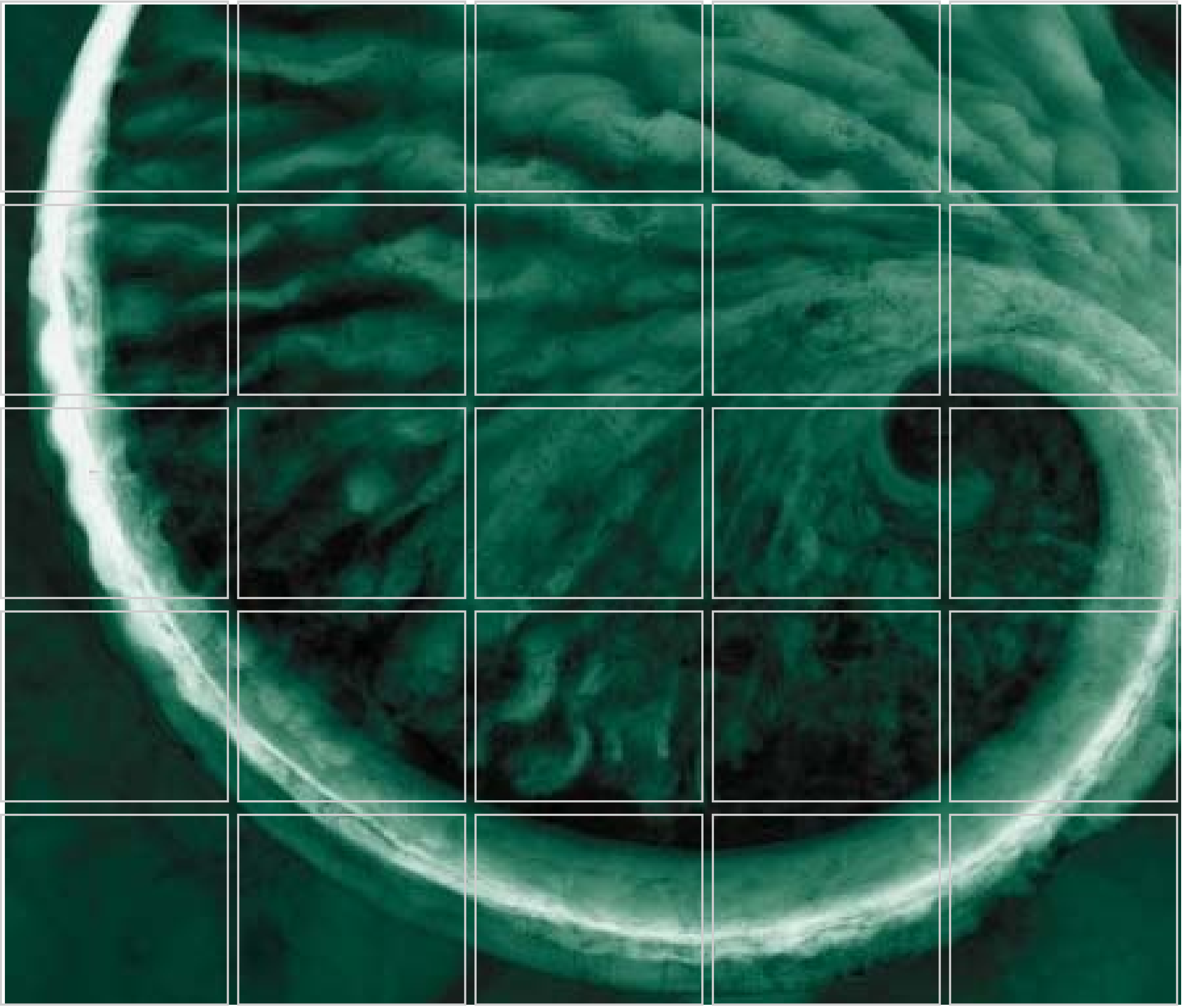

Upland Remedial Investigation Report Lots 3 & 4 and Tract A - Revision 1

Arkema, Inc.
Portland Facility

December 2005

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Upland Remedial Investigation Report Lots 3 & 4 and Tract A - Revision 1

Arkema, Inc.
Portland, Oregon

December 2005

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REGISTERED GEOLOGIST'S CERTIFICATION

I, Robert G. Carson, do certify that to the best of my knowledge the data, information, and interpretation presented in this Remedial Investigation report for the Arkema, Inc. Portland, Oregon facility is accurate and complete. In addition, I have reviewed and verified the authenticity of the information presented in this Remedial Investigation report.

Robert G. Carson III

1 December 2005

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LIST OF ACRONYMS

ARAR	Applicable or relevant and appropriate requirements
AST	Aboveground storage tank
ASTM	American Society for Testing and Materials
bgs	Below ground surface
BPA	Bonneville Power Administration
BTEX	Benzene, toluene, ethylbenzene, and xylene
CAS	Calcium polysulfide
CFR	Code of Federal Regulations
cfs	Cubic feet per second
COI	Constituent of interest
CPT	Cone penetrometer testing
CSM	Conceptual site model
DDE	1,1-dichloro-2,2- bis(p-chlorophenyl)ethylene
DNAPL	Dense non-aqueous phase liquid
ERM	ERM-West, Inc.
ESA	Environmental Site Assessment
ESR	Environmental Summary Report
°F	Degrees Fahrenheit
FS	Feasibility Study
GLISP	Guild's Lake Industrial Sanctuary Plan
HSA	Hollow-stem auger
IDR	Interim Data Report
IDW	Investigation-derived waste
IRM	Interim Remedial Measure
LOF	Locality of facility
MCB	Monochlorobenzene (or chlorobenzene)
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MIP	Membrane interface probe

MPR	Manufacturing process residue
MSB	Morrison Street Bridge
NAPL	Non-aqueous phase liquid
NGVD	National Geodetic Vertical Datum
NPDES	National Pollution Discharge Elimination System
NRWQC	National Recommended Water Quality Criteria
OAR	Oregon Administrative Rule
OCTF	Old Caustic Tank Farm
ODEQ	Oregon Department of Environmental Quality
ORP	Oxidation/reduction potential
PA	Preliminary Assessment
PAH	Polynuclear aromatic hydrocarbons
PBS	PBS Environmental
PCB	Polychlorinated biphenyls
p-CBSA	p-chlorobenzenesulfonic acid
PEC	Probable effect concentration
pH	Acidity/alkalinity
PID	Photoionization detector
PRG	Preliminary Remediation Goal
PVC	Polyvinyl chloride
QA	Quality assurance
RBC	Risk-based concentration
RCRA	Resource Conservation and Recovery Act
Rf	Response factor
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SVOC	Semivolatile organic compound
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total dissolved solid
TLC	Thin-layer chromatography
TOC	Total organic carbon

TPH	Total petroleum hydrocarbons
U.S.	United States
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VCP	Voluntary Cleanup Program
VES	Vapor extraction system
VOC	Volatile organic compounds
WBZ	Water-bearing zone
WQC	Water Quality Criteria
μg/L	Micrograms per liter

EXECUTIVE SUMMARY

A multi-phase Remedial Investigation (RI) was performed at the Arkema Inc., (Arkema) property adjacent to the Willamette River in Portland, Oregon (the "facility" or "Site") between September 1998 and March 2005. In response to environmental impacts observed in prior investigations, Arkema and the Oregon Department of Environmental Quality (ODEQ) entered into a Voluntary Agreement in August 1998 to address impacts to environmental media associated with the manufacture of DDT in the Acid Plant Area (the area of former pesticide manufacturing operations). As part of the Voluntary Agreement, Arkema prepared the *ATOFINA Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (the "RI/FS Work Plan"; Exponent 1998). The RI/FS Work Plan was approved by ODEQ in a letter dated 5 February 2003. The RI was conducted in accordance with the approved Work Plan.

Site Location and Description

The Site is located at 6400 N.W. Front Avenue in Portland, Oregon, in the Guild's Lake Industrial Sanctuary, zoned and designated "IH" for heavy industrial use. The Arkema facility occupies approximately 55 acres along the west bank of the Willamette River, and is divided into four upland lots (Lots 1 through 4) and one tract (Tract A, along the riverbank). Lots 3 and 4 were developed for manufacturing operations, while Lots 1 and 2 were left mostly undeveloped. All manufacturing activities took place on Lots 3 and 4; no manufacturing activities were conducted on Lots 1 and 2. Tract A is a narrow strip of land between the top of the riverbank and the river's edge (mean high water line). In 2001, the plant ceased operations and the facility was demolished concurrent with RI activities.

In an effort to expedite regulatory closure of Lots 1 and 2, Arkema prepared the *Environmental Summary Report, Lots 1 and 2* (the "ESR"; ERM-West, Inc. [ERM] 2003a). The ESR provided a focused RI/FS summary based on available data. Currently, additional investigative work is being conducted on Lots 1 and 2 based on ODEQ's review of the ESR. The focus of this report is on RI activities carried out on Lots 3 and 4 and Tract A.

Scope of Remedial Investigation

The initial focus of the RI was on the Acid Plant Area, where DDT was manufactured from 1947 to 1954. Over time, the scope of the RI was expanded to examine environmental conditions site-wide. The expansion in scope included investigations of the Chlorate Plant Area, where hexavalent chromium was used. Additional investigations were carried out in the Salt Pad area, the Old Caustic Tank Farm, former Ammonia Plant area, former transformer areas, the Bonneville Power Administration (BPA) Main Substation, and the Storm Water Drain System.

Constituents of Interest

Based on historical operations, the primary constituents of interest (COIs) in the Acid Plant Area include:

- Organochlorine pesticides (DDT and co-metabolites DDD and DDE);
- Volatile organic compounds (VOCs) (primarily chlorobenzene [MCB] and chloroform); and
- Perchlorate.
- Potential sources of these COIs within the Acid Plant Area include:
- The former Manufacturing Process Residue (MPR) Pond and Trench;
- The DDT Process Building;
- The MCB Recovery Unit;
- The DDT Dry Storage Area;
- Possible DDT Loading Areas;
- The fill area between the river and the MPR Pond and Trench; and
- Surface soil outside of the above areas.

Based on historical operations, primary COIs in the Chlorate Plant Area include:

- Hexavalent chromium;
- Perchlorate; and
- Chloride.

Potential sources of these COIs within the Chlorate Plant Area include:

- The Chlorate Cell Room;
- The Chlorate Process Building;
- The Chlorate Warehouse; and
- The Chlorate Tank Farm.

The following additional areas (and potential COIs) were investigated as part of the RI:

- Salt Pads (chloride);
- The Old Caustic Tank Farm (sodium hydroxide, petroleum hydrocarbons, and pesticides);
- The former Ammonia Plant (aqueous ammonia);
- Former Transformer Pads (polychlorinated biphenyls [PCBs]);
- The BPA Main Substation (PCBs); and
- The Storm Water Drain System (pesticides, metals, VOCs, semi-volatile organic compounds [SVOCs], perchlorate, and chloride).

Soil, groundwater, and storm water samples were collected to evaluate the geologic and hydrogeologic properties and the nature and extent of contamination in these areas. A total of 395 soil borings were advanced to characterize lithology, assess aquifer hydrogeologic properties, analyze soil and groundwater chemistry, and install monitoring wells. In addition, 262 groundwater samples were collected from 48 soil borings and 55 monitoring wells to characterize the nature and extent of groundwater impacts, and 55 storm water samples were collected to evaluate storm water quality. Both field and laboratory analytical techniques were used to assess the nature and extent of impacts and refine the conceptual model developed for the Site.

Site Geology and Hydrogeology

Results of the RI indicated the following regarding Site geology:

- The surficial geology consists of fill and alluvial deposits of the Willamette River;

- Fill materials occur from the surface to depths of approximately 25 feet below ground surface (bgs) in some areas along the river, and consist of clayey silt to silty sand with occasional fragments of wood, brick, metal piping, and asphalt;
- Native soils generally consist of laterally discontinuous, alternating layers of sand with varying amounts of silt and thinner silt layers with varying amounts of fine sand;
- Underlying the deepest silt layer, at a depth of approximately 35 feet, is a characteristic black to dark gray-brown sand layer; and
- Columbia River Basalt bedrock occurs below the fill and alluvium at depths of 49 to 55 feet bgs.

Groundwater occurs in four distinct zones, referred to as the shallow, intermediate, deep, and basalt groundwater zones. The shallow and intermediate groundwater zones are separated by a 6-inch to 4-foot thick silt layer present at approximately 35 to 36 feet bgs. This silt layer appears to be competent in the Acid Plant Area, , but it becomes discontinuous toward the east side of the Chlorate Plant Area.

In general, the depth to groundwater increases from west to east (i.e., toward the river) across the Site. Groundwater occurs at depths ranging from 6 to 12 feet bgs along the western edge of the Site, and from 14 to 32 feet bgs along the riverbank. The water table fluctuates seasonally, rising during periods of high rainfall (i.e., late fall through spring), and falling during periods of low rainfall (i.e., summer through early fall). The inferred groundwater flow direction is generally toward the northeast, in the direction of the Willamette River. Results of tidal influence monitoring suggest that river fluctuations are propagated inland through the intermediate and deep groundwater zones, but do not significantly alter the groundwater flow system at the Site.

Land and Beneficial Water Use Determination

A land and beneficial water use determination in the locality of the facility (LOF) was conducted as part of the RI. For the purposes of the upland investigation and this report, the LOF is assumed to be the Arkema property and the riverbank to the mean high Willamette River water level. Based on existing City of Portland planning documents, the future land use in the LOF will be industrial. The beneficial use for groundwater in the LOF is recharge to the Willamette River and the basalt aquifer.

Nature and Extent of Contamination

Acid Plant Area

Preliminary screening levels were developed for COIs in all media for evaluation of laboratory analytical data. The screening levels were derived from several sources, including: USEPA Region 9 PRGs, USEPA Sediment Quality Advisory Levels, USEPA National Recommended Water Quality Criteria, ODEQ Level II Ecological Screening Level Values, ODEQ Risk-Based Concentrations, ODEQ Water Quality Guidance Values, National Oceanic and Atmospheric Association (NOAA) Upper Effects Threshold values, and Probable Effect Concentrations (MacDonald et al. 2000).

DDT was observed in soil samples at concentrations up to 150,000 milligrams per kilogram (mg/kg) in the Acid Plant Area. The preliminary screening level for DDT is 7 mg/kg (USEPA Region 9 PRG). In general, the lateral extent of DDT (and its metabolites, DDD and DDE) is greatest in shallow soils and decreases with depth. Also, concentrations are generally greatest in shallow soils (up to 1 foot bgs) and decrease with depth. Although a significant amount of DDT-impacted soil was removed during a soil removal interim remedial measure (IRM), elevated DDT concentrations (up to 63,000 mg/kg) remain at the Site. The footprint of DDT-impacted soil is generally bounded north-south by the No. 2 and No. 1 Docks, and east-west by the Willamette River and the former Caustic Process Building.

MCB was observed locally at low concentrations in shallow and near-surface soil (0 to 4 feet bgs) in the Acid Plant Area. No shallow or near-surface soil contained MCB at concentrations greater than the preliminary screening level of 530 mg/kg. MCB was observed at greater concentrations (up to 66,600 mg/kg) in soil below 4 feet bgs, primarily in the former MCB Recovery Unit area. The highest MCB concentrations were observed just above the silt layer present at approximately 7.5 to 8 feet bgs in the former MCB Recovery Unit area. Although some MCB-impacted soil was removed during the IRMs, residual MCB concentrations above the preliminary screening level still exist in unsaturated soils below 14 feet bgs in the Acid Plant Area.

Pesticides, SVOCs and metals were detected in riverbank soil and sediment samples. DDT, DDD, and DDE impacts were observed in nearly all of the samples, at concentrations up to 120, 1.7, and 3.5 mg/kg, respectively. A few SVOCs were detected in one riverbank soil sample and one sediment sample, at concentrations up to 2 mg/kg. Only one metal (lead) was detected in a riverbank soil sample above its preliminary screening level, at a concentration of 2,090 mg/kg.

DDT and its metabolites were detected in shallow- and intermediate-zone groundwater downgradient of the Acid Plant Area. Due to potential cosolvency with MCB, DDT has been observed at concentrations up to 120,000 micrograms per liter (μg/L). The highest concentrations of DDT were observed in the shallow groundwater zone proximal to the former MPR Pond and Trench. DDT concentrations in the intermediate, deep, and basalt groundwater zones are significantly lower than the shallow zone concentrations.

DDD and DDE have been observed in shallow-zone groundwater at concentrations up to 6,400 and 2,700 μg/L, respectively. DDD concentrations were similar in magnitude or approximately one order of magnitude greater than total DDT concentrations in several of the monitoring wells, primarily the riverbank wells downgradient of the former MPR Pond. DDE concentrations were similar in magnitude or approximately one order of magnitude less than total DDT concentrations in most of the monitoring wells. The vertical and lateral extent of groundwater impacts were similar for DDT and its metabolites.

VOCs (primarily MCB) were detected in Site groundwater, primarily in and downgradient of the Acid Plant Area. The maximum MCB concentration detected in the shallow zone (260,000 μg/L) was approximately one order of magnitude greater than the maximum concentration detected in the intermediate zone (38,000 μg/L). Additionally, the lateral extent of MCB impact is greater in the shallow zone. MCB was also detected in deep- and basalt-zone monitoring wells, at concentrations three to five orders of magnitude less than the concentrations observed in the shallow zone. Since MCB is present as residual dense non-aqueous phase liquid (DNAPL) in saturated soils in the vicinity of the Acid Plant Area (see below), these results suggest that the silt layers separating the groundwater zones have impeded significant downward transport of MCB.

A two-phased DNAPL investigation was carried out to characterize the nature and extent of residual MCB DNAPL in the vicinity of the Acid

Plant Area. The investigation concluded that the residual DNAPL is generally confined to soils comprising the lower 6 feet of the shallow groundwater zone. Residual DNAPL has also been detected at intermediate zone depths directly below the former MPR Pond, and in well borings adjacent to the river. Field observations suggest that the residual DNAPL exists as ganglia in the subsurface, and thus is not readily mobile.

Chlorate Plant Area

Total chromium was observed in soil at concentrations up to 1,600 mg/kg in the Chlorate Plant Area.. The highest chromium concentrations are found within the footprint of the Chlorate Cell Room. There were no detections of total or hexavalent chromium above preliminary screening levels in soil outside the footprint of the Chlorate Cell Room.

Total and hexavalent chromium were detected in shallow-, intermediate-, and deep-zone groundwater samples collected in the vicinity of the Chlorate Plant Area. The highest total and hexavalent chromium concentrations detected in shallow-zone monitoring wells were 21 and 14.9 mg/L, respectively. Chromium also was detected in downgradient intermediate- and deep-zone monitoring wells, at concentrations up to 0.992 and 1.15 mg/L, respectively. This suggests that dissolved chromium has moved downward as it migrated downgradient from the Chlorate Plant Area.

Perchlorate was detected in shallow- and intermediate-zone groundwater, primarily in the Chlorate Plant Area, but also in a limited area downgradient of the Acid Plant Area. Concentrations up to 290 and 200 mg/L, respectively, were observed in the shallow and intermediate groundwater zones in the Chlorate Plant Area. Perchlorate concentrations detected in the Acid Plant Area were approximately one to two orders of magnitude lower than the concentrations observed in the Chlorate Plant Area.

Site-wide COIs/Other Areas of Interest

Chloride was observed in groundwater at all wells during all sampling events. Chloride is a naturally occurring ion in groundwater. However, elevated chloride concentrations were observed downgradient of the former Salt Pads, where salt was stockpiled and salt brine was produced.

Concentrations up to 190,000 mg/L, 31,000 mg/L, and 61,100 mg/L were observed in the shallow, intermediate, and deep groundwater zones, respectively. Chloride concentrations exist in all groundwater zones above the preliminary screening level of 230 mg/L. This is likely due the ubiquitous use of brine in the facility manufacturing processes. The highest chloride concentrations observed in the farthest upgradient shallow- and intermediate-zone monitoring wells were 303 mg/L and approximately 17.9 mg/L, respectively.

Ammonia was observed in groundwater samples collected from monitoring wells downgradient of the former Ammonia Plant at concentrations up to 19.7 mg/L. However, data from off-site wells and an upgradient direct-push groundwater sample indicate that ammonia has been detected upgradient of the Site at concentrations up to 34.5 mg/L. Consequently, the RI data suggest ODEQ's Contaminated Aquifer Policy applies to ammonia at the Site.

PCBs were detected in soil during a Phase II Environmental Site Assessment conducted by BPA in the BPA Main Substation. The BPA performed this investigation independent of the Arkema RI. PCBs were detected in shallow soil (0 to 5 feet bgs) at concentrations up to 1.25 mg/kg. In addition, petroleum hydrocarbons, polynuclear aromatic hydrocarbons, lead, DDT, and DDD were detected at low concentrations in soil samples collected in the substation area. The BPA excavated soil containing the highest observed concentrations of PCBs from the northwestern corner of the former substation.. Confirmation soil samples indicate that PCB concentrations up to 4.5 mg/kg remain on site within the former substation. Additionally, soil samples collected between the substation and N.W. Front Avenue indicate that PCB concentrations up to 0.91 mg/kg exist in this area.

Dissolved DDT was detected in five of eight storm water samples collected in the Acid Plant Area in 1999. Dissolved DDD and DDE were not detected in any of the eight samples. Total DDT, DDD, and/or DDE were detected in all but one of the eight storm water samples, suggesting that pesticide-containing particulate material was present in the storm water samples. Significant reductions in total DDT and metabolite concentrations in storm water were observed after the Phase I IRM was completed. Post-IRM concentrations of total DDT were approximately half of what had been previously observed, and DDT metabolite concentrations were approximately an order of magnitude less than previously-observed levels.

Organochlorine pesticides were detected in all four storm water outfalls throughout the 1-year storm water sampling program conducted between February 2004 and March 2005. This sampling was required by the National Pollutant Discharge Elimination System permit issued to Arkema in January 2004. Hexavalent chromium was detected in Outfall 004 in several of the monthly samples. Plant demolition activities were being carried out concurrently with the monthly monitoring. Several constituents exhibited temporary increases during this time, only to decrease again after demolition activities were complete.

Interim Remedial Measures

Arkema implemented several IRMs concurrent with the RI, as follows:

- A two-phase Soil Removal IRM to mitigate potential environmental impacts from elevated DDT concentrations in soil;
- Installation and operation of a soil vapor extraction system to reduce MCB concentrations in soil; and
- Three pilot studies and a bench-scale study to evaluate the effectiveness of potential remedial technologies.

The pilot studies were designed to address hexavalent chromium in groundwater in the Chlorate Plant Area, and elevated MCB concentrations and DNAPL in groundwater in the Acid Plant Area. The bench-scale study was implemented to evaluate the effectiveness of in situ anaerobic bioremediation for treating perchlorate in groundwater.

Summary

The RI has defined the nature and extent of most COIs in upland soil and groundwater at the Site. Nevertheless, further investigation is needed in some areas to complete the assessment. Ongoing IRMs (i.e., the *In Situ Air Sparging/Soil Vapor Extraction, Hexavalent Chromium Reduction, and Sodium Persulfate Oxidation IRMs*) have addressed many of the identified data gaps. The complete list of COIs identified in the RI will be screened further through the Source Control Evaluation process. The constituents that exist in Site media above Source Control Evaluation values will be further evaluated in the Baseline Risk Assessment, along with the source areas and potential transport pathways/receptors identified in the RI. Remedial alternatives for COIs/media posing unacceptable risks (as identified in the RI and Baseline Risk Assessment) will be evaluated in the Feasibility Study.

1.0 INTRODUCTION

The Arkema Inc. (Arkema), formerly ATOFINA Chemicals, Inc. (ATOFINA), property (the "facility" or "Site") is a former chemical manufacturing facility located adjacent to the Willamette River in the northwest industrial area of Portland, Oregon (Figure 1-1). The plant began operations at its current location in 1941 as a sodium chlorate plant. For the most part, the plant manufactured chlorine, sodium hydroxide, hydrogen, hydrochloric acid, and sodium chlorate. Other products and processes were added and discontinued over time: the insecticide 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane or dichlorodiphenyltrichloroethane (DDT) was manufactured at the plant between 1947 and 1954, ammonia was manufactured between the mid-1950's and 1990, and ammonium perchlorate was manufactured between 1958 and 1962. The plant is no longer operating as a manufacturing facility and has been decommissioned and demolished, with the exception of the main office building.

In June 1995, Elf Atochem requested a meeting with the Oregon Department of Environmental Quality (ODEQ) to discuss the DDT investigations and to submit an "Intent to Participate Form" for the ODEQ Voluntary Cleanup Program. In 1998, Arkema entered into a Voluntary Agreement (ODEQ No. ECVC-WMCVC-NWR-97-14, dated 26 August 1998) with the ODEQ to address impacts to environmental media associated with the manufacture of DDT in the Acid Plant Area and sediment in the Willamette River adjacent to the Site (*Voluntary Remedial Investigation/Feasibility Study Agreement for the Acid Plant Area Project* [ODEQ 1998a]). The Acid Plant Area has historically contained the majority of chemical manufacturing and processing activities (Elf Atochem 1999). As part of the Voluntary Agreement, Arkema prepared the *ATOFINA Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (the "RI/FS Work Plan"; Exponent 1998). The RI/FS Work Plan was approved by the ODEQ in a letter dated 5 February 2003.

Initial environmental investigations at the site focused on the former DDT manufacturing area in the Acid Plant Area. During the remedial investigation (RI), additional areas of potential environmental concern were identified at the Site. The scope of the RI was expanded to include these areas, in accordance with the RI/FS Work Plan.

The RI was conducted between September 1998 and March 2005 to supplement existing (i.e., pre-RI) Site data. The RI includes all of the investigative work through the completion of the monthly stormwater sampling in March 2005. However, additional investigative work continues to be conducted at the site through several interim remedial measures (IRMs). The IRMs are being implemented in accordance with ODEQ-approved work plans. Additional Site data and information is provided to ODEQ periodically through progress updates and comprehensive reports will be prepared and submitted to ODEQ upon completion of each IRM.

The RI/FS Work Plan included a scope of work for conducting both the human health and ecological risk assessments. Preliminary work for the human health and ecological risk assessments has been completed and was submitted to ODEQ under separate cover: the *Human Health Baseline Risk Assessment Scoping Document* (ERM 2004a) was submitted 26 May 2004 and the *Level I Site Ecology Scoping Report* (ERM 2005a) was submitted on 3 February 2005. The remaining risk assessment work will incorporate information and data presented herein and will be provided under separate cover.

The RI was conducted in accordance with Oregon Administrative Rule (OAR) 340-122-080 and the Voluntary Agreement.

1.1 PURPOSE OF REPORT

This RI report presents a comprehensive summary of environmental investigation activities conducted on Lots 3 and 4 and Tract A at the Site (Figure 1-2). Rationale, methodology, and results of the investigative activities are discussed. Data presented in the report comprise the complete data set for investigative work conducted at the Site, including work conducted prior to the execution of the scope of work defined in the RI/FS Work Plan (i.e., September 1998).

The overall objectives of the RI were to:

- Evaluate Site physical characteristics, including surface features and hydrogeology;
- Identify constituents of interest (COIs) related to former manufacturing activities at the facility;

- Delineate the nature and extent of COIs in soil, groundwater, and sediment;
- Evaluate ongoing or future COI migration pathways and receptors based on the physical features and processes identified at the facility;
- Summarize Site information to provide for evaluation of potential risks to human health or ecological receptors associated with COIs at the facility; and
- Provide a basis for conducting the Feasibility Study (FS).

1.2 SITE BACKGROUND

This section provides a brief description of the Site, information on the historical operations at the Site, and a general description of the physical setting of the Site. In this report, map directions given in the text are in reference to the layout of plant facilities rather than geographic directions, for consistency with usage at the Site as defined in the RI/FS Work Plan. For example, north (i.e., plant north) in the text and figures is equivalent to geographic northwest.

1.2.1 Site Description

The Site is located at 6400 N.W. Front Avenue in Portland, Oregon, along the west bank of the Willamette River, at approximately river mile 7.5 in the Guild's Lake Industrial Sanctuary (formerly the Northwest Portland Industrial Sanctuary), zoned and designated "IH" for heavy industrial use (Figure 1-1). The Site is bordered on the east by the Willamette River, on the south by CertainTeed Roofing Products Company, and on the north and west by Front Avenue (Figure 1-2). The Site occupies approximately 55 acres and is generally flat with surface elevations of approximately 25 to 38 feet National Geodetic Vertical Datum (NGVD) 1929. A majority of the Site is surrounded by steel security fencing.

The Arkema property is divided into four lots and one tract along the Willamette River bank (Figure 1-2). Manufacturing processes took place on the southern two lots at the Site (Lots 3 and 4) with the northern portion of the Site (Lots 1 and 2) left relatively undeveloped. All manufacturing activities took place on Lots 3 and 4, whereas no manufacturing activities were conducted on Lots 1 and 2. Tract A is a narrow strip of riverbank land between the top of the bank and the mean high water line, and extending from the northernmost property line to the southern area of the Salt Pads. The focus of this report is on RI activities carried out on Lots 3 and 4 and Tract A. Lots 3 and 4 comprise approximately two-thirds of the property (39 acres) and were developed with buildings, paved roads, rail spur access, and associated tanks and piping in support of manufacturing processes.

In an effort to expedite closure for the northern, undeveloped portion of the Site, Arkema prepared the *Environmental Summary Report, Lots 1 and 2* (ERM-West, Inc. [ERM] 2003a). The purpose of the Environmental Summary Report (ESR) was to support a "No Further Action" decision by the ODEQ for Lots 1 and 2. The ESR provided a focused Remedial Investigation/Feasibility Study (RI/FS) summary based on available data. The ESR is included as Appendix A to this RI report. Currently, additional investigative work is being conducted on soil and groundwater on Lots 1 and 2, based on ODEQ's review of the ESR. If the results of the additional investigative work on these lots indicate that potential risks exist to human health or the environment, Lots 1 and 2 may be included in the human health and ecological risk assessments for the remainder of the Site.

In 2001, the facility was shut down due to rising electricity costs. The plant was decommissioned and demolished in three phases over a 3-year period, concurrent with RI activities. Phase I consisted of removal of steel structures and tanks. Phase II involved demolition of Site buildings from Lot 3 and the northern portion of Lot 4. The Phase II demolition was performed in accordance with the ODEQ-approved *Phase II Demolition Work Plan*, dated 1 May 2003 and approved by the ODEQ on 9 May 2003 (ATOFINA 2003a). Phase III consisted of demolition of the remainder of Site buildings, with the exception of concrete slabs and foundations in the Acid Plant and Chlorate Plant Areas and was completed in January 2005. The Phase III demolition was performed in accordance with the ODEQ-approved *Phase III Demolition Work Plan*, dated 13 February 2004 (ATOFINA 2004), and approved on 3 March 2004. Concrete foundations in the Acid Plant and Chlorate Plant Areas were left in place to serve as a temporary environmental cap, in accordance with the *Phase III Demolition Work Plan* (ATOFINA 2004).

1.2.2 *Site Ownership History*

The facility started operations in 1941 to meet wartime needs for chlorate production in the western United States (U.S.). It was built by Pennsylvania Salt Manufacturing, which later became known as Pennwalt Corporation (Pennwalt).

In 1989, Societe Nationale Elf Aquitaine (ELF), an international manufacturer and distributor of petroleum, health care, and chemical products, purchased Pennwalt. Pennwalt's operations were combined with those of two other companies to form Elf Atochem North America, Inc., in 1990. In 2000, ELF merged with TOTALFINA to form TOTALFINA ELF and Elf Atochem became ATOFINA Chemicals, Inc. In 2004, ATOFINA Chemicals, Inc. became Arkema, Inc. Throughout this report the titles of referenced documents may refer to company names at the time of submittal. The facility is referred to as the Arkema facility or "Site" throughout this report.

1.2.3 *Site Operational History*

Before Pennsylvania Salt Manufacturing began construction of the facility in 1941, the property was primarily undeveloped. Aerial photographs and a property ownership map of the property before 1941 are included in Appendix B. A review of these documents indicated the following:

- On the 1910 property map, the property was owned by J. Frank Watson and the S. P. and S. Railway Company;
- In the 1923 aerial photograph, it appears that logging operations (i.e., removal of logs from the river) were taking place on the northern portion of the property, on current Lots 1 and 2, with the remainder of the facility undeveloped;
- In the 1936 aerial photograph, a road appears to cut northeast across the northern portion of the Site (Lots 1 and 2) and beneath the railroad bridge; and
- In the 1941 oblique aerial photograph, logging operations are visible at three docks on the northern portion of the Site (Lots 1 and 2) and just offshore along the entire riverbank. Construction of the Chlorate Plant foundation is evident in the foreground. Several cars and two small buildings are present along what is now Front Avenue. The buildings,

likely there for construction operations, are situated where the current front office is located.

Since 1941, various chemicals have been historically produced at the facility including: sodium chlorate, potassium chlorate, chlorine, sodium hydroxide, DDT, sodium orthosilicate, sodium hydroxide, magnesium chloride hexahydrate, ammonia, ammonium perchlorate, sodium perchlorate, and hydrochloric acid. Most recently, the facility was an operating chloro-alkali plant until the plant shut down in 2001.

A majority of the RI work was conducted in the Acid Plant and Chlorate Plant Areas, with additional investigative work conducted in the Salt Pad Area, the Old Caustic Tank Farm, the Former Ammonia Plant, the Bonneville Power Administration Main Substation, various transformer pads, and in the Storm Water Drain System (Figure 1-3). The following paragraphs provide a description of the operational histories of these areas.

A more detailed description of these activities is located in the *Preliminary Assessment for Elf Atochem North America* (the "PA"; Elf Atochem 1999) and the *Phase II Preliminary Assessment for Elf Atochem North America* (the "Expanded PA"; Elf Atochem 2000). The PA and Expanded PA have been included in this report as Appendices C and D, respectively.

1.2.3.1 Acid Plant Area Operational History

Over the operational history of the plant, the following activities took place in the Acid Plant Area:

- Manufacturing of DDT (1947 to 1954);
- Grass defoliant manufacturing (chlorination of acetone with chlorine gas; only a few months in 1950);
- Manufacturing of ammonium perchlorate (reaction of sodium perchlorate with ammonium chloride; 1958 to 1962); and
- Manufacturing of hydrochloric acid, which is how the area became known as the Acid Plant Area (1966 to 2001).

The area designated as the Acid Plant Area was used for all materials-handling operations associated with the manufacturing and handling of

DDT and associated wastes. 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 1-4). Manufacturing process residues were discharged to a floor drain in the DDT process building during the initial startup. This floor drain temporarily discharged via an underground pipe that ran to the south of the building and then east to the Willamette River (Figure 1-4). From 1948 to 1950, process residues were discharged directly to a manufacturing process residue (MPR) pond located northeast of the building. In approximately 1951 or 1952, a trench was reportedly constructed and extended north approximately 285 feet from the northeastern corner of the former MPR pond (Figure 1-4). The purpose of the trench was reportedly to expand the capacity of the MPR pond.

From 1950 until DDT manufacturing ceased in 1954, the manufacturing process residue was piped to an MCB recovery system and then into the shallow MPR pond. The wastes were conveyed through piping to the MCB recovery system, which was reportedly located immediately west of the former MPR pond (Figure 1-4). The recovery system consisted of a steam stripper, in which chlorobenzene was removed from the waste and returned to the process. The entire system was located on a curbed concrete slab. Wastes from the system reportedly were drained periodically to the former MPR pond.

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 on site and stored in an aboveground tank located inside the process building on a concrete floor. Chemical reactions to form DDT occurred inside the process building, where portable metal pans several feet square were filled with hot DDT. After the DDT 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 at the storage slab was transferred to the southwestern corner of the No. 2 Warehouse 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 the No. 2 Warehouse. A small amount of material was dissolved in diesel fuel and loaded into trucks and possibly railcars as a solution. The aboveground dissolving tanks were located immediately adjacent to the western side of the DDT process building. This building was extended westward after DDT operations ceased.

In 1958, after DDT manufacturing shut down, ammonium perchlorate operations were conducted in the former DDT process building. Sodium perchlorate (manufactured in the Chlorate Plant Area) was converted to ammonium perchlorate by using ammonium chloride. This material was sold as a solid propellant for guided missiles. The operations were shut down in approximately 1962. Some ammonium perchlorate handling took place in the No. 3 Warehouse, in the southeast portion of the Acid Plant Area.

Hydrochloric acid production began in 1966 in the Acid Plant Area, formerly located between the No. 2 Warehouse and the DDT Process Building (Figure 1-3 and PA Figure 5-2 [Appendix C]). Hydrochloric acid was produced by burning hydrogen gas in the presence of chlorine gas and absorbing the vapor in water. The acid was stored in two aboveground storage tanks in the Acid Plant Area. The acid was loaded into tanker trucks from these tanks or was piped to either a storage tank near the Chlorine Cell Room or to a storage tank adjacent to Track #6 (Figure 1-3 and Expanded PA Figure 5-2 entitled “Hydrochloric Acid” [Appendix D]).

The riverbank area, generally between the No. 1 and No. 2 Docks received miscellaneous fill for many years. Sources of this fill material included the City of Portland, private excavation contractors, and Elf Atochem. Fill materials included clean soil, asphalt, concrete, metal piping, and miscellaneous materials from spent chlorine cells. Most of this area lies within the Acid Plant Area.

Known releases of hazardous substances in the area include those associated with DDT manufacturing and a release of caustic from the rupture of a fiberglass sodium hydroxide storage tank. The caustic release impacted the storm drain system and is discussed in Section 1.2.3.8.

1.2.3.2 *Chlorate Plant Area Operational History*

Sodium chlorate manufacturing started in 1941 in its current location (Figure 1-3). Chlorate was produced by electrolysis of a sodium chloride solution. Sodium bichromate was added to the process as a corrosion inhibitor and to improve the electrical efficiency of the process. The bichromate was received in a dry form. Historically, the material came to the plant 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 material was dissolved in the 30-gallon drums and was siphoned into tanks for incorporation into the circulating liquor.

Historically, the sodium chlorate solution product contained sodium bichromate. Chlorate solutions were shipped either by truck or barge. Truck loading occurred on the southern side of the Chlorate Plant Area. Barge loading of chlorate solutions occurred at the No. 2 Dock. After the completion of a chlorate plant modernization project in 1990, very little sodium bichromate was contained in chlorate products. The sodium bichromate was separated from the chlorate solution and returned to the circulating liquor.

Potassium chlorate manufacturing also started in the Sodium Chlorate Area in 1941. This operation terminated in approximately 1978. Production operations were similar to sodium chlorate operation with the exception that potassium chloride was used as the source of salt rather than sodium chloride.

In 1952, production of a sodium chlorate-based cotton defoliant material was initiated. Magnesium chloride was brought into the plant and hydrated to form magnesium chloride hexahydrate. This activity was conducted in the former No. 1 Warehouse. The magnesium chloride hexahydrate was brought 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. This operation was conducted for approximately 10 years.

In 1958, sodium perchlorate was produced in the Chlorate Plant Area with a process similar that for production of sodium chlorate. The sodium perchlorate was transferred to the former DDT Process Building in the Acid Plant Area where it was converted to ammonium perchlorate using ammonium chloride. This operation was terminated in 1962.

1.2.3.3 *Operational History of Salt Pads*

The Arkema plant historically received salt (sodium chloride, NaCl) by ship. The salt was transferred onto asphalt-lined Salt Pads in the southeastern corner of the Site (Figure 1-3). The salt was dissolved in water while on the Salt Pads to produce brine for plant manufacturing operations. Salt was the primary raw material used at the Site throughout its operational history (1941 to 2001).

1.2.3.4 *Operational History of the Old Caustic Tank Farm*

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 1-3 and PA Figure 5-2 [Appendix C]). Tanks within the OCTF were used to store sodium hydroxide from 1946 to 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 rainwater. 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.

There have been two documented releases of sodium hydroxide in the OCTF, in 1993 and 1996. In each case, approximately 200 gallons of caustic (sodium hydroxide) were spilled to the floor of the tank farm. The caustic was collected in the sumps and pumped to the wastewater treatment system for neutralization. The OCTF was in use until 1996. The idle tanks were removed from the OCTF during the demolition activities in the spring of 2002.

During Site demolition activities, a composite soil sample was collected from beneath the base of a tank removed from the northeastern corner of the OCTF area. Soil was collected from seven different locations from the base of the tank and submitted as a composite sample for laboratory analysis of total petroleum hydrocarbons (TPH) and polychlorinated biphenyls (PCBs). Petroleum hydrocarbons were detected in the sample. No PCBs were detected. Based on the results of this preliminary investigation, Arkema conducted additional soil sampling in the OCTF area.

1.2.3.5 Operational History of the Ammonia Plant

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 1-3 and PA Figure 5-2 [Appendix C]).

On 16 July 1987, Pennwalt experienced a spill of 30 percent aqueous ammonia. It was estimated that approximately 400 gallons of solution containing approximately 896 pounds of ammonia spilled onto the ground. It is likely, based on the atmospheric conditions at the time (75 degrees Fahrenheit), that most of the ammonia would have volatilized rapidly. The location of the aqueous ammonia spill is shown on the figure entitled "Location of July 1987 Aqua Ammonia Spill" in the Expanded PA (Appendix D).

1.2.3.6 Operational History of Transformer Pads

Electrical transformers were historically installed at various locations throughout the Arkema facility (Figure 1-5). Arkema kept 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 disposed. During facility demolition, all transformers were removed. The pads on which the transformers had been located were tested for the presence of PCBs. The scope and results of that investigation are discussed in this report.

1.2.3.7 *Operational History of the Bonneville Power Administration Main Substation*

The Bonneville Power Administration (BPA) owned and operated an electrical substation on the Site. As shown on Figure 1-2, the substation, which is divided into the Main Substation and a substation annex to the north, occupied a total area of 1.28 acres of the facility. The Main Substation, also referred to as the Pennwalt Substation, is located along the western edge of Lot 3 of the Site (Figure 1-3). The substation annex was located on Lot 2 (Figure 1-2). 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 the fall of 2002.

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, PBS Environmental (PBS) performed a Phase II Environmental Site Assessment (ESA) for the BPA at the Main Substation. The scope and results of the Phase II ESA are discussed in the *Phase Two Environmental Site Assessment for Bonneville Power Administration – Pennwalt Substation* report (PBS 2002a), included as Appendix E and in Sections 3.8 and 5.7 of this report.

1.2.3.8 *Operational History of the Storm Water Drain System*

The layout of the plant's storm water system is shown on Figure 1-6. 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 rather deep (approximately 12 feet below ground surface [bgs] in certain locations).

The plant's storm water 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. As shown on Figure 1-6, the Parshall flumes for Outfalls 001, 002, and 003 are located between the southernmost dock (the Salt Dock) and the northernmost dock (No. 2 Dock), whereas Outfall 004 is located north of the No. 2 Dock. Discharge pipes and diffusers extend out into the river from each Parshall flume.

The facility was issued a National Pollution Discharge Elimination System (NPDES) permit on 28 January 1993, which authorized the discharge of process wastewater, cooling water, and storm water runoff. The permit allowed a discharge flow of up to 37.0 million 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 storm water.

On 7 February 1989, Pennwalt experienced a rupture of a sodium hydroxide fiberglass storage tank. The tank was located in a curbed area immediately west of the former DDT Process Building (within the Acid Plant Area). The caustic material flowed to the plants No. 1 and No. 2 storm sewers (Outfalls 001 and 002, respectively). Although partial treatment was provided by the plant's sewer neutralization system, approximately 3,840 gallons of sodium hydroxide entered the Willamette River as a result of this release. All appropriate agencies were notified of the release. The location of this spill is shown on the figure entitled "Location and Flow Paths of February 1989 Sodium Hydroxide Spill" in the Expanded PA (Appendix D). No additional actions were required by any of the regulatory agencies. Pennwalt immediately constructed a new concrete secondary containment system in the area and installed a new fiberglass tank to store sodium hydroxide.

1.3 REPORT ORGANIZATION

This RI report is organized into 11 sections:

- Section 1 provides general introductory information;
- Section 2 presents the scope and results of pre-RI investigations and other remedial work;
- Section 3 discusses the RI field program;
- Section 4 describes the physical characteristics of the study area;
- Section 5 discusses the nature and extent of contamination;
- Section 6 presents the conceptual site model;
- Section 7 summarizes interim remedial actions;

- Section 8 discusses land and beneficial water use;
- Section 9 discusses hot spots;
- Section 10 presents the summary of findings and conclusions; and
- Section 11 contains a list of references.

Appendices to the RI report are included following Section 11. A list of appendices is provided in the Table of Contents.

2.0 PREVIOUS INVESTIGATIONS AND REMEDIAL WORK

This section describes the early environmental investigative and remedial work conducted at the plant, which evolved into Arkema's participation in ODEQ's Voluntary Cleanup Program (VCP) and the implementation of the RI/FS process. The earliest environmental investigations and remedial work took place on Lots 1 and 2, the northern, undeveloped portion of the Arkema property. Results from those investigations led to the work conducted in the Acid Plant Area and remainder of Lots 3 and 4 and Tract A.

2.1 LOTS 1 AND 2

2.1.1 Brine Residue Pile and Pond

As previously stated, sea salt (NaCl) was used as a raw material for products manufactured at the Site. The impurities calcium (Ca) and magnesium (Mg) were precipitated from the brine as calcium carbonate ($CaCO_3$) and magnesium hydroxide ($Mg[OH]_2$) (CES 1988). These compounds (referred to as "brine residue" or "brine mud") were separated from the brine through clarification. Historically, the brine residue was removed from the bottom of a primary clarifier and disposed in either the brine residue pile or pond on Lot 2 (Figure 4-1 of the ESR; Appendix A). In the early 1990s, the plant installed a filter press, which eliminated the need to dispose of the material on site.

In 1988, the plant evaluated the potential sale of brine residue as an agricultural soil amendment. Samples were collected and analyzed to assess the suitability of the brine mud for this application. During that study, samples were analyzed for several trace metals. Results indicated very low levels that compared with average concentrations typically found in soil (CES 1988).

The brine pile was completely removed in February 1989. A front-end loader was used to load the brine mud from the pile into 10-yard truck and pups. The material in the pile was solid (no free liquids). The pile was initially removed so that all visible brine residue was removed, then an additional 6-inch soil cut was made to ensure removal of all brine residue materials. Visual inspection was made to ensure all brine residue material was removed. The material was transported to the Hillsboro Landfill and beneficially used as a soil amendment to the final landfill cap.

The brine residue pond was completely removed in August 1992. A front-end loader was used to load the brine mud from the pond into 10-yard truck and pups. Some free liquid was present in the pond from storm water accumulation. Over a foot of solid material from the entire pond bottom and the sidewall area was removed and mixed with the residue to thicken it sufficiently and absorb all free liquids. Visual inspection was made to ensure all brine residue material was removed. The material was transported to the Hillsboro Landfill and beneficially used as a soil amendment to the final landfill cap.

In 1995 and 1996, freshly generated brine residue was sampled and analyzed for Toxicity Characteristic Leaching Procedure (TCLP) metals. The 1995 sample result indicated that lead was the only metal detected, and its TCLP concentration was two orders of magnitude below the applicable regulatory limit. The 1996 result was non-detect for TCLP metals. The laboratory analytical reports for these TCLP samples are included as Appendix C of the ESR (Appendix A of this report).

Based on the non-hazardous nature of the brine residue, the ESR concluded there were no COIs associated with the brine residue pile or pond (ERM 2003a).

2.1.2 Asbestos Trenches and Pond

Arkema operated asbestos diaphragm cells in the Chlorine Cell Room. These cells utilized an asbestos-coated cathode and titanium anodes. The feed to the cells was salt brine and electricity. The cells produced chlorine gas, a weak caustic solution, and hydrogen gas. The cells needed to be rebuilt periodically to improve their efficiency. The rebuilding process involved recovering the salt brine solution from the cell and removing the anodes from the cathode cell assembly. Water was used to wash the asbestos diaphragm material from the cathode. The residue entered two earthen impoundments near the former Chlorine Plant. A manually controlled pump was used to transfer the slurry to a third surface impoundment, located on Lot 2 (Figure 4-1 of the ESR; Appendix A). In the past, the ponds were cleaned occasionally and the material was placed in trenches located on Lot 1 (Figure 4-1 of the ESR; Appendix A). This pond maintenance practice was reported to ODEQ in the PA (Elf Atochem 1999).

By the late 1980s, approximately 12 trenches had been filled with asbestos-containing residue on Lot 1 (Figure 4-1 of the ESR; Appendix A). These trenches were believed to be approximately 60 feet long by 15 feet wide by and 15 feet deep (ODEQ 1991). Pennwalt kept maps to identify the location of the trenches (Elf Atochem 1999).

ODEQ samples collected from the pond and trench areas indicated the material contained Chrysotile asbestos. Therefore, ODEQ determined that this material required handling and treatment as friable asbestos material.

In order to make the property useful for potential development, and to meet conditions in its renewed air permit, Arkema undertook a project to decommission the ponds and to voluntarily excavate the trenches containing asbestos residues. The asbestos removal work was conducted under a work plan approved by the ODEQ and under the agency's oversight. The procedure called for removal of all visible asbestos material, plus several additional inches of the surrounding soil. The project was completed in 1992 (Elf Atochem 1999).

With the exception of the DDT trench described in Section 2.1.3, the only hazardous substance associated with the asbestos pond and trenches was asbestos. Based on the complete removal of the trenches and pond, the ESR concluded there were no COIs associated with the asbestos trenches and pond (ERM 2003a).

2.1.3 DDT Trench

During the asbestos removal work in 1992, a trench identified on the northern property was found to contain what appeared to be pesticide residues (Figure 4-1 of the ESR; Appendix A). A sample of the trench residue was analyzed for organochlorine pesticides, semivolatile organic compounds (SVOCs), PCBs, petroleum hydrocarbons, and organic toxic constituents on the Resource Conservation and Recovery Act (RCRA) Characteristic Waste List. The only constituents detected were DDT and MCB. Arkema undertook additional investigations to identify, confirm, and characterize the source of the material in the DDT Trench. A review of prior operations at the plant indicated that the material in the trench came from a former DDT manufacturing process waste pond in the Acid Plant Area (Elf Atochem 1999).

In the fall of 1992, Arkema conducted a soil exploration program to assess the horizontal and vertical extent of the affected soil in the trench. The investigation determined that the trench was approximately 30 feet wide by 80 feet long and approximately 10 to 11 feet deep. The top of the trench was located 3 feet bgs. The COI identified in the soil was DDT residue in concentrations exceeding ODEQ simple soil cleanup rules. These cleanup levels were developed by ODEQ to provide conservative, residential standards for the cleanup of contaminated soil for the protection of human health. A composite sample of the trench was analyzed for volatile organic compounds (VOCs), organochlorine pesticides, and PCBs. The only chemicals detected in the soils in the trench were DDT and MCB. MCB concentrations were well below any of Oregon's simple soil cleanup levels. TCLP concentrations of MCB were below the leachate reference concentration of 3.0 milligrams per liter (mg/L) (OAR 340-122-045). Therefore, MCB was not a targeted COI during the cleanup activities (CH2M Hill 1995a).

Because the trench was a clearly defined, discrete unit, the trench was completely excavated during the summer of 1994. Approximately 1,700 tons of soil were removed and disposed at the Waste Management Subtitle C landfill in Arlington, Oregon. Post-excavation confirmation sampling showed that surrounding soils met Oregon's industrial soil cleanup levels, and with the exception of one sample, also met Oregon's residential cleanup levels. The results of the confirmation sampling are presented in Table 4-1 of the ESR (Appendix A). After sampling was performed, the excavation was backfilled to the ground surface with clean fill (CH2M Hill 1995a). Because the trench was originally located 3 feet bgs, backfilling resulted in 3 feet of clean fill over the former trench location. This soil removal action was documented in the *Remedial Action Report, North Plant Area*, dated April 1995 (CH2M Hill 1995a).

2.1.4 Bonneville Power Administration Substation Annex

Soil sampling was performed in November 2001 to support decommissioning of the BPA substation annex on Lot 2 of the Site. Four surface soil samples were collected from each side of the transformer located in the substation annex (Figure 4-1 of the ESR; Appendix A). These samples were analyzed for PCBs by United States Environmental

Protection Agency (USEPA) Method 8082A. Analytical results for these samples indicated "non-detect" for PCBs (detection level was 50 micrograms per kilogram). One sample was analyzed for VOCs, and the results for that sample were "non-detect" for VOCs. The sampling results were documented in the *Phase Two Environmental Site Assessment for Bonneville Power Administration; Pennwalt Substation* report (PBS 2002a), and the results of the analyses are included as Appendix B of the ESR (Appendix A).

Based on the soil sampling results, no further investigation or remediation was recommended by PBS (PBS 2002a) and the ESR concluded that there were no COIs associated with the substation annex.

2.2 ACID PLANT AREA

Investigations in the Acid Plant Area began in 1994 subsequent to the excavation and removal of the DDT Trench located on Lot 1. That work prompted Arkema to inquire as to the source of the pesticide residues found in the DDT Trench. Operational histories indicated that DDT had been manufactured in the Acid Plant Area and that a pond had been constructed in that area to receive manufacturing process residues. An aerial photograph from the early 1950s confirmed the presence of the pond. The pond was estimated to be approximately 25 by 35 feet in size. An investigation in the Acid Plant Area was then conducted in two phases.

2.2.1 Phase I Investigation

Much of the information presented in this section was obtained from the *Phase 2 Soil and Groundwater Investigation Work Plan for the Acid Plant Project* (Phase 2 Work Plan, dated June 1995; CH2M Hill 1995b). A copy of this document is provided as Appendix F to this report.

2.2.1.1 Purpose and Scope

The first phase of the investigation was performed in 1994 to assess the presence of DDT manufacturing-related impacts in the Acid Plant Area and to evaluate the lateral and vertical extent of the former MPR Pond. Three areas were identified for investigation:

- The former MPR Pond, which was reported to have contained wastes discharged from the former process building and MCB recovery system;
- The former DDT Dry Storage Area (south of the southwestern corner of Warehouse #2); and
- The overall Acid Plant Area.

The objectives of the Phase 1 investigation were to:

- Determine whether remnants of the former MPR Pond were present beneath the Acid Plant Area and, if so, to evaluate the nature and characteristics of the MPR Pond remnants;
- Identify potential COIs, if any, in the affected soil, including DDT, potential DDT degradation products, and MCB, by performing a limited field investigation;
- Estimate the volume of soil that may contain DDT residue originating from the MPR Pond, if any; and
- Assess the presence of DDT residue and related compounds, if any, in the uppermost groundwater in the vicinity of the former MPR Pond.

The scope of the Phase 1 investigation included collection of soil and groundwater samples using direct-push boring techniques and soil sampling from test pits (Phase 2 Work Plan Figure 3-1 [Appendix F]). Soil samples were visually inspected for the presence of DDT residues and soil and groundwater samples were analyzed for organochlorine pesticides, VOCs, and TPH. More detail on the scope of the Phase 1 investigation, including figures and analytical results, is available in the Phase 2 Work Plan (Appendix F). Phase 1 sampling locations are included on figures showing RI sampling locations discussed in Section 3.0.

2.2.1.2 *Summary of Findings*

The Phase 1 investigation revealed the following:

- The lateral extent of soil affected by the former MPR Pond was estimated to be approximately 60 by 56 feet (approximately 3,360 square feet). The vertical extent was confirmed to a depth of at least 15 feet within certain areas of the pond.

- Soil samples collected from within the inferred boundaries of the former MPR Pond and in areas with visually apparent pink residue had detected DDT concentrations ranging from 5,000 to 150,000 milligrams per kilogram (mg/kg). Samples collected 5 to 10 feet laterally beyond the visibly pink residue exhibited significantly lower DDT concentrations than samples collected from similar depths within visibly impacted soil.
- VOCs detected in the soil samples from the former MPR Pond area included MCB, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and total xylenes. MCB was detected in 12 of the 13 soil samples at concentrations ranging from 0.006 to 200 mg/kg.
- DDT was detected in 12 of the 13 soil samples collected from test pits within the general Acid Plant Area at concentrations ranging from 0.25 to 2,700 mg/kg.
- DDT was detected in the four groundwater samples at concentrations ranging from 0.00036 to 0.500 mg/L. Three of the four samples contained DDT at concentrations exceeding the solubility limit of DDT in water (approximately 0.0031 to 0.0034 mg/L). The elevated concentrations of DDT may have been the result of DDT adsorbed to suspended sediment in the groundwater samples or the increased solubility of DDT in the presence of MCB. The solubility of DDT is many orders of magnitude greater in an organic solvent (e.g., MCB) than aqueous solubility.
- MCB was the most prevalent VOC detected in the groundwater samples, at concentrations ranging from 0.870 to 370 mg/L. The highest MCB concentrations were observed in the sample collected in the direction that was assumed to be downgradient of the former MCB Pond.

Phase 1 results are presented in the Phase 2 Work Plan (Appendix F). As a result of the Phase 1 findings, a second phase of investigation was recommended for further delineation of impacted soil and groundwater.

2.2.2 *Phase 2 Investigation*

Much of the information presented in this section was obtained from the Phase 2 Work Plan (Appendix F) and the *Phase 2 Site Characterization: Acid Plant Project* (Phase 2 Report; CH2M Hill 1997). A copy of the Phase 2 Report is provided as Appendix G to this report. The Phase 2 Work Plan was provided to ODEQ on 28 June 1995 for their review and comment. ODEQ comments on the Phase 2 Work Plan were provided to Arkema in a letter dated 24 June 1996. Arkema submitted a response to the comments and a Work Plan Addendum to ODEQ in a letter dated 30 August 1996. The Phase 2 Work Plan Addendum was approved by ODEQ in a letter dated 17 September 1996. The Work Plan Addendum is also included in Appendix F.

2.2.2.1 *Purpose and Scope*

The purpose of the Phase 2 investigation was to gather additional information to support an assessment of potential risk posed by the DDT process residues in soil and groundwater in the Acid Plant Area. Between the completion of the Phase 1 work and the preparation of the Phase 2 Work Plan, additional review of historical operations revealed that an overflow trench had been constructed to provide greater capacity to the MPR Pond (Phase 2 Report Figure 1-3 [Appendix G]). The trench was assumed to extend several hundred feet to the north of the northeastern corner of the pond.

The objectives of the Phase 2 investigation were to:

- Evaluate the vertical and lateral extent of DDT process residue and related compounds in soil in the general Acid Plant Area;
- Further delineate the lateral and vertical extent of the affected soil around the former MPR Pond;
- Assess the presence and, if appropriate, the extent of the affected soil around the overflow trench;
- Evaluate the presence and extent of DDT process residue and related compounds, if any, in the uppermost water-bearing zone (WBZ);
- Characterize the local stratigraphy, including determination of the presence or absence of a silt layer underlying the uppermost WBZ;
- Assess flow direction and gradient in the uppermost WBZ; and
- Collect data necessary to develop remedial action objectives.

The scope of the Phase 2 investigation included soil and groundwater sampling using direct-push investigation techniques, cone penetrometer testing (CPT), installation and sampling of shallow monitoring wells, and laboratory analysis of soil and groundwater samples (Phase 2 Report

Figure 4-1 [Appendix G]). More detail on the scope of the Phase 2 investigation, including figures and analytical results, is available in the Phase 2 Report (Appendix G). Phase 2 sampling locations are also included on figures showing all sampling locations for all field investigations on Lots 3 and 4 and Tract A, discussed in Section 3.0.

2.2.2.2 *Summary of Findings*

In addition to confirming the Phase 1 findings, the Phase 2 investigation provided the following conclusions:

- Concentrations of DDT process residue decreased with depth beneath the ground surface in the general Acid Plant Area (i.e., outside the footprint of the former MPR Pond and overflow trench).
- The near-surface extent of the former MPR Pond is approximately 56 by 60 feet. The extent of affected soil appeared to expand approximately 20 to 30 feet beyond these boundaries at increasing depths in the unsaturated zone. The presence of DDT-affected soil below the groundwater table was still unknown, but was suspected, given the proximity of DDT-affected soil to the groundwater table and known groundwater table fluctuations. Low levels of MCB were associated with the DDT-affected soil beneath the former MPR Pond. Higher concentrations of MCB observed in soil at the west edge of the former MPR Pond were attributed to past operations of the former MCB recovery unit.
- The location and size of the MPR Pond overflow trench were confirmed. Affected soil associated with the overflow trench was found to be a maximum of 15 feet wide and to extend approximately 270 feet north from the former MPR Pond. The affected soil within and beneath the overflow trench was similar in appearance to soil within the footprint of the former MPR Pond. The affected soil reached its greatest depth (the groundwater table) immediately adjacent to the former MPR Pond, where the zones of affected subsurface soil associated with the pond and the end of the trench appear to merge. The depth of the affected soil beneath the trench gradually decreased with increased distance from the pond, reaching a minimum depth of approximately 5 feet near the north end of the trench.
- The shallow geology consists of interbedded alluvial silt/sand overlain by fill near the Willamette River, where a zone of imported fill

containing silt, sand, scattered gravel, and demolition rubble was placed to extend the riverbank eastward.

- The shallow WBZ is situated in the interbedded alluvial silt/sand deposits and portions of the overlying fill. It is underlain by a local low-permeability silt zone, the depth of which was not identified in the Phase 2 investigation. It was speculated that the silt zone encountered at a depth of 47 feet was the base of the shallow WBZ, but it was determined during subsequent investigations that the silt encountered at 47 feet separates the intermediate WBZ from the deep WBZ. The silt that occurs at the base of the shallow WBZ is situated at a depth of approximately 35 feet bgs in the Acid Plant Area.
- Groundwater depths of 13 to 24 feet were observed in the monitoring wells and direct-push borings. In general, the shallow groundwater flows eastward to the Willamette River, which is a regional groundwater discharge feature. However, under high river stage conditions, such as the flood conditions observed during the January 1997 groundwater sampling event, the river stage can rise above groundwater levels and cause a temporary reversal of gradient and these reversals are likely only temporary and have little effect on the long-term average groundwater flow direction at the site.
- MCB was detected in groundwater samples from the shallow WBZ at the site. Low concentrations of DDT were detected in groundwater in a few monitoring wells in the initial sampling event, but in only one well in the second event. Because the prevalence and concentration of DDT in the groundwater samples decreased between the first and second sets of samples, it was speculated that the DDT observed in the first monitoring event may have been associated with remnant aquifer disturbance from well installation.
- MCB concentrations in groundwater collected during unusually high Willamette River levels suggested that contaminant concentrations in monitoring wells can also be affected by river stage and groundwater gradients.

Phase 2 results are presented in the Phase 2 Report (Appendix G). These findings represent the first steps in developing the overall conceptual site model (CSM).

2.3 POST-PHASE 2 GROUNDWATER MONITORING

The Phase 2 investigation included the first two rounds (January and March 1997) of groundwater samples collected from Site monitoring wells (MWA-1 through MWA-4). Subsequent to the completion of the Phase 2 investigation, groundwater sampling continued in these wells. Additional samples were collected in June and September 1997 and May 1998. These groundwater samples were analyzed for organochlorine pesticides and VOCs. In addition, the May 1998 samples were also analyzed for SVOCs.

Tables 2-1 and 2-2 present summaries of concentrations for constituents detected in soil and groundwater in the Phase 1 and 2 investigations and the subsequent groundwater sampling.

2.4 RI/FS WORK PLAN DEVELOPMENT

Based on the findings of the Phase 1 investigation, Arkema determined that further investigations in the Acid Plant Area should be conducted under ODEQ's VCP. An Intent-to-Participate form was completed by Arkema and submitted to ODEQ at the same time as the Phase 2 Work Plan (28 June 1995). Subsequent to the submittal of the Intent to Participate, ODEQ assigned a project manager to review the Phase 2 Work Plan and all existing Site data.

The RI/FS Work Plan was submitted to ODEQ in September 1998. The RI/FS Work Plan summarized the results of the Phase 1 and 2 investigations in the Acid Plant Area, presented the CSM for the first time, and discussed the scope of the RI, risk assessment, and FS.

The CSM presented in the RI/FS Work Plan is presented on Figure 2-1. The CSM for the Acid Plant Area was informally updated as the RI progressed and new information was obtained.

The initial focus of the RI was on the Acid Plant Area. Eventually, the scope of the RI was expanded to examine environmental conditions site-wide. The expansion in scope was primarily the result of the PA (Elf Atochem 1999) and the Expanded PA (Elf Atochem 2000). The RI then evolved to include the Chlorate Plant Area and a CSM was developed specifically for that area. The current CSM, which addresses both the

Acid Plant and Chlorate Plant Areas, is presented and discussed in Section 6.0.

Expansions in scope also occurred to address additional data gaps identified as data were obtained, validated, and reviewed. Changes in scope were documented in correspondence between Arkema and ODEQ in accordance with the Work Plan, which states: "Mutual decisions that represent a significant modification or change in scope will be documented in the work plan or under separate correspondence at Elf Atochem's or ODEQ's option."

Field investigations of soil, groundwater, sediment, and storm water were conducted to meet the objectives presented in Section 1.1. RI activities conducted at the Site included both upland and in-water investigative work. Investigations conducted on the upland portion of the Site were completed concurrently with in-water investigations. This RI Report incorporates results of the upland investigations and monitoring activities completed to date. A separate in-water report, the *Phase II Stage 1 and 2 In-River Groundwater and Sediment Investigation Report*, summarizing in-water investigation activities was submitted to ODEQ on 9 December 2003 (Integral 2003).

3.0 FIELD PROGRAM

This section describes the RI field program, which was initiated in September 1998 and continued through March 2005. The nature and extent of contamination was evaluated based on field screening and laboratory analytical data collected from 1998 through 2005 as part of the RI field program as well as the following additional field investigations, pilot studies, and interim actions conducted in parallel with the RI:

- The Phase 1 Soil Removal Interim Remedial Measure (IRM) completed in the Acid Plant Area in 2000;
- The Phase 2 Soil Removal IRM completed in the Acid Plant Area in 2001 and 2002;
- Baseline sampling (groundwater and soil) and confirmation sampling (soil only) associated with the pilot test and full-scale implementation of the vadose zone vapor extraction system (VES) in the Acid Plant Area from 2000 to 2003;
- Baseline sampling associated with the In-situ Persulfate Oxidation Pilot Study conducted in the Acid Plant Area in 2001;
- The Phase I and Phase II Dense Non-Aqueous Phase Liquid (DNAPL) Investigations conducted in the Acid Plant Area in 2002;
- Soil sampling conducted within the BPA Main Substation in 2002;
- Baseline sampling associated with the DNAPL Remediation Pilot Study in 2003;
- Baseline sampling associated with the Hexavalent Chromium Reduction Pilot Study conducted in the Chlorate Plant Area in 2003;
- The Old Caustic Tank Farm Soil Investigation conducted in 2003 and 2004;
- The Former Transformer Pad Concrete Sampling Program conducted in 2004; and
- Storm water sampling from Manholes SW-1 and SW-02 in 1999 and 2001 and Outfalls 001 through 004 in 2004 and 2005.

Site investigations and remedial work conducted prior to initiation of the RI in 1998 are summarized in Section 2.

3.1 AREAS OF INVESTIGATION

Initial RI field activities were conducted between November 1998 and February 1999 with the installation of soil borings and monitoring wells in the Acid Plant Area. The scope and results of this early RI field work were discussed in the *Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report* (the "IDR", Exponent 1999). At the request of ODEQ, Arkema completed a PA for the Site in August 1999 and then completed an Expanded PA in April 2000 to address additional information requested by ODEQ. These documents (and related correspondence between Arkema [Elf Atochem] and ODEQ) identified data gaps and areas for additional investigation, including:

- Additional work in the Acid Plant Area;
- The Chlorate Plant Area;
- The Salt Pads;
- The Old Caustic Tank Farm;
- The Ammonia Plant;
- Various concrete transformer pads;
- The BPA Main Substation; and
- The Storm Water Drain System.

Table 3-1 presents a summary of potential contaminant sources, period of operation, and COIs for each area. Table 3-2 is a summary list of investigations conducted, including the date of the investigation, borings drilled, monitoring wells installed, and the location of the results of each investigation (i.e., references). Most of the investigative work was conducted to determine the nature and extent of impacts to soil and groundwater from historical practices in the Acid Plant Area. Many of the investigation borings for the Acid Plant Area were located in other areas of investigation (i.e., the Chlorate Plant Area, the former Ammonia Plant, etc.) and thus were analyzed for COIs beyond those associated with the Acid Plant Area. The investigations for each area are discussed below.

3.2 *ACID PLANT AREA*

Based on historical operations (Table 3-1), COIs in the Acid Plant Area include:

- DDT (and co-metabolites DDD and 1,1-dichloro-2,2- bis(p-chlorophenyl)ethylene [DDE]);
- VOCs (primarily MCB and chloroform and to a lesser extent other VOCs); and
- Perchlorate.

Potential sources of these COIs within the Acid Plant Area include (Figure 3-1):

- The former MPR Pond and trench;
- The DDT Process Building and MCB Recovery Unit;
- The DDT Dry Storage Area;
- Possible DDT Loading Areas;
- The fill area riverward of the MPR Pond and trench; and
- Surface soil outside the above areas.

Investigation activities carried out in the Acid Plant Area include:

- Surface, subsurface, and riverbank soil sampling;
- Chemical analyses and physical testing of site soils;
- Groundwater sampling from direct-push borings;
- Installation of monitoring wells in the shallow, intermediate, and deep groundwater zones;
- Groundwater elevation monitoring;
- Tidal influence monitoring;
- Aquifer testing;
- Groundwater sampling from monitoring wells;
- Chemical analysis of groundwater samples; and
- A two-phased DNAPL investigation.

3.2.1 *Acid Plant Area Soil Investigation*

Several phases of soil sampling were conducted in the Acid Plant Area for the purpose of evaluating the physical properties of the soil, field screening the soil, and delineating the nature and extent of COIs in the soil. Soil samples were collected from the following borings and/or locations:

- Soil sampling borings (48 borings);
- IRM borings (81 borings);
- VES borings (32 borings);
- Monitoring well borings (20 borings);
- In-situ Persulfate Oxidation Pilot Study borings (12 borings);
- DNAPL Pilot Study borings (13 borings);
- Surface soil sample locations (8 locations); and
- Riverbank soil sample locations (12 locations).

These borings are in addition to the 57 borings conducted as part of the Phase 1 and 2 investigations. The locations of these borings, including borings from previous investigations, are shown on Figures 3-2a and 3-2b. A summary of Acid Plant Area soil sampling is provided in Table 3-3. The following paragraphs describe the soil investigation tasks.

3.2.1.1 *Soil Sampling Borings*

A total of 48 soil sampling borings were advanced for collection of soil and groundwater grab samples in the Acid Plant Area (borings US-01 through US-03 and B-49 through B-115). These borings were advanced using either hand-auger, direct-push (Geoprobe®), or hollow-stem auger (HSA) drilling methods. Depths of these borings ranged from 2 to 36 feet bgs. A summary showing the boring number, date of completion, boring depth, drilling method, and analyses conducted on soil samples collected from each soil sampling boring is provided in Table 3-3. Boring logs for soil sampling borings are provided in Appendix H. Soil sampling boring locations are shown on Figures 3-2a, 3-2b, and 3-3.

Soil samples were collected from discrete depth intervals and most samples were field-screened after collection. Screening methods included thin-layer chromatography (TLC), Sudan IV® hydrophobic dye, photoionization detector (PID), and/or visual inspection. The methods and limitations of these screening techniques are described in Section 3.10. The soil samples were submitted to a laboratory for archiving and analysis. As indicated in Table 3-3, select samples were analyzed for:

- VOCs by USEPA Method 8260B; and/or
- Organochlorine Pesticides by USEPA Method 8081A.

One sample from soil boring B-53 was subjected to SPLP by USEPA Method 1312 and the leachate was analyzed for VOCs by USEPA Method 8260B and organochlorine pesticides by USEPA Method 8081A. The analysis was used to evaluate the potential for pesticides from Site soils to leach into groundwater or surface water. The extraction fluid used in the SPLP test is intended to simulate precipitation and provide a realistic assessment of constituent mobility under actual field conditions (i.e., what happens when it rains or snows). Extraction fluid with a pH of 5.00 is used for sites located to the west of the Mississippi.

Following completion, each boring was abandoned with bentonite grout.

The RI/FS Work Plan originally called for eight soil borings in the Acid Plant Area; however, the number and depths of the soil borings completed in the Acid Plant Area increased to facilitate delineation of the extent of COIs in the Acid Plant Area. Procedures described in the FSP were followed for all soil boring field activities to ensure data quality.

3.2.1.2 Interim Remedial Measure Borings

A Soil Removal IRM was implemented to address soil containing DDT near the former MPR Pond in the Acid Plant Area. The IRM was carried out in two phases in accordance with the *Interim Remedial Measures Work Plan, Acid Plant Area, Arkema Inc., Portland Facility* (Exponent 2000) *and Phase II Soil Interim Remedial Measure Workplan, ATOFINA Chemicals, Inc., Portland, Oregon* (ERM 2001a). The IRM is discussed in Section 7.1.

Eighty-one borings were advanced to delineate the extent of soil containing DDT (borings IB-1 through IB-96). These borings were completed in accordance with the work plans for the Soil Removal IRM. Approximately 42 of the 81 borings were completed in soils that were subsequently removed during the IRM. The IRM borings were advanced to depths from 5 to 13 feet bgs using direct-push (Geoprobe®) drilling methods. A summary of the borings is provided in Table 3-3. Logs for the borings are provided in Appendix H and the boring locations are shown on Figures 3-2a, 3-2b, and 3-4.

Soil samples were collected from discrete depth intervals and field-screened. Screening methods included TLC, Sudan IV® hydrophobic dye, PID, and/or visual inspection. As described in Table 3-3, soil samples were submitted to a laboratory for archiving and analysis of:

- Organochlorine pesticides by USEPA Method 8081A;
- VOCs by USEPA Method 8260B; and
- Metals (Cadmium, Chromium, Lead, and Zinc) by USEPA Method 6010.

Composite samples from IRM borings IB-21, IB-26, and IB-51 were subjected to TCLP by USEPA Method 1311 and analysis for VOCs by USEPA Method 8260B. The analysis was conducted to determine if soil at these locations exhibits characteristic toxicity for waste disposal purposes.

Following completion, each boring was abandoned with bentonite grout.

3.2.1.3 Vapor Extraction System Borings

Elevated MCB concentrations and MCB DNAPL were observed in IRM soil borings during the first phase of the Soil Removal IRM. In an attempt to reduce MCB concentrations in soil to below the RCRA regulated threshold level of 2,000 mg/kg (i.e., 20 times the hazardous waste toxicity characteristic of 100 mg/L), a soil VES was installed in the former MCB Recovery Unit Area. The system was installed in December 2000 in accordance with the *Workplan for Full-Scale Vapor Extraction System*, dated 26 September 2000 (ERM 2000). The VES consisted of up to five shallow horizontal vapor extraction wells at approximately 6 feet bgs. The VES is discussed in more detail in Section 7.2.

As part of the pilot test and full-scale implementation of the soil VES, 47 VES borings were completed, which included eight hand-auger borings (AP-1 through AP-8), 24 vapor monitoring point borings (VP-1 through VP-24), and 15 confirmation borings (CS-1 through CS-15). These borings were advanced to depths of 1 to 16 feet bgs using both hand-auger and direct-push (Geoprobe®) methods. A summary of VES borings is provided in Table 3-3. No boring logs were prepared for the hand-augered VES borings (AP-1 through AP-8). Logs for the other VES borings are provided in Appendix H. The VES boring locations are shown on Figures 3-2b and 3-5.

Soil samples were collected from discrete depth intervals and field-screened by TLC, Sudan IV® hydrophobic dye, PID, or visual inspection. As indicated in Table 3-3, soil samples were submitted to a laboratory for archiving and analysis of:

- VOCs by USEPA Method 8260B; and/or
- Organochlorine pesticides by USEPA Method 8081A.

Following completion, each boring was either abandoned with bentonite grout or completed as a vapor monitoring point with a polyvinyl chloride (PVC) well riser and screen for use during pilot testing and full-scale VES implementation.

3.2.1.4 *Monitoring Well Borings*

Soil samples were also collected from borings advanced for the installation of groundwater monitoring wells. Although the RI/FS Work Plan originally called for eight monitoring wells in the Acid Plant Area, a total of 20 monitoring well borings were completed in and around the Acid Plant Area, including 11 shallow-, seven intermediate-, one deep-, and one basalt-zone borings. These borings are in addition to the four monitoring well borings conducted during the Phase 2 Site Characterization (CH2M Hill 1997). The additional borings and monitoring wells (MWA-5 through MWA-22) were installed to address data gaps in the nature and extent of soil and groundwater contamination. The 20 borings includes the two borings advanced to replace abandoned monitoring wells MWA-6 (MWA-6r) and MWA-15 (MWA-15r).

Monitoring well borings were advanced using HSA or cable tool drilling methods to depths ranging from approximately 29.5 to 70 feet bgs. Where monitoring well borings were advanced through low-permeability silt zones, the borings were cased off to prevent direct vertical hydraulic connection between WBZs. A summary of borings is provided in Table 3-3, the logs are provided in Appendix H, and locations are shown on Figures 3-2a, 3-2b, and 3-6.

Soil samples from monitoring well borings were visually inspected and logged for lithology in accordance with procedures in the FSP. In addition, soil samples were collected from discrete depth intervals and many were field-screened. Screening methods applied included TLC, Sudan IV® hydrophobic dye, PID, and/or visual inspection. As indicated in Table 3-3, select soil samples were submitted to a laboratory for archiving and/or analysis of:

- Soil physical properties;
- VOCs by USEPA Method 8260B; and/or
- Organochlorine pesticides by USEPA Method 8081A.

Each monitoring well boring was completed as a monitoring well, as described in Section 3.2.2.2.

3.2.1.5 In Situ Persulfate Oxidation Pilot Study Borings

In 2001, a pilot study was conducted in the Acid Plant Area to evaluate the effectiveness of direct chemical oxidation of MCB by sodium persulfate (the "Persulfate Pilot Study"). The pilot study was carried out in an area immediately downgradient of the former MPR Pond and trench. The pilot study was performed in accordance with the *Final In Situ Persulfate Injection Pilot Study Workplan, Portland, Oregon* (Persulfate Pilot Study Work Plan; ERM 2001b). Six nested pairs of performance monitoring wells (12 wells designated as "NMP-") were installed in the shallow groundwater zone for performance monitoring purposes.

Soil samples from the performance monitoring well borings were visually inspected and logged for lithology. No soil samples were collected from the Persulfate Pilot Study borings for laboratory analyses. A summary of the borings is provided in Table 3-3, logs for the borings are provided in Appendix H, and the locations are shown on Figures 3-2b and 3-7. The Persulfate Pilot Study is discussed in more detail in Section 7.3.1.

3.2.1.6 DNAPL Pilot Study Borings

In 2003, a second pilot study was conducted in the Acid Plant Area to evaluate the effectiveness of air sparging and soil vapor extraction for the remediation of MCB DNAPL in the area of the former MPR Pond (the DNAPL Pilot Study). A total of 13 borings (AS-1 and AS-2, SVE-1 and SVE-2, VP-25 through VP-30, and PMP-1 through PMP-3) were advanced for the installation of air sparging wells, soil vapor extraction wells, vapor monitoring points, and performance monitoring wells. All borings were advanced into the shallow groundwater zone in accordance with the *Dense Non-Aqueous Phase Liquid Remediation Pilot Study Work Plan; Acid Plant Area* (DNAPL Pilot Study Work Plan; ERM 2003b).

Soil samples from the borings were visually inspected and logged for lithology, but no soil samples were collected for laboratory analyses. A summary of the borings is provided in Table 3-3, logs for the borings are provided in Appendix H, and locations are shown on Figures 3-2b and 3-7. The DNAPL Pilot Study is discussed in more detail in Section 7.3.2.

3.2.1.7 Surface Soil Sampling

Surface soil samples were collected at seven locations in the vicinity of the Acid Plant Area and south of No. 1 Dock, adjacent to the Willamette River, to characterize COIs in surface soil. Surface soil sampling locations are shown on Figures 3-2a, 3-2b, and 3-8. Surface soil samples were collected from depths of zero to 4 inches bgs at locations S-1 through S-8 and were analyzed for organochlorine pesticides by USEPA Method 8081A. Collection of surface soil samples was conducted as an additional RI task to further evaluate the nature and extent of COIs in the Acid Plant Area. Collection and analysis of surface soil samples was conducted in accordance with soil sampling methods described in the FSP.

3.2.1.6 Riverbank and Beach Soil Sampling

A total of 12 shallow soil samples were collected from the riverbank along the Willamette River. Four of the 12 samples were collected on beach sands (i.e., below the mean high water level) and eight were collected on Tract A soils (i.e., between the top of slope and the mean high water level). Of the eight Tract A soil samples, three were collected within approximately 5 feet of the top of slope and five samples were collected down-slope, closer to the mean high water level. Riverbank soil sampling locations are shown on Figure 3-2a. As indicated in Table 3-3, the riverbank soil samples were analyzed for:

- Organochlorine pesticides by USEPA Method 8081A;
- VOCs by USEPA Method 8260B;
- SVOCs by USEPA Method 8270C or 8270SIM;

- Total organic carbon by American Society for Testing and Materials (ASTM) D4129-82M;
- Total cadmium, chromium, lead, and zinc by USEPA Method 6010B; and/or
- Grain size by the Puget Sound Estuary Program (PSEP) Modified method.

Collection of the riverbank samples was conducted as an additional RI task to characterize the nature and extent of COIs in the riverbank and beach soils. Collection and analysis of riverbank soil samples was conducted in accordance with soil sampling methods described in the FSP.

3.2.1.7 *Soil Physical Testing*

Sixteen soil samples were collected from six monitoring well borings (MWA-8i through MWA-13d) for analysis of soil physical properties. Samples were tested for:

- Hydraulic conductivity;
- Bulk density;
- Liquid and plastic limits;
- Percent moisture;
- Grain size; and
- Total organic carbon (TOC).

These samples were collected to establish an understanding of geotechnical and hydrogeologic properties of the subsurface soil horizons in the Acid Plant Area. Samples were collected using Shelby® tubes. Table 3-3 includes a summary of physical testing conducted for the Acid Plant Area.

3.2.2 ***Acid Plant Area Groundwater Investigation***

The Acid Plant Area groundwater investigation included collection and laboratory analysis of grab groundwater samples from direct-push borings, installation of monitoring wells, measurement of groundwater levels, evaluation of aquifer hydraulic properties, and collection and laboratory analysis of monitoring well groundwater samples. Groundwater sampling locations are shown on Figure 3-9. A summary of Acid Plant Area groundwater sampling is provided in Table 3-4.

3.2.2.1 *Soil Boring Groundwater Grab Sampling*

Groundwater grab samples were collected from eight Acid Plant Area soil sampling borings. The borings from which groundwater grab samples were collected are summarized in Tables 3-3 and 3-4, and the locations of these borings are shown on Figure 3-9. As indicated in Table 3-4, samples were analyzed for:

- Organochlorine pesticides by USEPA Method 8081A;
- VOCs by USEPA Method 8260B;
- TPH-diesel range organics by Washington State Department of Ecology (Ecology) Method NWPTH-Dx; and/or
- Ammonia as nitrogen by USEPA Method 350.1.

Collection and analysis of grab groundwater samples was conducted using methods described in the FSP.

3.2.2.2 *Monitoring Well Installation and Development*

During the RI, 20 new monitoring wells were installed in and around the Acid Plant Area in four separate groundwater zones. These wells were installed in addition to the four shallow-zone monitoring wells installed during the Phase 2 Site Characterization. All groundwater monitoring wells were installed in accordance with OAR, Water Resources Department, Chapter 690, Division 240; ODEQ Groundwater Monitoring Well Drilling, Construction and Decommissioning Guidelines; and the RI/FS Work Plan. Wells were installed using HSA or cable tool drilling methods. Monitoring well locations are shown on Figure 3-9. A summary of monitoring well installation data and as-built construction specifications is provided in Table 3-5. Boring and well construction logs are provided as Appendix H. Generally, water table wells were constructed with 10-foot long screens straddling the water table, whereas piezometers were constructed with 5-foot long screens set at the target depth (typically immediately above an aquitard).

3.2.2.2.1 *Shallow-Zone Monitoring Well Installation*

Eleven new shallow-zone monitoring wells (MWA-5 through MWA-7, MWA-15 and MWA-15r, MWA-17si through MWA-20, and MWA-22) were installed to depths between approximately 29 and 38 feet bgs. The shallow-zone monitoring wells were installed and screened at elevations similar to those of the existing monitoring wells MWA-1 through MWA-4, which were installed as part of early investigative work at the Site, prior to the RI/FS Work Plan. In general, the shallow-zone monitoring wells are screened across the water table and/or with the bottom of the screen placed at or near the interface with an underlying silt horizon.

The shallow-zone monitoring wells were constructed with stainless steel wire-wrapped screens and stainless steel casing through the saturated zone and PVC casing through the vadose zone. Shallow-zone monitoring wells were constructed in accordance with the RI/FS Work Plan.

3.2.2.2.2 *Intermediate-Zone Monitoring Well Installation*

Seven intermediate-zone monitoring wells (MWA-8i through MWA-12i, MWA-14i, and MWA-16i) were installed to depths ranging from approximately 35 to 59 feet bgs. The intermediate-zone wells were screened within the intermediate alluvial sands below one or more confining silt or equivalent fine-grained soil horizons. Intermediate-zone monitoring wells were constructed similarly to the shallow-zone monitoring wells, with the exception that casing was used during installation to seal the overlying silt to prevent cross-contamination between aquifers.

3.2.2.2.3 *Deep-Zone Monitoring Well Installation*

One deep-zone monitoring well (MWA-13d) was installed to a depth of approximately 53 feet bgs. The deep-zone monitoring well was screened at the bottom of the deep alluvial silts and sands at the interface with the underlying basalt horizon. Deep-zone monitoring well construction procedures were similar to those for the shallow- and intermediate-zone monitoring wells, in accordance with the RI/FS Work Plan.

3.2.2.2.4 *Basalt-Zone Monitoring Well Installation*

One groundwater monitoring well (MWA-21b) was completed in the basalt zone underlying the deep zone. This boring was advanced to a depth of approximately 69 feet bgs. The construction procedures for the basalt-zone monitoring well were similar to those for the other new monitoring wells, in accordance with the RI/FS Work Plan.

3.2.2.2.5 *Monitoring Well Development*

Monitoring wells were developed between 24 hours and 1 week after installation by surging and over-pumping using a positive-displacement pump. Three of the four pre-RI wells (MWA-2, MWA-3, and MWA–4) were redeveloped by over-pumping with a positive displacement pump, in an effort to remove silt that had accumulated since the original installation and development.

Well development procedures were conducted as described in the FSP. A minimum of approximately 20 well casing volumes of groundwater was removed from each new monitoring well, which is more than proposed in the FSP. The additional development was required to remove the high amount of suspended solids in each well, in addition to the removal of drilling fluids (i.e., water) added during boring advancement in the intermediate zone and deeper wells.

3.2.2.2.6 *Abandonment and Replacement of Monitoring Wells*

Three monitoring wells (MWA-1, MWA-6, and MWA-15) were abandoned or removed during the RI. MWA-1 was abandoned because it was determined that the well was installed and screened across the lower permeability silt underlying the shallow groundwater zone and had the potential for permitting cross-contamination of the two WBZs. No well was installed to replace MWA-1. Monitoring well MWA-6 was abandoned because repeated attempts to properly develop the well had failed. Water extracted from MWA-6 was consistently extremely turbid. MWA-6 was replaced by MWA-6r. Monitoring well MWA-15 was abandoned to facilitate the excavation of impacted soil during the Soil Removal IRM. Upon completion of the excavation, MWA-15 was replaced by MWA-15r.

All of these wells were abandoned in accordance with State of Oregon well abandonment guidelines by removing casing, over-drilling, and backfilling with bentonite to the ground surface.

3.2.2.3 *Pilot Study Performance Monitoring Wells*

Six nested pairs of performance monitoring wells (12 wells designated as NMP-1S through NMP-6D) were installed in the shallow groundwater zone for performance monitoring purposes during the Persulfate Pilot Study. The wells were installed using a HSA in accordance with the *Final In Situ Persulfate Injection Pilot Study Work Plan* (ERM 2001b). Each pair contained one well screened across the water table and one well screened just above the confining silt at the base of the shallow groundwater zone.

Three performance monitoring wells (PMP-1 through PMP-3) were installed for the DNAPL Pilot Study. The wells were installed using a hollow-stem auger in accordance with the *DNAPL Pilot Study Work Plan, Acid Plant Area* (ERM 2003b). The wells were constructed with their screens set immediately above the silt layer at the base of the shallow groundwater zone.

All pilot study performance monitoring wells were constructed of PVC screen and riser pipe and completed with flush-mounted monuments. Performance monitoring wells were developed in the same manner as the remainder of RI monitoring wells. The locations the pilot study wells are shown on Figure 3-9. A summary of performance monitoring well completion data is provided in Table 3-5, and logs for pilot study wells are provided in Appendix H.

3.2.2.4 *Groundwater Elevation Monitoring*

Groundwater levels were measured in Acid Plant Area monitoring wells periodically, prior to groundwater quality sampling. Water levels were measured with an electronic water level indicator, in accordance with the procedures described in the FSP.

3.2.2.5 *Tidal Influence Monitoring*

Groundwater level monitoring wells were monitored using pressure transducers and data loggers to determine the effects of tidal fluctuations and river stage in the Willamette River on groundwater levels. The data were used to gain an understanding of groundwater gradients and flow directions beneath the Site. Daily tidal fluctuations were monitored during a typical mid-winter river stage on 3 to 8 February 1999. Pressure transducers were installed in five shallow-zone wells (MWA-2, MWA-3, MWA-4, MWA-5, and MWA-7), six intermediate-zone wells (MWA-8i, MWA-9i, MWA-10i, MWA-11i, MWA-12i, and MWA-14i), one deep-zone well (MWA-13d), and a river stage stilling well mounted on Dock #1. Results of the tidal influence monitoring are presented and discussed in Section 4.5.3.

The pressure transducers were mounted at a fixed depth so that changes in groundwater levels could be accurately recorded. The data loggers were synchronized and automatically recorded the water level in each well at 15-minute intervals for a period of approximately 120 hours. Water levels were manually collected at the beginning, middle, and end of the monitoring period to verify the automatically recorded data. Data were analyzed using a mathematical averaging method presented by Serfes (1991). The mathematically averaged data were used to generate a groundwater elevation map and to evaluate representative groundwater gradients and flow directions for the shallow and intermediate zones.

3.2.2.6 Hydraulic Conductivity Testing

Hydraulic conductivity testing was conducted on shallow-, intermediate-, and deep-zone monitoring wells (five shallow zone, six intermediate zone, and one deep zone), in accordance with the FSP. The testing was conducted to determine the appropriate hydraulic conductivity of each WBZ and to provide information on the vertical and horizontal variation in hydraulic conductivity in each zone.

The aquifer tests consisted of standard rising and falling head slug tests. A fixed-volume solid tube or “slug” was inserted and withdrawn from the water column in each monitoring well such that the rate of water level recovery in the well could be monitored before and after slug insertion and removal. Water level data for each slug test were collected using a pressure transducer and data logger that automatically recorded changes in water levels during the test. The slug test data were evaluated using the Bouwer and Rice (1986) analytical method. A description of the hydraulic conductivity testing is provided in the *Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report* (Exponent 1999). As a modification to the Work Plan scope, slug tests were conducted on one additional intermediate-zone monitoring well and the deep-zone monitoring well to better assess the hydraulic conductivity in these water-bearing zones. The results of the slug tests are presented and discussed in Section 4.5.4.

3.2.2.7 *Monitoring Well Groundwater Sampling*

Each RI monitoring well was developed and allowed to stand for a minimum of 7 days prior to sample collection. Pilot study performance monitoring wells were allowed to stand a minimum of 24 hours prior to sample collection. The first groundwater sampling event was conducted from 25 to 29 January 1999 on the 14 monitoring wells that existed at the time (MWA-1 through MWA-14i). Initially, wells were sampled using a pneumatic bladder pump and samples were collected after a minimum of three well casing volumes had been purged from the well. In a letter to ODEQ dated 31 May 2001, Arkema proposed the use of low-flow groundwater sampling procedures for the Site (ERM 2001c). Written approval of the low-flow procedure was provided by ODEQ on 6 June 2001. The description of the low-flow procedure is provided in the 31 May 2001 letter.

During purging of each monitoring well, field parameters (i.e., conductivity, dissolved oxygen, oxidation/reduction potential [ORP], acidity/alkalinity [pH], temperature, and turbidity) were measured within a flow-through cell to verify that water quality had stabilized prior to sample collection. Groundwater samples were then collected directly from the pump discharge tubing. Groundwater samples were collected in sample containers with the proper preservative (if required) and were packed in a cooler with ice for transport to the analytical laboratory under chain of custody. Groundwater sampling methods are described in more detail in the FSP of the RI/FS Work Plan and the 31 May 2001 letter describing low-flow sampling procedures.

Groundwater samples were analyzed for:

- Total and dissolved organochlorine pesticides by USEPA Method 8081A;
- VOCs by USEPA Method 8260B;
- SVOCs or polynuclear aromatic hydrocarbons (PAHs) by USEPA Method 8270C or 8270SIM;

- TPH-diesel range organics by Ecology Method NWTPH-Dx;
- Metals (Calcium, chromium, hexavalent chromium, iron, magnesium, manganese, potassium, and sodium) by USEPA Methods 6010B and 6020;
- Perchlorate by USEPA Method 314.0;
- Carbonate and bicarbonate alkalinity by USEPA Method 2320B and total alkalinity by USEPA Method 310.0;
- Ammonia as nitrogen by USEPA Method 350.1;
- Nitrate, nitrite, sulfate, and total chloride by USEPA Method 300.0, 353.2 or 354.1;
- TOC by USEPA Methods 415.1 and 9060 Mod;
- Chloral hydrate by USEPA Method 551.1;
- p-chlorobenzenesulfonic acid (p-CBSA); and/or
- Dissolved methane by USEPA Method RSK 175.

Pilot study performance monitoring wells were sampled and analyzed for parameters specific to each pilot study, which included many of the analytes listed above. A summary matrix of groundwater sampling events indicating the date, well number, and suite of analyses for each sample is provided in Table 3-4.

3.2.3 *Residual Dense Non-Aqueous Phase Liquid Investigations*

MCB DNAPL was observed in the shallow WBZ beneath the former MPR Pond and downgradient of the Acid Plant Area. The DNAPL was found primarily at the interface with the upper silt layer that separates the shallow and intermediate WBZs. The presence of elevated dissolved-phase chlorobenzene concentrations in MWA-15r also suggested that DNAPL might be a continuing source of dissolved MCB in Acid Plant Area groundwater.

A two-phased DNAPL investigation was initiated in early 2002 in accordance with the *Work Plan for Dense Non-Aqueous Phase Liquid Investigation, Acid Plant Area, ATOFINA Facility, Portland, Oregon* (ERM 2002a). The objective of the DNAPL investigation was to assess the extent of residual MCB DNAPL in the shallow and intermediate zones and to provide a basis for evaluating remedial alternatives. The DNAPL investigation boring locations are shown on Figures 3-2b and 3-10.

3.2.3.1 *Phase I DNAPL Investigation*

The Phase I DNAPL investigation utilized a combination of cone penetrometer testing (CPT), membrane interface probe (MIP) screening, and direct-push (Geoprobe®) groundwater sampling to characterize subsurface conditions, identify DNAPL, and verify the conceptual model of DNAPL distribution in the Acid Plant Area. The Phase I DNAPL investigation was carried out between 5 and 15 February 2002 and consisted of:

- Completing 19 CPT borings across the study area to estimate the depth to the silt horizon at the bottom of the shallow groundwater zone;
- Completing 17 MIP borings adjacent to the CPT borings to obtain a vertical profile of relative VOC concentrations in groundwater; and
- Collecting and analyzing 12 direct-push groundwater samples to check for the presence of DNAPL and quantify VOC concentrations in groundwater.

The field and laboratory results were summarized and evaluated to establish a linear correlation between MIP data and laboratory-reported MCB concentrations, to allow estimation of MCB concentrations at each location and depth where MIP data were recorded. The data were then plotted on MCB concentration contour maps in plan view and cross section to estimate the lateral and vertical extent of DNAPL in the shallow groundwater zone.

Detailed descriptions of the field methods and field program are presented in the *Work Plan for Dense Non-Aqueous Phase Liquid Investigation, Acid Plant Area* (ERM 2002a) and the report titled *Residual Dense Non-Aqueous Phase Liquid Investigation (Phase I), Acid Plant Area, ATOFINA Facility, Portland, Oregon* (ERM 2002b).

3.2.3.2 *Phase II DNAPL Investigation*

The Phase II DNAPL investigation was conducted to further characterize the nature and extent of DNAPL in the shallow groundwater zone and to evaluate the presence and extent of residual DNAPL in the intermediate zone. The Phase II DNAPL investigation was carried out between 10 June and 3 July 2002, and consisted of:

- Advancing seven direct-push borings (three primary and four step-out locations) in the area of the former MPR Pond. At each boring, continuous soil cores were collected from the shallow and intermediate groundwater zones and field-screened for the presence of residual DNAPL using a PID and Sudan IV hydrophobic dye.
- Collecting three direct-push groundwater samples from the intermediate zone for laboratory analysis of VOCs.
- Collecting three direct-push soil samples (two from the shallow zone and one from the intermediate zone) for laboratory analysis of TOC.

A HSA drill rig and a direct-push rig with a dual tube soil/water sampling system were used in combination to collect soil and groundwater samples. The augers served as a temporary conductor casing to isolate the shallow zone when the dual-tube probe rods were advanced through the shallow silt horizon into the intermediate zone.

Detailed descriptions of the field methods and field program are presented in the *Workplan Addendum for Residual Dense Non-Aqueous Phase Liquid Investigation (Intermediate-Zone Sampling), Acid Plant Area* (ERM 2002c) and the report titled *Phase II Residual Dense Non-Aqueous Phase Liquid Investigation (Intermediate-Zone Sampling), Acid Plant Area* (ERM 2002d).

3.3 CHLORATE PLANT AREA

The RI/FS Work Plan did not originally include investigation of the Chlorate Plant Area. This investigation was initiated as a result of the PA and Expanded PA identifying the locations of sodium bichromate usage at the plant. Based on historical operations, COIs in the Chlorate Plant Area include:

- Hexavalent Chromium;
- Perchlorate; and
- Chloride.

Potential sources of these COIs within the Chlorate Plant Area include (Figure 3-11):

- The Chlorate Cell Room;
- The Chlorate Process Building;
- The Chlorate Warehouse; and
- The Chlorate Tank Farm.

Investigation activities completed in the Chlorate Plant Area include:

- Subsurface soil sampling;
- Chemical analysis of Site soils;
- Groundwater sampling from direct-push borings;
- Installation of monitoring wells in the shallow, intermediate, and deep groundwater zones;
- Groundwater elevation monitoring;
- Groundwater sampling from monitoring wells; and
- Chemical analysis of groundwater samples.

3.3.1 Chlorate Plant Area Soil Investigation

Soil sampling was conducted in the Chlorate Plant Area for the purpose of field screening the soil and delineating the nature and extent of COIs in the soil. Soil samples were collected from the following borings and/or locations:

- Soil sampling borings (28 borings);
- Monitoring well borings (12 borings); and
- Hexavalent Chromium Reduction Pilot Study injection and performance monitoring well borings (9 borings).

The locations of these borings are shown on Figure 3-12. The Chlorate Plant Area soil sampling is summarized in Table 3-3. The following paragraphs describe the soil investigation tasks.

3.3.1.1 *Soil Sampling Borings*

A total of 28 soil sampling borings (borings B-68 through B-90 and B-116 through B-118) were advanced using direct-push methods to collect soil and groundwater grab samples in the Chlorate Plant Area. Depths of these borings ranged from 20 to 54 feet bgs. A summary of soil boring information is provided in Table 3-3, the logs are provided in Appendix H, and the locations are shown on Figure 3-12.

Soil samples were collected from discrete depth intervals and field-screened using a PID and visual inspection. Soil samples were submitted to a laboratory for archiving and analysis. Select samples from the borings were analyzed for chromium by USEPA Method 6020 (Table 3-3).

Following completion, each boring was abandoned with bentonite grout, as described in the FSP.

3.3.1.2 *Monitoring Well Borings*

Soil samples were also collected from soil borings advanced for the installation of groundwater monitoring wells. A total of 12 monitoring well borings were completed in and around the Chlorate Plant Area, including eight shallow-zone, two intermediate-zone, and two deep-zone monitoring well borings (MWA-23 through MWA-34i). These borings were advanced using HSA or cable tool drilling methods to depths ranging from approximately 26 to 60 feet bgs. Although originally designated as intermediate-zone wells, monitoring well borings MWA-28i and MWA-31i were completed in the deep groundwater zone. The names of these borings has been modified to designate them as deep-zone wells (i.e., MWA-28i(d) and MWA-31i(d)).

Monitoring well borings MWA-28i(d) and MWA-31i(d) borings were cased off to prevent direct vertical hydraulic connection between WBZs when the borings were advanced through low-permeability silt zones. This method was used for all Acid Plant Area intermediate-, deep-, and basalt-zone borings and was based on the conceptual model of the Site stratigraphy. Subsequent investigations in the Chlorate Plant Area indicated that the silts in the shallow and intermediate zones south of Dock No. 1 are discontinuous to the south; therefore, subsequent intermediate-zone borings (i.e., MWA-32i and MWA-34i) were advanced without casing off the boring as it passed through lower permeability zones.

The monitoring well boring information is summarized in Table 3-3, the logs are provided in Appendix H, and the well boring locations are shown on Figure 3-12.

Soil samples from monitoring well borings were visually inspected and logged for lithology, and field-screened using a PID and visual inspection in accordance with procedures in the FSP. Based on an oily sheen and slight odor identified in one monitoring well boring (MWA-30, 29.5 to 30 feet bgs), a soil sample from that depth was submitted to the laboratory for the following analyses (Table 3-3):

- VOCs by USEPA Method 8260B;
- Organochlorine pesticides by USEPA Method 8081A; and
- TPH-gasoline and TPH-diesel range by Ecology Methods NWTPH-Gx and -Dx, respectively.

Each monitoring well boring was completed as a monitoring well, as described in Section 3.3.2.2.

3.3.1.3 *Hexavalent Chromium Reduction Pilot Study Borings*

In 2003, a pilot study was conducted in the Chlorate Plant Area to evaluate the effectiveness of calcium polysulfide injections for the remediation of hexavalent chromium in Chlorate Plant Area groundwater. A total of nine borings were advanced for the installation of five injection wells (IW-1 through IW-5) and four performance monitoring wells (MWA-35 through MWA-38). All borings were completed in the shallow groundwater zone in accordance with the 18 July 2003 *Hexavalent Chromium Reduction Pilot Study Work Plan; Chlorate Plant Area* (ERM 2003c).

Soil samples from the pilot study borings were visually inspected and logged for lithology, but no samples were collected for chemical analyses. The pilot study boring information is summarized in Table 3-3, the logs are provided in Appendix H, and the pilot study monitoring well boring locations are shown on Figure 3-12. The Hexavalent Chromium Pilot Study is discussed in more detail in Section 7.3.3.

3.3.2 *Chlorate Plant Area Groundwater Investigation*

The Chlorate Plant Area RI groundwater investigation included collection and laboratory analysis of grab groundwater samples from direct-push borings, installation of monitoring wells, measurement of groundwater levels, and collection and laboratory analysis of monitoring well groundwater samples. The Chlorate Plant Area groundwater sampling locations are shown on Figure 3-12 and a summary of the groundwater sampling information is provided in Table 3-4.

3.3.2.1 *Soil Boring Groundwater Grab Sampling*

Groundwater grab samples were collected from all Chlorate Plant Area soil sampling borings, with the exception of borings B-86 and B-89. These two borings could not be sampled because refusal was encountered before advancing the borings to groundwater. Tables 3-3 and 3-4 indicate the borings from which groundwater grab samples were collected. The locations of the Chlorate Plant Area soil borings are shown on Figure 3-12. Grab groundwater samples were analyzed for chromium by either USEPA Method 6010B or 6020 (Table 3-4). Collection and analysis of grab groundwater samples was conducted using methods described in the FSP.

3.3.2.2 *Monitoring Well Installation and Development*

During the RI, 12 new monitoring wells were installed in and around the Chlorate Plant Area in three separate groundwater zones. All groundwater monitoring wells were installed in accordance with OAR, Water Resources Department, Chapter 690, Division 240; ODEQ Groundwater Monitoring Well Drilling, Construction and Decommissioning Guidelines; and the RI/FS Work Plan. Wells were installed using HSA or cable tool drilling methods. Monitoring well locations are shown on Figure 3-12. A summary of monitoring well installation data and as-built construction specifications is provided in Table 3-5. Boring and well construction logs are provided as Appendix H.

All Chlorate Plant Area monitoring wells were constructed with stainless steel wire-wrapped screens and stainless steel casing through the saturated zone and with PVC casing through the vadose zone. In general, water table wells were constructed with 10-foot long screens straddling the water table, whereas piezometers were constructed with 5-foot long screens set at the target depth, typically immediately above an aquitard.

3.3.2.2.1 *Shallow-Zone Monitoring Well Installation*

Eight new shallow-zone monitoring wells (MWA-23 through MWA-27, MWA-29, MWA-30, and MWA-33) were installed to depths between approximately 26 and 36 feet bgs. The shallow-zone monitoring wells were installed and screened at elevations based on observations made during installation of Acid Plant Area monitoring wells and advancement of direct-push borings conducted for soil and grab groundwater sampling. In general, the shallow-zone monitoring wells are screened across the water table.

3.3.2.2.2 *Intermediate-Zone Monitoring Well Installation*

Two intermediate-zone monitoring wells (MWA-32i and MWA-34i) were installed to depths ranging from approximately 38 to 44 feet bgs. The intermediate-zone wells were screened within the intermediate alluvial sands below one or more confining silt or equivalent fine-grained soil horizons.

3.3.2.2.3 *Deep-Zone Monitoring Well Installation*

Two deep-zone monitoring wells (MWA-28i(d) and MWA-31i(d)) were installed to depths of approximately 60 feet bgs. The deep-zone monitoring wells were screened within the deep alluvial silts. The deep-zone wells were constructed with a stainless steel wire-wrapped screen and stainless steel casing through the saturated zone and with PVC casing through the vadose zone.

3.3.2.2.4 *Monitoring Well Development*

Monitoring wells were developed as described in Section 3.2.2.2 for the Acid Plant Area monitoring wells.

3.3.2.3 *Hexavalent Chromium Reduction Pilot Study Performance Monitoring Wells*

Four monitoring wells were installed in the shallow groundwater zone for performance monitoring purposes during the Hexavalent Chromium Pilot Study. The wells, MWA-35 through MWA-38, were installed to depths between 33.5 and 35 feet bgs and were constructed in accordance with the Hexavalent Chromium Pilot Study Work Plan (ERM 2003c). The monitoring wells were constructed of PVC screen and riser pipe and completed with flush-mounted monuments. They were developed in the same manner as the other RI monitoring wells. The locations of the pilot study wells are shown on Figure 3-12, and a summary of the pilot study monitoring well completion data is provided in Table 3-5. Boring logs for the pilot study wells are provided in Appendix H.

3.3.2.4 *Groundwater Elevation Monitoring*

Groundwater levels were measured in Chlorate Plant Area monitoring wells periodically, prior to groundwater quality sampling. Water levels were measured with an electronic water level indicator, in accordance with the procedures described in the FSP.

3.3.2.5 *Monitoring Well Groundwater Sampling*

Groundwater samples were collected from Chlorate Plant Area groundwater monitoring wells as indicated in the boring summary (Table 3-4). The procedures used to sample the Chlorate Plant Area monitoring wells were similar to the procedures described in Section 3.2.2.2 for the Acid Plant Area (i.e., low-flow sampling techniques).

Chlorate Plant Area monitoring well groundwater samples were analyzed for:

- Organochlorine pesticides by USEPA Method 8081A;
- VOCs by USEPA Method 8260B;
- SVOCs or PAHs by USEPA Method 8270C;
- TPH-diesel range organics by Ecology Method NWTPH-Dx;
- Metals (calcium, chromium, hexavalent chromium, iron, magnesium, manganese, potassium, and sodium) by USEPA Methods 6010B and 6020;
- Perchlorate by USEPA Method 314.0;
- Nitrate, nitrite, sulfate, and total chloride by USEPA Method 300.0, 353.2 or 354.1;
- TOC by USEPA Methods 415.1 and 9060 Mod; and/or
- Dissolved methane by USEPA Method RSK 175.

The Hexavalent Chromium Pilot Study performance monitoring wells were sampled and analyzed for parameters specific to that pilot study, which included many of the analytes listed above. A summary matrix of groundwater sampling events indicating the date, well number, and suite of analyses for each sample is provided in Table 3-4.

3.4 SALT PADS

The RI/FS Work Plan did not originally include investigation of the salt pads. This investigation was initiated as a result of the PA, Expanded PA, and the known chloride concentrations in Site groundwater. The salt pads are situated within the area of investigation for the Chlorate Plant Area and share many of the same groundwater sampling locations. There are no groundwater monitoring wells solely associated with the salt pads. Chloride is the only COI associated with the salt pads. Investigation activities carried out to characterize impacts of the salt pads consisted solely of monitoring well groundwater sampling, as discussed in Section 3.3.2.5 for the Chlorate Plant Area groundwater investigation.

3.5 OLD CAUSTIC TANK FARM

The RI/FS Work Plan did not originally include investigation of the Chlorate Plant Area. After removal of the tanks during Site demolition, Arkema elected to collect and analyze samples to characterize tank sub-base soil. Based on historical operations, the COIs associated with the OCTF include:

- Sodium hydroxide (Caustic);
- TPH; and
- Organochlorine pesticides.

Potential sources of these COIs in the OCTF include (Figure 1-3):

- The aboveground storage tanks (ASTs); and
- Operations in the neighboring Acid Plant Area.

Investigation activities completed in the OCTF are limited to surface soil sampling. Two composite soil samples were collected from the base of each of the nine former tanks (18 total samples, OCTF-1 through OCTF-9).

Each sample was a composite sample comprised of soil from three locations beneath each tank. In addition to the 18 composite samples collected from the former tank locations, eight discrete soil samples were collected from four locations within the OCTF area. Samples were collected from 6 and 12 inches bgs using a hand auger. The composite samples were analyzed for:

- TPH as diesel and heavy oil, volatile hydrocarbons, and extractable hydrocarbons by Ecology Methods NWTPH-Dx, NWTPH-VPH, and NWTPH-EPH, respectively;
- VOCs by USEPA Method 8260;
- PAHs by USEPA Method 8270-SIM;
- PCBs by USEPA Method 8082;
- Organochlorine pesticides by USEPA Method 8081; and/or
- Metals (cadmium, chromium, and lead) by USEPA Method 6020.

The discrete soil samples were analyzed for organochlorine pesticides by USEPA Method 8081. Soil sampling was conducted in accordance with the *Soil Sampling and Analysis Work Plan; Old Caustic Tank Farm, ATOFINA Chemicals, Inc., Portland Facility* (ERM 2003d). Additional information on the soil sampling scope of work in the OCTF is provided in the *Soil Sampling and Analysis Report; Old Caustic Tank Farm; ATOFINA Chemicals, Inc. Portland Facility* letter report, dated 20 July 2004 (ERM 2004b). This letter report is provided herein as Appendix I.

There have been two known historical releases of sodium hydroxide in the OCTF. No specific groundwater investigation was conducted as a result of these releases. However, pH and alkalinity have been measured in the field and laboratory, respectively, for groundwater samples collected from the neighboring Acid Plant and Chlorate Plant Areas to characterize any impacts of caustic releases. The sampling activities are detailed in the Acid Plant and Chlorate Plant Area Groundwater Investigations sections (Sections 3.2.2 and 3.3.2).

3.6 AMMONIA PLANT

Based on the release of 400 gallons of a 30-percent anhydrous ammonia solution identified in the Expanded PA (Appendix D), an investigation was conducted to determine if the groundwater had been impacted. Two direct-push borings were conducted in the vicinity of the former Ammonia Plant (borings B-67 and B-119; Figure 3-2a). One of these borings was included in the discussion of soil borings for the Acid Plant Area (borings B-67). This boring was located downgradient of the former Ammonia Plant. A groundwater sample was collected from this boring and analyzed for ammonia as nitrogen by USEPA Method 350.1. As a result of the detection of ammonia in the groundwater sample collected from boring B-67, direct-push boring B-119 was advanced and sampled for the purpose of collecting a groundwater sample upgradient of the former Ammonia Plant. The sample was collected using the same method used for collection of groundwater samples for all other direct-push borings at the Site, as discussed in Section 3.2.2.1.

In addition to the two grab groundwater samples collected for purposes of characterizing ammonia impacts to groundwater, groundwater samples from two Acid Plant Area monitoring wells (MWA-5 and MWA-14i) were collected and analyzed for ammonia as nitrogen by USEPA Method 350.1.

3.7 TRANSFORMER PAD CONCRETE SAMPLING

Based on the prior operational use of potentially PCB-containing transformers at the Site, Arkema conducted an investigation of the former transformer pads after the transformers had been removed during demolition activities (Appendix J). The investigation of the transformer pads consisted of the collection and analysis of concrete chip samples from concrete pads where PCB-containing transformers were known or suspected to have been located. Concrete chip samples were collected in accordance with the *Standard Operating Procedure for Sampling Concrete in the Field* (USEPA 1997) and the *Sampling and Analysis Plan – PCBs in Concrete* (ERM 2002e). PCBs are the only COIs associated with the transformer pads. The locations of the former transformer pads are shown on Figure 1-5.

One of the oldest identified former transformer pads, located west of the Maintenance Shop, was sampled on 7 November 2002 and was analyzed for PCBs. A total of 15 concrete chip samples were collected from this pad. Based on the results of these analyses (low concentrations of PCBs detected in eight of the 15 samples, all less than 1.36 mg/kg), ODEQ requested additional sampling of concrete from transformer storage pads throughout the Site.

In the second round of concrete chip sampling, six composite samples were analyzed for the presence of PCBs. If PCBs were detected in a composite sample, the discrete samples from which that composite was prepared were analyzed for PCBs. Table 3-6 is a summary of discrete and composite chip samples analyzed for PCBs.

3.8 BONNEVILLE POWER ADMINISTRATION MAIN SUBSTATION

In November 2001, PBS performed a Phase II ESA for the BPA at the Pennwalt Substation. The Phase II ESA was conducted in accordance with the *Sampling and Analysis Plan, Phase II Environmental Site Assessment for Bonneville Power Administration, Pennwalt Substation, 6400 NW Front Avenue, Portland, Oregon* (PBS 2001). The purpose of the Phase II ESA was to "document the environmental condition of the facility at the time of decommissioning, evaluate cleanup requirements, and to collect sufficient information regarding the nature and extent of contamination to assist BPA in making informed business decisions." (PBS 2002a). The results of the Phase II ESA were reported in the *Phase Two Environmental Site Assessment for Bonneville Power Administration, Pennwalt Substation* report (PBS 2002, Appendix E).

Seventy-one soil samples were collected by PBS within the substation in November 2001. Soil samples were collected around oil-containing equipment with foundations and beneath racks with suspended oil-containing equipment. Samples were also collected from other areas of concern, such as stained soil and disturbed ground surfaces. In general, samples were collected approximately 0.5 foot from each concrete pad and from zero to 0.5 foot bgs. Sixty-four of the 71 BPA Main Substation soil samples were analyzed for PCBs by USEPA Method 8082. Additionally, select soil samples were analyzed for the following:

- TPH (diesel- and heavy oil-range) by Ecology Method NWTPH-Dx;
- Chlorobenzene and 1,1,1-Trichloroethane (method unspecified);
- Benzene, toluene, ethylbenzene, and xylenes (BTEX) (method unspecified);
- PAHs (method unspecified);

- Lead (method unspecified); and
- DDT and DDE (method unspecified).

In March 2002, eight additional soil samples (PENN-1-6 through PENN-6-18) were collected by BPA inside and outside the main substation. Two of the samples were collected within surface water drainage swales north and south of the substation (one sample from each swale). The location of these eight additional samples is shown on Figure 3-13.

After BPA had removed electrical equipment (i.e., transformers and circuit breakers), Arkema collected soil samples within the BPA substation (June 2002). Thirty-seven shallow surface soil samples (Samples BPA-1 through BPA-24 and "PD-" samples) were collected and were analyzed for diesel- and residual-range hydrocarbons by Ecology Method NWTPHDx and PCBs by USEPA Method 8082. Locations of these samples are shown on Figure 3-13.

As a result of the Arkema sampling, BPA conducted a soil removal in the northwestern corner of the substation to a depth of approximately 4 feet. Approximately 80 cubic yards (in-place measurement) were ultimately removed from the substation. The final extent of the soil removal excavation is shown on Figure 3-13. BPA collected confirmation samples (PEN-B1 through PEN-B5, and PEN-N, -S, -E, -W) from the bottom and sidewalls of the completed excavation. Confirmation samples consisted of a composite of four samples from each side of the excavation at three depths (zero, 1.5 , and 3 feet bgs) and four samples from the bottom of the excavation for a total of 16 confirmation samples.

In addition to the 12 confirmation samples, BPA collected eight discrete surface soil samples (Samples P-ROW-1 through P-ROW-8) in the area between the substation and Front Avenue. The discrete soil sample locations are shown on Figure 3-13.

Soil sampling conducted in and around the substation was conducted primarily by BPA. Therefore, sample collection, analytical, and data validation methods may have differed from the methods defined in the RI FSP. Samples collected by Arkema were collected in accordance with the RI FSP.

3.9 STORM WATER DRAIN SAMPLING

The RI/FS Work Plan included sampling storm water from manholes for two storm drain systems within the Acid Plant Area to evaluate potential COI impact to the storm water. Samples were collected from manholes SW-01 and SW-02 (Figure 1-6) on 22 January, 11 November, and 17 December 1999, and 27 March 2001. The sampling was conducted in accordance with the FSP.

The storm water samples were collected from each drain system at its point of entry to the manhole prior to mixing with non-contact cooling water discharge. Storm water samples were submitted to the laboratory for analysis of total and/or dissolved organochlorine pesticides by USEPA Method 8081A. The samples collected on 17 December 1999 were analyzed for total pesticides only. During storm water sample collection, field parameters (i.e., temperature, pH, specific conductance, ORP, dissolved oxygen, and turbidity) were measured in a separate aliquot of water. Table 3-7 provides a summary of storm water samples and analyses for the samples collected in 1999 and 2001.

ODEQ issued Arkema a new NPDES storm water discharge permit for runoff from the Site on 22 January 2004. A condition of the permit required Arkema to conduct a storm water characterization for legacy and 303(d) constituents for a 1-year period and to submit a report to ODEQ summarizing the sampling and results. The storm water characterization work consisted of monthly monitoring of storm water in Outfalls 001, 002, 003, and 004 (Figure 1-6). Storm water samples were analyzed for the following:

- Total dissolved solids (TDS);
- Metals (iron, manganese, mercury, and hexavalent chromium);
- DDT, DDD, and DDE;
- PAHs;
- PCBs;
- MCB;
- Pentachlorophenol;
- Perchlorate; and
- Chloride.

Samples were collected monthly from February 2004 through March 2005, with the exception of June and July 2004 and February 2005, due to dry weather and lack of adequate storm water flows. The storm water sampling as required by the January 2004 NPDES permit is discussed further in the *Storm Water Characterization Report* (Arkema 2005), included as Appendix K.

Because organochlorine pesticides and/or hexavalent chromium were detected in all of the outfalls, Arkema collected additional storm water data in an effort to delineate the source of pesticides and hexavalent chromium in the outfall samples. During the March 2005 sampling event, the sampling effort was expanded to include three to five additional samples per drain system in upstream manholes. The additional storm water sample locations are shown on Figure 3 in Appendix K.

3.10 RI FIELD SCREENING

As indicated in previous sections, select soil and groundwater samples were field-screened using one of the following methods:

- PID for the detection of VOCs;
- Sudan IV® hydrophobic dye for the detection of residual DNAPL; and
- TLC for the detection of DDT.

This section describes the methods and limitations of these field screening techniques.

3.10.1 Photoionization Detector

Select soil samples were screened for the presence of MCB and other VOCs using a PID, in accordance with procedures in the FSP. Typically, an aliquot of soil was placed in a Ziploc® bag and allowed to equilibrate to ambient air temperature. The PID inlet was then inserted into the bag to sample the headspace. PID screening results were documented in a field screening notebook and on boring logs.

3.10.2 Sudan IV® Hydrophobic Dye

Select soil and groundwater samples were screened for the potential presence of non-aqueous phase liquid (NAPL) using Sudan IV®

hydrophobic dye. Sudan IV® is a dye that turns NAPL bright red for easy visual detection. For NAPL detection in soil, approximately 10 grams of soil and a small amount of Sudan IV® (approximately 1 gram) were placed in a Ziploc® bag, hydrated with deionized water (approximately 50 milliliters), and thoroughly mixed. NAPL detection in groundwater was conducted by adding a small amount of Sudan IV® (approximately 50 milliliters) to an aliquot of water in a Ziploc® bag and mixing thoroughly. Positive results were qualified according to the intensity of color: positive/low for a slightly red or pink color or positive/high for a bright red color. Sudan IV® screening results were documented in a field screening notebook.

3.10.3 Thin-Layer Chromatography

Select soil and groundwater samples were screened for the presence of DDT using TLC. Approximately 10 grams of soil and 40 milliliters of water were extracted with methanol, spotted on silica gel slides, and allowed to develop in hexane until the solvent front reached within 5 millimeters of the end of the slide (approximately 5 minutes). Once developed, the slides were irradiated with short-wave ultraviolet light for 15 minutes to increase the intensity of the DDT spot (this was done for all samples and standards). The individual slides were then examined under short-wave ultraviolet (UV) light and compared to a set of DDT standards. DDT identification was determined by comparing the relative response factor (Rf) (distance of spot/distance of solvent front) on the sample slide to that of the standards. Relative concentrations were determined by comparing the intensity of the spot to the standards.

Detection limits of 50 mg/kg DDT in soil and 0.5 mg/L in water were established for this method. A detection limit of 10 mg/kg was achieved for DDT in soil for samples collected from two borings (borings B-65 and B-66). Standards were prepared at concentrations of 50, 100, 500, 1,000, and 5,000 mg/kg. Qualitative identification of DDD and DDE could also be determined from the TLC analysis. Quantification of DDD and DDE was not attempted with the TLC method.

TLC results were recorded in a field screening notebook.

3.11 FIELD SURVEYING

Upon completion of monitoring well installation and development, a horizontal and vertical control survey was conducted on new and existing monitoring wells and other sample locations (e.g., borings, vapor monitoring points, injection wells, air sparging wells, soil vapor extraction wells, and storm water sample locations) to establish coordinates and elevations of the sample locations. W&H Pacific, Inc., an Oregon-licensed surveyor, conducted the surveys. Reference elevations were established to the nearest 0.01 foot and are referenced to the City of Portland Datum. Horizontal coordinates were established to the nearest 0.1 foot and referenced to Oregon State Plane Coordinates. Survey data for all Site investigation borings is provided in Table 3-8. Survey data (i.e., ground surface elevation, top of casing elevation) for each of the Site wells are reported in Table 3-5.

3.12 INVESTIGATION-DERIVED WASTE MANAGEMENT

Investigation-derived waste (IDW) included soils, groundwater, decontamination fluids, and personal protective equipment generated during drilling, well installation, development, and sampling activities. IDW was placed in sealed, labeled 55-gallon drums. Based on soil and groundwater analytical results and drum composite sample analyses, the drum contents were profiled at the Site.

IDW from the Acid Plant Area was evaluated to determine if it was a listed hazardous waste, a characteristic waste, or a state pesticide residue waste. Written agreements have been established between Arkema and ODEQ to determine which IDW should be listed waste and analytical information was used to determine if a waste is characteristic. If a waste was neither listed or characteristic, it was managed as a state pesticide residue.

The majority of IDW from the Acid Plant Area was handled under the state pesticide residue waste management rules. No IDW from the Acid Plant Area has been classified as U-listed waste. Some IDW exceeded the criteria for toxicity characteristic leaching procedure (TCLP) for chlorobenzene and was classified as a characteristic hazardous waste. This characteristic waste was manifested to a Subtitle C facility for incineration. Wastes managed as state pesticide residue were transported to the Chemical Waste Management (CWM) Subtitle C facility in Arlington, Oregon for disposal. No IDW has been managed at either a Subtitle D facility or at the Arkema Site.

IDW from the Chlorate Plant Area was managed in a similar manner, but there were no listing criteria associated with chlorate. Some IDW exceeded the criteria for TCLP for chromium and was classified as a characteristic hazardous waste. Most IDW from the Chlorate Plant Area was managed at the CWM Subtitle C facility in Arlington, Oregon as non-RCRA regulated waste.

Over 4,700 tons of soil were removed from the Acid Plant Area during the two phases of the Soil Removal IRM. The soil was managed as state pesticide residue at the CWM facility in Arlington, Oregon. During 2003, Arkema demolished the former DDT Process building and the former DDT Warehouse (No. 2 Warehouse). Approximately 789 tons of debris was managed as a listed hazardous waste (U061) through macro-encapsulation followed by landfill at the CWM facility in Arlington, Oregon.

Other wastes generated through demolition activities at the plant in 2003 and 2004 were disposed at the Hillsboro Landfill in Hillsboro, Oregon. The concrete and brick walls of the No. 3 Warehouse and the Chlorate Plant were tested for perchlorate. The Chlorate Plant materials were also detected for chromium, but little was detected. Because perchlorate was detected in the concrete and brick from these areas, these materials were disposed at the Hillsboro Landfill. Concrete pads under the electrical transformers were tested for PCBs. None of the transformer pads contained regulated concentrations of PCBs. However, all pads that had detectable concentrations of PCBs were disposed at the Hillsboro Landfill.

Table 3-9 summarizes the wastes generated during the RI and plant demolition. All hazardous waste records were submitted to ODEQ, with copies retained by Arkema.

3.13 QUALITY ASSURANCE DATA REVIEW

The laboratory analytical data for soil, groundwater, and storm water samples collected during the RI were subjected to rigorous independent quality assurance (QA) review. Environmental Standards, Inc. of Valley

Forge, Pennsylvania, performed the QA reviews. The reviews were performed in accordance with the *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (USEPA October 1993); the *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (USEPA February 1994); the Quality Assurance Project Plan (Appendix B of the RI/FS Work Plan); and Environmental Standards' professional judgment.

Data were examined to determine the usability of the analytical results and compliance relative to the method requirements specified in USEPA's *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition*. Data qualifiers and project-specific descriptors were applied to the analytical results as appropriate based on the criteria evaluated. Use of these data qualifiers and descriptors allows the qualitative and/or quantitative reliability of the analytical results to be assessed. Detailed descriptions of the data review procedures and results are contained in the QA Project Plan (Appendix B of the RI/FS Work Plan, Exponent 1998) and in QA review reports submitted to ODEQ with previous data transmittals and progress reports.

After analytical data were reviewed, they were incorporated into an electronic database for storage, retrieval, data analysis, and reporting. The analytical data presented in this RI Report have undergone the review process summarized above.

Data obtained during the pre-RI work (i.e., the 1994 Phase 1 and 1996 Phase 2 Site Characterization work), pilot studies, and IRMs did not undergo the same level of data quality evaluation as did the RI data. However, the data are presented herein to provide more information for development of the site conceptual model. The usefulness of the unvalidated data for the risk assessments and FS will be determined during the execution of those tasks.

4.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section summarizes the physical characteristics of the Site, including demography and land use, climate, geology, surface water hydrology, hydrogeology, and ecological resources.

4.1 DEMOGRAPHY AND LAND USE

The Site has historically been used for industrial purposes. It is located in the heart of the Guild's Lake Industrial Sanctuary, zoned and designated "IH" for heavy industrial use. The Guild's Lake Industrial Sanctuary is defined as the area generally bounded by Vaughn Street on the south, St. Johns Bridge on the north, Highway 30 on the west, and the Willamette River on the east. The nearest residential structures are located outside of this industrial area, approximately 0.3 miles west and upgradient of the Site (Figure 1-1). Forest Park, a large, forested park, is located approximately 0.5 miles to the west of the Site. Heavy industrial land use surrounds the Site and isolates it from residential areas and Forest Park.

On 14 December 2001, the Portland City Council voted to adopt the Guild's Lake Industrial Sanctuary Plan (GLISP). The purpose of the GLISP is to maintain and protect the land within the sanctuary boundary as a dedicated area for heavy and general industrial uses. The GLISP became effective on 21 December 2001 (City of Portland 2001). The plan's vision statement, policies, and objectives were adopted as part of Portland's Comprehensive Plan and are implemented through amendments to the City's Zoning Code. As a result of the GLISP, the likely future land use of the Site is industrial.

Currently, the majority of the Site is paved, gravel covered, or covered with building foundations. The riverbank above the mean high water line of the Willamette River is steeply sloping and covered with large-sized rubble that is used for bank stabilization. A future greenway has been proposed for the Site adjacent to the Willamette River. The greenway setback extends 50-feet landward from the top of the riverbank and consists of a 25-foot setback requirement and an additional 25 feet for future landscaping. Due to security concerns, this area will not be accessible from off site and will be maintained as green space.

4.2 CLIMATE

The climate in the Portland area is temperate with dry, moderately warm summers and wet, mild winters. January and February receive 40 to 50 percent of the annual precipitation, and the summer months receive 25 percent of the annual precipitation (National Oceanic and Atmospheric Administration and U.S. Department of Commerce 1974).

The average annual precipitation in Portland is 37.6 inches. The average lake evaporation is 24 to 26 inches annually (U.S. Department of Commerce 1968). The monthly average relative humidity ranges from 65 to 84 percent. Monthly average temperatures range from 41 degrees Fahrenheit (°F) in the winter to approximately 70 °F in the summer. Daily minimum temperatures in January average 32 °F; daily maximum temperatures in July average 79 °F. Winds are generally aligned with the Willamette River Valley.

4.3 GEOLOGY

This section summarizes the regional geology in the Site vicinity based on published reports for the area. Information is also presented on the site-specific geology of the Arkema facility. The latter information is derived from site investigations leading up to and including the RI.

4.3.1 Regional Geology

The geology of the Portland area is characterized generally by a broad structural depression or basin bordered by the Cascade Mountains on the east and the Coast Range Mountains on the west. Geologic formations in the basin are also folded and dissected by a number of northwest-trending faults. The Tualatin Mountains form a northwest-trending anticlinal ridge that is faulted along its eastern flank by the Portland Hills Fault. The Willamette River flows along the base of the eastern side of the Tualatin Mountains, and the Arkema site is located on the west bank of the river. A number of additional faults are located approximately parallel or perpendicular to the Portland Hills Fault and are mapped along or near the Tualatin Mountains (Beeson et al. 1991).

The geologic formations of regional significance that are most likely to be present at or near the Site are described below, starting with the oldest formation (Columbia River Basalt Group).

4.3.1.1 *Columbia River Basalt Group*

The Portland basin is underlain by the Columbia River Basalt Group, which consists of flood basalt erupted 17 to 6 million years ago. These Miocene-age flood basalts are characterized by a thick sequence of dense basalt flows separated by permeable interflow zones. These interflow zones are recognized as highly productive aquifers. This unit has been folded and faulted and forms the Tualatin Mountain uplands southwest of the Site. The Columbia River Basalt Group dips steeply to the northeast near the Arkema site. The top of the Columbia River Basalt Group is at the ground surface west of St. Helens Road (about 0.5 miles west of the Site), and was encountered at depths of 49 to 55 feet below the Site in several RI borings. On the east bank of the river, basalt depths are estimated to be between 300 and 450 feet bgs (Madin 1990). The Columbia River basalt flows are overlain by fluvial sediments of the Troutdale Formation; near the Tualatin Mountains these deposits may be absent.

4.3.1.2 *Troutdale Formation*

The Troutdale Formation is of Miocene to Pliocene age and, in this area, consists of interbedded conglomerates and finer-grained deposits (Beeson et al. 1991). The Troutdale Formation is characterized by pebbly to cobbly conglomerates consisting primarily of Columbia River Basalt clasts with allocthonous clasts of volcanic, plutonic, and metamorphic rocks, and interbedded with micaceous arkosic and vitric sandstone (Tolan and Beeson 1984; Beeson et al. 1991). Major regional aquifers in the Troutdale Formation underlie east Portland. The thickness of the Troutdale Formation ranges from 900 feet near Troutdale to 200–300 feet in the western parts of the basin east of the Willamette River (Beeson et al. 1991). The Troutdale Formation is expected to be thin or locally absent at the Arkema Site and is not a significant aquifer in the vicinity of the Site.

4.3.1.3 *Catastrophic Flood Deposits*

During the Pleistocene, thick deposits of boulders, gravels, sands, and silts accumulated throughout the Portland basin as a result of the repeated failures of glacial ice dams that impounded the ancient glacial Lake

Missoula (Waitt 1985). These catastrophic flood deposits form the terrace surfaces in the eastern Portland area and are composed of three different facies. Coarse-grained pebble to boulder gravels and sand make up the core of these terraces, with fine-grained sand and silt deposits mantling the coarser-grained facies. A finer-grained, interlayered silt, sand, and gravel facies is found adjacent to the Columbia and Willamette river channels. The coarse-grained facies reaches a maximum thickness of 60 to 100 feet, whereas the fine-grained facies reaches a maximum thickness of 100 to 130 feet. The channel facies typically ranges in thickness from 15 to 45 feet (Beeson et al. 1991). Catastrophic Flood Deposits are not anticipated west of the Willamette River in the vicinity of the Site. These deposits are regionally significant, however, east of the Willamette River.

4.3.1.4 Recent Alluvium

Recent alluvium consists of Quaternary deposits of sands, silts, and gravels deposited by the Willamette and Columbia rivers. These deposits include the channel bottoms and floodplains of the rivers, and range up to 150 feet in thickness (Beeson et al. 1991).

In addition to geologic formations, anthropomorphic fill is common along many of the floodplain terraces adjacent to the Willamette and Columbia rivers. The primary source of this fill is dredged material from the shipping channels. Other sources of fill have also been documented at specific sites.

4.3.2 Site Geology

The surficial geology at the Site is characterized by fill and alluvial deposits of the Willamette River. Alluvial deposits are underlain by bedrock of the Columbia River Basalt Group. A cross section layout map and cross section diagrams for the Site are provided on Figures 4-1 through 4-5.

4.3.2.1 Fill Material

Fill materials occur from the surface to depths of approximately 25 feet bgs and consist of brown clayey silt to silty sand with occasional wood, brick, concrete, metal piping, and asphalt. 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 manufacturing area to approximately 25 feet along the riverbank.

The source of the fill is generally believed to be river dredge spoils and deposits from on- and off-site excavations. This was an accepted practice for near-shore areas of properties along the Portland Harbor. The City of Portland was reportedly allowed to dispose of used asphalt from roadways. The shallow, fine-grained soils are the result of dredged material from the Willamette River being placed on the upland portions of the Site. In some areas of the Site, this has resulted in an extension of the ground surface into the river by up to 300 feet. The approximate upland extent of fill material is shown on Figure 4-1 and Figures 4-3 through 4-5.

4.3.2.2 Alluvial Deposits

Based on boring logs completed for the RI (Appendix H), the native soil profile is generally characterized by laterally discontinuous, alternating layers of dark gray-brown sand with varying amounts of silt and thinner silt layers with varying amounts of fine sand. These sands and silts are massive to finely laminated and the contacts between the sand and silt can be gradational. In general, there are four alternating sand and silt layers; a sand layer occurs at the ground surface, underlain by a silt layer at approximately 8 feet bgs, which is underlain by additional sand and silt layers. The sand and silt layers are continuous over most of the Site. The lowest silt layer, approximately 35 feet bgs, becomes less continuous in the southern portion of the Site adjacent to the Willamette River.

Underlying the deepest silt layer, at a depth of approximately 35 feet, is a sand layer with black sands on the northern end of Lots 3 and 4 and dark gray-brown sands toward the south. A deeper silt layer with some clay and fine sand is situated beneath the black and dark gray-brown sand and above the basalt bedrock. Physical properties of select samples of alluvial soils are reported in Table 4-1.

Regionally, the Troutdale Formation, composed of sandstone and conglomerate, is inferred to be present below the unconsolidated fill and alluvium and is likely to be laterally discontinuous throughout the area (Geraghty & Miller 1991). The presence of the Troutdale Formation beneath the Site has not been confirmed by this or previous investigations. The limited occurrence of the Troutdale Formation is probably attributable to erosion by the ancestral Willamette River.

4.3.2.3 Bedrock

Columbia River Basalt is inferred at depth below the fill and alluvium throughout the area. Basalt was encountered in three monitoring well borings conducted as part of the RI (MWA-13d, MWA-14i, and MWA-21b), at depths of 49 to 55 feet bgs. These borings are located downgradient (east) of the Acid Plant Area. Basalt was not observed in two borings, MWA-11i and MWA-12i, that were advanced to depths of 51 to 52 feet bgs, upgradient of the Acid Plant Area, or in borings MWA-28i(d) and MWA-31i(d), advanced to depths of approximately 59 to 60 feet bgs, downgradient (east) of the Chlorate Plant Area. Regionally, the basalt surface dips to the east; however, a trough or basin has been identified in the upper basalt surface during other investigations near the facility (Geraghty & Miller 1991). This finding is supported by data from this investigation.

4.4 SURFACE WATER HYDROLOGY

The facility is located along the west bank of the Willamette River at approximately river mile 7.5. The daily mean Willamette River discharge in Portland ranges from 8,300 cubic feet per second (cfs) in summer (August) to 63,000 cfs in winter (December). The mean daily flow is 31,000 cfs for the period of 1972 to 1994. The confluence of the Willamette and Columbia Rivers is approximately 7.5 miles northwest of the Site. The Willamette River is not used as a drinking water source downstream of the Site.

The Willamette River is gauged at the Morrison Street Bridge (MSB) at river mile 12.8, approximately 5 miles upstream of the Site. The datum at the MSB is 1.55 feet NGVD (U.S. Army Corps of Engineers 1991). Thus, Willamette River stage data from the MSB are converted to NGVD by adding 1.55 feet.

The minimum monthly river stage along the Willamette River in the Portland Harbor area typically occurs during September and October. Maximum monthly stages usually occur in the winter (December through February) and in the spring (March through June), coincident with flood peaks on the Willamette and Columbia rivers (U.S. Army Corps of Engineers 1991). Two extreme daily stage levels were recorded on 9 February 1996, when the river stage reached more than 28 feet and on

2 February 1997 when the river stage reached nearly 23 feet. For water years 1973 to 1990, the minimum daily stage of 1.1 feet was recorded in November 1979 and the maximum daily stage of 23.8 feet was recorded in January 1974.

The Willamette River stage is influenced by upstream reservoir regulation on both the Willamette and Columbia rivers (up to the Bonneville Dam) and by tidal effects from the Pacific Ocean. Tidal effects are most pronounced, typically ranging from 2 to 3 feet in amplitude per tidal cycle, when the river stage is less than about 8 feet (MSB gauge). Tidal influences are more moderate (i.e., less than 2 feet in amplitude) between river stage elevations of 8 to 14 feet (MSB gauge). Above approximately 14 feet, tidal fluctuations are generally absent in the Portland Harbor. Tidal influences are most pronounced during the summer and fall when river flow and river stage are typically at their lowest (U.S. Army Corps of Engineers 1991).

The ground surface at the Site is generally flat. Site drainage is towards catch basins that contribute to four storm water outfalls, which discharge to the Willamette River (Figure 1-6).

4.5 SITE HYDROGEOLOGY

This section describes the hydrogeology of the Arkema Site. Geologic cross sections extending across the Site and into the Willamette River are shown on Figures 4-3 and 4-4. These cross sections identify well borings, screened intervals, and water levels. A summary of groundwater elevation data is provided in Table 4-2.

4.5.1 Groundwater Zones

Groundwater occurs in four distinct groundwater zones beneath the Site. Unconfined groundwater has been observed in the shallow groundwater zone at depths of approximately 6 to 32 feet bgs in the uppermost fill and sand alluvium. In general, the depth to groundwater increases from west to east across the Site (from Front Avenue toward the Willamette River). The saturated thickness of the shallow groundwater zone is defined as the depth from the potentiometric surface to the upper surface of the silt layer situated just above the black and dark gray-brown sand and ranges from approximately 15 to 25 feet near Front Avenue to approximately 2 to 15 feet near the Willamette River bank.

Confined or semi-confined groundwater is found in the alluvial black and dark gray-brown sands of the intermediate groundwater zone below the four uppermost alternating sand and silt layers. The intermediate groundwater zone occurs between depths of approximately 36 to 46 feet bgs in the Acid Plant and Chlorate Plant Areas. The intermediate groundwater zone has a saturated thickness of approximately 5 to 10 feet. The shallow and intermediate groundwater zones are separated by a continuous silt horizon (approximately 6 inches to 4 feet thick). This silt horizon becomes discontinuous in the eastern portion of the Chlorate Plant Area, adjacent to the Willamette River.

The deep groundwater zone is found in the finer-grained deposits below the alluvial sands and above the Columbia River Basalt. Below the sands, at depths of approximately 40 to 45 feet bgs, silt with some clay and fine sand is predominant. Because of the fine-grained nature of these deposits, groundwater is not expected to be readily transmitted through these deeper deposits.

Basalt-zone groundwater is situated beneath the alluvial deposits at the Site up to the maximum depth explored in the RI (approximately 70 feet bgs).

4.5.2 *Groundwater Flow Directions and Hydraulic Gradients*

In general, the groundwater flow direction across the Site is toward the Willamette River. The shallow groundwater surface fluctuates seasonally, rising during periods of high rainfall and infiltration and falling during mid- to late summer and low rainfall periods. Shallow groundwater in close proximity to the Willamette River will rise 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 close proximity to the river. These short-term flow reversals likely result in temporary lateral flow of groundwater to the north and/or south (i.e., parallel to the river), until the flood stage subsides.

4.5.2.1 *Groundwater Flow Directions – Acid Plant Area*

Groundwater flow direction has been inferred for the shallow, intermediate, and deep groundwater zones. Groundwater elevation and flow data in the Acid Plant Area are available dating back to December 1996. Groundwater flow direction in the shallow zone is more variable than in the intermediate zone. In the Acid Plant Area, the shallow groundwater flow direction has been observed to vary from east to northeast. Intermediate-zone groundwater flow direction has been observed to be more consistent, in a direction of plant east-northeast.

Figures 4-6 and 4-7 show variations in groundwater flow directions for the shallow and intermediate zones in the Acid Plant Area from June 1999 to June 2003. The 9 months represented in these figures are months in which comprehensive, site-wide water level data were collected. The groundwater elevation maps for June and September represent typical conditions at the beginning and end of the dry season, respectively, while the maps for November, March, and April represent typical conditions at the beginning and end of the wet season.

Hydrographs for selected wells in the Acid Plant Area through June 2003 are shown on Figures 4-8 through 4-13. River stage data also are plotted on these figures. The hydrographs show that, overall, water levels in the subject wells have generally decreased since water level measurements were first begun at each well (i.e., late 1996 or early to mid-1999). This is consistent with a general decrease in annual total precipitation for Portland, Oregon for the same period (Oregon Climate Service 2005). Superimposed on the general long-term decreasing trend for each well are a series of shorter-term seasonal fluctuations that generally correspond to periods of relatively high river stage/infiltration alternating with periods of relatively low river stage/infiltration. In places where these short-term fluctuations are absent from the hydrographs, the apparent lack of seasonal influence may reflect sparse water level data for the period in question, rather than a true departure from the normal seasonal trend.

It can also be seen from Figures 4-8 through 4-13 that at most well cluster locations, water levels are usually higher in the shallow wells than in the intermediate wells. Therefore, at most well cluster locations, a downward vertical hydraulic gradient normally exists; this downward gradient creates the potential for downward flow of groundwater from the shallow zone to the intermediate zone. The exception is well cluster MWA-5/

MWA-14i (Figure 4-11), where the water level in the shallow zone is usually slightly lower than the water level in the intermediate zone (thus creating the potential for upward groundwater flow). The water level in deep well MWA-13d is usually slightly lower than the water level in intermediate well MWA-9i (Figure 4-9), which implies the potential for downward groundwater flow from the intermediate zone to the deep zone at this well cluster location. It should be noted that shallow well MWA-15/15r and intermediate well MWA-11i (Figure 4-13) do not constitute a well cluster (the wells are roughly 50 feet apart); thus, these wells were not used to assess vertical gradients. Groundwater hydraulic gradients are discussed further in Section 4.5.2.4.

4.5.2.2 Groundwater Flow Directions – Chlorate Plant Area

The groundwater flow directions in the shallow and intermediate zones in the Chlorate Plant Area are generally to the east-southeast. Figures 4-14 and 4-15 show the groundwater flow directions for the shallow and intermediate groundwater zones for the Chlorate Plant Area for April 2002 and June 2003. Although groundwater elevation data are available for the Chlorate Plant Area dating back to October 2001, these months represent the most complete data set for Chlorate Plant Area wells.

A hydrograph for well cluster MWA-25/MWA-28i(d) in the Chlorate Plant Area is shown on Figure 4-16. Limited water level data are available for the Chlorate Plant Area wells because these wells are relatively new. Figure 4-16 shows that water levels in wells MWA-25 and MWA-28i(d) have generally increased since October 2001; however, this may be the effect of sparse water level data for the period from October 2001 to June 2003, rather than a departure from typical seasonal trends. Typically, October water levels would be expected to represent seasonal lows, whereas June water levels would be expected to represent seasonal highs. The water levels measured in intermediate well MWA-28i(d) are higher than the water levels measured in shallow well MWA-25, indicating the potential for upward groundwater flow between the intermediate and shallow zones at this well cluster location. Groundwater hydraulic gradients are discussed further in Section 4.5.2.4.

4.5.2.3 Groundwater Flow Directions – Deep Groundwater Zone

The inferred groundwater flow direction in the deep zone is east-northeast. Figure 4-17 shows the potentiometric surface for groundwater in the deep groundwater zone, measured in February 1999. Groundwater flow direction in the deep zone is based on data collected in February 1999, including data collected from an off-site well (MW-4d, located on the Rhone-Poulenc facility, upgradient of the Site) and from monitoring well W-19d, located on Lot 1.

4.5.2.4 Groundwater Hydraulic Gradients

Horizontal hydraulic gradients in the shallow groundwater zone have ranged from approximately 2.4×10^{-3} (November 2001) to 6.9×10^{-3} feet/feet (February 1999). Gradients in the intermediate groundwater zone have generally been more consistent and have ranged from approximately 3.8×10^{-3} (June 1999) to 6.9×10^{-3} feet/feet (September 1999).

Vertical hydraulic gradients varied widely over the duration of the investigation, from 5.23 feet downward to 2.04 feet upward over vertical distances of 9.6 to 18.3 feet (based on the distances between the midpoints of the well screens). Vertical hydraulic gradients between shallow- and intermediate-zone wells were calculated for the following monitoring well pairs: MWA-2/MWA-8i, MWA-3/MWA-9i, MWA-4/MWA-10i, MWA-5/MWA-14i, MWA-6r/MWA-16i, and MWA-7/MWA-12i. Variations in vertical hydraulic gradients were more pronounced along the eastern edge of the Site (i.e., along the Willamette River). All but one of the well clusters exhibited primarily downward hydraulic gradients. Wells MWA-5/MWA-14i exhibited primarily upward hydraulic gradients. The nested well pair on the western edge of the Site (MWA-7/ MWA12i) exhibited only downward gradients, whereas upward gradients were observed at one time or another in other shallow- and intermediate-zone well pairs.

Intermediate- and deep-zone monitoring well pairs (MWA-9i/MWA-13d and MWA-32i/MWA-31i(d)) exhibited vertical hydraulic gradients between 1.96 feet downward and 0.40 feet upward over vertical distances of 9.5 to 18.0 feet. These vertical gradients represent a less pronounced variation in groundwater elevations at depth.

Vertical hydraulic gradients between the deep and basalt wells (MWA-13d/MWA-21b) were observed to be upward and ranged from 0.10 to 0.35 feet over a vertical distance of approximately 13 feet (based on the distances between the midpoints of the well screens).

Only upward gradients were observed for the nested monitoring well pair in the Chlorate Plant Area (MWA-25/MWA-28i(d)). Upward gradients for this well pair ranged from 0.8 feet to 1.7 feet over a vertical distance of 27.6 feet. Monitoring well MWA-25 is a shallow zone well and MWA-28i(d) is screened in the deep groundwater zone silts.

4.5.3 Tidal Influence Monitoring

The tidal influence study, conducted 3 to 8 February 1999, provides 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.

During the period of tidal monitoring, the Willamette River stage ranged from about 11 to 13 feet (City of Portland Datum) and daily tidal fluctuations generally ranged from 0.5 and 1.0 feet, measured in the Willamette River, adjacent to the Site. During this period, shallow-zone groundwater levels were not affected by fluctuations in the river, whereas intermediate- and deep-zone groundwater levels exhibited some influence from Willamette River tidal fluctuations up to 300 feet from the river. Figure 4-18 is a hydrograph of clustered shallow-, intermediate-, and deep-zone groundwater monitoring wells located less than 100 feet from the river. The hydrograph clearly shows the separation between the shallow potentiometric surface (at MWA-3) and the intermediate- and deep-zone potentiometric surfaces (e.g., at wells MWA-9i and MWA-13d). The intermediate- and deep-zone potentiometric surfaces closely emulate the fluctuations in the Willamette River. It should be noted that the river surface is about 2 feet lower in elevation than the intermediate/deep groundwater surfaces during the monitoring period, indicating that the river stage does not substantially affect groundwater flow directions. A dampening and lag in the arrival time of the tidal 'peaks' can also be observed in the hydrograph, which illustrates the attenuation of the propagating pressure wave from the river to the groundwater monitoring wells.

Figure 4-19 shows the degree of influence that river stage fluctuations have on the intermediate-zone wells progressively further inland from the river. During the monitoring period, the Willamette River stage exhibited fluctuations on the order of 1 to 2 feet. Approximately 90 feet from the shoreline, MWA-9i exhibited groundwater elevation fluctuations on the order of 0.5 feet. Approximately 300 feet from the shoreline, tidal influences were still observed in MWA-11i, although slightly dampened, relative to MWA-9i. At monitoring well MWA-12i, approximately 900 feet from the shoreline, there was no evidence of influence from river stage fluctuations during the monitoring period.

Results of the tidal influence monitoring suggest that Willamette River fluctuations are propagated inland through the intermediate and deep groundwater zones, but do not significantly alter the groundwater flow system at the Site. Tidal influence has a small effect on vertical gradients: increases in river level result in small decreases in vertical gradients. Reversals of hydraulic gradients observed in some Site well clusters are not likely caused by tidal influences, but by seasonal changes in river stage.

4.5.4 Hydraulic Conductivity Estimates

A detailed description of the hydraulic conductivity testing is provided in the *Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report* (Exponent 1999). Based on the slug test results presented in Table 4-3, shallow-zone horizontal hydraulic conductivity ranges from 5.9 feet/day in MWA-7 to 34 feet/day in MWA-5, with a mean value of 17 feet/day. Data collected from MWA-6 were inconclusive and were not used in the estimation of hydraulic conductivity for the shallow zone. Monitoring well MWA-6 was abandoned and replaced by MWA-6r in August 1999.

Estimates of intermediate-zone horizontal hydraulic conductivities range from 0.04 feet/day in MWA-12i to 21 feet/day in MWA-9i, with a geometric mean value of 5.8 feet/day (Table 4-3). Test data from monitoring well MWA-10i showed a rapid well response, indicating that the test only evaluated the annular space surrounding the monitoring well, therefore data from MWA-10i were not used to estimate the hydraulic conductivity of the intermediate groundwater zone.

Slug test data collected from well MWA-13d in the deep groundwater zone indicate a horizontal hydraulic conductivity of 0.3 feet/day.

Published data indicate that the hydraulic conductivity in the upper interflow zone of the Columbia River Basalt ranges from 1.4 to 10.9 feet/day (AMEC 2001, Squier 2002).

These test results indicate that the horizontal hydraulic conductivity of the groundwater zones decreases with depth: the horizontal hydraulic conductivity in the intermediate zone is approximately half of that in the shallow zone, whereas the horizontal hydraulic conductivity in the deep zone is approximately an order of magnitude lower than that in the intermediate zone. This is consistent with the lithologic descriptors of the groundwater zones, which show that the aquifer materials are progressively finer-grained with depth.

Vertical hydraulic conductivity was also measured in three samples collected from monitoring well borings (MWA-10i, MWA-11i, and MWA-13d). The samples were collected using Shelby® tubes. The samples consisted of silt and/or clay and were selected to be representative of the lithologic units separating the groundwater zones. The results of vertical hydraulic conductivity tests are summarized in Table 4-1. The vertical hydraulic conductivities ranged from 0.0007 feet/day (MWA-11i, 39 to 40.25 feet bgs) to 0.0071 feet/day (MWA-13d, 48 to 50 feet bgs).

These results indicate that the horizontal hydraulic conductivity of the aquifer materials in the shallow and intermediate zones are approximately three to four orders of magnitude greater than the vertical hydraulic conductivities of the silt and clay materials. This is consistent with the observation of grain size in the lithologic logs and distribution of contaminants within the separate groundwater zones. That is, the silt below the shallow groundwater zone impedes downward migration of contaminants into the intermediate zone and the deeper zone impedes further downward migration into the deep and basalt zones.

4.6 ECOLOGY

The majority of the Site is covered by gravel, asphalt, or concrete pavement and building foundations for facilities that formerly housed manufacturing equipment and supplies. These areas do not provide ecological habitat. Natural areas at the Site are limited to the riverbank adjacent to the Willamette River (Tract A).

The riverbank provides a limited amount of wildlife habitat; however, much of this area shows the effects of physical disturbance (e.g., bank armoring). The riverbank is steeply sloped and covered with large chunks of concrete and asphalt for much of its length. The concrete and asphalt rubble serve as riprap for erosion control and slope stability. Natural vegetation along the riverbank is growing in between the riprap, and is characterized by early successional species (mainly invasive weeds) that thrive on disturbed areas.

Based on Site visits for ecological risk assessment purposes in 1999 and 2003 (ERM 2005a) and observations made during ongoing Site work, wildlife use of the Site and the adjacent riverbank appears to be minimal. Some rodents and birds occur in the vegetated areas of the riverbank. The shoreline of the Willamette River below the mean high water line is sandy and lacks vegetation. Species that may occur along the shoreline include nutria and piscivorous (fish-eating) wading birds. In addition, birds have been observed loafing in an open paved area near the center of the Site. At least one pair of Canada geese and possibly song birds have been documented to nest at the Site in the past (ERM 2005a).

No mammals were observed during the 2003 Site visit. However, nutria (large, semi-aquatic rodents) have reportedly been observed foraging along the shoreline of the Willamette River. Additionally, blacktail deer have reportedly been observed on the adjacent property in Lot 1, and are likely to utilize the future greenway and riverbank near the northern boundary of Tract A for access to the river. Large mammalian use of the developed portion of the Site is not expected due to the chain link fence that surrounds the Site and the gravel/pavement surface cover.

4.6.1 Ecologically Important Species/Habitats

There are no unique ecological features present at the Site. The Willamette River adjacent to the facility may constitute ecologically important habitat for some salmonid and waterbird species. Potential ecological risks associated with the Willamette River are being addressed in a separate assessment being conducted by the Lower Willamette Group and therefore, are not discussed in this report.

ODEQ's ecological risk assessment guidance (ODEQ 1998b) defines ecologically important species as any of the following:

- Individual listed threatened and endangered species;
- Local populations of species that are recreational and/or commercial resources;
- Local populations of any species with a known or suspected susceptibility to the site-related hazardous substance(s);

- Local populations of vertebrate species; and
- Local populations of invertebrate species that provide a critical food resource for higher organisms, perform a critical ecological function, or can be used as a surrogate measure of adverse effects for other species.

No wildlife was observed on the developed portion of the Site during the 2003 Site visit, and none is expected to occur in this area due to a lack of available habitat.

The riverbank (Tract A) and future greenway constitute the riparian zone for the Willamette River, and thus represent important habitat on this portion of the Site. Wildlife observed along the riverbank and future greenway during the 2003 Site visit included species typically associated with urban areas, such as Canada geese, gulls, and common songbirds. These species could be considered ecologically important according to ODEQ guidance. The riverbank and future greenway also could provide habitat for other species of migratory birds and waterfowl, as well as local amphibian and mammal species.

4.6.2 Threatened and Endangered Species

No threatened or endangered species or their habitats are known to occur on the Site. The developed nature of the Site limits wildlife use to those species that are common to the region and adapted to urban environments. The portion of the Site along the Willamette River contains limited wildlife habitat (herbaceous and shrub vegetation) that is sparsely distributed and dominated by invasive/exotic species. Therefore, there is no suitable terrestrial habitat for threatened or endangered species.

5.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the nature and extent of contamination identified in Site soils, groundwater, and storm water.

5.1 EVALUATION APPROACH

The general approach used to evaluate the nature and extent of contamination, including: data sources, identification of COIs, potential source areas evaluated, and the identification of preliminary screening levels, are described in the following subsections.

5.1.1 Data Sources

The nature and extent of contamination was evaluated based on field screening and laboratory analytical data collected from September 1998 through March 2005 as part of the RI field program as well as the following additional field investigations, pilot studies, and interim actions conducted in parallel with the RI:

- The Phase I Soil Removal Interim Remedial Measure (IRM) completed in the Acid Plant Area in 2000;
- The Phase II Soil Removal IRM completed in the Acid Plant Area in 2001 and 2002;
- Baseline sampling (groundwater and soil) and confirmation sampling (soil only) associated with the pilot test and full-scale implementation of the vadose zone vapor extraction system (VES) in the Acid Plant Area from 2000 to 2003;
- Baseline sampling associated with the In-situ Persulfate Oxidation Pilot Study conducted in the Acid Plant Area in 2001;
- The Phase I and Phase II Dense Non-Aqueous Phase Liquid (DNAPL) Investigations conducted in the Acid Plant Area in 2002;
- Soil sampling conducted within the BPA Main Substation in 2002;
- Baseline sampling associated with the DNAPL Remediation Pilot Study in 2003;

- Baseline sampling associated with the Hexavalent Chromium Reduction Pilot Study conducted in the Chlorate Plant Area in 2003;
- The Old Caustic Tank Farm Soil Investigation conducted in 2003 and 2004;
- The Former Transformer Pad Concrete Sampling Program conducted in 2004; and
- Storm water sampling from Manholes SW-1 and SW-02 in 1999 and 2001 and Outfalls 001 through 004 in 2004 and 2005.

Site investigations and remedial work conducted prior to initiation of the RI in 1998 are summarized in Section 2. Analytical results from these early investigations are provided as Appendices F and G. As indicated in Section 3.13, data collected prior to 1998 and a portion of the groundwater and soil data collected during recent pilot studies and IRMs did not undergo the same level of data quality evaluation as did the RI data. Pre-1998 data is not presented in this section but was considered during RI data evaluation and development of the CSM. The data from the recent pilot studies and IRMs are presented in this section, but have been identified as "not validated" in the associated data tables. These data were used to develop the current CSM; however, the usefulness and applicability of unvalidated data for the Risk Assessment and FS will be determined during the execution of those tasks.

Sample age and collection methods were considered in the interpretation of the contaminant data. Specifically, the most recent groundwater data is considered to be more representative of current site conditions than the older data because it is more recent and was collected using reproducible low-flow sampling methods. Therefore, the most recent data were generally used for the interpretations of contaminant nature and extent.

5.1.2 *Identification of Constituents of Interest*

Preliminary COIs were first identified for the Site during the Phase 1 and 2 investigations conducted in 1994 and 1996 based on available information related to the historical manufacturing processes. The list of preliminary COIs was revised following completion of the Phase 1 and 2 investigations, during preparation of the PA (Elf Atochem 1999) and Expanded PA (Elf Atochem 2000). As additional Site characterization data was collected and the CSM further refined through correspondence with

ODEQ, a focused list of COIs for each source area was developed and summarized in Section 3 and Table 3-1.

The text and figures presented in this section discuss the nature and extent of contamination for the focused list of COIs developed for each source area. Other constituents detected in Site samples are highlighted in the tables and are also noted in text as appropriate.

5.1.3 Potential Source Areas

Due to the complexity of contaminant distribution at the Site, the nature and extent of contamination is described by potential source area. The following potential on-site source areas were identified based on the operational history of the Site and the distribution of COIs in Site media:

- Acid Plant Area;
- Chlorate Plant Area;
- Salt Pads;
- Old Caustic Tank Farm;
- Ammonia Plant;
- Concrete Transformer Pads;
- BPA Main Substation; and
- Storm Water Drain System.

Potential source areas, periods of operation, and associated COIs are summarized in Table 3-1.

5.1.4 Preliminary Screening Levels

To evaluate the nature and extent of COIs at the Site, analytical results were compared to conservative regulatory screening levels identified through correspondence with ODEQ. The screening levels presented in this section are for preliminary RI screening purposes only, and have been identified to aid in the evaluation of the nature and extent of contamination. Contaminant fate and transport, potential receptors of concern, and exposure pathways will be considered in detail and further screening will be conducted as part of the site-specific risk assessment.

The preliminary screening levels presented in this section do not constitute applicable or relevant and appropriate requirements (ARARs). The identification of ARARs is an iterative process that will be conducted throughout the RI/FS and is based, in part, on the results of the site-specific risk assessment. The final determination of ARARs will be made as part of the final remedy selection.

Background concentrations of COIs have not been established for Site soils or groundwater. Background concentrations will be considered in the site-specific risk assessment and during the identification and evaluation of ARARs in the FS.

Preliminary screening levels identified for Site soils, groundwater, storm water, and surface water are summarized in the following subsections.

5.1.4.1 Preliminary Screening Levels for Upland Soil

Preliminary screening levels for the COIs identified for upland soil are summarized in Table 5-1. As appropriate, screening levels have also been provided on the data tables included in each section for the extended list of analytes. For conservatism, all available subsurface soil data has been compared to the preliminary screening levels presented in Table 5-1. However, potential receptors and exposure pathways for subsurface soils will be further evaluated in the site-specific risk assessment. In addition, contaminant fate and transport, including the soil to groundwater pathway, was considered in the development of the CSM presented in Section 6.

The Site is currently located in an area zoned and designated “IH” for heavy industrial use. Based on the Guild’s Lake Industrial Sanctuary Plan (GLISP, City of Portland 2001), which was adopted by the Portland City Council, future land use at the Site will also be industrial (see Section 8.0). As a result, USEPA Region IX Preliminary Remediation Goals (PRGs) for the direct contact exposure pathway for industrial soil were identified as preliminary screening levels for upland soil at the Site. For constituents that do not have USEPA Region IX PRGs (e.g., TPH), the ODEQ Soil Ingestion, Dermal Contact, and Inhalation Risk-Based Concentrations (RBCs) for the construction worker receptor scenario (ODEQ 2003) are used as preliminary screening levels.

5.1.4.2 *Preliminary Screening Levels for Riverbank and Beach Soils*

Preliminary screening levels for the primary COIs identified for riverbank and beach soils are summarized in Table 5-2. As appropriate, screening levels have also been provided on the riverbank and beach soil data tables for the extended list of analytes.

Probable effect concentrations (PECs) and other sediment quality values (SQVs) were conservatively selected as preliminary screening levels for riverbank and beach soils that have the potential to erode into the Willamette River. Where a PEC or SQV has not been established, the most stringent of the USEPA Region IX PRGs (direct contact pathway for industrial soil) and the Oregon DEQ Level II soil screening level values for terrestrial ecological receptors were used.

5.1.4.3 *Preliminary Screening Levels for Groundwater and Storm Water*

Preliminary screening levels for the COIs identified for Site groundwater and storm water are summarized in Table 5-3. As appropriate, screening levels have also been provided on the data tables included in each section for the extended list of analytes.

Criteria established for the protection of aquatic life in surface water were conservatively selected as preliminary screening levels for Site groundwater and storm water because both groundwater and storm water are potential contaminant transport pathways to the Willamette River. The selected screening levels do not take into account the effects of contaminant fate and transport between each sampling location and a potential future point of compliance. As a result, these preliminary screening levels are very conservative and likely only potentially relevant to the groundwater along the riverbank.

The following criteria and guidance were used to establish the preliminary screening levels for Site groundwater and storm water:

- USEPA National Recommended Water Quality Criteria (NRWQC), freshwater levels, 2004;
- ODEQ Water Quality Criteria (WQC), Tables 33A and 33B, freshwater levels, May 2004;
- ODEQ Water Quality Guidance Values, Table 33C, freshwater levels, May 2004; and

- ODEQ, Calculated SLV for perchlorate, as referenced in a letter from the ODEQ to ATOFINA Chemicals, Inc, dated 21 May 2004.

If a 2004 chronic NRWQC value is established for a given constituent, that value was selected as the preliminary screening level. If a NRWQC chronic value is not established, then the chronic WQC was selected. If neither a 2004 chronic NRWQC nor a chronic WQC are established, the lower of the 2004 acute NRWQC and acute WQC values was selected. If no acute values are established, Oregon DEQ Water Quality Guidance Values were used.

5.2 ACID PLANT AREA

This section describes the nature and extent of COI contamination identified in soil and groundwater associated with the Acid Plant Area.

5.2.1 Soil

A description of soil sampling activities associated with the Acid Plant Area is provided in Section 3 and summarized in Table 3-3. A majority of the soil samples were field screened, and select samples were submitted for laboratory analysis of organochlorine pesticides, VOCs, SVOCs, metals, and/or petroleum hydrocarbons. Perchlorate concentrations in soil was not investigated during the RI, but will be addressed during the FS. Field screening and analytical laboratory results for soil samples from the Acid Plant Area are presented in Tables 5-4 through 5-16.

The following subsections present available field screening and analytical results for surface, subsurface, riverbank, and beach soils associated with the Acid Plant Area.

5.2.1.1 Field Screening Results

Field screening was conducted on soil samples collected during the installation of monitoring wells and direct-push boreholes within the Acid Plant Area to select sampling locations for laboratory analysis of organochlorine pesticides and VOCs. Field screening results were also used to assist in the delineation of the MCB DNAPL. Field screening results are summarized in Table 5-4.

Select soil samples were field screened for DDT using TLC as described in Section 3.10.3. The TLC test results were compared with DDT concentrations measured in the laboratory. The comparison indicated that the TLC results exhibited a high degree of reliability in detecting the presence or absence of DDT at elevated concentrations. The results are also useful in identifying relative differences in the quantity of DDT present from location to location. However, when compared to laboratory analysis, the accuracy of the TLC test is relatively low (+/- 50 mg/kg). Thus, the TLC data were used to guide additional sampling efforts, but are not used to define the nature and extent of DDT contamination.

As discussed in Section 3.10.2, Sudan IV® hydrophobic dye testing was used during the DNAPL investigations conducted within the Acid Plant Area in 2002 . The results of those field screening tests were used to delineate the vertical and horizontal extent of the DNAPL.

5.2.1.2 *Surface Soil Samples (0 to 1 Foot Below Ground Surface)*

Fifty-one surface soil samples, including two duplicate samples, were collected from 0 to 1 foot below ground surface (bgs) to evaluate the nature and extent of organochlorine pesticides, VOCs, and/or metals (cadmium, chromium, lead, and zinc) associated with the Acid Plant Area.

Thirteen of the 51 surface soil samples were collected from areas excavated in 2000 and 2001 as part of the Phase I and Phase II Soil Removal IRM. Following completion of the soil removal activities, the excavated areas were backfilled with clean ¾-inch minus fill and paved to reduce the potential for ongoing contaminant transport due to storm water runoff. Sampling results from excavated areas are noted as such in the surface soil data tables and are not included on the associated figures. The following subsections summarize the surface soil analytical results for organochlorine pesticides, VOCs, and metals.

5.2.1.2.1 *Organochlorine Pesticides*

A total of 49 surface soil samples, including two duplicates, were used to evaluate the nature and extent of organochlorine pesticides in surface soils associated with the Acid Plant Area. The organochlorine pesticide results for these surface soil samples are summarized in Table 5-5 and shown on Figures 5-1 and 5-1a. Thirteen of the 49 samples were collected from areas subsequently removed during the Soil Removal IRM.

DDT was detected at 33 of the 34 surface sampling locations outside the Soil Removal IRM areas. The DDT concentrations ranged from 0.03 mg/kg (boring B-52) to 3,300 J mg/kg (boring B-100). Nineteen of the 33 locations had DDT concentrations above the preliminary screening level of 7 mg/kg. The highest surface soil concentrations were detected in the vicinity of the former DDT process building and MCB recovery unit, and DDT dry storage area. As shown on Figure 5-1, elevated DDT concentrations were also detected in the vicinity of the former MPR pond and trench and at two locations within the neighboring OCTF Area.

As shown on Figure 5-1a, most of the surface soil samples collected within the Acid Plant Area contained DDT concentrations greater than the preliminary screening level of 7 mg/kg. Samples collected from locations outside of the Acid Plant Area to the south of the No. 1 dock (S-2 through S-5) had significantly lower DDT concentrations, ranging from 0.33 mg/kg to 2.0 mg/kg. Figure 5-1a also shows several localized areas where DDT concentrations exceed 100 mg/kg.

DDD and/or DDE were detected at 26 of the 34 surface soil sample locations outside of the Soil Removal IRM areas. As shown in Table 5-5 and Figure 5-1, DDD and DDE concentrations were typically one to two orders of magnitude less than the DDT concentrations at the same locations. DDD concentrations ranged from 0.0026 mg/kg (boring B-97) to 32 mg/kg (boring B-100), and three of the samples contained concentrations greater than the preliminary screening level (10 mg/kg). DDE concentrations ranged from 0.029 mg/kg (boring B-115) to 190 mg/kg (boring B-96), and three of the samples contained concentrations greater than the preliminary screening level (7 mg/kg).

Endrin was detected in one sample (location IB-32) at a concentration of 1.5 mg/kg. This concentration is less than the preliminary screening level of 180 mg/kg, and surface soils in the vicinity of IB-32 were removed to a depth of approximately 2.5 feet during the Soil Removal IRM.

Methoxychlor was detected at a concentration of 0.0073 mg/kg in sample S-3 Dup, a field duplicate sample collected to the south of the No. 1 dock. This concentration is below the preliminary screening level 3,100 mg/kg, and methoxychlor was not detected in the primary sample from this location.

5.2.1.2.2 *Volatile Organic Compounds*

A total of 15 surface soil samples, including one duplicate, were used to evaluate the nature and extent of VOCs in the vicinity of the Acid Plant Area. The VOC results for these surface soil samples are summarized in Table 5-6 and shown on Figure 5-2. The VOC sampling locations were not affected by the Soil Removal IRM.

MCB was detected in 3 of the 15 surface soil samples. Concentrations ranged from 0.0047 mg/kg (boring B-101) to 0.021 J mg/kg (boring B-100), which are below the preliminary screening level of 530 mg/kg. All of the samples that contained MCB were collected in the vicinity of the former DDT process building and MCB recovery unit (Figure 5-2). Samples from boring B-100 also contained the highest detected concentrations of DDT and DDD in surface soil. Chloroform was not detected in any of the surface soil samples collected within the Acid Plant Area.

Low levels of three other VOCs (acetone, tetrachloroethene, and toluene) were detected at one or more locations within the Acid Plant Area. Concentrations of these three constituents were all below their preliminary screening levels. Acetone was detected in surface soil samples from borings B-100 (0.13 J mg/kg) and B-101 (0.045 J mg/kg). Tetrachloroethene was detected in boring B-100 (0.00072 J mg/kg) and B-100 Dup (0.0019 J mg/kg), and toluene was detected in B-100 (0.00048 mg/kg) and B-98 (0.043 mg/kg). As described above, two of these three locations also had detections of MCB and are within the DDT process building and MCB recovery unit. The third location B-98 is located northeast of the DDT process building and MCB recovery unit and east of the former MPR pond and trench.

5.2.1.2.3 *Metals*

One surface soil sample was collected from boring IB-44, located east of the Acid Plant Area, for metals analysis by Method 6010B. Results were reported for cadmium, chromium, lead, and zinc and are summarized in Table 5-7 and on Figure 5-3. All of the detected metals concentrations were below their respective preliminary screening levels.

5.2.1.3 *Subsurface Soil Samples (> 1 Foot Below Ground Surface)*

Subsurface soil samples were collected from depths greater than one foot bgs and above the water table to evaluate the nature and extent of organochlorine pesticides and VOCs in the vadose zone soil of the Acid Plant Area.

As described previously, soils in portions of the Acid Plant were excavated in 2000 during the Soil Removal IRM and backfilled with clean ¾-inch minus fill. A number of the subsurface soil samples were obtained from areas that were subsequently removed or capped during the Soil Removal IRM. Sampling results from excavated areas and from soil samples collected from below the groundwater table are noted as such in the data tables, are not shown on the associated figures, and are not used to interpret the nature and extent of contamination in the subsurface soil. The following subsections summarize the subsurface soil analytical results for organochlorine pesticides and VOCs.

5.2.1.3.1 *Organochlorine Pesticides*

A total of 142 subsurface soil samples, including nine duplicates, were used to evaluate the nature and extent of organochlorine pesticides in the vadose zone soils of the Acid Plant Area. The organochlorine pesticide results for subsurface soil samples are summarized in Table 5-8 and Figures 5-4 through 5-5b. Thirteen of the 142 samples were collected from areas subsequently removed during the Soil Removal IRM.

DDT was detected in 117 of the 129 samples collected from locations outside of the Soil Removal IRM areas. Concentrations ranged from 0.014 mg/kg (MWA-20, 15 to 16.5 feet bgs) to 31,000 mg/kg (MWA-11i, 6 to 8 feet bgs). Seventy-one of the 129 samples had detected DDT concentrations above the preliminary screening level of 7 mg/kg.

As shown on the isoconcentration maps for DDT in subsurface soils [Figures 5-4a (1 to 4 feet bgs), 5-5a (4 to 8 feet bgs), and 5-5b (> 8 feet bgs)], the highest concentrations of DDT were located in the vicinity of the former DDT Process Building and MCB Recovery Unit, and extend east toward the Willamette River. DDT concentrations were generally higher in near-surface soil samples collected from between one and four feet bgs than in surface soil samples (i.e., < 1 foot bgs) collected from the same location. Below four feet, the concentrations generally decrease with depth. However, DDT concentration spikes at depth were present in borings B-61, B-115, B-100, and IB-25 (Figure 5-5). The TLC results summarized in Table 5-4 also indicate DDT concentration spikes or elevated concentrations at depth in a number of the IRM, monitoring well, and vapor extraction system soil borings. Figure 5-6 provides a cross section completed through the Acid Plant Area, including the soil removal areas, with available DDT, DDD, and DDE concentrations. The DDT concentration spikes at depth may be the result of DDT migration with the MCB DNAPL. DDT in the upper ten feet of soil may be due to soil movement due to construction activities carried out during plant operation.

DDD and/or DDE were detected in 90 of the 129 subsurface soil samples located outside of the Soil Removal IRM areas. The DDD and DDE concentrations were typically one to two orders of magnitude less than their respective DDT concentrations. DDD concentrations ranged from 0.0032 J mg/kg (B-99, 0.5 to 1.5 feet bgs) to 430 mg/kg (MWA-11i, 6 to 8 ft bgs), and 31 of the samples contained concentrations greater than the preliminary screening level (10 mg/kg). DDE concentrations ranged from 0.0084 mg/kg (B-104, 0.5 to 1.5 ft bgs) to 100 mg/kg (IB-20, 3 to 4 feet bgs), and 20 of the samples contained concentrations greater than the preliminary screening level (7 mg/kg).

Four other organochlorine pesticides were detected in one or more of the subsurface soil samples located outside of the Soil Removal IRM areas:

- Alpha-BHC was detected in both samples collected from boring B-55. Concentrations ranged from 0.037 mg/kg (12 to 13 feet bgs) to 1.6 mg/kg (6 to 7 feet bgs). The DDT concentration detected in the sample collected from 6 to 7 feet bgs was above the preliminary screening level of 0.36 mg/kg.
- Endrin was detected in samples collected from borings AP-2 (70 mg/kg, 0 to 4 feet bgs) and AP-5 (63 mg/kg to 72 mg/kg, 0 to 2 feet bgs). Concentrations at both locations were below the preliminary screening level of 180 mg/kg.
- Gamma-BHC (lindane) was detected in one sample collected from boring B-99 (0.0061 mg/kg, 0.5 to 1.5 feet bgs). This concentration is below the preliminary screening level of 1.7 mg/kg.

- Gamma chlordane was detected in one sample collected from boring B-57 (0.14 mg/kg, 4 to 5 feet bgs). This concentration is below the preliminary screening level of 6.5 mg/kg.

The source of these other organochlorine pesticides is unknown because they were not produced at the facility and there is no known record of their use or storage at the facility.

5.2.1.3.2 *Volatile Organic Compounds*

A total of 119 subsurface soil samples, including four duplicates, were used to evaluate the nature and extent of VOCs in the vadose zone soils of the Acid Plant Area. The VOC results for subsurface soil samples are summarized in Table 5-9. Three of the 119 samples were collected from areas subsequently removed during the Soil Removal IRM.

MCB was detected in 94 of the 116 samples collected from locations outside of the Soil Removal IRM areas. Concentrations ranged from 0.0011 mg/kg (B-100, 0.5 to 1.5 feet bgs) to 66,600 mg/kg (CS-13, 8.5 ft). Forty-two of the 116 samples had MCB concentrations above the preliminary screening level of 530 mg/kg. As shown on Figure 5-7, none of the samples collected between one and four feet bgs contained MCB concentrations above the preliminary screening level of 530 mg/kg.

Isoconcentration maps of MCB in subsurface soils greater than 4 feet bgs are provided on Figures 5-8 and 5-8a. As shown on Figure 5-8a, the highest MCB concentrations detected in subsurface soils outside the Soil Removal IRM areas are beneath the former DDT Process Building and MCB Recovery Unit areas.

In general, the horizontal distribution of elevated MCB concentrations in subsurface soil is similar to the distribution of measured DDT concentrations. However, in contrast to the general vertical distribution of DDT, the MCB concentrations are generally lower near the surface and higher at depth. This is likely due to the much higher aqueous solubility of MCB (approximately 500 mg/L) compared to that of DDT (approximately 0.003 mg/L).

Chloroform was detected in eight of the 116 samples collected from locations outside of the Soil Removal IRM areas at concentrations ranging from 0.0019 mg/kg (VP-21 Dup, 7.5 to 8 feet bgs) to 0.31 mg/kg (VP-17, 12 feet bgs). None of the samples had measured chloroform concentrations above the preliminary screening level of 0.47 mg/kg. As shown in Table 5-9, 11 other VOCs were also detected in one or more subsurface soil samples collected outside of the Soil Removal IRM Areas. Only two of these VOCs (tetrachloroethene and 1,4-dichlorobenzene) were detected at concentrations above their preliminary screening levels. These other VOCs are briefly discussed below:

- 1,4-Dichlorobenzene was detected in 22 samples. Concentrations ranged from 0.071 mg/kg (VP-17, 16 feet bgs) to 49 mg/kg (VP-11, 8 feet bgs). Six of the 22 samples contained 1,4-dichlorobenzene concentrations above the preliminary screening level of 7.9 mg/kg.
- Tetrachloroethene was detected in 19 samples. Concentrations ranged from 0.0096 J mg/kg (VP-21, 7.5 to 8 feet bgs) to 14 mg/kg (B-55, 6 to 7 ft bgs). Ten of the 19 samples contained tetrachloroethene concentrations above the preliminary screening level of 1.3 mg/kg.
- 1,1,1-Trichloroethane was detected in 7 samples. Concentrations ranged from 0.8 mg/kg (VP-9, 12 feet bgs) to 18 mg/kg (VP-12, 8 ft bgs). All detected concentrations were below the preliminary screening level of 1,200 mg/kg.
- 1,2-Dichlorobenzene was detected in 13 samples. Concentrations ranged from 0.083 mg/kg (VP-14, 12 ft bgs) to 15 mg/kg (VP-11, 8 feet bgs). All detected concentrations were below the preliminary screening level of 600 mg/kg.
- 1,3-Dichlorobenzene was detected in three samples. Concentrations ranged from 0.22 mg/kg (VP-10, 8 feet bgs) to 1.2 mg/kg (VP-11, 8 feet bgs). All detected concentrations were below the preliminary screening level of 600 mg/kg.
- 4-Isopropyltoluene was detected in one sample from boring VP-11 (8 feet bgs) at a concentration of 1.1 mg/kg. No screening level has been established for 4-isopropyltoluene.
- Acetone was detected in eight samples. Concentrations ranged from 0.066 mg/kg (B-101, 0.5 to 1.5 feet bgs) to 340 mg/kg (VP-17, 16 feet bgs). All detected concentrations were below the preliminary screening level of 54,000 mg/kg.
- Bromobenzene was detected in one sample from boring CS-2 (8 feet bgs) at a concentration of 0.188 mg/kg. This concentration is below the preliminary screening level of 92 mg/kg.

- Ethylbenzene was detected in one sample from boring CS-2 (8ft bgs) at a concentration of 0.107 mg/kg. This concentration is below the preliminary screening level of 400 mg/kg.
- Meta & para Xylenes were detected in two samples. Concentrations ranged from 0.0095 J mg/kg (AP-3 Dup, 8 to 10 ft bgs) to 0.28 mg/kg (VP-11, 8 ft bgs). All detected concentrations were below the preliminary screening level of 420 mg/kg.
- Naphthalene was detected in one sample from VP-11 (8 feet bgs) at a concentration of 0.46 mg/kg. No screening level has been established for naphthalene.

5.2.1.3.3 *SPLP and TCLP Results*

To evaluate the potential for DDT migration from soils to groundwater, one sample from soil boring B-53 (4.5 to 6.0 feet bgs) was subjected to SPLP organochlorine pesticide analysis. Boring B-53 was located in the former MPR pond in the Acid Plant Area. The extraction fluid used in the SPLP test is intended to simulate precipitation and provide an assessment of constituent mobility under actual field conditions (i.e., what happens when it rains or snows). The SPLP DDT concentration in the sample from B-53 was 9 micrograms per liter (μg/L), which is greater than the preliminary screening level for DDT in groundwater (0.001 μg/L). The total DDT in sample B-53 (4.5 to 6.0 feet bgs) was 16,000 mg/kg, which was one of the highest DDT concentration detected in the subsurface soil samples and the rationale for analyzing the sample for SPLP DDT. The soil in the vicinity of boring B-53 was removed to a depth of approximately 12 feet during the Soil Removal IRM. However, the highest detected DDT concentration in soils following the IRM removal action was 63,000 mg/kg (Phase 1 Site Characterization boring SB-01, 15 feet bgs; Appendix F). Total and SPLP organochlorine pesticide results for boring B-53 are summarized in Table 5-10.

The same sample from boring B-53 (4.5 to 6 feet bgs) was also subjected to SPLP analysis for VOCs. MCB, chloroethane, chloroform, and tetrachloroethene were detected in the SPLP sample. The total and SPLP MCB concentrations were 1.4 mg/kg and 44 J μg/L, respectively. Both of these concentrations are below their respective preliminary screening levels of 503 mg/kg and 50 μg/L. The highest MCB concentration measured in soil outside of IRM removal areas was 66,600 mg/kg at boring CS-13 (8.5 ft bgs). Table 5-11 summarizes the total and SPLP VOC results for boring B-53.

Additionally, composite soil samples collected from 0 to 10 feet bgs from IRM borings IB-21, IB-26, and IB-51 were subjected to TCLP by USEPA Method 1311 and analysis for VOCs by USEPA Method 8260B. MCB was the only constituent detected in either the soil or TCLP extractions. The total and TCLP MCB concentrations for each sample were 8,800 mg/kg and 180 mg/L (IB-21), 2,900 mg/kg and 100 mg/L (IB-26), and 3,000 mg/kg and 110 mg/L (IB-51). Table 5-12 summarizes the analytical results for the total and TCLP VOC analyses for the three IRM boring soil samples

5.2.1.4 *Riverbank and Beach Soil Samples*

A total of seven riverbank soil samples from six locations and 12 beach soil samples from six locations were collected to evaluate the nature and extent of organochlorine pesticides, VOCs, SVOCs and/or metals (cadmium, chromium, lead, and zinc) in the riverbank and beach areas. All the riverbank samples were collected from above the mean high water mark at a depth of zero to 0.5 feet bgs. The samples were collected from three paired locations with one sample located near the top of the bank and the second sample collected immediately downslope from the first sample.

Two beach soil samples were collected from each location: one sample from zero to 0.3 feet bgs and the second sample from depths of 0.3 to 2 feet bgs.

Analytical results for the riverbank and beach soil samples are described in the following subsections.

5.2.1.4.1 *Organochlorine Pesticides*

All 19 riverbank and beach samples were used to evaluate the nature and extent of organochlorine pesticides in the riverbank and beach soils. The analytical results for all of the organochlorine pesticides are summarized in Table 5-13 and the DDT, DDD, and DDE results are shown on Figure 5-9.

DDT was detected in all 19 riverbank and beach samples at concentrations ranging from 0.034 mg/kg (RB-5) to 120 mg/kg (RB-10). As shown on Figure 5-9, sample RB-10 was collected from the top of the riverbank on the southeast side of the No. 2 dock. Sample RB-9, collected immediately downslope from RB-10, had the second-highest DDT concentration. DDT concentrations in all of the 19 samples except RB-5 were above the preliminary screening level of 0.0629 mg/kg.

In general, DDT concentrations detected in the riverbank samples collected near the top of the slope were lower than those detected in surface soil samples in the Acid Plant Area and higher than those measured in samples collected from the beach. As shown on Figure 5-9, the DDT concentrations in the riverbank and beach samples are highest near Dock 2 and decrease to the north and south. For the beach samples, DDT concentrations generally increased with depth.

DDD and/or DDE were also detected in all the riverbank and beach soil samples. DDD was detected in all 7 of the riverbank samples and 9 of the 12 beach samples. DDD concentrations ranged from 0.018 mg/kg (RB-4) to 1.7 mg/kg (RB-8), and 13 of the samples contained concentrations above the preliminary screening level of 0.28 mg/kg. DDE was detected in all 19 samples. Concentrations ranged between 0.023 mg/kg (RB-5) and 3.5 mg/kg (RB-10). Sixteen of the samples contained DDE concentrations greater than the preliminary screening level (7 mg/kg). Overall, DDD and DDE trends were similar to those described for DDT.

One additional pesticide, alpha-BHC, was detected in the sample collected from RB-8 at a concentration of 0.11 mg/kg. This concentration is slightly above the preliminary screening level of 0.1 mg/kg. No other organochlorine pesticides were detected in the riverbank or beach samples.

5.2.1.4.2 *Volatile Organic Compounds*

All 12 beach samples, collected from locations RB-1 through RB-6, were used to evaluate the nature and extent of VOCs in beach soils. Riverbank soil samples were not submitted for VOC analysis. The analytical results for VOCs in beach soils are summarized in Table 5-14.

No MCB or chloroform was detected in any of the beach samples. Tetrachloroethene was detected in one of the samples collected from RB-3

(0.3 to 1 foot bgs) at a concentration of 0.008 mg/kg. This concentration is below the preliminary screening value of 0.5 mg/kg, the USEPA Sediment Quality Advisory Level for tetrachloroethene. Because no other VOCs were detected in the beach samples, preliminary screening levels were not identified or included for the VOCs listed in Table 5-14.

5.2.1.4.3 *Semi-Volatile Organic Compounds*

All 19 riverbank and beach samples were used to evaluate the nature and extent of SVOCs in riverbank and beach soils. The analytical results for SVOCs in riverbank and beach soils are summarized in Table 5-15.

Trace levels of 16 VOCs were detected in one or more of the riverbank and beach samples (Table 5-15). All reported concentrations were below the preliminary screening levels with exception of the following five constituents:

- Benz[a]anthracene was detected at a concentration of 1.8 mg/kg in riverbank soil sample RB-8. This concentration is slightly above the preliminary screening level of 1.05 mg/kg. Benz[a]anthracene was also detected at trace levels in 9 of the 12 beach samples.
- Benzo[ghi]perylene was detected at a concentration of 0.8 mg/kg in riverbank soil sample RB-8. This concentration is slightly above the preliminary screening level of 0.3 mg/kg. Benzo[ghi]perylene was also detected at trace levels in all of the 12 beach samples.
- bis[2-Ethylhexyl]phthalate was detected at a concentration of 0.82 mg/kg in beach sample RB-3. This concentration is slightly above the preliminary screening level of 0.75 mg/kg. Bis[2-Ethylhexyl]-phthalate was also detected at trace levels in 6 of the 12 beach samples.
- Crysene was detected at a concentration of 1.9 mg/kg in riverbank soil sample RB-8. This concentration is slightly above the preliminary screening level of 1.29 mg/kg. Crysene was also detected at trace levels in 9 of the 12 beach samples.
- Indeno[1,2,3-cd]pyrene was detected at a concentration of 1 mg/kg in riverbank soil sample RB-8. This concentration is slightly above the preliminary screening level of 0.1 mg/kg. Indeno[1,2,3-cd]pyrene was also detected at trace levels in all of the 12 beach samples.

Analytical results for the five constituents listed above are shown on Figure 5-10. As shown on Figure 5-10, four of the five minor exceedences of preliminary screening levels were measured in riverbank sample RB-8, which was collected immediately downslope of sample RB-11, approximately half-way between the No. 1 and No. 2 docks. None of the 4 constituents detected in sample RB-8 were found in its upslope counterpart (RB-11). One of the 5 exceedences (bis[2-Ethylhexyl]-phthalate) was measured in beach sample RB-3 located immediately south of the No. 2 dock. No other SVOC exceedences were measured in any of the beach or riverbank samples.

5.2.1.4.4 *Metals*

A total of seven riverbank samples, including one duplicate sample, were used to evaluate the nature and extent of metals (cadmium, chromium, lead, and zinc) in riverbank soils. None of the beach soil samples were submitted for metals analysis and thus could not be used in this assessment. The analytical results for metals are summarized in Table 5-16 and on Figure 5-11.

Lead was detected in all 7 of the riverbank samples. Concentrations ranged from 45.7 mg/kg (RB-9) to 2,090 mg/kg (RB-8). Only the lead concentration measured in sample RB-8 (2,090 mg/kg) was above the preliminary screening level of 128 mg/kg. As shown on Figure 5-11, sample RB-8 is a downslope sample and its upslope counterpart, RB-11, had a lower lead concentration (51.5 mg/kg).

Cadmium was detected in 2 of the 7 riverbank samples. Concentrations ranged from 1.22 mg/kg (RB-7) to 1.4 mg/kg (RB-12 Dup). Both of these concentrations were below the preliminary screening level of 4.98 mg/kg.

Chromium and zinc were detected in all 7 riverbank samples. Chromium concentrations ranged from 17 mg/kg (RB-10) to 40.7 mg/kg (RB-8). All detected chromium concentrations were below the preliminary screening levels for total chromium (111 mg/kg) and hexavalent chromium (64 mg/kg). Zinc concentrations ranged from 72.2 mg/kg (RB-10) to 212 mg/kg (RB-11). All measured zinc concentrations were below the preliminary screening level of 459 mg/kg.

5.2.2 *Dense Non-Aqueous Phase Liquid*

The investigative activities used to evaluate the nature and extent of residual MCB DNAPL in the Acid Plant Area is provided in Section 3.2.3.

Suspected DNAPL in the soil core samples was first identified visually and with a PID and then confirmed using Sudan IV hydrophobic dye. The residual DNAPL zones were typically characterized by PID readings greater than 500 parts per million, a sheen coating the soil particles, and the presence of brown or red droplets. All of the DNAPL investigation data are presented in the reports, *Residual Dense Non-Aqueous Phase Liquid Investigation (Phase I), Acid Plant Area* (ERM 2002b) and *Phase II Residual Dense Non-Aqueous Phase Liquid Investigation (Intermediate Zone Sampling), Acid Plant Area* (ERM 2002d).

The results of that investigation show that residual MCB DNAPL is present in the form of ganglia or microglobules coating soil particles at discrete depths in the shallow groundwater zone. It was generally found either immediately on top of, or within a thin zone directly above, the first significant silt layer of the shallow silt aquitard. The thickness of DNAPL was greatest below the area of the former MPR pond (up to 6 feet in boring APMIP/INT-5) and decreased significantly outward from the pond area (up to a few inches in several borings). In every instance, the residual DNAPL was detected in sandy soils immediately above a silt layer or above a localized sand interval with relatively high silt content. In one boring (INT-7), residual DNAPL was detected in a 1-foot thick sand layer between two silt layers (each approximately 1.5 feet thick) within the shallow silt horizon.

DNAPL was detected in one intermediate groundwater zone boring (INT-5), located near the middle of the former MPR pond. The intermediate zone DNAPL was detected at approximately 38 feet bgs, directly above a 1-foot thick silt lens at 39 feet bgs. DNAPL also was detected in shallow zone soils in this boring, at depths of approximately 26, 29, and 33 feet bgs. None of the other six borings showed DNAPL in the intermediate zone.

The approximate horizontal extent of the residual DNAPL detected in the shallow and intermediate zones is shown on Figure 5-12. Cross sectional views of the DNAPL distribution are shown on Figures 5-13 and 5-14. The data displayed in these figures indicate that the thickest accumulations of residual DNAPL are found in the immediate vicinity of the former MPR pond. Downgradient of this area, residual DNAPL (where detected) is generally found in a thin layer not more than 0.1 feet thick. DNAPL also was detected in local sand layers or lenses between the silt layers that comprise the shallow silt horizon. Most of the residual

DNAPL mass is inferred to exist in the shallow zone within an oblong area, approximately 90 feet wide and 180 feet long, centered near the north corner of the former MPR pond (Figure 5-12). Based on detections of DNAPL in soil during installation of monitoring wells MWA-8i, MWA-13d and MWA-9i, a thin layer of residual DNAPL also appears to be present on top of the silt horizon at the base of the shallow groundwater zone downgradient of the Acid Plant Area, near the riverbank (Figures 5-12 and 5-13). The horizontal extent of residual DNAPL in that area is not well defined. Based on the detection of residual DNAPL at 38 feet bgs in boring INT-5, residual DNAPL is inferred to exist in the intermediate zone (Figures 5-12 and 5-13).

Additionally, a small area of residual DNAPL is inferred in the vadose zone soils in the area of the former MCB Recovery Unit.

The results of the DNAPL investigation support a conceptual model for MCB DNAPL distribution based on the hypothesis that an MCB release occurred at the former MPR pond and at the former MCB Recovery Unit. The MCB migrated vertically downward and then spread laterally upon encountering the shallow silt horizons. Most of the lateral spreading occurred downgradient of the MPR pond, toward the Willamette River. The spreading was likely driven mainly by gravity flow down the inclined surface of the silt horizon, but also to some degree by advective ground water flow. Local relief in the shallow silt horizon, such as an apparent trough extending east-northeast through the former MPR pond, appears to have played a limited role in controlling the migration of DNAPL. The investigation results indicate that in addition to spreading laterally, some DNAPL migrated into sand interbeds and/or lenses that occur within the shallow silt horizon beneath the former MPR pond.

5.2.3 *Groundwater*

Groundwater samples were collected from direct-push borings, groundwater monitoring wells, membrane interface probe (MIP) borings, and performance monitoring wells to evaluate the nature and extent of COIs identified for Acid Plant Area sources. A description of the groundwater sampling activities associated with the Acid Plant Area is provided in Section 3.2.2 and summarized in Table 3-4. The following subsections present groundwater analytical results for total and dissolved organochlorine pesticides, VOCs, SVOCs, metals, and petroleum hydrocarbons. Perchlorate results are discussed in Section 5.3 (Chlorate

Plant). Final field parameter measurements (i.e., conductivity, dissolved oxygen, ORP, pH, temperature, and turbidity) recorded during monitoring well groundwater sampling are included in Table 5-17.

5.2.3.1 *Organochlorine Pesticides*

Groundwater samples collected from the following direct-push borings and groundwater monitoring wells were used to evaluate the nature and extent of organochlorine pesticides in the groundwater:

- One RI soil boring (B-59) completed in the shallow groundwater zone;
- Thirty-six groundwater monitoring wells (MWA-1 through MWA-34i), including: 23 shallow-zone, 9 intermediate-zone, 3 deep-zone, and 1 basalt-zone monitoring well; and
- Twelve performance monitoring wells installed in the shallow groundwater zone, including six nested well-pairs (NMP-1S/NMP-1D through NMP-6S/NMP-6D) and DNAPL Pilot Study performance monitoring wells PMP-1 through PMP-3.

Data from PMP-1 through PMP-3, NMP-1S through NMP-6D, and MWA-36 through MWA-38 was not validated. Groundwater analytical results for organochlorine pesticides are described in the following subsections for the shallow-, intermediate-, deep-, and basalt-zone groundwater.

5.2.3.1.1 *Shallow-Zone Groundwater*

A total of 113 samples, including seven duplicates, from 35 shallow-zone groundwater monitoring wells were used to evaluate the nature and extent of organochlorine pesticides in the shallow-zone groundwater. One groundwater grab sample (B-59) was also collected for organochlorine pesticide analysis, but no organochlorine pesticides were detected in that sample. The organochlorine pesticide results for the shallow-zone groundwater are summarized in Table 5-18 and shown on Figure 5-15.

Total DDT was detected in 51 of the 113 monitoring well samples at concentrations ranging from 0.01 μg/L (MWA-30, April 2002) to 120,000 D μg/L (NMP-4D, June 2001). The second-highest reported DDT concentration (1,900 D μg/L) was detected in NMP-1D in June 2001; however, the elevated concentrations in NMP-4D and NMP-1D were qualified, indicating the values were obtained from dilutions, and these data have not been validated. The next-highest DDT concentration (450 µg/L) was detected in MWA-15r in March 2001. As shown on Figure 5-15, monitoring well MWA-15r is situated within the footprint of the former MPR pond, NMP-4D is located approximately 30 feet east (downgradient) of the former MPR pond and trench, and MWA-30 is located approximately 800 feet south (cross-gradient) from the Acid Plant Area.

The mean concentration of total DDT in the six groundwater samples collected from MWA-15/15r is approximately two orders of magnitude greater than the mean total DDT concentration for the remaining MWA series shallow-zone monitoring wells. With the exception of the samples collected from NMP-1D and NMP-4D in June 2001, DDT concentrations in the NMP-series wells, located east of the former MPR pond and trench, were of similar magnitude as the concentrations measured in MWA-15r. All the detected DDT concentrations were above the preliminary screening level of 0.001 µg/L, which applies to the total measured concentration of DDT, DDD, and DDE.

The most complete groundwater monitoring event was conducted in June 2003. During the June 2003 event, samples were collected from 18 shallow-zone monitoring wells and the results for DDT, DDD, and DDE are shown on Figure 5-15. DDT was detected in 10 of the 21 samples collected, and the concentrations ranged from 0.092 µg/L (MWA-5) to 282 µg/L (NMP-4D).

Total DDD was detected in 58 of the 107 samples collected And the concentrations ranged from 0.015 J µg/L (MWA-18, June 2001) to 6,400 PD µg/L (NMP-4D, June 2001). However, the sample collected from NMP-4D failed internal laboratory QC criteria and these data have not been validated. The next highest value of DDD was 37 µg/L (MWA-15r, March 2001). During the June 2003 event, DDD was detected in 10 of the 21 samples collected at concentrations ranging from 0.068 J µg/L (MWA-20) to 28.4 J µg/L (MWA-15r).

Total DDE was detected in 30 of the 113 samples collected, and the concentrations ranged from 0.021 J µg/L (MWA-30, April 2002) to 2,700 D µg/L (NMP-4D, June 2001). The concentration measured in NMP-4D and in the second highest sample from NMP-1D (8.1 D µg/L) were qualified, indicating the values were obtained from a dilution. Additionally, data from both of these wells has not been validated. The next highest DDT concentration was 4.2 μg/L (MWA-15r, April 2002). During the June 2003 event, DDE was detected in 4 of the 21 samples collected; however, three of the 4 samples failed laboratory QC and the data were qualified as "rejected". DDE was detected in the forth sample at a concentration of 0.233 μg/L (MWA-4).

The groundwater monitoring results summarized in Table 5-18 indicate DDT concentrations declined or remained stable at relatively low levels between January 1999 and June 2003. Total DDD concentrations were similar in magnitude or approximately one order of magnitude greater than total DDT concentrations in several of the monitoring wells, primarily in riverbank wells downgradient of the former MPR pond. DDD has a higher solubility limit than DDT and may explain the DDD concentrations observed in groundwater. Total DDE concentrations were similar in magnitude or approximately one order of magnitude less than total DDT concentrations in most of the monitoring wells. As shown on Figure 5-15, the highest total DDT, DDD, and DDE concentrations are located immediately in the vicinity of the former MPR pond and trench, and the concentrations drop dramatically within a few feet of that source area. The total DDT, DDD, and DDE plume is well defined in the shallow zone and extends approximately 900 feet in the north-south direction and 350 feet in the east-west direction. The plume is centered on the former MPR pond and trench and extends eastward toward the Willamette River.

Eight other pesticides have been previously detected in one or more shallow-zone monitoring well groundwater samples: alpha-BHC, alpha-chlordane, dieldrin, endosulfan I, endosulfan sulfate, endrin, gamma-BHC (lindane), and heptachlor epoxide. Concentrations of these constituents ranged from 0.05 μg/L (MWA-2 Dup, April 1999, gamma-BHC [lindane]) to 420 J μg/L (MWA-15r, April 2002, alpha-BHC). These other organochlorine pesticides were not consistently detected in the shallow-zone groundwater at the site, no obvious trends were identified, and none of these other pesticides were detected in the June 2003 samples. None of these pesticides were manufactured at the Site, nor is there any record of their use or storage at the Site.

Select shallow-zone groundwater samples were analyzed for dissolved organochlorine pesticides. Analytical results for the dissolved organochlorine pesticides are provided in Table 5-18. Dissolved DDT was detected in nine of the 24 shallow-zone samples at concentrations ranging from 0.05 μg/L (MWA-3, 24 August 1999) to 11 μg/L (MWA-15, 26 August 1999). Dissolved DDD was detected in eight of the 24 samples and dissolved DDE was detected in four of the 24 samples. Dissolved DDD and DDE concentrations were similar (typically within one order of magnitude) to dissolved DDT concentrations.

Two other dissolved pesticides, dieldrin and gamma-BHC (lindane), were detected in four shallow-zone groundwater samples(MWA-2, MWA-3, MWA-4, and MWA-6)at concentrations ranging from 0.05 to 0.6 μg/L.

5.2.3.1.2 *Intermediate-Zone Groundwater*

A total of 59 samples from nine intermediate-zone monitoring wells were used to evaluate the nature and extent of organochlorine pesticides in the intermediate-zone groundwater. The organochlorine pesticide results for the intermediate-zone groundwater are summarized in Table 5-18 and illustrated on Figure 5-16.

Total DDT was detected in 17 of the 59 samples at concentrations ranging from 0.012 μg/L (MWA-8i, April 2002) to 9 μg/L (MWA-9i, January 1999). Monitoring wells MWA-8i and MWA-9i are both located downgradient of the Acid Plant Area. All the detected DDT concentrations were above the preliminary screening level of 0.001 μg/L, which applies to the total measured concentration of DDT, DDD, and DDE.

During the June 2003 sampling event, samples were collected from nine intermediate-zone monitoring wells and the results for DDT, DDD, and DDE are provided on Figure 5-16. DDT was detected in two of the nine samples collected; however, one of the two samples failed laboratory QC and the result was qualified as "rejected". DDT was detected in the second sample at a concentration of 0.327 μg/L (MWA-34i). Monitoring well MWA-34i is located downgradient of the Chlorate Plant.

Total DDD was detected in 33 of the 59 samples collected from the intermediate-zone monitoring wells, and DDE was detected in six of the samples. Total DDD and DDE concentrations were similar in magnitude to total DDT concentrations for most of the intermediate-zone samples.

The groundwater monitoring results summarized in Table 5-18 indicate DDT concentrations declined or remained stable at relatively low levels between January 1999 and June 2003. As shown on Figure 5-16, there are two areas where the intermediate-zone groundwater contains total DDT, DDD, and DDE concentrations above the preliminary screening level of 0.001 µg/L: (1) a 450-foot by 200-foot plume located to the northeast of the former MPR pond and trench, and (2) a 300-foot by 100-foot plume located south of the No. 1 dock (and southeast of the Acid Plant). Both intermediate-zone plumes underlie the DDT (and metabolite) plume in the shallow zone, and the concentrations in the intermediate-zone are generally lower than the shallow-zone wells. Figures 5-17 and 5-18 provide cross sections along A-A′ and B-B′ showing DDT, DDD, and DDE concentrations measured during the June 2003 event. The DDT, DDD and DDE concentrations in the intermediate zone appear to be a continuation of the shallow-zone plume.

Two other organochlorine pesticides were detected in the intermediate-zone groundwater samples: alpha-BHC and endrin. Concentrations of these constituents ranged from 0.013 µg/L (MWA-11i Dup, June 2001, alpha-BHC) to 0.08 µg/L (MWA-9i, April 1999, endrin). These other organochlorine pesticides were not consistently detected in the intermediate-zone wells, no obvious trends were identified, and neither of them was detected in the June 2003 event samples.

Twenty samples, including one duplicate, from seven intermediate-zone monitoring wells were analyzed for dissolved organochlorine pesticides. A summary of analytical results for dissolved organochlorine pesticides in groundwater samples is provided in Table 5-18.

Dissolved DDT was detected in four of the 20 intermediate-zone monitoring well groundwater samples at estimated concentrations ranging from 0.6 µg/L (MWA-9i, 25 August 1999) to 8 µg/L (MWA-9i, 28 January 1999). Dissolved DDD was detected in six of the 20 samples, and dissolved DDE was detected in three of the 20 samples. The reported dissolved DDD and DDE concentrations were similar (typically within one order of magnitude) to the dissolved DDT concentrations.

One other dissolved pesticide, endosufan I, was detected in one intermediate-zone monitoring well groundwater sample. This constituent was detected in monitoring well MWA-8i at a concentration of 0.04 J µg/L.

5.2.3.1.3 *Deep-Zone Groundwater*

Thirteen samples, including one duplicate, from four deep-zone monitoring wells were used to evaluate the nature and extent of organochlorine pesticides in the deep-zone groundwater. The analytical results are summarized in Table 5-18 and illustrated on Figures 5-17 and 5-18.

Total DDT was detected in seven of the 13 samples at concentrations ranging from 0.065 μg/L (MWA-13d, April 2002) to 0.43 μg/L (MWA-13d, March 1999). All the detected concentrations were above the preliminary screening level of 0.001 μg/L, which applies to the total concentration of DDT, DDD, and DDE.

Total DDD was detected in seven of the 13 groundwater samples at concentrations ranging from 0.05 μg/L (MWA-13d, November 1999) to 0.091 μg/L (MWA-13d, April 2002). No other organochlorine pesticides were detected in the deep-zone groundwater samples.

Three samples from MWA-13d were collected in January, April, and August 1999 and analyzed for dissolved organochlorine pesticides by USEPA Method 8081A. Dissolved organochlorine pesticides were not detected in any of the deep-zone groundwater samples.

Monitoring well MWA-13d is co-located with intermediate-zone well MWA-9i and shallow-zone wells MWA-3 and MWA-17si. DDT concentrations were not detected in MWA-13d, MWA-9i, or MWA-17si in June 2003, compared to a relatively low detection of DDT in MWA-3 (0.362 μg/L). Data collected from 1999 through 2002 indicate DDT concentrations in MWA-13d were similar in magnitude or lower than corresponding samples collected from the shallow- and intermediate-zone wells.

5.2.3.1.4 *Basalt-Zone Groundwater*

Five samples, including two duplicates, from one basalt-zone monitoring well (MWA-21b) were used to evaluate the nature and extent of organochlorine pesticides in basalt-zone groundwater. Monitoring well MWA-21b is 150 feet downgradient of the Acid Plant Area and is co-located with shallow-zone wells MWA-3 and MWA-17si, intermediate-zone well MWA-9i, and deep-zone well MWA-13d (Figure 3-9).

Analytical results for the organochlorine pesticides detected in MWA-21b are summarized in Table 5-18 and illustrated on Figures 5-14 and 5-15.

Total DDT was detected in all five samples at concentrations ranging from 0.0074 µg/L (December 2001) to 0.022 µg/L (November 2001, duplicate sample). All detected concentrations were above the preliminary screening level of 0.001, which applies to total DDT, DDD, and DDE. Total DDD was detected in all five groundwater samples at concentrations ranging from 0.007 µg/L (November 2001) to 0.017 µg/L (November 2001, duplicate sample). No other organochlorine pesticides were detected in the groundwater samples collected from monitoring well MWA-21b.

Samples were collected from co-located wells MWA-21b, MWA-13d, MWA-9i, MWA-17si and MWA-3 during one sampling event in April 2002. DDT was not detected in MWA-9i, MWA-17si, or MWA-3 on that date. Low concentrations of DDT were detected in MWA-13d (0.08 µg/L) and MWA-21b (0.01 µg/L). However, these detected concentrations were below the laboratory detection limit achieved for samples from both MWA-9i and MWA-3 on that same date.

5.2.3.2 *Volatile Organic Compounds*

Groundwater samples collected from the following direct-push borings and groundwater monitoring wells were used to evaluate the nature and extent of VOCs in the groundwater:

- Eight RI soil borings (B-55, B-56, B-59, B-60, B-61, B-64, B-65, and B-67) completed in the shallow-zone groundwater;
- Eleven MIP borings (APMIP-4 through APMIP-18) completed in the shallow-zone groundwater;
- Three borings (INT-5, INT-10, and INT-11) installed in the intermediate groundwater zone;
- Thirty-five groundwater monitoring wells (MWA-1 through MWA-31i(d) and MWA-33a through MWA-34i), including: 23 shallow-zone, 8 intermediate-zone, 3 deep-zone, and 1 basalt-zone monitoring well; and
- Fifteen performance monitoring wells installed in the shallow groundwater zone, including six nested well pairs (NMP-1S/NMP-1D through NMP-6S/NMP-6D) sampled in 2001 and 2003 and three additional wells (PMP-1 through PMP-3) sampled in 2003.

Data from PMP-1 through PMP-3, NMP-1S through NMP-6D, and MWA-36 through MWA-38 was not validated. Groundwater analytical results for VOCs are described in the following subsections for the shallow-, intermediate-, deep-, and basalt-zone groundwater.

5.2.3.2.1 *Shallow-Zone Groundwater*

Nine groundwater grab samples, including one duplicate, were collected from eight direct-push RI borings (B-55, B-56, B-59, B-60, B-61, B-64, B-65, and B-67) for VOC analysis. RI soil sampling boring locations are shown on Figure 3-3 and the grab-sample VOC results are summarized in Table 5-19. Eight of the nine samples were analyzed for an abbreviated list of VOCs, which did not include MCB or chloroform. The remaining sample (from boring B-59) was analyzed for the full VOC list. Neither MCB nor chloroform was detected in B-59, which is located to the west (and upgradient of) the Acid Plant Area. Four other VOCs were detected in the B-59 grab sample: 2-butanone, 4-isopropyltoluene, acetone, and benzene. All detections were below preliminary screening levels, with the highest detection of 330 µg/L for acetone. No other VOCs were detected at any of the RI boring locations.

Thirteen groundwater grab samples, including one duplicate, were collected from 11 MIP borings (APMIP-4 through APMIP-18) and analyzed for MCB, chloroethane, chloroform, and tetrachloroethene. The MIP boring locations are shown on Figure 3-9 and the analytical results are summarized in Table 5-19. MCB was detected in all 13 samples at concentrations ranging from 48,000 µg/L (APMIP-18) to 502,000 µg/L (APMIP-10). These concentrations are above the MCB preliminary screening level of 50 µg/L, and indicate the presence of residual MCB DNAPL in the vicinity of the samples. These data were used to confirm the nature and extent of DNAPL beneath the former MPR pond and trench.

Chloroform was detected in four of the 13 APMIP grab samples at concentrations ranging from 272 µg/L (APMIP-9) to 793 µg/L (APMIP-7). Chloroethane and tetrachloroethene were detected in three of the 13 samples at APMIP-6, APMIP-7, and APMIP-10. All detected concentrations of these VOCs were below their respective preliminary screening levels.

A total of 118 samples, including six duplicates, from 38 shallow-zone monitoring wells were used to evaluate the nature and extent of VOCs in the shallow-zone groundwater. The VOC data for the shallow-zone samples are summarized in Table 5-19 and illustrated on Figure 5-19.

MCB was detected in 92 of the 118 shallow-zone groundwater samples at concentrations ranging from 0.72 μg/L (MWA-25, April 2002) to 260,000 μg/L (MWA-15r, March 2001). Monitoring well MWA-25 is located within the Chlorate Plant, approximately 500 feet south of the Acid Plant Area. Monitoring well MWA-15r is located within the footprint of the former MPR pond. The MCB concentration in the most recent sample collected from monitoring well MWA-15r (October 2003) was 180,000 D μg/L. MCB concentrations in 74 of the samples were above the preliminary screening level of 50 μg/L.

The most complete groundwater monitoring event was conducted in June 2003, when samples were collected from 15 shallow-zone monitoring wells. MCB results for the June 2003 sampling event are shown on Figure 5-19. Chloroform was not detected in any of the June 2003 shallow-zone groundwater samples. As shown on Figure 5-19, the highest MCB concentrations are located immediately northeast of the former MPR pond and trench and extend northeast toward the Willamette River. The MCB plume is well defined in the shallow zone and extends approximately 900 feet in the north-south direction and 350 feet in the east-west direction. The plume is centered on the former MPR pond and trench and extends eastward (downgradient) toward the Willamette River (Figure 5-19). A comparison of Figures 5-15 and 5-19 shows that the footprints of the MCB and DDT plumes in the shallow zone are nearly identical.

In monitoring wells where MCB was routinely detected, the highest MCB concentrations were generally observed in samples collected during the April 2002 groundwater sampling event. MCB concentrations were lower (relative to the April 2002 event) in nine of the 11 shallow-zone samples collected in June 2003, indicating a potential downward trend in MCB concentrations.

Chloroform was detected in 48 of the 118 samples at concentrations ranging from 0.59 μg/L (MWA-18, March 2001) to 1,200 D μg/L (NMP-4D, June 2001). However, the NMP-4D result was qualified with a "D" qualifier, indicating the result was from a dilution and this data has not undergone validation. The next highest chloroform concentration

(950 µg/L) was measured in MWA-15r in March 2001. MWA-18 is located downgradient of the Chlorate Plant, approximately 400 feet east of the former MPR pond. NMP-4D is located approximately 30 feet north of the former MPR pond, and MWA-15r is located within the former footprint of the MPR pond. None of the chloroform concentrations were above the preliminary screening level of 1,240 µg/L. Similar to the MCB data, the chloroform data show a recent downward trend in concentrations (Table 5-19).

Twenty-five other VOCs were detected in samples collected from shallow-zone groundwater monitoring wells. Concentrations of these constituents ranged from 0.5 to 1,000 µg/L, with most concentrations in the range of 0.5 to 25 µg/L. Only one constituent, tetrachloroethene, was detected in one sample (1,000 µg/L, MWA-6, January 1999) at a concentration above its preliminary screening level (840 µg/L). No other constituents were detected above preliminary screening levels.

5.2.3.2.2 Intermediate-Zone Groundwater

Four groundwater grab samples, including one duplicate, were collected from three intermediate-zone borings (INT-5, INT-10, and INT-11) for VOC analysis. The three INT borings were co-located with shallow-zone borings: APMIP-5, APMIP-10, and APMIP-11 (Figure 3-9). The four grab samples were analyzed for MCB, chloroethane, chloroform, and tetrachloroethene and the results are summarized in Table 5-19.

MCB was detected in all 4 INT grab samples at concentrations ranging from 80.9 µg/L (INT-11) to 61,600 µg/L (INT-5 dup). These MCB concentrations are one to four orders of magnitude lower than the MCB concentrations in the corresponding shallow-zone samples. MCB concentrations were greater than the preliminary screening level of 50 µg/L in all four intermediate zone groundwater samples. Chloroethane, chloroform, and tetrachloroethene were not detected in any of the four intermediate-zone groundwater samples.

A total of 62 samples, including three duplicates, from eight intermediate-zone monitoring wells were used to evaluate the nature and extent of VOCs in the intermediate-zone groundwater. The VOC data for the intermediate-zone samples are summarized in Table 5-19 and illustrated on Figure 5-20.

MCB was detected in 35 of the 62 intermediate-zone groundwater samples at concentrations ranging from 2.5 μg/L (MWA-11i, January 1999) to 38,000 μg/L (MWA-9i, January 1999). Monitoring well MWA-11i is located in the Acid Plant Area, slightly upgradient from the former MPR pond in the area of the former MCB Recovery Unit. Monitoring well MWA-9i is located approximately 150 feet downgradient of the former MPR pond. The MCB concentration in the most recent sample collected from monitoring well MWA-9i (June 2003) was 32,100 μg/L.

The most complete groundwater monitoring event was conducted in June 2003, when samples were collected from eight intermediate-zone monitoring wells. As shown on Figure 5-20, MCB was detected in five of the eight samples collected at concentrations ranging from 17.5 μg/L (MWA-16i) to 32,100 μg/L (MWA-9i).

The groundwater monitoring results presented in Table 5-19 indicate a general downward trend in MCB concentrations over time. Exceptions to this trend were observed in MWA-9i, where concentrations have remained relatively stable since 1999. As shown on Figure 5-20, there are two areas where the intermediate-zone groundwater contains MCB concentrations above the preliminary screening level of 50 μg/L: (1) a 450-foot by 200-foot plume located to the northeast (downgradient) of the former MPR pond and trench, and (2) a 300-foot by 100-foot plume located south of the No. 1 dock and southeast of the Acid Plant Area. A comparison of Figures 5-16 and 5-20 shows that the DDT and MCB plumes in the intermediate-zone groundwater have similar footprints. Moreover, the northern intermediate-zone MCB plume underlies the downgradient extent of the shallow-zone MCB plume (Figures 5-19 and 5-20). The southern intermediate-zone MCB plume extends slightly south from its shallow-zone counterpart.

Chloroform was detected in 11 of the 62 intermediate-zone samples at concentrations ranging from 1.1 μg/L (MWA-16i, November 2001) to 120 μg/L (MWA-9i, January 2002). None of the detected chloroform concentrations were above the preliminary screening level of 1,240 μg/L. Similar to the MCB data, the chloroform data show a general downward trend in concentrations (Table 5-19).

Fourteen other VOCs were detected in samples collected from intermediate-zone groundwater monitoring wells. Concentrations of these constituents ranged from 0.5 to 530 μg/L, with most concentrations observed in the range of 0.5 to 10 µg/L. None of these detections were greater than their respective preliminary screening levels.

5.2.3.2.3 *Deep-Zone Groundwater*

Twelve samples from deep-zone monitoring wells MWA-13d, MWA-28i(d), and MWA-31i(d) were collected over the period between January 1999 and June 2003 for VOC analysis by USEPA Method 8260B. One of the twelve groundwater samples was a duplicate sample. MCB was detected in all nine deep-zone groundwater samples from MWA-13d at concentrations ranging from 10.6 µg/L (June 2003) to 1,600 µg/L (August and November 1999). All detected concentrations were above the preliminary screening level of 50 µg/L, with exception of the most recent sample collected in June 2003. MCB was not detected in the samples collected from the deep-zone chlorate plant wells MWA-28i(d) and MWA-31i(d).

Chloroform was detected in one of the deep-zone samples collected from MWA-31i(d) in April 2002 (71 µg/L). The concentration of chloroform in this sample is below the preliminary screening level of 1,240 µg/L. Trace concentrations of five other VOCs were detected in five of the 12 deep-zone samples: 1,1-dichloroethane, 1,2-dichloroethane, benzene, bromodichloromethane, and bromoform. Concentrations of these constituents ranged from 0.59 µg/L to 3.5 µg/L. None of the concentrations were above preliminary screening levels.

Monitoring well MWA-13d is co-located with intermediate-zone well MWA-9i and shallow-zone wells MWA-3 and MWA-17si. MCB concentrations were measured to be one to three orders of magnitude lower in MWA-13d than corresponding concentrations measured in MWA-9i for all monitoring events conducted from January 1999 through June 2003. Clorobenzene concentrations in MWA-13d were also one to two orders of magnitude lower than concentrations measured in MWA-17si from January 1999 through June 2003.

Analytical results for VOCs measured in MWA-13d are summarized in Table 5-19. MCB results from June 2003 are also shown on cross sections A-A′ and B-B′ on Figures 5-21 and 5-22.

5.2.3.2.4 *Basalt-Zone Groundwater*

Five samples from basalt-zone monitoring well MWA-21b were collected in November and December 2001 and April 2002 for VOC analysis by USEPA Method 8260B. Two of the five groundwater samples were duplicate samples. MCB was detected in all five basalt-zone groundwater samples at concentrations ranging from 0.69 µg/L (April 2002) to 2.2 µg/L (December 2001, duplicate sample). The MCB concentration for the most recent sample collected from monitoring well MWA-21b (0.69 µg/L, April 2002) was approximately one-half of the mean MCB concentration in the four other samples collected from this well.

Chloroform was not detected in any of the samples collected from MWA-21b. One other VOC, methylene chloride, was detected in one of the five MWA-21b samples at a concentration of 1.3 µg/L (November 2001, duplicate sample). A preliminary screening level has not been established for methylene chloride, which is also a common analytical laboratory contaminant.

Samples were collected from co-located wells MWA-21b, MWA-13d, MWA-9i, MWA-17si, and MWA-3 during one sampling event in April 2002. The MCB concentration measured in MWA-21b (0.69 µg/L) in April 2002 was more than three orders of magnitude less than the concentration detected in MWA-13d (1,000 µg/L), more than four orders of magnitude less than the concentration measured in MWA-9i (26,000 µg/L), and more than 5 orders of magnitude less than the concentration measured in MWA-17si (140,000 µg/L). As described above, the concentration of MCB measured in MWA-3 in April 2003 was 130 µg/L.

Analytical results for VOCs measured in MWA-21b are summarized in Table 5-19. MCB results for MWA-21b from the April 2002 sampling event are shown on cross sections A-A′ and B-B′ on Figures 5-21 and 5-22.

5.2.3.3 *DDT and MCB Concentrations and Water Level Elevations*

A comparison between DDT and MCB concentrations and groundwater elevations was made for select monitoring wells: MWA-3, -9i, and -15/-15r. These wells were selected for comparison due to the relatively large amount of available groundwater data and because two of the wells (MWA-3 and MWA-9i) are co-located along the riverbank (and therefore exhibit significant fluctuations in groundwater elevation). Plots of DDT and MCB concentrations and groundwater elevations vs. time for the selected wells are presented on Figures 5-23a through 5-23e. In general, these plots indicate very little correlation between groundwater elevation and constituent concentration. With the exception of DDT in monitoring well MWA-9i, the correlation is poor. In MWA-9i, there is a general trend of decreasing constituent concentration with decreasing groundwater elevation before January 2000 (Figure 5-23a). However, the correlation becomes poor after that time, with a slightly increasing trend in groundwater elevation and a relatively flat trend in groundwater quality (DDT concentration). Overall, it is difficult to determine if groundwater elevation directly influences constituent concentrations in these monitoring wells.

5.2.3.4 *Semi-Volatile Organic Compounds*

Groundwater samples were collected from the following direct-push borings and groundwater monitoring wells for analysis of SVOCs by USEPA Method 8270C and 8270-SIM:

- One RI soil boring (B-59) completed in the shallow groundwater zone within the Acid Plant in 1999; and
- Twenty-five groundwater monitoring wells (MWA-1 through MWA-20, MWA-22, MWA-30, and MWA-32i) installed in the Acid Plant and Chlorate Plant Areas and sampled over the period between January 1999 and June 2003, including: 16 shallow-zone, 8 intermediate-zone, and 1 deep-zone monitoring well.

Groundwater analytical results for SVOCs are presented in Table 5-20 and discussed in the following subsections for the shallow-, intermediate-, and deep-zone groundwater.

5.2.3.4.1 *Shallow-Zone Groundwater*

One groundwater grab sample was collected from boring B-59 for analysis of SVOCs by USEPA Method 8270-SIM. Boring B-59 was located adjacent to the northwest corner of the Chlorine Finishing Building, west (and upgradient) of the Acid Plant Area. Six SVOCs were detected in the grab sample, including: 2-methylphenol, benzoic acid, benzyl alcohol, isophorone, naphthalene, and phenol. No SVOCs were detected above preliminary screening levels. The highest measured SVOC concentrations were benzoic acid (34 µg/L) and phenol (45 µg/L). SVOC results for the groundwater grab sample from B-59 are presented in Table 5-20.

Fifty-seven samples from 16 shallow-zone groundwater monitoring wells were collected over the period from January 1999 to June 2003 for SVOC analysis by USEPA Method 8270C or 8270-SIM. Four of the 57 samples were duplicate samples. Thirty-two SVOCs were detected in 43 shallow-zone groundwater samples. Of those 32 compounds, the five most prevalent (in frequency and concentration) were: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3- and 4-chlorophenol, and benzoic acid. These constituents were detected at concentrations ranging from 0.1 to 290 µg/L, with the highest concentrations observed in monitoring wells MWA-15/15r. Only two constituents exceeded preliminary screening levels (hexachlorobutadiene and pentachlorophenol). Exceedences of preliminary screening levels for these two constituents only occurred in two samples from MWA-6 (January 1999 and April 1999). Monitoring well MWA-6 was abandoned in August 1999 because the well produced very turbid water and would not clear, even after prolonged pumping. Concentrations of these two constituents were below screening levels in subsequent samples collected from MWA-6r, which was installed to replace MWA-6. The 25 other SVOCs were detected at relatively low concentrations that were generally at, or slightly greater than, method detection limits.

A summary of analytical results for SVOCs in monitoring well groundwater samples is provided in Table 5-20. Monitoring well locations are shown on Figure 3-9. The data summarized in Table 5-20 indicate a general downward trend over time for a majority of the SVOCs detected in shallow-zone groundwater wells.

5.2.3.4.2 *Intermediate-Zone Groundwater*

Forty-five samples from eight intermediate-zone groundwater monitoring wells were collected over the period from January 1999 through June 2003 for SVOCs by USEPA Method 8270C or 8270-SIM. Four of the 45 samples were duplicate samples.

Twenty-seven SVOCs were detected in 26 intermediate-zone groundwater samples. Of those 27 compounds, the most prevalent (in frequency and concentration) were: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3- and 4-chlorophenol, and benzoic acid. These constituents were detected at concentrations ranging from 0.2 to 180 µg/L, with the highest concentrations of these compounds observed in monitoring well MWA-9i. MWA-9i is located northeast (and downgradient) of the Acid Plant Area. The other 22 SVOCs were detected at relatively low concentrations that were generally at, or slightly greater than, method detection limits. None of the detected concentrations were above preliminary screening levels.

Analytical results for SVOCs in intermediate-zone groundwater samples are provided in Table 5-20. Monitoring well locations are shown on Figure 3-9. The data summarized in Table 5-20 indicate a general downward trend over time for a majority of the SVOCs detected in intermediate-zone groundwater wells. However, exceptions to this are evident for 1,4-dichlorobenzene, 2-chlorophenol, and benzoic acid in MWA-9i and MWA-15/15r, which appear to remain at relatively consistent low levels during the periods sampled.

5.2.3.4.3 *Deep-Zone Groundwater*

Six samples from monitoring well MWA-13d were collected over the period from January 1999 to June 2001 for SVOC analysis by USEPA Method 8270C or 8270-SIM. Six SVOCs were detected in four of the six deep-zone groundwater samples: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3- and 4-chlorophenol, dimethyl phthalate, and naphthalene. These constituents were detected at concentrations ranging from 0.1 to 6 µg/L. None of the measured concentrations were above preliminary screening levels.

Analytical results for SVOCs in deep-zone groundwater samples are provided in Table 5-20. Monitoring well locations are shown on Figure 3-9. Monitoring well MWA-13d is co-located with intermediate-zone well MWA-9i, and shallow-zone well MWA-3. The data summarized in Table 5-20 indicate fewer SVOCs were detected in either MWA-13d or MWA-3 compared to MWA-9i, and concentrations were generally lower.

5.2.3.5 *Metals*

This section presents groundwater sampling results for metals in the Acid Plant Area, with the exception of chromium. Elevated chromium concentrations present in Site groundwater are related to historical activities conducted in the Chlorate Plant and are discussed in Section

5.3.2.1. Groundwater samples were collected from the following groundwater monitoring wells located in the Acid Plant Area for metals analysis by USEPA Methods 6020 and 6010B:

- Twenty-two groundwater monitoring wells (MWA-1 through MWA-20) installed in the Acid Plant Area and sampled over the period between January 1999 and June 2003, including: 14 shallow-zone, 7 intermediate-zone, and 1 deep-zone monitoring well; and
- Fifteen performance monitoring wells installed in the shallow groundwater zone, including six nested well pairs (NMP-1S/NMP-1D through NMP-6S/NMP-6D) and three additional wells (PMP-1 through PMP-3). The NMP wells were installed as part of the Sodium Persulfate Oxidation Pilot Study in 2001 and the PMP wells were installed as part of the DNAPL Pilot Study in 2003.

Groundwater analytical results for metals are presented in Table 5-21 and in the following subsections for the shallow-, intermediate-, and deep-zone groundwater.

5.2.3.5.1 Shallow-Zone Groundwater

Seventy-three samples from 29 shallow-zone monitoring wells installed in the Acid Plant Area were collected over the period from January 1999 through October 2003 and analyzed for various metals by USEPA Method 6010B or 6020. A majority of the samples were collected in 1999. Five of the 73 samples were duplicate samples. Samples were analyzed for one or more of the following metals: total and dissolved antimony, total and dissolved barium, calcium, total and dissolved copper, total and dissolved iron, total and dissolved lead, magnesium, total and dissolved manganese, total and dissolved mercury, total and dissolved nickel, potassium, sodium, and total and dissolved zinc.

Groundwater analytical results for metals are presented in Table 5-21. Monitoring well locations are shown on Figure 3-9. The following metals were measured at concentrations greater than preliminary screening levels:

- Dissolved and/or total copper was detected in 12 of the 12 samples analyzed for this constituent. All twelve detections were greater than the conservative preliminary screening level of 0.0027 mg/L. Note that this preliminary screening level applies to the dissolved fraction and is hardness dependant. The highest measured concentration of total copper was 0.121 mg/L (NMP-3S, May 2001) and the highest measured concentration of dissolved copper was 0.0668 mg/L (NMP-4S, June 2001).

- Dissolved and/or total iron was detected in 46 of the 48 samples analyzed for this constituent. Forty of the 48 detections were greater than the conservative preliminary screening level of 1 mg/L. The highest measured concentration of total iron was 66.2 mg/L (MWA-7, January 1999) and the highest measured concentration of dissolved iron was 17.1 mg/L (NMP-5D, October 2003).
- Dissolved and/or total lead was detected in 13 of the 13 samples analyzed for this constituent. All thirteen detections were greater than the conservative preliminary screening level of 0.00054 mg/L. Note that this preliminary screening level applies to the dissolved fraction and is hardness dependant. The highest measured concentration of total lead was 0.758 mg/L (NMP-2S, June 2001) and the highest measured concentration of dissolved lead was 0.103 mg/L (NMP-5S, June 2001).
- Dissolved and/or total mercury was detected in 2 of the 3 samples analyzed for this constituent. Both detections were greater than the conservative preliminary screening level of 0.00077 mg/L. Note that this preliminary screening level applies to the dissolved fraction. Dissolved mercury was only measured in one sample and was not detected. The highest measured concentration of total mercury was 0.0013 mg/L (NMP-3S, May 2001).
- Dissolved and/or total nickel was detected in 11 of the 11 samples analyzed for this constituent. All eleven detections were greater than the conservative preliminary screening level of 0.016 mg/L. Note that this preliminary screening level applies to the dissolved fraction and is hardness dependant. The highest measured concentration of total nickel was 0.231 mg/L (NMP-3S, May 2001) and the highest measured concentration of dissolved nickel was 0.895 mg/L (NMP-1D, June 2001).
- Dissolved and/or total zinc was detected in 13 of the 13 samples analyzed for this constituent. All thirteen detections were greater than the conservative preliminary screening level of 0.0365 mg/L. Note that this preliminary screening level applies to the dissolved fraction and is hardness dependant. The highest measured concentrations of total and dissolved zinc were measured in NMP-1D in June 2001 (0.586 mg/L and 0.737 mg/L, respectively).

5.2.3.5.2 *Intermediate-Zone Groundwater*

Thirty samples from seven intermediate-zone monitoring wells were collected over the period from January 1999 through June 2003 for various metals analysis by USEPA Method 6010B. A majority of the samples were collected in 1999. One of the 30 samples collected was a duplicate sample. Samples were analyzed for one or more of the following metals: calcium, total iron, magnesium, potassium, and sodium.

Groundwater analytical results for metals are presented in Table 5-21. Monitoring well locations are shown on Figure 3-9. Total iron was detected in 29 of the 29 samples analyzed for this constituent. Twenty-eight of the 29 detections were greater than the conservative preliminary screening level of 1 mg/L. The highest measured concentration of total iron was 28.9 mg/L (MWA-11i, November 1999). Intermediate-zone monitoring well MWA-9i is co-located with shallow-zone wells MWA-3 and MWA-17si. Iron concentrations were generally higher in MWA-9i compared to the concentrations measured in MWA-3. No other metals were detected above their respective screening levels in intermediate zone wells in the acid plant area.

5.2.3.5.3 *Deep-Zone Groundwater*

Four samples from monitoring well MWA-13d were collected during four groundwater sampling events conducted in 1999 and analyzed for various metals by USEPA Method 6010B. Deep-zone groundwater samples were analyzed for calcium, iron, magnesium, potassium, and sodium. Groundwater analytical results for metals are presented in Table 5-21. Monitoring well locations are shown on Figure 3-9.

Total iron was detected in all four of the samples analyzed for this constituent at concentrations greater than the conservative preliminary screening level of 1 mg/L. The highest measured concentration of total iron was 3.04 mg/L (April 1999). Deep-zone monitoring well MWA-13d is co-located with intermediate-zone well MWA-9i and shallow-zone well MWA-3. Iron concentrations were generally the highest of the three wells in MWA-9i and lowest in MWA-3. No other metals were detected above their respective screening levels in intermediate zone wells in the Acid Plant Area.

5.2.3.6 Perchlorate

Groundwater samples were collected for perchlorate analyses in June and July 2003 from 24 groundwater monitoring wells in the Acid Plant and Chlorate Plant Areas. While perchlorate was detected in Acid Plant Area groundwater, the highest concentrations and greatest extent of perchlorate impacts were observed in the Chlorate Plant Area. Therefore, the nature and extent of perchlorate contamination in Site groundwater is discussed in Chlorate Plant Area Section 5.3.2.2.

5.2.3.7 Petroleum Hydrocarbons

Groundwater grab samples were collected from two direct-push borings completed within the Acid Plant Area in 1999 (borings B-55 and B-56) and analyzed for diesel-range organics by Northwest Method TPH-Dx. These two borings were located at the southern end of the Acid Plant Area, near the southwestern corner of No. 3 Warehouse (Figure 3-9). Diesel-range petroleum hydrocarbons were not detected in either groundwater grab sample and petroleum hydrocarbons are not considered to be a COI for the Acid Plant Area. Analytical results for petroleum hydrocarbons in groundwater are presented in Table 5-22.

5.3 CHLORATE PLANT AREA

This section presents the analytical data collected during the investigation of soil and groundwater associated with the Chlorate Plant Area.

5.3.1 Soil Investigations

A total of 23 soil sampling borings were advanced using direct-push drilling methods for the collection of soil and groundwater grab samples in the Chlorate Plant Area. Select samples were submitted for laboratory analysis of total and hexavalent chromium by USEPA Methods 6020 and 3060A. A description of soil sampling activities associated with the Chlorate Plant is provided in Section 3 and summarized in Table 3-3.

Soil sampling was also conducted in soil borings advanced for the installation of groundwater monitoring wells. A total of 12 borings were completed in and around the Chlorate Plant Area for the installation of shallow-zone, intermediate-zone and deep-zone groundwater monitoring wells. Based on an oily sheen and slight odor identified in one monitoring well boring (MWA-30, 29.5 to 30 feet bgs), a soil sample from that depth was submitted to the laboratory for the following analyses:

- VOCs;
- Organochlorine pesticides; and
- TPH-gasoline and TPH-diesel.

Sampling results for VOCs and organochlorine pesticides are discussed with other Acid Plant Area soil samples in Section 5.2.1. Analytical results for chromium and TPH in soil samples collected from the Chlorate Plant Area are discussed in the following subsections. The extent of potential perchlorate contamination in soil associated with the Chlorate Plant Area was not investigated during the RI. Perchlorate concentrations in Site soils will be addressed during the Feasibility Study.

5.3.1.1 Total and Hexavalent Chromium

Soil sampling was conducted in the Chlorate Plant Area in September and November 2001 to evaluate the nature and extent of total and hexavalent chromium concentrations. Eighty-six samples from 18 soil sampling borings were collected and analyzed for total chromium by USEPA Method 6020. Five of the 86 samples were duplicate samples. In addition, five of the 86 samples were analyzed for hexavalent chromium by USEPA Method 3060A. Chromium was detected in all 86 samples, at concentrations ranging from 10 mg/kg (boring B-87, 12 to 16 feet bgs) to 1,600 mg/kg (boring B-88, 10 to 12 feet bgs). Five of the 86 samples contained total chromium concentrations greater than the preliminary screening level of 450 mg/kg. The highest concentrations were detected at depths between 8 and 20 feet in samples collected from borings located in and around the Chlorate Cell Room.

Hexavalent chromium was detected in four of the five samples analyzed, at concentrations ranging from 9.7 mg/kg (boring B-75, 8 to 10 feet bgs) to 69 mg/kg (boring B-77, 8 to 10 feet bgs). Only the sample collected from boring B-77, 8 to 10 feet bgs, contained chromium at a concentration above the preliminary screening level (64 mg/kg). Analytical results for total and hexavalent chromium in soil samples collected from the Chlorate Plant Area are summarized in Table 5-23 and shown on Figures 5-24 and 5-25. In general, chromium concentrations were higher in the subsurface soil samples analyzed (greater than four feet bgs) than the samples collected from near the surface (zero to four feet bgs).

5.3.1.2 *Total Petroleum Hydrocarbons*

Based on observations of a 3-inch layer of dark, oily sand with a hydrocarbon odor observed in one monitoring well boring (MWA-30, 29.5 to 30 feet bgs) completed in March 2002, a soil sample from that depth was submitted to the laboratory for gasoline-range, diesel-range, and residual range organics analysis by Northwest methods NWTPH-Gx and NWTPH-Dx. TPH sampling results for the sample collected from MWA-30 are summarized in Table 5-24.

Gasoline-range, diesel-range, and residual-range organics were detected in the MWA-30 sample at 150 mg/kg, 29,000 mg/kg, and 40,000 mg/kg, respectively. The measured concentrations of diesel-range and residual-range organics were greater than the preliminary screening level of 23,000 mg/kg.

Monitoring well MWA-30 is located adjacent to the northeastern corner of the salt pads, adjacent to the Willamette River bank (Figure 3-9). The sample was collected from below the water table in alluvial sands and not in the overlying fill. The dark, oily sand appears limited in extent as it was not observed in monitoring wells MWA-19 and MWA-34i to the north, MWA-29 to the south, or MWA-27 to the west.

5.3.2 *Groundwater Investigations*

Groundwater samples were collected from direct-push borings and Site groundwater monitoring wells completed in the shallow-, intermediate-, and deep-groundwater zones to evaluate the distribution of COIs identified for Chlorate Plant Area sources. Groundwater analytical results for the primary Chlorate Plant Area COIs, including total and hexavalent chromium, perchlorate, and chloride are presented in the following subsections. Sampling results for metals (in addition to chromium) and petroleum hydrocarbons are also discussed. Final field parameter measurements (i.e., conductivity, dissolved oxygen, ORP, pH, temperature, and turbidity) recorded during monitoring well groundwater sampling are included in Table 5-17.

5.3.2.1 *Total and Hexavalent Chromium*

Groundwater samples were collected from the following direct-push borings and Site groundwater monitoring wells to evaluate the distribution of total and hexavalent chromium associated with the Chlorate Plant Area:

- Twenty-five RI soil borings completed in the shallow and deep groundwater zones within the Chlorate Plant in 2001 (B-68 through B-88, B-90, and B-116 through B-118);
- Nineteen groundwater monitoring wells installed in the Acid Plant and Chlorate Plant Areas and sampled between June 2001 and December 2003, including: 14 shallow-zone, three intermediate-zone, and two deep-zone wells; and
- Fourteen performance monitoring wells installed in the shallow groundwater zone in the Acid Plant and Chlorate Plant Areas. Four nested well pairs (NMP-1S/NMP-1D through NMP-4S/NMP-4D), NMP-5D, and NMP-6S were installed in the Acid Plant Area in 2001 as part of the Sodium Persulfate Oxidation Pilot Study. Wells MWA-25 through MWA-38 were installed as part of the Hexavalent Chromium Reduction Pilot Study.

Groundwater sampling locations are shown on Figures 3-9 and 3-12 and analytical results for chromium and hexavalent chromium in groundwater are provided in Table 5-21.

5.3.2.1.1 *Shallow-Zone Groundwater*

Twenty-eight groundwater grab samples from 24 direct-push borings completed in the shallow-zone were collected and analyzed for chromium by USEPA Methods 6010B (borings B-68 through B-84) and 6020 (borings B-86 to B-118). Four of the 28 samples were duplicate samples. Chromium was detected in 21 of the 28 groundwater grab samples at concentrations ranging from 0.0255 mg/L (boring B-68, 31 to 36 feet bgs) to 110 mg/L (boring B-80, 16 to 20 feet bgs). All the detected concentrations were above the conservative potential screening level of 0.011 mg/kg for dissolved-phase hexavalent chromium. No screening level has been established for unspeciated, total chromium. The highest chromium concentrations were observed in samples collected from borings in or adjacent to the Chlorate Cell Room and the salt pad east (downgradient) of the Chlorate Cell Room.

Shallow-zone monitoring well MWA-33 was installed adjacent to boring B-80, inside the Chlorate Cell Room. The groundwater sample collected from MWA-33 in June 2003 contained chromium at a concentration of 0.601 mg/L, approximately two orders of magnitude lower than the estimated ("J") concentration measured in the sample collected from direct-push boring B-80. This result suggests that the concentration of chromium in the groundwater sample collected from boring B-80 may be erroneously high. Chromium was not detected in the groundwater grab sample collected from boring B-77 (detection limit 0.029 mg/L, 28 to 32 feet bgs). This boring was advanced within a few feet of boring B-76, which contained chromium in a groundwater grab sample at a concentration of 21 mg/L (15 to 19 feet bgs).

Fifty-three samples from 28 shallow-zone monitoring wells were collected over the period between January 1999 and December 2003 for total chromium analysis by USEPA Methods 6010B or 6020. Five of the 53 samples were duplicate samples. Total chromium was detected in 48 of the 53 samples at concentrations ranging from 0.00117 mg/L (MWA-23, June 2003) to 21 mg/L (MWA-27, April 2002). Monitoring well MWA-27 is located downgradient of the Chlorate Plant Area, adjacent to the salt pads in the southeastern corner of the Site. The chromium concentration measured in the most recent sample collected from MWA-27 was 8.65 mg/L. Forty-two of the 53 samples collected contained total chromium concentrations greater than the conservative potential screening level of 0.011 mg/kg for dissolved-phase hexavalent chromium.

The most complete groundwater monitoring event was conducted in June 2003. During the June 2003 event, ten samples were collected from nine shallow-zone monitoring wells. One sample was a duplicate sample. Shallow-zone chromium results for the June 2003 event are shown on Figure 5-26. The total chromium results shown on Figure 5-26 indicate the highest chromium concentrations are located downgradient of the Chlorate Plant Area, extending east toward the Willamette River.

The available total chromium data indicate a general downward trend for total chromium concentrations in wells MWA-25, MWA-27, and MWA-30, which are located downgradient of the Chlorate Plant Area. Wells MWA-25 and MWA-27 contained some of the highest concentrations of chromium measured in groundwater wells at the site. A slight upward trend was observed in wells MWA-18, MWA-19, MWA-24, MWA-26, and

MWA-29, located outside of the zone with the highest measured chromium concentrations.

A total of 11 shallow-zone groundwater samples were collected from ten wells during the June 2001 and December 2003 sampling events for analysis of both total chromium and total hexavalent chromium. Hexavalent chromium was detected in eight of the eleven samples at concentrations ranging from 0.058 mg/L (MWA-6r, June 2001) to 14.9 mg/L (MWA-36, December 2003). All eight detected concentrations were greater than the conservative preliminary screening level of 0.011 mg/kg for dissolved hexavalent chromium. In general, the hexavalent chromium concentrations were slightly lower, but similar in magnitude to the total chromium concentrations. For example, the total hexavalent chromium concentration at MWA-36 was 14.9 mg/L compared to a total chromium concentration of 17.2 mg/L. Based on the available data, a majority of the total chromium present in site groundwater is likely in the hexavalent form.

A total of nine shallow-zone groundwater samples were collected from nine wells during the June 2001 and December 2003 sampling events for analysis of both total chromium and dissolved chromium. Dissolved chromium was detected in all nine samples at concentrations ranging from 0.0059 mg/L (NMP-1D and NMP-2D, June 2001) and 17.2 mg/L (MWA-36, December 2003). All nine samples contained concentrations greater than the conservative preliminary screening level of 0.011 mg/L dissolved hexavalent chromium. In general, the dissolved chromium concentrations were slightly lower, but similar in magnitude to the total chromium concentrations. For example, the total chromium concentration at MWA-27 was 8.65 mg/L compared to a dissolved chromium concentration of 7.74 mg/L. Based on the available data, a majority of the chromium present in site groundwater is likely in the dissolved form.

5.3.2.1.2 *Intermediate-Zone Groundwater*

Five samples from three intermediate-zone monitoring wells were collected for total chromium analysis. The three intermediate-zone wells sampled were located downgradient of the Chlorate Plant Area and adjacent to the Willamette River. Chromium was detected in all five samples at concentrations ranging from 0.007 mg/L (MWA-16i, June 2001) to 0.992 mg/L (MWA-16i, June 2003). Monitoring well MWA-16i is located on the riverbank downgradient of the Chlorate Plant Area, adjacent to the No. 1 Dock.

Intermediate-zone chromium results for the June 2003 event are shown on Figure 5-27. The total chromium results shown on Figure 5-27 indicate the highest chromium concentrations are located downgradient of the Chlorate Plant Area adjacent to the Willamette River. In general, chromium concentrations measured in the intermediate zone were similar in magnitude to concentrations measured in the shallow-zone groundwater. One of the wells sampled, MWA-32i, is co-located with shallow-zone well MWA-30. In June 2003, the total chromium concentrations measured in MWA-32i (0.238 mg/L) were lower than the concentrations measured in MWA-30 (0.562 mg/kg). Total chromium concentrations in groundwater for cross sections A-A′, C-C′, and D-D′ are provided on Figures 5-28 through 5-30.

One of the three intermediate-zone groundwater samples analyzed for total chromium was also analyzed for total hexavalent chromium (MWA-16i, June 2001). Hexavalent chromium was not detected in this sample above the method detection limit of 0.05 mg/L. The total chromium concentration measured in this sample was 0.007 mg/L.

5.3.2.1.3 *Deep-Zone Groundwater*

Two groundwater grab samples from two direct-push borings completed in the deep-zone (boring B-72, lower screened interval, and boring B-85) were collected and analyzed for total chromium. Chromium was detected in both samples at concentrations ranging from 1.4 J mg/L (boring B-72, 47 to 50 feet bgs) to 1.8 J mg/L (boring B-85, 50 to 54 feet bgs). The detected concentrations were above the conservative potential screening level of 0.011 mg/kg for dissolved-phase hexavalent chromium. Borings B-72 and B-85 are co-located downgradient of the Chlorate Plant, beneath the former footprint of Salt Pad No. 1.

Ten samples from two deep-zone monitoring wells, MWA-28i(d) and MWA-31i(d), were also collected for total chromium analysis. Chromium was not detected in any of the three samples collected from MWA-28i(d), which is located on the east side of the Chlorate Plant Area beneath the former location of Salt Pad No. 1. Chromium was detected in all seven of the samples from MWA-31i(d). One of the samples was a duplicate sample. The highest concentration measured in MWA-31i(d) (7 J mg/kg) was collected on March 7, 2002 from 46.2 to 48 feet bgs. The lowest concentration measured in MWA-31i(d) was 0.01 J mg/L (April 2002). Monitoring well MWA-31i(d) is located downgradient of the Chlorate Plant Area adjacent to the salt pads in the southeastern corner of the site.

Total chromium concentrations in groundwater for cross sections A-A′, C-C′, and D-D′ are provided on Figures 5-28 through 5-30. In June 2003, total chromium concentrations measured in deep-zone well MWA-31i(d) (1.15 mg/L) were higher than in co-located wells MWA-32i (intermediate zone, 0.238 mg/L) and MWA-30 (shallow zone, 0.562 mg/L). Total chromium was not detected in deep-zone well MWA-28i(d) during the June 2003 sampling event, while chromium was detected in co-located shallow-zone well MWA-25 at a concentration of 9.79 mg/L.

5.3.2.2 *Perchlorate*

Groundwater samples were collected in June and July 2003 from twenty-four groundwater monitoring wells installed in the Acid Plant and Chlorate Plant Areas, including: 14 shallow-zone, seven intermediate-zone, and three deep-zone monitoring wells. The perchlorate data collected in July 2003 has not been validated. Groundwater sampling results for perchlorate are presented in Table 5-25 and is discussed the following subsections.

USEPA Method 314.0 was used for analysis of perchlorate in groundwater. This method uses ion chromatography with conductivity detection (IC/CD) and is prone to false positive detections, especially at low perchlorate reporting concentrations, due to interferences from high chloride, high TDS, sulfate, etc. It should be noted that high chloride and TDS concentrations have been observed in Chlorate Plant Area groundwater. Therefore, the perchlorate data presented herein is suspect.

5.3.2.2.1 *Shallow-Zone Groundwater*

Seventeen groundwater samples from 14 shallow-zone monitoring wells were collected in June and July 2003 for perchlorate analysis by USEPA Method 314.0. Two of the samples were duplicate samples.

Perchlorate was detected in 11 of the 17 samples at concentrations ranging from 0.32 mg/L (MWA-33, June 2003) to 290 mg/L (MWA-25, July 2003). The July 2003 analytical results have not been validated. All the detected concentrations were greater than the preliminary screening level of 0.2 mg/L. Monitoring well MWA-33 is located inside the Chlorate Cell Room and MWA-25 is located immediately downgradient of the Chlorate Plant Area. Additionally, perchlorate was detected at a concentration of 210 mg/L in monitoring well MWA-27, which is slightly further downgradient of the Chlorate Plant Area than MWA-25.

Shallow-zone perchlorate results for the June and July 2003 sampling events are provided on Figure 5-31. As shown on Figure 5-31, the highest concentrations of perchlorate were measured downgradient of the Chlorate Plant Area in the vicinity of the former salt pads. Perchlorate concentrations greater than the preliminary screening level were also measured in shallow groundwater located northeast of the Acid Plant Area.

5.3.2.2.2 *Intermediate-Zone Groundwater*

Seven groundwater samples from seven intermediate-zone monitoring wells were collected during the June and July 2003 groundwater sampling events, and were analyzed for perchlorate by USEPA Method 314.0. Perchlorate was detected in four of the seven samples at concentrations ranging from 0.26 mg/L (MWA-10i, June 2003) to 200 mg/L (MWA-32i, June 2003). Monitoring well MWA-32i is located downgradient of the Chlorate Plant Area, adjacent to the salt pads in the southeastern corner of the Site. All the detected concentrations were greater than the preliminary screening level of 0.2 mg/kg.

Intermediate-zone perchlorate results for the June and July 2003 sampling events are provided on Figure 5-32. Perchlorate concentrations in groundwater for cross sections A-A′, C-C′, and D-D′ are provided on Figures 5-33 through 5-35. As shown on Figures 5-32 through 5-35, the highest concentrations of perchlorate in intermediate-zone groundwater (> 200 mg/L) were measured downgradient of the Chlorate Plant Area in the vicinity of monitoring well MWA-32i. Elevated perchlorate concentrations in the intermediate zone were located further downgradient than observed in the shallow-zone groundwater and were observed to extend over a smaller area.

Perchlorate concentrations greater than the preliminary screening level were also measured in shallow groundwater located northeast of the Acid Plant Area.

5.3.2.2.3 *Deep-Zone Groundwater*

Three groundwater samples from three deep-zone monitoring wells (wells MWA-13d, MWA-28i(d), and MWA-31i(d)) were collected during the June and July 2003 groundwater sampling events, and analyzed for perchlorate by USEPA Method 314.0. Perchlorate was detected in one of the three wells, MWA-31i(d), at a concentration of 4.7 mg/L. Monitoring well MWA-31i(d) is located downgradient of the Chlorate Plant Area adjacent to the salt pads in the southeastern corner of the site. The measured concentration in MWA-31i(d) is above the preliminary screening level of 0.2 mg/L.

Perchlorate concentrations in groundwater for cross sections A-A′, C-C′, and D-D′ are provided on Figures 5-33 through 5-35. In June 2003, perchlorate concentrations measured in deep-zone well MWA-31i(d) (4.7 mg/L) were lower than in co-located wells MWA-32i (intermediate zone, 200 mg/L) and MWA-30 (shallow zone, 7.9 mg/L). Perchlorate was not detected in deep-zone well MWA-28i(d) during the July 2003 sampling event, while perchlorate was detected in co-located shallow-zone well MWA-25 at a concentration of 290 mg/L. The July 2003 data has not been validated.

5.3.2.3 *Chloride*

Groundwater samples were collected from the following direct-push borings and groundwater monitoring wells to evaluate the distribution of chloride in Site groundwater:

- Thirty-three groundwater monitoring wells installed in the Acid Plant and Chlorate Plant Areas and sampled between January 1999 and December 2003, including: 23 shallow-zone, nine intermediate-zone, and three deep-zone wells; and
- Two performance monitoring wells installed in the shallow groundwater zone in the Acid Plant Area (NMP-3D and NMP-4D) and sampled in June 2003.

Groundwater sampling locations are shown on Figures 3-9 and 3-12 and a summary of analytical results for conventional parameters and miscellaneous constituents, including chloride, is provided in Table 5-25.

5.3.2.3.1 *Shallow-Zone Groundwater*

One-hundred and one groundwater samples were collected from 23 shallow-zone monitoring wells for total chloride analysis by USEPA Method 300.0. Eight of the samples were duplicate samples. Total chloride concentrations in the shallow-zone samples ranged from 4 mg/L (MWA-3, April 1999) to 190,000 mg/L (MWA-30, April 2002, duplicate sample). Monitoring well MWA-30 is located in the southeastern portion of the Site, downgradient of the salt pads and adjacent to the Willamette River bank. Chloride concentrations of 164,000 mg/L were measured in the most recent sample collected at this location in June 2003. Sixty-seven of the 101 samples had chloride concentrations above the preliminary screening level of 230 mg/L.

Analytical results for chloride in shallow-zone groundwater for the June 2003 sampling event are shown on Figure 5-36. As shown on Figure 5-36, the highest chloride concentrations were observed in monitoring wells MWA-19, MWA-27, MWA-29, and MWA-30. All four of these wells are located adjacent to the salt pads in the southeastern corner of the Site.

Although the data indicate a general downward trend with time in some of the wells sampled (e.g., MWA-7, MWA-15/15r, and MWA-25), overall chloride concentrations appear to be relatively constant over the period sampled.

5.3.2.3.2 *Intermediate-Zone Groundwater*

Fifty-nine intermediate-zone groundwater samples were analyzed for total chloride by USEPA Method 300.0. Chloride was detected in all fifty-nine samples at concentrations ranging from 5.6 mg/L (MWA-12i, April 2002) to 31,000 mg/L (MWA-32i, June 2003). Monitoring well MWA-32i is co-located with shallow-zone well MWA-30 in the southeastern portion of the Site, between the salt pads and the Willamette River bank. Fifty-one of the 59 samples had chloride concentrations above the preliminary screening level of 230 mg/L.

Analytical results for chloride in intermediate-zone groundwater for the June 2003 sampling event are shown on Figure 5-37. As shown on Figure 5-37, the highest chloride concentrations were observed in monitoring well MWA-32i. However, concentrations greater than 1,000 mg/L were observed in all of the intermediate-zone monitoring wells completed adjacent to the riverbank, in both the Acid Plant and Chlorate Plant Areas.

In June 2003, chloride concentrations were higher in the intermediate-zone wells located in the Acid Plant than those measured in co-located shallow-zone wells. However, downgradient of the Chlorate Plant Area, measured chloride concentrations were higher in sampled shallow-zone wells than in co-located intermediate-zone wells.

5.3.2.3.3 Deep-Zone Groundwater

Thirteen samples from three deep-zone groundwater monitoring wells were collected and analyzed for total chloride by USEPA Method 300.0. Chloride was detected in all thirteen samples collected at concentrations ranging from 5.3 mg/L (MWA-28i(d), April 2002) to 61,000 mg/L (MWA-31i(d), June 2003). Monitoring well MWA-31i(d) is co-located with shallow-zone well MWA-30 and intermediate-zone well MWA-32i in the southeastern portion of the Site, between the salt pads and the Willamette River bank. Eleven of the 13 deep-zone samples had chloride concentrations above the preliminary screening level of 230 mg/L.

In June 2003, chloride concentrations were similar in deep-zone monitoring well MWA-13d, compared to nearby intermediate-zone well MWA-9i, located in the Acid Plant Area. Downgradient of the Chlorate Plant Area, concentrations were higher in deep-zone well MWA-31i(d) than measured in co-located intermediate zone well MWA-32i. However, concentrations were lower in deep zone wells MWA-31i(d) and MWA-28i(d) than in each of their corresponding shallow-zone wells.

5.3.2.4 Metals

Groundwater samples were collected from the following direct-push borings and shallow-zone groundwater monitoring wells located in the Chlorate Plant Area for metals analysis by USEPA Methods 6020 and/or 6010B:

- One RI soil boring completed in the shallow-groundwater zone within the Chlorate Plant in 2001 (B-68);
- Five shallow-zone groundwater monitoring wells installed in the Chlorate Plant Area and sampled between November 2001 and December 2003; and

- Four shallow-zone performance monitoring wells (MWA-35 through MWA-38) installed in the Chlorate Plant Area in 2003 as part of the Hexavalent Chromium Reduction Pilot Study.

Groundwater sampling locations are shown on Figure 3-12 and groundwater sampling results for metals are provided in Table 5-21. The discussion of metals in Chlorate Plant Area groundwater does not include the evaluation of total or hexavalent chromium. The evaluation of total and hexavalent chromium was discussed in Section 5.3.2.1.

Three samples from three shallow-zone monitoring wells were analyzed for total and/or dissolved antimony, arsenic, beryllium, cadmium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. The following were measured at concentrations greater than preliminary groundwater screening levels in one or more of these three samples:

- Arsenic – Low concentrations of arsenic were detected in all three samples. One of the three detections (0.228 mg/L, MWA-27, December 2003) was slightly above the conservative preliminary screening level of 0.15 mg/L for dissolved arsenic.
- Copper – Low concentrations of copper were detected in all three samples at concentrations greater than the conservative preliminary screening level of 0.0027 mg/L for dissolved copper. Note that this preliminary screening level is hardness dependent. The highest concentration of dissolved copper was measured in MWA-36 in December 2003 (0.0919 mg/L).
- Mercury – Low concentrations of mercury were detected in all three samples. One of the three detections (0.000922 mg/L, MWA-36, December 2003) was greater than the conservative preliminary screening level of 0.00077 mg/L for dissolved mercury.
- Nickel – Low concentrations of nickel were detected in all three samples. Two of the three detections were slightly above the conservative preliminary screening level of 0.016 mg/L for dissolved nickel. Note that this screening level is hardness dependent. The highest concentration of dissolved nickel was measured in MWA-27 in December 2003 (0.0248 mg/L).
- Selenium – Low concentrations of selenium were detected in two of the three samples. One of the detections was greater than the conservative preliminary screening level of 0.005 mg/L for total selenium (0.00539 mg/L, MWA-27, December 2003).

Thirteen samples from nine wells were analyzed for total and/or dissolved iron. One of the samples was a duplicate sample. Iron was detected in five of the 13 samples, and four of the samples contained iron concentrations greater than the conservative preliminary screening level of 1 mg/L for total iron. The highest concentration of total iron was measured in MWA-33 in June 2003 (9.99 mg/L). One direct-push grab sample was also analyzed for dissolved iron, but it was not detected above the method detection limit of 0.15 mg/kg. These thirteen samples were also analyzed for total and/or dissolved manganese. Total and dissolved manganese were detected in all samples. However, a preliminary screening level has not been established for total or dissolved manganese.

5.3.2.5 *Petroleum Hydrocarbons*

Groundwater grab samples were collected in June 2003 from two groundwater monitoring wells completed within the Chlorate Plant Area (MWA-30 and MWA-32i). Groundwater monitoring well locations are shown on Figure 3-12 and groundwater analytical results are presented in Table 5-22 and described in the following subsections.

5.3.2.5.1 *Shallow-Zone Groundwater*

One groundwater sample collected from monitoring well MWA-30 on 4 June 2003 was analyzed for diesel- and heavy oil-range petroleum hydrocarbons by Method NWTPH-Dx. Collection of this groundwater sample was prompted by the observation of a 3-inch thick layer of dark, oily sand with a hydrocarbon odor at a depth of 29 feet bgs in this boring. Diesel-range petroleum hydrocarbons were detected in this sample at a concentration of 0.642 mg/L. Heavy-oil range petroleum hydrocarbons were not detected in this sample.

5.3.2.5.2 *Intermediate-Zone Groundwater*

Two groundwater samples collected from monitoring well MWA-32i on 4 June 2003 were analyzed for diesel- and heavy oil-range petroleum hydrocarbons by USEPA Method NWTPH-Dx. One of the two samples was a duplicate sample. Diesel-range petroleum hydrocarbons were detected in both samples at concentrations of 0.342 and 0.32 mg/L. Heavy-oil range petroleum hydrocarbons were not detected in either sample.

5.4 SALT PADS

Sea salt (NaCl) was used as a raw material for products manufactured at the Site throughout the plant's operational history (1941 to 2001). The salt was stored on several asphalt-lined pads located in the southeastern corner of the Site adjacent to the Chlorate Plant Area (Figure 1-3). The salt was dissolved in water while on the pads to produce brine for plant manufacturing. During plant shut-down in 2001, all salt was removed from the site.

Chloride has been detected in all groundwater monitoring wells at the site and is the only COI associated with the Salt Pads. As discussed above in Section 5.3.2.3, the highest chloride concentrations were measured in shallow-, intermediate-, and deep-zone groundwater monitoring wells located in the southeastern portion of the Site, adjacent to the salt pads. Analytical results for chloride in shallow- and intermediate-zone groundwater for the June 2003 sampling event are shown on Figures 5-36 and 5-37. The analytical results for chloride are consistent with the conductivity measurements made during monitoring well groundwater sampling (Table 5-17).

5.5 OLD CAUSTIC TANK FARM

This section presents the analytical data collected during the investigation of soil and groundwater associated with the Old Caustic Tank Farm.

5.5.1 Soil Investigations

Twenty-six surface soil samples were collected from thirteen locations within the Old Caustic Tank Farm in 2003 and 2004 to evaluate the nature and extent of organochlorine pesticides, VOCs, metals, PAHs, and TPH. The investigation was conducted because the tanks were constructed on sand foundations and oil had historically been mixed with the sand to reduce external corrosion to the tank bases. Surface soil sampling results from the Old Caustic Tank Farm are described in the following subsections.

5.5.1.1 *Organochlorine Pesticides*

A total of twenty six surface soil samples associated with the Old Caustic Tank Farm Area were collected in January 2004 for organochlorine pesticide analysis by USEPA Method 8081A. Organochlorine pesticide results for Site surface soil samples are summarized in Table 5-4 and shown on Figures 5-1 and 5-1a with surface soil samples collected from within the Acid Plant Area.

DDT was detected in 22 of the 26 samples collected at concentrations ranging from 0.0109 mg/kg (OCTF-3, 0 to 0.5 feet bgs) to 13,300 mg/kg (OCTF-11, 0 to 0.5 feet bgs). Two of the twenty-six samples had concentrations greater than the preliminary screening level of 7 mg/kg (OCTF-2, 0.5 to 1 foot bgs and OCTF-11, 0 to 0.5 foot bgs). DDT was not detected in the sample collected from OCTF-11 from 0.5 to 1 foot bgs, but that sample had an elevated detection limit that was several orders of magnitude higher than the preliminary screening level.

DDD and/or DDE were detected in all 26 surface soil samples associated with the Old Caustic Tank Farm. Measured DDD and DDE concentrations were generally similar in magnitude to the measured DDT concentrations. DDD concentrations ranged between 0.01 mg/kg (OCTF-5, 0 to 0.5 feet bgs) and 360 mg/kg (OCTF-11, 0 to 0.5 feet bgs), with two of the samples containing concentrations greater than the preliminary screening level (10 mg/kg). DDE concentrations ranged between 0.0118 mg/kg (OCTF-5, 0 to 0.5 feet bgs) and 18,200 mg/kg (OCTF-11, 0 to 0.5 ft bgs) with four of the samples containing concentrations greater than the preliminary screening level (7 mg/kg).

5.5.1.2 *Volatile Organic Compounds*

A total of 18 surface soil samples were collected from four locations within the Old Caustic Tank Farm for VOC analysis by USEPA Method 8260B. VOC results for Site surface soil samples are summarized in Table 5-6 and shown on Figure 5-2.

Neither MCB nor chloroform were detected any of the surface soil samples collected from the Old Caustic Tank Farm Area. Only one VOC, 1,2,4-trimethylbenzene, was detected in one of the samples collected from location OCTF-3. The measured concentration of 1,2,4-trimethylbenzene

(0.125 J mg/kg) was well below the preliminary screening level of 170 mg/kg.

5.5.1.3 *Metals*

A total of six surface soil samples were collected from three locations within the Old Caustic Tank Farm for metals analysis by USEPA Method 6010B. Results were reported for cadmium, chromium, and lead. Metals results for Site surface soils are summarized in Table 5-7 and on Figure 5-3. All of the measured metals concentrations were below their respective preliminary screening levels.

Cadmium was not detected in any of the six samples collected. Chromium was detected in all six samples at concentrations ranging from 6.29 mg/kg (OCTF-9, 0 to 0.5 feet bgs) to 17.8 mg/kg (OCTF-3, 0 to 0.5 feet bgs). Lead was detected in all six samples at concentrations ranging from 2.32 mg/kg (OCTF-1, 0.5 to 1 foot bgs) to 8.75 mg/kg (OCTF-9, 0.5 to 1 foot bgs).

5.5.1.4 *Polycyclic Aromatic Hydrocarbons*

A total of six surface soil samples were collected from three locations within the Old Caustic Tank Farm Area for SVOC analysis by USEPA Method 8270SIM. PAH results for Site surface soil samples are summarized in Table 5-26.

Trace levels of acenaphthene, acenapthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, crysene, fluoranthene, fluorene, naphthalene, phenanthrene, and/or pyrene were detected in one or more of the Old Caustic Tank Farm surface soil samples. All reported concentrations were below the preliminary screening levels with the exception of benzo(a)pyrene.

Benzo(a)pyrene was detected in five of the six samples collected at concentrations ranging from 0.174 mg/kg (OCTF-9, 0 to 0.5 feet bgs) to 0.775 mg/kg (OCTF-1, 0 to 0.5 feet bgs). Four of the five detected concentrations were slightly above the preliminary screening level of 0.21 mg/kg.

5.5.1.5 *Total Petroleum Hydrocarbons*

A total of 18 surface soil samples were collected from nine locations within the Old Caustic Tank Farm Area for analysis for volatile-, diesel-, and heavy-oil range organics by methods NWTPH-VPH and NWTPH-Dx. Analytical results for TPH in surface soils within the OCTF are summarized in Table 5-27 and on Figure 5-38. All detected TPH concentrations were below preliminary screening levels.

Volatile-range organics were detected in four of the six samples analyzed at concentrations ranging from 5.27 mg/kg (OCTF-9, 0.5 to 1 foot bgs) to 219 mg/kg (OCTF 0.5 to 1 foot bgs). Diesel-range organics were detected in 14 of the 18 samples collected at concentrations ranging from 246 mg/kg (OCTF-6, 0.5 to 1 foot bgs) to 2,840 mg/kg (OCTF-1, 0 to 0.5 feet bgs). Heavy-oil range organics were detected in 17 of the 18 samples collected at concentrations ranging from 56 mg/kg (OCTF-8, 0.5 to 1 foot bgs) to 4,750 mg/kg (OCTF-1, 0 – 0.5 feet bgs). In general, concentrations of heavy-oil range organics were higher than the measured concentrations of diesel- or volatile-range organics in the Old Caustic Tank Farm surface soil samples.

5.5.2 *Groundwater Investigations*

Tanks within the OCTF were used to store sodium hydroxide (caustic) from 1946 to 1996 and releases of approximately 200-gallons of sodium hydroxide have been documented on two occasions (1993 and 1996). The tanks were removed during site demolition activities in the spring of 2002.

Table 5-17 and Figures 5-39 and 5-40 provide pH, DO, and specific conductance data measured in shallow- and intermediate-zone groundwater monitoring wells in June 2003. There are no wells completed directly within the Old Caustic Tank Farm Area. Elevated pH was observed in monitoring well MWA-24, during the June 2003 sampling event. MWA-24 is cross-gradient from the OCTF. No other wells exhibited elevated pH downgradient of the OCTF.

5.6 *AMMONIA PLANT*

Anhydrous ammonia was produced within the Ammonia Plant Area from the mid-1950's until approximately January 1990. The Ammonia

Manufacturing Plant was situated in the same area as the southern portion of the New Caustic Tank Farm shown on Figure 1-3. A portion of the ammonia was mixed with water to produce aqueous ammonia. A spill of approximately 400 gallons of 30-percent aqueous ammonia was reported in this area in July 1987. Based on the operational history of this area, ammonia was identified as a COI for this area.

Four groundwater grab samples from two direct-push borings were collected and analyzed for ammonia as nitrogen by USEPA Method 350.1. The four samples represent two primary samples and two duplicate samples. Ammonia as nitrogen was detected at concentrations of 1.22 and 1.28 mg/L for the primary and duplicate samples from boring B-67. Boring B-67 was advanced downgradient of the former Ammonia Plant location in May 2001. Ammonia as nitrogen was detected at slightly higher concentrations (2.0 mg/L) in the primary and duplicate samples from boring B-119, which was located upgradient of the former Ammonia Plant in June 2002. Both borings B-67 and B-119 were completed in the shallow-zone. Acid Plant Area boring locations are shown on Figure 3-3.

Six groundwater samples were collected from shallow- and intermediate-zone groundwater monitoring wells MWA-5 and MWA-14i during two sampling events conducted in June 2001 and April 2002. Two of the samples were duplicate samples. Wells MWA-5 and MWA-14i are co-located downgradient from the former Ammonia Plant and Acid Plant Areas (Figure 3-9). Ammonia as nitrogen was measured in the shallow-zone well, MWA-5, at concentrations ranging from 15 mg/L (June 2001) to 20 mg/L (duplicate sample, April 2002). Ammonia as nitrogen was measured in intermediate-zone well MWA-14i at concentrations ranging from 2.4 mg/L (duplicate sample, April 2002) to 2.9 (June 2001).

5.7 TRANSFORMER PAD CONCRETE SAMPLES

Electrical transformers were historically installed at various locations throughout the Site. In January 2004, concrete samples were collected from the former transformer pads to determine if PCBs were present in the concrete as a result of historical leakage and to identify appropriate handling and disposal methods. Analytical results from the former transformer pad concrete sampling program are summarized in Table 5-28 and sampling locations are shown on Figure 5-41.

PCBs were detected above laboratory reporting limits in two of the six composite samples collected. Aroclor® 1260 was detected in sample Pad B-Comp at 0.231 mg/kg and Aroclor® 1254 was detected in sample Comp D at a concentration of 0.203 mg/kg. Based on these results, the discreet samples associated with the two composite samples were released for analysis. Three of the eight discreet samples analyzed for PCBs had detected concentrations of Aroclor® 1254 (1T) and/or 1260 (13 OCB, 55 OCB, and 1T). No staining or other evidence of oil release was observed at any of the concrete pads sampled. There have been no reported releases from these locations.

Based on the analytical results summarized in Table 5-28, the former concrete transformer pads are not considered PCB-contaminated material, as defined in 40 Code of Federal Regulations (CFR), Part 761. Therefore, this material does not require management as a PCB-contaminated material under the Toxic Substance control Act.

5.8 BONNEVILLE POWER ADMINISTRATION MAIN SUBSTATION

This section presents the analytical data collected during the investigation of soils associated with the former Bonneville Power Administration Main Substation. Samples from the former substation were collected for PCB and TPH analysis as described in the following subsections.

5.8.1 Polychlorinated Biphenyls

Seventy-one soil samples were collected by BPA within the Pennwalt Substation during the Phase II ESA conducted in November 2001 (PBS 2002a). Sixty-four of the 71 samples were analyzed for PCBs by USEPA Method 8082. PCBs were detected in nine of the 64 samples at concentrations ranging from 0.166 mg/kg to 1.25 mg/kg (total of seven Aroclor® compounds). In addition to PCBs, the following constituents were detected in the Phase II ESA:

- TPH in seven samples at concentrations ranging from 141 to 8,550 mg/kg (combined total of diesel- and heavy oil-range hydrocarbons);
- Seven PAH compounds in one sample at concentrations ranging from 0.05 to 0.171 mg/kg;
- Lead in one sample at a concentration of 543 mg/kg; and

- DDT and DDE in one sample at concentrations of 0.056 and 0.009 mg/kg, respectively.

No VOCs (MCB, 1,1,1-trichloroethane, or BTEX) were detected in any of the soil samples collected (PBS 2002a). Results of the Phase II ESA are provided in the *Phase Two Environmental Site Assessment for Bonneville Power Administration; Pennwalt Substation* (PBS 2002a), included as Appendix E.

In March 2002, eight additional soil samples were collected by BPA inside and outside the substation (Samples PENN-1-6 through PENN-6-18). Two of the samples were collected within surface water drainage swales north and south of the substation (one sample from each swale). The eight sample locations are shown on Figure 5-42. None of the eight additional soil samples collected by BPA in March 2002 contained PCBs above the method detection limit of 0.05 mg/kg. Results of the March 2002 PCB analyses are provided in Table 5-29.

In June 2002, after BPA removed the existing electrical equipment, Arkema collected 37 soil samples from within the substation (BPA-1 through BPA-24 and "PD-" samples. PCBs were detected in 11 of the 37 samples at concentrations ranging from 0.13 mg/kg to 8.5 mg/kg (sample number BPA-20). Sampling locations and analytical results are shown on Figure 5-42. Based on these results, BPA conducted soil removal in the northwestern portion of the substation. Composite confirmation samples from the excavation sidewalls revealed PCBs concentrations ranging from 2.4 to 4.5 mg/kg (surface samples), 0.16 to 2.7 mg/kg (1.5 feet bgs), and 0.15 to 3.1 mg/kg (3 feet bgs). Results of the June 2002 PCB analyses are provided in Table 5-29.

In addition to the soil excavation and confirmation sampling, eight discrete soil samples were collected between the former substation and Front Avenue in October 2002. Concentrations of PCBs in these eight samples ranged from non-detect (<0.15 mg/kg) to 0.91 mg/kg (Figure 5-42). Results of the October 2002 PCB analyses are provided in Table 5-29.

5.8.2 *Total Petroleum Hydrocarbons*

The 37 surface soil samples collected by Arkema in June 2002 from the former BPA substation (BPA-1 through BPA-24 and "PD-" samples) were analyzed for diesel- and heavy-oil range organics by Method NWTPH-Dx. Analytical results for TPH in Site surface soils are summarized in Table 5-27 and sampling locations are shown on Figure 5-42. All detected TPH concentrations were below preliminary screening levels.

Diesel-range organics were detected in seven of the 37 samples at concentrations ranging from 32 mg/kg (PD41-BE) to 14,000 J mg/kg (PD72-SW). Heavy-oil range organics were detected in four of the 37 samples collected at concentrations ranging from 160 mg/kg (PD72-SE) to 3,300 J mg/kg (PD72-SW). In general, concentrations of diesel-range organics were higher than the measured concentrations of heavy-oil range organics in the samples collected. The highest TPH concentrations were measured in samples collected from the former concrete pad locations.

5.9 STORM WATER DRAIN SAMPLING

This section presents the analytical data collected from on-site storm water manholes and outfalls. Samples from two storm water manholes were collected in 1999 and 2001, and monthly outfall sampling was conducted in 2004 and 2005.

5.9.1 Storm Water Manholes

Twelve storm water samples from two manholes (SW-01 and SW-02 on Figure 1-6) were collected during four sampling events conducted in 1999 and 2001. Samples were analyzed for total and/or dissolved organochlorine pesticides by USEPA Method 8081A. Four of the 12 samples were duplicate samples. Analytical results for the storm water manhole samples are provided in Table 5-30.

Total DDT was detected in all 12 storm water samples at concentrations ranging from 0.28 J μg/L (SW-02, March 2001) to 47 J μg/L (SW-01 dup, December 1999). The DDT concentration measured in the primary sample from this location in December 1999 (10 J μg/L) was significantly lower. All the detected concentrations were greater than the preliminary screening level of 0.001 μg/L for total DDT and its metabolites. Sample SW-01 was collected from a manhole located adjacent to the former MPR trench within the Acid Plant Area and sample SW-02 was collected from a manhole located north and downgradient of the Acid Plant Area (Figure 1-6). With the exception of the duplicate samples collected in December

1999, DDT concentrations measured in 1999 from location SW-02 were higher than the concentrations measured at SW-01. DDT concentrations in the most recent set of samples collected in March 2001 indicated higher DDT concentrations at SW-01.

Dissolved DDT was detected in the primary and duplicate samples collected from SW-01 in November 1999 and March 2001. Dissolved DDT was also detected in SW-02 in January and November of 1999. The dissolved concentrations were typically one to two orders of magnitude less than the corresponding total DDT concentrations suggesting the presence of DDT particulate matter in the stormwater.

Total DDD was detected in 11 of the 12 storm water samples collected at concentrations ranging from 0.0820 J µg/L (SW-02, March 2001) to 2.7 µg/L (SW-02, January 1999). Total DDE was detected in all 12 of the storm-water samples collected at concentrations ranging from 0.0230 J µg/L (SW-02, March 2001) to 2.1 J µg/L (SW-01 dup, December 1999). All the measured concentrations of both DDD and DDE were greater than the preliminary screening level of 0.001 µg/L (total DDT and its metabolites). Measured total DDD and DDE concentrations were less than corresponding total DDT concentrations in the storm water samples. No dissolved DDD or DDE were detected in any of the samples. No other pesticides were detected in any of the twelve storm water samples collected.

5.9.2 *Storm Water Outfalls*

Monthly storm water samples were collected from Outfalls 001 through 004 from February 2004 through March 2005 and analyzed for select organochlorine pesticides, VOCs, SVOCs, PCBs, metals, perchlorate, chloride, and total dissolved solids (TDS). Analytical results for the storm water outfall samples are summarized in Table 5-31. Storm water outfall locations are shown on Figure 1-6. The following constituents were detected in one or more of the monthly samples:

- Total DDT was detected in all the storm water samples collected, except for one sample collected from Outfall 001 on May 2004. The detected concentrations ranged from 0.067 µg/L (Outfall 001, April 2004) to 1.3 D µg/L (Outfall 003, April 2004). All the detected concentrations were above the preliminary screening level of 0.001 µg/L for total DDT and its metabolites.

- Total DDD was detected in 23 of the 40 storm water samples collected at concentrations ranging from 0.0096 μg/L (Outfall 004, November 2004) to 0.082 μg/L (Outfalls 002 and 004, October 2004). All the detected concentrations were above the preliminary screening level of 0.001 μg/L for total DDT and its metabolites.

- Total DDE was detected in 33 of the 40 storm water samples collected at concentrations ranging from 0.018 μg/L (Outfall 001, September 2004) to 0.76 D μg/L (Outfall 001, December 2004). All the detected concentrations were above the preliminary screening level of 0.001 μg/L for total DDT and its metabolites.

- Total iron was detected in all the storm water samples collected at concentrations ranging from 0.466 mg/L (Outfall 003, February 2004) to 11.4 mg/L (Outfall 001, March 2004). Thirty-five of the 44 samples collected had concentrations above the conservative preliminary screening level of 1 mg/L for total iron.

- Total manganese was detected in all the storm water samples collected at concentrations ranging from 0.0093 mg/L (Outfall 003, February 2004) to 0.184 mg/L (Outfall 001, March 2004). No preliminary screening level is established for manganese.

- Mercury was detected in one storm water sample collected from Outfall 002 in March 2004 at a concentration of 0.3 μg/L. This concentration is below the preliminary screening level of 0.77 μg/L for dissolved mercury.

- Total hexavalent chromium was detected in 11 of the 40 storm water samples collected at concentrations ranging from 10.1 μg/L (Outfall 001, March 2005) to 26.4 μg/L (Outfall 004, December 2004). Eight of the samples contained concentrations above the preliminary screening level of 11 μg/L for dissolved hexavalent chromium.

- Perchlorate was detected in 36 of the 40 storm water samples collected at concentrations ranging from 0.002 mg/L (Outfall 003, September 2004) to 0.608 mg/L (Outfall 001, September 2004). Five of the samples contained concentrations above the preliminary screening level of 0.2 mg/L for perchlorate. All five of these samples were collected from Outfall 001.

- Chloride was detected in all 40 of the storm water samples collected at concentrations ranging from 0.7 mg/L (Outfall 002, January 2005) to 354 mg/L (Outfall 004, April 2004). Two of the 40 samples contained concentrations above the preliminary screening level of 230 mg/L for chloride.

- Measured TDS concentrations ranged from 29 mg/L (Outfall 002, January 2005) to 2,050 mg/L (Outfall 004, March 2004).

The analytical results summarized above and in Table 5-31 indicate low levels of DDT, DDD, DDE, and iron were present in samples collected from all four storm water outfalls at concentrations above the preliminary screening levels. Concentrations of hexavalent chromium, and chloride were generally higher in samples collected from Outfall 004, and perchlorate concentrations were generally higher in samples collected from Outfall 001. Phase III demolition activities were being carried out concurrently with the monthly monitoring. Several constituents (perchlorate, chloride, TDS, and hexavalent chromium) exhibited temporary increases during this time, and decreased after demolition activities were complete.

6.0 CONCEPTUAL SITE MODEL

This section discusses the conceptual model for the Site. The CSM for the Site has been developed using the information obtained during the RI, pre-RI work, a general knowledge of Site conditions, chemical fate, and transport behavior. In addition, Appendix A-2 of the Draft CSM Site Summary for the Portland Harbor prepared by the Lower Willamette Group summarizes the CSM for the Arkema facility. The CSM presented herein includes information obtained from that document. Appendix A-2 of the CSM Site Summary is included as Appendix L to this report.

6.1 CONSTITUENTS OF INTEREST

The primary COIs in upland soil that will be evaluated in the Baseline Risk Assessment consist of:

- DDT, DDD, and DDE;
- Chlorobenzene; and
- Hexavalent chromium.

It is noted that the work described herein did not characterize perchlorate in soil. Characterization of perchlorate in Site soil will be conducted as part of the risk assessment/FS process.

The primary COIs in upland groundwater that will be evaluated in the Baseline Risk Assessment consist of:

- DDT, DDD, and DDE;
- Chlorobenzene;
- Hexavalent Chromium;
- Perchlorate; and
- Chloride.

It is noted that chloride will not be carried through the risk assessment process, but will be carried through the Source Control Evaluation for the Site.

The complete list of COIs in Site soil and groundwater to be evaluated through the Source Control Evaluation (SCE) process and risk assessments is provided in Table 6-1. The constituents that exist in site media above Source Control Evaluation screening values will be further evaluated in the risk assessment.

6.2 SOURCE AREAS

COIs in environmental media at the Site are primarily associated with Site manufacturing process residue, including DDT and its metabolites DDD and DDE, MCB (or chlorobenzene), perchlorate, and hexavalent chromium. This section presents information describing how various activities and operations that took place on Lots 3 and 4 of the Arkema facility may have been sources of these chemicals to Site soil and groundwater. Source areas have been identified based on the relationship between likely source areas identified in the PA and the distribution of COIs in Site soils and groundwater as observed during the RI. The following areas are considered to be on-site source areas:

- Acid Plant Area;
- Chlorate Plant Area;
- Salt Pads;
- Old Caustic Tank Farm;
- Ammonia Plant;
- Concrete Transformer Pads;
- BPA Main Substation; and
- Storm Water Drain System.

Figures 6-1 and 6-2 present a comprehensive overview of the extent of the primary COIs in shallow and intermediate groundwater, respectively. The plumes have been drawn based on the preliminary screening levels for each primary COI.

6.2.1 Acid Plant Area

The following list of COI sources within the Acid Plant Area was summarized from the draft CSM Site Summary for the Arkema facility

(Appendix L, Integral 2005). Because the site has undergone extensive remediation and demolition to date, including interim remedial source control measures, many of these areas may no longer function as sources of COIs. Interim remedial source control measures are discussed in Section 7. The conceptual model for the Acid Plant Area is illustrated on Figure 6-3.

- **Former MPR Pond** – A shallow unlined pond was constructed in 1948 northeast of the manufacturing building to receive MPR (i.e., waste containing sulfuric acid, MCB and DDT) and was used until about 1954 when DDT manufacturing operations ceased. Significant portions of the former MPR pond soils were removed during a soil IRM in 2000. The Soil Removal IRM is discussed in more detail in Section 7.1.

- **Former MPR Trench** – In 1951 or 1952, an 8 foot wide by 285 foot long trench 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. Impacted soil was removed in portions of the Acid Plant Area to depths of up to 12 feet bgs. The Soil Removal IRM is discussed in more detail in Section 7.1.

- **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 northwestern 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 mixing with ammonium chloride to form a solid propellant for guided missiles. The production of sodium perchlorate and ammonium perchlorate ceased in 1962.

- **Former MCB Recovery Unit** – From 1950 until DDT manufacturing ceased completely in 1954, the MPR was piped to an MCB recovery system and then into the shallow MPR Pond. The wastes were conveyed through piping to the MCB recovery system, which was reportedly located immediately west of the former MPR Pond (Figure

1-4). The recovery system consisted of a steam stripper, in which chlorobenzene was removed from the waste and returned to the process. The entire system was located on a curbed concrete slab. Wastes from the system reportedly were drained periodically to the former MPR Pond. Releases from the process resulted in the presence of MCB and DDT in the shallow silt (approximately 6 to 8 feet bgs) in the MCB Recovery Unit area.

- **Riverbank Soil** – 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 feet since the 1950s (CH2M Hill 1997). Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 feet along the riverbank. DDT residuals have been detected in some portions of the fill and have been addressed as part of the ongoing IRMs for the upland portion of the Arkema Site.

6.2.1.1 *Acid Plant Area Soil*

DDT and chlorobenzene have been detected in soil at concentrations up to 31,000 mg/kg (boring MWA-11i, 6 to 8 feet bgs) and 66,600 mg/kg (boring CS-13, 8.5 feet bgs), respectively, in the Acid Plant Area. High concentrations of MCB and DDT are present in the shallow silt (6 to 8 feet bgs) in the MCB Recovery Unit Area and in deeper soils within the footprint of the former MPR Pond. The extent of DDT and MCB impacts in the Acid Plant Area soil are shown on Figures 5-1, 5-2, 5-4, 5-5, 5-7, and 5-8. A total of approximately 4,715 tons of DDT- and chlorobenzene-contaminated soil exhibiting some of the highest constituent concentrations were removed from the Acid Plant Area through implementation of a Soil Removal IRM. Additionally, other areas where DDT and chlorobenzene were observed were addressed by installation of temporary cover or asphalt paving during implementation of the Soil Removal IRM to prevent transport of constituents via storm water runoff and erosion of surface soils. The Soil Removal IRM is described in Section 7.1.

6.2.1.2 *Acid Plant Area Groundwater*

Dissolved groundwater plumes at the Site are relatively stable and well-documented. Figure 6-3 presents a conceptual interpretation of the current Site model of groundwater plumes originating from the upland portion of the Acid Plant Area and entering into river sediments.

The highest concentration of DDT in shallow-zone groundwater measured during the RI was observed at monitoring well NMP-4D at a concentration of 120,000 D µg/L (June 2001, not validated). The highest validated concentration of DDT in shallow-zone groundwater measured during the RI was observed at monitoring well MWA-15r at a concentration of 450 µg/L (March 2001). DDT was detected in intermediate-zone groundwater at concentrations up to 9 µg/L (MWA-9i, January 1999). DDD and DDE have been observed in Acid Plant Area groundwater at concentrations up to 6,400 PD µg/L (NMP-4D, June 2001, not validated) and 2,700 D ug/L (NMP-4D, June 2001, not validated). The June 2001 data from monitoring well NMP-4D was collected as part of the baseline sampling event of the Persulfate Oxidation Pilot Study and was not validated. Moreover, subsequent sampling from that well demonstrates an approximately three orders of magnitude decrease in DDT, DDD, and DDE concentration. Figures 5-15 and 5-16 show DDT, DDD, and DDE concentrations observed during the June 2003 sampling event in shallow- and intermediate-zone groundwater, respectively. DDT, DDD, and DDE concentrations are shown on cross sections A-A′ and B-B′ on Figures 5-17 and 5-18, respectively.

The highest concentrations of chlorobenzene in shallow- and intermediate-zone monitoring wells detected during the RI were observed in the Acid Plant Area at monitoring wells MWA-15r and MWA-9i at concentrations of 260,000 µg/L (March 2001) and 38,000 µg/L (January 1999), respectively. Figures 5-19 and 5-20 show the extent of chlorobenzene in shallow- and intermediate-zone groundwater, respectively, for the June 2003 sampling event. Chlorobenzene concentrations are shown on cross sections A-A′ and B-B′ on Figures 5-21 and 5-22, respectively.

In addition to DDT manufacturing operations, ammonium perchlorate operations were conducted in the former DDT process building from 1958 until 1962. The Acid Plant Area is considered a source area of perchlorate. Although perchlorate was detected in groundwater downgradient of the Acid Plant Area, significantly higher perchlorate concentrations have been observed in groundwater downgradient of the Chlorate Plant Area.

6.2.1.3 *DNAPL in the Acid Plant Area*

The remedial investigation identified residual chlorobenzene DNAPL in groundwater in the Acid Plant Area. DNAPL was primarily observed either on top of or within a 6-foot zone directly above the low-permeability silt horizon at the base of the shallow zone. The presence of DNAPL was determined using visual inspection of soil from soil borings, using Sudan IV dye, and in the case of the DNAPL investigation, using a CPT rig outfitted with a membrane interface probe. The three methods demonstrated consistent results that shallow-zone DNAPL is situated primarily in an area approximately 90 by 125 feet just downgradient of the former MPR Pond, with sporadic detections further downgradient adjacent to the river. These observations are consistent with the nature of residual DNAPL.

DNAPL was also detected at one intermediate-zone elevation in one boring (boring INT-5). Dissolved-phase chlorobenzene concentrations in the intermediate zone tend to decrease with increasing distance from the location of the observed DNAPL, which is consistent with the conceptual model of DNAPL distribution. Results of the DNAPL Investigations are shown on Figures 5-12, 5-13, and 5-14.

DNAPL exists at the Site in residual form as ganglia and is not readily mobile. Residual DNAPL is typically bound in place by capillary forces and is relatively unaffected by hydrodynamics. During the In Situ Sodium Persulfate Pilot Study, DNAPL was observed in one monitoring well (MWA-4D). Attempts were made to recover DNAPL from the well and only 6 ounces was recovered over a 90-day period. The difficulty in recovery of DNAPL is consistent with the nature of residual DNAPL and the conceptual model of DNAPL in the subsurface. The In Situ Sodium Persulfate Pilot Study is discussed in more detail in Section 7.3.1.

Nevertheless, DNAPL contributes to the continued presence of dissolved phase MCB in groundwater. Dissolved-phase MCB concentrations are consistent with the location, nature, and extent of observed DNAPL and the distribution of MCB DNAPL is consistent with the conceptual model in the Acid Plant Area.

MCB DNAPL has also been observed in the upper silts in the MCB Recovery Area at a depth of approximately 6 to 12 feet bgs, which is consistent with the elevated MCB concentrations in soil at those depths shown on Figure 5-8a. The source of the MCB DNAPL in this area is from historic operation of the MCB Recovery Unit. Borings conducted during implementation of the VES in the MCB Recovery area confirmed the RI findings. The DNAPL in this area is situated in a competent silt and is not readily mobile. The area in the vicinity of the former MCB Recovery Area is paved, limiting the potential for downward migration due to leaching from infiltration.

6.2.2 Chlorate Plant Area

The Chlorate Plant Area consists of the Chlorate Cell Room, Chlorate Process Building, Chlorate Warehouse, Chlorate Tank Farm, and other associated structures. The following list of the sources of COIs within the Chlorate Plant Area was summarized from the draft 10 October 2005 CSM Site Summary for the Arkema facility (Appendix L, Integral 2005). The conceptual model for the Chlorate Plant Area is illustrated on Figure 6-4.

- **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 No. 2. Sodium bichromate was used as a corrosion inhibitor in the manufacturing process and is the source of hexavalent chromium in soil and groundwater in the Chlorate Plant Area.
- **Sodium Perchlorate Manufacturing** – The production of sodium perchlorate in the Chlorate Cell Room is the source of the main perchlorate plume.

6.2.2.1 Chlorate Plant Area Soil

Total chromium has been detected in soil in the Chlorate Plant Area at concentrations up to 1,600 mg/kg (boring B-88, 10 to 12 feet bgs). Hexavalent chromium has been detected in soil at concentrations up to 69 mg/kg (boring B-77, 8 to 10 feet bgs). As shown on Figures 5-24 and 5-25, the distribution of total and hexavalent chromium concentrations in soil greater than the preliminary screening level of 450 mg/kg is limited to the area within the footprint of the Chlorate Cell Room and Chlorate Process Building at depths between 8 and 20 feet bgs.

6.2.2.2 *Chlorate Plant Area Groundwater*

In the Chlorate Plant Area, two separate groundwater plumes of hexavalent chromium and perchlorate have been identified. Total chromium has been detected in groundwater in the Chlorate Plant Area in shallow- and intermediate-zone groundwater monitoring wells at concentrations up to 21 and 0.992 mg/L, respectively (monitoring wells MWA-27 and MWA-16i). Hexavalent chromium has been detected in shallow-zone groundwater at concentrations up to 14.9 mg/L (monitoring well MWA-36, December 2003). Hexavalent chromium was not detected in the one sample collected from the intermediate groundwater zone. Figures 5-26 and 5-27 show total chromium concentrations in shallow- and intermediate-zone groundwater, respectively. Cross sections through the Chlorate Plant Area showing chromium concentrations in groundwater are presented on Figures 5-28 and 5-29. Perchlorate was detected in groundwater downgradient of the Chlorate Plant Area at concentrations up to 290 and 200 mg/L in shallow- and intermediate-zone groundwater wells, respectively (MWA-25 and MWA-32i). Both plumes extend from the former Chlorate Cell Room building east toward the river. The plumes overlap and the upland portion of the plumes are nearly identical in their nature and extent.

6.2.3 *Salt Pads*

On the eastern edge of the former Salt Pads, chloride is found in high concentrations in groundwater. This area is immediately downgradient of the former Salt Pads, where salt was historically stockpiled and where salt brine was produced for use in the chlor-alkali manufacturing process that occurred from 1941 to 2001. Elevated chloride concentrations are found in groundwater beneath the eastern edge of the salt pads and extending in groundwater beneath sediments in the Salt Dock area. The highest groundwater chloride concentrations are in monitoring well MWA-30 in the upland portion of the Site (up to 190,000 mg/L, April 2002). Since manufacturing operations ceased in 2001, the source of chloride in the Salt Pad area no longer exists.

Smaller secondary sources of chloride may have existed during plant operation due to the ubiquitous use of brine as a raw material in many plant processes. Releases from piping, tanks, and other conveyance equipment are likely to have occurred. Because the plant has been decommissioned, these secondary sources no longer exist. Additionally, dechlorination of chlorinated compounds (i.e., DDT and chlorobenzene) may also be a secondary source of chloride in portions of Site groundwater (e.g., in the Acid Plant Area).

6.2.4 *Old Caustic Tank Farm*

Historic releases of sodium hydroxide from the OCTF have resulted in elevated pH levels in groundwater in the vicinity of the OCTF, as evidenced by the pH in MWA-24 (12.6, June 2003). Since the OCTF was abandoned in 1996, there is no continuing source of sodium hydroxide.

6.2.5 *Ammonia Plant*

Ammonia has been detected in groundwater samples collected from both direct-push borings and monitoring wells. Concentrations up to 20 mg/L were detected during the investigation (well MWA-5, April 2002). Groundwater samples collected from direct-push borings upgradient and downgradient of the former Ammonia Plant contained ammonia at concentrations of 2 mg/L (boring B-119, June 2002, upgradient) and 1.22 mg/L (boring B-67, May 2001, downgradient). Data presented in a report prepared for the Rhone-Poulenc property indicate that ammonia is present in groundwater at concentrations up to 34.5 mg/L in monitoring well cluster W-04, situated across Front Avenue from the Arkema property, upgradient of the former Ammonia Plant and monitoring well MWA-5. Based on this data, the former ammonia plant is not a source of ammonia in Site groundwater.

6.2.6 *Concrete Transformer Pads*

During the investigation of the former transformer pads, the highest PCB concentration detected in the concrete pads was 2.165 mg/kg. According to 40 Code of Federal Regulations (CFR) Part 761, a “PCB-contaminated” material is a non-liquid with PCB concentrations greater than 50 mg/kg. Based on the sampling results, the concrete pads are not considered to be a source of PCB contamination at the Site and should not be carried forward in the risk assessment. Transformer pads with detectable PCBs were removed during plant demolition and disposed off-site.

6.2.7 BPA Main Substation

Investigation results indicated that PCBs exist in soils at concentrations up to 4.5 mg/kg (Aroclor® 1016) within the former substation and up to 0.91 mg/kg (Aroclor® 1254) in soil in the area between the former substation and Front Avenue. Based on these results, the BPA Main Substation may be a source of PCBs in soil.

6.2.8 Storm Water

Storm water was sampled for the RI during four separate sampling events from 1999 to 2001. Storm water samples were collected in the Acid Plant Area from a storm drain system, prior to mixing with non-contact cooling water. Total DDT and its metabolites were detected at low concentrations, suggesting that some pesticide-containing material was present in the storm water that discharges into the Willamette River. However, significant reductions of these constituents in storm water were observed after the Phase I Soil Removal IRM was completed.

Comprehensive storm water monitoring was conducted monthly in 2004-2005 as a requirement for the renewal of an NPDES permit for the facility. Storm water 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. DDT and metabolites, hexavalent chromium, and perchlorate were detected in storm water samples. DDT and DDE were consistently detected in every outfall, hexavalent chromium was primarily detected in Outfall 004, and the highest perchlorate concentrations were detected in Outfall 001. A trend in the concentrations of hexavalent chromium and perchlorate in Outfalls 004 and 001, respectively, suggest that the presence of these constituents may have been related to demolition activities. The storm water conveyance system is a likely contaminant migration pathway and will be evaluated during the risk assessment. Arkema is planning an additional assessment of the storm drainage systems to support possible IRMs.

6.3 CHEMICAL PROPERTIES AND PERSISTENCE OF CONSTITUENTS OF INTEREST

An understanding of the chemical properties of the COIs is helpful for understanding the relationship between the source area distribution and the potential transport mechanisms for COIs in the environment. Chemical properties of the primary COIs are summarized in Table 6-2.

6.3.1 *DDT, DDD, and DDE*

DDT and its metabolites are organochlorine pesticides that are solid at ambient temperatures and have low aqueous solubilities and low volatilities. In aqueous solutions, DDT readily partitions to the solid or organic carbon phases in the matrix. DDT is, consequently, persistent in soils and generally found in groundwater at concentrations less than 1 μg/L, when present. However, DDT is highly soluble in some organic liquids and has a reported solubility in chlorobenzene of 740,000 mg/L (Sconce 1962). The mobilization of a water-insoluble chemical like DDT in a soluble and mobile chemical such as chlorobenzene is termed cosolvency. Cosolvency is the likely reason for the observed DDT concentrations in groundwater at the Site. DDT can be biologically degraded both aerobically and anaerobically, although extensive dechlorination of DDT is usually observed under anaerobic conditions.

6.3.2 *Chlorobenzene*

Chlorobenzene is a volatile organic liquid at ambient temperatures. It has a moderately high aqueous solubility and is highly volatile. Chlorobenzene does not readily partition to soil particles or solid organic carbon phases and is, therefore, mobile in aqueous solutions. Liquid chlorobenzene has a higher density (specific gravity of 1.106) and a lower viscosity than water (absolute viscosity of 0.80 centipoise). Therefore, non-aqueous phase liquid chlorobenzene migrates relatively easily downward through groundwater. Chlorobenzene degradation occurs by an aerobic pathway. The rate of degradation is highly dependent of the acclimatization of degrading microorganisms.

6.3.3 *Hexavalent Chromium*

Hexavalent chromium (Cr[VI]) usually exists as a highly stable anion (i.e., dichromate [$Cr_2O_7^{2-}$] or chromate [CrO_4^{2-}]). Another common form of chromium is trivalent chromium (Cr[III]). Trivalent chromium exists as a cation and is generally insoluble at a pH above 5-6. Trivalent chromium typically will precipitate as a chromic hydroxide, $Cr(OH)_3$, in an alkaline environment. Hexavalent chromium is more soluble and toxic than trivalent chromium. Typically, the most effective remediation or control strategy for hexavalent chromium is to reduce it to trivalent chromium using a reducing agent.

6.3.4 *Perchlorate*

Perchlorates are chemical compounds that contain the monovalent ClO_4^- radical (perchlorate anion). Perchlorate is generated by the dissolution of ammonium, potassium, magnesium, or sodium salts. Ammonium perchlorate (NH_4ClO_4) was produced at the Site using sodium perchlorate ($NaClO_4$). Perchlorates are crystalline solids at room temperature. Behavior of the perchlorate anion is controlled by its basic chemical properties. As an oxidant, the reduction of the chlorine atom occurs slowly. Perchlorate is very soluble in water and does not interact with the soil matrix in the aquifer. In addition, the half-life of perchlorate in the environment seems to be very long. Therefore, perchlorate travels at close to the speed of the groundwater. Bioremediation appears to be an effective treatment technology for reducing perchlorate mass and concentration in groundwater.

6.4 *POTENTIAL TRANSPORT PATHWAYS*

Various potential transport pathways have influenced the movement of COIs from source areas to where they are presently found in soil and groundwater. Potential pathways include:

- Infiltration;
- Groundwater migration via advection and hydrodynamic dispersion;
- DNAPL migration;
- Surface water discharge (overland flow);
- Storm water discharge (pipeline); and
- Air transport (vapors, particulates, dust).

Infiltration, groundwater migration, and DNAPL migration have all been observed and/or inferred at the Site and are integrated into the conceptual site model, as indicated on Figure 6-5. Discharge to the river via the storm water conveyance system is also inferred from the storm water sampling data and included in the conceptual site model (Figure 6-5. Overland stormwater flow and contaminant transport via air are potential migration pathways, but they have not been confirmed via sampling.

An evaluation was conducted to determine whether the storm drain system acts as a conduit for constituents in groundwater. Storm drain system manhole elevations were compared to groundwater elevations in monitoring wells nearest to the manholes. Invert elevations at 11 manholes in the Acid Plant and Chlorate Plant Areas were compared to minimum and maximum groundwater depths observed over the duration of the RI. Table 6-3 presents the results of the comparison. Based on the comparison, it has been determined that storm drain system invert elevations are uniformly above groundwater in both the Acid Plant and Chlorate Plant Areas. Therefore, the storm drain system is not a potential secondary transport pathway for COIs in groundwater.

6.5 PRELIMINARY EXPOSURE MODEL

The following have been identified as potential receptors of Site COIs:

- Site workers;
- Site construction workers;
- Site trench/excavation/utility workers;
- Trespassers;
- Willamette River human receptors (recreation); and
- Willamette River ecological receptors.

A preliminary conceptual model has been prepared for the risk assessments and is shown on Figure 6-5. The human health and ecological risk assessments for the Site will further discuss potential receptors.

7.0 SUMMARY OF INTERIM REMEDIAL ACTIONS

Concurrent with implementation of the RI, several IRMs and pilot studies were conducted at the Site. These IRMs and pilot studies consisted of the following:

- Performance of a two-phase Soil Removal IRM;
- Installation and operation of a soil VES; and
- Performance of three remediation pilot studies and a bench-scale remediation study.

A summary of the IRMs and pilot studies is provided in Table 7-1. The pilot and bench-scale studies are described here for completeness in understanding environmental work performed at the facility. The scope, implementation, results, and conclusions of these studies will be discussed in detail in the FS prepared for the Site. The following sections describe these interim remedial activities.

7.1 SOIL REMOVAL INTERIM REMEDIAL MEASURE

During the implementation of RI field activities, evidence of DDT- and chlorobenzene-contaminated soil was observed in the Acid Plant Area. Soils containing elevated concentrations of DDT and chlorobenzene were observed within the former MPR Pond and trench (identified as Area A), in an unpaved area approximately 150 feet west of the MPR Pond and trench (in the vicinity of soil boring B-49; Area B), in the unpaved area immediately north of the Acid Plant Area (Area C), and in the area north of the former MCB Recovery Unit Area and south of Warehouse No. 2 (Area D). Figure 7-1 shows the approximate extent of these areas. Elevated DDT and chlorobenzene concentrations were primarily identified from near ground surface to approximately 8 feet bgs. DDT and chlorobenzene were observed up to 22 feet bgs in the immediate vicinity of the former Acid Plant Area (boring B-61). Figures 5-1, 5-2, 5-4, 5-5, 5-7, and 5-8 show the residual DDT, DDD, DDE and MCB concentrations in the soil outside of the IRM soil removal areas. Figure 5-6 shows the soil removal areas and residual pesticide concentrations in the soil on a cross section through the Acid Plant Area.

In response to these elevated DDT and chlorobenzene concentrations, Arkema implemented a two-phased IRM to mitigate potential environmental impacts. The purpose of the IRM was to:

- Remove DDT-contaminated soil in Areas A, B, C, and D to the extent technically practical;
- Construct Site drainage improvements to ensure proper drainage and reduce ponding of surface water; and
- Construct limited paving and a temporary surface cover to minimize contamination resulting from storm water runoff and erosion of surface soils.

The IRM targeted DDT concentrations greater than 1,200 mg/kg. The DDT comparison value of 1,200 mg/kg was derived from the USEPA Region IX preliminary remediation goal (PRG) for DDT using a 1-in-10,000 cancer risk. This value, while equivalent to the ODEQ's default "hot spot" criteria for DDT, was used only as a screening value to identify which surface or near-surface soil might need to be addressed by the IRM.

IRM activities were carried out in two phases. Excavation and construction activities were carried out in accordance with the *Interim Remedial Measures Work Plan* (Exponent 2000), approved by ODEQ on 20 September 2000, and the *Phase II Soil Interim Remedial Measure Workplan* (ERM 2001a), approved by ODEQ in a letter dated 18 October 2001.

The Phase I Soil Removal IRM was performed between September and November 2000, and focused on the former MPR Pond and trench areas (Area A, Figure 7-1) and the areas surrounding borings B-49 and SB-05 (Areas B and C, Figure 7-1). The scope of the Phase I IRM included:

- Excavation and off-site disposal of DDT-contaminated soil;
- Grading, paving, and storm water conveyance improvements; and
- Construction of a temporary surface cover system over certain areas to minimize potential contamination from storm water runoff.

Excavations were conducted to depths of approximately 12, 2.5, and 1 foot in Areas A, B, and C, respectively. A total of approximately 3,800 tons of soil was excavated and removed as part of the Phase I soil IRM. Additionally, a temporary surface cover was constructed in the unpaved area east of the Acid Plant Area, where unpaved soil samples had been collected. The temporary surface cover consisted of a layer of visqueen plastic between two layers of geotextile, buried beneath approximately 2 inches of ¾-inch-minus gravel. Further details regarding the Phase I soil IRM activities are presented in the *Interim Remedial Measures Implementation Report*, dated 26 February 2001 (ERM 2001d).

The Phase II Soil Removal IRM was carried out between 5 and 16 November 2001, and focused on the area north of the former Acid Plant Area and south of Warehouse No. 2 (Area D, Figure 7-1), where sampling had revealed elevated DDT concentrations in soil. The scope of the Phase II soil IRM included:

- Excavation of soil up to 1 foot bgs over the entire Area D and to 7 feet bgs in the vicinity of soil boring B-61;
- Paving in the former Acid Plant Area and Area D to minimize the potential for contamination from storm water runoff; and
- Installation of a storm drain and associated piping west of the former Acid Plant Control House to collect storm water runoff.

A total of 915 tons of contaminated soil was removed from Area D as part of the Phase II soil IRM. A detailed description of the Phase II soil IRM activities is presented in the *Phase II Soil Interim Remedial Measure Final Report*, dated February 2002 (ERM 2002f).

The Phase I and II IRMs were effective in removing significant quantities of soil containing DDT and chlorobenzene and reduced the potential for transport of constituents in shallow soils.

7.2 MCB RECOVERY UNIT AREA SOIL VAPOR EXTRACTION SYSTEM

The Phase I and II soil IRMs were conducted to remove DDT-contaminated soils in and around the Acid Plant Area. However, no soil removal was conducted in the former MCB Recovery Unit Area due to high concentrations of chlorobenzene in shallow soil. A soil VES was installed in December 2000 to extract chlorobenzene mass from subsurface soils, thereby reducing chlorobenzene concentrations to allow disposal of the soil as a non-hazardous waste following future excavation activities. The preliminary remedial goal for chlorobenzene was 2,000 mg/kg (20 times hazardous waste toxicity characteristic of 100 mg/L). The system was expanded periodically over the 2-1/2 years of operation and ultimately included five horizontal extraction wells. The horizontal wells were situated approximately 6 feet bgs. The system was installed, operated, and monitored in accordance with the *Workplan for Full-Scale Vapor Extraction System* (ERM 2000) and subsequent work plan addenda approved by ODEQ. The locations of VES extraction wells are shown on Figure 3-5.

Detailed descriptions of the VES installation, operation, and monitoring, including analytical summary tables and laboratory analytical reports are presented in monthly progress reports and the *Confirmation Soil Sampling Summary Report*, dated 26 August 2003 (ERM 2003e).

Over the duration of VES operation, eight hand-auger borings, 24 direct-push vapor monitoring points, and 15 confirmation soil borings were advanced and sampled to characterize the soil conditions in the former MCB Recovery Unit Area and to monitor effectiveness of the VES. Analytical results for soil samples collected from these borings are presented in Table 5-9 and Figure 5-8a and discussed in Section 5.2.1.3.2.

Confirmation sampling results revealed chlorobenzene concentrations in soil greater than had been previously observed in the former MCB Recovery Unit Area (Table 5-9, Figure 5-8a). Generally, samples with higher chlorobenzene concentrations than those previously observed were located around the VES extraction wells. Additionally, NAPL chlorobenzene was observed at one of the confirmation borings. The VES was not designed to address DNAPL in the vadose zone silt and consequently, the system was shut down.

7.3 PILOT STUDIES

Three pilot studies and one bench-scale study were conducted at the Site to evaluate potential source control measures to address:

- Elevated chlorobenzene concentrations in groundwater in the Acid Plant Area;
- DNAPL in the Acid Plant Area;
- Chromium in the Chlorate Plant Area groundwater; and
- Perchlorate in the Chlorate Plant Area groundwater.

Each of these pilot and bench studies is described in the following subsections.

7.3.1 *In Situ Sodium Persulfate Pilot Study*

A pilot study was conducted to investigate the effectiveness of sodium persulfate as a chemical oxidant for the remediation of dissolved-phase MCB. The pilot study was designed based on the results of a successful bench-scale demonstration and was conducted in accordance with the *Final MCB Oxidation Pilot Study Work Plan* (ERM 2001e). Groundwater samples collected within the pilot study area had concentrations of MCB ranging from 25,000 to 270,000 μg/L (MCB aqueous solubility is 470,000 μg/L at 20 degrees Celsius), indicating that MCB DNAPL may be present. Beads of DNAPL were observed during the pilot study in one pilot study monitoring well (NMP-4D). Attempts were made to recover DNAPL from the well over a 90 day period. Only six ounces of DNAPL was removed during the first attempt. After the first removal attempt, no additional DNAPL was ever detected in the well. Because the pilot study was not designed to address the presence of DNAPL, the study was suspended while the extent of the residual DNAPL was evaluated (i.e., the two-phase DNAPL investigation described in Sections 3.2.3 and 5.2.2). Although the pilot study was not completed, early results indicated that sodium persulfate was an effective oxidant for remediation of MCB at lower initial dissolved-phase MCB concentrations (e.g., 10 to 25 mg/L). In addition, significant reduction in DDT, DDD, and DDE concentrations was observed during the initial monitoring with no observed rebound, indicating that sodium persulfate was also effective for remediating these pesticides.

Based on the success of the bench-scale demonstration and the results of the pilot study, sodium persulfate injections were determined to be an effective remedial technology for addressing MCB, DDT, and its metabolites in groundwater at lower dissolved concentrations, but not for cost-effective treatment of significant quantities of DNAPL. Therefore, a second pilot study was proposed to evaluate the remediation of DNAPL. The DNAPL remediation pilot study is described in Section 7.3.2.

A work plan for a full scale IRM to use sodium persulfate to treat MCB and DDT (and its metabolites) in groundwater (the *In Situ Persulfate Oxidation Interim Remedial Measure Work Plan*, ERM 2005b) was approved by ODEQ on 13 July 2005. Implementation of the work plan activities began in July 2005.

7.3.2 DNAPL Remediation Pilot Study

A pilot study was conducted to evaluate the effectiveness of air sparging to reduce the MCB DNAPL mass in the Acid Plant Area to levels that could be cost-effectively treated using sodium persulfate. The pilot study consisted of installing a pilot-scale air sparging/SVE system within the area where significant mass of residual MCB DNAPL was present along the edge of the former MPR Pond. The system consisted of two air sparging wells screened at the bottom of the shallow zone and two SVE wells installed in the vadose zone. The system was designed to evaluate the feasibility of extending the air sparging/SVE technology throughout the area of DNAPL-impacted groundwater in the vicinity of the MPR Pond.

The pilot study demonstrated that air sparging can effectively treat dissolved and free-phase MCB through volatilization as well as biodegradation. Significant mass reduction was observed across the pilot study area, including reductions observed after operation of the air sparging component of the study had been shutdown. The scope, methodology, and results of the DNAPL pilot study are discussed in the *Dense Non-Aqueous Phase Liquid Remediation Pilot Study Completion Report* (ERM 2004c).

A work plan to implement air sparging and SVE as a full-scale IRM for remediation of MCB DNAPL in the Acid Plant Area (the *Air Sparging/Soil Vapor Extraction Interim Remedial Measure Work Plan*, ERM 2004d) was approved by ODEQ on 1 September 2004. Implementation of the full-scale IRM began in December 2004.

7.3.3 Hexavalent Chromium Reduction Pilot Study

The hexavalent chromium reduction pilot study was conducted to:

- Evaluate the effectiveness of in situ chemical reduction by calcium polysulfide (CAS) injections;
- Develop recommendations for future groundwater remediation for the Chlorate Plant Area; and

- Reduce shallow groundwater concentrations of hexavalent chromium present near the former Chlorate Cell Room.

The pilot study consisted of injecting a 10-percent (by weight) CAS solution into five injection wells oriented perpendicular to the groundwater flow direction. Strategically located existing and newly installed monitoring wells were sampled during the pilot study to evaluate performance of the technology.

Results of the pilot study indicated that CAS injected in Site groundwater is capable of significantly reducing concentrations of dissolved hexavalent chromium. Decreases in concentrations of hexavalent chromium were observed through the 15-week duration of the performance monitoring period following injection. At that point, decreases in hexavalent chromium concentrations observed at the three wells (MWA-25, MWA-36, and MWA-37), located immediately downgradient of the injection wells, ranged from 91 to nearly 100 percent. Concentrations had decreased by 74 percent at well MWA-35, located cross-gradient from the injection locations. Priority pollutant metals were also sampled to evaluate potential adverse effects of injected CAS. Metals results showed that the injections did not result in adverse impacts to groundwater. The pilot study scope, methodology, and results are discussed in the *Hexavalent Chromium Reduction Pilot Study Completion Report* (ERM 2004e)

Based on the success of the pilot study, ODEQ approved a work plan for implementation of a CAS injection program as a full-scale IRM (the *Hexavalent Chromium Reduction Interim Remedial Measure Work Plan*, ERM 2005c) on 10 May 2005 for remediation of groundwater impacted by hexavalent chromium in the Chlorate Plant Area. Implementation of this full-scale IRM began in June 2005.

7.3.4 *Perchlorate Remediation Bench Study*

In addition to the pilot studies carried out at the facility, a bench-scale study has been initiated to evaluate the effectiveness of in-site anaerobic bioremediation to treat perchlorate in groundwater at the Site (*Scope of Work for Bench-Scale Testing of In-Situ Bioremediation to Treat Perchlorate in Groundwater at the Arkema, Inc. Facility in Portland, Oregon*, [ATOFINA Chemicals 2003b]). The bench-scale study was initiated in December 2003 and was ongoing as of November 2005.

8.0 LAND AND BENEFICIAL WATER USE

This section describes the current and reasonably anticipated land uses, and current and reasonably likely future beneficial uses of groundwater in the locality of facility (LOF). The results will support efforts to identify and evaluate exposure pathways, assess risks, and select a preferred remedial alternative.

8.1 LOCALITY OF FACILITY

According to OAR 340-122-115(35):

> "'Locality of the facility' means any point where a human or an ecological receptor contacts, or is reasonably likely to come into contact with, facility-related hazardous substances, considering:
>
> (a) The chemical and physical characteristics of the hazardous substances;
>
> (b) Physical, meteorological, hydrogeological, and ecological characteristics that govern the tendency for hazardous substances to migrate through environmental media or to move and accumulate through food webs;
>
> (c) Any human activities and biological processes that govern the tendency for hazardous substances to move into and through environmental media or to move and accumulate through food webs; and
>
> (d) The time required for contaminant migration to occur based on the factors described in (a) through (c)."

For the purposes of the upland investigation and this report, the LOF is assumed to be the Arkema facility and the riverbank to the mean high Willamette River water level. Groundwater impacts may not be confined to the Arkema Site along the southern portion of the facility (i.e., along the property boundary between the Site and the adjacent Certainteed Roofing Products site). Refinement of the LOF will be carried out during implementation of IRMs and during the FS.

8.2 CURRENT AND FUTURE LAND USE

This section describes the current and reasonably anticipated future land use in the LOF in accordance with OAR 340-122-0080(3)(e) and *Consideration of Land Use in Environmental Remedial Actions* (ODEQ 1998c). According to this guidance, in selecting a remedial action, the following must be taken into account:

- Current land uses;
- Zoning, comprehensive plan, or other land use designations;
- Land use regulations from any governmental body having jurisdiction;
- Concerns of the facility owner, the neighboring owners, and the community; and
- Other relevant factors.

The current and reasonably likely future land use in the locality of facility is well defined. The Site is located in the heart of the Guild's Lake Industrial Sanctuary, zoned and designated "IH" for heavy industrial use. On 14 December 2001, the Portland City Council voted to adopt the GLISP (City of Portland 2001). The plan is intended to preserve industrial land in the area generally bounded by Vaughn Street on the south, the St. Johns Bridge on the north, Highway 30 on the west, and the Willamette River on the east. The plan became effective on 21 December 2001.

The purpose of the GLISP is to maintain and protect this area as a dedicated place for heavy and general industrial uses. The plan's vision statement, policies, and objectives were adopted as part of Portland's Comprehensive Plan and are implemented through amendments to the City's Zoning Code. As a result of the GLISP, future land use in the LOF will be industrial.

8.3 BENEFICIAL WATER USE

Information regarding use of water potentially affected by former manufacturing operations had been collected as part of the Phase 2 Site Characterization (CH2M Hill 1997, Appendix G) and a beneficial water use survey conducted for a nearby facility (Woodward-Clyde 1997). Potential beneficial uses of nearby surface water (the Willamette River) include industrial use, recreational use, and ecological habitat in the LOF.

No drinking water wells are located on or near the LOF. Groundwater is not currently used nor is it reasonably likely to be used in the future as a drinking water source. A survey of wells within a 1-mile radius of the Site was conducted by CH2M Hill (CH2M Hill 1997). The 1997 CH2M Hill survey identified wells within the search radius of the Site, but concluded that there were no water supply wells identified downgradient of the Site. An updated inventory of wells situated within a 1-mile radius of the facility was conducted for the RI (Appendix M). Nine new wells classified as water supply wells were identified within the 1-mile search radius. Of those nine wells, seven were wells installed at the Arkema facility as monitoring wells (i.e., they were previously incorrectly classified in the Oregon Water Resources Department database). The two remaining wells consisted of one well (well log number 71437) determined to be a monitoring well situated on Port of Portland property across the Willamette River and one well (well log number 56735) installed for cathodic protection purposes. No new water supply wells were identified within the search radius.

Because of the proximity of the Site to the Willamette River, future industrial water needs (e.g., non-contact cooling water) are likely to be met by surface water or by the City of Portland municipal water supply, and to a limited extent, the basalt aquifer. The beneficial use for groundwater in the LOF is expected to be recharge to the Willamette River and the basalt aquifer. The potential beneficial uses of nearby groundwater in the basalt aquifer include recharge to the Willamette River and industrial water supply. The potential impacts from the upland area and associated groundwater on the adjacent river environment will be examined as part of the Baseline Risk Assessment and FS.

9.0 HOT SPOT EVALUATION

The ODEQ regulations require that certain actions be taken for "hot spots" of contamination. These actions are: (1) the identification of hot spots as part of the RI/FS, and (2) the treatment of hot spots, to the extent feasible, as part of a remedial action selected or approved by the Director of ODEQ (ODEQ 1998d).

The definition of hot spots is dependent on the medium that is contaminated. Generally, for water, a hot spot exists if contamination results in a significant adverse effect on the beneficial use of that resource and if restoration or protection of the beneficial use can occur within a reasonable amount of time. For media other than water (e.g., soil), a hot spot exists if the site presents an unacceptable risk and if the contamination is highly concentrated, highly mobile, or cannot be reliably contained (ODEQ 1998d).

According to ODEQ guidance, the following information is used to identify hot spots throughout the RI/FS process:

- Delineation of the nature and extent of contamination;
- Identification of current and reasonably likely future land use(s) and beneficial use(s) of water;
- Identification of significant contaminant migration routes and exposure pathways; and
- Evaluation of the protectiveness and feasibility of various remedial action alternatives (ODEQ 1998d).

9.1 GROUNDWATER AND SURFACE WATER

The Oregon Environmental Cleanup Rules define hot spots in groundwater and surface water as:

> *OAR 340-122-115(31)(a): For groundwater or surface water, hazardous substances having a significant adverse effect on beneficial uses of water or waters to which the hazardous substances would be reasonably likely to migrate and for which treatment is reasonably likely to restore or protect*

> *such beneficial uses within a reasonable time, as determined in a feasibility study.*

As discussed in Section 8.3, the beneficial use of groundwater in the LOF is recharge to the Willamette River and the basalt aquifer. The potential beneficial uses of nearby surface water in the Willamette River include industrial use, recreational use, and ecological habitat in the LOF. The potential beneficial uses of nearby groundwater in the basalt aquifer include recharge to the Willamette River and industrial water supply.

The State of Oregon has derived pre-calculated hot spot levels for use in identifying areas of contamination having a "significant adverse effect" on groundwater or surface water used for drinking water (the hot spot "look-up tables;" ODEQ 1998e). Because these pre-calculated hot spot levels assume a beneficial water use of drinking water, which is not the case at the Site, the levels are not applicable to the Site. Preliminary, site-specific hot spot levels for groundwater will be derived in the Baseline Risk Assessment. The Baseline Risk Assessment will be prepared and submitted as a separate report. Potential hot spots identified in the Baseline Risk Assessment will be further evaluated in the FS.

9.2 MEDIA OTHER THAN WATER

The Oregon Environmental Cleanup Rules define hot spots in media other than water as:

> *OAR 340-122-115(31)(b): For media other than groundwater or surface water (e.g., contaminated soil, debris, sediments, and sludges; drummed waste; 'pools' of dense, non-aqueous phase liquids submerged beneath groundwater or in fractured bedrock; and non-aqueous phase liquids floating on groundwater), if hazardous substances present a risk to human health or the environment exceeding the acceptable risk level, the extent to which the hazardous substances:*
>
> *(A) Are present in concentrations exceeding risk-based concentrations corresponding to:*
>
> *(i) 100 times the acceptable risk level for human exposure to each individual carcinogen;*
>
> *(ii) 10 times the acceptable risk level for human exposure to each individual non-carcinogen;*

> *(iii) 10 times the acceptable risk level for individual ecological receptors or populations of ecological receptors to each individual hazardous substance;*
>
> *(B) Are reasonably likely to migrate to such an extent that the conditions specified in subsection (a) or paragraphs (b)(A) or (b)(C) would be created; or*
>
> *(C) Are not reliably containable, as determined in the feasibility study.*

According to ODEQ guidance, assessing a site for hot spots in media other than water first requires an evaluation of the site's baseline risk. Preliminary, site-specific hot spot levels for soil will be derived in the Baseline Risk Assessment. Potential hot spots identified in the Baseline Risk Assessment will be further evaluated in the FS.

10.0 SUMMARY OF REMEDIAL INVESTIGATION FINDINGS AND CONCLUSION

This section summarizes the results of the RI sampling and analysis, based on data collected to date. Results are summarized by area of investigation (Acid Plant, Chlorate Plant, etc.).

10.1 ACID PLANT AREA

Soil and groundwater samples were collected in the Acid Plant Area to characterize the nature and extent of contamination. This section summarizes the results of the investigation conducted in the Acid Plant Area.

10.1.1 Acid Plant Area Soil

Pre-RI investigative work (Phase 1 and 2 investigations, CH2M Hill 1995b and CH2M Hill 1997) roughly delineated the lateral and vertical extent of the former MPR Pond and trench and initiated the characterization of soil impacts in the Acid Plant Area. Results indicated that soil had been significantly impacted within the 56 by 60 foot footprint of the pond. Analyses conducted on soil samples indicated that DDT and MCB were present in soil within the former MPR Pond footprint at concentrations up to 150,000 mg/kg (boring RP-SB-01, 8.5 feet bgs) and 200 mg/kg (boring RP-SB-15, 11 feet bgs), respectively. DDT concentrations decreased rapidly with increasing distance from the pond and trench. The highest concentrations of MCB observed during the Phase 1 and 2 investigations were in the area of the former MCB Recovery Unit, where MCB was observed at a concentration of 42,000 mg/kg (boring RP-SB-18, 10 feet bgs).

During the RI, DDT was observed in soil samples at concentrations of up to 31,000 mg/kg (boring MWA-11i, 6 to 8 feet bgs). In general, the lateral extent and concentrations of DDT (and its metabolites, DDD and DDE) is greatest in shallow soils and decrease with depth. The lateral extent of DDT in soil is illustrated on Figures 5-1a, 5-4a, 5-5a, and 5-5b. Although a significant amount of DDT-impacted soil was removed during the Soil Removal IRMs, elevated DDT concentrations remain at concentrations up to 63,000 mg/kg (Phase 1 investigation boring RP-SB-01, 15 feet bgs). The footprint of DDT-impacted soil generally bounded north-south by the No. 1 and No. 2 Docks, and east-west by the Willamette River and the former Caustic Process building. The source of the DDT in Acid Plant Area soil is from past manufacturing operations. Due to years of construction activities in the Acid Plant Area some of the impacted soils were likely excavated and incorporated in fill materials used to extend the property riverward. The distribution of DDD and DDE in Acid Plant Area soil is similar to that of DDT.

Chlorobenzene was observed locally at low concentrations in shallow and near-surface soil (zero to 4 foot bgs) in the Acid Plant Area. No shallow or near-surface soil contained MCB at concentrations greater than the preliminary screening level of 530 mg/kg (USEPA Region 9 PRG). Chlorobenzene was observed at significantly greater concentrations in soil deeper than 4 feet bgs, primarily in the former MCB Recovery Unit area, at concentrations up to 66,600 mg/kg (boring CS-13, 8.5 feet bgs). The highest chlorobenzene concentrations and a majority of the chlorobenzene mass were observed just above the silt layer situated at approximately 7.5 to 8 feet bgs. Although some chlorobenzene-impacted soil was removed during the IRMs, vadose zone soil remains in the Acid Plant Area at depths of at least 14 feet bgs containing MCB at concentrations greater than the preliminary screening level (530 mg/kg).

10.1.2 DNAPL in the Acid Plant Area

Residual MCB DNAPL was observed in shallow silts in the former MCB Recovery Unit area at depths of approximately 6 to 10 feet bgs and at shallow zone elevations downgradient of the former MPR pond. The shallow-zone residual DNAPL is generally confined to the lower portion of the shallow zone (i.e., within approximately 6 feet of the silt layer defining the bottom of the shallow zone) directly below and immediately downgradient of the former MPR pond. Shallow-zone DNAPL has also been observed to a lesser extent farther downgradient from the former MPR Pond (i.e., in riverbank well borings). Residual DNAPL was detected at one intermediate zone location directly below the former MPR pond. Field observations made during the RI have shown that the DNAPL is distributed as ganglia, and thus is not readily mobile in the subsurface. Nevertheless, MCB DNAPL is a likely on-going source of dissolved MCB in groundwater. Dissolved-phase MCB concentrations are consistent with the observed distribution of DNAPL.

10.1.3 *Acid Plant Area Groundwater*

The inferred groundwater flow direction is generally east to northeast (towards the Willamette River) in the Acid Plant Area. Three groundwater zones, designated as the shallow, intermediate, and deep zones have been identified at the Site. The shallow and intermediate zones are separated by a thin, low permeability layer. The deep zone consists of silt with some clay or sand. The three groundwater zones are underlain by water-bearing basalt bedrock (i.e., the basalt zone).

DDT and its metabolites were detected in shallow- and intermediate-zone groundwater downgradient of the Acid Plant Area. DDT is not typically observed in groundwater at concentrations greater than 1 μg/L. However, due to cosolvency with chlorobenzene, DDT has been observed in groundwater at concentrations up to 120,000 D μg/L (NMP-4D, June 2001). The highest concentrations of DDT were observed in and just downgradient of the former MPR pond and trench. DDT in intermediate-zone groundwater is present at significantly lower concentrations than in the shallow zone, which is consistent with the conceptual model for the Site. Historically, DDT has been observed in deep- and basalt-zone groundwater at concentrations up to 0.43 and 0.022 μg/L, respectively. These concentrations are approximately three and four orders of magnitude less than the DDT concentrations observed in shallow-zone groundwater.

Total DDD concentrations were similar in magnitude or approximately one order of magnitude greater than total DDT concentrations in several of the monitoring wells, primarily DDD in riverbank wells downgradient of the former MPR pond. DDD has a higher solubility limit than DDT, which may explain the higher DDD concentrations observed in groundwater. Total DDE concentrations were similar in magnitude or approximately one order of magnitude less than total DDT concentrations in most of the monitoring wells.

The horizontal extent of groundwater affected by DDT and its metabolites has been defined in the shallow and intermediate groundwater zones. The plume is defined upgradient, downgradient (Willamette River), and cross-gradient (north and south) of the Acid Plant Area. Total DDT has been observed in deep zone monitoring well MWA-13d and basalt zone monitoring well MWA-21b. The lateral extent of DDT impacts in the deep and basalt zones is unknown, but is expected to be limited due to the low concentrations observed and hydrogeologic properties of the materials in those zones.

VOCs (primarily chlorobenzene) were detected in Site groundwater, primarily in and downgradient of the Acid Plant Area (e.g., monitoring wells MWA-15r and MWA-2 [shallow zone], and monitoring wells MWA-9i and MWA-17si [intermediate zone]). The maximum observed chlorobenzene concentration in a shallow-zone monitoring well occurs within the footprint of the former MPR pond (260,000 ug/L, MWA-15r, March 2001) was approximately one order of magnitude greater than the maximum concentration observed in an intermediate-zone monitoring well (38,000 ug/L, MWA-9i, January 1999). Additionally, the lateral extent of chlorobenzene impact is greater in the shallow zone. Lower chlorobenzene concentrations were also detected in the deep- and basalt-zone monitoring wells (MWA-13d and MWA-21b) during the RI. The most recent chlorobenzene concentrations in the deep zone (10.6 µg/L, MWA-13d, June 2003) was approximately two to three orders of magnitude less than the maximum concentrations in the shallow zone. Further, concentrations in the basalt zone (0.69 µg/L, MWA-21b, 12 April 2002) were approximately four to five orders of magnitude less than concentrations in the shallow zone. Since chlorobenzene is present in some locations in the shallow zone as residual DNAPL, these results suggest that the lower-permeability silt layers separating the groundwater zones have impeded significant downward transport of chlorobenzene, which is consistent with the conceptual model for the Site.

This investigation has bounded groundwater affected by chlorobenzene upgradient and downgradient of the Acid Plant Area. The southern extent of chlorobenzene in the shallow zone and the northern extent of chlorobenzene in the intermediate zone have been well defined. However, further investigation is required to define northern extent of chlorobenzene in the shallow zone and the southern extent of chlorobenzene in the intermediate zone. This delineation work will be performed during the Persulfate Oxidation IRM.

10.2 CHLORATE PLANT AREA

Soil and groundwater samples were collected in the Chlorate Plant Area to characterize the nature and extent of contamination. This section summarizes the results of the investigation conducted in the Chlorate Plant Area.

10.2.1 Chlorate Plant Area Soil

Total chromium was observed in soil in the Chlorate Plant Area at concentrations up to 180 J mg/kg (boring B-88) from zero to 4 feet bgs, and up to 1,600 mg/kg (boring B-88, 10 to 12 feet bgs) greater than 4 feet bgs. The highest concentrations of chromium in soil are found within the footprint of the Chlorate Cell Room. There were no detections of total or hexavalent chromium in Chlorate Plant soil greater than their respective preliminary screening levels outside the footprint of the Chlorate Cell Room. Further, chromium concentrations decrease significantly within approximately 250 feet of the Chlorate Cell Room. As such, the existing data are sufficient to define the horizontal and vertical extent of chromium-impacted soil for the purpose of a risk assessment and FS.

Soil samples were not collected for analysis of perchlorate within the Chlorate Plant Area during the remedial investigation. Perchlorate in soil will be evaluated as part of the risk assessment and FS process.

10.2.2 Chlorate Plant Area Groundwater

The inferred groundwater flow direction in the Chlorate Plant Area is generally east to southeast. The same groundwater zones that occur in the Acid Plant Area exist in the Chlorate Plant Area; however, the silt separating the shallow and intermediate zones becomes discontinuous downgradient of the Chlorate Plant Area. The underlying basalt deepens towards the south side of the site and was not observed in borings conducted in the Chlorate Plant Area.

Chromium impacts to shallow-zone groundwater appear to extend from just upgradient of the former Chlorate Process Building on the west to the Willamette River on the east, and from the Old Caustic Tank farm on the north to about the property boundary on the south. The highest total and hexavalent chromium concentrations detected in shallow-zone groundwater were 21 mg/L (well MWA-27, April 2002) and 14.9 mg/L (well MWA-36, December 2003, not validated). Chromium was also detected upgradient of the Chlorate Plant Area in well MWA-23, at a concentration of 0.00117 mg/L (June 2003).

Chromium impacts to intermediate-zone groundwater are more prevalent downgradient of the Chlorate Cell Room and are more widely dispersed cross-gradient.

Chromium was detected in intermediate-zone and deep-zone groundwater at concentrations up to 0.992 mg/L (monitoring well MWA-16i) and 1.15 mg/L (well MWA-31i(d)) during the most recent site-wide groundwater sampling event (June 2003). These wells are downgradient of the area where the highest chromium detections have routinely been observed in shallow groundwater. This suggests that dissolved chromium has moved downward as it migrated downgradient from the Chlorate Plant Area. This is consistent with the local stratigraphy, which suggests that the silt between the shallow and intermediate groundwater zones becomes discontinuous toward the southeast portion of the Site. The RI has adequately defined the extent of chromium impacts in groundwater for the purposes of a risk assessment and FS.

Perchlorate was detected in shallow- and intermediate-zone groundwater, primarily in the Chlorate Plant Area, but also in a limited area downgradient of the Acid Plant Area. Concentrations up to 290 mg/L (MWA-25, June 2003) and 200 mg/L (were observed in the shallow and intermediate groundwater zones, respectively, in the Chlorate Plant Area. Perchlorate impacts in shallow-zone groundwater are more laterally extensive than those in the intermediate zone. The impacted area appears to be similar to that observed for Hexavalent Chromium. Additional sampling is required to better define the northern extent of perchlorate in shallow-zone groundwater in the Acid Plant Area and the southern extent in intermediate-zone groundwater in the Chlorate Plant Area.

Perchlorate was detected in Acid Plant Area shallow-zone groundwater at concentrations up to 1.4 mg/L (MWA-2, June 2003). Well MWA-2 was the northernmost well sampled for perchlorate. Sampling of the northernmost shallow-zone well (MWA-5) is required to define the northern extent of perchlorate impacts in shallow-zone Acid Plant Area groundwater. The highest perchlorate concentration observed in groundwater in the Acid Plant Area was 9.9 mg/L (MWA-17si, June 2003, shallow zone). Concentrations in the intermediate zone were approximately one order of magnitude lower than the maximum concentration in the shallow zone.

For the purposes of performing a risk assessment and FS, the RI has adequately defined the extent of perchlorate impacts in the shallow and intermediate zones.

10.3 RIVERBANK SOIL

Pesticides, SVOCs and metals were detected in riverbank soils. DDT, DDD, and DDE impacts were observed in nearly all riverbank and beach soil (sediment) samples. The extent of pesticide contamination has not completely been defined by the RI. A few SVOCs were detected in a riverbank and beach soil sample. The extent of SVOC impacts appears to be confined to a small area between the No. 1 and No. 2 Docks. Only one metal (lead) was detected in a riverbank soil sample above its preliminary screening level of 128 mg/kg (sample RB-8). There appear to be no other metals impacts to riverbank soil.

10.4 SALT PADS

Chloride was observed in groundwater at all wells during all sampling events. Chloride is a naturally-occurring ion in groundwater. However, elevated chloride concentrations were observed on the downgradient side of the former Salt Pads, where salt was stockpiled and where salt brine was produced for use in manufacturing. Concentrations up to 190,000 mg/L (MWA-30 dup, April 2002), 31,000 mg/L (MWA-32i, June 2003), and 61,100 mg/L (MWA-31i(d), June 2003) were observed in the shallow, intermediate, and deep groundwater zones, respectively.

While the highest concentrations of chloride exist in the vicinity of the downgradient edge of the Salt Pads, chloride concentrations exist site-wide in all groundwater zones above the preliminary screening level of 230 mg/L. This is likely due to the ubiquitous use of brine in the manufacturing processes that took place during facility operations. Chloride has been observed in the most upgradient shallow- and intermediate-zone monitoring wells at concentrations up to 303 mg/L (MWA-7, January 1999) and 17.9 J mg/L (MWA-12i, April 1999). Chloride in site groundwater will be evaluated further in the Source Control Evaluation.

10.5 AMMONIA PLANT

Ammonia was detected in the groundwater sample collected from boring B-67 at a concentration of 1.22 mg/L. In June 2001, ammonia was observed in groundwater samples collected from monitoring wells MWA-5 and MWA-14i at concentrations up to 15 and 2.9 mg/L, respectively. This data was presented to ODEQ in the Quarterly Progress Report prepared by Arkema, dated July 2001. In a letter to Arkema, dated 29 August 2001, ODEQ stated "additional characterization of the ammonia impacts to groundwater" was necessary and requested Arkema propose a strategy for additional evaluation of ammonia in groundwater (ODEQ 2001).

In response to ODEQ's 29 August 2001 letter, Arkema assembled groundwater quality data from off-site, upgradient wells, both shallow and intermediate. The data indicated that ammonia had been observed in off-site monitoring well W-04-S at a concentration up to 34.5 mg/L. Monitoring well W-04-S is located across NW Front Avenue from the Site, upgradient of the former Ammonia Manufacturing Plant and monitoring wells MWA-5 and MWA-14i (Figure 3-2a). Arkema presented this data to ODEQ in a letter dated 25 February 2002. ODEQ responded to this letter in a letter dated 21 March 2002, in which ODEQ agreed that the data from the upgradient monitoring wells indicated that it is likely that ammonia has migrated with groundwater onto Arkema property (ODEQ 2002b). In that letter, ODEQ also stated that Arkema was required to perform additional sampling before application of the Contaminated Aquifer Policy (ODEQ 1997).

In response to ODEQ's 21 March 2001 letter, direct-push boring B-119 was advanced upgradient of the former Ammonia Manufacturing Plant on June 2002 (Figures 1-3 and 3-2a). The groundwater sample collected from this boring contained ammonia at a concentration of 2.0 mg/L. This data was presented to ODEQ in the October 2002 Quarterly Progress Report.

Arkema has reviewed conditions A through D of the Contaminated Aquifer Policy and concludes that based on the analytical results for ammonia in the direct-push boring groundwater samples collected upgradient and downgradient of the former Ammonia Manufacturing Plant and analytical results from off-site, upgradient wells screened in the same groundwater bearing zones, the Contaminated Aquifer Policy applies to ammonia at the Site.

10.6 BPA MAIN SUBSTATION

Polychlorinated biphenyls were detected in soil during a Phase II ESA conducted by the Bonneville Power Administration (BPA) in the BPA Main Substation (referred to as the Pennwalt Substation, PBS 2002). PCBs were detected in shallow-zone soil (zero to 5 feet bgs) at concentrations up to 1.25 mg/kg (total of seven Aroclor® compounds). In addition to PCBs, TPH, seven PAHs, lead, DDT, and DDD were detected at low concentrations in soil samples collected in the substation area (PBS 2002a, Appendix E).

Soil samples collected in storm water drainage swales north and south of the substation did not contain PCBs above the detection limit of 0.05 mg/kg. Excavation of soil in the northwestern corner of the former substation removed soil containing the highest observed concentrations of PCBs. Confirmation samples indicate that soil containing PCBs at concentrations up to 4.5 mg/kg remain on site, within the former substation. Samples collected in the area between the substation and NW Front Avenue indicate that PCB concentrations in soil are less than 0.91 mg/kg. Based on these results, PCBs are included in the list of COIs for evaluation in the Baseline Risk Assessment. For the purposes of performing a risk assessment and FS, the available data have adequately defined the extent of impacts in the BPA Main Substation.

10.7 STORM WATER

Dissolved DDT was detected in five of eight samples collected from two manholes during early storm water characterization work in the Acid Plant Area in 1999. Dissolved DDD and DDE were not detected in any of the eight samples. Total DDT and its metabolites were detected in all but one of the 12 storm water samples at low μg/L concentrations, which suggests that some pesticide-containing particulate material was present in the storm water samples. Significant reductions in total DDT and metabolite concentrations in storm water were observed after the Phase I IRM was completed; total DDT concentrations were approximately half of what had been previously observed, and DDT metabolite concentrations were approximately an order of magnitude less than previously observed levels.

Arkema was issued a new NPDES discharge permit for storm water by ODEQ on 22 January 2004. A condition of the permit required Arkema to conduct a storm water characterization for legacy and 303(d) constituents for a 1-year period and to submit a report to ODEQ summarizing the sampling and results. The storm water characterization work consisted of monthly monitoring of storm water in Outfalls 001, 002, 003, and 004.

Organochlorine pesticides were detected in all four outfalls throughout the 1-year sampling program. Hexavalent chromium was detected in Outfall 004 in several of the monthly samples. In an effort to delineate the source of pesticides and hexavalent chromium in the outfall samples, Arkema collected additional storm water data, which included several locations within each of the four storm drain systems. Three to five additional samples were collected per drain system in upstream manholes. Phase III demolition activities were being carried out concurrently with the monthly monitoring. Several constituents exhibited temporary increases during this time, only to decrease again after demolition activities were complete.

Arkema is planning an additional assessment of the storm drainage systems to support possible IRMs.

10.8 DATA GAPS

The data presented and summarized in this report represents a significant amount of work to define the nature and extent of impacts to soil, groundwater, and storm water on Lots 3 and 4 and Tract A on the Site. The RI has also identified data gaps, which include:

- DDT, DDD, and DDE in shallow soil outside the Acid Plant and Chlorate Plant Areas and in riverbank soils south of the No. 1 Dock and north of the No. 2 Dock;
- Perchlorate in soil;
- The northern extent of MCB in shallow-zone groundwater;
- The southern extent of MCB in intermediate-zone groundwater;
- The northern extent of perchlorate in shallow-zone groundwater in the Acid Plant Area; and

- The southern extent of perchlorate in intermediate-zone groundwater in the Chlorate Plant Area.

These data gaps are acknowledged and have been (or will be) addressed in one or more of the following subsequent tasks:

- The In Situ Air Sparging/Soil Vapor Extraction IRM;
- The Hexavalent Chromium Reduction IRM;
- The Sodium Persulfate Oxidation IRM;
- The Human Health and Ecological Risk Assessments; and
- The FS.

10.9 CONCLUSION

The remedial investigation conducted at the Arkema facility in Portland, Oregon, has adequately defined the nature and extent of COIs in upland soil and groundwater and provides sufficient data for conducting the Baseline Risk Assessment and FS. Additional sampling has been (or will be) conducted during subsequent IRMs, the risk assessments, and FS to address the identified data gaps.

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