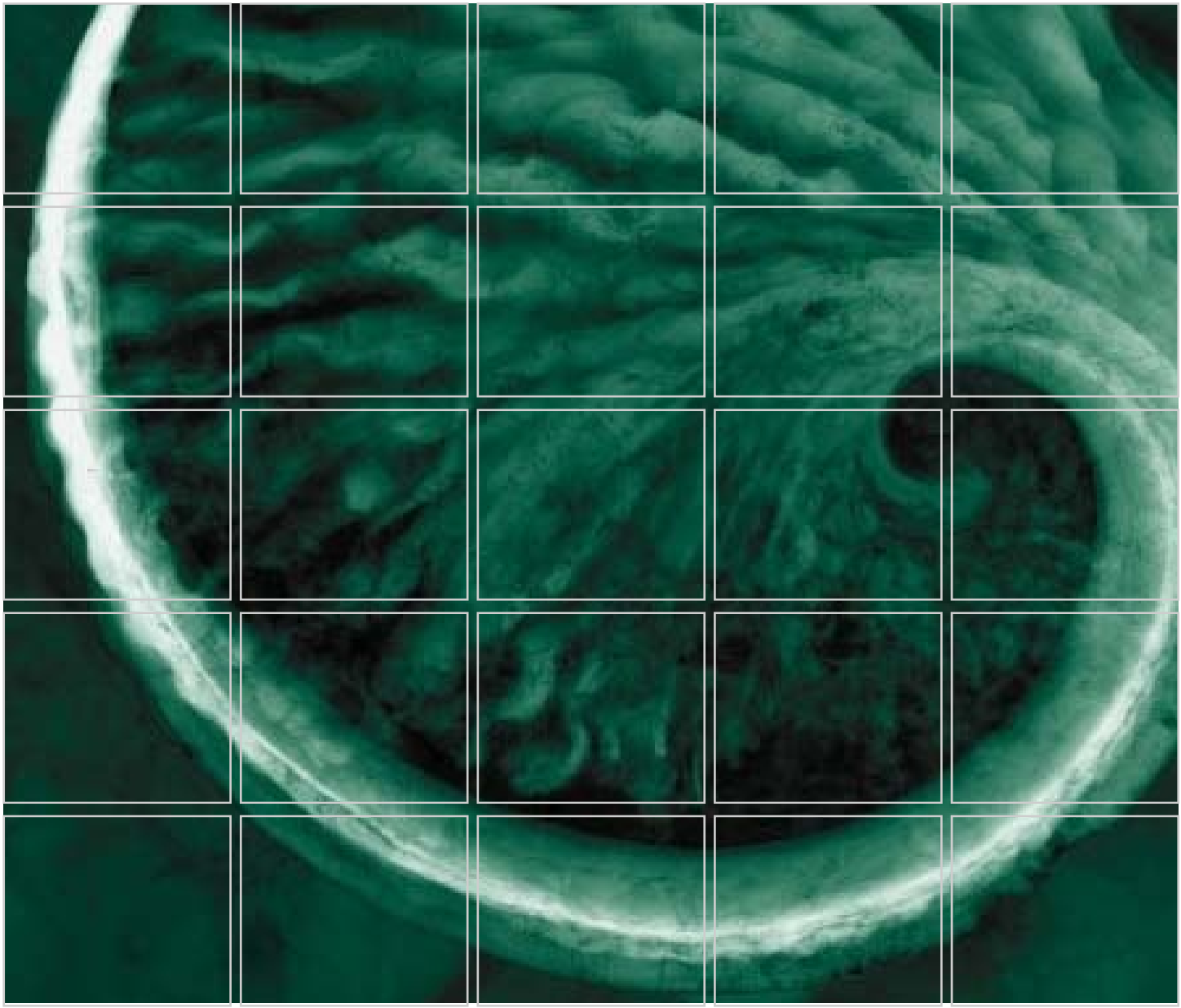


PRELIMINARY DRAFT

Scoping Technical Memorandum

Groundwater Source Control Interim Remedial Action

Arkema, Inc. Facility
Portland, Oregon

December 2006

www.erm.com

Delivering sustainable solutions in a more competitive world

ERM

Legacy Site Services LLC

PRELIMINARY DRAFT
Scoping Technical Memorandum Groundwater Source Control Interim Remedial Action
Arkema, Inc. Facility
Portland, Oregon

December 2006

Project No. 0058397.01.****

David P. Edwards, P.G.
Principal

Erik C. Ipsen, P.E.
Project Manager

ERM-West, Inc.
915 118th Avenue S.E., Suite 130
Bellevue, Washington 98005
T: 425-462-8591
F: 425-455-3573

TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 INTERIM REMEDIAL MEASURE OBJECTIVES 2

1.2 REPORT ORGANIZATION 2

2.0 BACKGROUND 3

2.1 SITE BACKGROUND 3

2.2 PREVIOUS REMEDIAL ACTIONS 3

2.3 JOINT SOURCE CONTROL STRATEGY AND SCREENING 4

2.4 REVISED REMEDIAL STRATEGY FOR SITE 5

3.0 CONCEPTUAL IRM APPROACH AND LAYOUT 6

3.1 CONTAINMENT BARRIER WALL 6

3.2 HYDRAULIC CONTAINMENT SYSTEM 7

3.3 OTHER CONSIDERATIONS 8

3.3.1 Interim Action Versus Final Remedy 8

3.3.2 Cleanup Goals 8

4.0 PROPOSED IRM TASKS AND SCHEDULE 9

4.1 IRM TASKS 9

4.1.1 Groundwater Modeling 9

4.1.2 Geotechnical Evaluation 10

4.1.3 Laboratory Treatability and Compatibility Studies 11

4.1.4 Focused Feasibility Study 12

4.1.5 Design and Specifications 13

4.1.6 Permitting 17

4.1.7 Installation, Startup, and Operation and Maintenance 17

4.1.8 Source Control Implementation Report 18

4.2 AGENCY REVIEW AND PUBLIC NOTIFICATIONS 18

4.3 PRELIMINARY SCHEDULE 19

5.0 IDENTIFICATION OF REMEDIAL TECHNOLOGIES FOR EVALUATION 20

5.1 CONSTITUENTS OF POTENTIAL CONCERN 20

5.2 CONTAINMENT TECHNOLOGIES 21

5.3 EX SITU GROUNDWATER TREATMENT TECHNOLOGIES 22

5.4 WATER HANDLING OPTIONS 23

6.0 REFERENCES 24

LIST OF FIGURES

Figure 3-1	*Conceptual Barrier Wall Layout*	*following text*
Figure 4-1	*Draft Outline for Focused Feasibility Study*	*page 14*
Figure 4-2	*Preliminary Project Schedule*	*following text*

LIST OF TABLES (following text)

Table 4-1	*Potential Treatability Studies and Associated Target Contaminants*
Table 5-1	*Groundwater Containment Technologies and Process Options*
Table 5-2	*Ex Situ Groundwater Treatment Technologies and Associated Target Contaminants*
Table 5-3	*Preliminary Evaluation of Ex Situ Groundwater Treatment Technologies*
Table 5-4	*Treated Groundwater Discharge Options*

LIST OF APPENDICES

APPENDIX A	*GROUNDWATER MODELING SCOPING TECHNICAL MEMORANDUM*

1.0 INTRODUCTION

On behalf of Legacy Site Services LLC (LSS), ERM-West, Inc. (ERM) has prepared this Scoping Technical Memorandum (TM) to address a proposed Groundwater Source Control Interim Remedial Measure (IRM) at the Arkema, Inc., (Arkema) facility in Portland, Oregon (the "site"). This IRM has been proposed to achieve upland groundwater source control by preventing the migration of impacted groundwater from the upland portion of the site to the Willamette River.

This TM has been prepared to satisfy a request of the Oregon Department of Environmental Quality (ODEQ) during the 19 September 2006 meeting between ODEQ and LSS. The purpose of this TM is to identify and outline the general concepts necessary to complete the IRM. These include:

- Present the rationale and objectives for the proposed groundwater source control IRM;
- Provide a conceptual overview of the IRM and its elements;
- Define the process through which the IRM will be developed;
- Provide recommendations for additional evaluations, as needed, to support the technology evaluation and implementation;
- Identify key milestones, decision points, and input periods for the agencies and public;
- Develop a list of preferred containment and ex situ treatment technologies for the constituents of potential concern (COPC) to be assessed as part of a focused alternatives evaluation;
- Develop a list of preferred treated water discharge handling options; and
- Define the criteria against which the remedial alternatives will be evaluated.

1.1 INTERIM REMEDIAL MEASURE OBJECTIVES

The objectives of this Groundwater Source Control IRM are to:

- Prevent migration of groundwater COPCs in excess of their respective Maximum Contaminant Levels (MCLs) (or alternatively risk-based concentrations) from the primary source areas at the Arkema site to the Willamette River through physical containment and hydraulic capture of groundwater;
- Reduce the potential for recontamination via the groundwater migration pathway of river sediments following sediment cleanup as part of the Arkema early removal action and Portland Harbor remediation;
- Create hydraulic discontinuity between the upland portion of the site and the Willamette River in advance of the final upland remedy to allow upland source control measures to proceed at an achievable schedule; and
- Implement a remedy, which to the extent practicable will complement and be compatible with the final upland remedy for the site.

1.2 REPORT ORGANIZATION

The remainder of this TM is organized as follows:

- Section 2 – Background;
- Section 3 - Conceptual IRM Approach and Layout;
- Section 4 - Proposed IRM Tasks and Schedule;
- Section 5 - Identification of Remedial Technologies for Evaluation;
- Section 6 – References; and
- Appendix A – Groundwater Modeling Scoping Technical Memorandum.

2.0 BACKGROUND

2.1 SITE BACKGROUND

The Arkema facility is located at 6400 N.W. Front Avenue in the Northwest Industrial Area of Portland, Oregon. The facility is bounded by Front Avenue on the north and west, the Willamette River on the east, and an asphalt roofing manufacturer on the south. The plant operated as a chemical manufacturing facility for over 50 years. Manufacturing activities at the facility were terminated in 2001 and the plant was decommissioned and dismantled in 2004.

In 1998, Arkema entered into a Voluntary Agreement with the ODEQ under the Oregon Voluntary Cleanup Program (ODEQ No. ECVC-WMCVC-NWR-97-14 [ODEQ 1998]) 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. The *Upland Remedial Investigation Report Lots 3 & 4 and Tract A – Revision 1* (RI Report; ERM 2005) was conditionally approved by ODEQ on 5 June 2006. The upland Human Health and Ecological Risk Assessments and the Hot Spot Evaluation are currently under development.

Readers requiring detailed information regarding environmental conditions at the site are referred to the RI Report, which contains detailed site description, background information, and discussion of nature and extent of contamination at the site.

2.2 PREVIOUS REMEDIAL ACTIONS

Since 2000, LSS has pursued a strategy of aggressive and innovative in situ remediation IRMs, whereby groundwater contaminants have been treated or destroyed in place without costly groundwater extraction. There were two drivers for this approach: 1) conventional groundwater extraction and treatment systems have been demonstrated to be inadequate at achieving proposed cleanup objectives and 2) LSS has a history of using innovative technologies to provide contaminant destruction and reduction of mobility, which LSS sees as a preferred end point. LSS has completed several soil and groundwater IRMs at the site, which have removed hot spots of soil contamination and reduced

groundwater concentrations of several constituents. These IRMs have included:

- Two soil removal IRMs;
- Soil vapor extraction IRM;
- In situ hexavalent chromium reduction IRM;
- In situ persulfate oxidation IRM; and
- Air sparging/soil vapor extraction IRM.

These IRMs have been successful, in part, at removing some sources of contamination and reducing concentrations of several groundwater contaminants. However, the in-water early removal action (i.e., in-water Engineering Evaluation/Cost Analysis [EE/CA]) schedule restricts the use of innovative technologies, in favor of a technology that merely controls contaminant flux while having little appreciable effect on contaminant mass.

2.3 JOINT SOURCE CONTROL STRATEGY AND SCREENING

Finalized in December 2005, the JSCS represents a framework for making upland source control evaluations at the Portland Harbor Superfund Site. The JSCS document does not constitute rulemaking by ODEQ or USEPA, and may not be relied upon to create a right or benefit, substantive or procedural, enforceable in law or equity, by any person, including the ODEQ or USEPA. Nonetheless, the JSCS states:

> *The overarching goal of the JSCS is to identify, evaluate, and control sources of contamination that may reach the Willamette River, in a manner consistent with the objectives and schedule of the Portland Harbor RI/FS. Upland source control should be completed to the extent practicable prior to sediment cleanup in the Portland Harbor Superfund Site.*

The JSCS tool identifies a process whereby concentrations of site constituents are compared to screening level values (SLVs). Exceedance of an SLV does not necessarily indicate the upland source poses an unacceptable risk to human health or the environment, rather it requires further consideration of the need for source control using a weight-of-

evidence evaluation. A remedial alternative evaluation (e.g., focused feasibility study [FFS]) is then performed, where complete contaminant migration pathways exist, to address upland sources as deemed necessary by the screening process and the weight-of-evidence evaluation.

A draft Source Control Screening evaluation for groundwater was prepared for LSS by Integral Consulting, Inc. and submitted to ODEQ in April 2006. Based on comments received from ODEQ and discussions with ODEQ during the meeting on 19 September 2006, LSS is in the process of revising and supplementing the screening evaluation, as necessary. Once finalized, the Source Control Screening evaluation will determine the areas of the site requiring further consideration (e.g., site-specific risk evaluations and contaminant fate and transport simulations) for upland groundwater source control.

2.4 REVISED REMEDIAL STRATEGY FOR SITE

As discussed above, the JSCS requires upland source control to the greatest extent practicable before or during the EE/CA removal action in order to reduce the potential for recontamination of the river following cleanup. Despite the success of several of the in situ IRM technologies, as stated above, LSS does not currently believe an in situ remedial approach will be capable of meeting the source control objectives in the USEPA-envisioned timeframe. In situ treatment technologies, by their nature, are constrained by reaction kinetics and media interferences which alter their ability to meet rapid and undefined groundwater source control objectives. In addition, the recalcitrant and/or persistent nature of some of the constituents anticipated to require containment/treatment (e.g., DNAPL) are expected to complicate an in situ approach for source control.

As a result of the factors described above, LSS has been left with no other option other than to pursue an alternative strategy of physical and hydraulic containment to achieve groundwater source control. LSS has discussed the revised remedial strategy for the site during several phone conversations and meetings with ODEQ, and it is LSS's understanding that both ODEQ and USEPA are in agreement with this new strategy.

The following sections describe the objectives of the proposed source control IRM and present the conceptual IRM approach.

3.0 CONCEPTUAL IRM APPROACH AND LAYOUT

The revised Groundwater Source Control IRM will consist of the following primary elements:

- **Containment barrier wall** located at the top of bank to physically separate the upland and in-water portions of the site; and
- **Hydraulic control ("groundwater extraction and treatment")** to prevent groundwater COPCs in excess of MCLs (or alternatively, risk-based concentrations) from moving around, over, or under the containment barrier wall.

These elements are discussed in more detail in the following sections.

3.1 CONTAINMENT BARRIER WALL

Although hydraulic capture alone is often sufficient to create groundwater containment, LSS currently plans to include a containment barrier wall to physically cut off groundwater flow from the site to the Willamette River. It is envisioned that this barrier wall will be installed along the top of the bank and will extend from above the top of the shallow groundwater aquifer to the confining basalt layer present beneath the entirety of the site. This basalt layer is present between 60 and 65 feet below ground surface within Lots 3 and 4 of the Arkema site and provides a laterally continuous, low permeability zone down to which to install the barrier wall. It should be noted that the barrier wall will not be "keyed" into the basalt bedrock (i.e., installed beneath the surface of the bedrock) due to the expected technically impracticable challenges associated with installation of this type. It is expected that the low permeability silts and clays that comprise the deep aquifer above the basalt bedrock will provide an appropriate zone into which to key.

It is currently envisioned the barrier wall will not completely encompass the upland source area, but would rather run adjacent to the river/top of bank and possess the necessary "wing walls" to help prevent migration of water around the ends of the wall (combined with groundwater extraction). A preliminary conceptual layout of the barrier wall is provided as Figure 3-1. The barrier wall is expected to contain groundwater within Lot 4 and a portion of Lot 3 (that is, from the

southeastern property boundary to the northwestern most No. 2 dock). This area represents the portion of the site where historical manufacturing operations have taken place and the vast majority of soil and groundwater impacts exist. The initial area of groundwater containment will be defined by the Source Control Screening process and the final area of groundwater containment will ultimately be defined in the site-specific evaluation conducted within the FFS.

Two primary types of barrier walls will be evaluated as part of this IRM: slurry walls and sheet pile walls. Discussion of specific barrier wall technologies is provided in Section 5.2.

3.2 HYDRAULIC CONTAINMENT SYSTEM

The purpose of the hydraulic containment system will be to maintain a hydraulic gradient inward/away from the river by capturing groundwater from key locations upgradient of the barrier wall. The system will include the following primary elements:

- Groundwater extraction wells;
- Conveyance piping;
- Groundwater treatment train capable of reducing contaminant concentrations to the appropriate levels (technologies discussed in Section 5.3); and
- Effluent water discharge system (options discussed in Section 5.4).

It is expected that the extraction wells will be placed at either end of the barrier wall and at other locations as necessary to maintain groundwater capture and a hydraulic gradient away from the river. Groundwater modeling will be performed in order to locate and optimize extraction well placement. The extraction well screens will be placed within the shallow and intermediate aquifers (the primary water bearing zones) so as to maximize influence.

Extracted water will be transmitted to a central treatment facility, although it is possible that some pretreatment may be performed for certain high concentration extraction areas or wells. Following treatment, water will be managed using one, or a combination, of the options listed

in Section 5.4. Further discussion of the treatment technologies and water handling options is provided in Sections 5.3 and 5.4, respectively.

3.3 OTHER CONSIDERATIONS

3.3.1 Interim Action Versus Final Remedy

LSS has elected to perform this source control action as an IRM in advance of the upland feasibility study (FS) for the site to ensure that the source control deadline can be met, and to allow focusing of resources on this priority project. Alternatives evaluation and remedy selection for the IRM will be performed through preparation of an FFS. To the greatest extent practicable, this IRM will be carried out in a manner consistent with potential final remedial approaches.

3.3.2 Cleanup Goals

As stated in the JSCS, SLVs are not cleanup levels, rather they are comparisons used to establish priority for potential source control. The USEPA Portland Harbor Record of Decision(s) will at some point in the future establish contaminant specific cleanup levels for the Portland Harbor Superfund Site. Presumably, these will include upland groundwater discharges to the river. Cleanup goals for the upland portion of the Arkema site will be developed through the comprehensive sitewide upland FS process, to be completed separately from this IRM. As such, the goal of this IRM is to provide hydraulic control of groundwater COPCs in excess of MCLs (or alternatively, risk-based concentrations for those COPCs which do not have an MCL). Therefore, in order to establish the required capture zone, some limited, site-specific risk evaluations will be required in the FFS for this IRM.

4.0 PROPOSED IRM TASKS AND SCHEDULE

The following sections discuss the tasks to be performed as part of this proposed IRM, present the method for agency review and public participation, and provide a preliminary project schedule.

4.1 IRM TASKS

The proposed Groundwater Source Control IRM will be performed through the following tasks:

- Finalize JSCS evaluation;
- Development and calibration of a site groundwater model;
- Performance of a geotechnical evaluation;
- Performance of laboratory treatability studies;
- Perform site-specific risk evaluation;
- Preparation of an FFS;
- Preparation of design and specifications;
- Permitting;
- Installation, startup, and operation and maintenance (O&M) of the remedial system(s); and
- Preparation of a Source Control Implementation Report (SCIR).

These tasks are discussed in the sections below.

4.1.1 Groundwater Modeling

A three-dimensional, numerical, groundwater model of the site will be developed to more fully characterize groundwater flow systems, to develop groundwater extraction and injection scenarios, and to perform fate and transport analysis of COPCs in groundwater. The site-wide

groundwater model developed will be the primary tool used to evaluate containment and extraction alternatives for the FFS and upland FS, and to develop preliminary design specifications for the selected remedial systems.

LSS will utilize a phased approach in the development of the groundwater flow and contaminant transport model. The first phase will consist of detailing the conceptual model for the groundwater flow systems at the site and documenting the subsurface transport properties of the site contaminants. The second phase will be the design, construction, and calibration of the groundwater model for the site. During this phase, the sensitivity of the model to the various input parameters will also be assessed. The third phase will be the application of the model to simulate and evaluate various remedial alternatives envisioned for the site and to perform various fate and transport analysis of selected COPCs.

Additional details about the planned modeling effort are presented in the technical memorandum provided as Appendix A.

4.1.2 Geotechnical Evaluation

The possible installation of a containment wall near the top of bank will require some additional geotechnical analysis to ensure slope stability during and after installation. In addition, permeability testing of the deep soils along the route of the barrier wall may be required. Design of the hydraulic containment system may also require determination of certain geotechnical parameters through direct laboratory measurement (e.g., permeability). This task will include:

- Collection of geotechnical samples from a variety of depths;
- Geotechnical analysis of the samples for standard parameters (e.g., porosity, Atterberg limits, classification, permeability);
- Slope stability analysis by a geotechnical engineer using computer simulation; and
- Preparation of a report presenting the geotechnical evaluation results. This report will be included with the FFS as an appendix.

In order to expedite the overall project schedule, it is LSS's intention to perform the geotechnical evaluation in conjunction with preparation of the FSS.

4.1.3 Laboratory Treatability and Compatibility Studies

Various treatability and compatibility studies will be required to evaluate ex situ groundwater treatment technologies and slurry wall mix designs. Treatability testing will likely be required to evaluate the effectiveness of one or more technologies and corresponding design parameters that have a significant cost impact. For the purposes of this preliminary technical memorandum, treatability testing is assumed to consist of the following:

- Collection of groundwater samples representative of the likely components of the influent generated by the full-scale hydraulic containment system (i.e., groundwater from both aquifers and both major plumes to be contained);

- Combining the representative samples collected at ratios bracketing the potential range of influent concentrations applicable to the full-scale groundwater treatment system;

- Testing of various treatment processes on the various ranges potential groundwater influent concentrations and evaluate potential achievable removal efficiencies;

- Revision of the conceptual process flow diagram (PFD) for the groundwater extraction and treatment system, if necessary, pending the treatability study results; and

- Preparation of a report presenting the treatability study results, changes to the conceptual PFD, and recommendations for pilot testing and/or full-scale system. This report(s) will be included with the FFS as an Appendix.

Compatibility testing will be performed similarly as described above to evaluate the compatibility of various slurry wall design mixtures with groundwater at the site.

Table 4-1 presents a range of potential treatability studies that may need to be performed if the preliminary evaluation results indicate that a given technology is potentially cost effective compared to other alternatives. Because treatment of the groundwater will likely require multiple sequential processes, careful attention will be needed when scoping the treatability studies so they are representative of full-scale conditions to the greatest extent practical.

To expedite the project schedule, it is LSS's intention to perform the treatability testing in conjunction with preparation of the FSS.

4.1.4 Focused Feasibility Study

Following agreement with the agencies on the Scoping TM, LSS will prepare an FFS for the IRM that will evaluate the groundwater treatment, containment, and water handling technologies identified in this Scoping TM. The FFS will be developed in general accordance with the Comprehensive Environmental Response Compensation and Liability Act Engineering Evaluation/Cost Analysis process (USEPA, 1993). The FFS will include:

- Summary of site conditions, including a summary of the Source Control Screening evaluation;
- Site-specific risk evaluation;
- Summary of treatability and compatibility testing performed;
- Evaluation and comparison of technologies based on their potential effectiveness, implementability (e.g., permitting requirements, physical limitations at the site, equipment availability), and cost;
- Summary of groundwater modeling remedial scenarios evaluation;
- Development of one or more conceptual PFDs for the groundwater treatment system;
- Development of a site plan showing proposed containment wall location, recovery and injection well locations, treatment system location, potential site development, discharge/injection location(s), available electric connections, and other physical site conditions;
- If required as part of the design, recommendations of potential data collection that may be needed to better evaluate one or more of the technologies; and
- If required as part of the design, recommendations for additional treatability testing that may be needed to better evaluate the effectiveness of a technology and assess design parameters with significant cost impacts.

A draft outline for the FFS is included in Figure 4-1. Upon completion of the draft, LSS will send an electronic version and two hard copies of the report to ODEQ for review. One electronic and one hard copy will be submitted to USEPA for review.

Figure 4-1 Draft Outline for Focused Feasibility Study

- Site characterization
  - Site description and background
  - Potential sources
  - Nature and extent of contamination
  - COPCs
  - Previous removal actions
  - Summary of Source Control Screening evaluation
  - Summary of treatability and compatibility testing
- Site-specific risk evaluation
- Identification of source control measure objectives
  - Source control IRM scope
  - Source control IRM schedule
- Identification and analysis of source control measure alternatives
  - Effectiveness
  - Implementability
  - Cost
- Comparative analysis of source control IRM alternatives
- Recommended source control measure alternative

4.1.5 Design and Specifications

With the conceptual engineering being completed and in order to keep the anticipated expedited schedule, the engineering work process for designing the containment wall and hydraulic containment system will consist of: a) the Draft Design and b) the Pre-Final/Final design.

4.1.5.1 *Draft Design*

In the Draft Design, the technical requirements of the IRM will be addressed and outlined to allow verification that the final design will provide an effective remedy. Supporting data and documentation will be provided with the design documents defining the functional aspects of the project.

The Draft Design will include the following elements:

- **Data Summary** - Necessary data will be summarized and submitted along with an analysis of the impact of the results on design activities. Additional surveys, if any, conducted to establish topography, rights-of-way, easements, and utility lines will be documented. Utility requirements and acquisition of access that are necessary to implement the IRM will also be discussed.

- **Design Criteria Report** - The concepts supporting the technical aspects of the design will be defined in detail and presented in this report. Specifically, the design criteria report will include the draft design assumptions and parameters, including:

  - Waste characterization;
  - Pretreatment requirements;
  - Volume of each media requiring treatment;
  - Treatment schemes (including all media and by-products);
  - Inputs/output rates;
  - Influent and effluent qualities;
  - Material and equipment;
  - Performance standards; and
  - Long-term monitoring requirements.

- **Outline of Draft Plans and Specifications** – Submittal will include an outline of the required plans and drawings, including sketches and layouts, describing conceptual aspects of the design, unit processes, etc. In addition, an outline of the required specifications, including performance standards, will be submitted.

- **Plan for Satisfying Permitting Requirements** – Plan will identify the permits that are required, the time required to process the permit applications and a schedule for submittal of the permit applications. Permits are discussed further in Section 4.1.6.

Specific tasks and objectives of the Draft Design related to the groundwater extraction and treatment system will include:

- Defining design objectives relative to how long the system will remain in operation (30+ years), operating frequency (24/7, downtime for maintenance), how the O&M will be performed, and level of automation required;

- Identifying major equipment needs and selecting vendors/manufacturers for non-standard treatment equipment and custom-designed components, which may involve obtaining competitive bids from more than one supplier;

- Finalizing the PFD, which is a single line diagram showing influents/effluents and other discharges, major equipment and pumps, and mass balance;

- Preparing the piping and instrumentation diagram, which shows treatment equipment and pumps (specifying type of pump and size), influent/effluent and discharge lines with sizing and materials of construction, piping components (e.g., valves, gauges, sample ports, control mechanisms), controls and interlocks, nomenclature of all equipment with indication of who is providing the equipment (e.g., vendor, client, others), and functional descriptions of controls;

- Developing control scheme related to integrating controls from various equipment;

- Developing a general equipment arrangement for sizing and locating a building to house the treatment equipment;

- Defining utility needs including electric for operating equipment, natural gas/propane for heating the building, steam for heat tracing and/or equipment operation, compressed air for instruments and system components, and potable water for cleaning and sanitary purposes/eyewash stations; and

- Developing a site plan showing locations of major site features, underground utility locations, treatment equipment building location, recovery and injection well locations, piping trench runs, and major utility sources and runs.

For the containment wall, specific tasks and objectives of the Draft Design will include:

- Developing plan and section view drawings based on the site plan described above and depicting the location and depth of the proposed containment wall; and

- Developing a Construction Quality Assurance Plan.

The Draft Design will also include a performance monitoring plan to evaluate the effectiveness of the Source Control IRM.

The Draft Design will be submitted for ODEQ and USEPA review. LSS will send an electronic version and two hard copies of the design submittal to ODEQ for review. One electronic and one hard copy will be submitted to USEPA for review.

4.1.5.2 Pre-Final and Final Design

The Pre-Final Design will function as the draft version of the Final Design. After agency review and comment on the Pre-Final Design, the Final Design will be submitted along with a memorandum indicating how the Pre-Final Design comments were incorporated into the Final Design. All Final Design documents will be certified by a Professional Engineer registered in the State of Oregon. The following items will be submitted as part of the Pre-Final/Final Design:

- **Complete Design Analyses** - The selected design will be presented along with an analysis supporting the design approach. Design calculations will be included;

- **Final Plans and Specifications** - A complete set of construction drawings and specifications will be submitted which describe the selected design; and

- **Final Construction Schedule** - A final construction schedule will be submitted.

The Pre-Final Design will be submitted for ODEQ and USEPA review. LSS will send an electronic version and two hard copies to ODEQ for review. One electronic and one hard copy will be submitted to USEPA for review. Comments on the Pre-Final Design will be incorporated into the Final Design, which will be used for bidding and construction purposes. Copies of this final document will be provided to ODEQ (2 hard copies and an electronic copy) and USEPA (one hard and one electronic copy).

4.1.6 Permitting

This task will include applying for, and negotiating, the necessary permits for installation and operation of the Groundwater Source Control IRM. Currently, it is envisioned that the following permits may be required:

- An Underground Injection Control permit (if reinjection of treated groundwater is planned);
- Possible groundwater extraction permits; and
- Negotiation with the City of Portland regarding the Greenway Overlay Zone (Greenway). The Greenway overlays limit development and fill (including pollution control structures) closer to the river than the landward edge of the Greenway setback. The overlays also impose specific development standards, planting requirements, and use restrictions. The proposed development must not be detrimental to the use and functioning of the river and abutting lands and must "conserve, enhance, and maintain scenic qualities and natural habitat." This overlay will need to be considered during planning and design of the containment wall.

Permitting activities will be performed during preparation and review of the Pre-Final/Final Design submittals.

4.1.7 Installation, Startup, and Operation and Maintenance

Following agency approval of the Pre-Final Design Submittal, the barrier wall and pump and treat system will be installed in accordance with the approved specifications and Construction Quality Assurance Plan and any modifications agreed upon from the comments to the Pre-Final Design submittal. Installation will likely need to occur during the dry season to avoid complications with construction. During construction, LSS will provide regular updates to ODEQ and USEPA regarding

construction progress and expected startup date. Following startup, LSS will provide regular project status updates to ODEQ and USEPA.

4.1.8 Source Control Implementation Report

Following installation and startup of the Source Control IRM, LSS will prepare and submit an SCIR in accordance with the JSCS. LSS understands that this report will be the sole report pertaining to the upland ground water source control evaluation. The purpose of the implementation report is to:

- Provide a summary of the remedial activities performed (i.e., construction report);
- Describe any significant deviations from the approved remedial systems design;
- Demonstrate the effectiveness of the source control measures; and
- Evaluate the completeness of the source control measures.

LSS will send an electronic version and two hard copies of the report to ODEQ for review. One electronic and one hard copy will be submitted to USEPA for review.

4.2 AGENCY REVIEW AND PUBLIC NOTIFICATIONS

It is expected that all significant Source Control IRM deliverables will be reviewed jointly by ODEQ and USEPA. As such, ODEQ and USEPA will be provided an opportunity to provide input on the source control measure including: the objectives, evaluation and selection process, design, implementation schedule, and the integration with the in-water RI/FS. Currently, a 60-day review time has been assumed for review by both agencies.

Public involvement requirements for source control decisions will be performed in accordance with ODEQ requirements. A public notice will be placed in a major Portland newspaper for the FFS, as the primary decision document. LLS will participate in public meetings and presentations with interested parties as necessary to explain source control activities and plans.

4.3 PRELIMINARY SCHEDULE

A preliminary project schedule for the Groundwater Source Control IRM is included as Figure 4-2.

5.0 IDENTIFICATION OF REMEDIAL TECHNOLOGIES FOR EVALUATION

The objective of this section is to provide a preliminary technology screening and to identify remedial technologies which will be evaluated as part of the FFS. As the presumptive approach for this IRM is a physical barrier wall coupled with a hydraulic containment system, only technologies relevant to these two response actions are considered.

The identified remedial technologies will be evaluated based on:

- **Effectiveness** (both sort- and long-term) of each alternative at protecting human health and the environment and reducing toxicity, mobility, or volume;
- **Implementability** as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining the remedial technology; and
- **Cost** (relative approximate or unit cost).

Compatibility with other remedial technologies which may be implemented at the site as part of the final remedy will also be considered.

5.1 CONSTITUENTS OF POTENTIAL CONCERN

As discussed above, the final list of COPCs will be initially screened during the Source Control Screening evaluation. The final determination will be provided in the FFS following the site specific risk evaluation. However, for the purposes of technology screening a tentative list of COPCs is provided below:

- Monochlorobenzene;
- Pesticides, including DDT, DDD, DDE, and total alpha-BHC;
- Other volatile organic compounds (VOCs), including 1,2-dichloroethane, benzene, carbon tetrachloride, chloroethane, chloroform, tetrachloroethene, and trichloroethene;

- Semi-volatile organic compounds (SVOCs), including fluoranthene and pyrene;
- Metals, including arsenic, chromium, lead, silver, and zinc; and
- Other inorganic constituents, including total chloride and perchlorate.

5.2 CONTAINMENT TECHNOLOGIES

Available groundwater containment technologies are listed in Table 5-1 with preliminary screening comments on feasibility, effectiveness, implementability, and cost of each technology.

Based on the preliminary technology screening in Table 5-1, the following groundwater barrier wall technologies are retained for evaluation in the FFS:

- Conventional slurry trench barrier wall;
- Vibrated beam slurry barrier wall; and
- Sealed steel sheet pile barrier wall.

Evaluation of groundwater containment technologies in the FFS will include identification of data gaps and the resulting uncertainties posed to the success of each technology, including, as appropriate:

- Compatibility with potential future riverbank grading, remediation, and/or capping;
- Transmissive zone thicknesses and hydraulic conductivity;
- Groundwater and surface water (including the river and on-site surface drainage) levels, flow paths, and flow velocity;
- Detailed topography of the barrier wall route, including the adjacent river bank, excavation work platform(s), and slurry mix pad(s);
- Limitations, or lack of limitations, on loads imposed on adjacent surfaces after construction;
- Vulnerability to seismic activity;

- Presence, type, thickness, extent, ability to remove, and need to maintain, replace, or restore to service existing overhead, surface and subsurface excavation obstructions;

- Range of initial and end dates of preferred construction season(s) and associated river stage, groundwater levels, and climatic conditions suitable for construction; and

- Availability of specialty equipment, personnel, and supplies.

5.3 EX SITU GROUNDWATER TREATMENT TECHNOLOGIES

Table 5-2 summarizes the ex situ groundwater treatment technologies selected for evaluation in the FFS along with the expected effectiveness for their target contaminants. Table 5-3 provides a preliminary evaluation of the effectiveness, implementability, and relative cost of each technology option. Minimal screening has been performed for groundwater treatment technologies at this early stage. Further evaluation, including groundwater modeling of expected contaminant concentrations and treatability testing, is needed to allow elimination of technologies.

The selected technologies and target contaminants for consideration in the FFS include:

- Air stripping (VOCs);

- Anaerobic biological treatment (primarily perchlorate, but may achieve some treatment for pesticides, VOCs, SVOCs);

- Chemical oxidation (pesticides, VOCs, SVOCs);

- Chemical precipitation (metals);

- Chemical reduction (pesticides, VOCs, hexavalent chromium, perchlorate);

- Ion exchange (perchlorate, possible metals depending on form); and

- Liquid-phase carbon adsorption (pesticides, VOCs, SVOCs).

Two technologies have been initially screened out and eliminated from further consideration: aerobic biological treatment and membrane

technologies. Aerobic biological treatment is not expected to be effective for many of the contaminants and provides little benefit from a cost perspective for those few compounds it may effectively treat. Membrane technologies are not believed to be necessary and would likely be more costly than any of the above technologies.

5.4 WATER HANDLING OPTIONS

Table 5-4 summarizes the discharge options to be considered for this project. Options currently under consideration include:

- Groundwater reinjection/infiltration (shallow or deep);
- Discharge to a publicly operated treatment works;
- Discharge to the municipal storm water system; and
- Direct discharge to the Willamette River.

In addition to treated groundwater, other discharges from the treatment processes will also need to be considered, which may include dewatered solids from a chemical precipitation process, ion exchange column backwash, and spent regenerant solution. Dewatered solids will likely be sent to a landfill, but the need for any treatment of the solids (e.g., solidification/stabilization) will be considered during the FFS evaluation. Ion exchange column backwash and spent regenerant solution can be problematic from a discharge standpoint and the only viable option may be a publicly operated treatment works due to the low flow, high concentration waste stream that will contain perchlorate and potentially other metals. Treating this discharge could be costly, and technologies capable of treating this high concentration stream may need to be considered. Additional preliminary considerations regarding water discharge options are provided in Table 5-4.

6.0 REFERENCES

AMEC 2001. *Draft Groundwater Transport Evaluation Data Needs Report, RPAC, Portland Site, Portland, Oregon. ATOFINA Chemicals, Inc., Portland, Oregon.* 2001.

ERM-West, Inc. (ERM) 2001. *Interim Remedial Measures Implementation Report, ATOFINA Facility, Portland, Oregon. ATOFINA Chemicals, Inc., Portland, Oregon.* 26 February 2001.

ERM 2005. *Upland Remedial Investigation Report Lots 3 & 4 and Tract A – Revision 1. ATOFINA Chemicals, Inc., Portland, Oregon.* December 2005.

ERM 2006a. *In Situ Persulfate Oxidation Interim Remedial Measure Status Update. ATOFINA Chemicals, Inc., Portland, Oregon.* 19 April 2006.

ERM 2006b. *Draft Acid Plant Area DNAPL Sampling Summary Report. ATOFINA Chemicals, Inc., Portland, Oregon.* 28 April 2006.

Exponent 1998. *ATOFINA Acid Plant Area Remedial Investigation and Feasibility Study Work Plan. ATOFINA Chemicals, Inc., Portland, Oregon.* September 1998.

Exponent 1999. *Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report. ATOFINA Chemicals, Inc., Portland, Oregon.* June 1999.

GeoSyntec 2006. *Workplan for a Pilot Test of In Situ Bioremediation of Perchlorate in Groundwater at the Former Atofina Chemicals Site, Portland Oregon. ATOFINA Chemicals, Inc., Portland, Oregon.* July 2006.

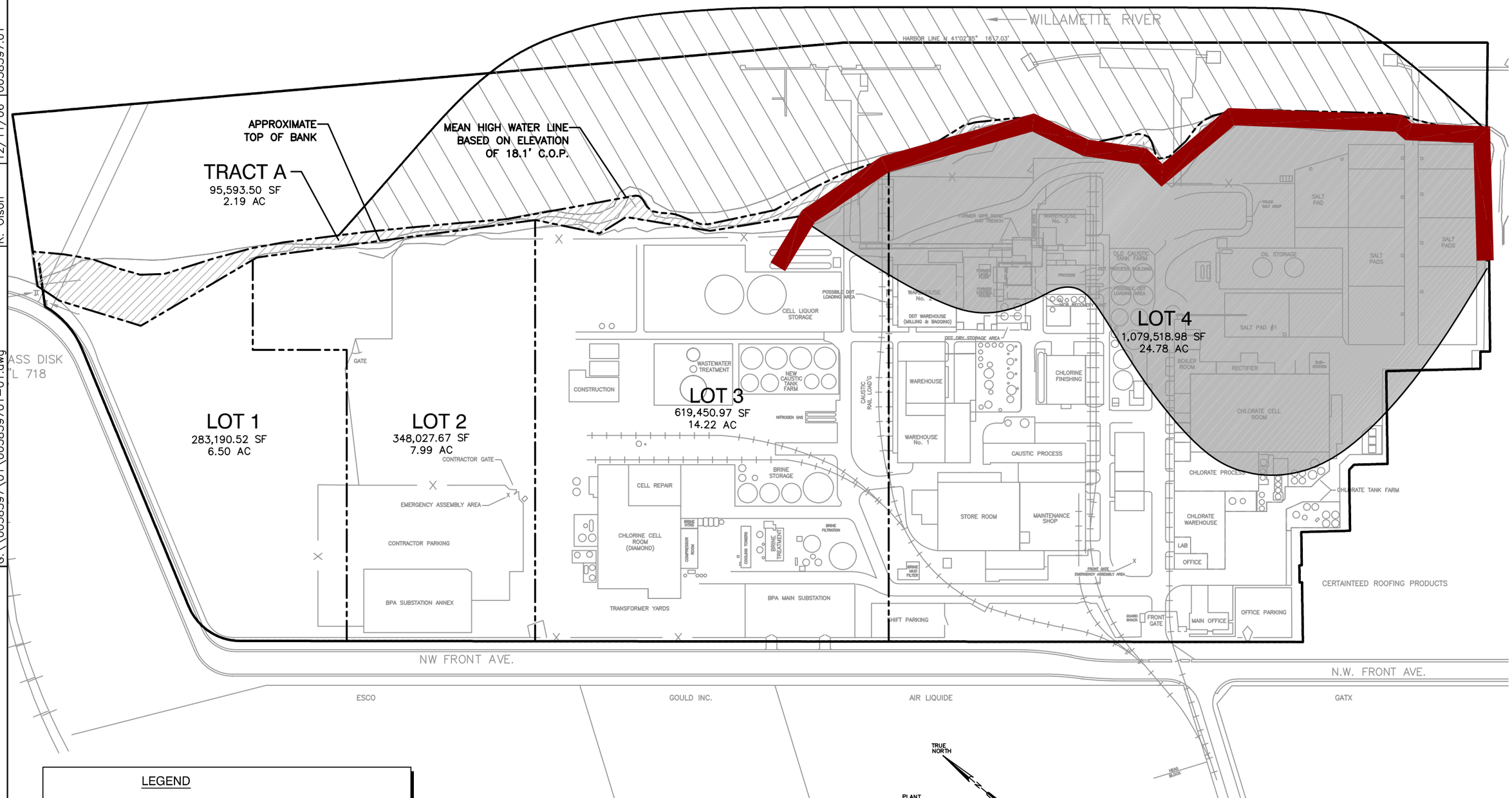
Integral 2003. *Phase II Stage 1 and 2 In-River Groundwater and Sediment Investigation Report. ATOFINA Chemicals, Inc., Portland, Oregon.* December 2003.

Oregon Department of Environmental Quality (ODEQ) 1998. Voluntary Remedial Investigation/Feasibility Study Agreement for the Acid Plant Area Project (ODEQ No. ECVC-WMCVC-NWR-97-14). 26 August 1998.

United States Environmental Protection Agency and Oregon Department of Environmental Quality 2005. *Final Portland Harbor Joint Source Control Strategy, Interim Final.* December 2005.

Figures

Project No. 0058397.01
Date: 12/11/06
Drawn By: R. Olson
CAD File: G:\0058397\01\005839701-01.dwg



LEGEND

- Site Boundary
- Preliminary Removal Action Area
- Approximate Lot Boundary
- Preliminary Upland Portion of the Arkema Site
- Conceptual Barrier Wall Location

Note:
Most buildings and structures noted on this diagram have been demolished and/or removed.

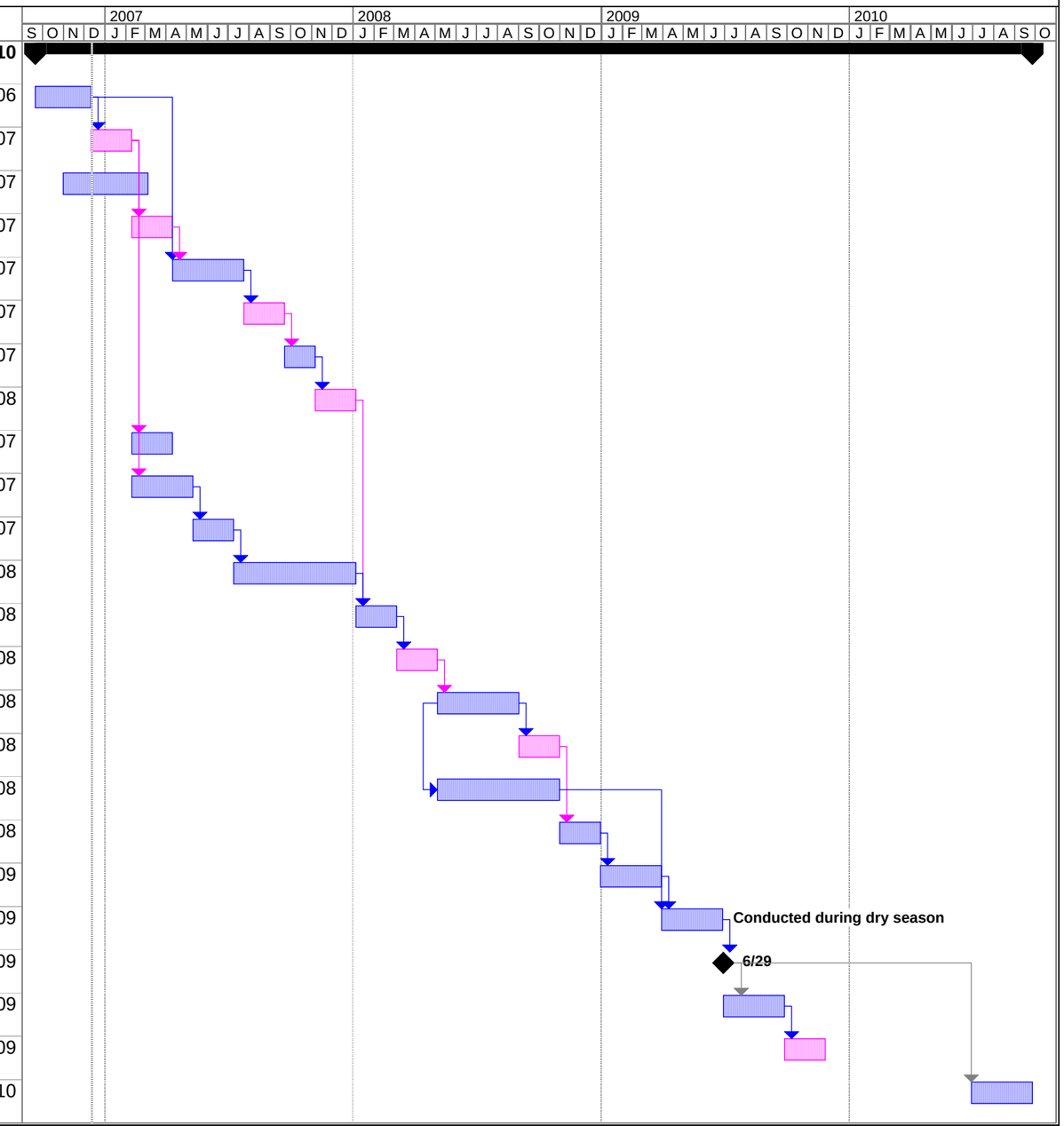
Figure 3-1
Conceptual Barrier Wall Layout
Groundwater Source Control IRM
Arkema Inc.
Portland, Oregon

ERM 12/06

12/12/2006 Revision

Figure 4-2
PRELIMINARY DRAFT SCHEDULE

ID	Task Name	Duration	Start	Finish
1	**GROUNDWATER SOURCE CONTROL IRM**	**1468 days**	**Thu 9/21/06**	**Mon 9/27/10**
2	Scoping Technical Memorandum	82 days	Thu 9/21/06	Mon 12/11/06
3	DEQ Review and Comment of Scoping Tech Memo	60 days	Tue 12/12/06	Fri 2/9/07
4	Groundwater Modeling and Report (or Meetings)	125 days	Wed 11/1/06	Mon 3/5/07
5	DEQ Review of Groundwater Modeling	60 days	Sat 2/10/07	Tue 4/10/07
6	Focused Feasibility Study (FFS)	105 days	Wed 4/11/07	Tue 7/24/07
7	DEQ Review and Comment on FFS	60 days	Wed 7/25/07	Sat 9/22/07
8	Revise and Resubmit FFS in response to comments	45 days	Sun 9/23/07	Tue 11/6/07
9	DEQ Approval and Public Review Notice	60 days	Wed 11/7/07	Sat 1/5/08
10	Geotechnical Evaluation	60 days	Sat 2/10/07	Tue 4/10/07
11	Treatability Studies	90 days	Sat 2/10/07	Thu 5/10/07
12	Groundwater Extraction and Treatment Pilot Study Planning	60 days	Fri 5/11/07	Mon 7/9/07
13	Groundwater Extraction and Treatment Pilot Study Performance	180 days	Tue 7/10/07	Sat 1/5/08
14	Draft Design Submittal	60 days	Sun 1/6/08	Wed 3/5/08
15	DEQ Review of Draft Design	60 days	Thu 3/6/08	Sun 5/4/08
16	Pre-Final Design Submittal and Specifications	120 days	Mon 5/5/08	Mon 9/1/08
17	DEQ Review and Approval of Pre-Final Design	60 days	Tue 9/2/08	Fri 10/31/08
18	Permitting	180 days	Mon 5/5/08	Fri 10/31/08
19	Final Design Submittal and Specifications	60 days	Sat 11/1/08	Tue 12/30/08
20	Procurement	90 days	Wed 12/31/08	Mon 3/30/09
21	Installation	90 days	Tue 3/31/09	Sun 6/28/09
22	Full System Startup	1 day	Mon 6/29/09	Mon 6/29/09
23	Groundwater Source Control Implementation Report	90 days	Tue 6/30/09	Sun 9/27/09
24	DEQ Review and Approval of Source Control Implementation Report	60 days	Mon 9/28/09	Thu 11/26/09
25	Performance/Enhancement Evaluation	90 days	Wed 6/30/10	Mon 9/27/10



Project Schedule

Task | Split | Milestone | Summary | Deadline

Note: Dates and duration of tasks shaded in gray are dependent on timing of agency review.

GW Source Control IRM Schedule.mpp

Tables

Table 4-1

Potential Treatability Studies and Associated Target Contaminants
Groundwater Source Control IRM Scoping Technical Memorandum
Arkema Inc. - Portland, Oregon

Potential Treatability Studies	Target Contaminants	General Description
Anaerobic Biological Treatment	Perchlorate is primary target. Remaining constituents may also be treated to some extent.	Standalone testing since likely to be first technology in the treatment process train. Fluidized bed reactor may be the preferred approach, but this will be determined in the FFS.
Chemical Oxidation	Pesticides, VOCs, SVOCs	If potentially cost effective based on preliminary evaluation, perform screening level study to assess potential effectiveness. If successful, perform more detailed testing to develop more accurate cost data.
Chemical Reduction/Precipitation	Hexavalent chromium and other metals	Standalone testing since likely to be first or second technology in the treatment process train. Will consider performing this testing on groundwater used for anaerobic biological treatment testing if sufficient volume can be generated. Chemical reduction step required for chromium to convert from hexavalent to trivalent state. Need to assess post-clarifier filtering requirements (if any) and solids settling characteristics.
Chemical Reduction	Pesticides, VOCs, SVOCs	If potentially cost effective based on preliminary evaluation, perform screening level study to assess potential effectiveness. If successful, perform more detailed testing to develop more accurate cost data.
Ion Exchange	Perchlorate is primary target. Metals may also be treated to some extent.	More complicated test since ion exchange may be the final technology in the treatment process train. Testing would likely require simulation of other treatment technologies to more accurately evaluate the performance of ion exchange. Anion exchange resin is required for perchlorate treatment, which may/may not treat other metals. Would need to assess quality of ion exchange resin backwash and spent regenerant solution to evaluate potential treatment/discharge options for these discharges.
Liquid-Phase Carbon Adsorption	Pesticides, VOCs, SVOCs	While liquid-phase carbon adsorption is a proven technology for these contaminants, performing some limited adsorption isotherm/capacity testing to evaluate major cost items such as carbon change-out frequency may be warranted. However, more complicated test since it may be the final or second to last technology in the treatment process train. Testing would likely require simulation of other treatment technologies to more accurately evaluate the performance of carbon. Will consider testing this without air stripping in the event liquid-phase carbon is more cost effective than air stripping with air emission control for treating VOCs.
Slurry Wall Chemical Compatibility	DNAPL, pH, TDS	Chemical compatibility testing of constituents in soil and ground water expected to be in contact with constructed containment components, including DNAPL, elevated pH, and TDS.

Notes:
SVOC = Semivolatile organic compound
VOC = Volatile organic compound
DNAPL = Dense non-aqueous phase liquid
TDS = Total dissolved solids

General Response Action	Remediation Technology	Process Option	Description	Effectiveness	Implementability	Cost	Summary of Evaluation
Containment	Ground Water Barrier Wall	Conventional Excavated Soil Slurry Wall	Construct barrier wall and related facilities in stages. • Clear surface and subsurface obstructions. • Grade excavation and slurry mix pads. • Excavate trench to depth supported by mined clay slurry; usually 3 feet wide. • Mix excavation spoil, slurry, and, if necessary, imported fines and/or mined clay to make soil-slurry backfill. • Place soil-slurry backfill in slurry trench in stages that fill trench without voids. • Due to limited slurry backfill slump and excavation clearances, a 60-VF deep wall would require 400 to 600 LF of trench to be open during all but initial and final stages of excavation. • Stabilize upper part of backfill to support surface loads, if necessary. • Construct well-drained low-permeability cap over slurry wall. • Provide ground water extraction facilities to maintain an adequate inward gradient and to control affected ground water flow. • Install pairs of piezometers on exterior and interior sides of the wall to confirm effectiveness of the wall.	Good effectiveness for containment of affected ground water. • Slurry backfill hydraulic conductivity usually less than 1 x 10E-07 cm/sec. • Can divert affected ground water toward a permeable reactive barrier or capture zone. • Needs ground water extraction to prevent increased ground water levels on upgradient side of wall, flow through the wall due to high hydraulic gradient across the wall, or migration around the end of the wall if not completely surrounding affected groundwater. .	Good potential for implementability in suitable locations: • Adequate site characterization and ground water modeling to select final location and ground water extraction rate needed. • Clearance of subsurface objects > 18-inch maximum dimension. • Adequate provision for permanent or temporary plugging of crossing pipes and site drainage during construction. • Clearance of structural surfacing. • Nearly level excavation pad approximately 20-feet wide. • Nearly level slurry mix pad with width approximately equal to trench depth. • Adequate quality slurry mix water supply. • Adequate native soil fines in excavation spoil or adequate quality and quantity of imported clay soil. • Adequate compatibility of slurry and slurry backfill with formation pore water and soil constituents, esp. TDS. • Limited, if any, affected excavation spoil and other affected waste. • Overall production rate expected to be roughly 50 LF per work day. • Proven technology used to control affected ground water at many similar sites in US.	Average range total present value. • Average range mobilization and demobilization costs. • Average range site preparation cost. • Average range construction cost. • Average CQA cost. • Low range post-RA cost. • Average overall present value.	• Retain for further screening and evaluation in the FFS.
		Shielded Ladder Trench Excavated Soil Slurry Wall	Similar to Conventionally Excavated Soil Slurry Wall, except: • Shallow slurry reservoir trench needed to provide slurry reserve. • No slurry mix pad required. • Trench supported by slurry and steel plate shield. • Usually 1 to 2 feet wide. • Mix excavation spoil, slurry, and, if necessary, imported fines and/or mined clay with ladder excavator-mixer in trench to make slurry backfill. • Only a few feet of trench open at any time.	Good effectiveness, similar to Conventional Excavated Soil Slurry Wall, except: • Depth is limited to approximately 35 VF below work platform.	Poor potential for implementability at this site; otherwise similar to Conventional Excavated Soil Slurry Wall, except:: • Needs clearance of subsurface objects > 6-inch maximum dimension. • Not practical for depths greater than 35 VF below excavation work platform. • Excavation to 60 VF depth needed would require excavation of many thousands of CY of affected soil and, if not allowed to be used as backfill, on-site or off-site disposal. • Overall production rate expected to be roughly 300 to 600 LF per work day.	Low to average range overall present value. • High range mobilization and demobilization costs. • Average range site preparation cost. • Low to average range construction cost. • Low to average waste management cost. • Low to average CQA cost. • Low range post-RA cost.	• Omit from further consideration because of inadequate depth capability.

General Response Action	Remediation Technology	Process Option	Description	Effectiveness	Implementability	Cost	Summary of Evaluation
		Conventional Excavated Plastic Concrete Slurry Wall	Similar to Conventional Excavated Soil Slurry Wall, except: • No slurry mix pad needed. • Portland cement of other suitable S/S reagent is added to slurry. • All native soil excavation spoil is placed in on-site or off-site waste disposed cell or landfill. • Key into prior partially-set plastic concrete wall when restarting work from overnight or weekend work break. • Usually have 50 to 100 LF of slurry trench open at a time.	Good effectiveness, similar to Conventional Excavated Soil Slurry Wall, except: • Hydraulic conductivity is typically one or two orders of magnitude higher that a soil slurry wall in similar conditions.	Good potential for implementability in suitable locations, similar to Conventional Excavated Soil Slurry Wall, except:: • Would require much more slurry trench excavation soil waste management. • Would require a higher rate of ground water extraction and treatment. • Overall production rate expected to be roughly 50 to 75 LF per work day.	Average to high overall present value. • Average range mobilization and demobilization costs. • Average range site preparation cost. • Average to high range construction cost. • High range waste management cost. • Average CQA cost. • Average range post-RA cost.	• Omit from further consideration because of much higher construction and waste management costs.
		Shielded Ladder Trench Excavated Plastic Concrete Slurry Wall	• Similar to Shielded Ladder Trench Excavated Slurry Wall, except: • Portland cement or other suitable S/S reagent is added to slurry.	Good effectiveness, similar to Shielded Ladder Trench Excavated Soil Slurry Wall, except : • Hydraulic conductivity is typically two or three orders of magnitude higher for similar conditions.	Poor potential for implementability at this site; otherwise similar to Shielded Ladder Trench Soil Slurry Wall, except:: • Would require a higher rate of ground water extraction and treatment. • Not practical for depths greater than 35 VF. • Overall production rate expected to be roughly 50 LF per work day. • Overall production rate expected to be roughly 300 to 500 LF per work day.	Average to high range overall present value. • High range mobilization and demobilization costs. • Average range site preparation cost. • Average to high range construction cost. • Low to average waste management cost. • Low to average CQA cost. • Average range post-RA cost.	• Omit from further consideration because of inadequate depth capability and higher construction and waste management costs.

General Response Action	Remediation Technology	Process Option	Description	Effectiveness	Implementability	Cost	Summary of Evaluation
		Vibrated Beam Plastic Concrete Slurry Wall	Construct barrier wall and related facilities in stages. • Clear surface and subsurface obstructions. • Grade excavation pads (no slurry mix pad is needed). • Excavate shallow slurry reservoir trench; approximately 50 to 75 LF open at a time. • Advance 4-inch wide x 3-LF excavation-slurry injection tool vertically from the surface to the target total depth by jetting cement slurry through nozzles in the base of the excavation tool. • Mix native soil and injected cement in panel as the excavation-injection tool is withdrawn. • Overlap excavation-injection panels to establish continuity of the wall. • Approximately 50 to 75 LF of panels open at a time; only one 3 LF panel worked at a time. • Panels gain strength usually adequate to support surface loads without further solidification. • Relatively small volume of expanded formation expelled from excavation could be placed in slurry trench, unless constituent concentrations require special management. • Construct well-drained low-permeability cap over slurry wall. • Provide ground water extraction facilities to maintain an adequate inward gradient and to control affected ground water flow. • Install pairs of piezometers on exterior and interior sides of the wall to confirm effectiveness of the wall.	Good effectiveness similar to a Conventional Excavated Soil Slurry Wall, except: • Hydraulic conductivity ranges between 10E-06 cm/sec and 10E-08 cm/sec. • The relatively thin wall produces much higher hydraulic gradients than conventional slurry walls, although permeability still multiple orders of magnitude less than the native formation.	Good potential for implementability in suitable locations, similar to Conventional Excavated Soil Slurry Wall, except: • Depth limited to approximately 80 VF. • Does not require exacavtion/removal of soil. • Can generally be constructed in areas with less width available for excavation-injection equipment. • Would require a higher rate of ground water extraction and treatment. • Overall production rate expected to be roughly 50 to 75 LF per work day.	Average range overall present value. • Average to high range mobilization and demobilization costs. • Average range site preparation cost. • Average range construction cost. • Low to average waste management cost. • Average range CQA cost. • Low to average range post-RA cost.	• Retain for further screening and evaluation in the FFS.

General Response Action	Remediation Technology	Process Option	Description	Effectiveness	Implementability	Cost	Summary of Evaluation
		HDPE Curtain Wall	Construct barrier wall and related facilities in stages similar to a Conventional Soil Slurry Wall, except: • Prior to placement of slurry backfill, deploy a HDPE membrane into the open trench using a crane supporting a deployment frame. • Seal panel joints using a suitable sealant resistant to ground water constituents and the formation. • Slurry backfill is placed on both sides of the membrane after the membrane is deployed to total depth.	Poor to excellent effectiveness, depending on quality of the installation, and similar to Conventional Excavated Soil Slurry Wall, except: • HDPE barrier, if installed properly, can greatly reduce the effective hydraulic conductivity of the barrier wall.	Poor potential for implementability at this site; otherwise similar to Conventional Excavated Soil Slurry Wall, except: • The relatively thin HDPE membrane is difficult to place and is susceptible to damage during placement in the slurry trench. • Overall production rate expected to be roughly 50 to 300 LF per work day	High range overall present value. • High range to high range mobilization and demobilization costs. • Average range site preparation cost. • Average to high range construction cost. • Low to average range waste management cost. • Average to high range CQA cost. • Low to average range post-RA cost.	Omit from further consideration because of high implementability uncertainty and high construction and waste management costs.
		HDPE Panel Wall	Construct barrier wall and related facilities in stages similar to a HDPE Membrane Wall, except: • Push 4- to 8-foot wide vertical HDPE panels directly into low permeability layer at the base of the formation using a mandrel frame. • Seal panel joints using a suitable sealant resistant to ground water and constituents affecting ground water and the formation.	Poor to excellent effectiveness, similar to the HDPE Membrane Wall, except: • HDPE barrier panel joints may be marginally more transmissive than the membrane in the panels.	Low potential for implementability at this site; otherwise similar to HDPE Membrane Wall, except: • Depth limited by resistance of the formation to the placement mandrel and HDPE panel, probably limiting the placement depth to much less than the 60 VF depth needed. • Excavation to 60 VF depth needed would require excavation of many thousands of CY of affected soil and, if not allowed to be used as backfill, on-site or off-site disposal. • Overall production rate expected to be roughly 50 to 300 LF per work day	High range overall present value. • High range mobilization and demobilization costs. • Average range site preparation cost. • Average range to high range construction cost. • Low to average range waste management cost. • Average to high range CQA cost. • Low to average range post-RA cost.	Omit from further consideration because of high implementability uncertainty and high construction and waste management costs.
		Biofilm Barrier	Construct barrier wall and related facilities in stages: • Construct nutrient injection wells. • Inject nutrient solution to establish and maintain vigorous and persistent low permeability microflora and microfauna barrier wall. • Monitor effectiveness with piezometers and monitoring wells similar to facilities for other barrier wall technology options.	Poor to excellent effectiveness, depending on: • Compatibility of the biofilm organisms to constituents in ground water and the formation. • May be poorly effective in zones affected by DNAPL. • Resulting effectiveness of ground water control. • Existence of storm sewer controls.	Poor to excellent potential for implementation at this site, depending on: • Number of zones to be injected and well spacing needed to produce an effective biobarrier. • Nutrient injection type and rate needed to establish and maintain biobarrier. • Acceptability of release of excess nutrients on the river side of the biobarrier.	Low to high overall present value. • Low range mobilization and demobilization costs. • Low range site preparation cost. • Average range construction cost. • Low to average range waste management cost. • Low range CQA cost. • Average to high range post-RA cost. Average overall present value.	Omit from further consideration because of high implementability uncertainty and lack of applicability to all site constituents.

General Response Action	Remediation Technology	Process Option	Description	Effectiveness	Implementability	Cost	Summary of Evaluation
		Frozen Earth Barrier	Construct barrier wall and related facilities in stages: • Construct network of refrigerant conduits in parts of the formation needing control. • Construct and operate a refrigeration plant to freeze groundwater in the zones desired. • Construct effectiveness monitoring piezometers and wells similar to other barrier wall technology options.	Poor to good effectiveness, depending on: • Compatibility of the freezing process with ground water, especially in areas affected by brine and elevated TDS. • May be poorly effective in zones affected by DNAPL. • Lack of storm sewer control needs to be added to surface water controls.	Poor potential for implementation at this site, depending on: • Number of refrigerant lines and plants needed to produce an effective barrier. • Ability to avoid subsurface obstructions. • Thermal conductivity of the formation and related refrigerant load. • Ability to establish and maintain an effective barrier at elevations adequate to control infiltration and exfiltration of affected ground water during and following seasonal and storm-caused high river stage.	High range overall present value. • Average range mobilization and demobilization costs. • Average range site preparation cost. • High range construction cost. • Average range waste management cost. • Average to high range CQA cost. • High range post-RA cost.	Omit from further consideration because of high implementability uncertainty and high construction cost.
		Conventional Steel Sheet Pile Wall	Construct barrier wall and related facilities in stages: • Clear surface and subsurface obstructions. • Drive steel sheet piles from surface into a low permeability layer at the base of the formation using a conventional pile driver. • Connect sheets with structural sheet, but unsealed, joints. • Cut off sheet pile below surface and cap with a compacted clay layer to reduce surface infiltration. • Provide ground water extraction facilities to maintain an adequate inward gradient and to control affected ground water flow. • Install pairs of piezometers on exterior and interior sides of the wall to confirm effectiveness of the wall.	Moderate to good effectiveness depending on: • Ability to drive to the depth needed. • Quality of the installation. • Joint configuration. • Joint spacing. • Hydraulic gradient across the joint gap.	Good potential for implementability at this site in suitable locations, similar to other barrier walls, except: • Proven technology of somewhat limited use for control of affected ground water. • Lengths in excess of 40 LF may require specialty supply and equipment; probably limited to max depth of 60 VF. • Any significant size durable subsurface obstructions can prevent placement. • Placement pad elevation and scope can vary more than for slurry walls. • No significant excavation required or excavation spoil generated. • Compatible with most soil constituents, but might be affected by contact with low pH and high TDS ground water and soil. • Overall production rate expected to be roughly 25 to 50 LF per work day.	High range overall present value. • Average range mobilization and demobilization costs. • Average to high range site preparation cost. • High range construction cost. • Low range waste management cost. • Low to average range CQA cost. • Low to average range post-RA cost	Omit from further consideration because of high implementability uncertainty and high construction cost.
		Sealed-Joint Steel Sheet Pile Wall	Construct barrier wall and related facilities in stages similar to Conventional Steel Sheet Pile Wall, except: • Connect sheets with structural sheet seal and suitable sealant resistant to affected ground water and formation.	Good effectiveness depending on uncertainties similar to Conventional Steel Sheet Pile Wall, plus: • the compatibility of the joint sealant with affected ground water and formation.	Good potential for implementability depending on uncertainties similar to Conventional Steel Sheet Pile Wall, plus: • Better suited to ground water control. • Long lengths may not be available. • Work platform excavation and backfill may be necessary to achieve target depth.	High range overall present value. • Average range mobilization and demobilization costs. • Average to high range site prep cost. • High range construction cost. • Low to average range waste management cost. • Average range CQA cost. • Low to average range post-RA cost.	Retain for further screening and evaluation in the FFS.

General Response Action	Remediation Technology	Process Option	Description	Effectiveness	Implementability	Cost	Summary of Evaluation
		Sealed-Joint PVC Sheet Pile Wall	Construct barrier wall and related facilities in stages similar to Sealed Steel Sheet Pile Wall, except: • Use PVC sheet pile in lieu of steel sheet pile. • Excavate a work platform to achieve a level compatible with the length limit of PVC sheet pile. • Apply and cure a suitable sealant to the full length of each joints that is resistant to ground water and constituents affecting ground water and the formation • Push PVC sheet pile from the work platform through the formation and into low permeability layer at the base of the formation using a mandrel frame.	Good to excellent effectiveness similar to Sealed Steel Sheet Pile Wall, plus: • Enhanced compatibility of the PVC sheet and sealant with affected ground water and formation.	Poor potential for implementability depending on uncertainties similar to Sealed Steel Sheet Pile Wall, plus: • Not a structural wall. • Needs extensive work platform excavation due to sheet length limits and depths needed. • May need supplemental barrier to cut of infiltration and exfiltration of affected ground water above the barrier during and flowing high river stage. • Compatible with most soil constituents, but might be affected by contact with organics, especially chlorinated solvents and related constituents.	Average to high range overall present value. • Average range mobilization and demobilization costs. • Average to high range site preparation cost. • Average to high range construction cost. • Low range waste management cost. • Average range CQA cost. • Low to average range post-RA.	Omit from further consideration because of high implementability uncertainty and high construction cost.
	Hydraulic Groundwater Barrier	Groundwater Extraction Using Conventional Vertical Wells	Create a hydraulic barrier to capture affected groundwater prior to migration off site: • Construct groundwater extraction wells, including nested wells if necessary. • Place well pumps to extract groundwater at rates that accomplish capture adequate to control migration of affected ground water.	Moderate to excellent effectiveness depending on: • Ability to capture ground water at necessary rates; • Compatibility of well, pumps, and related components with affected ground water and soil; and • Long term resistance to well efficiency decline due to biofouling, chemical precipitation, or corrosion.	Good potential for implementability at this site in suitable locations: • Proven technology if site is suitable. • Additional wells or well pump capacity makes system flexible for meeting GWE needs. • If used as a perimeter control without a barrier wall, will need to be sized to remove off-site ground water in addition to controlling migration of affected ground water. • Some well excavation spoil and well development water generated. • Treatment and discharge of affected ground water will be necessary.	Average to high range overall present value. • Low to average range mobilization and demobilization costs. • Low to average range site preparation cost. • Low to average range construction cost, excluding treatment. • Low range waste management cost. • Low to average range CQA cost. • Average to high range post-RA, excluding treatment.	Retain as a GWE component combined with an appropriate ground water barrier wall.

Table 5-2

Ex Situ Groundwater Treatment Technologies and Associated Target Contaminants
Groundwater Source Control IRM Scoping Technical Memorandum
Arkema Inc. - Portland, Oregon

Target Contaminant	Selected Ex Situ Groundwater Treatment Technologies						
	Air Stripping	**Anaerobic Biological Treatment**	**Chemical Oxidation**	**Chemical Precipitation**	**Chemical Reduction**	**Ion Exchange**	**Liquid-Phase Carbon Adsorption**
	Volatile compounds removed from groundwater via countercurrent flow of air through perforated trays	Compounds degraded by anaerobic bacteria in fluidized bed reactor	Compounds degraded using chemical oxidants (e.g., ozone, hydrogen peroxide)	Metals removed in insoluble form (e.g., hydroxide) via pH adjustment and settling	Compounds degraded using chemical reductants (e.g., zero-valent iron, sodium metabisulfite)	Ionic compounds adsorbed on polymeric resin and replaced by innocuous ions (e.g., chloride, sodium)	Compounds adsorbed on granular activated carbon
Pesticides							
DDT, DDD, DDE		X(1,2)	X(1,2)		X(1,2)		X
alpha-BHC		X(1,2)			X(1,2)		X
Volatile Organic Compounds (VOCs)							
1,2-Dichloroethane	X		X(2)				X
Benzene	X		X				X
Chlorobenzene	X		X				X
Chloroethane	X		X(2)				X
Chloroform	X		X				X
Chlorinated Ethenes (PCE, TCE, VC)	X	X	X		X(1,2)		X
Semivolatile Organic Compounds (SVOCs)							
Fluoranthene		X(1,2)	X				X
Pyrene		X(1,2)	X				X
Metals							
Arsenic				X		X(1)	
Chromium (includes hexavalent chromium)				X	X(3)	X(1)	
Lead				X		X(1)	
Silver				X		X(1)	
Zinc				X		X(1)	
Other Inorganics							
Perchlorate		X				X	

Notes:

X = Technology is expected to be effective for listed contaminant. Treatability testing may still be required.
(1) = Potentially effective. Technology may require specific site conditions for effectiveness or may not be proven in the field for particular contaminant. Treatability testing would be recommended if appears to be cost effective.
(2) = Partial treatment expected. Technology would be expected to result in incomplete treatment of contaminant.
(3) = Preliminary step before additional treatment.
Blank = Technology is not expected to be effective for listed contaminant.
PCE = Tetrachloroethene
TCE = Trichloroethene
VC = Vinyl chloride

Table 5-3

Preliminary Evaluation of Ex Situ Groundwater Treatment Technologies
Groundwater Source Control IRM Scoping Technical Memorandum
Arkema Inc. - Portland, Oregon

Remediation Technology	Effectiveness	Implementability	Cost	Summary of Evaluation
Air Stripping	Generally effective for volatile compounds, primarily VOCs.	Technically implementable. Potential equipment fouling from inorganic scaling and biological growth. Additional vapor-phase treatment technology may also be required for off-gas. Requires performance of periodic monitoring to ensure achievement of treatment goals.	Low capital. Low to moderate O&M.	Expected to be least costly treatment technology, and is preferred alternative for VOCs. Need for treatment of off-gas will increase cost.
Anaerobic Biological Treatment	Effective for perchlorate, and expected to provide limited treatment for pesticides, VOCs (primarily chlorinated ethenes), and SVOCs.	Technically implementable. Process requires fairly consistent characteristics and low concentrations of toxic compounds (e.g., pesticides) in influent, and can be prone to upset. Process will generate biosolids, requiring handling and disposal. Requires performance of periodic monitoring to ensure achievement of treatment goals.	High capital. High O&M.	Proven technology for perchlorate, and will be evaluated against ion exchange as preferred treatment option for perchlorate. Concern over ability of technology to adapt to changing influent conditions and presence of toxic compounds, as well as disposal of biosolids.
Chemical Oxidation	Generally effective for VOCs and SVOCs, and expected to provide limited treatment for pesticides.	Technically implementable. Effectiveness depends on selection of proper chemical oxidant, and other compounds present in influent may interfere with treatment and create high oxidant demand. Storage and handling of oxidant may present health & safety issues. Requires performance of periodic monitoring to ensure achievement of treatment goals.	Moderate capital. Moderate to high O&M.	Although potentially effective for treatment of pesticides, VOCs, and SVOCs, technology is not a preferred treatment alternative. If required, may be used as supplemental and/or polishing treatment step.
Chemical Precipitation	Generally effective for metals, assuming metals present in dissolved form and proper valence state.	Technically implementable. Effectiveness depends on form and valence state of metals in influent. Process will generate sludge, requiring handling and disposal. Additional filtering of treated effluent may be required to achieve discharge standards. Requires performance of periodic monitoring to ensure achievement of treatment goals.	High capital. High O&M.	Proven technology for metals, and will be evaluated against ion exchange as preferred treatment option for metals. Effectiveness of technology for metals removal must be evaluated. Concern over handling of sludge and need for additional filtration of effluent.
Chemical Reduction	Effective for hexavalent chromium, and expected to provide limited treatment for pesticides and VOCs (primarily chlorinated ethenes).	Technically implementable. Effectiveness depends on selection of proper chemical reductant, and other compounds present in influent may interfere with treatment. Storage and handling of reductant may present health & safety issues. Requires performance of periodic monitoring to ensure achievement of treatment goals.	Moderate capital. Moderate to high O&M.	Although potentially effective for treatment of pesticides and VOCs, technology is not a preferred treatment alternative. However, if chemical precipitation is selected for metals treatment, may be used to convert chromium from hexavalent to trivalent state.
Ion Exchange	Generally effective for perchlorate and metals, assuming metals present in ionized form (either dissolved (e.g., trivalent chromium) or complexed (e.g., chromate)).	Technically implementable. Perchlorate removed using anion exchange resin. Effectiveness for metals depends on form and valence state of metals in influent. Resin regeneration process will generate concentrated contaminant stream, requiring handling and disposal. Requires performance of periodic monitoring to ensure achievement of treatment goals.	High capital. High O&M.	Proven technology for perchlorate, and will be evaluated against anaerobic biological treatment as preferred treatment option for perchlorate. Effectiveness of technology for metals removal must be evaluated, and may result in use of cation and anion exchange resins in series. Spent regenerant solution would require special handling.
Liquid-Phase Carbon Adsorption	Generally effective for organic compounds, including pesticides, VOCs, and SVOCs.	Technically implementable. Proven technology for removal of organic compounds. Potential equipment fouling from solids. Periodic replacement of carbon beds required. Requires performance of periodic monitoring to ensure achievement of treatment goals.	Moderate capital. Moderate to high O&M.	Expected to be relatively low cost treatment technology, and is preferred alternative for pesticides and SVOCs. May also be used as polishing treatment step for VOCs.

Notes:
VOCs = Volatile organic compounds
SVOCs = Semivolatile organic compounds
O&M = Operation and maintenance

Table 5-4

Treated Groundwater Discharge Options

Groundwater Source Control IRM Scoping Technical Memorandum

Arkema Inc. - Portland, Oregon

Discharge Option[1]	General Description	Technical Considerations	Regulatory Considerations
Reinjection in Shallow Ground Water Zone	Treated groundwater would be injected into a series of shallow injection wells, trenches, basin, or infiltration gallery.	Infiltration/injection testing would be needed to assess ability of formation to accept groundwater. Could perform testing as part of pumping tests and discharge pumped groundwater into existing or new wells. May provide some benefit if it can be used in combination with pumping to maintain hydraulic control at a lower overall pumping rate. Fouling by solids and/or biological growth is a concern, and use of a biocide and/or periodic redevelopment of wells may be required.	Discharge option contingent upon receipt of underground injection control (UIC) permit from ODEQ. Discharge limits likely intermediate between POTW and storm sewer/river options. Reinjection (shallow and/or deep) may be preferred option if POTW will not accept treated groundwater.
Reinjection in Deep Ground Water Zone	Treated groundwater would be injected into a series of deep injection wells.	Injection testing would be needed to assess ability of formation to accept groundwater. Could perform testing as part of pumping tests and discharge pumped groundwater into existing or new wells. May provide some benefit if it can be used in combination with pumping to maintain hydraulic control at a lower overall pumping rate. Fouling by solids and/or biological growth is a concern, and use of a biocide and/or periodic redevelopment of wells may be required.	Discharge option contingent upon receipt of UIC permit from ODEQ. Discharge limits likely intermediate between POTW and storm sewer/river options. Reinjection (shallow and/or deep) may be preferred option if POTW will not accept treated groundwater. Injection into brackish deeper aquifers could result in lowered discharge requirements (relative to shallow aquifer) for chloride and other dissolved solids.
Discharge to POTW	Treated groundwater would be discharged to the municipal POTW sewer system.	Issues to consider include proximity of nearest discharge location and available capacity of the sewer line and down-pipe pumping stations. May be the only option for ion exchange resin backwash and spent regenerant solution since this will be a low flow, high concentration stream.	Discharge option contingent upon municipality acceptance of the discharge, and further evaluation of this option is recommended. Discharge limits may be less stringent relative to reinjection, storm sewer, and river options, as POTW pretreatment requirements will dictate the extent to which this water must be treated.
Discharge to Municipal Storm Water System	Treated groundwater would be discharged to the municipal storm water sewer system.	Issues to consider include proximity of nearest discharge location, available capacity of the storm water line, and acceptability to municipality.	Discharge option contingent upon municipality acceptance of the discharge, and likelihood of acceptance considered low due to eventual discharge of storm sewer to Willamette River. Assuming storm sewer discharges to river, Joint Source Control Strategy may dictate pretreatment requirements.
Discharge to Willamette River	Treated groundwater would be discharged directly to the Willamette River, either through a discharge pipe or diffuser.	Proper design of outfall necessary to prevent potential erosion and/or discharge issues.	Discharge limits could be most stringent under this scenario, as Joint Source Control Strategy will dictate pretreatment requirements.

Notes:

(1) - One or combination of discharge options may be used for treated groundwater.

ODEQ = Oregon Department of Environmental Quality

POTW = Publicly operated treatment works

UIC = Underground injection control

Appendix A

Groundwater Modeling Scoping Technical Memorandum

APPENDIX A - DESIGN AND CALIBRATION OF SITEWIDE GROUNDWATER MODEL TECHNICAL MEMORANDUM

A.1 INTRODUCTION

A three-dimensional, numerical groundwater model for the Arkema, Inc., (Arkema) facility in Portland, Oregon, is being developed to support the Focused Feasibility Study (FFS) of the impacted groundwater at the facility. This Technical Memorandum briefly describes the design of the groundwater model and the methods that will be used to calibrate the model to observed groundwater conditions at the facility.

The Arkema sitewide groundwater model will be designed and calibrated in accordance with the American Society for Testing and Materials (ASTM) guidelines for groundwater modeling (ASTM, 1996) and generally accepted industry practice (Anderson and Woessner, 1992; Zheng and Bennett, 1995). The ASTM guidelines were developed as part of a cooperative agreement between the United States Environmental Protection Agency (USEPA), the U.S. Geological Survey (USGS), and the U.S. Navy.

A.2 OBJECTIVES OF SITEWIDE GROUNDWATER MODEL

The Arkema sitewide groundwater model will be used to more fully characterize the groundwater flow system at the facility, and determine the fate and transport of constituents of concern in the groundwater. The groundwater model will also be used to evaluate containment and extraction alternatives for remediating groundwater at the facility, and to develop preliminary design specifications for the selected remedial systems in support of the FFS.

A.3 MODEL CODE SELECTION

A.3.1 GROUNDWATER FLOW

The model code that will be used to develop the Arkema sitewide groundwater flow model is MODFLOW, a three-dimensional, finite-difference, groundwater flow model developed by the USGS (McDonald and Harbaugh, 1988). MODFLOW was selected for development of the sitewide flow model because it is nonproprietary, well documented, and has been verified for a wide range of field problems (USEPA, 1993). Numerous models based on this code have been published in technical journals.

A.3.2 CONTAMINANT TRANSPORT

A.3.2.1 Advective Transport

The model code PATH3D will be used to simulate the advective transport of solutes in the groundwater. PATH3D is a three-dimensional, numerical, particle tracking code for calculating groundwater flow paths and travel times from the head solution output by MODFLOW. This model code was developed at the University of Wisconsin - Madison, and the Wisconsin Geological and Natural History Survey (Zheng, 1989). PATH3D is well documented and has been verified for a range of field problems.

A.3.2.2 Solute Transport

Solute transport will be simulated with the model code MT3DMS. MT3DMS is a three-dimensional, finite-difference, solute transport model code developed by Zheng and Wang (1999) with funding from the U.S. Army Corps of Engineers Waterways Experiment Station. MT3DMS was selected for solute transport simulation because it is nonproprietary, well documented, and is designed to be used with MODFLOW. Numerous models based on this and an earlier version of this code, MT3D (Zheng, 1990, 1993), have been published in technical journals.

MT3DMS offers several different methods for solution of the advection-dispersion-reaction equation. For the Arkema site-wide model, the MT3DMS transport simulations will be solved using a total variation

diminishing (TVD) method for solution of the advection term (Zheng and Wang, 1999). The TVD method implemented in MT3DMS is a third-order TVD method with a universal flux limiter. This TVD method minimizes numerical dispersion and suppresses spurious oscillations in the model concentration while preserving sharp concentration fronts.

A.4 MODEL DESIGN

The Arkema sitewide groundwater model will be designed and constructed with Groundwater Vistas™, a computer-aided design program for groundwater modeling (Environmental Simulations Inc., 2004). Groundwater Vistas™ fully supports the model codes MODFLOW (McDonald and Harbaugh, 1988), PATH3D (Zheng, 1989), and MT3DMS (Zheng and Wang, 1999), which will be to develop the sitewide groundwater model.

A.4.1 MODEL GRID

In a numerical groundwater model, the continuous groundwater flow field is approximated by a discretized domain consisting of an array of grid nodes and associated grid blocks. This nodal grid forms the framework of the numerical model.

MODFLOW uses a block-centered, finite-difference grid to simulate a continuous groundwater flow field (McDonald and Harbaugh, 1988). With this method the grid blocks are rectangular in shape and the grid nodes are located at the centers of the grid blocks.

The grid blocks are organized vertically into layers. The model grid layers represent the different hydrostratigraphic units within the groundwater flow field simulated by the model.

The model grid for the Arkema sitewide groundwater model will be a six-layer, uniformly spaced, finite-difference grid. The i-direction of the model grid will be oriented approximately north 50 degrees east, approximately parallel to the direction of groundwater flow. The row and column spacing of the model grid will be a uniform 25 feet. The model domain will encompass the Arkema site and adjacent facilities including the ESCO, Rhone-Poulenc, Gould, Metro, Schnitzer and City of Portland properties, and portions of the Siltronic and Gatx properties.

The major hydrostratigraphic units at the Arkema facility will simulated in the model by six layers:

- Layer 1 – shallow groundwater zone;

- Layer 2 – silt between the shallow and intermediate groundwater zones;
- Layer 3 – intermediate groundwater zone;
- Layer 4 – deep groundwater zone;
- Layer 5 – weathered Columbia River Basalt; and
- Layer 6 – unweathered Columbia River Basalt.

A.4.2 FLOW CONDITIONS

Flow conditions in Layer 1 (shallow groundwater zone) will be simulated as unconfined (MODFLOW layer type LAYCON=1). The transmissivity of this layer will vary during the model simulation period, and will be calculated from the saturated thickness and hydraulic conductivity specified for the layer (McDonald and Harbaugh, 1988). Flow conditions in the other five model layers will be simulated as unconfined/confined (MODFLOW layer type LAYCON=3). The transmissivities of these model layers will vary during the model simulation period, and will be calculated from the saturated thickness and hydraulic conductivity specified for the layers (McDonald and Harbaugh, 1988). The storage coefficients specified for these model layers may alternate between confined and unconfined values during the model simulation period.

A.4.3 BOUNDARY CONDITIONS

The following boundary conditions will be used in the Arkema sitewide groundwater model:

- Upper boundary of model grid – free-surface (water table) boundary;
- Southwest and northeast margins of model grid – constant-head boundaries;
- Northwest and southeast margins of model grid – no-flow boundaries;
- Lower boundary of model grid– no-flow boundary;
- Willamette River – constant-head boundary; and

- North Doane Lake and West Doane Lake – river (head-dependent-flow) boundaries.

The upper boundary of the model grid is a free-surface boundary. The free-surface boundary simulates the water table in the shallow groundwater zone. The elevation of this boundary is calculated by MODFLOW during the course of the simulation (McDonald and Harbaugh, 1988).

The lower boundary of the model grid is a no-flow boundary. Downward groundwater flow from the unweathered basalt is assumed to be negligible as a simplifying assumption of the model design.

The southwest and northeast margins of the model grid are constant-head boundaries. These constant-head boundaries simulate the horizontal gradients observed in the groundwater flow systems at the Arkema site.

The northwest and southeast margins of model grid are no-flow boundaries. These boundaries of the model grid are approximately parallel to the direction of groundwater flow in the shallow, intermediate and deep groundwater zones.

The Willamette River will be represented in the model as a constant-head boundary. The Willamette River stage (head) is not affected by groundwater flow into or from the river because of its size and depth. Therefore, stresses on the groundwater flow system, such as groundwater pumping, are unlikely to significantly impact the river stage.

North Doane Lake and West Doane Lake will be represented in the model as river boundaries. River boundaries are head-dependent flow boundaries that may contribute to or drain water from a model layer depending on the hydraulic gradient between the head-dependent flow boundary and the model layer. These boundaries will be used to simulate the interaction of North Doane Lake and West Doane Lake with the shallow groundwater flow zone.

A.5 MODEL INPUT PARAMETERS

A.5.1 TOP AND BOTTOM ELEVATION OF MODEL GRID LAYERS

The top and bottom elevations for the model grid layers will be obtained from the geologic logs of soil and well borings on the Arkema facility and adjacent properties.

A.5.2 RECHARGE

The Portland area climate is relatively mild throughout the year, characterized by cool, wet winters and warm, dry summers (Oregon Climate Service, 2005). The 30-year normal precipitation for the Portland area is 37.4 inches. Most of the precipitation occurs during the winter months with about 50 percent of the annual total occurring from December through February, lesser amounts in the spring and fall, and very little during the summer.

An initial recharge rate of 1 inch per year will be used in the Arkema sitewide model to simulate area recharge to the shallow groundwater zone by infiltration of precipitation and surface runoff. This recharge rate is approximately 3 percent of the 30-year normal precipitation in the Portland area. This recharge rate may be changed during model calibration, but will be assumed to be less than 5 percent of the 30-year normal precipitation since the model will be calibrated to groundwater levels measured during the fall season (Section A.6) when precipitation rates are typically low.

A.5.3 CONSTANT-HEAD BOUNDARY PROPERTIES – WILLAMETTE RIVER

The Willamette River will be represented in the model as a constant-head boundary (Section A.4.3). The elevation of the constant-head boundary representing the Willamette River will be estimated from the river stage elevations measured at the USGS gages at the Morrison Bridge in Portland (River Mile 12.8, 7 miles upstream of the Arkema facility) and at Oregon City (River Mile 26.2).

A.5.4 RIVER BOUNDARY PROPERTIES – NORTH DOANE LAKE AND WEST DOANE LAKE

North Doane Lake and West Doane Lake will be represented in the model as river boundaries (Section A.4.3). The vertical hydraulic conductivities of the bottom sediments of these lakes were estimated from seepage meters installed in the lakes by AMEC Earth & Environmental, Inc. ([AMEC], 2005). The hydraulic conductance for the river boundaries that will be used to represent the lake in the Arkema sitewide model will be calculated by the method outlined in McDonald and Harbaugh (1988) using the length and width of the lake segments within the model grid cells, the estimated vertical hydraulic conductivities of the bottom sediments form the seepage meter measurements, and an assumed uniform bottom sediment thickness of 1.0 foot. The river boundary stage elevations will be set at the fall lake elevations measured by AMEC (2005) or more recent measured elevations, if available.

A.5.5 HYDRAULIC CONDUCTIVITIES

The initial hydraulic conductivities of the model layers will be based on the estimated hydraulic conductivities from slug and pumping tests of wells at the Arkema facility and on adjacent properties. These initial conductivity values will be adjusted, as necessary, during model calibration, but will be kept within a reasonable range based on the aquifer tests and the lithology of the aquifers.

A.6 MODEL CALIBRATION

The Arkema sitewide groundwater model will be calibrated to demonstrate that the model is capable of accurately simulating observed groundwater conditions at the facility. Calibration of the groundwater model will be accomplished by determining the appropriate model design and input parameters that produce simulated groundwater elevations and flows that reasonably match field measurements.

The model calibration will be performed by manual trial-and-error adjustment of model input parameters. The general procedures used in the manual calibration of groundwater flow models are described in Anderson and Woessner (1992). Numerous models based on manual calibration methods have been published in technical journals, and have been accepted by regulatory agencies at the state and federal levels.

A.6.1 STEADY-STATE (HEAD) CALIBRATION

The groundwater model will first be calibrated to groundwater level measurements at the Arkema facility and adjacent properties, which are representative of quasi-steady-state groundwater conditions at the facility. Starlink Logistics, Inc. (SLLI) and ERM are currently working with the adjacent property owners to acquire a comprehensive set of groundwater level measurements for calibration of the model. The model will be calibrated by specifying initial estimates of recharge and hydraulic conductivity, and solving the model for steady-state flow conditions. These estimated input parameters will then varied in successive simulations until the steady-state head solution reasonably matches the calibration target water levels.

A.6.2 TRANSIENT (FLOW) CALIBRATION

After the model is calibrated to the steady-state water levels, the model will be calibrated to the pumping tests of PT-1, PT-2, and PT-3 (GeoSyntec Consultants 2006). The drawdown in water levels observed during these pumping tests are considered to be representative of the typical response of the shallow groundwater zone to pumping conditions.

A.6.3 CONVERGENCE CRITERION AND VOLUMETRIC MASS BALANCE

A convergence criterion of 0.001 foot for the head (HCLOSE in MODFLOW solver packages) and 0.001 cubic feet per day (ft3/day) for the flow (residual, RCLOSE in MODFLOW solver packages) will be specified for the model calibration simulations. A head convergence criterion three orders of magnitude smaller than the required accuracy of the model head solutions will be used to minimize errors in the model solutions due to floating-point truncation and rounding by the microprocessor. A flow convergence criterion of 0.001 ft3/day will be used to minimize localized errors in the volumetric mass balance of the model solutions.

The volumetric mass balance (difference between total groundwater inflow and outflow simulated by the model) will be monitored during model calibration as a check on the model solutions and to identify errors in the model design. Model solutions with less than one percent volumetric mass balance error will be considered as acceptable solutions.

A.6.4 EVALUATION OF MODEL CALIBRATION

The results of the model calibration will be evaluated both qualitatively and quantitatively. Model calibration results will be evaluated qualitatively by comparing contoured maps of calibration target water levels to the model head solutions. The variance in the model head solution will also quantified by determining the mean error, mean absolute error, standard deviation, and sum of squares for the model residuals. Model residuals are the difference between the target head and the model head.

As a further check on the steady-state model calibration, groundwater flow paths will be calculated for the model head solution with PATH3D to help visualize the groundwater flow field simulated by the model and to detect errors in the model design or input parameters that could not be identified solely by examining the model head solution. The groundwater flow paths will also be helpful in evaluating the interaction between the groundwater flow system and the Willamette Rive simulated by the model.

A.7 EVALUATION OF REMEDIAL ALTERNATIVES

The developed groundwater model will be used to simulate and evaluate possible remedial alternatives. Simulations will be run to evaluate several combinations of barrier wall configurations and pumping/reinjection configurations. This is an iterative process whereby remedial alternatives are simulated, the results are evaluated and then certain remedial alternatives may be modified as needed to achieve the groundwater source control objectives. The results of the remedial alternatives simulations will be used in the comparative evaluation of the remedial alternatives.

A.8 SUMMARY REPORT PREPARATION

After completion of the groundwater flow model evaluation, a summary report will be prepared to document:

- Model design;
- Input parameters;
- Procedures used to construct and calibrate the model;
- Methods used to apply the model to the site-specific environmental problems; and
- Results of the model simulations.

This report will present the key modeling concepts and results in a manner that can easily be understood by non-technical reviewers, and will include the necessary information for independent technical review by ODEQ and USEPA. LSS will send an electronic version of the report and two hard copies of the report to ODEQ for review. One hard copy will be submitted to USEPA for review.

Output from the model runs will be included in other related documents. For example, modeled plume conditions will be presented in the FFS, risk assessments, and upland FS. The groundwater model summary report will be the primary source for parties who are interested in the model details.

A.9 REFERENCES

AMEC Earth & Environmental, Inc., 2005, "Groundwater Transport Evaluation Report, RP – Portland Site," prepared for SLLI, Morissville, North Carolina.

American Society for Testing and Materials, 1996, ASTM Standards on Analysis of Hydrologic Parameters and Groundwater Modeling, ASTM Publication Number 03-418096-38, 148 pp.

Anderson, Mary P., and W.W. Woessner, 1992, Applied Groundwater Modeling, Academic Press, Inc., San Diego, CA, 381 pp.

Environmental Simulations, Inc., 2004, Guide to Using Groundwater Vistas, Version 4.0, Herndon, VA.

McDonald, M.G., and A.W. Harbaugh, 1988, "A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model," Techniques of Water-Resources Investigations of the United States Geological Survey, Book 6, Chapter A1, 576 pp.

Oregon Climate Service, 2005, "Climate of Multnomah County," www.ocs.oregonstate.edu/county_climate/Multnomah_files/Multnomah.html.

U.S. Environmental Protection Agency (USEPA), 1993, A Manual of Instructional Problems for the U.S.G.S. MODFLOW Model, EPA/600/R93/010.

Zheng, C., 1989, PATH3D, A Ground-Water Path and Travel-Time Simulator, Version 3.0, S.S. Papadopulos and Associates, Inc., Bethesda, MD.

Zheng, C., 1990, MT3D: A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems, Report to the U.S. Environmental Protection Agency, Ada, OK, 170 pp.

Zheng, C, 1993, "Extension of the Method of Characteristics for Simulation of Solute Transport in Three Dimensions". Ground Water, Vol. 31, No. 3, pp. 456-465.

Zheng, C., and G.D. Bennett, 1995, Applied Contaminant Transport Modeling, Van Nostrand Reinhold, New York, NY, 440 pp.

Zheng, C. and P.P. Wang, 1999, MT3DMS: A Modular Three-Dimensional Multispecies Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants In Groundwater Systems; Documentation and User's Guide, Contract Report SERDP-99-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.