source control effectiveness are provided in the IRM work plans for hexavalent chromium reduction (ERM 2005b) and *in situ* persulfate oxidation (ERM 2005c). Additional monitoring will also be conducted within the in-water portion of the site at a later date, after source control has been completed and upland groundwater monitoring shows a significant reduction in COIs. TZW monitoring offshore may includeTridentUltraSeep® or other technologies which were shown to be effective in the Portland Harbor RI groundwater monitoring study (Integral 2005a).

In addition, seep reconnaissances will be conducted during all field activities in support of the RA characterization and EE/CA. If active seeps are observed, representative samples will be collected and analyzed for COIs.

Finally, recontamination from potential upland sources will be evaluated for each remedial alternative in the EE/CA (refer to previous sections).

Upland source control will be required to achieve RAOs 6-7.

9 PROJECT SCHEDULE

A schedule for the RA project is outlined in the AOC Appendix B (SOW) and includes the following:

Schedule of Project Deliverables (from AOC Statement of Work)		
EE/CA Work Plan	Draft EE/CA Work Plan Final EE/CA Work Plan	Within 90 days after effective date of AOC. Within 30 days after receipt of EPA comments on draft.
Upland Source Control	Upland Source Control Evaluation Report	Evaluation of upland source control will be completed in accordance with the schedule in the final EE/CA work plan.
Removal Action Area Characterization Report	Draft Removal Action Area Characterization Reports Final Removal Action Area Characterization Report	Within 150 days after EPA approval of the EE/CA work plan unless otherwise approved in the schedule in the final EE/CA work plan if adequate justification is given and is approved by EPA. Within 30 days after receipt of EPA comments on draft report.

Schedule of Project Deliverables (from AOC Statement of Work)		
EE/CA Report	Technical Briefing on Proposed Remedial Alternatives	Within 30 days after approval of the Final Removal Action Area Characterization Report by EPA.
	First Draft EE/CA	Within 90 days of the Technical Briefing on Proposed Removal Alternatives.
	Second Draft (Public Review) EE/CA	Within 60 days after receipt of EPA comments on first draft EE/CA.
	Final EE/CA	Within 60 days after receipt of EPA comments on second draft EE/CA.
Biological Assessment and 404 Memorandum	Draft Biological Assessment and Draft Clean Water Act Section 404 Memorandum	Submitted with draft EE/CA
	Revised Biological Assessment and Revised Clean Water Act Section 404 Memorandum	Submitted with revised draft EE/CA, within 60 days after receipt of EPA comments on first draft EE/CA.
	Draft Final BA	If the ESA agencies determine that additional design information is necessary for a final BA, then a draft final BA shall be due as determined by the ESA agencies.

Schedule of Project Deliverables (from AOC Statement of Work)		
Project Design Documents	Conceptual (30 percent) Design	Within 90 days of EPA signature of the Action Memorandum.
	Prefinal (90 percent) Design	Within 90 days after receipt of EPA comments on conceptual design.
	Final (100 percent) Design	Within 60 days after receipt of EPA comments on prefinal design. The above deadlines may be modified in accordance with the schedule in the EE/CA final report if adequate justification is given and is approved by EPA.
Removal Action Work Plan	Draft Removal Action Work Plan	Within 60 days after EPA approval of the Contractor or in accordance with the schedule in the 100% design deliverable, if changes are justified in the document and approved by EPA.
	Final Removal Action Work Plan	Within 30 days after receipt of EPA comments on draft Removal Action Work Plan.
Implementation of Removal Action	Notification of Removal Action Start	Provide notification to EPA 30 days prior to initiation of Removal Action fieldwork to allow EPA to coordinate field oversight activities.
	Removal Action Start	30 days after Notification Removal Action

Schedule of Project Deliverables (from AOC Statement of Work)		
Removal Action Completion Report	Draft Removal Action Completion Report	Within 60 days after completion of Removal Action (construction phase).
	Final Removal Action Completion Report	Within 30 days after receipt of EPA comments on Draft Removal Action Completion Report.
Long-Term Monitoring and Reporting Plan	Draft Long-Term Monitoring and Reporting Plan	Within 60 days after EPA approval of the Final Design.
	Final Long-Term Monitoring and Reporting Plan	Within 60 days after completion of the removal action and receipt of EPA comments.
	Monitoring Data Reports	Schedule to be proposed by Respondent in the Long-Term Monitoring and Reporting Plan.

The project coordinators (for both LSS and EPA) will be responsible for overseeing implementation of the AOC and meeting the schedule for project deliverables.

9.1 SUMMARY OF MAJOR MILESTONES

Arkema and EPA entered into an AOC on June 27, 2005, which represents the first major milestone for the project. Once the AOC was signed, a review of existing studies was initiated by Arkema and its consultant to identify data gaps. This information shaped the development of the investigation program and the development of the draft EE/CA work plan. The draft EE/CA work plan was submitted to EPA and stakeholders (the government team) on September 26, 2005, for review and comment. Arkema received more than 500 comments on the draft work plan from the government team on November 1, 2005. Arkema and the government team attempted to resolve the comments; however, Arkema invoked dispute resolution for selected comments in January 2006. Arkema and the government team entered into informal dispute resolution and on March 3, 2006, came to an agreement for completion of the final EE/CA work plan. A schedule of interim deliverables was submitted by LSS and agreed to by the government team. This revised work plan incorporates responses to comments received

from the government team on November 1, 2005, and subsequent submittals. Responses to the November 1, 2005 directed changes and comments are provided in Appendix I. Agency approval of the final EE/CA work plan represents the second major milestone for the project.

The EE/CA report will be produced following completion of the site characterization study and the removal action area characterization report (third major milestone). The EE/CA report will include the critical environmental evaluation (including evaluation of cleanup levels) for project decision-making and selection of a preferred cleanup action for the RAA. The final EE/CA represents the fourth major milestone in the project. The final EE/CA is tentatively scheduled for completion in April 2008. The fifth major project milestone is EPA issuance of the action memorandum estimated for completion in October 2008. A preliminary biological assessment (BA) and 404 Memorandum will be submitted with the EE/CA. The final BA and 404 Memorandum will be completed contemporaneously with the project design.

Other major milestones on the project include the completion of project design documents, implementation of the removal action, and the preparation of the removal action completion report. Actual implementation of the removal action is tentatively scheduled for 2010. An estimate of completion for these major project milestones will be provided in the final EE/CA.

The timing of these major milestones is shown graphically in Figure 9-1. In producing this schedule, assumptions were made about the period of time required for EPA review of LSS documents and for coordination of in-water work with the fish window. These review periods and fish-window requirements are not defined in the AOC.

9.2 INTEGRATION AND TIMING OF UPLAND SOURCE CONTROL MEASURES

Appropriate upland source control will be completed before or soon after the final EE/CA. A condition of the SOW to the AOC requires LSS to continue to work under DEQ supervision on upland source control actions. The SOW states that the goal is for significant upland sources to be controlled to the greatest extent practicable before or during implementation of the removal action such that significant post-removal action recontamination is not predicted.

Currently, there are five primary upland source control measures that are ongoing at the Arkema site:

- *In Situ* Sodium Persulfate IRM
- DNAPL Remediation IRM

- Hexavalent Chromium Reduction IRM
- Perchlorate IRM
- Stormwater IRM.

The status and schedule for evaluation of each of these source control actions is described below.

9.2.1 *In Situ* Sodium Persulfate IRM

Bench- and pilot-scale studies were conducted to determine the effectiveness of persulfate injection for the *in situ* treatment of MCB and DDT and metabolites in the groundwater plume located in the Acid Plant area. Persulfate injections were found to be effective, and full-scale persulfate injections were implemented in July 2005. Additional *in situ* persulfate treatment injections are scheduled once DNAPL isolation has occurred (see discussion in Section 9.2.2 below). Additional injections are anticipated to occur in 2007, and, if needed, in 2008.

9.2.2 DNAPL Remediation IRM

A pilot-scale study was conducted to evaluate the effectiveness of air sparging and soil vapor extraction (AS/SVE) to treat dissolved and NAPL associated with the MPR pond and trench in the Acid Plant area. Full-scale implementation of the AS/SVE system occurred between December 2004 and June 2006. The effectiveness of the AS/SVE system was curtailed by the presence of a larger NAPL mass than had previously been identified in the MPR pond and trench area.

LSS is currently preparing a work plan for the isolation and treatment of the DNAPL. The objective of the work plan will be to isolate the DNAPL (i.e., with a sheet pile wall) so that the DNAPL will not be in contact with the immediately surrounding groundwater and DNAPL treatment can occur on a time frame independent of other upland source control measures IRMs. Once DNAPL isolation occurs in late 2006 or early 2007, persulfate injections (see Section 9.2.1) can resume in the remainder of the MCB and DDT groundwater plume.

9.2.3 Hexavalent Chromium Reduction IRM

A pilot-scale study was conducted to determine whether the injection of calcium polysulfide would be effective at immobilizing hexavalent chromium in groundwater from the Chlorate Plant area. The pilot-scale study showed calcium polysulfide injection to be effective. Full-scale implementation of calcium polysulfide injection was

implemented in June 2005 and November 2005, and monitoring continued through April 2006.

9.2.4 Perchlorate IRM

Bench-scale studies of *in situ* anaerobic bioremediation of perchlorate were conducted from December 2003 through March 2006. On the basis of the bench-scale tests, an active (groundwater and nutrient recirculation system) enhanced *in situ* bioremediation has been recommended for the perchlorate groundwater plume. In addition, for the active approach, a pilot test will be performed for a passive, enhanced, *in situ*, anaerobic bioremediation. Pilot–testing of the perchlorate *in situ* bioremediation is scheduled for late 2006 and 2007, and a final pilot-scale perchlorate bioremediation report will be submitted by October 2007. Full-scale implementation of perchlorate bioremediation is currently scheduled for 2008.

9.2.5 Stormwater IRM

Stormwater monitoring data have shown that COIs are present in stormwater at concentrations exceeding JSCS criteria and requiring source control measures. A final stormwater IRM work plan was submitted to DEQ in June 2006. In 2006, best management practices, supplemental source control sampling, and a stormwater feasibility study and design will be implemented. Implementation of the stormwater IRM is currently scheduled for late 2006.

9.2.6 Source Control Evaluation and Timing

Monitoring is an element of each of the source control actions summarized above. For the groundwater IRMs, monitoring data from riverbank wells downgradient from each of these source control measures will be used in the source control evaluation. For the stormwater IRM, monitoring data from outfalls to the Willamette River will be used in the source control evaluation. To determine source control effectiveness for groundwater, time-series plots of groundwater chemical concentrations will be prepared to evaluate contaminant reduction trends. In addition, groundwater and stormwater monitoring data will also be compared to JSCS criteria to determine whether there is a reduction in the priority level of the site (i.e., medium or low priority).

The evaluation of upland source control actions for all COIs will be undertaken during preparation of the EE/CA in order to determine whether source control will be accomplished prior to the removal action implementation. If during the EE/CA evaluation, it is determined that source control will not be sufficient to ensure insignificant post-removal action recontamination in one or more of the IRM treatment areas, the EE/CA will include an evaluation of hydraulic control measures.

LSS's upland source control activities are targeted for substantial completion by 2008. The majority of the work anticipated under the groundwater and soil IRMs will be complete or nearly complete by that date. The goal of the ongoing upland *in situ* groundwater source control IRMs is to achieve the chronic water quality criteria for the Willamette River in monitoring wells adjacent to the riverbank. The initial source control evaluation report will be completed in September 2007. If the IRMs have not fully achieved the goal but are showing a continuing trend towards achieving upland source control, additional work may be scheduled in late 2007 and 2008 to complete source control such that recontamination of a sediment remedy is not anticipated. The evaluation of upland source control activities is an ongoing process that will extend through 2009. If it is determined that upland source control efforts are not on track to prevent unacceptable recontamination of sediment, the time period for implementation of hydraulic containment measures would be the first order of business of the removal action implementation in 2010.

Some constituents on the Arkema site, such as chloride, are highly soluble and will pass through sediments. Upland sources of chloride, salt and brine, were removed from the plant site soon after plant shutdown in 2001. Monitoring of chloride concentrations in plant groundwater since plant shutdown has shown a continuing decrease in chloride concentrations. Arkema is not anticipating upland source control for chloride and proposes to continue to monitor the decrease of concentrations. Perchlorate is also not anticipated to adsorb onto sediments and should not directly impact the timing of the in-water remedy.

9.3 INTEGRATION OF SELECTED ARARS EVALUATIONS IN PROJECT SCHEDULE

EPA has requested that LSS provide detailed information on the following ARAR evaluations:

1. 401 Water Quality Certification
2. Clean Water Act 404(b)(1)
3. Endangered Species Act, Section 7
4. Others to be identified.

This section summarizes the information needs required to perform the ARARs analysis for the first three ARARs listed above. No other ARARs have been identified that require discussion at this time.

9.3.1 401 Water Quality Certification

EPA will issue a 401 water quality certification for the preferred alternative. Water quality testing and modeling, as specified in Section 8 of this work plan, will be utilized to design a water quality monitoring program and recommend performance standards for the preferred alternative. This information will be submitted with the draft EE/CA report.

9.3.2 Clean Water Act 404(b)(1)

A dredge/fill evaluation is required according to Section 404(b)(1) of the Clean Water Act. The draft 404 evaluation will be completed for the preferred alternative and will be submitted with the draft EE/CA work plan. Once a preferred alternative is selected and EPA issues an action memorandum for the site, the 404 evaluation can be finalized.

9.3.3 Endangered Species Act, Section 7

A draft BA will be prepared and submitted with the draft EE/CA. The BA memorandum requires a review and compilation of all information relevant to exiting threatened and endangered species and their habitat relevant to the RAA, including consultations with the relevant agencies. The BA establishes the baseline habitat conditions and considers the effects of the removal action utilizing the preferred alternative. The BA makes a determination regarding the effects of the preferred alternative on species and their habitat. Once a preferred alternative is selected and EPA issues an action memorandum for the site, the BA can be finalized and submitted with the removal action design.

10 PROJECT TEAM AND RESPONSIBILITIES

Figure 10-1 shows the team and organization for the removal action; the roles of the team members are discussed below.

Legacy Site Services, LLC (LSS). The project coordinators (for both LSS and EPA) will be responsible for overseeing implementation of the AOC, including the development of the EE/CA. **Todd Slater** is the designated LSS project manager and will coordinate all activities with the EPA and DEQ project coordinators. Mr. Slater will be responsible for contracting with and directly supervising the environmental consultant(s) who will conduct the field, laboratory, analysis, and reporting tasks for the EE/CA. He will direct the consultant(s) on a day-to-day basis and provide primary review of all reports and other work products. Mr. Slater will also coordinate with EPA regarding the AOC for the removal action of the site.

Integral Consulting Inc. Integral was selected by LSS to conduct the EE/CA for the Portland Harbor site and is responsible for written work products, implementation of the field program, including field sampling, and laboratory analysis, data analysis, and reporting. **David Livermore**, a registered geologist in Oregon, is the Integral principal-in-charge and will serve as the point of contact for LSS. He will be responsible for implementing and executing the technical, quality assurance, and administrative aspects of the EE/CA, including the overall management of the project team. Mr. Livermore will be responsible for the quality and timeliness of Integral documents. Mr. Livermore will be assisted by **Mark Herrenkohl**, the EE/CA task manager. Mr. Herrenkohl is accountable for ensuring that the EE/CA is conducted in accordance with applicable plans and guidelines, including the work plan, SAP, QAPP, and HASP. He will communicate all technical, quality assurance, and administrative matters to the Integral and LSS project managers. He will ensure that any deviations from the approved work plans are documented, communicated to LSS, and approved before implementation.

The project engineer, **Reid Carscadden, P.E**., will assist the project and task managers with the EE/CA activities of the project, including an evaluation of remediation alternatives for the site.

Les Williams, Ph.D., will lead the ecological and human health risk screening for the Arkema site.

The overall management of the project-specific quality assurance activities is the responsibility of the quality assurance manager, **Laura Jones**. Ms. Jones is responsible for implementation of site-specific quality assurance activities, including field and laboratory quality control. In addition, Ms. Jones will coordinate with the Integral project and task

managers and other project staff, as applicable, during the reduction, review, and reporting of analytical data.

The Integral health and safety manager, **Eron Dodak**, a registered geologist in Oregon, is responsible for the implementation of the site-specific HASP. Mr. Dodak, who will also be the field operations manager, will advise the project staff on health and safety issues, conduct health and safety training sessions, and monitor the effectiveness of the health and safety program conducted in the field.

As the field operations manager, Mr. Dodak, will be responsible for managing and supervising the field investigation program and providing consultation and decision-making on day-to-day issues relating to the sampling activities. He will monitor the sampling to ensure that operations are consistent with plans and procedures and that the data acquired meet the analytical and data quality needs. When necessary, Mr. Dodak will document any deviations from the plans and procedures for approval. He will be assisted in the field by other technical personnel to be determined.

The services of several subcontractors (e.g., drilling contractor, land surveyors, laboratory services) will be necessary for the performance of the field investigation and implementation of project objectives. The EE/CA task manager, with assistance from the field manager, as necessary and appropriate, will be the primary liaison between Integral, the Arkema project manager, and each of the subcontractors. Subcontractors are responsible for performing work according to the requirements in this work plan.

Columbia Analytical Services, Inc. (CAS) of Kelso, Washington, will perform the chemical and physical analyses of water, soil, and sediment samples collected for this project. Northwest Aquatic Services, Inc. (NAS) of Newport, Oregon, will analyze the bioassay samples. The drilling and surveying contractors have not yet been determined. The project manager for each subcontractor will be responsible for coordination with Integral, FSP/QAPP implementation, and analytical data quality.

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