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FOCUSED REMEDIAL INVESTIGATION

EVANITE FIBER CORPORATION

CORVALLIS, OREGON

Prepared for

Evanite Fiber Corporation

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EXECUTIVE SUMMARY

This focused remedial investigation (FRI) report for the Evanite facility in Corvallis, Oregon, was prepared pursuant to Order on Consent No. WMCSR-WR-00-19 (Order) issued by the Oregon Department of Environmental Quality (DEQ) to Evanite on April 10, 2001. As agreed to by both parties, the Order requires Evanite (1) to conduct an FRI that satisfies the applicable requirements of OAR 340-122, (2) to evaluate the performance of the soil vapor extraction (SVE55) and groundwater treatment systems at the site, and (3) to continue the corrective action program.

The consent order outlined a number of project objectives to guide the overall project approach and scope. The intent of the parties was to incorporate, to the extent possible, the extensive amount of existing information in meeting a group of objectives defined for cleaning up the site.

The FRI is comprised of two primary elements: site characterization and an assessment of risk to human health or the environment posed by chemical impacts at the site. Risk assessment elements will be provided as separate reports (i.e., Screening Level Ecological Risk Assessment Report, and the Human Health Risk Assessment Report). Investigation activities consisted of the following tasks:

- Synthesize data from existing sources for each of the environmental media—soil, groundwater, surface water and sediments, and air. Review and evaluate data for useability and for information gaps with respect to a preliminary conceptual hydrogeologic model; prepare a phase 2 workplan.

- Implement phase 2 field work that consisted of geoprobe boring and soil analysis, soil vapor extraction (SVE) probe installation, and SVE radius of influence testing.

- Conduct a focused site assessment to evaluate other potential site sources or chemicals of potential concern (COPCs).

- Monitor groundwater for water levels, water quality, and natural attenuation parameters.

The investigation found that the site is well-characterized with respect to hydrogeology and the nature and extent of contaminants. Findings are synthesized in the conceptual hydrogeologic model which describes what is known or suspected about contamination sources, release mechanisms, and the transport and fate of those contaminants. Furthermore, it delineates the locality of facility (LOF), which in turn aids in developing the conceptual site model used to assess risk to potential receptors.

The hydrogeologic framework is a simple layered model with unsaturated silt and silty sands to a depth of approximately 20 feet that overlie a sandy gravel aquifer. Groundwater in the aquifer (under non-pumping conditions) flows northeast where it discharges to the Willamette and Mary's rivers. The pump and treat system significantly dewaters the aquifer to roughly half the thickness of the potential (non-pumping) saturated thickness of 20 feet, and creates a groundwater divide along the Willamette River, along which groundwater flow appears to have stagnated.

Contamination in the form of spilled trichloroethene (TCE) migrated from the Submicro downward through unsaturated silt to aquifer material where it spread laterally. Recent soil analytical results in the unsaturated zone indicate that volatile organic compounds (VOCs) are still present at elevated concentrations. Moreover, it appears that the SVE has not contributed to uniform cleanup of the Willamette Silt in the Submicro area. VOC removal is likely controlled to a large extent by the soil type (fine- versus coarse-grained) and proximity to the SVE wells, with the greatest removal efficiency near SVE wells in coarser-grained soil.

Within the aquifer, an area of dense nonaqueous-phase liquid (DNAPL) appears to be limited just east of the Submicro to an enclosed depression along the upper surface of the clay aquitard. A VOC groundwater plume subsequently migrated downgradient toward the Willamette and Mary's rivers where it discharges to surface water. Water well pumping in areas proximal to Evanite, induced contaminants to migrate crossgradient to the east-southeast. In addition, historical sources of VOCs, including TCE, tetrachloroethene (PCE), and fuel related compounds, which are documented upgradient of the site to the southwest and west, apparently feed other VOC plumes that overlap with the limit of the Evanite VOC plume.

Conceptually, the DNAPL continues to provide an ongoing source of dissolved VOCs in groundwater. The dissolved plume is controlled to a large extent by the pump and treat system, which increases gradients along the upgradient sides of the plume and allows clean water to flush through impacted parts of the aquifer and restore the water quality to near detection limits. Given optimal conditions (i.e., source containment and flushing the aquifer with fresh water), it has been shown by water quality trends that the aquifer can fully restore itself within a relatively short period of time, less than 10 years. However, within a large area of the VOC plume, a substantial thickness of aquifer is unsaturated due to continuous pumping drawdown, and hence not being flushed or treated. Due to a drop in production schedules over the last nine months, Evanite has periodically shut down the treatment system (e.g., during weekends). This results in "pulsing" of the treatment system, and consequent flushing of the unsaturated zone. Contaminant removal data from this time period reflect an improvement in TCE removal efficiency.

Downgradient of the source area where groundwater has stagnated along the groundwater divide, there is no mechanism to flush contaminants from the aquifer and VOCs are biodegrading naturally under anaerobic conditions. This reduction in TCE mass occurs at a relatively slower rate than in upgradient areas, where greater quantities of clean water are allowed to more fully flush the aquifer.

The primary contaminant at the site is TCE. Related COPCs include *trans/cis*-1,2-dichloroethene (DCE), 1,1-DCE, 1,1-dichloroethane (1,1-DCA), and vinyl chloride. In addition to TCE and breakdown products, methylene chloride was retained as a COPC. The occurrence of trace detections of PCE in groundwater is likely associated with multiple, off-site, upgradient sources and for this reason, it was not retained as a COPC.

The LOF for the Evanite site was conservatively established as follows:

- **Soil.** The area of soil impacts is east of the Submicro and was based on the extent of VOCs in soil using both historical (from 1985-86) and recent (2002) soil data.

- **Surface Water and Sediment.** Both of these media have the same LOF since both are in contact with each other. The LOF represents areas where VOCs have been detected historically in surface water and includes the shoreline where the VOC plume in groundwater discharges to surface water; VOCs were not detected in sediment samples collected in the past.

- **Groundwater.** The boundary for the groundwater LOF is defined by the historical extent of site-related VOCs detected in groundwater, including its spread cross gradient to the east-southeast.

The area within the LOF and nearby properties is zoned residential, commercial, general industrial and intense industrial. Future land use is expected to remain similar to existing uses although the comprehensive plan calls for industrially-zoned areas to transition to mixed uses such as limited industrial, commercial, office, residential and park/open space.

Homes and business in the area are supplied by municipal water service, however shallow groundwater within the LOF is used to a limited degree for domestic water supply and landscape irrigation. Future use of groundwater is expected to include these uses. In addition, groundwater recharges surface water of the Willamette and Mary's rivers and for that reason contributes to beneficial uses of those rivers.

Pending the outcome of the risk assessment, the following recommendations are presented: (1) evaluate continued operation of the SVE against balancing factors such as cost, effectiveness, contaminant removal, and mitigation of risk, and (2) evaluate the benefits of enhanced aquifer flushing of unsaturated parts of the aquifer by shutting down extraction wells outside areas of DNAPL influence (i.e., at MW-11 and MW-12) and/or implementing a pulse-pumping operational regime.

1 INTRODUCTION

On behalf of Evanite Fiber Corporation (Evanite), McKenna Environmental, LLC (M/E), prepared this focused remedial investigation (FRI) report for the Evanite facility in Corvallis, Oregon. The document was prepared pursuant to Order on Consent No. WMCSR-WR-00-19 (Order) issued by the Oregon Department of Environmental Quality (DEQ) to Evanite on April 10, 2001. The Order requires Evanite (1) to conduct an FRI that satisfies the applicable requirements of OAR 340-122, (2) to evaluate the performance of the soil vapor extraction (SVE) and groundwater treatment systems at the site, and (3) to continue the corrective action program. This document satisfies the FRI report described in the scope of work (SOW), Attachment B, to the Order.

Evanite is the owner and operator of a disposal facility under the Resource Conservation and Recovery Act (RCRA). Under authority granted by the U.S. Environmental Protection Agency (EPA), the DEQ oversees post-closure care and corrective action of closed hazardous waste management (disposal) facilities by issuing post-closure permits. For this site, the corrective action obligations and compliance schedules of the Order are incorporated by reference and made a condition to Evanite's post-closure permit, which was issued April 30, 2001.

The SOW calls for a number of documents, including the FRI report, that address elements of the SOW. Future submittals will evaluate site data with respect to potential risk posed to human health and the environment, and evaluate the treatment system to identify changes in the operation of the system that may provide for more effective cleanup.

An FRI workplan (M/E, 2001) developed the approach and rationale to meet the requirements stated above. The plan described the types and methods of data analysis outlined in the SOW, and detailed the field activities and groundwater monitoring proposed to supplement existing data. A subsequent phase 2 workplan (M/E, 2002) proposed a scope of work to address data gaps.

1.1 Objectives

The consent order SOW outlined a number of project objectives to guide the overall project approach and scope. The objectives are specific to the tasks described in the

SOW with the ultimate project goal of developing, evaluating, and selecting an appropriate removal or remedial action to address TCE impacts at the site.

The intent of the parties in developing the SOW was to incorporate, to the extent possible, the extensive amount of existing information in meeting a group of objectives defined for cleaning up the site. This was distilled within the context of thirteen objectives specified in the consent order:

1. Evaluate onsite soil conditions in the vicinity of the existing vapor extraction system to:

    i Determine the current extent of impacted soils in the vadose zone.

    ii Determine the effectiveness of the past 10 years of soil vapor extraction corrective actions.

2. Evaluate the effectiveness of the current corrective action systems (i.e., the DNAPL extraction system, and groundwater and soil vapor extraction and treatment systems).

3. Continue to operate the corrective action systems until an alternative corrective action/remedial action is approved. DEQ-approved modifications to the current corrective actions may be implemented if warranted by new data gathered during site characterization or treatment system evaluation.

4. Ensure data of sufficient quality are used for site characterization, risk assessment, and the subsequent analysis of remedial alternatives.

5. Confirm the list of chemicals of potential concern (COPCs).

6. Develop the information necessary to define the locality of the facility.

7. Confirm the nature, extent and distribution of hazardous substances in the locality of the facility.

8. Confirm the direction and rate of migration of hazardous substances.

9. Identify and confirm migration pathways and receptors.

10. Determine the potential risk to human health and/or the environment.

11. Evaluate reasonably likely future land and beneficial water use in the locality of the facility.

12. Identify (preliminary) hot spots of contamination in the locality of the facility.

13. Develop the information necessary to evaluate current remedial actions and future remedial action alternatives, if any.

The FRI was comprised of two primary elements: site characterization and an assessment of risk to human health or the environment posed by chemical impacts at the site. Of the specific objectives listed above, nine translate directly to characterizing the site and providing data that support the risk assessment portion of the FRI. The remaining four relate to the treatment system evaluation, which will be addressed at a later date.

Overall goals for the site characterization phase helped link specific objectives with tasks developed in the scope-of-work. These included:

- Characterization of the hazardous substances.
- Characterization of the site.
- Identification of potential receptors.
- Collection and evaluation of information relevant to the identification of hot spots of contamination to the extent that this work has not been completed to date for the regulated unit.
- A focused site assessment to obtain information regarding current and historical site practices, manufacturing processes, and chemical uses (including chemical types, storage and use areas, and waste management practices).

Many of the tasks proposed in the FRI workplan (M/E, 2001) consisted of assimilating existing data and reviewing it for completeness, as it will be ultimately used to assess human health or ecological risk. Other tasks specifically called for assessing the effectiveness of the soil vapor extraction (SVE) system. An interim report on the status of the data assimilation efforts was presented in the phase 2 workplan (M/E, 2002) which also identified supplemental data needs necessary to complete the risk assessment or SVE system evaluation.

Objectives considered relevant to the phase 2 work scope included the following:

- Evaluate on-site soil conditions in the vicinity of the existing vapor extraction system to:
  - Determine the current extent of impacted soils in the vadose zone.
  - Determine the effectiveness of the past 10 years of soil vapor extraction corrective actions.
- Evaluate the effectiveness of the current SVE system.

- Determine the potential risk to human health or the environment.

The primary goal of the phase 2 workplan focused on acquiring additional field data to meet those objectives, and completing site characterization, risk assessment, and the treatment system evaluation.

1.2 Scope of Work and Approach

The approach to site characterization was iterative. Because of the substantial amount of work completed at the site, the first task synthesized data from existing sources for each of the environmental media—soil, groundwater, surface water and sediments, and air. Data then was reviewed and evaluated for data gaps with respect to a preliminary conceptual hydrogeologic model and a phase 2 workplan prepared (M/E, 2002). That workplan also contained a preliminary conceptual site model (CSM) that identified sources of contamination, media of concern, potential pathways, and potential exposure points. The CSM was used to more effectively focus remaining site characterization activities to those media and exposure points that truly posed a potential risk to human health or the environment.

Also feeding into the phase 2 workplan was information derived from the focused site assessment and level 1 ecological scoping assessment (TAS, 2002a). The data analysis presented in that phase 2 workplan identified a number of areas where additional field data were needed to complete the risk assessment or the SVE system evaluation. From this analysis, three primary tasks were developed to satisfy the data needs. These included:

- SVE Well Testing for VOCs - provided data for a baseline risk assessment for volatilization of VOCs from the unsaturated zone to outdoor air and vapor intrusion to buildings; supported analysis of the SVE system effectiveness; and evaluated how current vapor levels correlated with residual concentrations of VOCs in soil samples.

- Test Shallow Soil for VOCs - completed our understanding of the nature and extent of residual soil impacts and distribution of VOCs near and beneath the building; better constrained the area considered at risk from soil volatilization; physical parameters provided more realistic assumptions for site-specific volatilization modeling; defined areas of residual impacts in relation to areas of system capture; provided current soil data for a quantitative assessment of the effectiveness of 10 years of remediation, and identified areas, if any, that could be targeted in future soil remediation efforts.

- Test Effective Radius of SVE System - determined whether residual soil impacts identified in an earlier task was within or outside areas of capture; identified whether SVE wells were effectively capturing residual soil impacts; and evaluated whether operating SVE wells were interfering with each other's capture zones, thus creating stagnant zones.

Phase 2 work was implemented in the spring 2002. Findings from that work, combined with the historical site information, forms the basis of this report. In addition, findings from the SVE well testing and shallow soil testing will also used in the human health risk assessment, which is a part of the overall SOW.

2 SITE BACKGROUND

The section provides background information on the facility, its regulatory status and history of hazardous materials management relevant to the FRI, and reviews progress with cleanup through the remedial actions operating at the site. This data was originally presented in Section 6 of Evanite's Part B permit application (Evanite, 1988), in supplemental investigations, or as performance data recorded for the corrective action program. The information is being reprised here for completeness.

2.1 Site Location and Description

The Evanite site is located in the south part of Corvallis in Benton County, Oregon, Section 2 in Township 12 South, Range 5 West (see Figure 2-1). The site covers approximately 25 acres and is bounded by the Mary's and Willamette rivers on the north, and Crystal Lake Drive on the south.

The current Evanite facility includes the Submicro building (warehouse only), the Glass Plant 1, Glass Plant 2 and Hardboard buildings, and the Technology and Engineering (T&E) Center which is used as Evanite's main office. There are also several smaller structures that house maintenance and repair shops, paved parking and storage areas, raw water storage (intake pond) and the millrace culvert, which conveys off-site surface water from upstream through the facility to the Mary's River (see Figure 2-2). A security fence encloses the site along the south and west perimeters. The Willamette River flows along the northeast perimeter.

2.2 Topography and Climate

The Evanite site sits on a recent, fairly level terrace deposit of the Willamette and Mary's rivers. The ground surface elevation in the vicinity of the Glass Fiber No. 2 and Submicro buildings is about 220 feet above mean sea level (msl). This slopes gradually towards the unimproved parts of the site along the Willamette River at an elevation of approximately 200 feet msl (see Figure 2-2).

The climate of the Corvallis area is typical of the Pacific Northwest interior. It is characterized by a long, cool, rainy season from October to May, and a short, warm, dry season from June to September. The transition between these two seasons is long and gradual.

The climate is influenced primarily by prevailing westerly winds that carry moisture from the Pacific Ocean and provide the coast with abundant rainfall. A persistent offshore high-pressure system blocks most maritime frontal systems from entering the area during the summer months. During the winter, however, this high moves southward to the coast of California and consequently has minimal effect on the movement of Pacific frontal systems.

The Cascade Mountain Range to the east blocks out most continental weather, including winter storms that are common west of the Continental Divide. However, occasional influxes of cold air from the north penetrate the Willamette Valley through the Columbia Gorge. Temperatures in the area seldom exceed 90°F or fall below 0°F. Rainfall averages approximately 40 inches annually and occurs primarily between October and March. The maximum recorded 24-hour rainfall was 4.3 inches in January 1965 (Miller et al., 1973). Winds at the Evanite site are typically from the south and west at speeds of less than 6 mph.

2.3 Site History

The Evanite site is an active industrial facility that manufactures wet process hardboard and glass fiber. Battery separator material was historically manufactured at the site. Glass-fiber battery separator material was manufactured until 1992 in what is now Glass Plant 2. Between 1975 and 1996, Evanite manufactured polyethylene-silica separator material in the Submicro building. Production of the polyethylene-silica separator material required the use of trichloroethene (TCE) to extract oil from the separator and create a micro-porous matrix. The Submicro operation was sold in 1996 and the equipment removed from the building.

2.3.1 Historical Site Features

The site has an extended history dating back to the late 1800s. Aerial photographs dating to 1948 were reviewed in 1987 during preparation of the Part B permit application. The photographs are owned by Benton County and the City of Corvallis and can be viewed at the county courthouse and city hall.

Major features identified at the site were "old" millrace channels that apparently date to the late 1800s. The original channel carried water from the upper Mary's River to a wheat mill at the present site of the Evanite Hardboard building. Excerpts from the aerial review are summarized below.

1948 Photograph. In 1948, the millrace channel followed the existing Crystal Lake Drive, but was blocked off before flowing below the current Hardboard building. At that point, flow split at a spillway and followed a bypass channel north across the Evanite property to the Willamette River. A petroleum bulk storage facility, where many large above-ground tanks are visible, is located directly south of Submicro.

1963 Photograph. The "old" millrace channel had not changed by 1963. The petroleum bulk storage facility appears to have expanded. A large surface water pond is visible upstream and adjacent to the millrace, and may be associated with a mill. An industrial site, perhaps a lumber mill, was located in the field next to the millrace.

1969 Photograph. The bypass channel was filled and the millrace was diverted to the north, through the Evanite property. The deserted channel was left unfilled and appears to be ponded. Two large ponds located where the T&E Center now resides were used for wastewater treatment. A third smaller pond was used for the process cooling water. The industrial site is deserted.

1976 Photograph. The wastewater treatment ponds were filled and the T&E Center built. The cooling water pond was filled and intake pond built. The upper millrace millpond was filled and industrial site completely cleared.

1987 Photograph. With the re-routing of Crystal Lake Drive in 1985, the millrace was re-excavated and routed through a culvert between the Submicro and Battery Separator buildings (Glass Plant 2). All previous channels were filled, although two bridges still exist on Old Crystal Lake Drive to the southwest of the Hardboard building (where the main and spillway channel crossed Old Crystal Lake Drive).

2.3.2 Hazardous Substance Release

In 1978, an estimated 1,400 gallons of TCE leaked from the treatment system carbon vessels onto an unpaved surface along the east side of the Submicro building. In addition to the 1978 spill, Evanite discovered an annular opening in the wall of the Submicro wastewater sump in 1985. This opening was created by a 2-inch pipe passing though 4-inch opening in the sump wall approximately 4 feet up from the sump bottom. The wastewater sump, which was set below grade, was replaced with a new system shortly thereafter. However, the opening may have enabled process wastewater to escape from the sump.

TCE was discovered in subsurface soil in August 1985 when a deep trench for the new millrace culvert was excavated just east of the Submicro building. Approximately 400 cubic yards of contaminated soil were eventually transported to the hazardous waste landfill in Arlington, Oregon, for disposal. In mid 1986, TCE was detected in groundwater samples collected from domestic irrigation wells located along the north side of Vera Avenue (see Figure 2-2). The source of TCE contamination was attributed to the 1,400-gallon spill.

2.4 Regulatory History

Based on extensive discussions with the DEQ and the Region 10 office of the EPA, Evanite was advised to submit a Part B post-closure permit (permit) application to close the site of the 1978 TCE spill as a landfill and implement a corrective action program to remove TCE from soil and groundwater. The final permit application was submitted on June 9, 1988, and Evanite received a joint DEQ EPA permit on approximately April 1, 1990.

Evanite's initial 10-year Post-Closure permit expired on April 29, 2000, and was renewed in 2001. The renewed permit outlined the standards and conditions that needed to be met while cleaning up solvent-contaminated soil and groundwater at the facility. Under the new permit, Evanite would:

- Confirm the nature, extent and distribution of hazardous substances at the facility, and confirm the direction and rate of migration of hazardous substances.
- Identify the potential risk of site contaminants to human health and the environment.
- Evaluate the effectiveness of the existing groundwater extraction, soil vapor extraction, and pooled solvent extraction and treatment systems.

2.5 Remedial Actions

Following DEQ and EPA issuance of the 1990 closure permit, a detailed system design was completed by Evanite staff and the system constructed by a subcontractor. The design included a network of six soil vapor extraction (SVE) wells, six groundwater extraction wells, a packed-tower air stripper for treatment of extracted groundwater, and use of Evanite's existing granular activated carbon beds for treatment and recovery of TCE vapors from the air stripper and SVE wells. The SVE and groundwater extraction systems were started in January to February 1991. After several months of operation, it became clear that DNAPL recovery was necessary using a separate fluids recovery system. Three separate DNAPL pumping systems were subsequently installed in wells MW-3, MW-16, and MW-17 over one year.

Over the past 10 years, removal actions have significantly reduced the concentration of TCE in soil, groundwater and surface water from the levels initially present. The following sections summarize the current status of corrective action at the Evanite site. Updates of this information are provided quarterly to the DEQ.

2.5.1 TCE Removal

The total mass of TCE recovered since January 1991 is 120,402 pounds (see Table 2-1) of which 57.8 percent has come from groundwater, 20.1 percent from DNAPL and 22.2 percent from SVE. In the first year of remediation, 23,900 pounds of TCE were recovered from groundwater, 12,300 pounds from DNAPL recovery, and 12,600 pounds from the SVE. Through October 2002, the twelfth year of remedial action, approximately 1,361 pounds of TCE were recovered which included 1,130 pounds from groundwater extraction, 142 pounds from DNAPL recovery, and 89 pounds from SVE.

The combined groundwater extraction flow rate from the five extraction wells for 2002 was 44 gpm. This ranged from 37 gpm in July 2002 to 50 gpm in April 2001. Instantaneous pumping rates per well varied from 3 to 4 gpm at well MW-12 up to 22 gpm at well MW-3. Extraction well MW-17 has remained off since April 1995.

The pumping emphasis currently targets wells MW-3 and MW-16, which lie within the core region of the TCE plume. Together these two wells account for over 56 percent of the total groundwater extracted each month. Through October 2002, approximately 276.7 million gallons of groundwater representing almost 8 contaminant plume pore volumes have been extracted and treated. The removal efficiency (i.e., the number of gallons per pound of TCE removed) decreased steadily from 1991 to 2000 (Figure 2-3). In 2001 and 2002, removal efficiency improved, likely as a result of the pulse pumping associated with intermittently shutting down the system.

A review of the tabulated data for 2002 showed monthly DNAPL recovery volumes ranged from 2.1 gallons in April and June to 0.8 gallons in September, with all DNAPL recovered from extraction well MW-16. The TCE concentration in the combined flow from the six soil venting wells ranged from 7 mg/m^3 (March) to 33 mg/m^3 (September).

2.5.2 Hydraulic Control

Groundwater elevation measurements for September 2001 and March 2002 were used to prepare potentiometric surface contour maps for seasonal low and high groundwater conditions (Figures 2-4 and 2-5, respectively).

When the system is pumping, groundwater elevation contours show a region of convergent flow, or area of capture, that extends from extraction wells MW-3 and

MW-16 to MW-11 and as far east as MW-12. Capture of groundwater impacted by TCE is indicated by both drawings except for the area on the river side of the groundwater divide, which flows toward the Willamette River. Variables that affect the amount of capture include overall groundwater elevation (i.e., seasonal high or low) and pumping rates at each of the wells.

3 INVESTIGATION ACTIVITIES

This section describes the process of assimilating older data and methods of acquiring new data at the site. Findings are presented in subsequent chapters.

3.1 Data Assimilation and Data Gap Analysis

The data gap analysis was organized into four elements:

- Review data assimilation efforts and data needs by media.
- Present findings of the focused site assessment as they relate to identifying data gaps.
- Identify data needs to more fully assess the effectiveness of the SVE system and to define the current extent of impacts in unsaturated soil.
- Define risk assessment data needs. For human health, present a preliminary conceptual site model (CSM), and for ecological risk, summarize findings from the level 1 ecological scoping assessment.

The data analysis identified a number of areas where additional field data were needed to complete the risk assessment or the SVE system evaluation. From those, three primary tasks were completed to satisfy the data needs; these are shown in Table 3-1 as they relate to the specific data uses. This section presents the rationale for the work scope and describes how the data will be used in risk assessment or remediation system evaluation elements of the overall scope of work.

3.1.1 SVE Well Testing for VOCs

This task provided data to perform a baseline risk assessment for volatilization of VOCs from the unsaturated zone to outdoor air and vapor intrusion to buildings. This task was completed in October and December 2001 to take advantage of a time when the system was shut down for routine maintenance. Two conditions will be evaluated in the risk assessment: when the groundwater pump and treat and SVE systems are off, which will mimic current baseline conditions; and when the remediation systems are operating, which will provide information under controlled conditions. It is anticipated that the soil gas VOC concentrations will be used in modeling subsurface vapor transport with the Johnson and Ettinger Model (EQM, 2000).

In addition to the risk assessment, the data will support analysis of the SVE system effectiveness and how current vapor levels correlate with residual concentrations of VOCs in soil samples.

3.1.2 Test Shallow Soil for VOCs

Testing shallow soils near the Submicro building provides data that will be used in a number of ways. With respect to site characterization, it furthers our understanding of the nature and extent of residual soil impacts and distribution of VOCs near and beneath the building. Defining the extent of soil impacts also better constrains the area considered at risk from soil volatilization or from exposure to soil through the excavation worker pathway. Further, testing soil samples for physical parameters provides more realistic assumptions that can be used in site-specific volatilization modeling.

In terms of evaluating the SVE system, characterizing the extent of shallow soil impacts defines areas of residual impacts in relation to areas of system capture, provides current soil data for quantitative assessment of the effectiveness of 10 years of remediation (i.e., what is the reduction in VOC concentrations in soil from before system startup in 1991 to the present), and identifies areas, if any, that could be targeted in future soil remediation efforts.

3.1.3 Test Effective Radius of SVE System

There is no current field performance data on the radius of influence of SVE treatment wells. Knowing the effective radius of capture for SVE wells allows the following assessment:

- Determine whether residual soil impacts identified in an earlier task is within or outside areas of capture.
- Identify whether SVE wells are effectively capturing any residual soil impacts. If a well is no longer treating significant soil impacts, it may be advisable to shut that well down.
- Evaluate whether operating SVE wells are interfering with each other's capture zones. Interference can lessen the effectiveness of capturing VOCs by creating stagnant zones.

3.2 Phase 2 Field Work

3.2.1 Geoprobe Borings and Testing

Geoprobe testing is a highly effective, rapid method of sampling shallow, fine-grained soils. It was used as the primary method for characterizing the current extent of residual soil impacts near and beneath the Submicro building. Soil cores were collected continuously with depth and examined for lithology or set aside and preserved for analytical testing. Boring logs can be found in Appendix A.

Sample Locations. Nine (9) Geoprobe boring locations defined the limits of residual VOC impacts (Figure 3-1) between the Submicro building and western-edge of the Millrace culvert fill. Two (2) of the nine borings were located within the Submicro building. Three borings were placed at approximately the same boring locations tested in 1986 (e.g., next to SB-1, SB-2, and SB-8) to allow direct comparison of original soil VOC concentration with current levels.

Soil was sampled continuously to a depth of 20 to 25 feet (boring GP-7 inside the Submicro building was pushed to a depth of 30 feet where it met refusal), and samples collected at approximately five-foot intervals. The five-foot samples were field tested for VOCs with a photo-ionization detector (PID). The sample with the highest reading from each boring (within the Willamette Silt) was preserved for laboratory analysis. Horizontal coordinates for each boring were measured relative to known features (e.g., building corners).

SVE Monitoring Probe Installation. Borings GP-4, GP-5, and GP-6 were converted to SVE monitoring probes. Locations were distances of approximately 20, 10, and 36 feet, respectively, from SVE well VW-3. The probes were constructed of 5-foot long, 1-inch diameter, PVC well screen and riser. Well screens were placed at a depth of 13 to 18 feet below ground surface, which is within the 8- to 18-foot screened interval of VW-3. Completion diagrams are provided in Appendix A.

Analytical Testing. One sample per boring from the Willamette Silt was tested for VOCs on the basis of highest field FID reading. Samples were tested at CH2M HILL's Corvallis laboratory by U.S. Environmental Protection Agency (USEPA) Method 8260B.

In addition, total organic carbon (TOC) and physical parameters were tested on samples collected from GP-2, GP-6, and GP-7 (Table 3-2). At each location, three samples were collected to define a vertical profile, one from the fill and two from the silt unit at roughly equal depth intervals. Physical parameters included moisture content, dry bulk density, and particle size distribution (Appendix A).

3.2.2 SVE Radius of Influence Testing

Vacuum pressure monitoring was conducted from July 10 to 18, 2002, to determine the effective radius of influence at VW-3. This was conducted as follows:

1) On July 10, the vacuum at VW-3 during normal system operation was measured in inches of water.

2) Vapor extraction wells were then isolated so that vacuum was only being applied to VW-3. The vacuum at VW-3 was monitored and adjusted (using an ambient air intake valve) on July 10 until the vacuum measured in the first task was re-established.

3) The system was allowed to obtain steady-state conditions from July 10 to 18.

4) On July 18, the vacuum at VW-3, the three monitoring probes, and adjacent SVE wells were measured.

5) Normalized vacuum readings were evaluated against the radial distance from the extraction well. Results of the radius of influence evaluation are provided in Appendix B.

3.2.3 SVE Well Testing for VOCs

The SVE system consists of six vapor extraction wells along the east side of the Submicro building completed with screens that extend from 8 to 18 feet below grade. Wells are spaced approximately 50 to 75 feet apart. The system has been operating continuously since 1991, except for brief periods of preventive maintenance.

System-off sampling was conducted on October 11, 2001, after the system had been shut down for approximately one week during a period of system maintenance. Before sampling, each well was field tested for total VOCs with an OVM. Samples were collected in Summa canisters from the three wells with the highest readings. Samples were collected through a ¼-inch diameter rigid polyethylene tubing inserted down the well head to the screened interval (i.e., the bottom of the tubing was lowered to a depth of approximately 16 feet below ground surface). Samples were analyzed by CH2M HILL Laboratory in Corvallis for VOCs by EPA Method TO-14A (Appendix C).

The system-on samples were collected December 4, 2001, from a fitting on the well head while the SVE system was operating. An air pump was connected in-line between the well head and OVM or Summa canister to provide adequate gas flow during testing. Pre-sample readings were completed on only three wells because steady (and heavy) rainfall created moisture in the OVM, which subsequently malfunctioned.

3.3 Focused Site Assessment

3.3.1 Findings for Site

The site was evaluated for historical and current chemical use, storage, and disposal activities in order to help establish the list of potential chemicals of concern. This section summarizes the results of several tasks, including aerial photograph review, employee interviews, document and file review, and a site visit. The work was conducted in accordance with the Scope of Work attached to the 2001 Consent Order. Details of the site evaluation are included in Appendix J.

3.3.1.1 Historical Site Activities

Interviews with key Evanite personnel, aerial photograph review, and a review of historical documents were utilized to establish historical site activities and to evaluate potential chemicals of concern associated with these activities.

Employee Interviews. Several employees were interviewed to ascertain historical chemical use and disposal practices. Mr. Jay Doyle (Environmental Coordinator) and Mr. Mike Aman (Safety Coordinator), provided historical perspectives and a tour of the facility. The millraces date back to the 1800s. The site was primarily used as a sawmill from the turn of the twentieth century to the late 1960s. The site operations then transitioned into the hardboard operation (compressed wood fiber), and the battery separator operation commenced in about 1975 (polyethylene-silica separator material production).

The Evanite name has been associated with activities at the Corvallis site since 1984. However, the name and Corvallis facility have been owned and operated by several different parent companies. In terms of chemical use and disposal, little has changed for the hardboard division, which utilizes very little in terms of hazardous materials. The main hardboard operation resulted in washed chips (product), wastewater (sent to the ponds for treatement/discharge), air emissions (mainly steam, and some VOCs associated with paint), and chip washer solids (mainly dirt and debris managed as solid waste).

As is the case today, the final hardboard products were painted, but there is no indication of significant releases, spills, or disposal of paint or solvent materials at the site. Essentially, the in-door operation involves spraying paint directly onto the hardboard products and allowed them to dry.

There was a release of linseed oil at the hardboard plant (estimated to be sometime in the 1970s). The release occurred during transfer of linseed oil from a rail car to the plant. The release was immediately contained and cleaned-up. In addition, in 1991 there was a release of approximately 700 gallons of bunker fuel from a pump to the ground surface. The release was reported to DEQ (LUST site 02-91-4381). DEQ files indicate the spill was immediately contained and cleaned-up, and that no further action was necessary (see Appendix J).

The battery separator material operation began in 1975 and ceased in 1996. This operation included the use of TCE. It was from this operation that the 1978 release of approximately 1,400 gallons of TCE occurred on the exterior of the east-side of the Submicro Building. Other than TCE and mineral spirit oil, no other significant chemical use for the battery plant operation was reported. Particularly, it was determined that PCE and methylene chloride were not used at the site in the production processes. There may have been some incidental uses of these compounds in aerosol spray cans (i.e., as a low-percentage ingredient), but the total volume would be considered negligible, and there is no evidence of release, spill, or on-site disposal of these compounds. Evanite has an on-going environmental management program that monitors product purchasing, including a review of product chemical makeup, and does not allow the purchase or use of TCE, PCE, and methylene chloride.

The facility had a total of seven (7) underground storage tanks (USTs), all but one of which have been decommissioned. The tanks included:

- a 990 gallon fuel tank (gasoline) on the west side of the T&E Building (removed in 1980s, no contamination);
- a 1,500 gallon mineral spirits tank in the middle of the Battery Separator Plant (removed in 1989, no contamination);
- a 16,000 gallon boiler oil (Bunker C fuel) tank at the Battery Separator Plant (removed in 1992, no contamination);
- a 15,000 gallon mineral spirit tank at the Battery Separator Plant (removed in 1992, no contamination);
- a 24,000 gallon bunker C fuel tank a the west side of the Hardboard plant (removed in 1992). There were some detected impacts to soil, which was excavated and disposed off-site;
- a 30,000 gallon process oil tank near the Submicro Building (decommissioned in-place in 1992);
- a 6,000 gallon paint thinner tank was located at the Hardboard plant. The use of this tank was discontinued in 1977, and the tank was removed in 1989 (no contamination).

- The only UST still in operation is a 11,800 gallon bunker C fuel tank on the west side of the Hardboard facility.

Aerial Photos. The Evanite site has an extended history dating back to the late 1800's. Aerial photographs of the site dating to 1948 were reviewed in conjunction with preparation of the Part B permit application in 1987. The photographs are owned by Benton County and the City of Corvallis and can be viewed at the county courthouse and city hall. A review of the aerial photographs is provided in Section 2.3.1 of this report.

Historical Documents. Numerous historical documents related to the site were reviewed. A list of documents is found at the end of this report (References). Also of particular use were the original Part B Permit Application (CH2MHill, 1988), Phase I Environmental Site Assessment (Safe Research, 1991), and various documents copied from the DEQ files. Pertinent sections of these documents are provided in Appendix J.

The DEQ file review includes a report of the discovery of a drum containing hazardous substances (paint-related material), unearthed by the City of Corvallis during excavation activities near 1555 Crystal Lake Drive. This location is just south-southeast of the Evanite facility. The City was in the process of developing a boat ramp and park. The physical description of the drum (i.e., the number of metal rings and the size of the container) indicated it was several decades old, and therefore disposed long before commencement of Evanite plant activities. There was no indication from the drum or its contents that it was associated with any Evanite operation or activity. The City of Corvallis took responsibility for removing the drum and excavating impacted soil from the area around the drum.

3.3.1.2 Current Site Activities

The site operations are generally divided into two categories: Hardboard operations and Glass Fiber operations. A review of the current operations indicates the chemical use, storage and disposal activities have been relatively consistent over the past twenty years. The major exception is the discontinued use of TCE in 1996. The following summarizes the results of the investigation, which is presented in Appendix J.

Evanite is a Conditionally Exempt Small Quantity Generator (CEG) of hazardous waste (40 CFR 261.5), and therefore is not subject to regulation under 40 CFR 262 through 266, 268, and Parts 270 and 124. The Environmental Coordinator maintains the specific regulatory requirements and exclusions for CEGs, and assists the Hardboard Division and Glass Fiber Division Managers with compliance.

Shipments of hazardous waste that do require hazardous waste manifests. Land Disposal Restriction (LDR) forms and reports, and waste disposal certificates are coordinated by the Hardboard and Glass Fiber Division Managers, with assistance from the

Environmental Coordinator. Copies of the hazardous waste documents are maintained at the site.

Evanite has developed a written Environmental Management System (EMS) for the Corvallis facility. The Environmental Coordinator reviews this document annually in order to determine if modifications or changes are necessary. In addition, the EMS document is updated whenever new solid waste streams are identified, or when significant changes to existing solid waste streams occur.

Specific solid wastes generated at the facility were evaluated to determine if they contain hazardous constituents, or if they would result in generation of hazardous wastes. The evaluation did not include commonly occurring solid wastes that are typically managed at commercial and industrial sites (e.g., general refuse, and scrap paper and cardboard from office and process areas that are not subject to mixing with hazardous constituents).

The following is a list of chemicals used and solid waste streams generated for Hardboard Division:

- Lead Acid Batteries
- Wastewater
- Aerosol Spray Cans
- Flashlight Batteries
- Used Fluorescent Tubes
- Mercury Switches or Thermostats
- Oil in Absorbent
- Spent Parts Cleaning Solvent
- Used Oil
- Used Antifreeze
- Waste Paint Solids
- Waste UV Paint
- Caul Tank Solids
- Ash from Boiler No.3
- Dried Catalyzed Topcoat Solids
- Hazardous Waste Used Rags
- Whitewater Pipeline Solids
- Chip Washer Solids
- Non-Hazardous Used Rags
- Caustic Wash Solution
- Paint Cans\Waste Latex Paint

The following is a list of chemicals used and solid waste streams generated for the Glass Division:

- Lead-Acid Batteries
- Wastewater
- Aerosol Spray Cans
- Flashlight Batteries
- EDM Fluid Filters
- EDM Solids with Oil
- Glass Patties, fiber, and cullet
- Hydraulic Shed Trough Sediments

Used Fluorescent Tubes	Oil Shed Trough Sediments
Mercury Switches or Thermostats	Sandblast Aggregate and Dust
Oil in Absorbent	Vacuum Filter Cake
Spent Parts Cleaning Solvent	Waste Batch Mix
Used Oil	Barium Carbonate
Used Antifreeze	Dolomite
Bushing Refractory	

The chemical properties, waste constituents, and disposal methods for the above listed compounds is found in Appendix J. It was determined upon review of historical site practices and an assessment of current operations that the only known significant release of hazardous substances to the environment is TCE (and its breakdown products). The releases include the 1978 spill at the Submicro Building, and the possible discharge of TCE to subsurface soil from the annular opening in a wastewater sump outside of the Submicro Building. Both of these issues are discussed in the Part B permit and the 2001 Consent Order.

3.3.2 Findings from Wastewater Impoundment Area Reports

In its approval for the FRI workplan, the DEQ recommended that the previous findings from sampling at the wastewater impoundments be discussed. Figure 2-2 shows the locations of impoundments across the Willamette River to the northeast. There were two documents submitted to the DEQ that provided analytical results and a discussion of findings. The first study completed in 1987 (CH2M HILL, 1987), sampled sludge disposal areas, sludge from the bottom of the ponds, and groundwater from newly installed monitoring wells. That study found:

- Analytical results for soil samples from the sludge disposal field were all below method reporting limits.

- Out of ten sludge samples collected from the bottom of the ponds, only two VOCs were reported above method reporting limits: chloroform at 0.5 milligrams per kilogram (mg/kg) from Pond 3, attributed to laboratory contamination; and TCE at 0.9 mg/kg from a sample in Pond 3.

- In the sample from groundwater monitoring well MW-3, *trans*-1,2-dichloroethene (*trans*-1,2-DCE) was detected at 3 micrograms per liter (µg/L).

Results from the second study (CH2M HILL, 1995) were submitted to the DEQ August 17, 1995, and are on file in the DEQ's Salem office. That study collected sludge samples from the bottom of impoundments 3 and 4, and groundwater from each of the four monitoring wells; split samples were also taken by the DEQ. Findings were as follows:

- No VOCs were detected in the sludge samples.
- No VOCs were detected in groundwater samples from the monitoring wells.

From this data, it is clear that the aeration in the impoundments effectively treats any residual VOCs that are part of the effluent from the treatment system, and that the ponds are not sources of contamination to groundwater. The isolated detection of TCE in one sludge sample was far below any relevant standard (e.g., USEPA PRG for surface soil is 127 mg/kg); continual aeration processes in the pond likely volatilize any residual VOCs. In all, groundwater was sampled four times in wells near the ponds: in February, 1987, March 1992, January 1994, and May 1995. Only one VOC, *cis*-1,2-DCE, was detected the first sampling event at 3 µg/L in MW-3 (an order of magnitude below the drinking water standard of 70 µg/L); no other VOCs were detected in any of the events. A summary of groundwater analytical results is shown at the end of the groundwater database in Appendix D.

3.4 Groundwater Monitoring

Tasks proposed in this section included the monitoring program defined in the SOW and supplemental monitoring. Information was used to better define the gradients and interaction between the aquifer and river, and to provide new data on natural attenuation processes in the aquifer.

3.4.1 Water Level Monitoring

Depth-to-water was measured in site wells and at the river gauge when sampling groundwater. Groundwater depth was measured manually with an electronic sounder to the nearest 0.01 foot from a mark at the top of the casing. Depth was converted to an elevation relative to mean sea level and stored in an electronic database. Water level data is evaluated for horizontal gradients, seasonal fluctuations in groundwater levels, and interaction between the river and aquifer in Section 4.6.

3.4.2 Corrective Action Monitoring

Groundwater monitoring continued according to the schedule in Table 3-3. The table shows sampling required by the cleanup program and (in separate columns) the supplemental natural attenuation testing proposed in the FRI workplan (M/E, 2001). Sampling procedures were described in the SAP and documented in quarterly reports submitted to the DEQ.

3.4.3 Natural Attenuation Monitoring

Data collected under this task was used to evaluate the degree to which natural attenuation occurs at the site. Groundwater samples from five wells were collected and tested for an EPA-recommended suite of field and laboratory parameters (EPA, 1998a). The wells included: (1) an upgradient well (MW-1) unaffected by site contaminants, (2) a well in the DNAPL source area (MW-3), (3) a well downgradient of the source along the river (MW-4), and (3) two wells along the perimeter of the site (MW-7 and MW-15). Groundwater was collected quarterly for one year and tested for the following parameters:

- Field parameters or measurements:
  - Dissolved oxygen
  - Oxygen-reduction potential (Redox)
  - Hydrogen sulfide
  - Ferrous iron (Fe^{2+})
- Laboratory parameters:
  - Nitrate
  - Sulfate
  - Chloride
  - Dissolved organic carbon
  - Alkalinity
  - Methane, ethane, and ethene
  - VOCs, including daughter products of TCE

Samples were collected and handled as described in the SAP; sampling procedures were documented in quarterly reports submitted to the DEQ.

3.5 Data Useability and Data Validation

Analytical data was reviewed to assess whether it met project-specific data quality objectives according to two protocols. The first reviewed historical data through the beginning of the FRI scope of work—essentially all data since inception of the project in the mid 1980s through June 2001. This pre-FRI data was further evaluated as part of the Risk Assessment Guidance for Superfund (RAGS), Part D Volume 1 (EPA, 1998b) criteria tables submitted with the phase 2 workplan. Beginning with the September 2001 sampling event, water samples were collected consistent with the FRI workplan (M/E, 2001), and therefore review followed procedures specified in that workplan's SAP.

3.5.1 Historical Data

M/E reviewed copies of laboratory reports attached to historical reports, data transmittals, or quarterly reports in Evanite's archives in developing a database for soil, sediment, surface water, and groundwater. Data from the hard copies were entered into an Excel spreadsheet for a primary suite of commonly-detected chemicals. The data was further organized by sample point and chronologically by sample date. Water levels were organized by measuring point, reference point, and chronologically by date of measurement.

Laboratory quality assurance and quality control data were not rigorously reviewed as part of the current scope of work because it was assumed that adequate review was performed by the laboratory and previous consultants before submittal of the data. The substantial size of the database in itself, lends to the credibility of the data trends established over 10 years of almost quarterly sampling. Moreover, the consistency of trends and distribution of chemicals in groundwater and surface water further justify its use. In addition, the continuity of using the same laboratory over the project's history reduces to insignificant any variability or uncertainties associated with different laboratories.

Another initial task of the data review examined the appropriateness of data in meeting standardized reporting consistent with tables and worksheets identified in RAGS. The RAGS Part D standard tables (referred to in the guidance as Table 1 and Tables 2-1 through 2-5) were presented in Appendix B of the phase 2 workplan.

3.5.2 Validation of FRI Data

Procedures intended to validate and verify analytical data collected as part of the FRI scope of work included checks for internal consistency, transmittal errors, laboratory protocol, and laboratory QA/QC. As needed, the QA/QC sample results and information documented in field notes were used to interpret and evaluate laboratory results.

Validation of laboratory data followed applicable portions of USEPA guidelines for organic and inorganic data review (USEPA, 1994, 1999, and 2002) and incorporated the following elements:

- Compared chain-of-custody documentation (analyses requested) with laboratory report (analyses performed).
- Proofed data for anomalies; investigated and corrected where reasonably possible.
- Proofed laboratory reports for detection limits, holding times, surrogate recovery performance, and spike recovery performance.
- Checked computerized data entries.

In addition, M/E reviewed the reported results of routine laboratory procedures intended to promote measuring precision and accuracy, including replicate analyses, standard reference materials, matrix spikes, and procedural blanks.

Analytical data review memoranda for water quality and soil data are attached in Appendix E. Qualified data are noted in the database. None of the data was found to be unuseable as a result of poor laboratory quality control.

4 HYDROGEOLOGY

This section synthesizes over 15 years of information collected for this site. The primary goal is to provide a framework for developing the conceptual hydrogeologic model for the site, which will be used in constraining the locality of the facility (LOF) and in identifying exposure pathways in the risk assessment conceptual site model (CSM).

4.1 Surface Water

The Evanite site lies near the south bank of the Mary's River near its confluence with the Willamette River. About one mile west of the site, the Mary's River curls to the south, essentially surrounding the site and neighboring community on three sides. During heavy runoff periods, a millrace ditch brings water from the upper Mary's River onto and across the plant site.

4.1.1 Drainage Areas and General Information

The Willamette River is the major drainage of the Willamette Valley. The Willamette River basin above Corvallis has a drainage area of 4,400 square miles (USACE, 1971). Data from the U.S. Geological Survey stream gauge at Albany (between 1969 and 1982 has measured the average discharge at 15,000 cubic feet per second (cfs), but ranges from about 5,500 cfs in July and August to as high as 32,000 cfs in the winter, from November to March.

The Mary's River has a drainage area of 300 square miles. Stream flow data from the U.S. Geological Survey gauge at Philomath (between 1941 and 1982) averages 460 cfs, with peak flows of 1,000 to 1,200 in December through February and low flows of 19 to 34 cfs from July through September.

4.1.2 Physical Attributes of Surface Water Bodies

The morphology of surface water features (e.g., meandering outside erosional bend) and depth of the stream bed can directly influence the interaction between groundwater and surface water and whether the dynamics of streamflow promote sedimentation. This section describes physical attributes of surface water features with respect to how they interact with groundwater.

The Willamette River near the facility flows from southeast to the north, with the outer part of a meander forming the northeast side of the Evanite property. Along this stretch, the river erodes and forms a steep bank (i.e., southwest bank of the river) from a terrace elevation of between 210 and 220 feet above msl. Due to the erosional nature of the river along the Evanite bank of the Willamette River, little if any sedimentation occurs. In fact, only a small section of river bank (northeast of MW-6) at the confluence of the Mary's River, provides the physical environment for sedimentation. River sediments at this point appear to be thinly wedged against riverbank outcrops of Willamette Silt and aquifer gravels.

Streambed elevations of the Willamette River, measured by the Oregon State Highway Division (OSHD, 1988) during construction of the Highway 34 overpass, are close to 180 feet msl just north of the site. Profiles at other locations farther upriver (USACE, 1971) show streambed approximately 20 feet below the average river level along cut banks. Opposite the Evanite site, this would result in a streambed elevation of approximately 175 feet msl. CH2M HILL reported Willamette River water levels near the confluence with the Mary's River of 167 feet msl in June 1986. This suggests streambed elevations lower than that. Overall, cuts along the bank of the river could range between 30 and 50 feet. From visual observation during low river stage, the river bottom just offshore consists of cemented gravels, which are most likely un-eroded aquifer gravels.

The Mary's River likely contributes to the erosion of the streambed near the site where it flows into the Willamette along the north side of the property. While a much narrower river than the Willamette, it has a streambed elevation of approximately 182 feet at the Highway 99 bridge, approximately 0.2 miles upriver of its mouth (USACE, 1971). This matches the streambed elevation of the Willamette River in the area.

The millrace cuts roughly a north-south trace across the property. Streambed elevations along a profile begin at 205 feet msl just south of the railroad tracks, and fall to approximately 200 feet msl at its mouth at the Mary's River. Construction plans for the millrace culvert installed in 1985 show an invert elevation of 202 feet msl where it rejoins the millrace on the north (downstream) side of Crystal Lake Drive.

4.2 Regional Geology and Hydrogeology

4.2.1 Regional Geology

The Willamette Valley is situated in an alluvial valley stretching between the Pacific Coast range to the west and the Cascade Mountains to the east. The valley is comprised primarily of thick sequences of glacial- and fluvial-transported sediments and basalt flows that have progressively subsided in the valley floor. The valley is not extensively faulted and there is relatively infrequent seismic activity.

Geologic units in the area can be placed into two groups: the older, consolidated rocks of Eocene, Oligocene, and Miocene age that form highlands and also occur beneath the valley floor; and the younger unconsolidated fluvial and glaciofluvial materials of Pleistocene and Holocene age that comprise the valley fill (Frank, 1974). The principle older geologic formations in the site vicinity include from oldest to youngest, the Siletz River Volcanics, and the Tyee, Spencer, and Eugene formations.

The Siletz River Volcanics consist of approximately 3,000 feet of basaltic lava flows that are interbedded with tuffaceous siltstone, shale, and fine tuff. The lavas, which are of marine origin, frequently show pillow textures with secondary mineralization by zeolites. The Tyee and Eugene formations are marine sequences of tuffaceous sandstone, siltstone, and shale (original and reworked) with an approximate thickness of 4,000 feet and 1,500 feet, respectively. The Spencer formation consists of up to 4,500 feet of fine- to medium-grained arkosic and micaceous sandstone with lesser sequences of basaltic sandstone. Also included in the Tyee and Spencer formations are dike and sill-like intrusions composed of gabbro and basalt.

From bottom to top, the valley fill includes terrace deposits of poorly-sorted gravel, sand, and clay; older alluvium consisting of sand and gravel interspersed with sand, silt, clay; and younger (Recent) alluvium consisting primarily of coarse gravel in the flood plain of the Willamette River. In the immediate site vicinity, the geology is characterized by 5 to 20 feet of Willamette Silt (Allison, 1953) which overlie approximately 5 to 25 feet of coarse sand and gravel cemented with fine sand and silt (the Linn Gravel), both of which are underlain by blue clay (Calapooia Clay) up to one hundred feet thick (OSHD, 1988).

4.2.2 Regional Hydrogeology

The highest-yielding wells in the Corvallis area typically occur in the sand and gravel of the younger alluvium. Well yields range from ten to several hundred gallons per minute (gpm) depending on the aquifer's saturated thickness and the well design. The younger alluvium associated with the Willamette River and its tributaries comprise the principle water bearing strata in the Corvallis area and are considered the only viable aquifer for large-scale groundwater development (Frank, 1974).

Water bearing strata in the younger alluvium are generally confined. However, unconfined or semi-confined water does occur locally within the Willamette Silt, and in the Linn Gravel where the overlying silt has been removed by erosion.

In general, the groundwater levels in the unconsolidated alluvial deposits fluctuate between 2 and 15 feet during the year. Groundwater levels rise with increased precipitation and infiltration starting about November, and continue throughout the rainy season. Water levels begin dropping in June and reach their lowest levels in September and October of each year.

4.2.3 Regional Groundwater Flow, Recharge, and Discharge

Frank (1974) presents a water table contour map for September 1971, of the Corvallis area. This map shows the regional groundwater flow direction within the alluvial aquifer beneath the Evanite site to the east-northeast. The natural groundwater flow system at the Evanite site fits into this overall flow pattern, with localized deviations caused by the prevailing stage in the Mary's or Willamette rivers.

The Corvallis area aquifers are recharged mostly during late autumn and winter, which are the seasons of greatest precipitation. The unconsolidated alluvial deposits are recharged directly from precipitation and are generally at their highest levels by January or February. In some cases, the water table reaches the ground surface and produces waterlogged conditions in late winter.

Groundwater discharges from alluvial aquifers to the Willamette River and its tributaries. The generalized water table map presented by Frank (1974) shows that even in the dry season, the water table in the aquifer is higher than the rivers, indicating the river gains base flow from the aquifer and does not act as a recharge source. A reversal of this condition (where the rivers provide recharge to a limited area of the aquifer along the riverbank) is possible during extreme flooding events.

4.3 Site Geology and Hydrogeology

An understanding of the subsurface geology at the Evanite site was developed from a review of previous reports, State of Oregon well logs, logs of exploratory soil borings and monitoring wells for the site, and recent phase 2 drilling. Surficial geologic deposits beneath the site consist of the Older Alluvium mapped by Frank (1974), which is separated into three units. From the ground surface down, these consist of the Willamette Silt, Linn Gravel and Calapooia (Blue) Clay. At the ground surface to depths of about 20 feet, silt and clay (Willamette Silt, Allison, 1953) form a semi-confining layer. These overlie about 20 feet of sandy gravel and silty (cemented) sandy gravel (Linn Gravel, Allison, 1953). This gravel is the only recognized aquifer in the area. At depths between 30 and 45 feet below land surface, the Linn Gravel sits unconformably on a uniform clayey silt to clay deposit (Calapooia Clay). This aquitard is found throughout the valley as the lower unit in the Older Alluvium (CH2M HILL, 1987) and is reported to be up to 100 feet thick in the Willamette Valley. The basal contact of the Calapooia Clay with the underlying Tertiary marine strata is inferred to be an unconformity. Figures 2-2 and 4-1 illustrate the location and geologic cross sections prepared from site-specific information.

Below are detailed descriptions taken from logs of monitoring wells and test borings of the individual geologic units at the Evanite site. Logs from the Geoprobe borings, showing the lithologic variability, can be found in Appendix A.

4.3.1 Willamette Silt

The surficial silt (Willamette Silt) found to a depth of 18 to 20 feet is mapped by the Soil Conservation Service (SCS, 1975) as a silty clay loam. In site borings, this unit ranges visually from brown organic silt (OL) to brown or gray, plastic silt and clay (ML/MH, CL/CH) with varying degrees of fine sand, occasionally interbedded with thin lenses (less than 0.5 foot) of sandy silt (ML), silty sand (SM), or sand (SP). At its base, the contact with the underlying sandy gravel (aquifer) is gradational with soils ranging from brown silty sand (SM) and sand (SP), to very fine sandy silt (ML). Quantitative classification of samples from the unit by the geotechnical laboratory showed a variety of soil types including highly plastic silt and clay (MH/CH), sandy silt (ML) and silty sand (SM) with roughly equal proportions of sand and fines, and clayey silt (MH/CH) with almost no sand. A summary of geotechnical laboratory data is provided in Appendix A.

Fill material, comprised of a range of brown silty gravel with sand (GM) to silty sand with gravel (SM), overlies the Willamette Silt in developed areas of the site. The fill is generally well compacted and, in several of the Evanite borings away from paved areas, was saturated.

4.3.2 Linn Gravel

The sandy gravel interval from about 20 to 40 feet below the surface represents the uppermost aquifer in the area. This aquifer is generally screened in nearby, up- and cross-gradient residential wells from 30 to 40 feet below the surface. The grain size distribution in this deposit is not consistent, ranging from sandy gravel (GM) with silt (that acts as cement), to sandy gravel (GP) or gravelly sand (SP), with a low percentage (less than 10 percent) of fines. The deposit consists of layers of silty, highly compacted zones separated by cleaner coarse zones. Often, the lower section from about 30 to 40 feet below the surface is relatively silt-free.

4.3.3 Calapooia (Blue) Clay

This formation typically varies from a silty clay to clay. It is characterized primarily by its blue-gray color, medium plasticity and stiff to very stiff consistency. The deepest penetration of the clay (32 feet) came from deepening the borehole of existing well MW-3 (CH2M HILL, 1989). A geological investigation just north of the site by the Oregon State Highway Division (OSHD 1988) fully penetrated the clay and reported thicknesses up to 100 feet. Site wide, the clay has been encountered in nineteen of the boreholes; none has fully penetrated the formation. Samples from each of the borings indicate that the clay is laterally continuous beneath the site and is vertically consistent with respect to color, density, and plasticity to that logged in MW-3.

The contact between the gravel and underlying clay appeared to be distinct in each boring at the site. Local water well drillers use this sharp contact as the bottom of the aquifer and generally set well screens (or torch cut slots in steel casing) within the 10-foot interval above the contact. The structural surface represented by this contact is likely an erosional feature formed by scouring associated with deposition of the overlying alluvial gravel. Mapping the surface of this feature using site borings that have penetrated to the clay is discussed further in Section 4.4.3.

4.4 Hydrogeologic Unit Characteristics

The aquifer (Linn Gravel) beneath the site was evaluated on the basis of boring logs that fully penetrated the aquifer to quantify the relative percentages of fine and coarse material. Five of the wells (MW-1 through MW-7, excluding MW-4) were completed by drillers' with no oversight or soil logging by a geologist. MW-8 through MW-19 were overseen by a geologist from CH2M HILL. The lithologic descriptions of the drillers' logs were subsequently interpreted by geologists as follows:

- Clay (driller) = silt or clay (geologist) [Willamette Silt]
- Sand and Gravel (driller) = SP or GP (geologist); relatively clean sand or gravel [Linn Gravel]
- Cemented brown sand or gravel (driller) = GM or SM (geologist); implies cemented with silt [Linn Gravel]
- Blue Sticky Clay (driller) = Calapooia Clay aquitard (CL)

Lithologic units in the aquifer were divided into clean sands and gravels (SP, GP, SW, GW) or silty and clayey sands and gravels (SM, SC, GM, GC). Where units were labeled as GM/GP (i.e., a combination of interbedded clean and silty sand or gravel), the total thickness of the unit was quantified by splitting the distribution 50:50 between the two soil types. Isopleths representing three different measures of lithologic attributes were then plotted (Section 4.4.2).

4.4.1 Aquifer Thickness

The Linn Gravel aquifer ranges between 10 and 25 feet thick under most of the site (Figure 4-2). The thickest parts underlie the central part of the site, near Submicro/Glass Plant #2. The aquifer thins to the north between MW-2 and MW-6; this appears to be caused by a depression in the top of the coarser-grained sediments that was filled in with finer grained silty sand and sandy silt (see cross section A-A' in Figure 4-1).

Along Willamette River to the northeast; the aquifer is fully truncated by erosion of the Willamette River, and most likely to the north by the Mary's River on the basis of streambed elevations discussed in Section 4.1.2. Residual islands of aquifer material (cemented gravels) can be found in the middle of the river just off the bank between MW-6 and MW-15.

4.4.2 Aquifer Lithologic Characteristics

To better define the distribution of coarse versus fine material in the aquifer, three plots were created on the basis of well logs. This characterization assists in explaining the distribution of VOCs and also can be used to define natural constraints to contaminant transport and remedial efforts.

Thickness of Clean Sand/Gravel. The cumulative thickness of aquifer classified as clean sand and gravel (SP/SW/GP/GW) is represented by the contours in Figure 4-3. The thickest part underlies the Submicro at greater than 15 to 20 feet. Clean sands and gravel generally become thinner to the northeast where the aquifer is predominantly silty and clayey sand and gravel. Along the Willamette River in MW-13 and MW-15, clean sand or gravel was not apparent in drill cuttings.

Percent Clean Sand/Gravel. Another way of examining the aquifer character is to plot the thickness of clean sand and gravel relative to the overall aquifer thickness expressed as a percent (Figure 4-4). The highest percentage of clean sand and gravel (greater than 75 percent) occupies a swatch oriented northwest-southeast beneath the Submicro. Along the Willamette River, the aquifer becomes very silty and clayey (0 percent clean sand/gravel). The orientation of the cleaner zone is roughly perpendicular to the natural groundwater gradient, which may limit the rate of groundwater flow toward its point of discharge.

Basal Unit Lithology. The basal unit of the aquifer, just above the aquitard is predominantly clean sand or gravel in the central part of the site, below the Submicro, although at MW-3 the lower five feet of aquifer is cemented with silt (GM). The basal aquifer becomes clayey and silty in the northeast, east, and south parts of site (Figure 4-5).

4.4.3 Top of Aquitard

The top of the Calapooia Clay aquitard represents a geologic surface that likely resulted from the scouring by fluvial action associated with deposition of the Linn Gravel. Scouring typically creates an undulating surface with localized depressions and mounds that laterally, can vary rapidly at the scale of feet. Because of its importance in trapping the downward migration of DNAPL, and potentially in limiting the horizontal extent, the top of the aquitard was contoured to evaluate possible constraints on DNAPL extent.

Structure contour maps were generated with Surfer® using three gridding algorithms (surfer output plots can be found in Appendix F):

- Kriging by linear variogram method: a flexible geostatistical method used for gridding most data sets, and effective for small data sets. Kriging attempts to express trends that are suggested by data, rather than isolate data.

- Radial Basis Function by multiquadratic method: considered one of the best methods to fit the data and produce a smooth surface, it functions as an exact interpolator.

- Minimum Curvature: widely used in the earth sciences, the surface is analogous to a thin linearly-elastic plate passing through each of the data values with a minimum amount of bending to produce the smoothest possible surface while attempting to honor the data.

Each of the maps resulted in similar outcomes, with a closed depression around MW-17 that elongates northeast toward MW-3 and MW-16 (Figure 4-6). There also appear to be higher areas southeast and northwest of the low area. The overall trend of the aquitard top rises gently between 3 and 5 feet to the northeast, toward the Willamette River. At the river, the top of the surface is truncated by erosion, similar to how the original surface was formed.

While the contour maps provide a general impression of the aquitard top, there are uncertainties inherent in their construction. First, aquitard elevations obtained for MW-1 to MW-6 were from drilling contractor records, the integrity of these data cannot be verified. Second, spacing between many data points is on the order of hundreds of feet, which does not allow the degree of elevation control to identify smaller swales or high areas that may be present. And thirdly, the contouring programs interpolate data based on algorithms that inherently assume regularity of features; natural fluvial processes can produce more erratic or severe features that cannot be idealized through mathematical models.

4.5 Hydraulic Characteristics

Samples from the unsaturated zone were collected during phase 2 drilling in May 2002. Soil cores from the Willamette Silt were classified by the laboratory as high plasticity silts and clays with varying amounts of sand, from less than 10 percent up to 40 percent. Interbedded with the silt are infrequent layers of silty sand with approximately equal percentages of fines and fine sand. The water content of the fine grained unit ranges from 26 to 27 percent. Results can be found in Appendix A.

Aquifer parameters for the Linn Gravel were estimated with a series of single well slug tests, recovery tests, and a short term pumping test conducted in 1986 and 1987. Hydraulic conductivity results vary depending on the method of analysis, but generally range from 20 to 40 feet per day (ft/day). These values correspond to a clean sand, or slightly silty sand and gravel. Storativity is about 1×10^{-4}, suggestive of a confined aquifer. Results of aquifer testing are summarized in Table 4-1.

The vertical hydraulic conductivity of the underlying Calapooia Clay was tested in 1989 as part of the clay aquitard investigation (CH2M HILL, 1989). Laboratory tests from a sample collected from the boring for MW-3 at a depth of 72 to 72.5 feet ranged from 1×10^{-8} to 2×10^{-8} centimeters per second (0.12 to 0.25 inches per year).

4.6 Water Levels

Water levels at the site have been measured quarterly since starting the remediation system. Before that time, water levels were measured less regularly as part of site investigations. A database for site wells is available on request. The following discussion centers on water level relationships between wells and surface water, both during pumping and nonpumping hydraulic conditions.

4.6.1 Groundwater Elevations and Seasonal Variations

Hydrographs for well are shown in Figures 4-7 to 4-12. The wells are grouped to illustrate relationships common to each other or with surface water bodies. From these figures, the following relationships have been observed.

- Groundwater elevations are seasonal with the highest typically in the early winter and lowest in the late summer to early fall.
- Water levels in upgradient wells vary between 5 and 10 feet depending on the year (Figure 4-7).
- Wells along the southern side of the facility (MW-7 and MW-8) responded to pumping after 1991 by showing a smaller range of water levels, generally fluctuating less than 5 feet annually. Wells outside the capture zone (e.g., MW-14) generally show a wider range of fluctuation, up to 10 feet between seasons (Figure 4-8).
- Water levels in wells along the river are almost always higher than the river, even at flood stage (there were isolated measurements with slightly higher river elevations, but it is rare). This indicates that on average, a groundwater divide is maintained between the river and area of groundwater depression caused by site pumping (Figures 4-9 and 4-10).
- On average, groundwater elevations in MW-4, MW-6, MW-13, and MW-15 are 2.8 feet higher than river. During highest measured water levels in those wells, the groundwater averaged 4.2 feet higher than the river, and during lowest water, groundwater was 6.5 feet higher than the river.
- Seasonal differences in extraction well groundwater elevations vary from less than 5 feet to greater than 10 feet depending on the climate, amount of recharge to the aquifer, and pumping rates (Figures 4-11 and 4-12).

The shape of the groundwater surface varies depending on whether the remediation system is pumping. Before 1991, groundwater contours were roughly parallel to the river (contour maps for 1988 can be found in Appendix F). Some older groundwater contour maps showed a mounding in the vicinity of MW-13 (e.g., for the September 12, 1988 data), possibly resulting from the slow release of water from aquifer material composed primarily of clayey sand and clayey gravel in this area. Current maps suggest this mound can still form along the groundwater divide created by pumping.

Under pumping conditions, an enclosed groundwater low forms between MW-3 to the west, MW-2 to the north and MW-12 to the east (Figure 2-4 and 2-5). Groundwater elevations in this area of withdrawal are lower than river stage and separated from the river by a groundwater divide forming roughly parallel to the river along MW-6, MW-15, MW-13, and MW-4.

Under non-pumping hydraulic conditions, groundwater elevations are very close to the top of the aquifer, depending on the time of year (Figure 4-13). During periods of low groundwater (Figure 4-14), the water table can fall to below the top of the aquifer, creating unconfined conditions below much of the site, especially where the aquifer is thicker (see discussion in Section 4.4.2 on aquifer thickness). During periods of high groundwater in the winter and spring, the potentiometric surface rises above the top of the aquifer creating semi-confined conditions.

4.6.2 Effect of Pumping on Unsaturated Zone Thickness

The pump and treat system significantly dewaters the aquifer. Water levels during pumping conditions draw down up to 10 feet within the aquifer (Figure 4-15 shows the difference in water levels between September 19, 2001 [pumping] and October 11, 2001 [non-pumping]). Within the area of greatest drawdown, there is approximately 10 to 14 feet of unsaturated aquifer out of a potential saturated thickness of 20 feet (i.e., roughly half of the aquifer is dry). Contours of unsaturated and saturated aquifer thickness are shown in Figures 4-16 and 4-17. These plots illustrate that the greatest thickness of unsaturated aquifer centers on extraction wells, as expected. During periods of system shut down, the groundwater level recovers quickly (within a day) to the approximate base of the Willamette silt, and then returns to pumping equilibrium within approximately a day of restarting the pumps.

4.6.3 Groundwater and Surface Water Interaction

The discharge of groundwater to surface water greatly limits the distribution of contaminants in the subsurface. This section describes where this potentially occurs on the basis of morphology of surface water features relative to hydrogeologic units and the implications of water levels in surface water on the groundwater.

Willamette and Mary's Rivers. The streambeds of both of the these rivers cut below the base of the Linn Gravel, thus exposing the aquifer completely along the bank of the river. For most of the year, the aquifer is submerged by the river. However, during periods of low river stage, some thickness of aquifer is above river level and groundwater seeps along the bank are possible. By cutting completely across the aquifer, the rivers serves as physical hydrogeologic boundary to the Linn Gravel downgradient of the site.

Surface water-groundwater interactions are rapid along the banks of the river because of the relatively good permeability of aquifer material, short distance between river and wells, and connectedness to the river. This is reflected by the almost identical hydrograph patterns between the river stage and wells along the bank. Short of flood stage, the river provides the base elevation for the aquifer potentiometric surface (i.e., the point to which the aquifer drains) and the river is expected to have minimal effect on water levels in the aquifer. During flood stage, there are short periods when the river level exceeds groundwater elevations and the drainage divide breaks down, allowing groundwater to move toward the pumping-induced depression. On average, however, groundwater flows from the drainage divide toward the river.

Millrace. There is a potential for groundwater to provide baseflow to the millrace under limited hydraulic conditions. Figure 4-18 illustrates the relationship between the base of the millrace at the culvert and where it joins the Mary's River, and groundwater elevations in wells along the millrace. It also shows the elevation of the top of the aquifer in MW-6.

The plots show that before 1991 (the time when pumping began), potentiometric elevations rose above the base of the millrace (202-203 meet msl) seasonally and likely provided baseflow. Since pumping began, water levels have mostly dropped below the base of the millrace culvert, although there are isolated events of high groundwater (e.g., MW-17 in winter of 1996 and 1997). Away from the strong pumping influences, groundwater elevations still seasonally rise above the base of the millrace culvert (e.g., at MW-19) or where the millrace joins the Mary's River (at MW-6).

4.7 Groundwater Flow

Groundwater elevation contour maps were prepared from water level measurements taken before and during site remediation efforts. In addition water levels were collected when the system was off last fall.

4.7.1 Flow Direction and Gradients

4.7.1.1 Non-Pumping Conditions

Under natural (i.e., nonpumping) site conditions, groundwater flows to the north-northeast and discharges to the Willamette River. This was the normal flow regime until pumping at the Evanite site began in 1991 (Appendix F). This nonpumping flow regime reconstitutes soon after the pumping system is shut down as illustrated by the groundwater contours for October 2001 (Figure 4-13). Gradients for 1988 and 1989 ranged from 0.009 to 0.02 with an average of 0.016 for the two-year period. In the upgradient part of the site, the gradient is typically lower, while along the river, especially when river stage is low, the gradient is higher because of the elevation drop between groundwater elevations and its discharge point at the river elevation.

Prior to implementing groundwater remediation, the use of domestic irrigation wells southeast of the site affected the natural low gradients in this area, likely resulting in cross-gradient contaminant migration (i.e., to the east-southeast). Remediation pumping, and to a lesser degree discontinued use of domestic irrigation wells along the north side of Vera Avenue, control the gradients to the north-northwest.

4.7.1.2 Pumping Conditions

Even though the regional flow direction is toward the Willamette and Mary's rivers to the northeast under pumping conditions, on site, where the flow field has been significantly altered, groundwater flows toward the pumping wells and a groundwater divide forms near the Willamette River. The elevation of the groundwater divide is higher than the river level indicating that the aquifer still recharges the river, but wells along the river are in an area of relatively stagnant groundwater flow because of low gradients along the groundwater divide.

4.7.2 Groundwater Velocity

Groundwater velocities were calculated for pumping and nonpumping conditions. For nonpumping conditions, a range of gradients was taken from the 1988-89. Gradients assumed during pumping were taken from low and high water conditions for three different well pairs that are representative of the range of gradients induced by pumping at the site. Lower gradients peripheral to the effects of pumping more closely resemble those of nonpumping conditions.

The groundwater velocity was calculated using the following form of Darcy's Law:

$$v = (\mathrm{K} \times i)/n_e$$

where

v = average linear groundwater velocity (ft/day).

K = saturated hydraulic conductivity (ft/day).

i = hydraulic gradient (ft/ft).

n_e = effective porosity (unitless).

Assuming a hydraulic conductivity of 40 ft/day and an effective porosity of 25 percent, the range of groundwater velocity varies as follow:

- Nonpumping: 0.9 to 1.9 ft/day with average of 1.5 ft/day
- Pumping: 2.5 to 4.8 ft/day with average of 4 ft/day

To summarize, groundwater velocities are affected by a number of conditions, some natural and others induced. Under nonpumping conditions, velocities are slower where gradients are lower, such as south and southwest of the facility, and where the aquifer has a higher percentage of fine material, such as along the river. Throughout much of the aquifer at the site, pumping has the overall effect of increasing gradients, which can more than double velocities near extraction wells. However, pumping also creates a groundwater divide along the river which stagnates flow and slows the volume of water flushing through the aquifer and discharging to the river.

5 NATURE AND EXTENT OF CONTAMINANTS

This section presents a summary of the extent of contamination before corrective action was implemented and then describes how remediation has affected the extent and trends of VOCs in environmental media. Finally, it provides information relevant to recommendations for site cleanup.

5.1 Extent of Contaminants – 1985 to 1990

Subsurface conditions between 1985 and 1990 reflected the extent of TCE impacts before implementing the corrective action program. Data for that period provided a design basis for the SVE and groundwater remediation systems and will be used in this report to delineate the LOF. Drawings from the earlier reports that illustrated historical extent of VOCs were provided in the FRI workplan.

Soil Gas Sampling. Soon after the discovery of TCE in the Millrace culvert excavation in June 1985, soil gas test results revealed relative TCE concentrations from less than 0.002 parts per million (ppm) to 0.33 ppm, with the highest concentrations in the area around the Submicro building. This information was used to guide subsequent soil and groundwater investigations.

Soil Sampling. Based on the soil gas sampling results, the horizontal and vertical distribution of TCE in soil was investigated by collecting soil samples from 17 exploratory borings and test pits at depths from the surface to 30 feet. Drilling was conducted in phases between September 1985 and January 1987. TCE concentrations ranged from less than 1 milligram per kilogram (mg/kg) to 10,300 mg/kg. The highest concentrations were detected near the southeast corner of the Submicro building, in borings SB-1, SB-2 and SB-8 at depths between 20 and 30 feet. The distribution of VOCs in soil is discussed further in Section 5.3.

Groundwater Sampling. Groundwater has been sampled at the site since 1987. Work has included routine testing of (1) up to 19 on-site monitoring wells and 27 off-site domestic/irrigation wells for plume assessment monitoring purposes, and (2) a smaller subset of wells for remedial action performance monitoring. The lateral distribution of TCE in groundwater inferred from data obtained before remediation (1986-88) is shown in Figure 5-1. This information, which illustrated the lateral extent of VOCs in groundwater is used in defining the limits of the groundwater LOF.

Surface Water Sampling. Surface water sampling has included collection of samples from the Millrace culvert, the intake pond and the Willamette River. The highest concentrations (over 1 mg/L) were detected in the millrace, just downgradient of the culvert. Significantly lower concentrations of TCE (up to 20 µg/L) had been detected in the Willamette River. Since the early 1990s, TCE has not been detected in surface water samples collected from the intake pond or the Willamette River.

Summary of Findings. The extent of TCE in soil and groundwater at the site was defined using analytical data obtained from multi-phase investigations conducted between September 1985 and December 1990. General findings from that time period are as follows:

- Appendix IX testing of groundwater confirmed TCE as the primary contaminant of concern. *Cis*-1,2-DCE and vinyl chloride, transformation products resulting from the natural degradation of TCE in the environment, were detected less frequently at significantly lower concentrations.
- The extent of TCE in unsaturated soil (Willamette Silt) was defined by an approximately 20-foot long by 75-foot wide area along the east side of the Submicro building where approximately 900 tons of TCE-containing soil were removed in 1985. TCE concentrations ranged from not detected at a reporting limit of 1 mg/kg up to 10,300 mg/kg in samples collected at depths between the surface and 30 feet.
- An approximate 25-acre area of TCE-impacted groundwater was defined in the Linn Gravel at depths between 20 and 45 feet. TCE concentrations up to 683 mg/L (MW-16) were detected in groundwater samples collected during the 1985 to 1990 assessment monitoring period. The highest observed concentrations were detected in MW-3 and MW-16; laterally, these decreased rapidly to concentrations between 1 and 10 mg/L at the east and west margins of the Evanite property. The geometry of the plume was consistent with the north to northeast groundwater flow direction and the location of the TCE source area in the vicinity of MW-3. Pumping of domestic irrigation wells along the north side of Vera Avenue between 1978 and 1986 probably mobilized the TCE cross-gradient of the source, to the east-southeast.
- Dense phase TCE (70-percent) and oil (30-percent) lie at the base of the Linn Gravel at a depth of approximately 45 feet and appear bounded by wells MW-3, MW-16 and MW-17.

- Testing of soil samples from the blue clay aquitard beneath the Linn Gravel confirmed no significant migration (TCE concentrations were less than 1 mg/kg) below a depth of approximately 48 feet.

5.2 VOCs in Surface Water and Sediments

The extent of VOCs in surface water and sediments at the site is limited both in extent and in time. Only a limited reach of the millrace, from the culvert (EMR-4) to its confluence with the Mary's River (EMR-6), has been affected by VOCs since 1993. Concentrations at EMR-4 decreased rapidly after remediation began in 1991 to below 10 µg/L (Figure 5-2). In the past three years, TCE has been detected twice at EMR-4, once at 6.5 µg/L in March 2001 and once at 1.7 µg/L in December 2001. A sample collected at EMR-6 in June 2002 detected 1 µg/L of TCE. VOCs have not been detected at Willamette River sampling points since September 1992.

Other than TCE, VOCs historically detected more than once include vinyl chloride and *tran/cis*-1,2-DCE at EMR-4, ending in December 1990; and *cis*-1,2,-DCE at WR-2 and WR-3, ending in September 1992.

Sediments from the Millrace were tested as part of site characterization in 1986. The results were non detect for chemicals of interest (Appendix G). As this sampling event was closer in time to the releases of TCE and before any soil or groundwater remediation, it is assumed that the samples represent a worst-case scenario for the potential binding of the chemicals to sediment within the millrace. Since the chemicals of interest (COIs) were not detected in these samples, it seems unlikely that they would be detected in downstream river samples where the COI concentrations in surface water have attenuated. Other sediment samples collected in 1986 were from the bottom of the intake pond. Each of the samples, tested for TCE only, were nondetect at 1 mg/kg.

5.3 VOCs in Soil

5.3.1 Original Data Distribution

Soil quality from initial soil boring program in 1986 was evaluated by contouring soil TCE concentrations for each depth interval tested. Because this testing was before groundwater pump and treat began, most of the samples collected below depths of approximately 20 to 25 feet reflect TCE concentrations in saturated sediments, below the water table.

- Concentrations are limited along the east side of the Submicro, and west of the Millrace at depths less than 20 feet. From depth to depth, the highest-concentration areas vary, sometimes centered on SB-8 and sometimes on SB-2. In general, highest concentrations consistently centered near SB-1 and SB-2.

- Beginning at 20 feet bgs, concentrations begin to spread eastward to SB-7. At 25 and 30 feet, the TCE appears to spread progressively northeast toward SB-6 and SB-5, respectively. This probably represents migration of contaminants in the saturated zone below the Millrace.

- The highest concentrations in SB-1, SB-2, and SB-8 are the deepest (25 to 30 feet) at the interface with the aquifer.

- TCE was not detected in soil borings distant from the Submicro area, for instance at SB-14 or in MW-8, or MW-9. This indicates that migration of TCE in the unsaturated zone was limited to the Submicro area.

- SB-10, which was drilled to a depth of 15 feet, constrained the extent of soil impacts west of the Submicro building. TCE was not detected at a depth of 10 feet in that boring but at 15 feet, TCE was detected at 24 mg/kg.

One of the objectives in identifying areas with residual TCE was to delineate the LOF for soil, which will be used in assessing risk associated with exposure. Since the site specific LOF is defined as areas where contamination has been detected in the past, and exposure will be assessed for construction workers (presumably the trench worker exposed to soil to a depth of 10 to 12 feet in excavations), Figure 5-3 was constructed for the Submicro area to illustrate the extent of TCE within the upper 12 feet. The contours, which represent the highest concentration in the upper 12 feet show a broad area oriented north-south, with the highest concentrations centered on SB-2 at over 100 mg/kg. Data from the 1985 borings can be found in Appendix G.

5.3.2 Current Extent and Concentration in Soil

In the more recent phase 2 drilling, soil geoprobe borings were drilled: (1) to evaluate the current extent of TCE in soil, and whether its distribution is consistent with earlier data, (2) near old borings to evaluate the effectiveness of the past 10 years of soil remediation by comparing current versus older TCE concentrations in soil, and (3) to install SVE probes with which to measure the radius of influence of SVE wells. Laboratory reports can be found in Appendix C.

5.3.2.1 Extent of VOCs in Soil

TCE concentrations ranged from 0.103 mg/kg to 2,250 mg/kg (Table 5-1). Most of the samples were collected from depths of between 15 and 20 feet because shallower samples did not have relatively elevated PID readings, typically less than 10 parts per million (ppm), compared to deeper samples. While low PID readings generally correlated with low TCE concentrations, elevated TCE concentrations were almost always accompanied by high PID readings over 100 ppm. This suggests that where sampled, the upper soil interval (less than 12 feet) represented by low PID readings should have correspondingly low TCE concentrations, less than 0.5 mg/kg (see for example results at GP-1 and GP-2). This is not inconsistent with the older data that show a somewhat sporadic distribution in the shallower depths, becoming more uniformly distributed deeper, near the base of the Willamette Silt.

As to the westward extent of TCE beneath the Submicro building, results at boring GP-7, which was located beneath one of the old Submicro process lines, indicate minimal soil impacts: PID less than 10 ppm from the surface to 15 feet, and TCE at 0.415 mg/kg (PID at 639 ppm) at a depth of 19 feet, within the Willamette Silt just above the contact with the aquifer. At GP-6, just inside the Submicro building door, the PID concentrations were less than 5 ppm at the 5- and 10-foot samples, 260 ppm at 15 feet and 1,200 ppm at 19 feet; TCE was detected at 3.03 mg/kg in the soil sample from 19 feet.

Other VOCs detected included *cis*-1,2-DCE up to 6.4 mg/kg, and vinyl chloride, tetrachloroethene (PCE), 1,1,1-trichoroethane, 1,1,2-trichloroethane, and carbon tetrachloride, all at less than 1 mg/kg.

5.3.2.2 Evaluation of Reduction in VOC Concentrations

One of the tasks specified in the FRI scope of work was to evaluate the effectiveness of 10 years of remediation (i.e., what was the reduction in VOC concentrations in soil from before system startup in 1991 to the present). This was done by drilling Geoprobe borings near three of the 1985-soil borings and comparing differences in VOC concentrations between the two. Results for this comparison are shown in Table 5-2.

While the recent soil borings attempted to best approximate the locations of older borings, the older borings had not been surveyed and field locations of the recent borings may not be representative of older conditions. Assuming that the newer borings were reasonably near the older borings, the differences in soil quality are variable, from the SVE apparently removing most of the TCE near SB-1 and SB-8, to having limited effect near SB-2. At the very least, the results demonstrate heterogeneity of soil concentrations. Possible causes for the similarities and discrepancies include:

- GP-2/SB-8: these borings are very near VW-5 and may in fact demonstrate that when very close to SVE wells, TCE removal can be extremely effective (i.e., greater than 95 percent), even in fine grained soil. These locations had the greatest confidence in siting the new boring near the older boring because of proximity to the SVE well.

- GP-1/SB-1: this location had the greatest uncertainty with respect to siting near the old boring. For that reason, it is not clear whether the results represent soil heterogeneities or reflect cleanup related to more permeable layers (e.g., silty sand and gravelly layer) near the sampling interval which transmit vacuum more efficiently than the clay and silt layers and therefore enhance VOC removal.

- GP-8/SB-2: this location was nearest the source area and approximately 20 feet from VW-4. Results show a 50 percent improvement (at a depth of 19 feet) to essentially no effect at a depth of 15 feet. Soils, both in the old and new borings, were highly plastic clayey silt, and illustrates the limited effectiveness of the SVE in tight soil of the Willamette Silt.

In summary, it is clear that the SVE has not contributed to uniform cleanup of the Willamette Silt in the Submicro area. Removal is likely controlled to a large extent by the soil type (fine- versus coarse-grained) and proximity to the SVE wells, with the greatest removal efficiency near SVE wells in coarser-grained soil.

5.3.2.3 Radius of Influence of SVE on Soil Cleanup

Results from the radius of influence testing show limited and directional influence from the SVE wells to the probes. Of the three probes monitored, the one at a distance of 20 feet from the SVE (GP-4) has the greatest response to vacuum. The probe closest at 10 feet (GP-5) had minimal response, and the most distant probe (GP-6) had no response. A memorandum presenting the methods and findings of the SVE probe testing is provided in Appendix B.

The most likely explanation for these results is that the primary control on VOC removal through vapor extraction is the permeability of the soil. Probes that are interconnected with the SVE well by a common permeable layer will effect a response. Likewise, SVE wells that are screened across more permeable sandy and gravelly layers in the Willamette Silt will more effectively remove VOCs. What this means is that the effectiveness of vapor removal depends less on distance to the SVE well than on having permeable lithologies intersected by the SVE well which mobilizes VOCs within those zones.

5.3.3 VOCs in Soil Gas

Testing was described in Section 3.2.3; sample results are shown in Table 5-3. VOCs detected included TCE and *cis*-1,2-DCE, with the highest concentrations at VW-3; low to trace concentrations of benzene (VW-4 and VW-5) and methylene chloride (VW-3 and VW-5) were also detected. Concentrations were significantly higher during the system-off sampling event by at least an order of magnitude.

Current vapor levels in soil gas from SVE wells are within the historical area of highest VOC concentrations in soil and their distribution in VW-3, VW-4, and VW-5 is generally consistent with residual concentrations of VOCs in soil samples collected in May 2002.

5.4 VOCs in Groundwater

VOCs have been tested at the site since 1985. This section discusses the current nature, extent, and trends of selected chemicals. A groundwater quality database summary table listing the primary VOCs of concern can be found in Appendix D.

5.4.1 Distribution of VOCs and Ratios

VOC isoconcentration contour maps were generated for total VOCs, TCE, TCE daughter products cis-1,2-DCE and vinyl chloride, PCE, and for ratios between TCE and its daughter products (Figures 5-4 through 5-10). To represent current conditions and account for seasonal variations, isoconcentration contours represent the average concentration at each well for September 2001 and March 2002. For wells not sampled in that time period, the most recent historical concentration is used. Some of the VOCs shown on the distribution maps are outside and upgradient of the on-site plume. This are indicated as coming from other sources as discussed in Section 5.5. The following observations can be noted from the figures:

- TCE is the most widely distributed VOC at the site with highest concentrations of over 19,000 µg/L near the source at MW-3. Concentrations decline to nondetect within a relatively short distance upgradient, to the south and southwest. Residual concentrations below 5 µg/L are still consistently detected at R-665Vr.

- Total VOC distribution generally mimics the TCE concentrations, however non site-related contaminants such as PCE are shown upgradient of the site contours.

- The edge of the plume on the downgradient side along the Willamette River is presumed to dilute to nondetect where the river truncates aquifer.

- *Cis*-1,2-DCE has the same general distribution as TCE, with the highest concentration centered near MW-3. At downgradient well MW-15, the concentration of *cis*-1,2-DCE is significantly higher than TCE.

- Vinyl chloride has the highest concentrations along the river at MW-15 with relatively lower concentrations near the source area. Detections of vinyl chloride off site at MW-9 are presumably related to an upgradient source of PCE.

- PCE has been detected fairly continuously at MW-14 and MW-10, and recently at MW-3 and MW-16. For each well, the PCE source is presumed to be off site and upgradient, on the basis of groundwater flow direction and hydraulic control provided by the extraction system. Off-site sources are discussed in Section 5.5.

- Ratios of *cis*-1,2-DCE/TCE and vinyl chloride/TCE are greater than 1.0 centered on MW-15. In general, it appears that a higher ratio of TCE daughter products concentrates along the river in the area of the groundwater divide, and where the aquifer has a higher clay and silt content.

5.4.2 Trends of VOCs

Trends of VOCs are shown in plots presented in Appendix D. Wells are grouped by area or type, either monitoring or extraction. The following observations are based on a qualitative examination of the plots.

- Overall TCE trends for monitoring and extraction wells are down since 1991, when extraction began.
  - Southern wells continue to decline although at slower rates; MW-7 has essentially cleaned up from an initial concentration of 300 mg/L. MW-14 is clean (started at approx. 0.030 mg/L), and MW-10 is clean with initial concentration of almost 1 mg/L. Wells closer in, MW-8 and MW-18, are tailing at concentrations still above the MCL.
  - TCE concentrations in wells along the river also have begun to tail, with MW-15 showing low TCE, but correspondingly higher daughter product concentrations; TCE at MW-6 is extremely variable season to season, with concentrations between 0.04 and 1.0 mg/L.
  - Extraction wells appear to begin tailing in 1997 at concentrations between 0.1 and 1.0 mg/L for the downgradient wells and from 1.0 to 10 mg/L for wells near historically-detected DNAPL (MW-3 and MW-16).

- Vinyl chloride and cis-1,2-DCE are relatively stable in MW-15, at 0.2 mg/L which is higher than TCE which has tailed at approx. 0.01 mg/L (Figure D-5).

- In MW-10, PCE has declined from close to 0.1 mg/L in 1987 to ND in 2001; in MW-14, PCE began to be detected consistently in 1996 and now varies between 0.002 and 0.003 mg/L (Figure D-6).

- MW-4, MW-14, and MW-15 show relatively good correlation between high VOC concentrations and low water levels in the aquifer. MW-6 showed poor to moderate correlation. No other wells showed a correlation, which may be masked by other more significant influences such as declining overall concentration trends.

5.5 Off-Site Sources of VOCs

A few of the perimeter wells at the lateral edges of the Evanite plume have historically detected VOCs other than TCE and its degradation products. These chemicals (e.g., PCE and 1,4-dichlorobenzene [1,4-DCB]) have been attributed to sources other than Evanite because they were found upgradient or significantly cross gradient of the Submicro source and because the chemicals were not used at the facility. The presence of these chemicals in groundwater, and their proximity and overlap with the TCE plume identified with Evanite, however, affect how one delineates the LOF and determines which chemicals will be evaluated in the risk assessment.

Three areas that border the Evanite TCE plume are monitored by three different Evanite wells. These include: MW-9, MW-10, and MW-14. A unique set of circumstances at each location supports different sources of chemicals for each. The remainder of this section discusses the reasons why these chemicals are not considered site-related based on the following factors:

- Groundwater flow direction, both pre- and post-remedial action.

- Suites of chemicals, timing of appearance, or trends.

- Proximity to documented off-site sources.

- Area-wide and site water quality.

5.5.1 Evanite PCE Concentrations

A basic premise in identifying a source of a chemical is that the highest concentrations are associated with the source area, with progressively lower concentrations present downgradient. In examining the PCE concentrations of monitoring and extraction wells at Evanite, one notices the distinct lack of elevated concentrations of that chemical in groundwater downgradient of the TCE source (Appendix D). In fact, most of the monitoring wells downgradient have been nondetect for PCE, although there have been isolated low level detections in a few of the wells. In areas where it is presumed that TCE migrated cross gradient southeast of the site, in some locations at significant concentrations (i.e., at R665), PCE has never been detected, even in the late 1980s, before the remediation system began pumping. This is strong evidence that the Evanite is not a source of PCE in groundwater.

5.5.2 Off-Site Sources for Chemicals Detected at Evanite Perimeter Wells

MW-9 Area. This well is directly upgradient, southwest of the Evanite source area by approximately 300 feet (Figure 5-8). The direction of groundwater flow in the area is northeasterly to northerly, before pumping began in 1991, and more strongly northeasterly since remedial pumping. The suite of chemicals historically detected in this well includes: TCE and its breakdown products (Figure D-7); 1,4-DCB, 1,2-dichloroethane (1,2-DCA), and isolated detections of 1,1,1-trichloroethane (TCA), 1,2-DCB, and PCE. These are shown in Table 5-4.

Approximately 100 feet upgradient of MW-9, in wells installed at the former Chevron bulk terminal, all of the VOCs cited at MW-9 were detected at higher concentrations (RZA, 1991). In addition, a number of gasoline-related compounds were detected, including benzene, toluene, ethylbenzene, and xylenes. Results from recent sampling events (DEQ, 2002) detected VOCs (e.g., *cis*-1,2-DCE and vinyl chloride) over two orders of magnitude higher than those detected downgradient at MW-9.

The presence of a similar suite of chemicals in wells upgradient of MW-9 strongly suggests that the source of VOCs in that well is not related to the Evanite site. This is further supported by northeasterly groundwater gradients, both historical and current, and VOC concentrations that are higher upgradient of MW-9. If Evanite was the source of TCE, the concentration in MW-9 should be higher than at the former bulk terminal; this is not the case.

MW-10 Area. This well is northwest of the Evanite source area by 500 feet. Hydraulically, before pumping began, the well was cross-gradient of the source; currently it is upgradient to more directly cross-gradient of the source (see Figure 2-3). The suite of chemicals unique to this well is a fairly continuous suite of halogenated VOCs including PCE and TCE (Figure D-8), *cis/trans*-1,2-DCE, vinyl chloride, 1,1-DCE, and 1,1-DCA. Two compounds detected in this well in the late 1980s, which are not seen on site, include 1,2-dichloroethane (1,2-DCA) and TCA.

It is unlikely that chemicals detected in this well originated from the south, at the former bulk terminal, since few of the VOCs detected at the bulk terminal were also detected at significant concentrations in MW-1, which is roughly midway between that terminal and MW-10. It appears more likely that VOCs detected at MW-10 originated from off site to the west or southwest of MW-10. This is supported by the following reasons:

- Concentrations at MW-10 are higher than PCE concentrations ever detected at the Evanite site as described in Section 5.1.1. It is not possible to have lower concentrations in the presumed source area (i.e., at Evanite) than at the point of migration. Therefore, the source of PCE at MW-10 must be from the west or southwest.

- Two other VOCs detected at MW-10 have never been detected at the Evanite site (1,2-DCA and TCA). Again, these must have originated from upgradient of MW-10, to the west or southwest.

The evidence suggests that Evanite is not the source of TCE detected at MW-10. Intuitively, if non-site related contaminants migrated to MW-10 from an as yet identified source, it would follow that the TCE also originated at that same source, or from another source in the same upgradient direction. There are a number of VOC sources currently being investigated by the DEQ in the south Corvallis area, one of which is at the corner of Allen Street and Avery Avenue (DEQ, 2002). While this is southwest and potentially upgradient of MW-10, the only VOC detected in domestic wells near the Allen Street site is TCE. Therefore, since the source(s) of PCE and other VOCs is upgradient of MW-10, it is likely the source of TCE in this well is also upgradient of MW-10.

MW-14 Area. At MW-14, PCE was not initially detected during site characterization sampling events in the late 1980s. Only after the remedial pumping had operated for 5 years, did PCE begin to be detected, in 1996 (Figure D-6). If Evanite was the source of PCE at this well, then PCE would have been detected at the outset of sampling that well in 1988. The timing of the detections strongly suggests that PCE was pulled to that well from upgradient to the south by remedial pumping. Evidence of PCE in domestic wells south of MW-14 (at 1360 Crystal Lake, 690 Chester, and 1515 Bethel) bolsters this argument (data shown in Appendix G). This source of PCE could also be related to TCE detected in this area where concentrations appeared to be getting higher to the south in those wells, away from Evanite (see Figure 5-1).

5.6 Site DNAPL Characterization

DNAPL at the site was recognized during site characterization to be limited to the area bounded by MW-3, MW-16, and MW-17; in no other wells or borings was DNAPL or visual indications of DNAPL indicated. DNAPL has at various times been recovered from each of the those wells, but is now only being regularly pumped from MW-16. Migration beyond this source area was not indicated either by direct measurement in wells, or visually in soil samples. Stabilized TCE concentrations in other site monitoring wells of below 1 percent of the effective solubility of TCE (i.e., below 11 mg/L) further suggests the DNAPL is limited in extent to that area.

The distribution of DNAPL was likely affected by the aquifer materials it encountered while migrating vertically downward, and by the surface structure of the aquitard that is thought to be limiting its further downward and lateral migration. With respect to migration through the aquifer, the Linn gravels are relatively homogenous in terms of water-bearing capacity but likely to be heterogenous at the scale that influences DNAPL migration. The materials can vary from sand and gravel with few fines to dense, silt-cemented gravels within a distance of a few feet horizontally and 1 to 2 inches vertically. Silt-sized material present as thin lenses (less than 1 to 2 inches thick) acts to retard downward migration of DNAPL, and forces lateral spreading along the path of least resistance, resulting in distribution of the free-phase as a discontinuous mass of globules or ganglia throughout the aquifer. This results in residual saturation that is not uniform or readily predictable due to the minute variations in pore size distributions, soil texture, structure, and mineralogy. While residual DNAPL can be relatively immobile under normal subsurface conditions, it also tends to act as a long-term source for continuing dissolution of contaminants into water in adjacent pores. The degree of hetereogeneity of the aquifer with respect to "clean" versus "silty" layers was described in Section 4.4.2. With the available lithologic information, it was not feasible to provide more detailed correlation of lower permeability zones, either vertically or laterally, within the aquifer.

In terms of its downward vertical migration, the Calapooia clay aquitard appears to have been effective in limiting the migration of free phase to pool above a depth of approximately 40 feet. At that lithologic contact, DNAPL has been noted in MW-3, MW-16, and MW-17. As discussed in Section 4.3.3, the clay has a reported thickness of at least 32 feet below the site (at MW-3) and could be greater than 100 feet. The morphology of the top of the aquitard (see Section 4.4.3) appears to limit further lateral migration by virtue of a low area (swale) near the source, in which the DNAPL seems to have settled.

The clay aquitard was sampled in the source area during characterization in 1989 to assess whether TCE and DNAPL had penetrated the clay to a significant depth (CH2M HILL, 1989). Breakdown of the clay structure due to the solvents in the aquitard was not visually present (i.e., no secondary porosity or piping was noted), however, analytical results showed that TCE had migrated approximately 11 feet into the clay (see results below). Whether this depth is representative of other locations is not known, but this location is considered the worst case estimate on the basis of consistently high TCE detections in groundwater from this well and DNAPL observed on top of the clay.

TCE Results for Clay Aquitard Samples

Depth Interval (in feet)	Depth below top Aquitard[b]	TCE Concentration (mg/kg)
44.6	3.6	3,140[a]
45.4	4.4	8,290[a]
46.0-47.5	5.0-6.5	1,760
47.5-49	6.5-8.0	35.9
49.0-50.5	8.0-9.5	1.5
50.5-52.0	9.5-11.0	3.5
55.0-56.5	14.0-15.5	<1.0
65.5-66.5	24.5-25.5	<1.0
70.0-71.5	29.0-30.5	<1.0

[a] Analytical results from April 1988.

[b] Assumes depth of the clay aquitard is 41 feet.

The potential for continued migration of TCE though the clay aquitard is largely controlled by pore water velocity through clay and the retardation factor for TCE in clay. These mechanism are complex in a clay-type environment, and as indicated by the actual concentrations of TCE at depth in the clay, may not strictly adhere to the theoretically expected migration on the basis of vertical hydraulic conductivity, effective and total porosity of the clay, and the soil water partition coefficient for TCE. However, given the limited lateral extent of DNAPL, the removal of DNAPL from on top of the aquitard, and the thickness of the clay aquitard (100 feet potentially and known to be at least 32 feet), the vertical migration of TCE into the clay is not considered significant.

5.7 Findings from Natural Attenuation Monitoring

Natural attenuation is defined as a reduction in contaminant concentrations by chemical, physical, and biological mechanisms without active remediation. Mechanisms of natural attenuation can be biotic or abiotic. Biotic natural attenuation results from intrinsic biodegradation of contaminants by indigenous microorganisms that use the contaminants as a food source or as an electron acceptor in metabolic processes. A number of conditions must be met for intrinsic biodegradation of site chemicals to occur, such as the presence of microbial nutrients, suitable oxidation-reduction conditions, and availability of a suitable electron acceptor (either the contaminant itself or another compound, depending on the process). Abiotic natural attenuation results from chemical and physical processes such as dilution, volatilization, and transformation (e.g., chemical oxidation or reduction).

Much of the following discussion on biological degradation processes is summarized from technical articles or documents on natural attenuation (EPA 1998a, Brady et al, 1999, and Smith, 1998). Abiotic processes will be discussed further in Section 5.7.2. Analytical results of natural attenuation monitoring is summarized in Table 5-5.

5.7.1 Biological Degradation Processes for Chlorinated Solvents

The biodegradation processes for organic contaminants are based on the nutritional requirements of microorganisms found in the subsurface. Microorganisms use nutrients for the material necessary to synthesize cytoplasm (a carbon source), to provide an energy source for cell growth and biosynthetic reactions (electron donors), and as acceptors for the electrons released in the energy-yielding reactions (electron acceptors). The actual process whereby microorganisms use these nutrients consists of an enzyme catalyzed reaction in which hydrogen atoms are removed from a hydrogen donor substance (electron donor) that, as a result, is oxidized. The liberated hydrogen atoms are provided to a hydrogen acceptor (electron acceptor), that as a result, is reduced. The energy to conduct this process is provided by a carbon source.

Because of the limited number of hydrogen atoms (electrons) present in common chlorinated solvents such as PCE and TCE, these hydrocarbon compounds do not serve as electron donors but rather as electron acceptors. The process by which the more chlorinated (oxidized) solvents are biodegraded is termed reductive dechlorination. However, in biodegradation reactions, dissolved oxygen is the thermodynamically preferred electron acceptor. Therefore, if oxygen is present, it will undergo reduction reactions before the less thermodynamically favorable compounds will. Based on this, biodegradation of highly chlorinated solvents will not typically proceed under aerobic conditions, but rather anaerobic conditions. In anaerobic degradation of chlorinated solvents, because the chlorinated solvents become the electron acceptors, another source of electron donors (e.g., anthropogenic carbon or naturally occurring organic carbon) must be present. Thus, this process is typically electron-donor and carbon-source limited.

In addition to reductive dechlorination (electron-acceptor based destruction), chlorinated solvents also may be biodegraded as electron donors or through co-metabolism. As described in the technical guidance (EPA, 1998a), only vinyl chloride, the least-oxidized chlorinated aliphatic hydrocarbon, may be used as an electron donor. Based on the relatively large number of available hydrogen atoms compared to chlorine atoms in a molecule of vinyl chloride (3 to 1), reductive dechlorination is not a thermodynamically favorable reaction, although it will occur. Vinyl chloride is better suited for degradation as an electron donor under aerobic conditions (oxygen as an electron acceptor). The more chlorinated hydrocarbons (PCE and TCE), however, will not degrade under aerobic conditions.

In summary, there are two important points. First, the more oxidized, or chlorinated, solvents will be degraded under anaerobic conditions by reductive dechlorination. Second, the less oxidized, or less chlorinated, solvents will be more easily degraded under aerobic conditions by oxidation. Therefore, in order for the complete biodegradation of the more chlorinated solvents (PCE and TCE) to carbon dioxide and chloride ions, both anaerobic and aerobic conditions must be achieved at varying times during the natural attenuation process. Under anaerobic conditions, vinyl chloride will ultimately be reduced to ethane. However, the vinyl chloride is degraded more slowly under reducing conditions and accumulation of vinyl chloride will likely occur.

Reductive dechlorination can occur under nitrate- and iron-reducing conditions, but the most rapid biodegradation rates occur under sulfate-reducing and methanogenic conditions. In general, after depletion of dissolved oxygen (DO), anaerobic microbes will use nitrate as an electron acceptor, followed by iron (III), then sulfate, and finally carbon dioxide (methanogenesis). Each sequential reaction drives the oxidation reduction potential (ORP) of the groundwater downward into the range in which reductive dechlorination is most efficient—the range of sulfate-reduction and methanogenesis. The next subsection describes monitoring findings with respect to natural biodegradation processes and groundwater quality at the site.

5.7.2 Monitoring Findings

At Evanite, two primary lines of evidence indicate that a significant amount of natural attenuation is occurring:

- Observed reduction in contaminant concentration along the flow path downgradient from the contaminant source.

- Documented loss of contaminant mass using geochemical data (e.g., loss of parent compound, appearance of daughter compounds, depletion of electron donors and acceptors, and the accumulation of metabolic byproducts).

Dissolved Oxygen (DO). Reductive dechlorination requires DO conditions generally below 1 mg/L, and preferably below 0.5 mg/L. Field DO measurements at the site, which range from below 2 mg/L up to 6.6 mg/L, appear to be biased above beyond the optimal range of biodegradation. This can be explained by well sampling procedures, which rely on dedicated electric submersible pumps in most wells and likely creates artificially high DO due to agitation during purging. For other wells which are sampled by bailing, measurement of accurate DO is limited and likely not reliable due to exposure of the samples to the atmosphere.

Oxidation-Reduction Potential (ORP). The ORP of ground water is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. Oxidation-reduction reactions in groundwater containing organic compounds (natural or anthropogenic) are usually biologically mediated, and, therefore, the ORP of a groundwater system depends on and influences rates of biodegradation. While affected to a similar degree by purging procedures as DO measurements are, ORP measurements for the site generally show low to negative values that are within the range needed for reductive dechlorination.

Nitrate. After dissolved oxygen has been depleted in the microbiological treatment zone, nitrate may be used as an electron acceptor for anaerobic biodegradation of organic carbon via denitrification. In order for reductive dechlorination to occur, nitrate concentrations in the contaminated portion of the aquifer must be less than 1.0 mg/L. Except for one sampling event in which nitrate at MW-4 was detected at 1.27 mg/L, all other samples tested below 1 mg/L, indicating favorable conditions for reductive dechlorination.

Iron (II). In some cases, iron (III) is used as an electron acceptor during anaerobic biodegradation of organic carbon. During this process, iron (III) is reduced to iron (II), which may be soluble in water. Iron (II) concentrations can thus be used as an indicator of anaerobic degradation of vinyl chloride. Native organic matter may also support reduction of iron (II). Care must be taken when interpreting iron (II) concentrations because they may be biased low by reprecipitation as sulfides or carbonates or may be affected by well construction which is a possibility at Evanite where many of the wells are constructed with steel casing. Elevated concentrations of iron (II) in downgradient well MW-15 suggest potential oxidation of vinyl chloride to carbon dioxide and water under anaerobic conditions with iron (III) acting as an electron acceptor.

Sulfate. After dissolved oxygen and nitrate have been depleted in the microbiological treatment zone, sulfate may be used as an electron acceptor for anaerobic biodegradation. This process is termed "sulfate reduction" and results in the production of sulfide. Background concentrations of sulfate at the site range from 9 to 18 mg/L. Concentrations are significantly lower downgradient (2 to 3 mg/L), strongly suggesting that sulfate is acting as an electron acceptor, and also indicating that reductive dechlorination is operating in the optimal range for that biologic process.

Methane. During methanogenesis, acetate is split to form carbon dioxide and methane, or carbon dioxide is used as an electron acceptor, and is reduced to methane. Methanogenesis generally occurs after oxygen, nitrate, and sulfate have been depleted in the treatment zone. The presence of methane in ground water is indicative of strongly reducing conditions. Methane also is associated with spills of pure chlorinated solvents, but it is not known if the methane comes from chlorinated solvent carbon or from native dissolved organic carbon. Methane, while present in upgradient wells at the site at a relatively low concentration (approximately 10 µg/L) is significantly enriched downgradient in MW-15 (750 µg/L) and MW-4 (83 µg/L), indicating optimal conditions for reductive dechlorination to occur in the downgradient portion of the plume.

Alkalinity. There is a positive correlation between zones of microbial activity and increased alkalinity. Increases in alkalinity result from the dissolution of rock (e.g., calcite cement in pores) driven by the production of carbon dioxide produced by the metabolism of microorganisms. Alkalinity is significantly higher in downgradient well MW-15, suggesting an area of increased microbial activity.

Chloride. Chlorine is the most abundant of the halogens. Although chlorine can occur in oxidation states ranging from Cl^- to Cl^{7+}, the chloride form (Cl^-) is the only form of major significance in natural waters (Hem, 1989). Chloride ions generally do not enter into oxidation-reduction reactions, form no important solute complexes with other ions unless the chloride concentration is extremely high, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces, and play few vital biochemical roles (Hem, 1989). Thus, physical processes control the migration of chloride ions in the subsurface. During biodegradation of chlorinated hydrocarbons dissolved in ground water, chloride is released into the ground water. This typically results in chloride concentrations in ground water in the contaminant plume that are elevated relative to background concentrations. Chloride concentrations at the site, however, are not entirely consistent with this model of biodegradation: higher concentrations are upgradient (at MW-1) and at the source area (MW-3) than at downgradient wells.

Decrease in Parent Compound. As reviewed in Section 5.4.1, TCE decreases in concentration downgradient from the source area; concentrations in wells along the Willamette River are consistently lower than at source area wells. In addition, in areas outside the source area (e.g., near MW-11 and MW-12), concentrations have declined significantly since the early 1990s, over 2 orders of magnitude.

Increase in Daughter Compounds. Another indication of biodegradation of chlorinated compounds is the production of daughter products in the plume. At Evanite, some of the highest concentrations of daughter products, and high ratios of daughter product to parent compounds, are downgradient of the source.

- *Cis*-1,2-DCE has the same general distribution as TCE, with the highest concentration centered near MW-3. The concentration at downgradient well MW-15 is significantly higher than the TCE concentration at that well.

- Vinyl chloride has the highest concentrations along the river at MW-15 with relatively lower concentrations near the source area.

- Ratios of *cis*-1,2-DCE/TCE and vinyl chloride/TCE are greater than 1.0, centered on MW-15. In general, it appears that a higher ratio of TCE daughter products concentrates in wells near the river.

Further evidence of total biological breakdown through the full sequence of daughter product VOCs via reductive dechlorination is the presence of ethene and ethane in downgradient wells.

5.7.3 Natural Attenuation Conclusions

The weight of evidence strongly supports the conclusion that natural attenuation through anaerobic biological processes occurs at the Evanite site. The presence and distribution of daughter products downgradient indicate reductive dechlorination, and the presence of methane, low sulfate concentrations, and iron (II) within the plume suggest the biological processes primarily responsible include sulfate reduction, methanogenesis, and to a lesser degree, iron (III) reduction.

5.8 Contaminant Fate and Transport

The following subsections provide a summary of fate and transport processes most applicable to the VOC plume at Evanite.

5.8.1 Character of TCE

TCE is a halogenated hydrocarbon with a solubility of 1,100 mg/L in water at 20 C. Common breakdown products caused by biodegradation include *trans*- and *cis*-1,2-DCE and vinyl chloride. TCE has a density of 1.46, and, in high concentrations, forms a heavy phase immiscible layer or DNAPL. The Evanite DNAPL has an amber color and is a mixture of TCE and oil. This fluid was tested in the laboratory during the 1980's characterization on two occasions and is reported to consist of approximately 70 percent TCE and 30 percent oil. It is heavier than water and readily accumulates into small beads or pools in the presence if water (i.e., is immiscible). The fluid was referred to as "miscella" at the Evanite site and was generated during the battery separator manufacturing process.

5.8.2 VOC Transport and Fate Processes

The environmental fate and transport of a contaminant is controlled by the compound's physical and chemical properties and the nature of the subsurface media through which the compound migrates. Several processes are known to cause a reduction in the concentration and/or mass of a contaminant dissolved in ground water. Those processes that result only in the reduction of a contaminant's concentration but not of the total contaminant mass in the system are termed "nondestructive." Those processes that result in degradation of contaminants are referred to as "destructive." Nondestructive processes include advection, hydrodynamic dispersion (mechanical dispersion and diffusion), sorption, dilution, and volatilization. Destructive processes include biodegradation and abiotic degradation mechanisms. Biodegradation may be the dominant destructive attenuation mechanism acting on a contaminant, depending upon the type of contaminant and the availability of electron donors or carbon sources. Abiotic degradation processes are also known to degrade chlorinated solvents; where biodegradation is not occurring, these may be the only destructive processes operating. However, the rates of abiotic processes are generally slow relative to biodegradation rates. With respect to DNAPL, partitioning of the contaminant to groundwater represents the primary source of dissolved contamination in groundwater. The breakdown of VOCs in the environment results from the integration of all the subsurface attenuation mechanisms (both nondestructive and destructive) operating at a given site. At Evanite, decreases in contaminant concentration can be attributed to a combination of these processes, although certain processes appear to predominate in specific areas of the site.

Nondestructive processes such as advection, dispersion, and dilution are likely most responsible for reduction in contaminant mass along the perimeter of the plume (near MW-14, MW-10 and MW-6) and in areas that were once upgradient of the source (near MW-7, -8, -9, and residential wells). In these areas, clean water from upgradient flushes the full saturated thickness of the aquifer continually, in addition the aquifer tends to have less fine-grained material, which allows higher flushing capacity. This flushing increased with the advent of pumping in 1991, when higher gradients were created near the site. Some minimal dilution is also possible through rainfall infiltrating unpaved areas of the site, however, unpaved areas are limited in extent. Ultimately, contaminants are diluted upon discharge from the aquifer to the Willamette or Mary's rivers.

Destructive processes are more dominant within the VOC plume primarily under anaerobic conditions, especially downgradient along the river where groundwater is relatively stagnant due to a pumping-created groundwater divide.

5.8.3 Direction and Rate of Contaminant Migration

The direction and rate of contaminant migration has changed greatly since remedial efforts began in 1991. Before groundwater pump and treat was implemented, VOCs had migrated downgradient to where the aquifer is truncated by the Willamette River, a distance of roughly 700 to 800 feet, it also had been pulled (apparently by domestic well pumping) laterally cross-gradient to the east-southeast to the residential neighborhood, a distance of approximately 1,000 feet. Currently, VOCs are hydraulically controlled by remedial pumping which controls both the direction and rate of contaminant movement at the site. An area of convergent flow, the zone of capture, is centered near extraction wells MW-3, MW-16 and MW-11, extending east to MW-12. The groundwater flow pattern indicates capture (i.e., hydraulic control) of a significant volume of groundwater on site, but also of groundwater upgradient and off site along the north side of Vera Avenue, and to the west, roughly south of Chapman Place. Wells along the river are in an area of relatively stagnant groundwater flow because of low gradients along the groundwater divide. Contaminants outside this area of hydraulic control, which includes the limited area northeast of the groundwater divide and southeast of MW-12, would migrate downgradient where they would ultimately discharge to the Willamette River.

Contaminants migrate along with groundwater, but at a somewhat slower rate based on the chemical's properties and site-specific aquifer variables. These are quantified by a retardation factor, which in the case of TCE at the Evanite site, slows its migration by a factor of approximately 1.7 (i.e., 0.6 times the normal groundwater flow rate). Given average groundwater velocities of between 1.5 ft/day (nonpumping) to 4 ft/day (pumping), rates of contaminant migration would be on the order of 0.9 and 2.4 ft/day, respectively.

5.9 Pore Volume and Flushing Cleanup Calculations

Many of the wells at Evanite along the upgradient perimeter of the plume have cleaned up (from 100 µg/L or more to less than 5 µg/L) in the last 10 years of remedial efforts. This is encouraging because it demonstrates that areas of the plume that are not downgradient of the source area, can be effectively cleaned up in a reasonable time-frame as long as the source is controlled. This section quantifies rates of cleanup in three areas unaffected by a continued DNAPL source using the batch flush model Zheng et al, 1991). Spreadsheets showing backup calculations are attached as appendix Tables H-1 through H-3. The reasonableness of the calculations is supported by the actual cleanup times taken from time-series concentration plots illustrated in D-1 and G-2.

5.9.1 Batch Flush Model

The batch-flush model calculates the number of pore volumes required to achieve numerical cleanup goals as a function of the initial concentration at specific wells and contaminant transport characteristics (retardation). The equation for the batch-flush model is

$$PV = -R \times \ln C_g/C_i$$

where C_i = area-averaged initial contaminant concentration, C_g = cleanup goal concentration (current concentration for this exercise), R = retardation factor, ln = natural logarithm, and PV = number of pore volumes required to achieve C_g. The retardation factor is calculated as

$$R = 1 + (\rho_b/n)(K_d)$$

where ρ_b = the material bulk density, n = the water-filled porosity of the formation (essentially the total porosity for a saturated formation), and K_d = the distribution coefficient for the solute in the soil. K_d can be determined experimentally or estimated from empirical relationships. The retardation factor accounts for adsorption effects that slow contaminant flushing from the aquifer. An important assumption of the batch-flush model is that there is no upgradient source of contamination. The batch-flush model does not account for dispersion, diffusion, and biological attenuation that might also be acting to some degree on the plume.

A TCE retardation factor of 1.73 was calculated for the site aquifer. The retardation factor was calculated using a site specific bulk density of 1.65 grams per cubic centimeter, a porosity of 0.35, and a distribution coefficient K_d of 0.15. The distribution coefficient was calculated using an empirical relationship that correlates the partitioning of TCE between groundwater and the soil to the tendency of TCE to partition between water and an organic solvent (octanol) Calculation of K_d is based on fraction organic carbon (f_{oc}) of 0.001 (i.e., 0.1 percent) (organic carbon of Willamette Silt samples were less than 0.2 percent and it is assumed that the aquifer has less carbon content than the overlying aquitard) and literature values (Karickhoff et al., 1979) for the octanol-water partition coefficient (K_{ow}). Assumed values and calculations are presented in Appendix H. The number of pore volumes required to achieve the current concentration at a specific well (e.g., R665Vr) was then calculated from the batch-flush model.

5.9.2 Calculations

To calculate the amount of time for one plume pore volume to pass a particular monitoring well, the distance from the monitoring well to the upgradient estimate of the plume (i.e., the plume boundary in 1986) before pumping began was measured. This distance was then divided by the groundwater velocity for the time needed for a clean particle of water to move from outside the plume boundary past the well. The groundwater velocity was calculated from Darcy's law using a representative hydraulic gradient for the well. To calculate the time to reach the reduced concentration, the number of pore volumes needed was then multiplied by the time to pass a pore volume of water past the monitoring point (i.e., from the edge of the plume to the well). This calculated time is compared with the actual cleanup time below:

Well	Initial C_o (µg/L)	Current C_g (µg/L)	Actual Time (Years)	Calculated Time (Years)	Number of Pore Volumes
MW-7	160,000 – 300,000	1	9-10	11 - 12	21
R665Vr	2,000	3	5-10	11	10.8
MW-14	84	1	3-5	3.3	7.7

As shown, the actual cleanup times are reasonably close to those calculated. Given hydraulic control of the source area, these estimates support the possible cleanup of larger areas of the plume that are not directly affected by DNAPL or in positions hydraulically-downgradient of the DNAPL source.

6 CONCEPTUAL HYDROGEOLOGIC MODEL

A conceptual hydrogeologic model is a three-dimensional representation that summarizes what is known or suspected about contamination sources, release mechanisms, and the transport and fate of those contaminants. It provides the basis for delineating the LOF, which in turn aids in developing the conceptual site model used to assess risk to potential receptors. Conceptual hydrogeologic models are commonly illustrated with cross sections and groundwater flow maps developed during the site characterization phase. The following subsections summarize findings from the FRI in the context of the conceptual hydrogeologic model.

6.1 Site Hydrogeology

The hydrogeologic framework is a relatively simple layered model with unsaturated silt and silty sands to a depth of approximately 20 feet that overlie a sandy gravel aquifer. The aquifer is somewhat heterogeneous, with sequences of relatively clean sand and gravel interbedded with zones that are cemented with silt and clay. The thickest part of the aquifer underlies the Submicro area; this is also the area with the lowest percentage of fines. Silt and clay percentage increases and the overall aquifer thickness decreases toward the river. The entire sequence rests on a fluvially-eroded clay aquitard that has an undulating surface of high and enclosed low areas. Overall, the clay aquitard rises in elevation toward the Willamette River.

Groundwater in the aquifer (under non-pumping conditions) flows northeast toward the Willamette River. The aquifer discharges fully into the Willamette River where it is truncated by river erosion along the northeast edge of the property. Groundwater elevations rise and fall seasonally in response to rainfall and recharge from upgradient. On average, the groundwater elevations are higher than the river, even during times of flood stage. The aquifer is unconfined during the drier months, but during periods of high groundwater, it can be partly confined in places. Under pumping conditions, an enclosed groundwater low forms between MW-3 to the west, MW-2 to the north, and MW-12 to the east. Groundwater elevations in this area of withdrawal are lower than the river stage but separated from the river by a groundwater divide that forms roughly parallel to the river along MW-6, MW-15, MW-13, and MW-4.

The pump and treat system significantly dewaters the aquifer, to roughly half the thickness of the potential (non-pumping) saturated thickness of 20 feet. The groundwater table recovers quickly (within a day) to the approximate top of the aquifer (i.e., base of the Willamette Silt) when the remediation system is shut down, and returns to equilibrium pumping conditions within approximately a day of restarting the pumps.

The streambeds of the Willamette and Mary's rivers cut below the base of the Linn Gravel, thus exposing the aquifer completely along the bank of the river. For most of the year, the aquifer is submerged by the river. However, during periods of low river stage, some thickness of aquifer is above river level and groundwater seeps along the bank are possible. By completely truncating the aquifer, the rivers serves as a physical hydrogeologic boundary to the Linn Gravel downgradient of the site.

Surface water-groundwater interactions are rapid along the banks of the river because of the relatively good permeability of aquifer material, short distance between river and wells, and hydraulic connectedness to the river. Short of flood stage, the river provides the base elevation for the aquifer potentiometric surface (i.e., the point to which the aquifer drains) and the river is expected to have minimal effect on water levels in the aquifer at a distance beyond where bank storage/drainage occurs. During flood stage, there are short periods when the river level exceeds groundwater elevations and the drainage divide breaks down, allowing groundwater to move toward the pumping-induced depression. On average, however, groundwater flows from the drainage divide toward the river.

There is a potential for groundwater to provide baseflow to the millrace under limited hydraulic conditions. Before pumping began in 1991, potentiometric elevations rose above the base of the millrace seasonally and likely provided some baseflow. Since pumping began, water levels have mostly dropped below the base of the millrace culvert, although there are isolated events of high groundwater. Away from the strong pumping influences, groundwater elevations still seasonally rise above the base of the millrace culvert (e.g., at MW-19) or where the millrace joins the Mary's River (at MW-6).

6.2 Contaminant Sources and Fate

Contamination in the form of spilled TCE migrated from the Submicro downward through unsaturated silt to aquifer material where it spread laterally. The DNAPL appears to be limited to an enclosed low area along the upper surface of the clay aquitard just east of the Submicro. The highest concentration portion of a dissolved VOC groundwater plume subsequently migrated downgradient toward the Willamette and Mary's rivers where it discharges to surface water. Pumping in areas proximal to Evanite, had induced contaminants to migrate crossgradient to the southeast. In addition, historical sources of VOCs, including TCE, PCE, and fuel related compounds, which are documented upgradient of the site to the southwest and west, apparently feed other VOC plumes that overlap with the limit of the Evanite VOC plume.

6.3 Discussion

The groundwater pump and treat system has operated at Evanite since 1991. Three primary objectives for the system continue to be met:

- Pumping hydraulically controls the VOC plume.
- Pumping has contracted the plume and pulled contaminants from off site, including non-site related contaminants.
- Pumping has removed a significant mass of VOCs (including product from the DNAPL recovery system and vapors from the SVE system).

Conceptually, the DNAPL continues to provide an ongoing source of dissolved VOCs in groundwater. The dissolved plume is controlled by the pump and treat system which creates a groundwater depression in the central part of the site. Lower groundwater levels within this depression result in mostly unsaturated, unconfined conditions in the aquifer throughout the site for a majority of the year. In addition, the closed groundwater depression creates a groundwater divide between the area of groundwater withdrawal and the Willamette River. The groundwater divide is an area of stagnation where groundwater velocities are low; the only recharge along the divide is through rainfall infiltration. During short periods when the remediation system is shut down for routine maintenance, water levels recover quickly, in less than one day.

The pumping has increased gradients along the upgradient sides of the plume allowing clean water to flush through impacted parts of the aquifer and restoring the water quality to near detection limits. This has occurred at MW-7, MW-10, MW-14 and MW-19. At MW-18, TCE concentrations are approaching the MCL. This demonstrates that given optimal conditions (i.e., source removal or containment, and flushing impacted parts of the aquifer with fresh water) the aquifer can fully restore itself within a relatively short period of time, less than 10 years. However, a large part of the VOC plume, where a substantial thickness of aquifer is unsaturated, is not being treated. Parts of the aquifer that have cleaned up relatively rapidly are also characterized by relatively higher percentages of clean sand and gravel (i.e., lower percentage of fines), although this is not always the case (e.g., MW-14). But in MW-7, MW-10, and MW-19, greater than 75 percent of the aquifer was clean sand or gravel. Wells slower to clean up (e.g., MW-12 and MW-18) have higher percentage of fines and the relative percent of unsaturated thickness tends to be greater.

Outside the source area, in the downgradient part of the aquifer, groundwater has stagnated along a groundwater divide and the lithology has a higher percentage of fines. Both of these factors slow down groundwater movement and consequent natural flushing of the system. The only recharge mechanism is rainfall infiltration. With hydraulic control of the source provided by the pump and treat system, no new contaminants can migrate to the part of the aquifer along the river, however, because there is no mechanism to flush them from the aquifer, the remaining contaminants persist. This results in natural anaerobic biodegradation of TCE as the predominant mechanism of aquifer restoration, and is reflected in daughter product to TCE ratios above 1.0. The biodegradation and reduction in TCE mass occurs at a relatively slower rate than in upgradient areas, where greater quantities of clean water are allowed to flush the aquifer.

7 LAND AND WATER USE

Land and water use determinations are part of the broader process of assessing whether or not sites pose a risk to human health or the environment. Typically, information about land and water use and their associated activities is used to focus the site investigation and risk assessment on the most likely exposure pathways. At later stages of the cleanup process, final determinations of land and water use are integral to fashioning an effective remedial action.

Within this context and at this stage of the cleanup process at Evanite, the land and water use determination will narrow the spectrum of exposure pathways used to assess human health and ecological risk.

Land and water use determinations for the site are discussed consistent with current DEQ guidance (1998a,b). The area within which the land and water use determination is conducted is referred to as the locality of facility (LOF). Both the LOF and the land and water use determinations are combined in this chapter because of their close linkage in the cleanup process.

7.1 Locality of Facility

The cleanup rules define the LOF as "any point where a human or an ecological receptor contacts or is reasonably likely to come into contact with facility-related hazardous substances. The locality of the facility takes into account the likelihood of the contamination migrating over time so is typically larger than the facility (OAR-340-122-0115[34])." Identifying the LOF is useful because it limits the extent of the beneficial water use determination by identifying which environmental media are likely to be impacted over time. Ultimately, a final LOF determination is made after the risk assessment and is used to decide which areas exceed acceptable human health or ecological risk and therefore require remedial action.

Determination of the LOF flows directly from the conceptual hydrogeologic model presented in Section 6. That section described the extent of impacts and potential migration pathways of site–related chemicals. The LOF for a particular environmental medium includes both the current extent of hazardous substances and the projected future extent if chemicals are expected to migrate. At Evanite, the method to project future extent of chemical migration will be based on historical extent, since the pre-remediation extent provides an empirical baseline for uncontrolled VOC migration from the site. The LOF determination is preliminary because an assessment of risk has not yet concluded whether or not the concentrations pose an excess risk to human health and whether the current remedial measure or additional measures are needed to manage that exposure.

The LOF for each of the media are shown in Figures 5-1 and 7-1. Assumptions for determining each LOF are described below:

Soil. The only area of soil impacts is east of the Submicro (Figure 7-1). A conservative LOF was determined based on the extent of VOCs in soil, both from historical (1985-86) and recent (2002) soil data.

Surface Water and Sediment. Both of these media have the same LOF since both are in contact with each other (Figure 5-1). The LOF represents areas where VOCs have been detected historically in surface water—along the millrace and from shoreline samples in the Willamette River; VOCs were not been detected in sediment samples collected in the past.

Groundwater. The boundary for the groundwater LOF is defined by the historical extent of site-related VOCs detected in groundwater, including its spread cross-gradient to the south and southeast (Figure 5-1). The chemicals of interest include TCE and its breakdown products, but specifically exclude PCE. This is because PCE in groundwater is not site-related and therefore PCE was excluded as a chemical from the LOF (i.e., at MW-10 and MW-14). In addition, another VOC plume with a larger suite of VOCs, including halogenated VOCs (e.g., PCE, TCE and their breakdown products) and non-halogenated VOCs (e.g., benzene, 1,4-dichlorobenzene) appears to be related to an off-site source documented at the former Chevron bulk terminal, just upgradient of MW-9. Based on its proximity and position immediately downgradient of this source, MW-9 also was excluded from the LOF.

7.2 Land Use

Land use information was acquired from the City of Corvallis planning division, and from known historical uses of the property and surrounding neighborhood as documented in earlier reports. The city's planning division met with M/E staff (in November 2001) and answered standard questions recommended in the DEQ guidance on land use; a copy of their response is provided in Appendix I along with relevant sections of the city code provided by city staff. The following information was reviewed to support classification of land use expected in the future:

- General zoning use and specific activity use on the properties within the LOF.

- Zoning map, comprehensive plan designation, and applicable regulations provided by the City of Corvallis.

7.2.1 Current Land Use and Zoning

The site and surrounding area is zoned for general industrial, intense industrial, high-density residential, linear commercial, and low-density residential uses. Current land uses in the vicinity of the site include commercial (tire store, self storage, rental shop, grocery store), industrial (Evanite), low density residential, recreational (BMX track, boat ramp), and open space (vacant lots).

The property is described as tax lot 100, in Section 2, Township 12 South, Range 5 West of the Willamette Meridian, in Benton County, Oregon. The central part of the site is designated II (intensive industrial) and the northwestern and southeastern parts of the property are designated GI (general industrial). Current use of the site as II is a pre-existing, nonconforming use, and is allowed conditionally on that part of the property designated as II. In addition to the GI and II land use classifications, part of the site has a Willamette River Greenway Overlay. This means that any future expansion or intensification of industrial activities at the site would require additional review by using the Greenway review criteria.

The city's response to the questionnaire also identified that parts of the Evanite property are within the 100-year floodplain and that a small creek (the millrace) runs through the property.

7.2.2 Expected Future Land Use

Land use in the foreseeable future is expected to remain similar to existing uses. Long-term planning by the city is encompassed by its comprehensive plan (Figure 7-2). The City of Corvallis is in the process of updating its Land Development Code and district map to be consistent with the comprehensive plan map; currently, both are being reviewed by the state for approval.

The Evanite property is located within the "South Corvallis Area Refinement Plan." The final report for this land use plan presents findings of the planning process for the riverfront area. The South Corvallis subarea plan identifies the Evanite property as being "Mixed Use Riverfront," which is implemented through the "Mixed Use Transitional" zone identified on the comprehensive plan map. Mixed Use Transitional is intended to provide a mechanism for existing general and intensive industrial uses to transition over time to less intensive uses including residential, commercial, limited industrial, parks, and open space.

7.3 Water Use

As with the land use evaluation, the primary purpose of evaluating beneficial uses of water is for completing a conceptual site model that will be useful for assessing risk to potential receptors. Some of these pathways may ultimately be deemed incomplete in assessing the conceptual site model, and therefore, even though a beneficial use potentially exists, it would not be affected by site-related contaminants.

Beneficial water use evaluations typically consider factors such as yield, inherent water quality (background quality), and availability of alternate water supplies. These two factors are discussed to provide context for the review of beneficial uses of water.

7.3.1 Suitability of Groundwater

The primary water-bearing zone in the area is the Linn Gravel. This aquifer provides water of drinking quality in the area and was used extensively for domestic uses and for irrigation. Well yield is adequate for most domestic uses (15 to 25 gpm listed on Department of Water Resources [DWR] well logs for the area). Because of the relatively thin saturated aquifer thickness (less than 20 feet) and zones of cemented sand and gravel, which tend to reduce yield, the aquifer does not provide a substantial-enough yield for industrial or commercial needs.

7.3.2 Municipal Supply

The City of Corvallis obtains its water for the municipal supply from two sources: the Rock Creek Watershed (also referred to as the Corvallis Watershed), which is comprised of approximately 10,000 acres near Mary's Peak; and the Willamette River. Each source contributes approximately one-half of the city's needs. Intakes from both sources route water to two water treatment facilities before distribution. The City supplies water to neighborhoods adjacent to the site as well as to the Evanite facility.

7.3.3 Groundwater

In 1986, Evanite completed a comprehensive survey of well construction logs for a large area encompassing the site. This work was conducted in support of an Initial Action Plan (DEQ, 1986) to assess TCE contamination in off-site groundwater. The action plan involved a door-to-door survey to identify water wells in the area and the type of water usage at each residence. It also collated well logs from the DWR that were available for the area. To update this study, M/E searched the DWR online website for water wells in Sections 2 and 11 of Township 12 South, Range 5W. Table 7-1 combines relevant information from both surveys and cross references the wells from the DWR files with those from the earlier survey. Table 7-1 also lists well construction information acquired from the interviews conducted in 1987 and from well logs.

7.3.3.1 Historic and Current Groundwater Use

Available well logs for the area (i.e., in Sections 2 and 11) dating back to the 1940s show that water wells were drilled for domestic use (well logs from the DWR database are in Appendix I). In approximately 1965, groundwater was supplanted by the Corvallis municipal supply in the South Corvallis area. At the same time, municipal water was also provided to the Evanite facility and to nearby businesses. There are no records indicating the presence of an on-site well that could have been used by the Evanite facility or earlier site occupants, although the large diameter of MW-4 suggests possible higher-yield usage.

In mid-1986, Evanite, in response to TCE groundwater impacts at the site, undertook a door-to-door survey and monitoring program in the neighborhood north of Chester Avenue, including SE Vera Avenue and SE Vica Way. The results of the survey revealed that by the mid 1980s, groundwater was still used, however only to supplement domestic irrigation needs. Municipal water was provided to the area, although many of the older homes maintained wells for irrigation use, primarily for gardens during the drier summer months. Because of this anticipated continued use, and to reduce interference with Evanite's groundwater pumping program, residents on the north side of Vera Avenue ceased using their wells (i.e., City water is now used for irrigation).

In addition to providing beneficial uses via well pumping, groundwater at the site also discharges directly to the Willamette and Mary's Rivers along northern and eastern site property boundaries. In this respect, it contributes to the habitat of aquatic life, to recreational activities, and to the aesthetic appeal of the rivers.

7.3.3.2 Potential Future Use

The comprehensive plan for this areas calls for similar residential uses in adjacent neighborhoods, for ongoing industrial, and for Mixed Use Transitional which is intended to provide a mechanism for existing general and intensive industrial uses to transition over time to less intensive uses including residential, commercial, limited industrial, parks, and open space.

With respect to potential groundwater beneficial uses in this area, planned future land use translates to continued irrigation (limited to summer months), some isolated well use for domestic drinking water, and surface water recharge. The ready availability of a municipal water supply would appear to make future use of groundwater for domestic purposes unnecessary. However, escalating costs associated with connecting to the city water supply is a disincentive for single-family residences where less expensive or more convenient alternatives, such as installing a new well or maintaining an existing well, exist.

For larger developments that hypothetically might be part of future land redevelopment (i.e., on the Evanite property), municipal water is the most likely source for two reasons: availability and quality of municipal supply, and the limited aquifer yield. Where an industrial or commercial use calls for higher yield, not attainable by water wells, surface water is an alternate source that can be used for landscaping associated with parks or for process water (as currently employed by the Evanite facility).

Finally, groundwater discharge to surface water will remain a future beneficial use.

7.3.4 Surface Water

The Willamette River is the major drainage for the Willamette Valley. The Mary's River, a tributary of the Willamette River, feeds into the Willamette River from the west. The Evanite site is located on the southwest side of the confluence of the Mary's and Willamette rivers. A third surface water body, the millrace, flows through the property from the south to north where it empties at the mouth of the Mary's River. The millrace is a perched water body (i.e., its base is at an elevation above the groundwater table) that was originally constructed in the late 1800s to provide water to a wheat mill at the site of the present day Hardboard facility. The source of the millrace was the Mary's River southeast of the site, but is now limited to surface water drainage from South Corvallis.

7.3.4.1 Historic and Current Surface Water Use

The Willamette and Mary's rivers are currently used for recreational activities and contribute to aquatic life while also providing aesthetic appeal to their environs. Evanite obtains raw process water from its Willamette River intake structure located at the Hardboard plant, and approximately two miles upriver, the City of Corvallis pumps water from the river to its Taylor water treatment plant, before distribution to municipal users.

The millrace, in particular the old millrace, was used to apparently supply river power to the milling of grain. The current channel of the millrace is no longer used for any commercial or industrial purpose, although it provides limited habitat for aquatic and terrestrial animal life and for vegetation (TAS, 2002a).

7.3.4.2 Potential Future Use

Future uses of the Willamette and Mary's rivers are likely to remain similar to current uses: drinking water, industrial uses, recreation, aquatic life, and aesthetics. Aside from stormwater drainage, uses of the millrace are limited to aquatic life and terrestrial habitat.

7.4 Summary of Current and Reasonably Likely Land and Beneficial Water Use

Current and future beneficial uses of water are summarized in Table 7-2. On the basis of current zoning allowed in the area and future zoning anticipated under the comprehensive plan for the South Corvallis Area, the following land and water use findings relevant to the risk evaluation and development of the conceptual site model were developed:

- The area within the LOF and nearby properties is zoned residential, commercial, general industrial and intense industrial. Future land use is expected to remain similar to existing uses although the comprehensive plan calls for industrially-zoned areas to transition to mixed uses such as limited industrial, commercial, office, residential and park/open space.

- Part of the property is also designated with a Willamette River Greenway Overlay that would require a conditional development permit for any future development.

- Homes and business in the area are supplied by municipal water service, however shallow groundwater (i.e., from the Linn Gravel) within the LOF is used to a limited degree for domestic water supply and landscape irrigation. Future use of groundwater is expected to include these uses.

- Groundwater recharges surface water of the Willamette and Mary's rivers and for that reason contributes to beneficial uses of those rivers.

- The Willamette River is currently used as a source for drinking water and industrial needs, as well as supporting aquatic life, and recreational and aesthetic beneficial uses. Future uses are expected to be the same as current uses.

8 CONCLUSIONS AND RECOMMENDATIONS

The purpose of the FRI was to synthesize available data and, as necessary, gather additional technical information to support risk assessment and an evaluation of the corrective measures or controls necessary to ensure management of any calculated risk. This section presents conclusions relevant to completing the risk assessment and the remediation evaluation, and recommendations that should be considered given an acceptable outcome of the risk assessment.

The following subsections are organized according to primary subject areas defined by overall project objectives.

8.1 Conclusions

The consent order SOW outlined a number of project objectives to guide the overall project approach and scope. Conclusions shown below that address those objectives were distilled from the conceptual hydrogeologic model. Additional FRI conclusions are directly relevant to evaluate on-site soil conditions in the vicinity of the existing vapor extraction system and to evaluate the effectiveness of the current SVE system.

8.1.1 Hydrogeology

- The hydrogeologic framework is a simple layered model with unsaturated silt and silty sands that overlie a sandy gravel aquifer. This, in turn, rests on a fluvially-eroded clay aquitard that has an undulating surface of high and enclosed low areas.
- Groundwater in the aquifer (under non-pumping conditions) flows northeast where it discharges to the Willamette and Mary's rivers. The rivers completely truncate the aquifer and serve as physical hydrogeologic boundary to the Linn Gravel downgradient of the site.
- Under pumping conditions, an enclosed groundwater low forms between extraction wells and is separated from the river by a groundwater divide that forms roughly parallel to the river. The groundwater divide is an area of

stagnation where groundwater velocities are low and the only recharge is through rainfall infiltration.

- The pump and treat system significantly dewaters the aquifer, to roughly half the thickness of the potential (non-pumping) saturated thickness of 20 feet, although the groundwater table recovers quickly when the remediation system is shut down, and returns to pumping equilibrium within approximately a day of restarting the pumps.
- There is a potential for groundwater to provide baseflow to the millrace under limited hydraulic conditions (i.e., when the system is not pumping in the winter or in areas away from the strong pumping influences).

8.1.2 Nature Extent, and Distribution of COPCs at Site

- Contamination in the form of spilled TCE migrated from the Submicro downward through unsaturated silt to aquifer material.
- DNAPL, which appears to be limited just east of the Submicro to an enclosed low area along the upper surface of the clay aquitard, continues to provide an ongoing source of dissolved VOCs in groundwater.
- The dissolved VOC groundwater plume migrated downgradient toward the Willamette and Mary's rivers where it discharges to surface water. The dissolved plume is hydraulically controlled by the pump and treat system which creates a groundwater depression in the central part of the site.
- Historical water well pumping in areas proximal to Evanite, induced contaminants to migrate crossgradient to the east-southeast.
- Other sources of VOCs, including TCE, PCE, and fuel related compounds, which are documented upgradient of the site to the southwest and west, apparently feed VOC plumes that overlap with the limit of the Evanite VOC plume.
- Remediation pumping has increased gradients along the upgradient sides of the plume allowing clean water to flush through impacted parts of the aquifer and restoring the water quality to near detection limits. This demonstrates that given optimal conditions (i.e., source containment and flushing the aquifer with fresh water), the aquifer can fully restore itself within a relatively short period of time, less than 10 years.

- A substantial thickness of aquifer that is unsaturated because of drawdown associated with continuous remediation pumping, is not being treated by flushing. However, improved removal efficiency that correlates with shutting down the system in the past 9 months suggests that this unsaturated portion of the aquifer could potentially be treated with a more systematic program of pulse pumping.

- In downgradient parts of the aquifer, where groundwater has stagnated along a groundwater divide, there is no mechanism to efficiently flush contaminants from the aquifer and VOCs persist. This results in conditions conducive to natural anaerobic biodegradation of TCE, which is reflected in daughter product to TCE ratios above 1.0.

- The primary contaminant at the site is TCE. Related chlorinated COPCs include *trans/cis*-1,2-DCE, 1,1-DCE, 1,1-DCA, and vinyl chloride. In addition to TCE and breakdown products, methylene chloride will be evaluated as a COPC. The occurrence of trace detections of PCE in groundwater is likely associated with multiple, off-site, upgradient sources and for this reason will not be assessed for risk because the PCE is not site related.

8.1.3 LOF and Land and Water Use

The LOF for the Evanite site was conservatively established for each of the media using the historical nature and extent of contamination as follows:

- **Soil.** The area of soil impacts is east of the Submicro and was based on the extent of VOCs in soil using both historical (from 1985-86) and recent (2002) soil data.

- **Surface Water and Sediment.** Both of these media have the same LOF since both are in contact with each other. The LOF represents areas where VOCs have been detected historically in surface water—along the millrace and from shoreline samples in the Willamette River—and includes the shoreline where the VOC groundwater plume potentially discharges to surface water; VOCs were not detected in sediment samples collected in the past.

- **Groundwater.** The boundary for the groundwater LOF is defined by the historical extent of site-related VOCs detected in groundwater, including its spread cross gradient to the east-southeast.

Land and water use conclusions are summarized as follows:

- The area within the LOF and nearby properties is zoned residential, commercial, general industrial and intense industrial. Future land use is expected to remain similar to existing uses although the comprehensive plan calls for industrially-zoned areas to transition to mixed uses such as limited industrial, commercial, office, residential and park/open space.

- Part of the property is also designated with a Willamette River Greenway Overlay that would require a conditional development permit for any future development.

- Homes and business in the area are supplied by municipal water service, however shallow groundwater (i.e., from the Linn Gravel) within the LOF is used to a limited degree for domestic water supply and landscape irrigation. Future use of groundwater is expected to include these uses.

- Groundwater recharges surface water of the Willamette and Mary's rivers and for that reason contributes to beneficial uses of those rivers.

- The Willamette River is currently used as a source for drinking water and industrial needs, as well as supporting aquatic life, and recreational and aesthetic beneficial uses. Future uses are expected to be the same as current uses.

8.1.4 Soil and SVE Conclusions

- The analytical results demonstrate heterogeneity of soil concentrations.

- The SVE has not contributed to uniform cleanup of the Willamette Silt in the Submicro area. Removal is likely controlled to a large extent by the soil type (fine- versus coarse-grained) and proximity to the SVE wells, with the greatest removal efficiency near SVE wells in coarser-grained soil.

- Results from the radius of influence testing show limited and directional influence from the SVE wells to the probes. The most likely explanation for these results is that the primary control on VOC removal through vapor extraction is the permeability of the soil. SVE wells that are screened across more permeable sandy and gravelly layers in the Willamette Silt will more effectively remove VOCs within those layers.

8.2 Recommendations

Pending the outcome of the risk assessment, there are two recommendations that should be examined within the context of effectiveness of the remedial measures currently operating at the site.

Evaluate whether SVE operation is effective. The results of testing the area of influence of SVE wells as well as the soil analyses illustrate that after 10 years of operation, there still are significant concentrations of VOCs in soil. Given the limited effectiveness of SVE in fine-grained soil of the Willamette Silt, operation of the SVE should be evaluated against balancing factors such as cost, effectiveness, contaminant removal, and mitigation of risk.

Improve flushing of aquifer. A significant part of the aquifer is not being treated by the remediation pumping because drawdown associated with continuous pumping has stranded VOCs in the upper unsaturated aquifer. Creating opportunities to resaturate the aquifer could facilitate flushing of the unsaturated part of the aquifer, increase TCE removal, and enhance restoration. This could be done by implementing a systematic program of pulse pumping and by shutting down extraction wells outside areas of DNAPL influence (i.e., at MW-11 and MW-12). Hydraulic control would be limited to the area of the site where DNAPL has been characterized, near MW-3 and MW-16.