FEASIBILITY STUDY

FORMER MILL E/KOPPERS FACILITY

EVERETT, WASHINGTON

Prepared for

Weyerhaeuser Company

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SUMMARY

The Former Mill E/Koppers Facility (the Site) is an 8.9 acre site located on Weyerhaeuser property in Everett, Washington. Historical activities at the Site, primarily wood treatment and maintenance facility operations, appear to have resulted in soil and groundwater contamination by arsenic, chromium, copper, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, pentachlorophenol, and/or dioxins/furans. To characterize the nature and extent of this contamination, Weyerhaeuser performed a remedial investigation. Results indicate that the primary contaminant transport pathway is from soil to groundwater, with subsequent discharge to the adjacent Snohomish River. Contaminant receptors (and secondary transport pathways) are the Snohomish River and its sediments.

A baseline risk assessment was conducted using the findings of the remedial investigation. Results of this assessment indicate that the estimated hazard index (HI) for noncarcinogenic indicator hazardous substances is 0.13. Because this value is less than 1.0, noncarcinogenic health effects from the substances evaluated in the assessment do not appear to be of concern for the site according to the regulatory criteria considered. The estimated excess carcinogenic risk for carcinogenic indicator hazardous substances at the Site is 5×10^{-5}. This level of risk exceeds the Washington Model Toxics Control Act total risk level of 1×10^{-5}. In addition to the baseline risk assessment, site sampling data were compared with potentially applicable standards (e.g., ambient water quality criteria); several contaminants exceeded the corresponding standards.

As a result of the contamination identified and the associated risk, a feasibility study was performed to evaluate potential cleanup actions for the Site. This feasibility study was performed using the Model Toxics Control Act as the primary guiding regulation. It was also performed to be consistent with the Comprehensive Environmental Response, Compensation, and Liability Act.

Pursuant to these regulations and associated guidance, the first step of the feasibility study was a scoping process that established the framework in which the rest of the study was performed. The primary results of the scoping process were contaminant and media-specific action levels, delineation of areas and volumes of media with contaminant concentrations exceeding the action levels, and the development of remedial action objectives for both human and environmental receptors.

The next step in the feasibility study was to identify cleanup technologies that could be used to address the remedial objectives identified in scoping. After a preliminary list of technologies was assembled, the technologies were screened based on three criteria: effectiveness, implementability, and cost-effectiveness. Three potentially applicable technologies required treatability studies to determine if they were suitable for use at the Site. These technologies were soil washing, bioremediation, and stabilization. The results of the treatability studies indicated that both stabilization and soil washing may be effective at minimizing contaminant mobility and volume, respectively. Bioremediation did not appear to be a viable treatment alternative for the Site because of its limited ability to degrade all the organic constituents of concern and its ineffectiveness in treating metals.

Once a final list of applicable technologies was prepared, 10 preliminary cleanup action alternatives were developed. These preliminary alternatives represented a broad range of possible cleanup actions ranging from containment, soil excavation and treatment, groundwater extraction and treatment, to in situ treatment. In order to reduce the number of alternatives that were subsequently evaluated in detail, the preliminary alternatives were screened against the same three criteria as the technologies: effectiveness, implementability, and cost-effectiveness. After screening, the following six alternatives were retained for detailed analysis:

- **Alternative 1** - No action
- **Alternative 2** - Site-wide capping, product recovery, and groundwater monitoring
- **Alternative 3** - Site-wide capping, vertical containment of saturated hot spot soil, product recovery, and groundwater monitoring
- **Alternative 4** - Soil consolidation, capping, product recovery, vertical containment, and groundwater monitoring
- **Alternative 6** - Hot spot soil excavation, stabilize excavated soil, site-wide capping, and groundwater monitoring
- **Alternative 7** - Excavation and stabilization of all impacted soil, and groundwater monitoring

In the detailed analysis portion of the feasibility study, the retained alternatives were developed in detail, including information on the specific areas and volumes of contamination being treated or contained, permitting requirements, and capital and operation and maintenance costs. Next, each alternative was evaluated against the criteria in the Model Toxics Control Act (WAC 173-340-360).

After each alternative was individually compared against the evaluation criteria, the alternatives were compared against each other, and a preferred alternative was selected. This evaluation resulted in the selection of Alternative 4 as the preferred alternative.

Alternative 4 includes the following major components:

- Excavation and screening of approximately 14,000 cubic yards (cy) of soil exceeding action levels that are located outside the proposed vertical containment area and consolidation of the screened soil inside the vertical containment area

- Installation of approximately 1,700 linear feet of low-permeability sheet piling around the saturated hot spot soil

- Installation of a low-permeability asphalt cap above the vertical containment area

- Performance of passive product recovery from approximately four, newly-installed product recovery wells in the former blow pit area

- Performance of groundwater monitoring

When implemented, this alternative would provide significant and long-term protection of human health and the environment. This alternative has estimated construction costs of $1,910,000 and present worth operation and maintenance costs of $750,000.

Over $2,000,000 has been expended in performing site characterization studies, treatability studies, interim remedial actions, and evaluation of remedial technologies and approaches to develop the most practicable and feasible remediation solution for the Site.

1 INTRODUCTION

This report presents the findings of the feasibility study (FS) conducted by EMCON for the Former Mill E/Koppers Facility, an 8.9-acre site located on Weyerhaeuser Company property in Everett, Washington. The remedial investigation (RI) conducted by EMCON indicated that historical practices at the site, primarily wood-treating operations and maintenance and fueling activities, appear to have resulted in soil and groundwater contamination.

The Washington Department of Ecology (Ecology) conducted a site hazard assessment of the Weyerhaeuser Company's Everett Facility and assessed a No. 1 ranking, pursuant to regulations and guidance for implementing the state's Model Toxics Control Act (MTCA). The Former Mill E/Koppers Facility is part of the Weyerhaeuser-Everett site; as such, the FS followed procedures specified in the implementing regulations of MTCA, chapter 173-340 of the Washington Administrative Code (WAC). The RI/FS was conducted as an independent action. Procedures described in the National Contingency Plan (40 CFR Part 300) and associated guidance, developed pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), were also followed in conducting the FS.

The scope of work and the rationale for specific FS activities are described in detail in "Work Plan for Remedial Investigation/Feasibility Study of Former Mill E/Koppers Facility" (EMCON, 1992).

1.1 Purpose

This FS was undertaken to develop and evaluate a range of potential cleanup action alternatives for the Former Mill E/Koppers Facility. Remediation technologies were evaluated for all media of concern at the site. A screening process was used to develop several cleanup action alternatives. The options ranged from no action to containment to complete excavation and treatment of contaminated soil. These alternatives were then evaluated in detail to identify the preferred cleanup action for the site.

1.2 Feasibility Study Report Organization

- Section 1 provides an introduction to the report and explains how the report is organized.
- Section 2 presents information regarding site location and features, site history, climate, geology, hydrogeology, land use, soil and groundwater conditions at the site, and the nature and extent of on-site contamination.
- Section 3 summarizes applicable regulatory requirements and soil and groundwater cleanup standards that may apply to the site, delineates the areas of contamination, and identifies the remedial action objectives.
- Section 4 identifies potentially applicable remediation technologies and presents the results of the technology screening process.
- Section 5 describes the development and screening of on-site cleanup action alternatives.
- Section 6 presents the detailed evaluation of various cleanup action alternatives for possible on-site implementation.
- Section 7 presents a comparative analysis of the cleanup action alternatives and the recommended cleanup action alternative.

2 SITE BACKGROUND

This section summarizes the physical, geologic, and hydrogeologic characteristics of the site, the nature and extent of contamination, and the fate and transport of contaminants as described in "Remedial Investigation Report for Former Mill E/Koppers Facility" (EMCON, 1994). Additional, post-RI groundwater and sediment data are also summarized. Drawing 1 (in pocket) shows all sampling locations.

2.1 Site Description and History

The Former Mill E/Koppers Facility (the Site) is located on Weyerhaeuser property in Everett, Washington (Figure 2-1). The Site is next to the Snohomish River, approximately 2 miles upstream from the river mouth at Port Gardner Bay. The current Site boundary is defined by the existing fence that surrounds the Site and is approximately 8.9 acres in size (Figure 2-2). Historically, the Site was defined as the approximately 7 acre property that was used for wood treating operations as shown in Figure 2-2. Structures remaining on the Site include a bulkhead constructed to retain dredge fill, the concrete foundation of the 7,800-square-foot former wood treatment building, which was later converted to a maintenance facility, the 21,000-square-foot concrete slab foundation of former Mill E, and a portion of the former narrow-gauge rail system (Figure 2-2). Approximately 14 percent of the Site is covered with building foundations or asphalt pavement with the remaining portion of the site covered with crushed rock ballast.

2.1.1 Land Use

Both the Site and the overall Weyerhaeuser property have been used for industrial purposes since development. The Site is not currently in use, and operations at the Weyerhaeuser property have been curtailed. The Weyerhaeuser property and, specifically, the Site, are planned for continued industrial use.

The Site and the adjacent property currently are zoned M-2, heavy manufacturing, by the city of Everett.

2.1.2 Local History

A complete history of surrounding land uses is not available. The known historical land uses near the Site are summarized below:

- A smelter and ore refinery (lead, copper, gold, and silver) was operated by Puget Sound Reduction Company from approximately 1894 to 1903 on property near what is now the intersection of East Marine View Drive and State Route 529, approximately 2,000 feet northwest of the Site. ASARCO bought the smelter in 1903 and continued smelter operations until 1908. An arsenic processing plant also operated at the smelter site from approximately 1898 until 1912. The smelter and the processing plant were dismantled in 1914.

- Burlington Northern Railroad (BNRR) currently operates a rail yard west of the Site. It was a single rail in 1892, was expanded to multiple rail lines by 1910, and has been in operation since that time. The early rail lines were operated by Great Northern.

- Weyerhaeuser began Everett area operations in 1902. Mill B, a large sawmill complex located west and north of the Site, was completed in 1915.

2.1.3 Site History

A detailed discussion of the Site history is presented in the RI report. Site activities are summarized below:

Wood Treating --

- The Site was used as a lumber storage area from 1915 until American Lumber and Treating Co. (ALTC) constructed a wood treatment facility on leased Weyerhaeuser property in 1948.

- Koppers Company (later known as Beazer East, Inc.) acquired ALTC in 1954. Wood treatment at the facility continued until 1963, when the lease expired and Weyerhaeuser began to use the Site for maintenance activities.

- The wood treatment facility included aboveground storage tanks, two steel pressure retorts, aboveground and underground piping, and railroad supply lines. Wood treatment processes included the use of creosote, sometimes with a petroleum hydrocarbon carrier, Wolman salts (chromated copper arsenate [CCA]), "Minolith" fire retardant, and pentachlorophenol (PCP) with an oil carrier during the mid-1950s to 1963. Treated wood was stored on the Site or shipped immediately. During retort depressurization, air and liquid reportedly were blown into a pit southeast of the treatment building (the blow pit area; Figure 2-2) (Hart Crowser, 1989).

Maintenance --

- Beginning in 1963, the former wood treatment facility was gradually converted by Weyerhaeuser into an equipment maintenance facility (the retorts and the aboveground storage tanks were removed). The maintenance facility operated from 1963 to 1984. Activities at the maintenance facility included petroleum fueling and maintenance of vehicles and engines. Gasoline, diesel fuel, lube oil, waste oil, and minor quantities of chlorinated and nonchlorinated solvents reportedly were stored and used at the building (Figure 2-2) (Hart Crowser, 1989). The petroleum tanks and some petroleum-contaminated soil were removed in 1988.

Mill E Sawmill --

- Weyerhaeuser built a sawmill, named "Mill E," at the north end of the Site in 1971. Mill E was designed to handle small diameter logs (i.e., 4 to 12 inches) and produce dimensional lumber. Mill E was shut down in 1984 and the building was demolished, except for the foundation, in 1988.

Post-1984 Activities --

- Since 1984, when both the vehicle maintenance and Mill E operations shut down, the site has largely been unused. The former wood treating/maintenance building was used periodically for storage of miscellaneous equipment. Currently, the only structures remaining on site are the foundations of the former wood treating/maintenance building and Mill E. The former wood treating/maintenance building will be referred to as the "building" in this report.

2.2 Site Physical Characteristics

2.2.1 Surface Topography

The Site is adjacent to the Snohomish River, 2 miles upstream from the river mouth at Port Gardner in Puget Sound. The main channel of the river is approximately 750 feet wide and flows next to the Site. The Site is within the low-lying floodplain of the river. The floodplain is bounded on the west and east by steeply sloped ridges and hills reaching to 500 feet above mean sea level. The Site is relatively flat and slopes gently toward the west, away from the river.

2.2.2 Climate

Wind direction is typically from the southeast in the fall and winter and from the west in the spring and summer. Coastal marine air dominates the moisture and temperature patterns, producing cool, wet, mild winters and warm, often dry, summers.

Winds, storms, and temperatures are typically mild year-round in the Everett area. Occasionally, winter storms will bring heavy rainfall, strong winds, or snowfall. The annual average daily temperature is 50.5°F. Average daily temperatures are 62.9°F in July and 38.4°F in January.

Precipitation in the Everett area is primarily in the form of rain. The average annual rainfall is 34 inches, with most falling from October to March.

2.2.3 Surface Water Hydrology

Water is present on the Site surface in three separate forms: surface water, seeps, and storm water.

Surface Water. On-site surface water exists only intermittently in small shallow pools during prolonged rainfall. The only surface water body near the Site is the Snohomish River, which forms the eastern Site boundary along the bulkhead. The average annual flow of the river, as measured by the U.S. Geological Survey 10 miles upstream near Monroe, is 280 cubic meters per second (9,890 cubic feet per second) (Williams, Pearson, and Wilson, 1985). The maximum and average daily tidal ranges of the river at Everett (NOAA, 1991) are 15.5 feet and 8.3 feet above mean sea level, respectively. Tidal saltwater intrusions into the Snohomish River channel during the dry season reach as far upstream as 6.8 miles from Puget Sound.

Seeps. Localized water/seeps emanate into the Snohomish River along the length of the Site from small openings in the bulkhead, upward from the base of pilings, and directly from exposed sediment next to the bulkhead. The flow rates of individual seeps range from a trace to approximately 1 to 2 gallons per minute (gpm). Seep water sources are interpreted to be groundwater discharge and sediment dewatering.

Storm Water. Storm water at the Site generally infiltrates surface soil without runoff. A limited quantity of storm water discharges through existing conveyance ditches and drains, along inferred connections, and out discharge points (see Figure 2-3).

Historically, river water flowed into stormwater discharge piping at the northeast corner of the Site at high tide, then is released back to the river at low tide. Soil around the catch basins was periodically exposed to river water at high tides, as the water infiltrates through breaks in the storm water structures. In 1995, Weyerhaeuser installed a tide gate at the end of the discharge piping, effectively preventing river water from entering this storm drain system.

2.2.4 Regional Geology

Everett is located at the northern end of the north-northwesterly trending Snohomish River valley. The valley lies in the Puget Sound lowland, a tectonic/geomorphic depression between the Olympic Mountains and the Cascade Range. The Snohomish River is one of several major rivers draining west from the Cascade Range into the Puget Sound. The Site is on the floodplain of the Snohomish River, where several hundred feet of alluvial sands, gravels, silts, and clays were deposited in a tidally influenced, estuarine-fluvial environment (Booth, 1984).

The Everett area is underlain by several hundred feet of unconsolidated Pleistocene glacio-marine and glacio-fluvial sediment, over a basement of Tertiary marine sediment and volcanic rocks.

A summary of the regional geology and geologic history of Snohomish County is presented in SE/E (1991).

2.2.5 Site Geology

Drawing 1 shows the locations of all borings and test pits on-site to date; Appendix A of the RI report includes the logs of these borings and test pits. Stratigraphic thicknesses and topographic surfaces of each of the geologic units are presented in Appendix B of the RI report. The geologic deposits underlying the Site consist of man-made and dredge fill overlying natural estuarine and fluvial sediment.

Fill materials and native fluvial and estuarine sediment encountered during the investigations are divided into the following geologic units, listed from youngest to oldest:

- Grade fill and mixed fill unit
- Upper sand unit (dredge fill)
- Upper silt unit (estuarine)
- Lower sand unit (fluvial)

Grade and Mixed Fill Units. Grade fill or mixed fill was encountered at the surface at most of the test pit and soil boring locations. One to 4 feet of grade fill material apparently was placed on the level site after 1974 to improve the working surface. The fill is composed of sandy gravel, asphalt, angular pebbles and boulders of crushed rock, wood debris, and bark. The top few inches contain abundant organic and wood debris and are vegetated in many areas. The grade fill forms a very dense and compacted, although permeable, layer at the surface. Additional fill types (mixed fill) consisting primarily of medium sand with gravel have been identified beneath the building, at other locations near former Mill E, west and north of the building, and along former rail lines. No grade or mixed fill was placed west of the Site. Figure 2-4 depicts the distribution of grade fill and mixed fill at the Site.

Upper Sand Unit. The upper sand unit is composed of gray, brown, or black, fine to medium sand with some coarse sand. Thin (less than 2 inches thick) lenses of coarse sand or silty fine sand, faint horizontal bedding, and a general coarsening of grain size (up to fine gravel) with depth was seen in most soil borings, confirming a hydraulic emplacement of the dredge fill. The upper sand unit ranges from less than 1 to 10.5 feet thick averaging 5 to 6 feet. The upper sand unit is thickest to the east and the north of the building and thinnest to the south and below former Mill E. The average thickness of the upper sand unit in the area west of the Site is 2.5 feet.

Upper Silt Unit. The silt unit is composed of stiff, low-plasticity to nonplastic, gray-brown to dark brown silt, with abundant wood fragments and organic matter in the upper layers of the unit. Lenses of fine sand, sandy silt, and silty sand, 0.1 to 0.2 feet thick, were encountered in most borings and were found at all depths in the unit. The average thickness is 8 feet and ranges from 1 foot to 17 feet. The thickest zone of silt appears to lie in a north-south orientation beneath the building. The silt becomes thinner (e.g., 4 to 6 feet thick) east of the building towards the river. The thinnest portion of the upper silt unit is in the area of the former blow pit, where the silt appears to be less than 2 feet thick. Topographic depressions in the top of the silt unit are found east and north of the building. The unit is a former estuarine tideflat.

Lower Sand Unit. The lower sand unit is composed of medium to coarse sand, with some gravel and wood debris. It is coarser and denser than the upper sand unit and becomes finer grained with depth. The lower sand unit is at least 63 feet thick, and it appears to become thicker towards the Snohomish River. At least 3 feet of silt were encountered in MW-11D2 and MW-23D2 at approximately 75 and 65 feet below the ground surface (bgs). Medium to coarse sand was encountered in boring MW-23D2 below this silt layer, from 67 to 99 feet bgs. The base of the lower sand unit was not encountered in MW-23D2.

The lower sand unit is interpreted to be fluvial sediment deposited by the Snohomish River. It probably extends beneath the entire Site.

Figure 2-5 shows the orientation of the geologic cross sections of the Site presented in Figures 2-6 and 2-7.

2.2.6 Site Hydrostratigraphy

Local groundwater flow systems in the fluvial and estuarine sediments and in the man-made fill are influenced by surface topography and composition, precipitation patterns, underground utilities, and local surface water bodies. Local flow systems are recharged by precipitation and discharge from deeper flow systems. Discharge is primarily to the Snohomish River.

Hydrostratigraphic Units. Four hydrostratigraphic units were identified. They correspond to the geologic units described above.

- **Grade Fill and Mixed Fill.** The grade and the mixed fill units were unsaturated in all areas during the RI, but may be part of the capillary fringe in the wet season. The grade and the mixed fill units locally inhibit infiltration or store perched water at the Site, but in general the fill units do not impede recharge by infiltration of precipitation.

- **Upper Sand Aquifer.** The upper sand aquifer is the unconfined saturated portion of the upper sand geologic unit. The average water table depth is about 4 feet bgs. The water table fluctuates an average of 2.5 feet between seasonal maximum and minimum elevations. The saturated thickness ranges from approximately 2 to 7 feet. The upper sand aquifer is monitored by 30 on-site and 7 off-site monitoring wells, screened from the base of the unit to above the water table.

  Groundwater flow in the upper sand aquifer is generally horizontal perpendicular to the Snohomish River (Figure 2-8). Groundwater flow paths along the base of the aquifer may more closely follow the topography of the base of the aquifer within zones of coarse sand, and may move preferentially toward points of discharge at the Snohomish River bulkhead (i.e., at seeps). Average groundwater elevations in the upper sand aquifer are 3 feet higher than in the lower sand aquifer. A downward vertical gradient, therefore, exists between the upper and the lower sand aquifers. A minor component of groundwater flows downward through the upper silt, primarily during low tide.

  The upper sand aquifer is recharged by surface infiltration of precipitation. It discharges to units below and to the east, then into the Snohomish River. Discharge to the river is restricted by the timber bulkhead along the shoreline, which appears to act as a hydraulic barrier to groundwater flow. Groundwater elevations in the upper sand aquifer are generally 3 feet higher than the average river elevation. Water elevations in the upper sand aquifer are not significantly influenced by tidal fluctuations.

- **Upper Silt Aquitard.** The upper silt unit is a low permeability layer (i.e., aquitard) between the two sand aquifers. No monitoring wells were installed to monitor water quality in the upper silt aquitard. Sand stringers interbedded within the silt may act as conduits for vertical flow into or through the silt layer. Timber pilings driven through the silt at former Mill E or the building may have created vertical flow paths.

  The aquitard is recharged by the upper sand aquifer and most likely discharges groundwater downward to the lower sand aquifer and east into the Snohomish River.

- **Lower Sand Aquifer.** The lower sand unit is partially to completely confined, tidally influenced, and bounded above and below by low-permeability silt layers. The lower sand aquifer is monitored by nine wells screened at its top (wells labeled with a "D" suffix) and two wells screened at its presumed base (labeled with a "D2" suffix). Water elevations are influenced by tidal fluctuation of the Snohomish River. A 7-foot tide cycle caused a 4- to 6-foot change in groundwater elevations in the lower sand aquifer. The tidal time lags ranged from 40 to 117 minutes, increasing with distance from the river. Tidal efficiency ranged from 58 to 34 percent, decreasing with distance from the river. At lowest tides, the lower sand becomes unconfined at all lower sand monitoring well locations except HC-11D and MW-30D.

  The horizontal groundwater gradient in the lower sand aquifer varies with the tide cycle. The average groundwater flow direction of the lower sand aquifer (Figure 2-9) appears to be perpendicular to the Snohomish River shoreline in an easterly direction.

  The lower sand aquifer probably recharges from sources below and lateral to the unit, and by downward flow from the upper sand aquifer. The unit discharges into the Snohomish River.

The aquifer parameters measured or estimated in the RI are summarized in Table 2-1.

2.2.7 River Sediment

The Snohomish River is maintained from its mouth at Jetty Island to a settling basin upstream of the I-5 bridge. The channel is dredged every 2 to 3 years. Although sediment tends to accumulate along the west bank of the river next to the Site, the U.S. Army Corps of Engineers does not dredge this area. The last time the sediments near the Site appear to have been dredged was in 1981 during the construction of a new log haul out facility for Mill E (Dalton, Olmsted, and Fuglevand; 1996). These sediments were reportedly barged to nearby Ferry Baker Island, off-loaded, and graded inside a diked area along with other dredge spoils from the Snohomish River. Recent testing of the dredged sediments on Ferry Baker Island show that contaminant concentrations are well below MTCA industrial cleanup levels and in all but one case, below residential cleanup levels.

The sediment in the river next to the Site is composed primarily of fine to medium, poorly graded sand with less than 2 percent total organic carbon (TOC). Potential sources of contaminants to the river sediment identified near the Site include three combined sewer overflows from the city of Everett, the outfall to the Everett Wastewater Treatment Plant, and two wood treatment facilities. The wood treatment facilities identified as potential sources include Buse Timber, located on Smith Island, and Canyon Lumber, located west of the Snohomish River near the entrances to Steamboat and Union sloughs.

Sediment Characterization Summary. Sediment samples were collected at locations exposed during low tides (Phases I and III) and at more dynamic river locations (Phase II). Sediments were characterized through a review of historical data and through RI sampling and analysis. Characteristics of Snohomish River sediments near the Site can be summarized as follows:

- Sediments were dark gray to black sandy silt and silty sand.
- Reduced surface sediments, indicative of poorly oxygenated sediment, were observed throughout the study area.
- Dredging does not appear to influence sediment characteristics in the study area.
- Groundwater flow and sediment dewatering appear to occur at localized sites (i.e., seeps) through the bulkhead.

2.3 Nature and Extent of Contamination

2.3.1 Data Sources

The soil, groundwater, sediment, and surface water data used to evaluate the nature and extent of site contamination were derived from field investigations conducted between 1992 and 1995. The field investigation results are fully described in the RI report and other subsequent reports (EMCON, 1994c, 1994d, 1995a, 1995b, 1996a and 1996b) and are briefly summarized below. Quarterly groundwater monitoring was conducted from August 1992 through August 1993 and has been conducted semiannually since then. Results of the first five quarterly groundwater sampling events were summarized in the RI report. The results of the subsequent three years of semiannual groundwater monitoring are summarized in the tables in this section. The results of all sampling events are summarized below. No significant uniform upward or downward trends were noted over the eleven groundwater sampling events from August 1992 to August 1996. Data and statistical summaries for all other media evaluated in this FS are tabulated in Appendix G of the RI report. Laboratory reports are on file at EMCON.

2.3.2 Soil

Surface soil samples were collected in the grade fill and mixed fill units. Subsurface samples were collected at the base of the two fill units, in both the unsaturated and saturated zones of the upper sand unit, and at the top of the upper silt unit. Sample location rationale is described in detail in the work plan. Soil samples were analyzed for metals, polychlorinated biphenyls (PCBs), total petroleum hydrocarbons (TPH), volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and dioxins/furans. The compounds of concern are arsenic, chromium, TPH, carcinogenic polycyclic aromatic hydrocarbons (CPAHs), and PCP.

Fill. Figures 3-1 through 3-6 of the RI report present concentrations of contaminants in the fill units. Table 2-2 of this FS report summarizes the primary locations and ranges of detected concentrations of the contaminants of concern.

Upper Sand. Figures 3-7 through 3-12 of the RI report present contaminant concentrations in the upper sand unit. Table 2-3 of this FS report summarizes the locations and ranges of the contaminants of concern.

Light nonaqueous phase liquid (LNAPL) sampled at monitoring well HC-12 measured approximately 55 percent as TPH-diesel and 12 percent as TPH-other. LNAPL at well P-1 measured approximately 55 percent as TPH-diesel, 16 percent as noncarcinogenic polycyclic aromatic hydrocarbons (NCPAHs), 0.79 percent (7,900 milligrams per liter [mg/L]) PCP, 2,500 mg/L CPAH, and 170 mg/L TPH-gasoline. LNAPL at well TW-1 measured approximately 80 percent as TPH-diesel, 20 percent as NCPAH, and 1 percent PCP. Trace amounts (less than 0.05 feet thick) of LNAPL have also been detected, but not analyzed, at monitoring wells HC-15, HC-22, MW-23, and piezometer P-2.

Dense NAPL (DNAPL) was noted at the base of the upper sand (saturated soil) unit at and near the blow pit area and northeast of the building below former Mill E. A sample of DNAPL collected at well TW-1 contained approximately the same proportions of the same compounds detected in LNAPL. LNAPL and DNAPL were removed from the wells during interim recovery activities (see Section 2.6).

Concentrations of the lighter TPH compounds in the upper sand unit in the blow pit area are two to three orders of magnitude higher than those in the fill units. The SVOC concentrations in the upper sand unit are one to two orders of magnitude higher than in the fill units.

The 2,3,7,8-tetrachlorodibenzodioxin (TCDD) congener was not detected in any of 17 soil samples analyzed. The 2,3,7,8-tetrachlorodibenzofuran (TCDF) congener was detected in 6 of 17 samples. The hepta and octa congeners were the most frequently detected dioxins and furans.

Several samples were analyzed using the toxicity characteristic leaching procedure (TCLP) to determine if the soil might be considered a dangerous/hazardous waste if it were excavated. Arsenic concentrations ranged from 0.1 to 0.7 mg/L, and chromium concentrations ranged from 0.01 to 0.08 mg/L. Barium was detected at 0.6 and 0.8 mg/L. PCP concentrations ranged from 0.011 to 0.06 mg/L. All concentrations were well below the dangerous/hazardous waste limits (WAC 173-303-090[8]).

Upper Silt. Few samples of the upper silt were collected for chemical analysis, and those were generally analyzed only for arsenic. Arsenic concentrations ranged from 18.2 to 1,250 milligrams per kilogram (mg/kg), with a geometric mean of 72 mg/kg. Arsenic was randomly distributed in the upper silt unit on site.

Lower Sand. Trace quantities (less than 200 milliliters) of NAPL were detected in well HC-15D in August 1995. Product was removed in August and October 1995 and measurable quantities have not been detected since.

2.3.3 Groundwater

Upper Sand Aquifer. Groundwater samples were analyzed for total and dissolved metals, TPH, VOCs, and SVOCs. Of these, the compounds of concern identified in the RI were arsenic, copper, and PCP. Elevated groundwater TPH concentrations were found, generally below and downgradient of elevated TPH concentrations in soil.

Contaminant concentrations vary seasonally and are influenced by flushing, dilution, and leaching of contaminants by surface water infiltration. No significant uniform upward or downward trends were noted over four years of quarterly and semiannual sampling events.

Figures 3-13 through 3-15 of the RI report present average contaminant concentrations in the upper sand aquifer for the first five quarterly sampling events (August 1992 to August 1993). Tables 2-4 through 2-7 of this FS report provide a statistical summary of contaminants detected in the upper sand aquifer perimeter wells (HC-10, MW-31, HC-07, MW-23, HC-09, MW-32, HC-02, HC-01) during the six most recent semiannual sampling events (February 1994 to August 1996). Figures 2-10 through 2-12 present the average concentrations of arsenic, total TPH, and PCP over the last six monitoring events. There were no significant differences in contaminant concentration or distribution between the quarterly and the semiannual data.

Lower Sand Aquifer. Groundwater samples were analyzed for total and dissolved metals, TPH, VOCs, and SVOCs. In general, contaminants were detected near and downgradient of the blow pit area, primarily at HC-15D, HC-23D, and MW-31D. However, no compounds of concern were identified for this aquifer in the RI. Tables 2-8 through 2-11 of this FS report provide a statistical summary of contaminants detected in the lower sand aquifer perimeter wells (HC-10D, MW-31D, HC-23D, MW-09D, HC-01D) during the six most recent semiannual sampling events. Figures 2-13 and 2-14 present the average concentrations of arsenic and TPH in the lower aquifer over the last six monitoring events. There were no significant differences in contaminant distribution between the earlier quarterly data summarized in the RI report and the more recent semiannual data. Increased concentrations were noted for some compounds, and compounds of concern were subsequently identified for this aquifer (see Section 2.4.4).

2.3.4 Surface Water

Snohomish River. Surface water samples were analyzed for metals, TPH, and SVOCs. Samples collected both adjacent to, and upriver from, the Site showed elevated concentrations of copper.

Seeps. Seep samples were collected and analyzed for metals, TPH, VOCs, SVOCs, and total suspended solids (TSS). Metals concentrations were elevated relative to river water samples. SVOCs were detected at two seep sampling locations.

Storm Water and Storm Drain Sediments. Storm water samples were analyzed for metals, TPH, SVOCs, and TSS. Arsenic, copper, and lead were detected at concentrations slightly above method detection limits (MDLs). Storm drain sediment samples were analyzed for total and TCLP metals, TPH, and SVOCs. Lead concentrations were elevated relative to Site soil. Where detected, TCLP concentrations were below toxicity characteristic regulatory criteria (WAC 173-303-090(8)).

2.3.5 Sediment

Surface sediment and sediment core samples were collected from 30 locations adjacent to the Snohomish River site and from one upstream location during Phase I and II sampling. Sediment samples were analyzed for metals, VOCs, SVOCs, TOC, and additional selected parameters. The most frequently detected compounds were arsenic and PAHs. The highest concentrations were found in association with seeps and storm drain outfalls. Concentrations of contaminants decreased with depth and with distance from the shoreline. Seven sampling locations, all beside the shoreline, showed arsenic or PAH concentrations that were elevated relative to average sediment concentrations.

Phase III surface sediment samples were collected in the summer of 1995 to augment data collected during the 1992 Phase I and II sampling events. Phase III sampling locations were placed in areas where the 1992 samples showed chemical concentrations greater than the Sediment Management Standards (SMS) marine sediment cleanup screening levels (CSLs) for one or more contaminants (chapter 173-204 WAC). Three chemicals, arsenic, naphthalene, and acenaphthene, exceeded screening criteria for identification of a station cluster of potential concern. The Phase III sampling results indicated that PAH concentrations did not exceed the marine sediment quality standards (SQS) chemical criteria. Arsenic concentrations measured at a location near a reconstructed storm water outfall (near station SR-01) were greater than the SQS chemical criterion and indicated that the outfall may be an ongoing source of arsenic. This outfall drains area adjacent to and upgradient of the Site. The arsenic concentrations were lower than previously measured, and did not exceed the arsenic CSL criterion.

Based on the Phase I and II sampling results, and prior to receipt of the Phase III data, Ecology listed the sediment adjacent to the Site on its Sediment Management Standards Contaminated Sediment Site List (Ecology, 1996). The "Mill E/Koppers sediment site" was assessed an ecological score of 6 out of a maximum possible score of 100. Based on the Phase III results and discussions with Ecology, Ecology is expected to delist this sediment site. As such, sediments were eliminated as a medium of concern for the FS.

2.3.6 Air

Three potential air pathways currently exist for contaminant transport: wind-entrained soil particles, volatilization of contaminants from soil, and volatilization of contaminants from groundwater. Each air pathway was evaluated in the RI by using emission models. The modeled annual and 24-hour ambient air contaminant concentrations for each air pathway were significantly lower than the corresponding acceptable source impact levels (ASILs) of chapter 173-460 WAC.

The potential maximum eight-hour worker exposure was evaluated by comparison with the National Institute for Occupational Safety and Health permissible exposure limits (PELs) and the American Conference of Governmental Industrial Hygienists threshold limit values (TLVs). The maximum ambient contaminant concentrations were well below the corresponding limits.

2.3.7 Upgradient Arsenic Assessment

As noted in the local history summary, an arsenic processing plant was operated by ASARCO from approximately 1898 to 1912, at a location approximately 1,700 feet northwest of the building near what is now the intersection of East Marine View Drive and State Route 529. As part of the RI, an upgradient arsenic assessment was conducted to evaluate the smelter operations as a potential source of arsenic contamination at the Site. EMCON reviewed available literature and collected samples to identify upgradient arsenic sources (e.g., slag) and to determine an area background concentration for soil and groundwater for comparison with those concentrations detected on site. ASARCO completed soil, groundwater, and surface water investigations upgradient of the site. A remedial investigation and feasibility study of the upland area west of East Marine View Drive was completed in September 1995 (Hydrometrics, 1995a, 1995b). A supplemental investigation of the lowland area lying between East Marine View Drive and the Snohomish River, including portions of Weyerhaeuser and Burlington Northern Railroad property was completed in July 1996 (Hydrometrics, 1996).

Results of EMCON's assessment are summarized below.

- The average concentration of arsenic in soil in the upgradient assessment area (i.e., the upper sand on Weyerhaeuser property west of the Site) is 56 mg/kg.

- The groundwater arsenic concentration in the upper sand aquifer upgradient of the Former Mill E/Koppers Facility Site was approximately 0.054 mg/L (Hydrometrics, 1994). Average arsenic in the upper sand aquifer immediately upgradient of the Site (on Weyerhaeuser property) was 0.443 mg/L, and maximum concentrations were 2.87 mg/L (this report). Arsenic-contaminated groundwater flows from the upgradient assessment area to the Site and is considered to contribute to groundwater contamination beneath the Site.

- Groundwater arsenic concentrations in the lower sand aquifer upgradient of the Site were at or below the MDL and are not considered to contribute to arsenic contamination in the lower sand aquifer at the Site.

2.4 Baseline Risk Assessment

A baseline risk assessment was conducted as part of the RI to evaluate potential impacts to human health and the environment posed by selected contaminants encountered in soil, surface water, groundwater, and sediments at or adjacent to the Site. Section 4 of the RI report contains a detailed discussion of the baseline risk assessment results. The results for soil, surface water, and groundwater are summarized below.

2.4.1 Background

Land Use. The city of Everett zoned the Site M-2, heavy manufacturing. Weyerhaeuser property lies immediately west and south of the Site. It is also zoned M-2. This land use is expected to continue for the foreseeable future. The Snohomish River lies east and north of the Site. A more detailed discussion of the industrial designation of the Site is found in Section 3.2.1.

Groundwater Use. Groundwater beneath the Site currently is not used as a public or private drinking water source and is not expected to be used for this purpose in the future, for the following reasons. Municipal drinking water in the Site area is derived from surface water sources well to the east of the Site, and the reserves are considered adequate. Groundwater flow is toward the Snohomish River; however, the river is not used as a source of drinking water. As noted above, the Site is zoned for industrial purposes, and this use is expected to continue for the foreseeable future. Furthermore, the salinity of the river water adjacent to and downgradient of the Site makes it unsuitable for use as drinking water. For these and other reasons related to natural or background water quality in the area, use of groundwater as drinking water was not evaluated in the baseline risk assessment under the potential future land use scenario.

Identification of Indicator Hazardous Substances. For the characterization of potential risks to human health, the following compounds were selected as indicator hazardous substances (IHSs) in soil:

- Arsenic
- Benzo(a)anthracene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Chromium
- Chrysene
- Dioxins/Furans
- Indeno(1,2,3-cd)pyrene
- PCP
- TPH-gasoline, -diesel, or -other

This selection was based on the following criteria as described in the RI report: chemical toxicity, critical toxicity values, frequency of detection, and background concentrations.

As previously noted, it is unlikely that groundwater will be used as a public or private drinking water source. Consequently, potential human health impacts associated with ingestion, inhalation, and dermal contact with groundwater during normal household use were not evaluated in the baseline risk assessment. Compounds in groundwater could, however, volatilize and diffuse through soil and into the air. Therefore, the compounds detected in groundwater were considered for inclusion as IHSs for the vapor inhalation pathway only. Volatilization of VOCs in groundwater to ambient air was evaluated in the RI. Air concentrations were compared with ASILs, PELs, and TLVs. Since modeled ambient air concentrations for all receptors were well below these standards, inhalation of vapors from groundwater was eliminated from the risk assessment, and no human health IHSs were chosen for groundwater.

Primary IHSs for environmental risks were identified in the baseline risk assessment through a comparison of data with published environmental criteria (e.g., ambient water quality criteria [AWQC]). The following compounds were identified as IHSs for groundwater:

- Arsenic
- Copper
- PCP

2.4.2 Human Health Risk Characterization

Results of human health risk assessment indicate that the hazard index (HI) for the Site is approximately 0.13. Because it is less than 1.0, noncarcinogenic health effects from the IHSs evaluated in the baseline risk assessment are, according to the regulatory criteria considered, not of concern for this Site. The total potential excess cancer risk for the Site is approximately 5×10^{-5}. This risk is within the risk range of 1×10^{-4} to 1×10^{-6} established by the U.S. Environmental Protection Agency (USEPA); however, it exceeds the MTCA-established risk level of 1×10^{-5} (WAC 173-370-708).

Results of the human health and environmental risk evaluations were used to refine a conceptual site model, further discussed in Section 2.5.1.

2.4.3 Environmental Risk Characterization

To characterize potential risks to the environment posed by the Site in its existing condition, hazardous substances detected in groundwater and surface water were compared with published environmental criteria. Results of the environmental risk characterization indicated the following:

- Groundwater beneath the Site and storm water runoff from the Site contain contaminants at concentrations greater than the associated AWQCs. Background concentrations of arsenic in groundwater also exceed associated water quality criteria.

- Metals detected in surface (river) water samples are lower than AWQCs, with the exception of copper. The one detection of TPH as gasoline was substantially below the state's water quality guideline for oil and grease (Ecology, 1987) and may reflect an off-site source.

2.4.4 Update of Groundwater IHSs

As described in Section 2.3, six additional rounds of groundwater sampling were conducted from February 1994 through August 1996. Statistical summaries of these data are presented in Tables 2-4 through 2-11. To update the environmental risk characterization and groundwater IHSs identified for the Site, the most recent data were compared with current ambient water quality criteria. This comparison is presented in Appendix A.

A compound was identified as an IHS if the frequency of detection was greater than 5 percent, and if the concentration associated with the 95 percent upper confidence of the mean (UCL95) exceeded the most stringent ambient water quality criterion. Where the most stringent criterion was below the practical quantitation limit (PQL) for the compound, the PQL was used.

Based on this comparison of recent groundwater data and updated water quality criteria, the IHSs for the upper sand aquifer were arsenic, copper, chromium, TPH, benzene, and PCP. For the lower sand aquifer, arsenic and TPH were identified as IHSs.

2.5 Contaminant Fate and Transport

2.5.1 Conceptual Site Model

A conceptual model was developed for the Site based on the results and conclusions of the RI. This model, shown in Figure 2-15, summarizes potential contaminant sources, release mechanisms, routes of exposure, and receptors. Contaminant source areas and their associated constituents are summarized in Table 2-12.

Principal contaminants of concern for potential risks to human health are arsenic, chromium, and CPAHs. Principal contaminants of concern for potential risks to the environment are arsenic, copper, chromium, benzene, PCP, and naphthalene. TPH and dioxins/furans (except 2,3,7,8-TCDD) were found in elevated concentrations on site; MTCA assessment methods do not prescribe a method for quantifying risks associated with these compounds.

The fate and transport of the contaminants of concern depend on the physical and chemical characteristics of the contaminant (in both pure form and mixtures), the physical characteristics of the Site (e.g., piping, pavement), and the physical and chemical characteristics of Site soil, surface water, groundwater, and sediment.

2.5.2 Sources of Contamination

Four apparent on-site source areas (the blow pit area, the building, the rail lines, and former Mill E) and an apparent off-site source (ASARCO smelter site and smelter-related materials) have been identified. Potential sources of soil contamination include historical spills or leaks from tanks and piping systems, drippage along rail lines or in storage areas, and the former wood treatment and maintenance shop operations. During retort depressurization, air and liquid reportedly were blown into the blow pit area. The ASARCO smelter site is a potential off-site source of arsenic that may have reached the Site via airborne deposition or placed upgradient of the Site.

2.5.3 Contaminant Migration

Migration Pathways. The primary contaminant migration pathway is from soil to groundwater and then to the Snohomish River. Soil and groundwater contamination were found primarily at or downgradient of the on-site source areas. The secondary contaminant pathway is from seeps and storm water to the river. Contaminant concentrations in the seep, storm water, storm drain sediment, river water, and river sediment were significantly lower than in soil and groundwater, suggesting limited transport in the secondary pathways. As described in the RI report, volatilization of contaminants and particulate entrainment do not appear to be significant transport pathways.

Potential Receptors. Contaminant receptors (and secondary contaminant transport pathways) are the Snohomish River and its sediment. Sediment contaminant concentrations decrease significantly with distance from the bulkhead, indicating limited migration of contaminants through sediment.

Transport Mechanisms. The two main contaminant transport mechanisms associated with the Site are the following:

- **Advection.** Advection, or transport with moving water, is the predominant mechanism for migration of water-soluble metals and dissolved organic compounds from soil to and within groundwater. Metals transport has most likely been attenuated by absorption to clay and organic particles in the silt aquitard. Dissolved TPH has moved by advection from the source areas to the river, and attenuated by sorption to organic carbon in the soil and by degradation processes.

  Based on the presence of sand stringers within the upper silt aquitard, similar seasonal fluctuations of groundwater between the upper and lower sand aquifers, and the downward vertical gradient between the upper and lower sand aquifer, it appears that the upper sand aquifer is probably hydraulically connected to the lower sand aquifer. Surface infiltration of precipitation near the blow pit area probably moves downward through the upper sand unit into the upper sand aquifer, downward through permeable or thin zones of the upper silt aquitard, and then into the lower sand aquifer. Periodic small changes in TPH and arsenic concentrations in the lower sand aquifer monitoring wells correspond to the fluctuating groundwater elevations. This implies that infiltration of surface water and vertical groundwater flow in the blow pit area, where the silt aquitard is thin, affects the rate of contaminant transport through the silt aquitard and the contaminant concentrations in the lower sand aquifer.

- **Product (pure phase) flow.** Pure phase floating product, composed primarily of TPH and PAHs, has not moved significant distances from source areas at the blow pit area and former Mill E. Pure phase sinking product, also composed primarily of TPH and PAHs, has migrated vertically downward through the upper sand aquifer and has collected in topographic depressions at the top of the silt aquitard beneath the blow pit area. It does not appear that sinking product has migrated significantly beyond these depressions. Transport of dissolved PAHs and PCP downgradient of source areas has probably been enhanced by pure phase flow and by mixing and dissolving with a petroleum compound.

2.6 Interim Actions

Since the RI, Weyerhaeuser has performed several interim actions at the Site, as described below.

2.6.1 Building Demolition

The building was demolished in the summer of 1995. Steel from the building was sold for scrap, salvageable timbers sold, and wood debris was recycled on-site. A small amount of asbestos floor tile was abated and disposed of in a permitted landfill. The building foundation is still in place.

2.6.2 Fencing

A 6-foot-high chain-link fence was installed around the Site in April, 1995. Signs that warn of the potential hazards associated with the Site were placed along the length of the fence. Although access to the entire Weyerhaeuser property (which includes the Site) is controlled, the fence prevents people who are on the East Site property from inadvertently entering the Site.

2.6.3 Product Recovery

A trial passive product recovery program was initiated at the Site July, 1996. Product recovery was attempted at all monitoring wells and piezometers where product had been detected or suspected in previous monitoring events (wells MW-23, MW-33, HC-12, HC-15, HC-15D, HC-22, P-1, P-2, and test well TW-1).

Product recovery was initially performed twice a month. Depths to groundwater and product (LNAPL or DNAPL), if present, were measured in each well. If the apparent product thickness was measured at greater than 0.01 foot, a peristaltic pump was used to extract the LNAPL or DNAPL. The recovered product, along with some water, was pumped into 5-gallon containers for temporary storage. The water/product mixture was characterized on the basis of previous analytical data for the product and shipped off site for disposal less than 90 days from the time of generation.

The results of the three-month product recovery effort were as follows:

- No product was ever measured in four of the monitoring wells (MW-23, MW-33, HC-15D, and HC-22).
- A total of six recovery events were completed between July 10 and October 7, 1996. The first four events were conducted at approximate two-week intervals. Because of poor product recovery rates during the third and fourth events, the last two events were conducted one month apart. No product was recovered from any well during the last event (October 7, 1996). A summary of the work performed during each of the six events is provided in Table 2-13.
- A total of 3.3 gallons of product was recovered during the six events. Approximately 85 percent (2.8 gallons) was recovered from TW-1, with 2.3 gallons recovered during the first event. Of the remaining wells, well P-2 produced approximately 24 ounces, and the remaining wells all produced less than 10 ounces each.

Given the limited recovery during the six events, the passive product recovery efforts were terminated. The results of the trial product recovery program indicate that there is insufficient product present to warrant the use of an active (i.e., pumped) product recovery system. Passive product recovery is reevaluated as a component of the cleanup actions in Sections 5 through 7.

3 FEASIBILITY STUDY SCOPING

This section establishes the framework in which the FS (e.g., technology identification, detailed analysis of alternatives) was conducted. The regulatory requirements that affect the FS process are identified, cleanup standards and action levels are defined, and remedial action objectives are developed.

3.1 Regulatory Requirements

Various state and federal regulatory requirements were used as guidelines for this FS. Ecology requirements for conducting an FS and guidelines for selection of the remedial action are presented in WAC 173-340-350 and -360; these MTCA regulations were the governing regulations for the FS. The FS was also prepared in a manner consistent with procedures developed by the USEPA to conduct an FS (presented in 40 CFR Part 300-430[e] as part of CERCLA). Other guidance documents and directives from USEPA were also used as appropriate, including:

- Contaminants and Remedial Options at Wood Preserving Sites (USEPA, 1992a)
- Presumptive Remedies for Soils, Sediments, and Sludges at Wood Treater Sites (USEPA, 1995)
- Considerations in Groundwater Remediation at Superfund Sites and RCRA Facilities - Update (USEPA, 1992b)

Below, the specific regulations used to guide the FS are described.

3.1.1 Model Toxics Control Act

MTCA regulations were the primary regulations used during the FS. In general, MTCA defines FS methods for determining appropriate cleanup standards for specific contaminants and areas of concern in contaminated media. The cleanup standards and action levels identified for the Site are described in Section 3.2. MTCA regulations also contain criteria for identifying and evaluating methods or technologies to best achieve the cleanup standards determined for the Site. The MTCA evaluation criteria for the cleanup alternatives identified for this Site are given in Section 6.1.1.

3.1.2 Applicable, or Relevant and Appropriate Requirements

In addition to MTCA, there are other applicable, or relevant and appropriate requirements (ARARs) for this FS. "Applicable state and federal laws" are defined in WAC 173-340-710(1)(a) as those requirements that are (1) legally applicable, and (2) considered relevant and appropriate. "Legally applicable" and "relevant and appropriate" requirements are defined by WAC 173-340-710(2) and (3), respectively. Those definitions are summarized below. Applicable, or relevant and appropriate requirements, are typically referred to as ARARs.

Legally applicable requirements include those standards and other requirements, criteria, or limitations promulgated under state and federal law that specifically address a hazardous substance, cleanup action, location, or other circumstance at the site. Though not legally applicable, *relevant and appropriate* requirements include those requirements designed to address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the site.

As with MTCA, CERCLA limits the scope of ARARs to promulgated requirements. In addition, promulgated state standards more stringent than federal standards can be considered as potential ARARs under CERCLA.

ARARs are identified on a site-specific basis and are driven by the specific chemicals of concern identified at the site, the proposed remedial actions, and the site characteristics. A list of potential ARARs for the Site is presented in Table 3-1. Based on site-specific conditions, the most significant ARARs for the Site are those described in the following sections.

Dangerous Waste Regulations. Remediation of any soil on the Site may require compliance with state dangerous waste regulations for treatment, storage, or disposal of dangerous wastes. These requirements apply to a site if: (a) the excavated soil or other media generated at the site contain listed dangerous waste or are designated as characteristic dangerous waste, or (b) the remediation activity at the site will constitute treatment, storage, or disposal of dangerous waste. The dangerous waste regulations are codified in chapter 173-303 WAC and implement the Washington Hazardous Waste Management Act (Chapter 70.105 RCW). These regulations reflect most of the federal hazardous waste regulations promulgated pursuant to the Resource Conservation and Recovery Act (RCRA). Washington is a delegated state under the RCRA program for most of the federal hazardous waste regulations.

Once soil is excavated from the ground or groundwater is extracted, it must be characterized or "designated" to determine the applicability of state or federal dangerous/hazardous waste regulations. One potentially relevant regulation for the site consists of waste codes F032, F034, and F035. These codes pertain to wastewaters, process residuals, preservative drippage, and spent formulations from wood preserving processes generated at plants that currently use or have previously used chlorophenolic formulations (F032), creosote formulations (F034), or inorganic preservatives containing arsenic or chromium (F035).

PCP is known to have been used at the Site for wood preserving (Beazer, 1994), as well as CCA. Through application of the "contained-in" policy, environmental media such as soil and groundwater can be classified as listed dangerous/hazardous wastes, whereby the soil or groundwater that came into contact with the listed dangerous/hazardous waste must be managed as a dangerous/hazardous waste upon excavation or extraction (57 FR 61497). The contained-in policy, which was a series of interpretive USEPA memos until codified in 57 FR 37225, states that any mixture of a nonsolid waste (e.g., soil) and a RCRA-listed hazardous waste must be managed as a hazardous waste as long as it "contains" the listed waste. "Contains" has been interpreted to mean concentrations above health-based levels. Under the applicable regulations, the USEPA or an authorized state must make a determination as to whether contaminant concentrations in a particular volume of soil or groundwater are below health-based levels and therefore do not require management as a dangerous/hazardous waste. For the Site, contaminated soil or groundwater may be regulated as F032, F034, or F035 upon excavation or extraction, unless Ecology determines that the media no longer contain F032, F034, or F035 above health-based levels.

Because several of the potential remedial alternatives include the probable treatment, storage, or disposal of RCRA-listed wastes, the federal Land Disposal Restriction (LDR) regulations under 40 CFR Part 268 may relate to on-site activities. The LDR regulations restrict placement of a listed or characteristic RCRA waste into a land disposal unit (e.g., landfill) either on site or off site, without meeting RCRA's best demonstrated available technologies (BDAT) treatment standards. When RCRA hazardous waste is moved from an "area of contamination", RCRA disposal requirements apply to the area and the waste received.

Both the federal RCRA regulations and the state of Washington's dangerous waste regulations (chapter 173-303 WAC) contain provisions to allow for the treatment, storage, or disposal of hazardous/dangerous waste during the course of remedial actions. The federal policies and regulations dealing with this issue are in a state of transition. The current approach is to use the concept of a corrective action management unit (CAMU). Using this concept, remedial activities that occur within a CAMU are exempt from the LDR and minimum technical requirements, as well as from RCRA permitting requirements (40 CFR Part 264 Subpart S). The USEPA's proposal of the hazardous waste identification rule (HWIR) in April 1996 (61 FR 18780) would make significant changes in the way contaminated media are managed. Briefly, this approach would define contaminated media as either high risk or low risk. Low-risk media would be eligible for a case-specific exemption from most of the hazardous waste management regulations, while high-risk media would still have to comply with most of the hazardous waste regulations. When finalized, the HWIR rule would supersede the existing CAMU approach.

The state of Washington's equivalent of CAMU is contained in a September 6, 1991, interprogram policy statement generally referred to as the "area of contamination" policy (Ecology, 1991). This policy is used to identify situations in which excavation and movement of contaminated materials (e.g., soil) at MTCA cleanup sites would not trigger various dangerous/hazardous waste requirements (e.g., waste generation, disposal, and treatment). The policy currently states that it is applicable only to sites being cleaned up under an order or decree issued by MTCA or CERCLA authorities.

In addition, the state Hazardous Waste Management Act (RCW 70.105) was amended in 1994 to exempt "state-only" dangerous waste or extremely hazardous waste from the requirements of chapter 173-303 WAC if the wastes are generated pursuant to a consent decree under MTCA. MTCA was also amended in 1994 to exempt remedial actions conducted under a consent decree, order, or agreed order from the procedural requirements of certain state and local laws. The exemption includes the state Hazardous Waste Management Act and the state Water Pollution Control Act. Permits normally required by these laws need not be obtained; however, Ecology must ensure that the substantive provisions of these laws are met and must establish procedures to carry out the exemption provisions. Ecology has prepared policy and procedure directives 130B, both issued on February 17, 1995, to define how the agency will implement the exemptions from the procedural requirements of certain state and local laws.

Water Quality Regulations. Section 402 of the Federal Water Pollution Control Act created the National Pollutant Discharge Elimination System (NPDES) program to regulate the discharge of pollutants to surface water. Washington established an authorized NPDES program, whose implementing regulations are found in chapter 174-220 WAC. As part of the NPDES program, any person proposing to begin discharging pollutants to surface water must file a permit application. In general, the program specifies that no discharge may occur until the application has been approved and a permit has been issued. Remedial actions involving discharges to surface water may require obtaining an NPDES permit before discharging. As noted above, these procedural requirements may be exempted by MTCA.

Health and Safety Regulations. Regulations issued pursuant to the Washington Industrial Safety and Health Act contain PELs for some of the contaminants identified at the Site. Compliance with particular PELs may be required, for example, during certain remediation activities involving soil removal or movement (e.g., soil excavation and sieving). In addition, hazardous substance cleanup operations must comply with the requirements of chapter 296-62 WAC (e.g., training, engineering controls for remedial worker protection).

3.2 Cleanup Standards

Cleanup standards are defined in MTCA (WAC 173-340-700(2)) as comprising three separate components: cleanup levels, points of compliance, and additional regulatory requirements. Cleanup levels and points of compliance are described in the following sections. The additional regulatory requirements that may apply to specific cleanup actions are addressed in the evaluation of cleanup action alternatives in Section 6.

3.2.1 MTCA Cleanup Levels

This section describes the three methods for establishing cleanup levels under MTCA and the rationale for selecting one of those methods for the Site.

Types of Cleanup Levels. MTCA provides three methods of determining cleanup levels. **Method A** applies to sites undergoing routine cleanup or to sites where numerical cleanup standards are available for all indicator hazardous substances in all media of concern. This method is not applicable to the site. **Method B** is the standard approach. Cleanup levels are determined according to risk-based equations in the regulations, which assume a "reasonable maximum exposure" (RME) of soil ingestion by a child and ingestion of groundwater as drinking water. **Method C** applies in cases where Method A or B cleanup levels are below background concentrations, where the Method A or B cleanup levels are not technically possible to achieve, where achieving Method A or B levels will result in greater risk, or where the site is defined as an industrial site and meets certain criteria. As with Method B, cleanup levels are calculated by using risk-based equations provided in the regulations that assume an RME. The RME for Method C is soil ingestion by an adult and ingestion of groundwater as drinking water. Under both Methods B and C, alternate (nondrinking water) exposure assumptions may be established for groundwater on a case-by-case basis.

Selection of appropriate cleanup levels is discussed separately for each medium of concern (soil and groundwater) below.

Selection of Cleanup Levels. Method A is not appropriate for the Site because Method A cleanup levels are not available for all hazardous substances in all impacted media and the Site is not a routine site (i.e., per MTCA, there is not an obvious and limited choice among cleanup methods). The decision whether to use Method B or Method C cleanup levels is based primarily on whether the Site is defined as "industrial property," according to the criteria defined in WAC 173-340-745(1)(b):

i. The area of the site where industrial property soil cleanup levels are proposed meets the definition of an industrial property under WAC 173-340-200. **The Former Mill E/Koppers Facility Site has been used for industrial purposes since the early 1900s. The Site, and surrounding Weyerhaeuser and non-**

Weyerhaeuser property, are zoned M-2, heavy manufacturing, by the city of Everett, designating it for continued industrial use. The city is conducting land-use planning under chapter 36.70A RCW (Growth Management Act).

ii. The cleanup action provides for appropriate institutional controls to limit potential exposure to residual hazardous substances. **As described in Section 6.2, all cleanup actions being considered for implementation at the Site include the use of institutional controls.**

iii. Hazardous substances remaining at the property after remedial action would not pose a threat to human health or the environment at the site or in adjacent nonindustrial areas. **All adjacent areas are zoned industrial and designated for continued industrial use. The selected cleanup action will be protective of human health and the environment, with consideration for the factors in WAC 173-340-745(1)(b)(iii).**

Because the Site meets the criteria for an industrial site, as described above, Method C will be the primary method used to determine cleanup levels for soil and groundwater.

3.2.2 Cleanup Levels and Action Levels for Soil

IHSs for Soil. Indicator hazardous substances (IHSs) for soil at the Site are arsenic, chromium, PCP, CPAHs, dioxins/furans, TPH-gasoline (G), TPH-diesel (D), and TPH-oil (O). Although dioxins/furans were identified as an IHS, toxicity data for these compounds are not available in the integrated risk information system (IRIS) and no alternative values have been established by Ecology. WAC 173-303-708 does not prescribe a method of establishing cleanup levels for this IHS. Dioxins/furans were therefore not evaluated quantitatively in the FS; they are evaluated qualitatively in the analysis of cleanup action alternatives in Section 7.1.2.

Soil Cleanup Levels. As previously noted, Method C cleanup levels are appropriate for soil. There are no Method C "formula" (published) cleanup levels for TPH compounds (Ecology 1996b). However, site-specific cleanup levels can be calculated per WAC 173-340-745(4).

Soil Action Levels for IHSs. "Action levels," as defined for this FS, are the concentrations that will potentially be achieved by a particular cleanup action. For non-TPH IHSs, the cleanup levels have also been used as action levels (Table 3-2). For TPH compounds, the Method A cleanup levels are not practical for use at the Site, for the following reasons:

- The MTCA Method A cleanup levels for TPH compounds are based on protection of groundwater as a drinking water source to prevent adverse aesthetic characteristics (i.e., odor and taste) in the drinking water.

- As described in Section 3.2.3 below and in the baseline risk assessment, groundwater beneath the Site is not currently a drinking water source. It is unlikely it will be used as a drinking water source in the future. As such, there is no risk to human health from ingestion of groundwater at any concentration of TPH.

- While not currently addressed through MTCA, potential risks to human health through ingestion of TPH-contaminated soil will be minimized at all residual (postremediation) concentrations through institutional controls such as fencing, restricted access, and deed restriction.

For purposes of this FS, a soil *screening* level of 2,500 mg/kg (total TPH) was used. The objective for setting a TPH screening level was to define the maximum area and volume of soil that may require remediation. That area and volume were then used to develop remedial alternatives. Once an alternative is selected for implementation, a final TPH cleanup level will be established, with the objective of preventing groundwater with concentrations of TPH in excess of 10 mg/L from discharging to surface water (see Section 3.2.3 below). The 2,500-mg/kg TPH screening level is a value that has been used at other industrial sites including an adjacent Weyerhaeuser site which has similar site characteristics and, on the basis of Ecology's evolving approach to setting TPH cleanup levels, is likely to be more stringent than a final cleanup level. It is therefore a conservative value.

Point of Compliance. The point of compliance for soil refers to the point or points where cleanup levels will be attained. Where soil cleanup levels are based on protection of groundwater, the point of compliance is generally the soil throughout the site (WAC 173-340-740[6]). For cleanup levels based on human exposure via direct contact, the point of compliance is generally the soils throughout the site, from the ground surface to 15 feet bgs.

Where containment is used, cleanup levels will typically not be met at these points of compliance. In such cases, however, it can be determined that the cleanup action complies with cleanup standards, provided institutional controls and a compliance monitoring program is designed to ensure the long-term integrity of the containment system (WAC 173-340-740[6][d]).

3.2.3 Groundwater

IHSs for Groundwater. IHSs for groundwater at the Site are copper, arsenic, chromium, TPH, benzene, and PCP.

Groundwater Cleanup Levels. Groundwater beneath the Site is not currently used as a public or private drinking water source and is not expected to be used for this purpose in the future, for the following reasons. As discussed above, the Site is, and will continue to be, used for industrial purposes. Furthermore, it is unlikely that state and county health officials would approve a water well on the Site, for the following reasons:

- On-site wells in either the upper or lower sand aquifer would require variances to meet construction standards (WAC 173-160-205), because of the shallow depth to groundwater and the difficulty of preventing infiltration of surface water into a well.
- The Site has readily available municipal drinking water supplies, derived from surface water sources that are considered adequate for the foreseeable future.
- The Snohomish River at the Site is not a source of drinking water due to high salinity caused by salt water intrusion.
- Upgradient arsenic concentrations (approximately 0.443 mg/L) in the upper sand aquifer are elevated, well above the potentially applicable Safe Drinking Water Act maximum contaminant level (MCL) of 0.05 mg/L.
- The naturally occurring background concentrations of iron (18 and 14 mg/L in the upper and lower aquifers, respectively) exceed the secondary MCL of 0.3 mg/L (USEPA, 1992).
- The naturally occurring background concentration of total dissolved solids in the lower sand aquifer upgradient of the Site has exceeded 10,000 mg/L, which renders this aquifer unsuitable for drinking.

For all these reasons, groundwater at the Site is not a current or potential future source of drinking water, and an alternate (nondrinking water) Method C cleanup level for groundwater is appropriate. Because groundwater discharges to the adjacent river, protection of surface water was used to establish cleanup levels for groundwater.

Relevant and appropriate requirements for development of groundwater cleanup levels that protect surface water are surface water quality standards (chapter 173-201A WAC), federal AWQC for protection of aquatic organisms (USEPA, 1986), and federal AWQCs for protection of human health pursuant to section 304 of the Clean Water Act (40 CFR Part 131). These standards and criteria were used to establish Method C groundwater cleanup levels for the Site, pursuant to WAC 173-340-720(4)(d) and (6)(d). Because salinity in the Snohomish River adjacent to the Site varies from marine to freshwater, the most stringent federal or state, marine or freshwater, water quality standard or criterion was considered.

No TPH water quality standards or criteria have been established. However, Ecology has established criteria for hydrocarbons in Water Quality Guidelines for Oil and Grease (Ecology, 1987). These criteria were used to establish a TPH groundwater cleanup level for the Site.

Action Levels for IHSs. For the groundwater IHSs, action levels are the same as the most stringent proposed cleanup levels, and are shown in Table 3-3.

Point of Compliance. As described above, the cleanup levels for groundwater at this Site are based on protection of surface water. For sites like this, Ecology may approve a conditional point of compliance that is located *within the surface water* as close as technically possible to the point or points where groundwater flows into the surface water [WAC 173-340-720(6)(d); emphasis added]. If a conditional point of compliance is not approved, the point of compliance is generally the affected portions of the aquifer throughout a site.

For purposes of this FS, a conditional point of compliance for groundwater is assumed to be located at the downgradient edge of the Site (i.e., as measured by the downgradient perimeter monitoring wells). This is the point closest to the surface water that can be evaluated using a monitoring well network.

3.3 Delineation of Remediation Areas and Volumes

This section defines the portions of the Site that, based on the results of the RI and the action levels defined above, were the focus of the cleanup actions developed during the FS. For each of the impacted media (i.e., soil and groundwater), the areal extent and associated volume of contaminated media were defined.

3.3.1 Soil

The contaminated soil at the Site is present in three different strata: the fill, the unsaturated upper sand, and the saturated upper sand. Because potentially applicable remedial actions for each of these strata may vary, the areas and volumes of impacted soil were defined separately for each stratum. The action levels defined in Section 3.2.2 were used to estimate the areas and volumes of impacted soil. "Hot spots" were also identified for soil (see definition below).

Most soil data collected during the RI were from the fill and unsaturated upper sand strata, with limited soil data collected below the water table (i.e., from the saturated upper sand). Using these data, "impacted" soil in the fill and unsaturated upper sand strata were delineated by comparing soil data to action levels. Because of the inherent difficulties in differentiating between groundwater contamination and saturated soil contamination, an area exceeding action levels was not identified for the saturated upper sand. Rather, hot spots for the saturated upper sand were identified (see below).

Definition of Hot Spot Soil. Contaminated soil presents a potential risk to human health and the environment via two pathways: (1) direct exposure, or (2) leaching contaminants to groundwater where they can present a risk (see Sections 2.4 and 2.5). From a practical standpoint, the soil closest to the surface (i.e., the fill and unsaturated upper sand) poses the greatest potential risk via the direct exposure pathway. Conversely, the highly contaminated soil in direct contact with groundwater (i.e., the saturated upper sand), especially soil that contains residual NAPL, poses the greatest threat to groundwater.

Therefore, to identify soils that present the greatest potential risk via these two pathways, hot spots were defined as either:

- Areas or volumes of unsaturated soil (i.e., fill and upper sand above the water table) that pose the highest risks via the direct exposure pathways. For the FS, unsaturated soil contaminated at levels that represent a 1×10^{-4} excess cancer risk, or is 10 times the applicable action level, was defined as a hot spot.

- Areas or volumes of saturated soil that could act as a significant source of contamination to groundwater. NAPL in soil is the most significant source of groundwater contamination. Therefore, saturated soil was defined as a hot spot if it contained, or was located in, some form of NAPL.

The determination of where NAPL is present was based on field observations made during RI drilling, and saturated soil data. The correlation of the NAPL areas with the general distribution of groundwater contaminants is a strong indication that this is an appropriate definition of hot spots for saturated soil.

Areas and Volumes Exceeding Soil Action Levels. Using the soil action (or screening) levels shown in Table 3-2, the areas and volumes of impacted soil are as follows:

- **Fill** - Figure 3-1 shows the areal extent of the fill that exceeds the soil action levels for the IHSs identified in Section 3.2.2. Most of the contaminated fill is located around the building, in the vicinity of the blow pit area, and along the former narrow-gauge railroad track. Approximately 164,000 square feet (sf) (3.8 acres) of the fill exceeds the action levels. Using the measured thickness of 2 to 3 feet of fill in this area, the total volume of impacted fill is estimated to be approximately 14,900 cubic yards (cy). On the basis of observations from the RI, it is estimated that approximately 50 percent of the fill consists of oversized material (i.e., crushed rock and wood debris larger than 1 inch in size).

- **Unsaturated Upper Sand -** Figure 3-2 shows the areal extent of the unsaturated upper sand that exceeds the action levels. As with the fill, the contamination is located beneath and around the building, the blow pit area, and the former narrow gauge railroad tracks. Approximately 196,000 sf (4.5 acres) of the unsaturated upper sand exceeds the action levels. Using the measured thickness of 2 to 2.5 feet of unsaturated upper sand in this area, the total volume of impacted fill is estimated to be approximately 16,550 cy. With the exception of some minor wood debris, very little oversized material was observed in the sand during the RI.

Areas and Volumes Exceeding Soil Hot Spot Levels. Using the hot spot definitions above, the areas and volumes exceeding these levels are as follows:

- **Fill and Unsaturated Upper Sand -** As shown in Figure 3-1, approximately 27,000 sf (0.6 acres) and 5,000 cy of the fill is considered a hot spot. As shown in Figure 3-2, approximately 53,000 sf (1.2 acres) and 2,770 cy of the unsaturated upper sand is considered a hot spot.

- **Saturated Upper Sand -** Figure 3-3 shows the approximate area where saturated hot spot soil (including DNAPL, LNAPL, and residual NAPL) is presumed to be present. Approximately 114,000 sf (2.6 acres) and 12,450 cy of saturated upper sand contains highly contaminated soils or have some form of NAPL present. Beneath the building and blow pit area, this volume was calculated using the full saturated thickness of the sand, plus the top 6 inches of the silt (Area A in Figure 3-3). In the area beneath the former Mill E foundation, boring logs indicated product in a relatively thin layer at the bottom of the upper sand. Beneath the former Mill E, the volume of hot spot soil was estimated using a thickness of 1 foot of sand plus the top 6 inches of silt (Area B in Figure 3-3).

A comparison of the hot spots for the unsaturated and saturated strata show a significant overlap. In general, the former treatment building and blow pit area display the highest contaminant concentrations (Area "A" in Figure 3-3). One notable aspect of saturated hot spot soil distribution is the NAPL lobe that appears to start just west of the southwest corner of the old Mill E foundation and extends 150 feet or more to the east (Area "B" in Figure 3-3). Its source appears to be at the west end of the Mill E foundation, near soil boring SB-40.

3.3.2 Groundwater

As previously noted, the IHSs for groundwater in the upper sand aquifer are arsenic, chromium, copper, PCP, benzene, naphthalene, and TPH. The IHSs for groundwater in the lower sand aquifer are arsenic, benzene, and TPH. These compounds were identified on the basis of a comparison of concentrations detected in groundwater with the most stringent potential cleanup levels established for protection of the Snohomish River. Most of the upper aquifer exceeds one or more of the potential cleanup levels (see Figures 2-10 through 2-12 for arsenic, TPH, and PCP distribution). In the lower aquifer, the distribution of IHSs exceeding cleanup levels appears to be limited to the blow pit area and east toward the river (see Figures 2-13 and 2-14 for arsenic and TPH distribution).

3.4 Remedial Action Objectives

Remedial action objectives (RAOs) form the basis for evaluating potential remedial alternatives for the Site. The RAOs are based on an evaluation of the RI data, contaminant-specific ARARs, and risk factors identified in the baseline risk assessment. They focus on remediating areas of contamination that exceed action levels, that may present unacceptable risks to potential receptors, or both. RAOs for human and environmental receptors are listed below.

3.4.1 Human Health RAOs

RAOs for protection of potential human receptors are as follows:

- Prevent potential receptors (e.g., on-site workers) from contacting or ingesting soil that has concentrations of IHSs exceeding action levels.

- Prevent or minimize groundwater with concentrations of IHSs in excess of action levels from migrating to the Snohomish River.

3.4.2 Environmental RAOs

RAOs for protection of potential environmental receptors are as follows:

- Prevent or minimize groundwater with concentrations of IHSs in excess of action levels from migrating to the Snohomish River.

- Prevent or minimize IHSs in the soil from migrating to the groundwater.

3.5 General Response Actions

General response actions describe actions that satisfy the RAOs. General response actions typically include containment, in-situ treatment, ex-situ treatment, offsite disposal, institutional controls or some combination of these actions. General response actions for the Site are listed in Table 3-4. Like the RAOs for the Site, these general response actions are medium-specific. During the development of remedial alternatives in Section 5, different combinations of these general response actions were evaluated to address the RAOs.

4 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

4.1 Preliminary Technology Identification

This section identifies technologies that were developed into cleanup alternatives to meet the RAOs described in Section 3.4. The list of potentially applicable technologies was based on the general response actions discussed in Section 3.5, which in turn were based on the IHSs and the type of media impacted.

Soil and groundwater were identified as environmental media potentially requiring remedial action. Primary remedial technologies and actions related to soil include containment, in situ treatment, ex situ treatment, volume reduction, excavation, and disposal. Remedial technologies and actions related to groundwater include institutional controls, containment, collection, in situ treatment, and ex situ treatment.

A variety of potentially applicable technologies exist, because of the number of contaminants of concern and affected media. Table 4-1 lists the potentially applicable technologies evaluated as part of the FS.

4.2 Technology Screening

Each technology identified in Section 4.1 was compared with the following screening criteria: effectiveness, implementability, and cost-effectiveness. The comparison was qualitative and was used to screen out technologies not applicable to the Site. Tables 4-2 and 4-3 list, for soil and groundwater respectively, each preliminary technology, summarize how it compares with the screening criteria, and recommend whether the technology should be retained for alternative development.

4.3 Treatability Studies

To better understand the potential applicability of certain technologies at the Site, a series of treatability studies was performed for several of the technologies described in the previous section. An expanded summary of these treatability studies is found in Appendix B.

4.3.1 Soil Technologies

Bench-scale treatability studies for three soil treatment technologies (bioremediation, soil washing, and solidification/stabilization) were conducted in accordance with EMCON's "Proposal for Treatability Study Program at the Former Mill E/Koppers Facility." The treatability studies are summarized in Appendix B of this report.

The results of the treatability studies indicated that both solidification/stabilization and soil washing appear to be potentially viable treatment technologies for the Site. Bioremediation does not appear to be a viable treatment alternative for the Site because of its limited ability to degrade all the organic contaminants of concern and its ineffectiveness in treating metals.

When developing and evaluating remedial alternatives in this FS, solidification/stabilization will be used when treatment of soil is required because it is a more established technology. Solidification/stabilization and soil washing have comparable costs. If an alternative requiring soil treatment is selected for implementation, the decision to use solidification/stabilization rather than soil washing will be reevaluated during remedial design.

4.3.2 Groundwater Technologies

Contaminated groundwater was collected from on-site pump tests and well purging for use in simple bench-scale treatability tests. The tests provided information that was used to design an on-site pilot-scale treatment system that treated approximately 40,000 gallons of groundwater. The process selected was chemical treatment of the water using ferric chloride to precipitate the arsenic, followed by coagulation and flocculation to remove the precipitate and other suspended particulates. Finally, the water was treated using activated carbon to remove dissolved organic compounds. As described in Appendix B, this process resulted in significant reductions in contaminant concentrations.

4.4 Retained Technologies

After the screening process described above, the potentially applicable technologies were reduced to the technologies shown in Table 4-4. For convenience, a brief description of each technology retained for use in alternative development is presented below.

4.4.1 Soil Technologies

Institutional Controls. This includes physical measures (access restrictions) as well as legal and administrative mechanisms (land-use restrictions). Access restrictions (e.g., fencing) are used to prevent contact with contaminated media on site and to protect the integrity of other remedial measures implemented at a site (e.g., site cap, groundwater pumping system). Land-use restrictions (deed restrictions) are used to control or prohibit site development, construction activities, or both. They are implemented through restrictive covenants placed on the property title.

Asphalt/Concrete Cap. An asphalt or concrete cap is generally better suited than other types of caps (e.g., soil or geomembrane) for high-traffic areas or areas requiring substantial structural support or integrity. These caps can effectively reduce infiltration and prevent direct contact or ingestion of contaminated soil. Asphalt or concrete caps can either be modified to include low-permeability layers within the asphalt or be used in conjunction with other low-permeability caps (e.g., geomembrane) when infiltration must be minimized.

In general terms, an asphalt or concrete cap consists of compacted structural fill covered with either asphalt or concrete. In modified low-permeability asphalt caps, a membrane is placed between a base layer of asphalt and the wearing surface. The cap is sloped to drain storm water runoff. The capping material type and thickness are based primarily on loadings anticipated to occur above the cap (e.g., heavy truck traffic and equipment placement).

Geomembrane Cap. A geomembrane cap effectively reduces the potential for ingestion and direct contact with affected soil. A geomembrane cap also reduces the potential for contaminant migration due to infiltration of surface water (e.g., precipitation).

The standard practice in geomembrane cap installation is a 60-mil geomembrane, such as high-density polyethylene for a final capping system. The geomembrane is covered with a permeable sand/gravel drainage layer to collect and transmit infiltration down the slope. A nonwoven geotextile is used over the drainage layer to separate the overlying vegetation, soil, and topsoil. A geomembrane cap over the extent of the contaminated soils will greatly reduce the amount of surface water entering the site and will correspondingly reduce the potential for contaminant migration.

In Situ Soil Washing/Flushing. In situ soil washing or flushing uses a groundwater extraction/reinjection system to inject a water-based solution through contaminated soil into the aquifer. The system typically includes extraction wells drilled in the contaminated soil zone, reinjection wells upgradient of the contaminated area, and a wastewater treatment system. After treatment, the groundwater is reinjected upgradient of the extraction wells and leaches through the contaminated soil. The leachate is then collected, treated, and reinjected into the system, creating a closed loop.

Stabilization/Solidification. Stabilization and solidification processes reduce contaminant mobility, either by chemically altering the contaminant to reduce mobility (stabilization) or by physically restricting its contact with a mobile phase (solidification).

Binding agents for stabilization fall into several classes. The most common binders are cementitious materials. They include Portland cement, fly ash/lime, and fly ash/kiln dust. These agents form a solid, resistant aluminosilicate matrix that binds various contaminants and reduces the permeability of the waste/binder mass. Many organic compounds encountered at wood treatment sites can hinder the effectiveness of stabilization or solidification. Proprietary agents commonly are added to improve process performance.

In situ stabilization generally is performed by mixing contaminated soil media with modified drilling augers while introducing stabilization compounds.

Ex situ stabilization typically is performed by excavating contaminated soil, placing it into a mixing reactor, and introducing stabilization compounds. After sufficient mixing, the stabilized soil can either be placed back into the excavation, or transported off site for disposal.

Rotary Kiln Incineration. A rotary kiln is the most commonly used incinerator to destroy hazardous organic contaminants. The kiln is a refractory-lined, slightly inclined, rotating cylinder that serves as a combustion chamber. Combustion begins in the primary chamber, which usually operates in the temperature range of 1,000°F to 1,800°F. Since conversion of organic contaminants is inadequate in the primary chamber, the system sends the partially combusted gases to a secondary combustion chamber that usually operates from 1,600°F to 2,200°F. The off-gases require treatment to remove particulates and to neutralize and remove acid gases. The treated (sterile) soil can be reused as on-site fill.

Dewatering. Dewatering refers to the general group of technologies used to remove free water from soil, either in place or once they have been excavated. In-place dewatering usually involves extracting groundwater by using wells or trenches. Dewatering excavated soil generally involves placing the soil in a pile or a bed and allowing the water to drain out. In certain environmental applications, these dewatering areas are lined, and the water is collected for treatment or disposal.

Excavation. Excavation involves removing well-defined areas of contaminated soil by using conventional heavy construction equipment such as backhoes, trackhoes, front-end loaders, or clamshell buckets. After special handling to remove any debris or large solids, the soil is then either treated on site or placed into waste-hauling trucks and manifested for shipment off site to an approved waste treatment/disposal facility.

Care must be taken during excavation to prevent generation and dispersion of dust. Care must also be taken during excavation of saturated soil to prevent increased groundwater contaminant concentrations.

Soil Screening/Sieving. These technologies are used to reduce the quantity of hazardous waste or contaminated soil that requires additional treatment or disposal. One such volume reduction technology is soil sieving, which separates soil by size. The technology is effective when contaminants are primarily associated with a distinct range of particle sizes, and when this range of particle sizes can be separated from the rest of the soil or debris by screening or sieving. To realize significant volume reductions, the contaminants must have a particle size range that comprises a low percentage of the total soil matrix (e.g., less than 50 percent). Soil sieving can be particularly effective when large quantities of debris and other large-size material are present in the soil matrix.

Soil sieving typically involves excavating contaminated soil and processing it through one or more screens that retain or reject progressively smaller particles. The contaminated fraction of soil, typically the fines or small-size particles, are collected for further treatment (e.g., solidification), resource recovery, or disposal. If soil sieving is used appropriately, the rejects can simply be placed back in the ground or disposed of as solid waste. It is possible, however, that the rejects may still contain elevated contaminant levels that require additional treatment or special disposal.

Off-site Landfill. Disposal of contaminated soil in an off-site landfill is a well-established remedial technology. It involves excavation and transport of contaminated soil to an approved landfill appropriately permitted for disposal. LDR regulations (40 CFR Part 268) require many wood waste contaminants to be treated (e.g., solidified) before disposal.

This technology can also be used to dispose of residuals produced by remedial alternatives that include a destructive technology (e.g., chemical, biological, or thermal).

4.4.2 Groundwater Technologies

Groundwater Monitoring. Groundwater monitoring is an institutional control method to evaluate the present risks posed by the medium or the effectiveness of a previously implemented remedial measure. Monitoring is performed via a system of wells installed upgradient and downgradient of contaminated or uncontaminated areas of the site. Groundwater monitoring continues until statistical evaluation indicates that the required level of groundwater quality has been achieved.

Institutional Controls. Deed restrictions are methods of controlling or prohibiting site development, construction activities, or both. They are implemented through restrictive covenants placed on the property title.

Extraction Methods. *Extraction Wells.* Groundwater extraction is a remedial technology used to remove contaminated water, contain a contaminant plume, or hydraulically control contaminant migration.

Groundwater extraction (pumping) is a versatile remedial measure that can be modified to address site-specific hydrogeologic conditions. Contaminants can be extracted from specific parts of the saturated zone (e.g., at or close to the water table surface for contaminants with specific gravities lower than water, or toward the base of the aquifer for those with densities greater than water).

A groundwater extraction system typically involves installing several extraction wells at regularly spaced intervals in respective aquifers, then extracting contaminated groundwater for treatment and disposal. Pumping groundwater from impacted aquifers induces hydraulic gradients that prevent or minimize off-site transport of contaminated groundwater. The feasibility of installing a groundwater extraction system is a function of the hydraulic properties of the aquifer, the desired aquifer response, and the successful treatment and disposal of contaminated water.

Interceptor Trenches. Interceptor trenches are typically installed for groundwater gradient control and recovery. Trenches installed hydraulically upgradient of contaminated areas are used to intercept and divert groundwater, thereby slowing contaminated groundwater migration. Trenches installed downgradient of contaminated areas collect and extract groundwater for subsequent treatment, disposal, or both. Interceptor trenches usually are excavated vertically to the depth of a confining layer and perpendicular to the direction of groundwater flow. A porous pipe is usually installed on the bottom of the trench to allow for extraction of the water collected in the trench.

Product Recovery. Product recovery technologies are similar to groundwater extraction technologies (e.g., wells, trenches) except that they are used to extract LNAPL, DNAPL, or both. Where NAPL is present in the subsurface as a separate phase, wells or interceptor trenches can be installed directly in the NAPL and extracted by pumps. The extracted NAPL is collected and treated or disposed of as appropriate. Section 2.6 describes the interim product recovery efforts attempted at the Site. In general, it appears that limited passive product recovery may be possible at the Site, because of limited quantities of recoverable product.

Treatment Technologies. The general types of water treatment technologies potentially applicable are described below. A more detailed treatment approach is described in Section 4.5.

Oil and Water Separation. Oil and water separation removes oil from water by providing surface contact that coalesces oil particles from the water phase. Oil and water separation is a frequent pretreatment step for other treatment technologies.

Gravity Settling. Gravity settling removes solids from a liquid by providing a quiescent condition that permits solids or liquids with a higher specific gravity to sink. Gravity settling commonly precedes or follows other treatment technologies.

Solids Filtration. Solids filtration isolates solid particles by running a fluid stream through a porous medium. Filtration techniques may include separation by centrifugal force, vacuum, or high pressure.

Carbon Adsorption. Carbon adsorption binds a substance to the surface of activated carbon by physical and chemical means. The imbalance of electrical forces in the pore walls of the carbon allows contaminants to attach and concentrate. Once adsorption has occurred, the molecular forces in the pore walls stabilize. When the carbon has been saturated, it can be regenerated in place, removed and regenerated at an off-site facility, or disposed.

Carbon adsorption has been shown to remove PAHs, other polar organic compounds, PCP, nonhalogenated aromatics, dioxins, furans, and some nonvolatile and volatile metals from water at wood-preserving sites.

Advanced Oxidation Processes. Both inorganic and organic compounds can be oxidized to render them nonhazardous or to make them more amenable to subsequent removal or destruction processes. This technology originally was developed as a polishing step for dilute aqueous industrial wastes. Advanced oxidation uses one or more oxidizing agents (e.g., ultraviolet radiation, ozone, or peroxide) to oxidize contaminants. This innovative technology effectively destroys many wastes encountered at wood-preserving sites. These include PCP, nonhalogenated aromatics, PAHs, other polar organic compounds, nonvolatile and volatile organics, and metals.

Metals Precipitation. Metals precipitation is a physical/chemical process that transforms dissolved metals into an insoluble solid, facilitating the removal of metals from the liquid phase by gravity settling or filtration. The process usually includes pH adjustment, addition of a chemical precipitant, flocculation and settling, or filtration. Metals usually precipitate in the form of hydroxides, sulfides, or carbonates. The solubility of the specific metal contaminants and the required cleanup standards dictate the specific process.

Hydraulic Control Technologies. *Slurry Wall.* Slurry walls are used as vertical barriers to help control lateral migration of contaminated groundwater. Slurry walls are constructed by excavating a trench while using a bentonite and water slurry to support its sidewalls. The trench is then backfilled with lower permeability materials than surrounding native soils.

Several types of backfill material can be used in the trench, including a soil-bentonite mixture, a cement-bentonite mixture, or lean concrete. Several slurry wall configuration variations are also possible.

Equipment requirements for slurry wall installation may include trackhoe excavators, crane-mounted clamshell buckets, or dragline buckets.

Sheet Piling. Sheet piling can be an effective vertical barrier. It is installed by driving interlocking steel piles down to a low-permeability layer. Installation techniques using cranes and pile-drivers are well established. This technology is limited by site characteristics such as soil type, depth to groundwater, and depth to a confining layer. The depth to which sheet piles can be driven without damage is at least 30 feet. Integrity of deeper sheet piling would be suspect. Recent advances in sheet piling technology include interlocking seals with channels into which grout can be injected and the use of HDPE and PVC as barrier wall materials. The lifetime of a sheet piling wall depends on the pH and salinity of the groundwater and the waste constituents.

4.5 Groundwater Treatment

The methods for treatment of water described below utilize the general technology types retained in Section 4.4.2 and were developed based on the bench- and pilot-scale treatment tests. The treatment approach was also driven by the potential for the treatment system to operate on an irregular schedule (depending on the site remediation activities). Because of the potential for an unpredictable schedule and the start/stop nature of the system, biological treatment was eliminated from further consideration. Bench- and pilot-scale tests demonstrated that treatment could be achieved using ferric chloride as a coagulant for suspended particulate and as a coprecipitator for arsenic, followed by sodium hydroxide neutralization and metals precipitation. Next, a polymer would be added for flocculation and an up-flow, inclined plate clarifier used to remove treated particulate material. Finally, a sand filter would remove any residual particulate before treatment with granular activated carbon to remove residual organic compounds. The water would then be discharged.

Sludge produced in the treatment system would be periodically transferred to a sludge accumulation tank, from which it would be pumped to a plate and frame filter press. The dewatered solids would be collected in 55-gallon drums for subsequent off-site disposal.

The water treatment system must be capable of handling flow rates ranging from 25 to 150 gpm. The higher rate could be encountered during excavation dewatering. An evaluation of various operating scenarios showed that storing water in tanks throughout the day and night, and then treating the water in batch mode at a rate of 150 gpm, would be the most cost-effective approach.

5 DEVELOPMENT AND SCREENING OF CLEANUP ACTION ALTERNATIVES

The potentially applicable remedial technologies identified in Section 4.4 were assembled into preliminary cleanup actions, developed specifically to mitigate potential risks to human health and the environment. Cleanup actions to treat contaminated water generated during remediation (e.g., during excavation dewatering, as treatment residuals, or during groundwater extraction and treatment) were described and evaluated separately in Section 4.5. The recommended water treatment approach is incorporated into the main cleanup actions described in Section 5.1.

The cleanup actions described in Section 5.1 represent a range of potentially effective remedial approaches. They include containment, hot spot removal/treatment, groundwater extraction and treatment, and in situ treatment alternatives. These actions are screened against three criteria (protectiveness, implementability, and cost-effectiveness) to eliminate inapplicable or less-effective actions. Cleanup actions retained after screening are evaluated in detail in Section 6.

5.1 Development of Preliminary Cleanup Action Alternatives

Ten cleanup action alternatives (including the no-action alternative) were assembled from the technologies selected in Section 4. The alternatives represent a broad range of possible cleanup actions, ranging from containment with groundwater monitoring to complete soil excavation/treatment with groundwater extraction and treatment. Descriptions are general, but provide sufficient detail for evaluation against the three screening criteria (protectiveness, implementability, and cost-effectiveness) presented in Section 5.2.

Table 5-1 summarizes the 10 preliminary cleanup action alternatives described below.

5.1.1 Alternative 1 - No Action

No cleanup action would be taken in this alternative. Only institutional controls (site access and deed restrictions) required by MTCA and groundwater monitoring are included in this alternative. The existing fence and building foundations would remain as they are.

5.1.2 Alternative 2 - Site-wide Cap, Product Recovery, Groundwater Monitoring

In this alternative, all areas where unsaturated soil (i.e., fill and unsaturated sand strata) exceed the soil action levels would be covered with a low-permeability ($<10^{-6}$ centimeters per second [cm/sec]) cap, DNAPL would be recovered from the blow pit area, and groundwater would be monitored to evaluate long-term contaminant concentrations.

As described in Section 3.3, the total soil area requiring a cap would be approximately 325,000 sf or 7.5 acres. Because the Site will be used for industrial purposes in the future, the low-permeability cap would be a modified asphalt cap.

Passive recovery of DNAPL in and around the blow pit area would take place. Passive recovery of LNAPL is not deemed practical because product thickness is estimated at only 1 to 2 inches in the blow pit area. Recovered product would be accumulated in drums or tanks on site, then periodically sent to a permitted treatment, storage, or disposal (TSD) facility.

Other assumptions for implementing this alternative include the following:

- The building and Mill E foundations would be leveled to the extent necessary to allow placement of a low-permeability cap in these areas. The debris would be decontaminated, as necessary, and disposed of off site.
- Development restrictions for the portion of the Site covered by the cap and for use of Site groundwater would be recorded.
- Storm water runoff would be directed off the cap and into existing stormwater conveyances or allowed to infiltrate into uncontaminated areas.
- Groundwater monitoring would be conducted semiannually in approximately six monitoring wells screened in the upper sand aquifer and four wells in the lower sand aquifer.

5.1.3 Alternative 3 - Site-wide Cap, Product Recovery, Vertical Containment for Saturated Hot Spot Soil, Groundwater Monitoring

Alternative 3 would include all of the actions in Alternative 2 (site-wide cap, product recovery, and groundwater monitoring) and would add vertical containment around the saturated hot spot soil (i.e., saturated upper sand where NAPL is present; see Section 3.3.1 for discussion).

Vertical containment around the hot spot soil would consist of low-permeability ($<10^{-6}$ cm/sec) steel sheet piling with sealable joints. Based on the estimated extent of NAPL shown in Figure 3-3, approximately 1,600 linear feet of sheet piling would be required. Before installation, additional exploratory soil borings may be required to better define the extent of NAPL in certain areas. The sheet piling would be installed beneath the 7.5-acre low-permeability cap described for Alternative 2.

Other assumptions for implementation of this alternative include the following:

- Development restrictions for the portion of the Site covered by the cap and for use of Site groundwater would be recorded.
- Storm water runoff would be directed off the cap and into existing stormwater conveyances or allowed to infiltrate into uncontaminated soil.
- Groundwater monitoring would be conducted semiannually in approximately four monitoring wells screened in the upper sand aquifer and four wells in the lower sand aquifer.

5.1.4 Alternative 4 - Soil Consolidation, Cap, Product Recovery, Vertical Containment, Groundwater Monitoring

Alternative 4 would include most of the actions of Alternative 3 but would excavate soils exceeding action levels located outside the vertical containment and consolidate them inside the vertical containment area. The cap would extend only over the vertical containment area and be approximately 4.5 acres in size.

Approximately 1,700 linear feet of low-permeability ($<10^{-6}$ cm/sec) steel sheet piling with sealable joints would be installed around most of the saturated hot spot soils. Both saturated and unsaturated soil exceeding action levels located outside the sheet piling would be excavated and consolidated within the limits of the sheet piling. The excavations would be backfilled with clean imported fill. A low-permeability asphalt cap would be constructed over the contaminated soil within the sheet piling containment area. Before these actions were implemented, the former Mill E and treatment building foundations and other near-surface site features would be leveled at the current grade.

Passive recovery of DNAPL in and around the blow pit area would take place as described for Alternative 2.

Other assumptions for implementing this alternative include the following:

- Development restrictions for the portion of the Site covered by the cap and for use of Site groundwater would be recorded.
- Storm water runoff would be directed off the cap and into existing stormwater conveyances or allowed to infiltrate into uncontaminated areas.
- Groundwater monitoring would be conducted semiannually in approximately three monitoring wells screened in the upper sand aquifer and four wells in the lower sand aquifer.

5.1.5 Alternative 5 - Site-wide Cap, Product Recovery, Groundwater Recovery and Treatment

Alternative 5 would include the components of Alternative 2 (site-wide cap, product recovery and groundwater monitoring) and add groundwater recovery and treatment.

Contaminated groundwater below the Site would be recovered by a series of extraction wells or an interceptor trench located along the downgradient Site boundary, next to the Snohomish River. Groundwater from the upper sand aquifer would be recovered and pumped to an aboveground water treatment system. Groundwater would be treated using one of the alternatives evaluated in Section 5.3. After treatment, the water would be discharged to the river through a new NPDES-permitted outfall.

5.1.6 Alternative 6 - Hot Spot Soil Removal, Stabilize Excavated Soil, Site-wide Cap, Groundwater Monitoring

In this alternative, hot spot soil would be excavated and treated on site by solidification and stabilization (stabilization). Approximately 20,350 cy of soil would be removed, treated, and then backfilled in this alternative. Excavation of this soil would require the use of sheet piling, which would be left in place. After excavation, treatment, and backfilling, the Site would be covered with an approximately 7.6-acre low-permeability cap to reduce the potential for direct exposure to the untreated soil and to reduce infiltration inside the sheet pile left in place after excavation. Groundwater would be monitored to evaluate the effectiveness of source-removal in reducing groundwater contaminant concentrations.

Excavation of the hot spot soil areas would be complicated by several factors including the relative thinness of the silt in the blow pit area, the presence of a net upward head between the upper and lower sand aquifers, and the presence of NAPL across large portions of the Site. During the excavation it would be important not to disturb or breach the silt aquitard beneath the upper sand. The silt layer is thin in certain areas to be excavated (e.g., the blow pit area), and the lower sand aquifer is partially confined and places an upward pressure on the overlying silt layer, so care must be taken during excavation to prevent the silt from heaving. Heaving could occur when the soil and water above the thin silt layer area are removed during excavation.

The method of excavation most likely would involve dewatering the upper sand aquifer as described below, then removing the contaminated soil by using standard construction equipment. Dewatering the upper aquifer would involve installing sheet piling around the areas to be excavated, then pumping out the water inside the sheet piling. Once dewatered, the contaminated soil would be excavated and treated.

As noted above, the excavated soil would be treated by stabilization. Treatability studies indicate that this technology effectively reduces the leaching potential of contaminants in soil. As excavation proceeds, clean soil would be used to backfill the excavation up to the high water table; treated soil would be used as backfill above the water table inside the sheet piling placed for excavation purposes. The backfilled areas would be capped, primarily to minimize infiltration into the treated soil placed in the sheet pile enclosure. Residual process water and groundwater collected during dewatering would be treated on site.

Storm water control and groundwater monitoring would be handled as described for Alternative 3.

Other assumptions for implementation of Alternative 6 include the following:

- Contaminated groundwater and process wastewater would be treated as described in Section 5.3 and discharged to the Snohomish River through a new outfall.

5.1.7 Alternative 7 - Excavate and Stabilize All Impacted Soil, Groundwater Monitoring

This alternative would be similar to Alternative 6 in that impacted soil would be excavated, treated using stabilization, and placed back into the excavation. The amount of soil excavated in this alternative would include all unsaturated and saturated soil in the fill and upper sand units exceeding the action levels identified in Section 3.2. The same problems associated with heaving of the silt aquitard during excavation, discussed for Alternative 6, would be encountered. Groundwater would be monitored as described for Alternative 3.

The total volume of soil requiring excavation and stabilization would be approximately 44,000 cy. As in Alternative 6, liquid organic waste generated during excavation would be transported to an off-site TSD facility. Water generated during soil dewatering would be treated on site, as described in Section 5.3, and discharged under an NPDES permit.

5.1.8 Alternative 8 - Same as Alternative 7, Except Treat Soil as Necessary for Off-site Disposal

This alternative includes excavating approximately 44,000 cy of impacted soil, as described for Alternative 7, and off-site disposal of the excavated soil. Soil excavated from relatively "clean" areas of the Site would probably not require treatment before disposal in a lined solid or hazardous waste landfill. Soil from hot spots could contain contaminants restricted from land disposal without prior treatment. If so, soil would be treated on site (stabilized) to meet land disposal restriction treatment standards before off-site disposal.

Because all impacted soil would be removed from the Site, this alternative would not include installation of a low-permeability cap. Groundwater monitoring would be conducted as for Alternative 3.

5.1.9 Alternative 9 - Same as Alternative 7, Except Add Groundwater Recovery and Treatment

This alternative would include excavating impacted soil, with subsequent stabilization, as described for Alternative 7. Residual groundwater contamination would be addressed by recovery and treatment. Groundwater extraction site-wide would require approximately three to five wells in the shallow aquifer and 2 to 4 wells in the deeper aquifer.

5.1.10 Alternative 10 - In Situ Treatment (Soil Washing, Stabilization), Product Recovery, Groundwater Monitoring

Contaminated soil in the saturated and unsaturated zones would be treated in situ by soil washing, stabilization, or both. A series of infiltration basins and injection trenches would be installed at various locations for soil washing. Infiltration basins would be located in areas with high levels (i.e., hot spots) of contaminants in the unsaturated zone. Injection trenches would be located in areas where contamination is limited to the saturated zone. Washing solution would be introduced to the subsurface soil through basins and trenches. It would percolate through the soil and be recovered by a series of downgradient interceptor trenches next to the river. The extracted wash solution/groundwater would be routed to an aboveground treatment unit for further processing. Treated groundwater would be discharged to the river under an NPDES permit.

Contaminated areas where in situ soil washing did not achieve action levels in a specified time period would be stabilized in situ. Long-term groundwater monitoring would be conducted as described for Alternative 2.

5.2 Screening of Preliminary Cleanup Action Alternatives

The 10 alternatives described above were evaluated against three screening criteria: protectiveness, implementability, and cost-effectiveness. Both the short- and long-term aspects of each criterion were evaluated. Short term refers to few years after the cleanup action is implemented (up to 5 years), while long term generally refers to a much longer period (20 years or more). The screening process was developed to identify several potentially viable cleanup action alternatives, representing a range of possible actions. Cleanup actions that either did not adequately meet any of the screening criteria, or did not appear to be as effective as similar alternatives, were eliminated from further consideration. For this FS, cost-effectiveness was defined as a relative measure of an alternative's effectiveness compared with the cost of implementing the alternative.

Table 5-2 summarizes the screening of the preliminary cleanup action alternatives.

5.2.1 Alternative 1 - No Action

Protectiveness. No cleanup actions other than groundwater monitoring and deed restrictions are included in this alternative. Because this alternative would not reduce or minimize the potential short- or long-term risks posed by contaminants at the Site, it would be ineffective in protecting human health or the environment.

Implementability. Technically, the no-action alternative would be feasible, since no action would be taken. From an administrative standpoint, however, this option would probably not be approved by regulatory agencies, because it would not protect human health and the environment.

Cost-effectiveness. This alternative would not be cost-effective because the expense of conducting groundwater monitoring and preparing deed restrictions would not effectively reduce potential risks posed by contaminants at the site.

Summary. This alternative would take no action to contain or remove contamination at the Site, would not provide short- or long-term protection to human health or the environment, and would not be cost-effective. This alternative, however, was retained as required by CERCLA and for use as a baseline reference against which to compare other cleanup action alternatives.

5.2.2 Alternative 2 - Site-wide Cap, Product Recovery, Groundwater Monitoring

Protectiveness. Capping soil in place with a low-permeability cap would reduce the amount of exposed soil and eliminate the direct contact and ingestion exposure routes. Recovery of product could also reduce the potential for long-term migration of contaminants from the blow pit area to the lower sand aquifer. By greatly reducing the amount of infiltration contacting contaminated soil, potential impacts to groundwater and surface water would be reduced. This alternative would be protective of human health in the short term. Because contaminated groundwater would continue to be discharged to the river, this alternative would not substantially reduce environmental risks in the short or long term.

Implementability. Construction of a site cap and product recovery system would be very implementable. From an administrative or regulatory standpoint, this type of containment alternative, although not prohibited, would generally not be considered a preferred technology.

Cost-effectiveness. Through recovery of DNAPL, this alternative would reduce the mass of contaminants present on site. Because most NAPL at the Site is either residual or present in thin unrecoverable layers, substantial quantities of contaminated media would remain on site. Use of capping technologies would reduce the human health risk exposure to soil to acceptable levels. Given the volume of contaminated soil, this alternative may be cost-effective relative to alternatives involving soil excavation and disposal.

Summary. This alternative would involve covering contaminated soil with impermeable materials and recovering DNAPL in the blow pit area. It would eliminate major exposure pathways (i.e., ingestion and direct contact). It would reduce the major human health risk, but would not address potential environmental risks in the short- or long-term. It would be technically feasible and appears to be cost-effective. This cleanup action alternative was therefore retained for detailed analysis.

5.2.3 Alternative 3 - Site-wide Cap, Product Recovery, Vertical Containment for Hot Spot Soil, Groundwater Monitoring

Protectiveness. This alternative would be similar to Alternative 2, except that vertical containment would be provided around saturated hot spot soil. Vertical containment would provide significant protection against horizontal contaminant migration. The site-wide cap and the vertical containment would reduce potential risks to human health, including direct contact and ingestion, in the short and long term. The combination of the cap and vertical containment would also reduce downward contaminant migration to the lower aquifer by reducing the average hydraulic head in the upper aquifer. Although groundwater discharges would continue, inclusion of source control (i.e., vertical containment) could make this alternative protective to the environment in the long term.

Implementability. Implementation of the site-wide cap, product recovery, vertical containment, and groundwater monitoring features of this alternative are easily implemented, well-established technologies. With the addition of vertical containment, this alternative would comply with more of MTCA's selection criteria (WAC 173-340-360) than Alternative 2.

Cost-effectiveness. Use of a site cap and vertical containment of saturated hot spot soil would be cost-effective methods to contain contaminated soil, reduce potential contaminant migration, and reduce risks to human health and the environment.

Summary. This alternative appears to be implementable and effective. The alternative would provide levels of protection greater than Alternative 2 and appears to be relatively cost-effective. Therefore, Alternative 3 was retained for further consideration.

5.2.4 Alternative 4 - Soil Consolidation, Cap, Product Recovery, Vertical Containment Groundwater Monitoring

Protectiveness. This alternative would be similar to Alternative 3, except that approximately 14,240 cy of soil exceeding action levels located outside the vertical containment would be excavated and consolidated inside the vertical containment area constructed around the saturated hot spot soil. Vertical containment would be provided around the primary contaminant hot spot areas. Soil consolidation would significantly reduce the area of the Site where contaminants are left in place, and place these soils inside a containment cell. Vertical containment would provide protection against horizontal contaminant migration. The cap and the vertical containment would reduce potential risks to human health, including direct contact and ingestion, in the short and long term. The combination of the cap and vertical containment would also reduce downward contaminant migration to the lower aquifer by reducing the average hydraulic head in the upper aquifer. Although groundwater discharges would continue, the inclusion of containment of the groundwater contaminant sources could make this alternative protective to the environment in the long term.

Implementability. Implementation of the soil excavation and consolidation, asphalt cap, product recovery, vertical containment, and groundwater monitoring features of this alternative is readily achievable using well-established technologies. With the addition of soil consolidation, this alternative would comply with more of MTCA's expectations regarding remedy selection (WAC 173-340-360) than Alternative 3. By minimizing the area where soil exceeding cleanup levels remains, this alternative is more consistent with anticipated future uses for the Site compared to Alternative 3.

Cost-effectiveness. Soil consolidation combined with a cap and vertical containment of all soil exceeding action levels would be a cost-effective approach to contain contaminated soil, reduce potential contaminant migration, and reduce risks to human health and the environment. When compared to Alternative 3, the increased costs associated with soil excavation and consolidation would be partially offset by the reduced cost of containment (i.e., a smaller cap will be required).

Summary. This alternative appears to be implementable and effective. The alternative would provide levels of protection somewhat greater than Alternative 3 and appears to be relatively cost-effective. Therefore, Alternative 4 was retained for further consideration.

5.2.5 Alternative 5 - Site-wide Cap, Product Recovery, Groundwater Recovery and Treatment

Protectiveness. Human health protection would be similar to Alternatives 2 through 4. Addition of groundwater extraction and treatment would significantly reduce the discharge of contaminated groundwater to the river, thereby reducing short- and long-term environmental risks.

Implementability. Both capping and groundwater recovery and treatment technologies are technically feasible to implement. The use of recovery and treatment technologies without active source removal or control, however, would not be practical. Because of the presence of NAPL in the subsurface, the groundwater recovery and treatment system would run into the distant future, even with product recovery. The addition of groundwater treatment would comply with more of MTCA's selection criteria (WAC 173-340-360) for a cleanup action alternative. The potential regulatory status of the Site groundwater (i.e., potential classification as an F032, F034 or F035 waste) could complicate storage, treatment, and disposal of the extracted groundwater.

Cost-effectiveness. This alternative would not include removal or treatment of contaminated soil or, with the exception of passive DNAPL recovery in the blow-pit area, other sources of groundwater contamination. Extraction and treatment of contaminated groundwater would, therefore, be a lengthy (>50 years) and costly element of this cleanup action alternative. The alternative cannot be considered cost-effective, as it would most likely take many decades to achieve significant groundwater cleanup.

Summary. Because extraction and treatment of contaminant sources would not be addressed by this alternative, the time and expense required for extraction and treatment of contaminated groundwater would not make this alternative cost-effective. Therefore, this cleanup action alternative was not retained for further evaluation.

5.2.6 Alternative 6 - Hot Spot Soil Removal, Stabilize Excavated Soil, Site-wide Cap, Groundwater Monitoring

Protectiveness. Excavation and stabilization of hot spot soil would effectively protect human health immediately after implementation and in the long term by removing most contaminants from the subsurface, although placing a cap over the Site would still be required to prevent direct contact and ingestion of soil containing some low-level contamination. Excavation could, however, volatilize certain contaminants, enable windblown transport of soil, or cause heaving in the silt confining layer, if proper precautions were not taken. By removing the source of groundwater contamination, this alternative should be protective of the environment in the long term.

Implementability. Excavation and stabilization of hot spot soil would be technically feasible; however, care must be exercised during excavation above portions of the silt aquitard to avoid damaging the silt layer and increasing downward contaminant migration. Because this alternative makes use of a permanent treatment technology, it would comply with more of MTCA's selection criteria (WAC 173-340-360) than alternatives that do not use treatment technologies. The regulatory status of the Site soil and groundwater could complicate the on-site management of these media during remediation.

Cost-effectiveness. Excavation and stabilization of hot spot soil would stabilize the mass of contaminants remaining on site and reduce the potential for further contamination of soil and groundwater. It would be more costly than Alternatives 2 through 4 and may not provide a significant protectiveness. This alternative would be more cost-effective, but less protective, than one including treatment of all contaminated soil.

Summary. This alternative would involve removal and treatment of hot spot soil. It appears to be effective and implementable, although some difficulties related to excavation above the thin silt layer may exist (see Section 6.2.5 for discussion). Removal and treatment of contaminant sources is potentially more permanent than alternatives that do not stabilize the mass of contaminants on site, although it may not be significantly more protective. Alternative 6 will be costly to implement. For these reasons, and to evaluate a cleanup action with removal and treatment of soil, Alternative 6 was retained for further evaluation.

5.2.7 Alternative 7 - Excavate and Stabilize All Impacted Soil, Groundwater Monitoring

Protectiveness. Excavation and treatment of all impacted soil above action levels would be extremely effective in protecting human health immediately after implementation and in the long term. By removing impacted soil and associated NAPL, the potential for future groundwater contamination from contaminated soil would be greatly reduced. Excavation would have to be performed with caution to avoid heaving in the silt aquitard, and to minimize volatilization and windblown release of contaminants. This alternative would be protective of the environment in the long term.

Implementability. The large volume of soil to be excavated and removed would require significant engineering controls and dewatering to avoid soil heaving and rupturing of the silt aquitard. Dewatering would require a substantial water treatment operation. Excavation, stabilization, and water treatment operations are technically feasible, although some significant difficulties could arise during excavation. Removal and treatment of all impacted soil would comply with more of MTCA's selection criteria (WAC 173-340-360) for remedy selection than alternatives that address smaller volumes of soil or rely primarily on containment. The regulatory status of site soil and groundwater could complicate the on-site management of these media during remediation.

Cost-effectiveness. This alternative would be substantially costlier than Alternatives 2 through 6, but could provide higher levels of protection than alternatives that only contain or treat hot spot soil. The temporary installation of water treatment facilities during dewatering activities might not be cost-effective.

Summary. This alternative would remove and treat a large volume of contaminated soil. The alternative appears to be protective, although difficult and costly to implement. Because this alternative could offer a higher level of protection than other alternatives and would address all of the soil exceeding action levels, it was retained for further evaluation.

5.2.8 Alternative 8 - Same as Alternative 7, Except Treat Soil as Necessary for Off-site Disposal

Protectiveness. This alternative would provide a slightly higher level of protection compared to Alternative 7 because the contaminated soil will be removed from the Site. There are, however, some increased potential risks to human health during implementation because of the high level of traffic associated with using trucks to haul the soil off site for disposal.

Implementability. The implementability of this alternative is similar to Alternative 7, except that off-site disposal of the treated soil may not comply with as many of MTCA's selection criteria (WAC 173-340-360) for remedy selection when compared with alternatives that call for on-site disposal of treated soil. The regulatory status of site soil and groundwater could complicate the on-site management of these media during remediation.

Cost-effectiveness. This alternative would be substantially costlier than Alternatives 2 through 6, and even higher than Alternative 7, and might provide only marginally higher levels of protection than alternatives that address smaller volumes of soil. The temporary installation of a large water treatment facility during dewatering might not be cost-effective.

Summary. Through removal, treatment, and off-site disposal of contaminated soil, this alternative would provide a slightly higher level of protection than Alternative 7 in the long-term, and would be less protective in the short-term due to the additional soil movement. Because the costs associated with off-site disposal are higher than the on-site disposal costs in Alternative 7, and due to increased short-term risks, this alternative was not retained for further evaluation.

5.2.9 Alternative 9 - Same as Alternative 7, Except Add Groundwater Recovery and Treatment

Protectiveness. Excavation and treatment of all affected soil and extraction and treatment of contaminated groundwater at the Site would be extremely effective in protecting human health and the environment immediately after implementation and in the long term. By removing impacted soil and associated NAPL, the potential for future groundwater contamination from contaminated soil would be greatly reduced. Excavation would have to be performed with caution to avoid rupturing the silt aquitard and to minimize volatilization and windblown release of contaminants. Groundwater extraction and treatment would be protective of the environment.

Implementability. The large volume of soil to be excavated and removed would require significant dewatering to avoid soil heaving and rupturing of the silt aquitard. The water treatment operation would be substantial to address the large amount of water generated from dewatering and from the contaminated aquifer. Excavation, solidification and stabilization, and water treatment operations are technically feasible, although excavation would pose difficulties. Removal and treatment of all impacted soil and active groundwater recovery and treatment would comply with more of MTCA's selection criteria (WAC 173-340-360) for remedy selection than alternatives that address smaller volumes of soil and those that do not include groundwater treatment. The regulatory status of site soil and groundwater could complicate the on-site management of these media during remediation.

Cost-effectiveness. Because of the volume of soil and groundwater requiring excavation and treatment, this alternative would be one of the most expensive. The stabilization of contaminant mass and reduction of risk, when compared with other alternatives (e.g., Alternative 6 and 7), might not be cost-effective.

Summary. This alternative would be effective in eliminating risks to human health and the environment because it would remove and treat of all affected soil and groundwater.

But because this alternative would be extremely expensive and may not be cost-effective, it was not retained for further evaluation.

5.2.10 Alternative 10 - In Situ Treatment (Soil Washing, Stabilization), Product Recovery, Groundwater Monitoring

Protectiveness. In situ soil washing and product recovery could provide long-term human health protection by reducing the volume of soil, NAPL, and groundwater contaminants. There might be insufficient hydraulic control for complete recovery of washing fluids. Therefore, vertical migration of contaminants could be enhanced. Stabilization of incompletely washed soil would reduce contaminant mobility.

Implementability. As mentioned above, complete hydraulic control may not be possible. The nature of the contaminants would require that the washing fluid contain surfactants or other chemicals in addition to water. Introduction of a chemical substance to groundwater would make regulatory acceptance of this process difficult to obtain. In addition, the length of time for completion of cleanup could be long (i.e., decades).

Cost-effectiveness. The cost of intensive in situ treatment and the length of time required for completion of cleanup make this alternative very costly to implement. Because it would probably not provide greater protection than other alternatives, it is not considered cost-effective.

Summary. This alternative may be effective in reducing the long-term risks to human health by reducing the volume of soil and groundwater contamination. Because the time required for cleanup, the uncertainty of regulatory acceptance, and low cost-effectiveness, this alternative was not retained for further evaluation.

5.3 Groundwater Management Approach

In this section, the general approach toward groundwater management at the Site, and the rationale for that approach, is presented. Of the six alternatives that are retained for detailed analysis, none involves a groundwater extraction and treatment component. The two main reasons are upgradient contaminant concentrations and the overall impracticability of using groundwater extraction and treatment to achieve very low cleanup goals, especially when NAPLs are present.

The first reason, upgradient contaminant concentrations, is fairly straightforward. Arsenic in the shallow aquifer is present upgradient of the Site at concentrations over 80 times the action level of 5 micrograms per liter (μg/L). As long as this condition exists, it would not be possible to extract groundwater on site and ever reach action levels.

The second reason, the impracticability of achieving low action levels using groundwater extraction, has received considerable evaluation by the USEPA and other organizations over the last several years. In September 1993, the USEPA released "Guidance for Evaluating the Technical Impracticability of Groundwater Restoration," OSWER Directive 9234.2-25. In that document, the USEPA states that:

> . . . experience over the past decade has shown that restoration to drinking water quality (or more stringent levels where required) may not always be achievable due to the limitations of available remediation technologies.

The document cites three primary factors that can inhibit groundwater restoration: hydrogeologic factors, contaminant-related factors, and remediation system design inadequacies.

At the Former Mill E/Koppers site, the hydrogeology is fairly amenable to groundwater extraction (e.g., high-permeability soils, low organic content). It is the second factor, contaminant-related issues, that makes the potential for groundwater restoration through extraction and treatment technology impracticable at the Site. The guidance document states that the presence of NAPL, and especially DNAPL, poses severe technical limitations to aquifer restoration. Specifically, the difficulty in locating and removing all DNAPL sources, and the chemical and physical properties of DNAPL, make achieving low-level cleanup goals with extraction and treatment technology difficult. At the Site, PCP is one of the contaminants of concern for groundwater. It is a component of the NAPL present in large portions of the Site and also has a very low action level (10 µg/L). The combination of the presence of DNAPL and a low action level makes it extremely unlikely that groundwater extraction would be effective in achieving cleanup levels in a reasonable time (i.e., <50 years).

The third factor, design-related concerns, points to the agency's observation that the design of extraction and treatment systems is often inadequate to meet the goal of groundwater restoration. This could be a result of inadequate site characterization (a factor not present here) or other factors, including hydrogeologic factors.

Primarily because of the presence of DNAPL and extremely low cleanup levels for DNAPL-related compounds, it was determined that achieving action levels through the use of extraction and treatment technology is not practicable. The best strategy for improving groundwater quality over the long term is containment or removal of the sources. As a result, the development of water treatment techniques is focused on treatment of wastewater generated during other remediation activities.

5.4 Summary of Retained Alternatives

Through the screening process described above, the original list of 10 alternatives was reduced to five cleanup action alternatives and the no-action alternative. These six alternatives were carried forward for detailed analysis, as described in Section 6. As shown in Table 5-3, the five cleanup alternatives include three "containment" alternatives, one "hot spot" cleanup alternative, and one "total site cleanup" alternative. Table 5-3 also summarizes how each of these alternatives compares with the screening criteria.

6 DETAILED EVALUATION OF CLEANUP ACTION ALTERNATIVES

6.1 Evaluation Criteria

The criteria used to evaluate cleanup actions under MTCA are described in WAC 173-340-360. These criteria, when used in conjunction with the action levels established in Section 3.2, form the basis for selecting the preferred cleanup action. This section describes the criteria, defined in WAC 173-340-360, used to evaluate cleanup actions under MTCA. Ecology defines two types of criteria: threshold and "other." In addition to these evaluation criteria, MTCA regulations contain a series of "expectations" that provide additional guidance on selection of a cleanup action.

Threshold Criteria. WAC 173-340-360(2) requires that all cleanup actions conducted under MTCA meet the following threshold criteria:

- Protect human health and the environment.
- Comply with cleanup standards.
- Comply with applicable state and federal laws.
- Provide for compliance monitoring.

These threshold criteria represent minimum standards that must be achieved for a cleanup action to be acceptable.

Protectiveness of Human Health and the Environment. This criterion evaluates how the cleanup action, as a whole, achieves and maintains protection of human health and the environment. When evaluating this criterion, the following factors are considered:

- The degree to which existing risks are reduced
- The time required to reduce risk at the facility and attain cleanup standards
- On-site and off-site risks resulting from implementing the alternative
- The degree to which the alternative may perform to a level higher than the cleanup standards
- The overall improvement of environmental quality

Compliance with Cleanup Standards. WAC 173-340-700 through 760 describe methods for establishing MTCA cleanup standards for all media (groundwater, surface water, soil, air, and sediment). MTCA cleanup standards have three components: (1) cleanup levels, (2) a point of compliance, and (3) additional regulatory requirements.

- **Cleanup Levels** - As described in Section 3.2, the applicable MTCA cleanup levels for soil at the Site are the Method C cleanup levels for industrial sites (WAC 173-340-745[4]). For groundwater, Method C cleanup levels based on the protection of surface water are appropriate (WAC 173-340-720[4][d] and [6][d]).

- **Point of Compliance** - The point of compliance is the location on the site where cleanup levels must be attained.

- **Additional Requirements** - Depending on the type and location of the remedial action being implemented, additional requirements specified in applicable state and federal laws are part of the cleanup standards. These requirements are established in conjunction with the selection of the specific cleanup action.

Cleanup standards for this FS are defined in Section 3.2.

Compliance With Regulatory Requirements. WAC 173-340-710 describes types of state and federal regulations governing MTCA cleanup actions. In general, MTCA uses the same concept of applicable, or relevant and appropriate requirements (i.e., ARARs) as CERCLA. ARARs for the Site are described in Section 3.1.2.

Provision for Compliance Monitoring. MTCA regulations (WAC 173-340-410) require that all cleanup actions provide for compliance monitoring, which include the following:

- Protection monitoring is used to confirm that human health and the environment are being adequately protected during construction and operation of a cleanup action.

- Performance monitoring is used to confirm that cleanup actions have attained cleanup standards or alternate performance goals.

- Confirmational monitoring is used to establish the long-term effectiveness of a cleanup action.

Other Requirements (Balancing Criteria). In addition to the threshold requirements described above, MTCA identifies a series of other requirements to be evaluated when selecting a cleanup action. These other requirements, which are similar to the primary balancing factors in CERCLA, are used to differentiate alternatives that meet threshold requirements. The other requirements to be evaluated under MTCA are the following:

- Use of permanent solutions to the maximum extent practicable (WAC 173-340-360[4], [5], [7], and [8])

- Provide for a reasonable restoration time frame (WAC 173-340-360[6])

- Consider public concerns raised during public comment on the draft cleanup action plan (WAC 173-340-360[10] through [13])

Each of these other requirements, especially the use of permanent solutions, has several components. These are discussed in more detail below.

Use of Permanent Solutions to the Maximum Extent Practicable. The four components evaluated when determining whether a cleanup action meets this criterion are the following:

- Use of preferred cleanup technologies (WAC 173-340-360[4]). MTCA has established a cleanup technology hierarchy. In general, technologies that reuse, recycle, destroy, or detoxify hazardous substances are preferred over containment technologies and institutional controls. This section of MTCA explicitly recognizes that combining technologies may be appropriate at a particular site and that, where appropriate, lower preference technologies may be used.

- Permanent solutions (WAC 173-340-360[5]). This section of MTCA contains an extensive list of other criteria that, when evaluated together, determine whether a cleanup action is "permanent to the maximum extent practicable." MTCA defines a permanent solution as one in which cleanup standards can be met without further action. To determine whether a cleanup action is "permanent to the maximum extent practicable," the following criteria should be evaluated:

  - Overall protection of human health and the environment
  - Long-term effectiveness
  - Short-term effectiveness
  - Permanent reduction in the toxicity, mobility, or volume of hazardous substances
  - Implementability
  - Cleanup costs
  - The degree to which community concerns are addressed

Each of these criteria is further defined in MTCA (WAC 173-340-360[5][d]). As can be seen from this list, there is some redundancy with other threshold and modifying requirements. Unique to the above list are long- and short-term effectiveness, implementability, and cost. Several other criteria or requirements described in MTCA (WAC 173-340-360[5]) state a preference for permanent solutions.

How cleanup costs are evaluated is an important issue during the determination of what is practicable. MTCA regulations describe the use of disproportionate cost analysis. This type of analysis is noted in WAC 173-340-360(5)(vi):

> A cleanup action shall not be considered practicable if the incremental cost of the cleanup action is substantial and disproportionate to the incremental degree of protection it would achieve over a lower preference cleanup action.

- Groundwater restoration (WAC 173-340-360[7]). This component requires treatment to achieve cleanup levels in groundwater, including beyond the point of compliance, where such treatment is practicable. When treatment to achieve groundwater cleanup levels is not practicable, MTCA requires the following:

  - Treatment shall be used to reduce contaminant levels to the maximum extent practicable.

  - Groundwater containment shall be used to the maximum extent practicable to avoid lateral and vertical migration of the contaminants.

  - Source control measures shall be implemented to prevent or reduce additional releases to groundwater.

  - Adequate groundwater monitoring shall be conducted.

  In addition, the practicability of achieving cleanup levels through treatment must be reevaluated periodically. Finally, appropriate groundwater use restrictions must be placed until cleanup levels are achieved.

- Containment actions (WAC 173-340-360[8]). This section limits the use of containment as a primary component of a cleanup action to cases where it is not practicable to reuse, destroy, or detoxify hazardous substances to concentrations below cleanup levels. Where containment is the selected cleanup action, long-term monitoring and institutional controls are required until site cleanup levels are reached.

Restoration Time Frame (WAC 173-340-360[6]). MTCA requires that the selected cleanup action "provide for a reasonable restoration time frame." The criteria used to define "reasonable" include the following:

- Potential risks the site poses to human health and the environment
- Practicability of achieving a shorter restoration time frame
- Current and potential uses of the site, surrounding areas, and associated resources that are, or may be, affected
- Toxicity of hazardous substances at the site

MTCA also makes an allowance for sites where elevated background concentrations of hazardous substances would result in site recontamination. In those cases, the portion of the cleanup action that would achieve cleanup levels below background concentrations can be delayed until off-site sources of hazardous substances are controlled. The remedial action is considered an interim action until final cleanup levels are achieved.

Consideration of public concerns raised during public comment on the draft cleanup action plan (WAC 173-340-360[10] through [13]). This criterion is addressed once the Cleanup Action Plan (CAP) is prepared and public comment is received.

MTCA "Expectations." WAC 173-340-360(9) provides a list of other Ecology expectations for cleanup actions conducted under MTCA:

- Treatment technology would be used wherever practicable. Treatment should be emphasized at sites containing liquid wastes, areas contaminated with high concentrations of hazardous substances and highly mobile materials, discrete areas that lend themselves to treatment, or all of the above.

- At sites containing small volumes of hazardous substances, hazardous substances would either be destroyed, detoxified, or removed to below cleanup levels.
- For large volumes of materials with relatively low concentrations of wastes, engineering controls (e.g., containment) can be appropriate when treatment is impractical.
- Institutional controls (e.g., land use or deed restrictions) would supplement engineering controls.
- Cleanup actions would return usable groundwaters to their beneficial uses wherever practicable, within a reasonable restoration time frame. When restoration is not practical, measures to minimize/prevent further migration, minimize ongoing releases, and prevent exposure would be required.

- To minimize migration of hazardous substances, active measures would be taken to prevent precipitation and runoff from contacting contaminated soils and wastes.
- When hazardous substances remain on site at concentrations exceeding cleanup levels, they would be consolidated to the maximum extent practicable, where consolidation is needed to minimize direct contact or migration potential.
- For sites adjacent to surface waters, active measures would be taken to prevent or minimize releases to surface water via surface runoff and groundwater discharges. Dilution would not be the sole method to demonstrate compliance with cleanup standards.
- Cleanup actions conducted under MTCA would not result in a significantly greater overall threat to human health and the environment than other alternatives.

Ecology recognizes that there are sites where the expectations summarized above are not appropriate [WAC 173-340-360(9)].

6.2 Detailed Description of Alternatives

In this section, the five cleanup action alternatives retained after the preliminary alternative screening described in Section 5.2, plus the no-action alternative, are evaluated further to provide the detail necessary to compare them with the screening criteria (Section 6.3) and with each other (Section 7.1). The following detailed information is provided for each of the remaining alternatives:

- Detailed descriptions of the remedial actions
- Estimated construction (capital) and O & M costs
- Estimated time for implementation/restoration
- Permitting requirements
- Cleanup standards achieved and any residual risks remaining after implementing the alternative

Construction (capital) and operation and maintenance (O&M) costs for each of the alternatives are also estimated. These costs are intended to have an approximate accuracy of plus 40 percent to minus 20 percent. The O&M costs are calculated using a present value analysis based on a 30-year O&M period. Although monitoring or other activities may continue beyond 30 years for some alternatives, the net present value of O&M costs beyond 30 years is not considered significant. When calculating present value costs, a 4 percent discount rate (i.e., the difference between inflation and the cost of capital) is used. For comparison purposes, the undiscounted cost of O&M activities is also provided.

6.2.1 Alternative 1 - No Action

Detailed Cleanup Action Description. As previously described, no cleanup action of any kind would be taken in this alternative. Institutional controls, (i.e., limitations on site access, deed restrictions, and groundwater monitoring), would be included in the no-action alternative, as required by MTCA. The results of groundwater monitoring would be summarized in annual reports. Monitoring wells would be maintained (e.g., redevelop wells, repair monuments) as necessary to ensure their long-term usability.

Estimated Construction and O&M Costs. The total estimated cost for implementation of Alternative 1 is approximately $570,000. Construction costs of $75,000 are associated with abandonment of existing wells and piezometers and installation of 10 new monitoring wells. Estimated long-term O&M costs have a present value of approximately $490,000, as shown in Table 6-1. The undiscounted O&M costs for this alternative would be $820,000.

Estimated Time for Implementation/Restoration Time Frame. Monitoring well abandonment and installation of new wells could be accomplished in two to six months. Cleanup levels would most likely never be achieved with this alternative.

Permitting Requirements. No permits would be required to implement this alternative.

Cleanup Standards Achieved and Residual Risk. This alternative would not achieve compliance with the cleanup standards for soil or groundwater. There would be no reduction in risk to human health or the environment beyond that already provided by the existing site access restrictions and fencing.

6.2.2 Alternative 2 - Site-wide Cap, Product Recovery, Groundwater Monitoring

Detailed Cleanup Action Description. This cleanup action would have three main components: (1) capping areas where fill and unsaturated sand exceed soil action levels, (2) passive recovery of DNAPL in the blow pit area, and (3) groundwater monitoring. Each component is described below.

Before cap construction, the existing site surface would be prepared. Most preparation would involve leveling the building foundation, the associated tank pads, and the former Mill E foundation to the extent necessary to construct the cap. Demolition debris would be decontaminated as necessary to remove residual contamination, then disposed of off site in an appropriate landfill or recycled, as appropriate. Existing monitoring wells and piezometers would be abandoned and 10 new monitoring wells installed.

After surface preparation activities were complete, the cap would be installed in the area shown in Figure 6-1. This area is approximately 325,000 sf, or 7.5 acres, in size. To achieve the grades necessary for the cap to drain properly, approximately 3,000 cy of clean fill would be imported, and existing surface soil would be regraded. Because the Site will be used for industrial purposes in the future, a modified asphalt cap with low permeability would be specified. The cap would consist of the following three layers (shown in Figure 6-2): (1) a 4-inch asphalt base course overlain by, (2) a special low-permeability geomembrane such as Petromat®, and (3) covered with a final 2-inch asphalt wearing course. The cap would be graded to promote storm water runoff and to prevent ponding. Storm water runoff would be directed off the cap and allowed to infiltrate into uncontaminated areas.

Product recovery would consist of passive recovery of DNAPL in and around the blow pit area (see Figure 6-1). As noted earlier, LNAPL recovery is not considered practical due to its thin layer (i.e., 1 to 2 inches). DNAPL recovery would be accomplished by periodic (e.g., quarterly) bailing from several newly installed recovery wells. For purposes of this FS, it is assumed that four product recovery wells would be installed. Well locations would be based on the results of a limited soil investigation in the blow pit area, which would attempt to locate pockets or pools of DNAPL. Recovered product would be accumulated on site in drums or tanks, then shipped to an off-site, permitted incineration facility on a periodic basis. Removing or reducing the amount of DNAPL in this area would reduce its potential long-term migration downward into the lower aquifer.

Groundwater monitoring would be conducted in 10 monitoring wells: six (one upgradient and five downgradient) in the upper sand aquifer and four wells (one upgradient and three downgradient) in the lower sand aquifer. Monitoring would be semiannual for the first five years and annual thereafter. The results of groundwater monitoring would be summarized in annual reports. Also, monitoring wells would be maintained (e.g., redevelop wells, repair monuments) as necessary to ensure their long-term usability.

Restrictive covenants would be placed on the Site deed to restrict certain activities and development of areas covered by the cap, in accordance with WAC 173-340-440. Use of groundwater at the Site would also be restricted.

Estimated Construction and O&M Costs. The total estimated cost (present value) for implementing Alternative 2 would be approximately $1,920,000. The estimated construction cost for Alternative 2 is $1,070,000, as shown in Table 6-2.

The estimated present value of O&M costs for Alternative 2 is approximately $847,000, as shown in Table 6-2. Assumptions not explicitly stated on the table include the following:

- Product recovery will occur quarterly, with the recovered product transported off site for treatment.

- The asphalt cap would be resurfaced every 15 years to maintain its integrity.

The undiscounted O&M costs for this alternative would be $1,530,000.

Estimated Time for Implementation/Restoration Time Frame. Once design of the cleanup action starts, it is estimated that 12 to 18 months would be required to have all components of Alternative 2 constructed and fully operational. Protection of human health from exposure to soil would be achieved immediately on completion of the cap. It is not anticipated that natural attenuation would reduce groundwater concentrations in either the upper or lower aquifer to below action levels in all but the very long term (i.e., > 100 years).

Permitting Requirements. Permits required to implement this alternative would include a shoreline permit and possibly a grading permit from the City of Everett. If this action were selected and implemented under a decree or order with Ecology, permits could be waived pursuant to the 1994 statutory amendments to MTCA as long as the substantive requirements of the permits are met. If the action were conducted pursuant to a consent decree, solid waste from the dangerous waste regulations of chapter 173-303 WAC that would otherwise be designated as a state-only dangerous waste might be exempted by Ecology. Ecology's implementation of the "area of contamination" policy or a permit waiver would allow management of dangerous waste (recovered product) on site without a storage permit.

If the recovered product were a regulated dangerous hazardous waste (i.e., F032, F034, F035), management of the product would have to be conducted in accordance with dangerous waste generator requirements (e.g., less than 90-day storage).

Cleanup Standards Achieved and Residual Risk. Construction of the site-wide cap would achieve compliance with the soil cleanup standards and effectively eliminate the most significant exposure pathway for humans (i.e., direct contact and ingestion), greatly reducing the overall risk to human health. Through implementation of the O&M portion of this alternative, the cap would be maintained, providing long-term risk reduction.

This alternative would not achieve compliance with the groundwater cleanup levels at the conditional point of compliance (i.e., perimeter monitoring wells), representing a potential human health risk from consumption of organisms (e.g., fish, shellfish) impacted by contaminated groundwater discharging to the river. This alternative would not control or reduce this potential risk except in the shallow aquifer by reducing infiltration. It should be noted that in the RI it was demonstrated that as groundwater discharges to the river, there is a 650:1 mixing ratio within 1 foot of the bulkhead, greatly reducing the actual exposure point concentrations and the potential risk.

Potential environmental risks relate to exposure of aquatic organisms to groundwater discharges exceeding cleanup levels from either the upper or lower aquifer. On the basis of sediment and surface water sampling results, it would not appear that a significant risk exists from this pathway. Nonetheless, this alternative would not achieve significant reductions in potential environmental risk. Because the sources of groundwater contamination have not been removed or contained, it is not expected that groundwater cleanup standards would be achieved in the long term. The combination of product removal, capping, and natural attenuation could, however, eventually reduce contaminant levels to below action levels in the very long term.

On the basis of the results of the interim product recovery effort described in Section 2.6, DNAPL recovery from the blow pit area would be expected to have a beneficial effect on groundwater quality only over the long-term and would also be expected to result in reduced downward migration of contaminants to the lower aquifer.

6.2.3 Alternative 3 - Site-wide Cap, Product Recovery, Vertical Containment of Hot Spot Soil, Groundwater Monitoring

Detailed Cleanup Action Description. Alternative 3 would include all of the actions of Alternative 2 (site-wide cap, product recovery, groundwater monitoring) and would add vertical containment around saturated hot spot soil. With some minor modifications noted below, the capping, product recovery, and groundwater monitoring components of this alternative would be as described in Section 6.2.2.

Figure 6-3 shows the major components of Alternative 3, including the proposed location of vertical containment. Because it would be important to minimize infiltration of rainfall inside the containment area, the site-wide cap proposed in Alternative 2 would be extended slightly in the area north of former Mill E and west of monitoring well HC-09 to cover the vertical containment cell. This addition would add approximately 15,000 sf to the cap area, for a total area of 330,000 sf (7.6 acres).

Vertical containment around the saturated hot spot soil would consist of. a low-permeability barrier wall (e.g., steel sheet piling with sealable joints or equivalent). Based on the estimated extent of the saturated hot spot soil shown in Figure 3-3, approximately 1,600 linear feet of low-permeability sheet piling would be required to surround the hot spot area. Based on existing stratigraphic data, the average depth of the sheet piling is estimated to be approximately 10 feet. This depth would allow sheet piling to be installed approximately 2 feet into the silt aquitard, providing a good seal. The top of the sheet piling would be driven just below the existing grade and would be covered by the cap.

Additional exploratory soil borings may be required before installation to better define the extent of NAPL in certain areas and the depth to the silt layer. The sheet piling would be installed after site preparation and demolition are complete and before construction of the low-permeability cap.

Estimated Construction and O&M Costs. The total estimated cost (present value) for implementing Alternative 3 is approximately $2,460,000. Estimated construction costs for Alternative 3 would be approximately $1,610,000, as shown in Table 6-3. An assumption not explicitly stated on the table is that all demolition debris can be disposed of in a solid waste or demolition debris landfill.

Estimated O&M costs (present value) for Alternative 3 are approximately $847,000, as shown in Table 6-3. Assumptions not explicitly stated on the table include the following:

- Product recovery will occur quarterly, with the recovered product transported off site for treatment.

- The asphalt cap would be resurfaced every 15 years to maintain its integrity.

Undiscounted O&M costs are estimated at $1,530,000.

Estimated Time for Implementation/Restoration Time Frame. Once design for the cleanup action starts, it is estimated that 12 to 18 months would be required to have all components of Alternative 3 constructed and fully operational, including the necessary permits. Protection of human health from exposure to soil would be achieved immediately on completion of the cap.

Because this alternative would contain groundwater contamination sources in the upper aquifer, it would significantly reduce contaminant concentrations in groundwater discharges to the river through the upper aquifer. Assuming all saturated hot spot areas are within the containment cell, the sources of groundwater contamination would be contained immediately on completion of the sheet pile wall. With the sources cut off, contaminant concentrations in groundwater discharges could be expected to begin declining within several years, and to continue to decline thereafter.

With respect to the lower aquifer, the combination of product recovery, capping, and vertical containment will reduce the downward migration of contaminants from the upper aquifer. It appears that downward migration increases during the wet months, when water levels in the upper aquifer are high and the downward vertical hydraulic gradient is also high. Once the cap and vertical containment are constructed, the water levels in the upper and lower aquifers will tend to equilibrate. This will reduce the downward vertical gradient and related contaminant migration. Water levels inside the vertical containment would be monitored periodically to evaluate vertical gradients.

Permitting Requirements. Permits required to implement this alternative would include a shoreline permit and possibly a grading permit. If this action were selected and implemented under a decree or order with Ecology, these permits could be waived pursuant to the 1994 statutory amendments to MTCA as long as the substantive requirements of the permits are met. If the action were conducted pursuant to a consent decree, solid waste that would otherwise be designated as a state-only dangerous waste might be exempted from the dangerous waste regulations of chapter 173-303 WAC by Ecology. Ecology's implementation of the "area of contamination" policy or a permit waiver would allow management of dangerous waste (recovered product) on site without a storage permit.

If the recovered product or groundwater were a regulated dangerous waste, management of the product would have to be conducted in accordance with dangerous generator requirements (e.g., less than 90-day storage).

Cleanup Standards Achieved and Residual Risk. Construction of the site-wide cap would achieve compliance with the soil cleanup standards and effectively eliminate the most significant exposure pathway for humans (i.e., direct contact and ingestion), greatly reducing the overall risk to human health. Through implementation of the O&M portion of this alternative, the cap would be maintained, providing long-term risk reduction.

This alternative's addition of a vertical barrier wall to the capping and product recovery of Alternative 2 would effectively contain the major sources of contamination in the upper aquifer and reduce downward migration of contaminants from the upper to the lower aquifer. As a result, this alternative could achieve compliance with the groundwater cleanup levels at the conditional point of compliance (i.e., perimeter monitoring wells) for most contaminants over the long term. By significantly reducing the flux of contaminants from the upper aquifer to the river, and to a lesser extent, to the lower aquifer, this alternative would significantly reduce potential risks to human health and the environment.

6.2.4 Alternative 4 - Soil Consolidation, Cap, Product Recovery, Vertical Containment, Groundwater Monitoring

Detailed Cleanup Action Description. Alternative 4 would include all of the actions of Alternative 3 (asphalt cap, vertical containment, product recovery, groundwater monitoring) and would add excavation and on-site consolidation of soil exceeding cleanup levels located outside the vertical containment cell. With the modifications noted below, the capping, vertical containment, product recovery, and groundwater monitoring components of this alternative would be similar to those described in Sections 6.2.2 and 6.2.3.

A series of site preparation activities would take place first. Site control and decontamination facilities would be set up. Access controls, such as temporary barricades or fencing, would be implemented. Decontamination facilities such as truck and equipment washes, decontamination residuals management facilities, and personnel decontamination stations would be built.

Figure 6-4 shows the major components of Alternative 4, including the proposed areas that would be excavated and the alignment of the vertical containment. Approximately 13,800 cy of unsaturated soil and 400 cy of saturated soil that exceed cleanup levels would be excavated and consolidated inside the vertical containment cell. Excavated fill would be screened to remove oversize (e.g., > 1-inch) material, resulting in an approximately 50 percent reduction in volume of the soil to be consolidated. The oversize material would be washed with water and used for clean backfill in the excavations.

Unsaturated soil would be excavated to the approximate mean low water levels while saturated soils would be excavated down to, or slightly into, the silt layer. Note that in the area where saturated soil would be excavated, remedial investigation data indicate that the silt layer is thick enough to allow for excavation using conventional measures, without endangering the integrity of the silt layer.

The excavations would be backfilled to approximately the existing grade, with clean imported fill including the screened and washed oversize material. The maximum elevation of the area inside the vertical containment, including the cap, would be approximately 2 feet above the existing ground surface.

Once the excavated soil is consolidated, an approximately 4.4-acre asphalt cap will be constructed over the containment cell, as shown in Figures 6-4 and 6-5. The areas that are excavated and no longer contain soil exceeding cleanup levels will not be capped.

Estimated Construction and O&M Costs. The total estimated cost (present value) for implementing Alternative 4 is approximately $2,660,000. Estimated construction costs for Alternative 4 would be approximately $1,910,000, as shown in Table 6-4. Assumptions not explicitly stated on the table include the following:

- All demolition debris can be disposed of in a solid waste or demolition debris landfill.
- Soil that may be a listed RCRA waste can be excavated and consolidated on site without having to be treated or meet BDAT standards before placement.
- The screened and washed oversize material will not be a regulated material and can be used as backfill on-site.
- Excavation activities will occur in the summer to minimize the amount of dewatering and run-on/run-off water that must be managed.

Estimated O&M costs (present value) for Alternative 4 are approximately $750,000, as shown in Table 6-4. Assumptions not explicitly stated on the table include the following:

- Groundwater monitoring would be biannual for the first five years, then annual thereafter.
- The asphalt cap would be resurfaced every 15 years to maintain its integrity.

Undiscounted O&M costs are estimated at $1,300,000.

Estimated Time for Implementation/Restoration Time Frame. Once the design of the cleanup action starts, it is estimated that 12 to 18 months would be required to have all components of Alternative 4 constructed and fully operational, including the necessary permits. Protection of human health from exposure to soil would be achieved immediately after the soil was consolidated and capped.

Alternative 4 will result in the same reductions in contaminant concentrations in groundwater as described for Alternative 3.

Permitting Requirements. Permits required to implement this alternative would be the same as described for Alternative 3.

Cleanup Standards Achieved and Residual Risk. Consolidation of contaminated soil to an area within the vertical containment and construction of a cap over the containment cell would achieve compliance with the soil cleanup standards and effectively eliminate the most significant exposure pathway for humans (i.e., direct contact and ingestion), greatly reducing the overall risk to human health. Through implementation of the O&M portion of this alternative, the cap would be maintained, providing long-term risk reduction. This alternative would result in slightly lower residual risk to human health and the environment than Alternative 3.

6.2.5 Alternative 6 - Hot Spot Soil Removal, Stabilize Excavated Soil, Site-wide Cap, Groundwater Monitoring

Detailed Cleanup Action Description. In this alternative, the hot spot soil defined in Section 3.3 would be excavated and stabilized. In addition, this alternative would include the asphalt cap and groundwater monitoring components of Alternatives 2 and 3.

Figure 6-6 shows the approximate areas that would be excavated and treated. Approximately 7,880 cy of unsaturated hot spot soil (i.e., 5,000 cy of fill and 2,880 cy of unsaturated sand) and 12,450 cy of saturated hot spot soil would be removed and treated. The 5,000 cy of fill would be screened to remove oversize material (i.e., >1-inch), resulting in approximately 2,500 cy of soil requiring treatment. The total quantity of soil to be treated in this alternative is approximately 18,000 cy. During the excavation process, the NAPL (both floating and sinking) and contaminated groundwater in the excavation area would be removed and treated.

As previously noted, excavation of the hot spot soil would be complicated by several factors. These include the relative thinness of the silt in the blow pit area, a partially confined lower sand aquifer, and NAPL present across large portions of the Site. During the excavation, it would be very important not to disturb the silt aquitard beneath the upper sand. Because this silt layer is relatively thin in some areas to be excavated (e.g., the blow pit area), and the lower sand aquifer is partially confined and places an upward pressure on the overlying silt layer, care would have to be taken during excavation to prevent the silt from rupturing because of upward pressure from the lower aquifer.

A potential for rupturing would exist when the soil and water above an area with a thin silt layer were removed during excavation. On the basis of a geotechnical review of the area, it appears that most of the Site east of the building (approximately 80,000 to 100,000 sf) has a potential for heaving. The following detailed discussion addresses the technical feasibility of this component of the alternative, and is also pertinent to the technical feasibility of Alternative 7.

Geotechnical/Engineering Considerations. The thin silt layer would have to be stabilized so that excavation could proceed. Three main methods of stabilizing the silt have been identified: (1) jet grouting the silt layer to provide additional structural strength and weight, (2) excavating the contaminated soil without dewatering the upper sand aquifer, and (3) pumping the lower sand aquifer during excavation to reduce the head to a level that would not rupture the silt layer.

The first option would involve placing a 2- to 4-foot-thick layer of grout beneath the silt layer by using jet grouting technology. With the silt layer stabilized, the upper aquifer could be dewatered and the soil excavated down to the silt layer without rupturing the silt. Because jet grouting over the area at risk would require drilling thousands of holes through the silt, increasing the potential for downward contaminant migration, this option is not considered practical. Furthermore, jet grouting costs at least $100 per sf; grouting this large an area would cost at least $8 to $10 million, possibly more. When compared with total remedial action costs for this and other alternatives, this technology clearly is not cost-effective in this application.

The second option is to perform the excavation without dewatering the upper aquifer. A portion of the impacted area would be surrounded by sheet piling, then excavated without dewatering. The water left in the excavation would load the silt layer and overcome the upward pressure of the lower aquifer. The contaminated water would have to be treated before the excavation could be backfilled and the stabilized soil placed back in the excavation above the water table. To accomplish this, the contaminated water would be pumped out, treated in an on-site treatment system, and discharged back into the excavation to keep the required pressure on the silt. The water would continue to be recirculated until it was clean enough to allow backfilling. This whole process would be repeated in several cells until the entire hot spot area had been treated.

This option has several significant disadvantages. First, it would be difficult to excavate the soil below the water table because the bottom of the excavation would not be visible and it would not be easy to determine if all contaminated soil had been removed. This method also presents an increased risk of penetrating the silt with the excavation equipment. If the silt layer was penetrated, it would difficult to detect because of the water in the excavation and even if a penetration was detected, it would be extremely difficult to repair or plug the hole without completely dewatering the excavation. A possible solution would be to use a hydraulic dredge to "vacuum" the sand and DNAPL from the bottom of the excavation, although the effectiveness of this approach is uncertain. Second, it would be difficult to backfill the excavation when it is full of water and achieve the required soil compaction needed to support the stabilized soil and the cap. Third, in some areas, water would have to be added to the excavation to develop enough pressure to keep the silt in place, increasing the amount of water requiring treatment.

Finally, it is not known how long contaminated water in the excavation would have to be recirculated and treated until it was clean enough to backfill the excavation. The amount of recirculation required would, in large part, determine the size (and cost) of the treatment system. For example, if two or three pore volumes would provide adequate treatment, a treatment system flow rate ranging from 75 to 100 gpm would be required. If five, ten, or more pore volumes were required to provide adequate treatment, the treatment system flow rate of 200 to 300+ gpm would be required, so treatment costs would be high.

The third option, pumping the lower aquifer, would allow excavation of soil above the silt to proceed by using standard construction (e.g., sheet piling, dewatering, and excavation) techniques. This option also has several disadvantages:

- Installation of numerous wells into the lower sand aquifer
- Pumping these wells at high rates to lower pressure in the lower aquifer to a level where it is not a threat to the silt aquitard during excavation
- Potentially treating extracted groundwater before discharge
- The potential to penetrate the thin silt with the excavation equipment. If a penetration occurred, residual contaminants remaining in the excavation could migrate into the lower aquifer. If the penetration was detected, it could possibly be repaired by placing a betonite or grout "plug" over the penetration; the efficacy of this type of repair is uncertain. There is also the risk that the

penetration would not be detected and the excavation backfilled with the penetration open.

Flow rates required to lower the pressure in a roughly 20,000-sf excavation area are estimated to range from 200 to 300 gpm. Installing the required wells and pumping them at this rate would be costly, but should not be prohibitively expensive or technically difficult to implement. However, a large and costly treatment system would be needed to treat this amount of groundwater 24 hours a day for 30 to 50 days (minimum time estimated for excavation and treatment). If the water were extracted from the upper portion of the lower sand aquifer, it would probably require treatment before discharge. If, however, the water were extracted from near the base of the aquifer, where contaminants have not been detected, it might be possible to discharge the water without treatment, resulting in substantial cost savings.

Irrespective of the selected option, excavation of contaminated soil in the blow pit area would be difficult and costly. To decide between options, a detailed engineering analysis was conducted. Given that jet grouting would be prohibitively expensive and that excavation without dewatering poses significant implementability problems, pumping the lower aquifer would appear to be the preferred approach. If groundwater extracted from the lower aquifer could be discharged or reinfiltrated directly without treatment, this option may not be prohibitively expensive. If treatment were required, however, costs would increase substantially and it is not clear whether any of the options would be cost-effective.

For purposes of this FS, including cost estimating, it was assumed that excavation would proceed by pumping the lower aquifer and that the extracted groundwater could be discharged directly to the Snohomish River without treatment.

In those areas where rupture of the silt layer is not likely, soil excavation would be accomplished by surrounding the area with sheet piling, dewatering the upper sand aquifer inside the enclosure, then excavating the soil down to the silt. Because the sheet piling would be installed to an average depth of 20 feet to provide the necessary lateral strength, it would fully penetrate the silt in most places. Removing the sheet piling could create new migration pathways into the lower aquifer. To prevent this, all sheet piling installed during excavation would be left in place.

Contaminated groundwater removed from the excavation would be treated in an on-site system. The system would be designed to treat 75 to 100 gpm and would consist of the components discussed in Section 5.3.

Excavated soil would be treated by stabilization, shown in treatability studies to be effective at reducing contaminant mobility in most cases to below action levels. The primary treatment objective for saturated hot spot soil would be to immobilize residual NAPL; stabilization should be effective in achieving this objective. As treatment proceeded, treated soil would be stockpiled on site until the entire cell was completely excavated and the excavation was backfilled with clean fill to the high water table in the upper aquifer. The stabilized soil would then be backfilled into the cell. Excess treated soil that did not fit back into the excavation would be spread uniformly over the surface, inside the sheet piling. This would raise the ground surface inside the sheet piling approximately 4 feet above existing grade. After excavation and soil treatment were complete and all areas backfilled, the entire Site would be capped in the manner described for Alternative 2. Groundwater would also be monitored, as described for Alternative 3.

Process waste water generated by the stabilization process, which is expected to be limited, would be treated on site in the same system used for water collected during dewatering.

Estimated Construction and O&M Costs. The total estimated cost (present value) for implementing Alternative 6 is approximately $9,340,000. Estimated construction costs for Alternative 6 are approximately $8,570,000, as shown in Table 6-5. Assumptions not explicitly stated on the table, or described above, include the following:

- All demolition debris could be disposed of in a solid waste or demolition debris landfill.
- Approximately 3,000 linear feet of regular (i.e., not low-permeability) sheet piling would be used to divide the excavation into approximately five or six cells for excavation. Because the excavation would advance right up to the sheet piling, it would be installed to an average depth of 20 feet to provide required lateral strength. The estimated cost assumes that this sheet piling would be left in place.
- One million gallons of water from the shallow aquifer would be treated during excavation dewatering. This assumption is based on treatment of one pore volume from inside the excavation.
- The $200/cy cost of stabilization would include mobilization/demobilization, equipment decontamination, and the cost to treat excess process water.
- Stabilizing the silt in the blow pit area during excavation would include installation of extraction wells into the lower aquifer. Extracted lower aquifer groundwater would be discharged directly to the river without treatment.

Estimated O&M costs (present value) for Alternative 6 are $772,000, as shown in Table 6-5. Undiscounted O&M costs are estimated to be $1,440,000.

Estimated Time for Implementation/Restoration Time Frame. From the time design for the cleanup action starts, it would take approximately two years to have all components of Alternative 6 constructed and fully operational. Specifically, it would take approximately 9 to 12 months to design, prepare plans and specifications, and select contractors and vendors. Because the actual excavation should be performed at low water, if possible, excavation and treatment would be scheduled to begin in July or August. Once excavation starts, it would take approximately two to three months (assuming a 400 cy/day processing rate) to complete soil treatment and another two months to complete the cap.

Because this alternative would treat and contain groundwater contamination sources, it would significantly reduce contaminant concentrations in groundwater discharges to the river via the upper aquifer. Assuming that all hot spot areas had been excavated and treated, the sources of groundwater contamination would be removed. With the sources eliminated, contaminant concentrations in groundwater discharges could be expected to begin declining within several years, and to continue to decline thereafter.

Permitting Requirements. The permits required to implement this alternative would be the same as described for Alternative 3. In addition, before placement of the treated soil back into the excavation, it may be necessary for the Department of Ecology to make a determination that the soil no longer "contained" listed dangerous waste.

Treated shallow groundwater and process water, along with untreated groundwater from the lower aquifer, would be discharged to the Snohomish River under an NPDES permit.

Cleanup Standards Achieved and Residual Risk. Excavation and stabilization of hot spot soil, followed by construction of a site-wide cap, would achieve compliance with the soil cleanup standards and effectively eliminate the most significant exposure pathway for humans (i.e., direct contact and ingestion), greatly reducing the overall risk to human health. Through implementation of the O&M portion of this alternative, the cap would be maintained, providing long-term risk reduction.

Treatment of the saturated hot spot soil, in conjunction with the sheet piling that would be left in place, would effectively immobilize and contain the major sources of contamination in the upper aquifer and reduce downward migration of contaminants from the upper to the lower aquifer. As a result, this alternative could achieve compliance with the groundwater cleanup levels at the conditional point of compliance (i.e., perimeter monitoring wells) for most contaminants over the long term. By significantly reducing the flux of contaminants from the upper aquifer to the river and to the lower aquifer, this alternative would effectively control potential risks to human health and the environment.

6.2.6 Alternative 7 - Excavate and Stabilize All Impacted Soil, Groundwater Monitoring

Detailed Cleanup Action Description. This alternative would be similar to Alternative 6 in that impacted soil would be excavated, the soil stabilized on site, then placed back into the excavation. Soil removed would include all unsaturated and saturated fill and upper sand unit soil exceeding action levels identified in Section 3.2. Figure 6-7 shows the areas to be excavated in Alternative 7. The same problems associated with heaving of the silt aquitard during excavation, discussed for Alternative 6, would be of concern here and would be addressed in the same manner. The Site would not be capped in Alternative 7 because all soil exceeding action levels would be treated.

Groundwater would be monitored in the same manner described for Alternative 6.

The total volume of soil requiring excavation is approximately 43,900 cy (i.e., 14,900 cy of fill, 16,550 cy of unsaturated sand, and 12,450 cy of saturated sand). Screening the fill would remove approximately 7,450 cy of oversized material from the total requiring solidification and stabilization. The total volume of soil to be stabilized would be approximately 36,450 cy. Wastewater generated during soil dewatering would be treated on site and discharged to the river.

Estimated Construction and O&M Costs. The total estimated cost (present value) to implement Alternative 7 is approximately $13,620,000. Estimated construction costs for Alternative 7 are approximately $13,120,000, as shown in Table 6-6. Assumptions not explicitly stated on the table include the following:

- Approximately 3,000 linear feet of regular (i.e., not low-permeability) sheet piling would be used to divide the excavation into approximately five or six cells for excavation. Because the excavation would advance right up to the sheet piling, it would be installed to an average depth of 20 feet to provide required lateral strength. The estimated cost assumes that this sheet piling would be left in place.
- The $200/cy cost of stabilization includes mobilization/demobilization, equipment decontamination, and the cost to treat process water.
- One million gallons of water would be treated during excavation dewatering. This assumption is based on treatment of approximately one pore volume from inside the sheet piling.
- Stabilizing the silt in the blow pit area during excavation would include installation of extraction wells into the lower aquifer. Extracted lower aquifer groundwater would be discharged directly to the river without treatment.

Estimated O&M costs (present value) for Alternative 7 are $495,000, as shown in Table 6-6. Undiscounted O&M costs are estimated to be $820,000.

Estimated Time for Implementation/Restoration Time Frame. From the time design of the cleanup action starts, it would take approximately two years to have all components of Alternative 7 constructed and fully operational. Specifically, it would take approximately 9 to 12 months to design, prepare plans and specifications, and select contractors and vendors. Because the actual excavation should be performed at low water, if possible, excavation and treatment would be scheduled to begin in July or

August. Once excavation starts, it would take approximately four to six months (assuming a 400 cy/day processing rate) to complete soil treatment.

Because this alternative would treat and contain groundwater contamination sources, it would significantly reduce contaminant concentrations in groundwater discharges to the river via the upper aquifer. With the sources eliminated, contaminant concentrations in groundwater discharges could be expected to begin declining within several years, and continue to decline thereafter.

Permitting Requirements. Permits to implement this alternative would be the same as for Alternative 6.

Cleanup Standards Achieved and Residual Risk. Excavation and stabilization of soil exceeding action levels would achieve compliance with the soil cleanup standards and effectively eliminate the most significant exposure pathway for humans (i.e., direct contact and ingestion), nearly eliminating risks to human health.

Treatment of the soil exceeding action levels would effectively immobilize the major source of contamination in the upper aquifer and reduce downward migration of contaminants from the upper aquifer to the lower aquifer. As a result, this alternative could achieve compliance with the groundwater cleanup levels at the conditional point of compliance (i.e., perimeter monitoring wells) for most contaminants over the long term. By significantly reducing the flux of contaminants from the upper aquifer to the river and to the lower aquifer, this alternative would effectively control the potential risk to human health and the environment.

6.3 Detailed Analysis of Alternatives

In this section, the no-action and the other alternatives are compared against the MTCA evaluation criteria defined in Section 6.1.1, with the exception of "consideration of public concerns." Public concerns will be addressed during the public comment period for this FS and the CAP. The discussions focus strictly on comparing individual alternatives against the criteria. Some evaluation criteria components are more relevant to the comparison of one alternative to others. For example, evaluation of "practicable" in the "use of permanent solutions to the maximum extent practicable" criterion involves a disproportionate cost analysis between alternatives. These inter-alternative comparisons are presented in Section 7.

6.3.1 Alternative 1 - No Action

Protection of Human Health and the Environment. This alternative does little to reduce risks to human health or the environment beyond the existing access controls and fencing. All contaminants would be left in place and no exposure pathways would be eliminated. Because no soil or groundwater is handled in this alternative, there would be no increases in short-term risks to human health or the environment as a result of implementation.

Compliance With Cleanup Standards.[1] This alternative would not achieve compliance with cleanup standards. All of the contaminants at the Site would remain in place and no containment technologies would be used to prevent exposure to contaminated soil. It is unlikely that groundwater action levels would ever be achieved at the point of compliance under this alternative.

Compliance with ARARs. This alternative would not comply with the ARARs identified in Section 3.1.

Provides for Compliance Monitoring. Although this alternative would not include any cleanup action at the Site, it would provide for long-term groundwater monitoring to evaluate discharges to the river.

Use of Permanent Solutions to the Maximum Extent Practicable. This alternative would not make use of MTCA's preferred technologies (e.g., reuse, recycling, destruction, and detoxification). This alternative would not be permanent because cleanup standards would not be met, and the toxicity, volume, and mobility of the contaminants would not be reduced.

Provides for Reasonable Restoration Time Frame. Because this alternative would not result in any reduction in risks to human health or the environment or achieve cleanup levels, site restoration would never be achieved.

6.3.2 Alternative 2 - Site-wide Cap, Product Recovery, Groundwater Monitoring

Protection of Human Health and the Environment. Because the cap would eliminate the direct exposure and ingestion pathways, Alternative 2 would substantially reduce the risks the Site poses to human health. Institutional controls, including deed restrictions, would also increase this alternative's protectiveness of human health. The alternative would not actively address groundwater discharges; therefore, it would not provide for a significant reduction in environmental risk.

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1 As a reminder, cleanup standards consist of cleanup levels, a point of compliance, and other regulatory requirements (WAC 173-340-700). For purposes of this FS, the cleanup levels are those defined as action levels in Section 3.2. The point of compliance for soil is established on an alternative-by-alternative basis. For groundwater, a conditional point of compliance is assumed, i.e., at the perimeter monitoring wells located adjacent to the river. The "other" regulatory requirements are discussed as they apply to individual alternatives.

Implementation of this alternative should not present any significant short-term risk either to human health or the environment. Regrading the surface soil may present a potential risk for fugitive dust emissions. Through use of engineering controls and dust suppressants, these risks could be minimized.

Compliance With Cleanup Standards. Although most of the contaminants currently present at the Site would remain after the alternative is implemented, this alternative would achieve compliance with cleanup standards for soil through the use of containment technologies (WAC 173-340-740[6][d]).

Compliance with the groundwater cleanup standards would not be achieved, except possibly in the very long term (i.e., > 100 years).

Compliance with ARARs. This alternative would not comply with most of the significant ARARs identified in Section 3.1.

Provides for Compliance Monitoring. This alternative would provide for long-term groundwater monitoring to evaluate long-term effectiveness on discharges to the river. Air monitoring would be performed during construction to ensure that short-term releases of contaminants would be minimized. Performance monitoring of the cap would be conducted to ensure that it was functioning as designed.

Use of Permanent Solutions to the Maximum Extent Practicable. This alternative would make little use of MTCA's preferred technologies (e.g., reuse, destruction, and detoxification). The only exception would be the recovery and incineration of DNAPL. The primary technology used in this alternative is containment, a lower technology in the MTCA hierarchy.

With respect to soil, this alternative would be permanent because cleanup standards would be met through containment, but the toxicity and volume of contaminants would not be significantly reduced. The mobility of contaminants in near-surface soil would be reduced by a cap. This alternative would be protective of human health in that the significant exposure routes (e.g., direct contact and ingestion) would be eliminated. With respect to groundwater, this alternative is not permanent.

Environmental risks would not be actively addressed by this alternative because groundwater contaminant discharges would not be eliminated or significantly reduced. This alternative would not remove or immobilize the sources of groundwater contamination.

Provides for Reasonable Restoration Time Frame. This alternative would reduce potential risks to human health to acceptable levels immediately on cap completion. As long as the cap was adequately maintained, protection would continue over the long term.

Groundwater would not be restored to below action levels except in the very long term (i.e., > 100 years).

6.3.3 Alternative 3 - Site-wide Cap, Product Recovery, Vertical Containment of Hot Spot Soil, Groundwater Monitoring

Protection of Human Health and the Environment. Because the cap would eliminate direct exposure and ingestion pathways, Alternative 3 would substantially reduce the potential risks to human health posed by the Site. Institutional controls, including deed restrictions, would also increase this alternative's protectiveness of human health. Installation of low-permeability sheet piling around the saturated hot spot soil would effectively control groundwater contamination sources, and therefore significantly reduce discharges of contaminated shallow groundwater to the river. The combination of the cap, product recovery, and sheet piling would reduce downward migration of contaminants to the lower aquifer. Overall, this alternative would provide for significant reductions in environmental risk over time.

Implementation of this alternative should not present any short-term risk either to human health or the environment. Although regrading the surface soil may present a potential risk for fugitive dust emissions, these risks can be minimized through use of engineering controls and dust suppressants.

Compliance With Cleanup Standards. Although most of the contaminants currently present at the Site would remain after the alternative is implemented, this alternative would achieve compliance with cleanup standards for soil through the use of containment technologies (WAC 173-340-740[6][d]).

Isolating the sources of groundwater contamination would result in significant decreases in contaminant concentrations over the short to medium term. Groundwater cleanup standards could be achieved in the long term.

Compliance with ARARs. This alternative would comply with most of the significant ARARs identified in Section 3.1. The only ARARs not achieved are some of the MTCA requirements described elsewhere in this section.

Provides for Compliance Monitoring. This alternative would provide for long-term groundwater monitoring to evaluate long-term effectiveness of the vertical barrier wall and cap on discharges to the river. Air monitoring would be performed during construction activities to ensure that short-term releases of contaminants would be minimized. Performance monitoring of the cap would be conducted to ensure that it was functioning as designed.

Use of Permanent Solutions to the Maximum Extent Practicable. The primary technology used in this alternative is containment, one of the lower technologies in the MTCA hierarchy. Using low-permeability sheet piling and a low-permeability asphalt cap would, however, provide a high level of containment. It would also provide a significantly higher level of environmental protection than a capping-only alternative.

With respect to soil, this alternative is permanent because cleanup standards would be met through containment, but the toxicity and volume of contaminants would not be significantly reduced. The mobility of contaminants contained in near-surface soil would be reduced through the use of a cap. The mobility of contaminants contained in saturated hot spot soil would be reduced through the use of vertical barriers. This alternative would be protective of human health in that the significant exposure routes (e.g., direct contact and ingestion) would be eliminated.

With respect to groundwater, this alternative might be permanent in the long term. Environmental risks would be reduced by this alternative because groundwater contaminant sources are contained and discharges to the river would decline over time.

Provides for Reasonable Restoration Time Frame. This alternative would reduce potential risks to human health to acceptable levels immediately upon cap completion. As long as the cap is adequately maintained, this protection would continue over the long term. Groundwater discharges from the upper aquifer would be significantly reduced shortly after completion of the vertical containment, and would likely be restored to below action levels in the long term. Groundwater discharges from the lower aquifer would not be restored to below action levels except in the long term (i.e., > 100 years).

6.3.4 Alternative 4 - Soil Consolidation, Cap, Product Recovery, Vertical Containment for Saturated Hot Spot Soil, Groundwater Monitoring

Protection of Human Health and the Environment. Because the cap would eliminate direct exposure and ingestion pathways, Alternative 4 would substantially reduce the potential risks to human health posed by the Site. Consolidating the contaminated soils inside the vertical containment cell and implementing institutional controls would also increase this alternative's protectiveness of human health.

Installation of low-permeability sheet piling around the saturated hot spot soil would effectively control groundwater contamination sources, and therefore significantly reduce discharges of contaminated shallow groundwater to the river. The combination of the cap, product recovery, and sheet piling would reduce downward migration of contaminants to the lower aquifer. Overall, this alternative would provide for significant reductions in environmental risk over time.

Implementation of this alternative should not present any short-term risk either to human health or the environment. Although regrading the surface soil may present a potential risk for fugitive dust emissions, these risks can be minimized through use of engineering controls and dust suppressants.

Compliance With Cleanup Standards. Although most of the contaminants currently present at the Site would remain after the alternative is implemented, this alternative would achieve compliance with cleanup standards for soil through the use of containment technologies (WAC 173-340-740[6][d]). By excavating and consolidating contaminated soil from outside the vertical containment, this alternative would minimize the areal extent of the Site that exceeds action levels.

Isolating the sources of groundwater contamination would result in significant decreases in contaminant concentrations over the short to medium term. Groundwater cleanup standards might be achieved in the long term.

Compliance with ARARs. This alternative would comply with most of the significant ARARs identified in Section 3.1. This assumes that the RCRA BDAT treatment standards would not apply to this alternative, or have been waived by Ecology. The only significant ARAR that might not be achieved is compliance with groundwater cleanup levels in the short term.

Provides for Compliance Monitoring. This alternative would provide for long-term groundwater monitoring to evaluate long-term effectiveness of the vertical barrier wall and cap on discharges to the river. Air monitoring would be performed during construction to ensure that short-term releases of contaminants would be minimized. Performance monitoring of the cap would be conducted to ensure that it was functioning as designed.

Use of Permanent Solutions to the Maximum Extent Practicable. The primary technology used in this alternative is containment, one of the lower technologies in the MTCA hierarchy. Using low-permeability sheet piling and a low-permeability asphalt cap, and consolidating soils inside the vertical containment would, however, provide a high level of containment. It would also provide a significantly higher level of environmental protection than a capping-only alternative.

With respect to soil, this alternative is permanent because cleanup standards would be met through containment, but the toxicity and volume of contaminants would not be significantly reduced. Mobility of contaminants contained in near-surface soil would be reduced through consolidation of soils inside the vertical containment and the use of a cap. Consolidation of soils from outside the vertical containment will reduce the areal extent of the Site where contaminated soil remains by approximately 40 percent, significantly improving the Site's usability for future industrial activities. The mobility of contaminants contained in saturated hot spot soil would be reduced through the use of vertical barriers.

This alternative would be protective of human health in that the significant exposure routes (e.g., direct contact and ingestion) would be eliminated.

With respect to groundwater, this alternative would most likely be permanent in the long term. Environmental risks would be reduced because groundwater contaminant sources would be contained and discharges to the river would decline over time.

Provides for Reasonable Restoration Time Frame. This alternative would reduce potential risks to human health to acceptable levels immediately on cap completion. As long as the cap was adequately maintained, this protection would continue over the long term. Groundwater discharges from the upper aquifer would be significantly reduced on completion of the vertical containment, and would likely be restored to below action levels in the long term. Groundwater discharges from the lower aquifer would not be restored to below action levels except in the long term (i.e., > 100 years).

6.3.5 Alternative 6 - Hot Spot Soil Excavation, Stabilize Excavated Soil, Site-wide Cap, Groundwater Monitoring

Protection of Human Health and the Environment. Because hot spot soil would be excavated and treated, and remaining soil exceeding action levels capped (thereby eliminating the direct exposure and ingestion pathways), Alternative 6 would substantially reduce the risks the Site poses to human health. Institutional controls, including deed restrictions, would also increase this alternative's protectiveness of human health. Treating the saturated hot spot soil and leaving the sheet piling around the excavations would effectively immobilize the major source of groundwater contamination and, therefore, would provide for a significant reduction in environmental risk over time. Short-term environmental risks due to groundwater discharges would not be substantially reduced.

Because this alternative would involve excavation, handling, and treatment of highly contaminated soil, implementing this alternative may present some short-term risk to human health or the environment. Large excavations would be open almost continuously for 40 to 60 days or longer, and fugitive emissions of VOCs would have to be addressed during implementation.

Compliance With Cleanup Standards. This alternative would achieve compliance with soil cleanup standards using a combination of treatment and containment. Groundwater cleanup standards may be complied with in the upper aquifer in the long term, since the sources will have been treated or contained. Compliance with cleanup standards in the lower aquifer may only be achieved in the long term (i.e., > 100 years).

Compliance with ARARs. This alternative would comply with most of the major ARARs listed in Section 3.1. This assumes that the RCRA BDAT treatment standards would not apply to this alternative, or have been waived by Ecology. The only significant

ARAR that might not be achieved is compliance with groundwater cleanup standards in the short term.

Provides for Compliance Monitoring. This alternative would provide for long-term groundwater monitoring to evaluate the long-term effectiveness of source control on discharges to the river. Air would be monitored during construction to evaluate short-term releases of contaminants and to determine if controls would be effective. Samples of treated soil would be collected to determine whether the solidification and stabilization process was achieving performance standards. Performance monitoring of the cap would be conducted to ensure that it was functioning as designed.

Use of Permanent Solutions to the Maximum Extent Practicable. With respect to soil, this alternative uses MTCA's preferred technologies (reuse, destruction, and detoxification). Approximately 20,000 cy of contaminated soil would be treated by using solidification and stabilization. Although approximately 24,000 cy of low to moderately contaminated soil would remain on site, this alternative is considered permanent for soil. The mobility of contaminants contained in the remaining soil is reduced through the use of a cap and this alternative is protective of human health and the environment.

With respect to groundwater, this alternative could be permanent in the long term. Environmental risks would be reduced by this alternative because groundwater contaminant sources are contained and discharges to the river would decline over time.

Provides for Reasonable Restoration Time Frame. This alternative would reduce potential risks to human health immediately on stabilization of the hot spot soil and cap completion. As long as the cap was adequately maintained, this protection would continue over the long term. Groundwater discharges from the upper aquifer should be restored to below action levels in the long term. Groundwater discharges from the lower aquifer would not be restored to below action levels except in the long term (i.e., > 100 years).

6.3.6 Alternative 7 - Excavate and Stabilize All Impacted Soil, Groundwater Monitoring

Protection of Human Health and the Environment. Because all soil exceeding action levels would be excavated and stabilized, thereby eliminating direct exposure and ingestion pathways, Alternative 7 essentially eliminates the risks the site soil poses to human health. Institutional controls, including deed restrictions, would also increase this alternative's protectiveness of human health. Treating the hot spot soil and leaving the sheet piling around the excavations would effectively eliminate the major source of groundwater contamination and would provide for a significant reduction in environmental risk in the long term.

Because this alternative would involve excavation, handling, and treatment of highly contaminated soil, implementing this alternative may present some short-term risk to human health or the environment. Large excavations would be open almost continuously for 100 days or longer, and fugitive emissions of VOCs and dust would have to be addressed during implementation.

Compliance With Cleanup Standards. This alternative is designed to achieve action levels for soil. Most of the contaminants at the Site would be removed and destroyed after the alternative is implemented. Because a 15-foot point of compliance may not be achieved, soil cleanup standards may not be met with this alternative. Groundwater cleanup standards should be achieved over the long term, since the sources have been treated, contained, or both.

Compliance with ARARs. This alternative would comply with the major ARARs listed in Section 3.1. This assumes that the RCRA BDAT treatment standards would not apply to this alternative, or have been waived by Ecology.

Provides for Compliance Monitoring. This alternative would provide for long-term groundwater monitoring to evaluate short and long-term effects on discharges to the river. Air would be monitored during construction to evaluate short-term releases of contaminants and to determine if controls would be effective. Samples of treated soil would be collected to determine whether the stabilization process achieved performance standards.

Use of Permanent Solutions to the Maximum Extent Practicable. This alternative makes extensive use of MTCA's preferred technologies (reuse, destruction, and detoxification). Approximately 36,450 cy of contaminated soil would be treated by stabilization. With respect to groundwater, this alternative is considered permanent because cleanup standards should be achieved over the long term.

Provides for Reasonable Restoration Time Frame. This alternative would reduce the potential risks to human health to acceptable levels immediately on completion of the soil excavation and treatment. Groundwater discharges should be restored to below action levels over the long term.

7 RECOMMENDED CLEANUP ACTION

The no-action and five other alternatives that were evaluated individually in Section 6.3 are compared to each other in Section 7.1. A preferred cleanup action alternative is recommended in Section 7.2.

7.1 Comparison of Alternatives

7.1.1 Protectiveness

Human Health. The major component of human health risk is direct contact and ingestion of contaminated soil. With the exception of Alternative 1 (no action), all the alternatives would be protective of human health by eliminating this pathway. Alternatives 2, 3, and 4 would rely on containment to achieve protection. Alternative 6 would use soil stabilization and containment to provide the level of protection necessary. Alternatives 2, 3, 4, and 6 would all use institutional controls (e.g., deed restrictions) to improve protectiveness. Alternative 7 is the only alternative that would rely entirely on soil treatment to reduce human health risks to acceptable levels and would not rely on containment.

Groundwater discharges to surface water also present a potential risk to human health, although much less than direct exposure to soil. Alternatives 1 and 2 would not address groundwater discharges and would not be protective of human health for that pathway. Through containment or treatment of the primary sources of groundwater contamination, Alternatives 3, 4, 6, and 7 would significantly reduce contaminated groundwater discharges and the associated potential risks.

For Alternatives 6 and 7, and to a lesser extent Alternative 4, there would be potential short-term human health risks associated with implementing the alternatives. Specifically, excavation and treatment of large quantities of contaminated soil have the potential to release contaminants through volatilization and fugitive dust. The primary risk would be encountered by remediation workers. By using appropriate personal protective equipment (PPE), these risks could be mitigated. Because of the isolated location of the Site, the potential risks to off-site residential or worker populations would be negligible.

Environment. Groundwater discharges to the Snohomish River present the primary threats to the environment. Alternatives 1 and 2 do not address groundwater discharges and would therefore not be protective of the environment. Through containment or treatment of the primary sources of groundwater contamination, Alternatives 3, 4, 6, and 7 would significantly reduce contaminant concentrations in groundwater discharges over time, resulting in protection of the environment in the medium to long term.

7.1.2 Compliance With Cleanup Standards

Soil. With the exception of Alternative 1 (no action), all the alternatives would comply with the soil cleanup standards. Alternative 7 is the only alternative that potentially would achieve the cleanup standards solely through treatment of soil and would not rely on containment. Alternative 6 would remove and stabilize significant quantities of soil, but would rely on capping to achieve compliance with cleanup standards. Alternatives 2, 3, and 4 would rely on containment to achieve compliance with cleanup standards.

Although dioxins are not evaluated quantitatively in this FS, a qualitative evaluation of how each alternative addresses potential concerns related to dioxins/furans is appropriate. Dioxins/furans are commonly associated with PCP (USEPA 1992a). To the extent that an alternative contains or treats the primary contaminant sources associated with PCP (e.g., blow pit area), dioxins/furans would also be contained, removed, or treated.

Groundwater. Alternatives 3, 4, 6, and 7 would all contain or treat the primary source of groundwater contamination. With the contaminant source removed or cut off, contaminant concentrations in groundwater discharges would decline over time and may eventually achieve cleanup standards through natural attenuation.

Alternatives 1 and 2 do not address groundwater discharges and it is unlikely that cleanup standards would be achieved in all but the very long term.

7.1.3 Compliance With ARARs

In the detailed analysis in Section 6.3, each of the alternatives is evaluated for compliance with ARARs. With the exception of the no-action alternative, most of the alternatives comply with the identified ARARs.

One set of ARARs that warrants additional discussion is the various RCRA regulations relating to management of listed wood-treating wastes (i.e., F032, F034, and F035 wastes). As described in Section 3.1.2, because wood-preserving agents that contain PCP, creosote, and arsenic/chromium were used at the Site, wastes generated from wood-treating operations that used these chemicals, including wastewaters, process residuals, and drippage, are classified as F032, F034, or F035 wastes. Furthermore, environmental media that contain those listed wastes may themselves be required to be managed as a listed waste until Ecology makes a determination that they no longer "contain" F032/F034/F035. As discussed in Section 3.1.2, MTCA was amended in 1994 to exempt remedial actions conducted under a consent decree, order, or agreed order from the procedural requirements of the state Hazardous Waste Management Act. This would include exemptions from permits that would ordinarily be triggered by the treatment, storage, of disposal of a dangerous/hazardous waste. The discussions below assume that the cleanup action would not be exempted from these regulatory requirements, as would be the case for an independent cleanup action.

Assuming that the environmental media at the Site contain F032/F034/F035, once an affected medium is removed from the environment (e.g., excavation of soil), it has been "generated" as a waste and must be managed as listed waste. For alternatives that treat media or waste containing F032/F034/F034 wastes, the two major RCRA requirements that must be complied with are: (1) treatment restrictions for a generator, and (2) a determination from Ecology that the treated material no longer contains the listed wastes.

Generators of hazardous/dangerous waste are permitted to treat their waste as long as treatment is performed within 90 days of generation and in a contained manner. Complying with the 90-day treatment requirement would not be anticipated to be a problem. Soil excavated from the source area would be stabilized and returned to the excavation within 90 days.

The requirement for the treatment to be conducted in a contained manner must also be complied with for Alternatives 6 and 7. The USEPA has defined "in a contained manner" to mean that treatment must occur in a tank, container, or containment building. Excavated soil would be staged on impervious, bermed surfaces before treatment and the stabilization would occur in tanks or other contained vessels. Similarly, wastewater generated during dewatering would be treated in a system composed of tanks and containers.

Once the listed waste-containing media had been treated, they would have to be determined to not contain listed wastes before disposal (e.g., backfilling). This determination would be made by Ecology on a case-by-case basis. "Contains" has been interpreted to mean concentrations above health-based levels. Assuming that Ecology determined that a medium would contain listed waste at a certain concentration, this concentration must be met before replacing the medium back into the environment. In effect, this "contained-in" concentration would become a treatment goal.

7.1.4 Compliance Monitoring

All of the alternatives would have appropriate compliance monitoring for the cleanup actions performed. Alternative 1 has groundwater monitoring; no other monitoring would be included in the no-action alternative. Alternatives, 2, 3, and 4 would add performance monitoring for the asphalt cap.

Alternatives 6 and 7 would include extensive confirmation sampling (performance monitoring) during excavation to ensure that the target soil had been removed. Samples of the treated soil would also be collected to establish the performance of the stabilization technology and to ensure that treatment standards had been met. Ambient air monitoring during cleanup action implementation would also be performed to protect workers. Wastewater discharges would be monitored to ensure compliance with applicable permit discharge limits.

7.1.5 Use of Permanent Solutions

Use of Preferred Technologies. Alternatives 6 and 7 make use of technologies that reduce the amount of hazardous substances remaining on site. In MTCA's technology hierarchy, solidification and stabilization is a moderate-preference technology that immobilizes the hazardous substances in the environmental media. Treatment of groundwater generated either by excavation dewatering or by groundwater extraction would be achieved by using technologies that separate hazardous substances from the water (e.g., oil/water separation, metals precipitation, activated carbon absorption); the residual hazardous substances would be subsequently destroyed (e.g., incineration of product, carbon regeneration) or stabilized and securely disposed of (e.g., the treatment sludge).

With the exception of passive product recovery, Alternatives 2, 3, and 4 do not use high-preference technologies. Rather, these alternatives would rely on isolation or containment technologies to achieve protection of human health and the environment. Alternative 1 would not take any cleanup action and therefore would not use any preferred technologies.

Permanence. MTCA requires that cleanup alternatives be "permanent to the maximum extent practicable." To evaluate the "permanent" part of this criterion, the alternative is compared against several subcriteria, including overall protection, short- and long-term effectiveness, and permanent reduction in toxicity, mobility, or volume of hazardous substances. To evaluate whether an alternative is permanent "to the maximum extent practicable," the alternative is evaluated for implementability and then for cost-effectiveness.

Alternative 7 is the most "permanent" alternative because it would treat all of the soil that exceeds action levels. It would be very protective of human health and the environment over time. Alternative 6 also would treat the most highly contaminated soil and would be a permanent alternative, but would require using some containment to achieve complete protection. Alternatives 3 and 4, which would be protective of human health and the environment in the long term, would reduce the mobility of contaminants through containment; therefore, Alternatives 3 and 4 would be considered nearly as permanent as Alternatives 6 and 7. Although protective of human health, Alternative 2 would not be as protective of the environment, and would therefore be less permanent than Alternatives 3, 4, 6, or 7. Alternative 1 would not be protective of human health or the environment and is therefore not permanent.

Because all of the alternatives have been determined to be implementable, the evaluation of "to the maximum extent practical" is primarily then a cost-effectiveness evaluation. MTCA regulations allow for the use of a disproportionate cost analysis in support of this evaluation. In these analyses, the effectiveness of an alternative is compared against another, more expensive alternative, and a determination made as to whether the benefits, if any, of the more expensive alternative warrant the increased expenditure.

Alternative 1 (present worth of $570,000) would be the least expensive alternative; it would be ineffective at reducing risks and cannot, therefore, be cost-effective. Alternative 2 (present worth of $1,920,000) would be protective of human health but not the environment except in the very long term, and therefore can only be considered marginally cost-effective. Alternative 3 (present worth of $2,460,000) would be protective of both human health and the environment. Alternative 3 achieves a much higher level of permanence when compared with Alternative 2. The increased cost of $540,000 over Alternative 2 would be considered cost-effective because this would be the least expensive alternative that achieves protection of both human health and the environment. Alternative 4 (present worth of $2,660,000) would provide very similar (but somewhat higher) levels of protection and permanence when compared with Alternative 3. Because it consolidates contaminated soil into a smaller area, reduces restrictions on approximately 3 acres of the site, and costs $200,000 more than Alternative 3, it is also considered cost-effective.

Although Alternative 6 (present worth of $9,340,000[2]) would be considered more permanent than Alternatives 3 and 4, it would cost three to four times more than those alternatives. Because it would not be significantly more protective of human health and the environment than Alternatives 3 or 4, and would present increased risks related to maintaining the integrity of the silt layer during excavation, Alternative 6 is not considered cost-effective.

Alternative 7 (present worth of $13,620,000) would be the most permanent, and most expensive, of all the alternatives. It would be slightly more protective of human health, but has approximately the same long-term protectiveness of the environment as Alternative 6. Because Alternative 6 was not considered cost-effective, the increased expenditure of approximately $4,000,000 would be not considered practicable.

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2 The estimated present values for Alternatives 6 and 7 are based on the assumption that excavation techniques similar to, or at least similar in cost to, those described in Section 6.2 are appropriate.

Groundwater Restoration. This criterion requires that where practicable, treatment be used to achieve action levels in groundwater. Where groundwater treatment would not be practicable for purposes of achieving action levels, MTCA requires use of treatment to reduce contaminant levels to the maximum extent practicable, and requires the use of containment, source control, and monitoring.

Alternatives 6 and 7 would both use soil treatment, containment, or both, to limit the potential for migration of contaminants and to control the source of groundwater contamination. Alternatives 3 and 4 would rely on containment and product recovery for source control. Alternative 2 would rely solely on product recovery. Alternative 1 would not address groundwater at all.

7.1.6 Restoration Time Frame

Human Health. Alternatives 2, 3, 4, and 6 would achieve protection of human health as soon as the cap was complete (i.e., within 12 to 24 months). For Alternative 7, protection would be achieved when soil treatment was complete (i.e., within 24 months). If Alternative 7 would comply with cleanup standards, it would be the only alternative that achieved compliance solely through the use of treatment, and no further action would be required to maintain protection. For the other alternatives, maintenance of the cap would be required for the alternative to be protective in the long term. Because no action would be taken, Alternative 1 would not be protective over any time frame.

Environment. Alternatives 3, 4, 6, and 7 all contain or eliminate the major sources of groundwater contamination, and therefore would be protective of the environment in the long term. Alternatives 1 and 2 would not address groundwater contamination and would not be expected to achieve cleanup levels in a reasonable time.

7.1.7 Public Acceptance

This criteria has not yet been evaluated, but would be addressed during the comment period for this FS and the CAP.

7.2 Recommendation of a Preferred Cleanup Action

On the basis of the detailed analysis of each of the six retained alternatives in Section 6.3, and the comparison of alternatives against each other, Alternative 4 is recommended for implementation at the Site. This alternative is protective of both human health and the environment, would contain the major sources of groundwater contamination, would be consistent with the anticipated future industrial use of the site, and would be cost-effective when compared with other alternatives that achieve similar levels of protection and compliance with cleanup standards.

Selection of Alternative 4 complies with many of the MTCA expectations contained in WAC 173-340-360(9). Specifically:

- -360(9)(c) - Alternative 4 would make use of "engineering controls, such as containment" to mitigate risk at portions of the Site "that contain large volumes of materials with relatively low levels of hazardous substances where treatment is impracticable".
- -360(9)(d) - Alternative 4 would use institutional controls, "such as water use restrictions and deed restrictions . . . to supplement engineering controls in order to prevent or limit exposure to hazardous substances and protect the integrity of the cleanup action."
- -360(9)(e) - Alternative 4 would implement source control measures to "minimize/prevent further migration, minimize ongoing releases," and "prevent exposure to contaminated water".
- -360(9)(f) - Alternative 4 would "minimize the potential for migration of hazardous substances" by "taking active measures . . to prevent precipitation and subsequent runoff from contacting contaminated soil and waste materials."
- -360(9)(h) - Alternative 4 would take "active measures" (vertical containment and product recovery) "to prevent/minimize releases to surface water via runoff and groundwater discharges." Also, "dilution will not be used as the sole method for demonstrating compliance with cleanup standards."

The recommendation for Alternative 4 is also consistent with the intended future use of the Site for industrial purposes.

LIMITATIONS

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, nor the use of segregated portions of this report.

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TABLES

Table 2-1

Summary of Aquifer Parameters

Aquifer Parameter	Upper Sand Aquifer	Upper Silt Aquitard	Lower Sand Aquifer
Hydraulic conductivity (horizontal; cm/sec)	5×10^{-2}	NM	5×10^{-2}
Hydraulic conductivity (vertical; cm/sec)	2 to 10 times lower than horizontal	2.2×10^{-7}	2 to 10 times lower than horizontal
Hydraulic gradient (horizontal; ft/ft)	0.0037	NM	0.00046
Hydraulic gradient (vertical; ft/ft)	NM	0.20	NM
Effective porosity	0.30	0.40	0.30
Groundwater velocity (horizontal; ft/day)	1.8	NM	0.2
Groundwater velocity (vertical; ft/day)	NM	3.1×10^{-4}	NM
Aquifer storage	0.30	--	0.0005

NOTE: NM = not measured.

Table 2-2

Location and Range of Soil Contaminants of Concern - Fill Unit

Contaminant of Concern	Location of Contamination	Range of Concentrations (mg/kg)
Arsenic	Rail lines, building	6.8 - 187
Chromium	Rail lines, building	15.6 - 243
TPH	Building	4 - 14,700
CPAHs	Rail lines, building	0.68 - 380
PCP	Rail lines, building	0.055 - 110

Table 2-3

Location and Range of Soil Contaminants of Concern - Upper Sand Unit

Contaminant of Concern	Location of Contamination	Range of Concentrations (mg/kg)
Arsenic	Blow pit, rail lines, building	4.0 - 459
Chromium	Blow pit, building, rail lines	18.2 - 906
TPH	Blow pit, building, rail lines, former Mill E	0.85 - 20,000
CPAHs	Blow pit, rail lines, building	.038 - 219
PCP	Blow pit, rail lines, building	0.042 - 410

Table 2-4

Statistical Summary of Total Metals in Groundwater - February 1994 through August 1996, Shallow Perimeter Wells

Element	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
Arsenic	46	46	0.014	15.7	2.56	14.3	-	-
Chromium	41	46	0.0009	0.877	0.053	0.0917	0.00075	0.003
Copper	36	46	0.0016	0.056	0.012	0.0146	0.0006	0.003
Lead	34	46	0.0006	0.018	0.0033	0.0041	0.0007	0.003

NOTE: - indicates no relevant value.

Table 2-5

Statistical Summary of Total Petroleum Hydrocarbons in Groundwater - February 1994 through August 1996, Shallow Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L) Low	Detection Limits (mg/L) High
Diesel	39	46	0.078	37.0	5.56	35.5	0.076	1.25
Heavy Oil	27	46	0.240	20.0	2.01	2.77	0.19	3.9
Gasoline	21	46	0.078	45.0	11.1	*	0.05	0.05
Total (G, D, and Oil)	39	46	0.078	80.0	13.0	*	0.095	1.58

Note: * = default to maximum value per statistical guidance.

Table 2-6

Statistical Summary of Benzene, Toluene, Ethylbenzene, and Total Xylenes in Groundwater - February 1994 through August 1996, Shallow Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
Benzene	19	39	0.0008	2.80	0.556	*	0.010	0.010
Toluene	18	39	0.0006	5.00	1.18	*	0.010	0.010
Ethylbenzene	14	39	0.002	0.260	0.093	*	0.010	0.010
Total Xylenes	18	39	0.001	1.40	0.363	*	0.010	0.010

NOTE: * = default to maximum value per statistical guidance.

Table 2-7

Statistical Summary of Semivolatile Organic Compounds in Groundwater - February 1994 through August 1996, Shallow Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
Phenol	6	46	0.013	0.190	0.081	*	0.010	1.0
bis(2chloroethyl)Ether	0	46	-	-	-	-	0.010	1.0
2-Chlorophenol	0	46	-	-	-	-	0.010	1.0
1,3-Dichlorobenzene	0	46	-	-	-	-	0.010	1.0
1,4-Dichlorobenzene	0	46	-	-	-	-	0.010	1.0
1,2-Dichlorobenzene	0	46	-	-	-	-	0.010	1.0
2-Methylphenol	11	46	0.003	0.210	0.059	*	0.010	0.530
2,2-oxybis(1-Chloropropane)	0	46	-	-	-	-	0.010	1.0
4-Methylphenol	14	46	0.001	0.650	0.154	*	0.010	1.0
N-nitroso-Di-n-Propylamine	0	46	-	-	-	-	0.010	1.0
Hexachloroethane	1	46	0.029	-	-	-	0.010	1.0
Nitrobenzene	0	46	-	-	-	-	0.010	1.0
Isophorone	0	46	-	-	-	-	0.010	1.0
2-Nitrophenol	0	46	-	-	-	-	0.010	1.0
2,4-Dimethylphenol	13	46	0.001	0.093	0.025	*	0.010	1.0
bis(2-Chloroethoxy)Methane	0	46	-	-	-	-	0.010	1.0
2,4-Dichlorophenol	7	46	0.006	0.038	0.014	*	0.010	1.0
1,2,4-Trichlorobenzene	0	46	-	-	-	-	0.010	1.0
Naphthalene	19	46	0.014	11.0	2.77	*	0.010	0.013
4-Chloroaniline	0	46	-	-	-	-	0.010	1.3
Hexachlorobutadiene	0	46	-	-	-	-	0.010	1.0
4-Chloro-3-Methylphenol	0	46	-	-	-	-	0.010	1.0
2-Methylnaphthalene	14	46	0.004	0.830	0.298	*	0.010	0.530
Hexachlorocyclopentadiene	0	46	-	-	-	-	0.010	1.0
2,4,6-Trichlorophenol	1	46	0.002	-	-	-	0.010	1.0
2,4,5-Trichlorophenol	14	46	0.002	0.170	0.057	*	0.010	1.3
2-Chloronaphthalene	1	46	0.016	-	-	-	0.010	1.0
2-Nitroaniline	0	46	-	-	-	-	0.010	1.3
Dimethyl phthalate	0	46	-	-	-	-	0.010	1.0
Acenaphthylene	1	46	0.006	-	-	-	0.010	1.0
2,6-Dinitrotoluene	0	46	-	-	-	-	0.010	1.0
3-Nitroaniline	0	46	-	-	-	-	0.010	1.3
Acenaphthene	17	46	0.002	0.190	0.065	*	0.010	0.530
2,4-Dinitrophenol	0	46	-	-	-	-	0.010	1.3
4-Nitrophenol	1	46	0.021	-	-	-	0.010	1.3

Table 2-7

Statistical Summary of Semivolatile Organic Compounds in Groundwater - February 1994 through August 1996, Shallow Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
Dibenzofuran	10	46	0.002	0.067	0.030	*	0.010	1.0
2,4-Dinitrotoluene	0	46	-	-	-	-	0.010	1.0
Diethylphthalate	0	46	-	-	-	-	0.010	1.0
4-Chlorophenyl-phenylether	0	46	-	-	-	-	0.010	1.0
Fluorene	12	46	0.001	0.064	0.026	*	0.010	1.0
4-Nitroaniline	0	46	-	-	-	-	0.010	1.3
4,6-Dinitro-2-Methylphenol	0	46	-	-	-	-	0.010	1.3
N-Nitrosodiphenylamine	1	46	0.003	-	-	-	0.010	1.0
4-Bromophenyl-phenylether	0	46	-	-	-	-	0.010	1.0
Hexachlorobenzene	0	46	-	-	-	-	0.010	1.0
Pentachlorophenol	21	46	0.001	9.30	3.10	*	0.010	0.150
Phenanthrene	9	46	0.001	0.022	0.009	*	0.010	1.0
Anthracene	2	46	0.001	0.005	0.003	*	0.010	1.0
Carbazole	10	46	0.002	0.150	0.061	*	0.010	1.0
Di-n-Butylphthalate	0	46	-	-	-	-	0.010	1.0
Fluoranthene	2	46	0.002	0.003	0.003	*	0.010	1.0
Pyrene	2	46	0.002	0.003	0.003	*	0.010	1.0
Butylbenzylphthalate	0	46	-	-	-	-	0.010	1.0
3,3'-Dichlorobenzidine	0	46	-	-	-	-	0.010	1.0
Benzo(a)anthracene	0	46	-	-	-	-	0.010	1.0
Chrysene	1	46	0.001	-	-	-	0.010	1.0
bis(2-Ethylhexyl)phthalate	9	46	0.001	0.039	0.009	*	0.010	1.0
Di-n-Octyl Phthalate	1	46	0.007	-	-	-	0.010	1.0
Benzo(b)Fluoranthene	0	46	-	-	-	-	0.010	1.0
Benzo(k)Fluoranthene	0	46	-	-	-	-	0.010	1.0
Benzo(a)Pyrene	0	46	-	-	-	-	0.010	1.0
Indeno(1,2,3-cd)Pyrene	0	46	-	-	-	-	0.010	1.0
Dibenz(a,h)Anthracene	0	46	-	-	-	-	0.010	1.0
Benzo(g,h,i)Perylene	0	46	-	-	-	-	0.010	1.0

NOTE: - indicates no relevant value.
* = default to maximum value per statistical guidance.

Table 2-8

Statistical Summary of Total Metals in Groundwater - February 1994 through August 1996, Deep Perimeter Wells

Element	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
Arsenic	23	24	0.0019	0.0470	0.0147	0.0278	0.003	-
Chromium	23	24	0.0011	0.0163	0.0061	0.0087	0.003	-
Copper	10	24	0.0012	0.0039	0.0018	*	0.00095	0.0071
Lead	15	24	0.0004	0.0075	0.0017	0.0018	0.0004	0.003

NOTE: - indicates no relevant value.
* = default to maximum value per statistical guidance.

Table 2-9

Statistical Summary of Total Petroleum Hydrocarbons in Groundwater - February 1994 through August 1996, Deep Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
Diesel	21	24	0.100	9.10	2.17	*	0.078	0.20
Heavy Oil	10	24	0.160	0.830	0.412	*	0.19	3.2
Gasoline	21	24	0.064	14.0	4.00	*	0.05	0.05
Total (G, D, and Oil)	23	24	0.064	22.5	5.81	*	0.20	-

NOTE: - indicates no relevant value.
* = default to maximum value per statistical guidance.

Table 2-10

Statistical Summary of Benzene, Toluene, Ethylbenzene, and Total Xylenes in Groundwater - February 1994 through August 1996, Deep Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confidence Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
Benzene	18	23	0.001	0.320	0.094	*	0.010	0.010
Toluene	14	23	0.001	0.021	0.005	*	0.010	0.010
Ethylbenzene	16	23	0.002	0.170	0.046	0.150	0.010	0.010
Total Xylenes	18	23	0.001	0.045	0.018	*	0.010	0.010

NOTE: * = default to maximum value per statistical guidance.

Table 2-11

Statistical Summary of Semivolatile Organic Compounds in Groundwater - February 1994 through August 1996, Deep Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confide-e Limit (mg/L)	Detection Limits (mg/L) Low	Detection Limits (mg/L) High
Phenol	7	24	0.002	0.010	0.005	*	0.010	0.250
bis(2chloroethyl)Ether	0	24	-	-	-	-	0.010	0.250
2-Chlorophenol	0	24	-	-	-	-	0.010	0.250
1,3-Dichlorobenzene	0	24	-	-	-	-	0.010	0.250
1,4-Dichlorobenzene	0	24	-	-	-	-	0.010	0.250
1,2-Dichlorobenzene	0	24	-	-	-	-	0.010	0.250
2-Methylphenol	1	24	0.003	-	-	-	0.010	0.250
2,2-oxybis(1-Chloropropane)	0	24	-	-	-	-	0.010	0.250
4-Methylphenol	0	24	-	-	-	-	0.010	0.250
N-nitroso-Di-n-Propylamine	0	24	-	-	-	-	0.010	0.250
Hexachloroethane	0	24	-	-	-	-	0.010	0.250
Nitrobenzene	0	24	-	-	-	-	0.010	0.250
Isophorone	0	24	-	-	-	-	0.010	0.250
2-Nitrophenol	0	24	-	-	-	-	0.010	0.250
2,4-Dimethylphenol	5	24	0.005	0.021	0.010	*	0.010	0.250
bis(2-Chloroethoxy)Methane	0	24	-	-	-	-	0.010	0.250
2,4-Dichlorophenol	0	24	-	-	-	-	0.010	0.250
1,2,4-Trichlorobenzene	0	24	-	-	-	-	0.010	0.250
Naphthalene	12	24	0.001	5.50	1.51	*	0.010	0.012
4-Chloroaniline	0	24	-	-	-	-	0.010	0.250
Hexachlorobutadiene	0	24	-	-	-	-	0.010	0.250
4-Chloro-3-Methylphenol	0	24	-	-	-	-	0.010	0.250
2-Methylnaphthalene	17	24	0.001	0.810	0.217	*	0.010	0.012
Hexachlorocyclopentadiene	0	24	-	-	-	-	0.010	0.250
2,4,6-Trichlorophenol	0	24	-	-	-	-	0.010	0.250
2,4,5-Trichlorophenol	0	24	-	-	-	-	0.010	0.620
2-Chloronaphthalene	0	24	-	-	-	-	0.010	0.250
2-Nitroaniline	0	24	-	-	-	-	0.010	0.620
Dimethyl phthalate	0	24	-	-	-	-	0.010	0.250
Acenaphthylene	0	24	-	-	-	-	0.010	0.250
2,6-Dinitrotoluene	0	24	-	-	-	-	0.010	0.250
3-Nitroaniline	0	24	-	-	-	-	0.010	0.620
Acenaphthene	21	24	0.001	0.210	0.063	0.082	0.010	0.010
2,4-Dinitrophenol	0	24	-	-	-	-	0.010	0.620

Table 2-11

Statistical Summary of Semivolatile Organic Compounds In Groundwater - February 1994 through August 1996, Deep Perimeter Wells

Compound	Number Detected	Number Analyzed	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)	95 % Upper Confide-e Limit (mg/L)	Detection Limits (mg/L)	
							Low	High
4-Nitrophenol	0	24	-	-	-	-	0.010	0.250
Dibenzofuran	8	24	0.004	0.049	0.023	*	0.010	0.250
2,4-Dinitrotoluene	0	24	-	-	-	-	0.010	0.250
Diethylphthalate	0	24	-	-	-	-	0.010	0.250
4-Chlorophenyl-phenylether	0	24	-	-	-	-	0.010	0.250
Fluorene	11	24	0.001	0.052	0.023	*	0.010	0.012
4-Nitroaniline	0	24	-	-	-	-	0.010	0.620
4,6-Dinitro-2-Methylphenol	0	24	-	-	-	-	0.010	0.620
N-Nitrosodiphenylamine	0	24	-	-	-	-	0.010	0.250
4-Bromophenyl-phenylether	0	24	-	-	-	-	0.010	0.250
Hexachlorobenzene	0	24	-	-	-	-	0.010	0.250
Pentachlorophenol	1	24	0.003	-	-	-	0.010	0.620
Phenanthrene	6	24	0.001	0.007	0.004	*	0.010	0.250
Anthracene	0	24	-	-	-	-	0.010	0.250
Carbazole	11	24	0.006	0.077	0.038	*	0.010	0.012
Di-n-Butylphthalate	0	24	-	-	-	-	0.010	0.250
Fluoranthene	0	24	-	-	-	-	0.010	0.250
Pyrene	0	24	-	-	-	-	0.010	0.250
Butylbenzylphthalate	0	24	-	-	-	-	0.010	0.250
3,3'-Dichlorobenzidine	0	24	-	-	-	-	0.010	0.250
Benzo(a)anthracene	0	24	-	-	-	-	0.010	0.250
Chrysene	0	24	-	-	-	-	0.010	0.250
bis(2-Ethylhexyl)phthalate	8	24	0.001	0.096	0.020	*	0.010	0.250
Di-n-Octyl Phthalate	0	24	-	-	-	-	0.010	0.250
Benzo(b)Fluoranthene	0	24	-	-	-	-	0.010	0.250
Benzo(k)Fluoranthene	0	24	-	-	-	-	0.010	0.250
Benzo(a)Pyrene	0	24	-	-	-	-	0.010	0.250
Indeno(1,2,3-cd)Pyrene	0	24	-	-	-	-	0.010	0.250
Dibenz(a,h)Anthracene	0	24	-	-	-	-	0.010	0.250
Benzo(g,h,i)Perylene	0	24	-	-	-	-	0.010	0.250

NOTE: - indicates no relevant value.
* = default to maximum value per statistical guidance.

Table 2-12
Apparent Source Areas and Associated Constituents

Apparent Source Area	Associated Constituents of Concern
Blow pit area	As, Cu, Cr, TPH, CPAHs, PCP, Dioxins/Furans
Building[a]	As, Cu, Cr, TPH, CPAHs, PCP
Rail lines	As, Cu, Cr, TPH, CPAHs, PCP
Former Mill E	TPH
Off site	As

[a] Building includes former aboveground wood treatment chemical storage tanks, and former and existing underground pipelines.

Table 2-13

Interim Product Recovery Summary

Well	Recovery Event Date						Total
	7/10/96	7/25/96	8/8/96	8/23/96	9/5/96	10/7/96	
MW-23	NP	NP	NP	NP	NP	NP	0
MW-33	NP	NP	NP	NP	NP	NP	0
HC-22	NP	NP	NP	NP	NP	NP	0
HC-15D	NP	NP	NP	NP	NP	NP	0
HC-15	1/0[a]	NP	NP	NP	NP	NP	1/0
HC-12	<1/0	1/0	1/0	3/0	6/0	NP	12/0
P-1	6/0	4/0	<1/0	<1/0	NP	NP	12/0
P-2	10/0	6/0	2/0	2/0	4/0	NP	24/0
TW-1	140/190	28/2	8/35	1/0	NP	NP	177/227
Total	158/190	39/2	12/35	7/0	10/0	0/0	226/227

NOTE:
NP = no product recovered.
[a] Estimated quantity of product recovered in ounces. First value is amount of LNAPL recovered and second value is amount of DNAPL recovered.

Table 3-1

Identification of Potential ARARs

Requirement	Not Applicable	Applicable	Relevant & Appropriate	To Be Considered	Rationale
Washington Regulations					
Model Toxics Control Act chapter 173-340 WAC		X			Administrative requirements for cleanup of state sites.
Model Toxics Control Act, RCW 701.105D as amended by ESSB 6123		X			Encourages and expands the use of industrial cleanup standards. Allows Ecology to exempt wastes generated at a site under a consent decree from state-only dangerous waste requirements.
Model Toxics Control Act, RCW 701.105D as amended by ESSB 6339		X			Allows Ecology to exempt procedural requirements of certain state and local laws for remedial actions conducted under a consent decree, order, or agreed order. procedural requirements of Washington Clean Air Act, Solid Waste Management Act, hydraulic project approvals, Washington Water Pollution Control Act, Shoreline Management Act, and other local government permits and approvals. Also requires Ecology to integrate procedural requirements of SEPA with those of the Model Toxics Control Act where practicable.
Water Quality Standards for Surface Waters of the State of Washington chapter 173-201A WAC		X			Water quality standards for surface water. Establish/protect quality of Snohomish River from surface runoff, groundwater discharge, or discharge from treatment option. Designates Snohomish River as Class A waters.
SEPA Procedures chapter 173-802 WAC		X			SEPA requirements. Checklist and Determination of Nonsignificance is required prior to construction activities. Applicable unless waived by Ecology.
NPDES Permit Program chapter 173-220 WAC		X			NPDES Permit regulations. NPDES permit is required to limit/control discharges of pollutants.
Dangerous Waste Regulations chapter 173-303 WAC		X			These regulations control the generation, transportation, treatment, storage, and disposal of dangerous waste.

Table 3-1

Identification of Potential ARARs

Requirement	Not Applicable	Applicable	Relevant & Appropriate	To Be Considered	Rationale
Washington Regulations (cont)					
Submission of Plans and Reports for Construction of Wastewater Facilities chapter 173-240 WAC		X			Treatment system construction approval required for facilities such as groundwater treatment systems.
Washington Clean Air Act chapter 173-460 WAC		X			Requirements for the control of new sources of toxic air pollutants.
Washington Industrial Safety and Health Act chapter 296-62 WAC		X			Health and safety training requirements for on-site workers. State requirements are generally more stringent than federal requirements.
Federal Requirements					
National Contingency Plan 40 CFR Part 300			X		To be used as general guidelines for minimum requirements of cleanup objectives. State cleanup requirements must be at least as stringent as federal laws. Includes guidance requiring federal agencies to act as trustees for Indian tribes.
RCRA Land Disposal Restrictions 40 CFR Part 268		X			Land Disposal Restriction requirements. Waste treatment standards for F032 wastes have not been promulgated. If waste exhibits Toxicity Characteristics for pentachlorophenol, arsenic, or chromium, then LDR may apply. Contains regulations concerning the use of containment buildings - not considered a land disposal process.
Safe Drinking Water Act 40 CFR Part 141				X	Groundwater not to be considered as a drinking water source. Injection of treated groundwater back into aquifer to be considered.
Occupational Safety and Health Administration 29 CFR Part 1910.1200		X			Health and safety training requirements for on-site workers.

Table 3-1

Identification of Potential ARARs

Requirement	Not Applicable	Applicable	Relevant & Appropriate	To Be Considered	Rationale
Federal Requirements (cont)					
Clean Water Act 40 CFR Part 100 - 149		X		X	Prohibits the discharge of dredged or fill material into waters of the U.S. without a permit from the U.S. Corps of Engineers. Water quality standards of CWA only to be considered. Ingestion of surface water or groundwater not currently a pathway of concern. Wetlands are not present on site.
National Ambient Air Quality Standards 40 CFR Part 50			X		Consideration of airborne contamination as a result of remediation activities.
Underground Injection Control Program 40 CFR Part 144				X	Injection of treated groundwater into aquifer to be considered.
40 CFR Part 403			X		Discharge of pollutants to POTW to be considered.
Groundwater Remediation - NAPL Discussions USEPA Directive No. 9283.1-06				X	Groundwater remediation at sites with NAPLs present.
Disposal of Dangerous Waste, Soil, Debris- Areas of Contamination Ecology Interprogram Policy Memo - September 6, 1991			X		Policy identifying situations under which excavation and movement of contaminated materials would not constitute generation or disposal of a hazardous waste.
Local Requirements					
Puget Sound Air Pollution Control Agency		X			Construction approval required for air contaminant sources and air pollution control equipment. Procedural requirements may be waived by Ecology.
Snohomish County -building permit -grading permit -shoreline permit		X			Building permit will be needed prior to construction of permanent structures; grading permit needed prior to removal or placement of soil; shoreline permit needed prior to outfall construction and other improvements within 200 feet of shoreline. Procedural requirements may be waived by Ecology.

Table 3-2
Soil Cleanup and Screening Levels

Compound	MTCA Method C[a] (mg/kg)	Other (mg/kg)[b]
Pentachlorophenol	109	—
Benzo(a)anthracene	1.8	—
Chrysene	1.8	—
Benzo(b)fluoranthene	1.8	—
Benzo(k)fluoranthene	1.8	—
Benzo(a)pyrene	1.8	—
Ideno(1,2,3-cd)pyrene	1.8	—
Dibenz(a,h)anthracene	1.8	—
Total CPAHs	12.6[c]	—
Dioxins/furans	NA[d]	—
TPH-Gasoline	—	2,500[e]
TPH-Diesel	—	2,500[e]
TPH-Other	—	2,500[e]
Chromium	1,750[f]	—
Arsenic	21.9	—

a Values listed were calculated using standard MTCA Method C methodology. For individual carcinogens, each value represents a 1×10^{-6} excess cancer risk such that the cumulative excess cancer risk is less than 1×10^{-5}.

b Where MTCA Method C is not applicable, alternate action levels are presented.

c Value represents summation of the action levels for the seven carcinogenic polycyclic aromatic hydrocarbon (CPAH) compounds, and is equivalent to a 7×10^{-6} excess cancer risk.

d Dioxin/furan action levels not calculated due to unavailability of toxicity data for these compounds per WAC 173-340-708 provisions.

e Value shown is a *screening* level for total TPH (i.e., sum of -G, -D, and -O fractions) that will be used to define areas and volumes of soil that may require remediation (see Section 3.2.1). A final action level will be determined for the recommended cleanup action in Section 7.

f Assumes all chromium present as hexavalent chromium.

Table 3-3
Groundwater Cleanup Levels

Compound[a]	Groundwater Cleanup Level[b] (mg/L)	Exceeds in Upper Aquifer?	Exceeds in Lower Aquifer?
Pentachlorophenol	10	Yes	No
Benzene	710	Yes	No
TPH[c]	10,000	Yes	Yes
Arsenic	5	Yes	Yes
Copper	7	Yes	No
Chromium	50	Yes	No

[a] Appendix A contains the detailed comparison of groundwater data to the potentially applicable standards.
[b] Values shown are based on the most stringent surface water standard for either protection of human health through consumption of organisms or protection of aquatic life. Where most stringent value is below the practical quantitation limit (PQL), the PQL is used as the cleanup level. See Appendix A for detailed comparison of groundwater data to standards and PQLs.
[c] There are no AWQC for TPH. The 10 mg/L value for total oil and grease (Ecology, 1987) is shown.

Table 3-4
General Response Actions

General Response Actions by Media		
Soil	Groundwater	Miscellaneous
No action Institutional controls (e.g., deed restrictions) Containment (e.g., capping) In situ treatment Ex situ treatment Volume reduction Removal (e.g., hot-spot or total contaminant) Disposal (e.g., on or off site)	No action Institutional controls (e.g., monitoring) Containment (e.g., vertical barriers, hydraulic controls, subsurface horizontal barriers) Source control (e.g., removal, containment) Collection/ex situ treatment/discharge In situ treatment	Control storm water run-on/runoff

Table 4-1

Summary of Potentially Applicable Technologies

Preliminary Technologies by Media			
Soil		Groundwater	
General Response Action	Technology	General Response Action	Technologies
Institutional Controls	Access Restrictions	Institutional Controls	Groundwater Monitoring
	Deed Restrictions		Deed Restrictions
Containment	Asphalt/Concrete Cap	Collection	Extraction Wells
	Soil Cap		Interception Trenches
	Geomembrane Cap		Product Recovery
	Composite Cap	Ex Situ Treatment	
	On-Site Landfill	Physical/Chemical	Oil/Water Separation
In Situ Treatment	Vapor Extraction		Gravity Settling
	Air Sparging		Solids Filtration
	Steam Stripping		Air Stripping
	Soil Washing/Flushing		Steam Stripping
	Vitrification		Carbon Adsorption
	Bioremediation		Ultrafiltration
	Stabilization/Solidification		Ion Exchange
Ex Situ Treatment			Advanced Oxidation Processes
Biological Treatment	Landfarming		Metals Precipitation
	Composting		Solvent Extraction
	Slurry-Phase Reactor	Biological Treatment	Activated Sludge
	Anaerobic Digestion		Fixed Bed Reactor
	White Rot Fungus		Sequencing Batch Reactor
Thermal Treatment	Fluidized Bed Incineration		Anaerobic Digestion
	Rotary Kiln Incineration	In Situ Treatment	Vapor Extraction
	Infrared Thermal Incineration		Air Sparging
	Pyrolytic Incineration		Biological Treatment
	Low Temperature Thermal Desorption	Containment	Groundwater Extraction (i.e., hydraulic control)
	Asphalt Incorporation		Slurry Wall
Physical Treatment	Soil Washing		Sheet Piling
	Solidification/Stabilization		Grout Curtain
	Solvent Extraction		Grout Injection
	Super-critical Fluid Extraction		
	Dewatering (various)		
Chemical Treatment	Glycolate Dechlorination		
	Oxidation/Reduction Processes		
Volume Reduction	Soil Screening/Sieving		
	Size Reduction		
Removal	Excavation		
Disposal	Off-Site Landfill		

Table 4-2

Remedial Technology Identification and Initial Screening- Soil

General Response Action	Process Option	Effectiveness[a]	Implementability	Cost-Effectiveness	Retained	Comments
No Action	NA	NA	NA	NA	Yes	Retained to evaluate baseline or "No-Action Alternative"
Institutional Controls	Access Restrictions	Low	High	High	Yes	Can be part of more comprehensive alternatives
	Land Use Restrictions	Low	High	High	Yes	Can be part of more comprehensive alternatives
Containment	Asphalt/Concrete Cap	Medium	High	Medium/High	Yes	Suitable for areas where post-remediation use of site is required.
	Soil Cap	Medium	High	Medium	No	Potentially less effective and more expensive than geomembrane cap.
	Geomembrane Cap	Medium	High	Medium	Yes	Very effective at moderate cost.
	Composite Cap (e.g., RCRA cap)	Medium	Medium	Low	No	Composite cap not required for protectiveness; very high costs relative to other capping options.
	On-site landfill	Medium	Low	Low	No	Potential permitting problems limit implementability
In Situ Treatment	Vapor Extraction	Low	High	High	No	Ineffective for heavier organic compounds (e.g., PAHs, PCP, fuel oils) and metals
	Air Sparging	Low	High	High	No	Ineffective for heavier organic compounds (e.g., PAHs, PCP, fuel oils) and metals
	Steam Stripping	Low/Medium	Medium	Medium	No	Although more effective than vapor extraction and air sparging, still relatively ineffective for heavier organic and metals
	Soil Washing/Flushing	Medium	Medium	Medium	Yes	Innovative technology. Effectiveness and implementability not well established.
	Vitrification	High	Low	Low	No	Technology still not completely developed and has not been used at non-nuclear sites. Also, extremely expensive.

Table 4-2

Remedial Technology Identification and Initial Screening- Soil

General Response Action	Process Option	Effectiveness[a]	Implementability	Cost-Effectiveness	Retained	Comments
In Situ Treatment (continued)	Bioremediation	Low/Medium	Low/Medium	Medium	No	Not applicable to metals; treatability study determined that bioremediation was ineffective for organic compounds of concern.
	Stabilization/fixation	Low/Medium	Medium	Medium	No	Difficult to ensure complete treatment has been achieved. Applicability to soils with high concentrations of organic contaminants unclear.
	Encapsulation	Low/Medium	Medium	Medium	No	Permanence of technology unclear. Difficult to ensure complete encapsulation.
Ex Situ Treatment						
Biological Treatment	Landfarming	Low/Medium	High	Medium	No	Not applicable to metals; treatability study determined that bioremediation was ineffective for organic compounds of concern.
	Composting	Low/Medium	Medium	Medium	No	Same problems as landfarming; also generates more treatment residuals.
	Slurry-Phase Reactor	Medium	Medium/High	Low/Medium	No	Not applicable to metals; treatability study determined that bioremediation was ineffective for organic compounds of concern.
	Anaerobic Digestion	Low/Medium	Low/Medium	Low/Medium	No	Use of anaerobic treatment for contaminated soils not well established. Anaerobic systems generally take longer than comparable aerobic treatments.
	White Rot Fungus	Medium	Medium	Low/Medium	No	Very innovative technology that does not yet have an established track record in the field.

Table 4-2

Remedial Technology Identification and Initial Screening- Soil

General Response Action	Process Option	Effectiveness[a]	Implementability	Cost-Effectiveness	Retained	Comments
Thermal Treatment	Fluidized Bed Incineration	High	Low	Low	No	Implementability of on-site incineration is very low. For off-site incineration, rotary-kiln is predominant technology used.
	Rotary Kiln Incineration	High	Low	Low	Yes	Due to very low implementability of on-site incineration, and extreme expense of off-site soils incineration, rotary kiln incineration in off-site, permitted incineration facilities is only being retained for treatment of remediation residuals (e.g., concentrated organics).
	Infrared Thermal Incineration	High	Low	Low	No	See Fluidized Bed Incineration.
	Pyrolytic Incineration	Medium/High	Low	Low	No	See Fluidized Bed Incineration.
	Low Temperature Thermal Desorption	Medium	Medium	Medium	No	Appears effective for lower molecular weight organic contaminants such as diesel, and LPAH compounds. Effectiveness on HPAH compounds and pentachlorophenol unknown. Potential for dioxin formation.
	Asphalt Incorporation	Low/Medium	Medium	Medium/High	No	Typically only used for petroleum contaminated soils.
Physical Treatment	Soil Washing	Medium/High	Medium/High	Medium	Yes	Treatability studies established effectiveness for broad range of organic and inorganic contaminants present in site soils.
	Solidification/ Stabilization	Medium/High	Medium/High	Medium	Yes	Treatability studies established effectiveness for broad range of organic and inorganic contaminants present in site soils.
	Solvent Extraction	Low/Medium	Low/Medium	Low/Medium	No	Not demonstrated for suite of contaminants present at site.

Table 4-2

Remedial Technology Identification and Initial Screening- Soil

General Response Action	Process Option	Effectiveness[a]	Implementability	Cost-Effectiveness	Retained	Comments
Physical Treatment (continued)	Super-critical Fluid Extraction	Low/Medium	Low/Medium	Low	No	Not a proven technology for remediation of contaminated soils.
	Dewatering (various)	High	High	High	Yes	Likely technology type for alternatives involving treatment of saturated soils.
Chemical Treatment	Glycolate Dechlorination	Low	Medium	Low	No	Only applicable to halogenated organic contaminants (e.g., PCP); other contaminants unaffected.
	Oxidation/Reduction Processes	Low/Medium	Medium	Low/Medium	No	Not a proven technology type for soil treatment.
Volume Reduction	Soil Screening/Sieving	High	High	High	Yes	Likely component of alternatives that involve *ex situ* treatment of soils.
	Size Reduction	High	High	Medium/High	Yes	Possible component of alternatives that involve *ex situ* treatment of soils.
Removal	Excavation	High	High	Medium/High	Yes	Likely component of alternatives that involve *ex situ* treatment of soils.
Disposal	Off-site Landfill	Medium	Medium/High	Medium	Yes	May be limited due to RCRA land disposal restrictions.

[a] Effectiveness defined as ability to reduce risks posed by contaminated site soils via the primary exposure pathways (i.e., direct contact, inhalation, ingestion).

Table 4-3

Remedial Technology Identification and Initial Screening - Groundwater

General Response Action	Process Option	Effectiveness[a]	Implementability	Cost-Effectiveness	Retained	Comments
No Action	NA	NA	NA	NA	Yes	Retained to evaluate baseline or "no-action" alternative.
Institutional Controls	Groundwater monitoring	Low	High	High	Yes	Can be part of more comprehensive alternatives.
	Deed restrictions	Low	High	High	Yes	Can be part of more comprehensive alternatives.
Collection	Extraction wells	High	High	High	Yes	Can be used to remove contaminated groundwater and/or provide hydraulic control.
	Interception trenches	High	High	High	Yes	Can be used to remove contaminated groundwater and/or provide hydraulic control.
	Product Recovery	High	High	High	Yes	Can be used to extract "free product" directly from subsurface.
Ex Situ Treatment (Physical/Chemical)	Oil/water separation	Medium	High	High	Yes	Effective at removing "free product" from extracted groundwater. Likely part of a more extensive treatment train.
	Gravity settling	Medium	High	Medium/High	Yes	Effective at removing settleable solids from groundwater. Likely part of more extensive treatment train.
	Solids filtration	Medium	High	Medium	Yes	Depending on filter media used, can remove large percentage of particulates. Part of more extensive treatment train.
	Air stripping	Low	Medium	Medium	No	Ineffective for heavier organic contaminants (e.g., PAHs, PCP, fuel oils) and metals
	Steam stripping	Low/medium	Medium	Medium	No	Ineffective for heavier organic contaminants (e.g., PAHs, PCP, fuel oils) and metals

Table 4-3

Remedial Technology Identification and Initial Screening - Groundwater

General Response Action	Process Option	Effectiveness[a]	Implementability	Cost-Effectiveness	Retained	Comments
Ex Situ Treatment (continued)	Carbon adsorption	High	High	Medium	Yes	Very effective for organic compounds; ineffective for arsenic
	Ultrafiltration	Low	Medium	Low/Medium	No	Will require extensive pretreatment prior to ultrafiltration, at which point normal solids filtration technology and gravity settling will be as effective
	Ion Exchange	Low	Medium	Low	No	Ineffective for organic compounds
	Advanced Oxidation Processes	High	High	Medium	Yes	Potentially effective at treating wide range of organics in addition to metals
	Metals precipitation	High	High	Medium/High	Yes	Effective for treatment of dissolved metals; can also be effective at breaking chemical and physical emulsions
	Solvent extraction	Low/Medium	Low/Medium	Low	No	Not proven technology for contaminants present at site; typically produces significant quantity of treatment residuals.
Ex Situ Treatment (Biological)	Activated sludge	Low/Medium	Medium	Medium	No	Not applicable to metals; treatability study determined that bioremediation was ineffective for organic compounds of concern.
	Fixed bed	Low/Medium	Medium	Medium	No	See activated sludge.
	Sequencing batch reactor	Low/Medium	Medium	Medium	No	See activated sludge.
	Anaerobic digestion ??	Low/Medium	Low/Medium	Low/Medium	No	Not applicable to metals. Effectiveness of anaerobic biological process not well established at full-scale level, especially for organics present at site.

Table 4-3

Remedial Technology Identification and Initial Screening - Groundwater

General Response Action	Process Option	Effectiveness[a]	Implementability	Cost-Effectiveness	Retained	Comments
In situ Treatment	Vapor extraction	Low	Medium	Medium/High	No	Ineffective for heavier organic contaminants (e.g., PAHs, PCP, fuel oils) and metals
	Air sparging	Low	Medium	Medium	No	Ineffective for heavier organic contaminants (e.g., PAHs, PCP, fuel oils) and metals
	Biological treatment	Low/Medium	Low/Medium	Medium	No	See activated sludge. Also, difficult to install and monitor.
Containment	Groundwater extraction (i.e., hydraulic controls)	High	High	Medium	Yes	Effective at maintaining hydraulic control.
	Slurry wall	High	Medium	Medium	No	More costly and potentially more difficult to install than sheet-piling at this site.
	Sheet piling	High	High	High	Yes	Most applicable vertical containment technology for site conditions.
	Grout curtain	Medium	Medium	Low/Medium	No	Potentially less effective than, and more difficult to install, than either sheet piling
	Grout Injection	Low/Medium	Medium	Medium	Yes	Only technology for providing horizontal barrier beneath silt aquitard.

[a] Effectiveness defined as ability to reduce risks posed by contaminated groundwater via primary exposure pathways (i.e., discharge to surface water).

Table 4-4

Summary of Technologies Retained for Alternative Development

Retained Technologies by Media			
Soil	**Groundwater Control**	**Groundwater Treatment**	**Miscellaneous**
Institutional Controls-	Institutional Controls-	Oil/Water Separation	Rotary Kiln Incineration (Organic Liquids)
Access Restrictions	Groundwater Monitoring	Gravity Settling	Air Abatement Technologies
Land Use Restrictions	Deed Restrictions	Solids Filtration	Building Demolition
Containment-	Collection-	Carbon Adsorption	Decontamination Technologies
Asphalt/Concrete Cap	Extraction Wells	Advanced Oxidation Process-	
Geomembrane Cap	Interception Trenches	UV/Ozone	
In Situ Treatment-	Product Recovery	UV/Peroxide	
Soil Washing	Containment-	Ozone/Peroxide	
Ex Situ Treatment-	Groundwater Extraction (hydraulic control)	Metals Coagulation/Precipitation	
Rotary Kiln Incineration	Slurry Wall		
Soil Washing	Sheet Piling		
Solidification/Stabilization	Grout Injection		
Dewatering			
Volume Reduction			
Soil Screening/Sieving			
Size Reduction			
Removal			
Excavation			
Disposal (Off-site Landfill)			

Table 5-1

Preliminary Cleanup Action Alternative Development

		General Response Action												
		Soil								Groundwater				
		Deed Restrictions	Cap	Removal		Treatment/Disposal		Volume or Area Reduction	In Situ Treatment	Deed Restrictions/ Groundwater Monitoring	Vertical Containment	Hot Spot Soil Removal	Product Recovery	Recovery and Treatment
Cleanup Action Alternative				Hot-Spot	Total	On/On	On/Off							
No. 1	No action	X								X				
No. 2	Site-wide cap, product recovery, groundwater monitoring	X	X							X			X	
No. 3	Site-wide cap, product recovery, vertical containment for hot spot soil, groundwater monitoring	X	X							X	X		X	
No. 4	Excavation and consolidation of contaminated soil, cap, product recovery, vertical containment, groundwater monitoring	X	X					X		X	X		X	
No. 5	Site-wide cap, product recovery, groundwater recovery and treatment	X	X							X			X	X
No. 6	Hot-spot soil removal, stabilize excavated soil, site-wide cap, groundwater monitoring	X	X	X		X		X		X		X		
No.7	Excavate and stabilize all impacted soil, groundwater monitoring				X	X		X		X		X		
No. 8	Same as No. 7 except treat soil as necessary for off-site disposal				X		X	X		X		X		
No. 9	Same as No. 7 except add groundwater recovery and treatment				X	X		X		X		X		X
No. 10	In situ treatment (soil washing, stabilization), product recovery, groundwater monitoring	X							X	X			X	

Table 5-2

Preliminary Cleanup Action Screening

Preliminary Cleanup Action Alternative	Protectiveness		Implementability		Cost-Effectiveness		Retained for Further Consideration
	Short-Term	Long-Term	Technically	Administratively	Capital	O & M	
No. 1 No action	Low	Low	High	Low	Low	Low	Yes. Will be retained to provide baseline for cost comparisons in detailed analysis.
Containment Actions							
No. 2 Site-wide cap, product recovery, groundwater monitoring	High	Low-Medium	High	Low-Medium	High	High	Yes.
No. 3 Site-wide cap, product recovery, vertical containment of hot spot soil, groundwater monitoring	High	Medium	Medium-High	Medium	Medium	High	Yes.
No. 4 Excavation and consolidation of contaminated soil, cap, product recovery, vertical containment, groundwater monitoring	High	Medium	Medium-High	Medium-High	Medium	High	Yes.
No. 5 Site-wide cap, product recovery, groundwater recovery and treatment	High	High	High	Medium	Medium	Low	No. Although Alternative 4 is protective and implementable, pump and treat system will operate "forever" without source control.
Hot-Spot Removal/Source Control Actions							
No. 6 Hot-spot soil removal, stabilize excavated soil, site-wide cap, groundwater monitoring	Medium	Medium	Medium	High	Medium	High	Yes.

Table 5-2

Preliminary Cleanup Action Screening

Preliminary Cleanup Action Alternative	Protectiveness		Implementability		Cost-Effectiveness		Retained for Further Consideration
	Short-Term	Long-Term	Technically	Administratively	Capital	O & M	
"Total" Cleanup Actions							
No. 7 Excavate and stabilize all impacted soil, groundwater monitoring	Medium	High	Medium	High	Low-Medium	High	Yes.
No. 8 Same as Alternative 7, except treat soil as necessary for off-site disposal	Medium	High	Medium	Medium	Low-Medium	High	No. Off-site disposal not as preferable as on-site treatment; costs may also be higher depending on level of treatment required.
No. 9 Same as Alternative 7, except add groundwater recovery and treatment	Medium	High	Medium	Medium	Low	Medium-High	No. Nominal increase in protectiveness provided by groundwater pump and treat does not warrant large increase in cost.
In Situ Actions							
No. 10 In situ treatment (soil washing, stabilization), product recovery, groundwater monitoring	High	Medium	Low-Medium	Low-Medium	Medium	Medium	No.

Table 5-3

Cleanup Action Alternatives Retained for Detailed Analysis

Cleanup Action Alternative	Protectiveness		Implementability		Cost	
	Short-Term	Long-Term	Technically	Administratively	Capital	O&M
No. 1 No action	Low	Low	High	Low	Very Low	Very Low
Containment Actions						
No. 2 Site-wide cap, product recovery, groundwater monitoring	High	Low-Medium	High	Low-Medium	Low	Low
No. 3 Site-wide cap, product recovery, vertical containment of hot spot soil, groundwater monitoring	High	Medium	Medium-High	Medium	Medium	Medium-High
No. 4 Excavation and consolidation of contaminated soil, site-wide cap, product recovery, vertical containment, groundwater monitoring	High	Medium	Medium-High	Medium-High	Medium	Medium-High
Hot-Spot Removal/Source Control Actions						
No. 6 Hot-spot soil removal, stabilize excavated soil, site-wide cap, groundwater monitoring	Medium	Medium	Medium	High	Medium-High	Low
"Total" Cleanup Actions						
No. 8 Excavate and stabilize all impacted soil, groundwater monitoring	Medium	High	Medium	High	High	Low

Table 6-1

Construction and Operation and Maintenance Costs
Alternative 1 - No Action

Construction Costs					
ITEM	UNIT COST	UNITS	QUANTITY		COST
Monitoring Well Abandonment/Replacement					
a. Abandon Existing Shallow Monitoring Wells	$400	EA	35		$14,000
b. Abandon Existing Deep Monitoring Wells	$800	EA	10		$8,000
c. Install New Shallow Monitoring Wells	$2,000	EA	6		$12,000
b. Install New Deep Monitoring Wells	$4,000.00	EA	4		$16,000
Construction Cost Subtotal				$	50,000
Engineering (15%)				$	7,500
Construction Cost Contingency (20 %)				$	10,000
Subtotal				$	70,000
Taxes (7.2%)				$	5,000
Estimated Total Construction Costs				$	75,000

Operation and Maintenance Costs					
Activity		**Average Annual Cost**	**Length of Operation**		**PW[1] Project Lifetime**
Groundwater Monitoring (Biannual)	$	24,000	5 years	$	107,000
Groundwater Monitoring (Annual)	$	12,000	25 years	$	154,000
Groundwater Monitoring Reports	$	5,000	30 years	$	86,000
Monitoring Well Maintenance	$	2,000	30 years	$	35,000
O&M Costs Subtotal				$	380,000
O&M Cost Contingency (20 %)				$	80,000
Subtotal				$	460,000
Taxes (7.2%)				$	33,000
TOTAL ESTIMATED O&M PRESENT WORTH COST (1996 DOLLARS)				$	490,000
TOTAL ESTIMATED CONSTRUCTION PRESENT WORTH COST (1996 DOLLARS)				$	75,000
TOTAL ESTIMATED ALTERNATIVE 1 PRESENT WORTH COST (1996 DOLLARS)				$	570,000

[1] PW = present worth, calculated assuming a 4% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = annual cost
i = discount rate
n = number of years

For comparison purposes, the non-discounted O & M costs were also calculated using the same 30-year operational time frame as for the present worth calculations.

The estimated non-discounted O & M cost for this alternative is:	$	820,000
The total estimated cost for this alternative (construction plus non-discounted O & M) is:	$	900,000

Table 6-2

Construction and Operation and Maintenance Costs
Alternative 2 - Site-Wide Cap, Product Recovery, and Groundwater Monitoring

Construction Costs						
	ITEM	UNIT COST	UNITS	QUANTITY		COST
1	**Site Facilities and Preparation**	$25,000	LS	1		**$25,000**
2	**Foundation Leveling and Disposal**					
	a. Foundation Leveling	$50.00	CY	500		$25,000
	c. Imported Fill to Bring Site to Final Grade	$7.35	CY	3,000		$22,100
	Subtotal					**$47,000**
3	**Asphalt Cap**					
	a. Finish Grade Areas	$0.45	SY	35,900		$16,155
	b. Asphalt Treated Base (4")	$9.00	SY	35,900		$323,100
	c. Petromat with Tackcoat	$1.35	SY	35,900		$48,465
	d. Asphalt Wearing Course (2")	$6.00	SY	35,900		$215,400
	Subtotal					**$603,000**
4	**Product Recovery Wells**	$3,000	LS	4		**$12,000**
5	**Abandon/Replace Monitoring Wells**					
	(See Alternative 1)	$50,000	LS	1		$50,000
	Subtotal					**$50,000**
				Construction Cost Subtotal	**$**	**740,000**
				Engineering (15%)	$	111,000
				Construction Cost Contingency (20 %)	$	148,000
				Subtotal	**$**	**1,000,000**
				Taxes (7.2%)	$	72,000
				Estimated Total Construction Costs	**$**	**1,070,000**

Table 6-2

Construction and Operation and Maintenance Costs
Alternative 2 - Site-Wide Cap, Product Recovery, and Groundwater Monitoring

Operation and Maintenance Costs					
Activity		Average Annual Cost	Length of Operation		PW[1] Project Lifetime
Groundwater Monitoring (Biannual)	$	24,000	5 years	$	107,000
Groundwater Monitoring (Annual)	$	12,000	25 years	$	154,000
Groundwater Monitoring Reports	$	5,000	30 years	$	86,000
Monitoring Well Maintenance	$	2,000	30 years	$	35,000
Quarterly Product Recovery and Disposal	$	8,000	10 years	$	65,000
Annual Cap Inspection and Maintenance	$	1,000	30 years	$	17,000
Cap Resurfacing (Years 15 and 30)	$	225,000	NA	$	194,000
			O&M Costs Subtotal	**$**	**660,000**
			O&M Cost Contingency (20 %)	$	130,000
			Subtotal	$	790,000
			Taxes (7.2%)	$	57,000
TOTAL ESTIMATED O&M PRESENT WORTH COST (1996 DOLLARS)				**$**	**847,000**
TOTAL ESTIMATED CONSTRUCTION PRESENT WORTH COST (1996 DOLLARS)				**$**	**1,070,000**
TOTAL ESTIMATED ALTERNATIVE 2 PRESENT WORTH COST (1996 DOLLARS)				**$**	**1,920,000**

[1] PW = present worth, calculated assuming a 4% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = annual cost
i = discount rate
n = number of years

For comparison purposes, the non-discounted O & M costs were also calculated using the same 30-year operational time frame as for the present worth calculations.

The estimated non-discounted O & M cost for this alternative is:	$	**1,530,000**
The total estimated cost for this alternative (construction plus non-discounted O & M) is:	$	**2,600,000**

Table 6-3

Construction and Operation and Maintenance Costs
Alternative 3 - Site-Wide Cap, Vertical Containment, Product Recovery, and Groundwater Monitoring

Construction Costs					
ITEM		UNIT COST	UNITS	QUANTITY	COST
1	**Site Facilities and Preparation**	$50,000	LS	1	**$50,000**
2	**Foundation Leveling and Disposal**				
	a. Foundation Leveling	$50.00	CY	500	$25,000
	c. Imported Fill to Bring Site to Final Grade	$7.35	CY	3,000	$22,100
	Subtotal				**$47,000**
3	**Asphalt Cap**				
	a. Finish Grade Areas	$0.45	SY	36,700	$16,515
	b. Asphalt Treated Base (4")	$9.00	SY	36,700	$330,300
	c. Petromat with Tackcoat	$1.35	SY	36,700	$49,545
	d. Asphalt Wearing Course (2")	$6.00	SY	36,700	$220,200
	Subtotal				**$617,000**
4	**Product Recovery Wells**	$3,000	LS	4	**$12,000**
5	**Vertical Containment**				
	a. Field Investigation to Support Design	$20,000.00	LS	1	$20,000
	b. Low Permeability Sheet Piling	$20.00	SF	16,000	$320,000
	Subtotal				**$340,000**
6	**Abandon/Replace Monitoring Wells**				
	(See Alternative 1; two fewer shallow wells)	$46,000	LS	1	$46,000
	Subtotal				**$46,000**
				Construction Cost Subtotal	**$ 1,110,000**
				Engineering (15%)	$ 166,500
				Construction Cost Contingency (20 %)	$ 222,000
				Subtotal	**$ 1,500,000**
				Taxes (7.2 %)	$ 108,000
				Estimated Total Construction Costs	**$ 1,610,000**

Table 6-3

Construction and Operation and Maintenance Costs Alternative 3 - Site-Wide Cap, Vertical Containment, Product Recovery, and Groundwater Monitoring

Operation and Maintenance Costs					
Activity		Average Annual Cost	Length of Operation		PW[1] Project Lifetime
Groundwater Monitoring (Biannual)	$	24,000	5 years	$	107,000
Groundwater Monitoring (Annual)	$	12,000	25 years	$	154,000
Groundwater Monitoring Reports	$	5,000	30 years	$	86,000
Monitoring Well Maintenance	$	2,000	30 years	$	35,000
Quarterly Product Recovery and Disposal	$	8,000	10 years	$	65,000
Annual Cap Inspection and Maintenance	$	1,000	30 years	$	17,000
Cap Resurfacing (Years 15 and 30)	$	225,000	NA	$	194,000
			O&M Costs Subtotal	**$**	**660,000**
			O&M Cost Contingency (20 %)	$	130,000
			Subtotal	$	790,000
			Taxes (7.2%)	$	57,000
TOTAL ESTIMATED O&M PRESENT WORTH COST (1996 DOLLARS)				**$**	**847,000**
TOTAL ESTIMATED CONSTRUCTION PRESENT WORTH COST (1996 DOLLARS)				**$**	**1,610,000**
TOTAL ESTIMATED ALTERNATIVE 3 PRESENT WORTH COST (1996 DOLLARS)				**$**	**2,460,000**

[1] PW = present worth, calculated assuming a 4% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = annual cost
i = discount rate
n = number of years

For comparison purposes, the non-discounted O & M costs were also calculated using the same 30-year operational time frame as for the present worth calculations.

The estimated non-discounted O & M cost for this alternative is:	**$**	**1,530,000**
The total estimated cost for this alternative (construction plus non-discounted O & M) is:	**$**	**3,140,000**

Table 6-4

Construction and Operation and Maintenance Costs
Alternative 4 - Soil Consolidation, Asphalt Cap, Vertical Containment, Product Recovery, and Groundwater Monitoring

	ITEM	UNIT COST	UNITS	QUANTITY	COST
	Construction Costs				
1	**Site Facilities and Preparation**	$50,000	LS	1	**$50,000**
2	**Foundation Leveling and Disposal** (see Alternative 2)	$47,000.00	LS	1	**$47,000**
3	**Soil Consolidation**				
	a. Excavate Unsaturated Soil	$2.60	CY	14,240	$37,000
	b. Screen and Wash Fill	$15.00	CY	10,370	$155,600
	c. Excavate Saturated Soil	$5.60	CY	400	$2,200
	d. Temporary sheet piling	$12.00	SF	3,000	$36,000
	e. Haul and Place Soil Inside Containment	$4.35	CY	9,055	$39,400
	f. Confirmation Testing	$50,000	LS	1	$50,000
	g. Backfill Washed Oversize Material	$4.35	CY	5,185	$22,600
	h. Backfll to grade with Imported Soil	$7.35	CY	9,055	$66,600
	f. Water Management	$40,000	LS	1	$40,000
	Subtotal				**$449,400**
4	**Asphalt Cap**				
	a. Finish Grade Areas	$0.45	SY	21,300	$9,600
	b. Asphalt Treated Base (4")	$9.00	SY	21,300	$191,700
	c. Petromat with Tackcoat	$1.35	SY	21,300	$28,800
	d. Asphalt Wearing Course (2")	$6.00	SY	21,300	$127,800
	Subtotal				**$358,000**
5	**Product Recovery Wells**	$3,000	LS	4	**$12,000**
6	**Vertical Containment**				
	a. Field Investigation to Support Design	$20,000.00	LS	1	$20,000
	b. Low Permeability Sheet Piling	$20.00	SF	17,000	$340,000
	Subtotal				**$360,000**
7	**Abandon/Replace Monitoring Wells** (See Alternative 1; three fewer shallow wells)	$44,000	LS	1	**$44,000**
				Construction Cost Subtotal	**$ 1,320,000**
				Engineering (15%)	$ 198,000
				Construction Cost Contingency (20 %)	$ 264,000
				Subtotal	**$ 1,780,000**
				Taxes (7.2%)	$ 128,000
				Estimated Total Construction Costs	**$ 1,910,000**

Table 6-4

Construction and Operation and Maintenance Costs
Alternative 4 - Soil Consolidation, Asphalt Cap, Vertical Containment, Product Recovery, and Groundwater Monitoring

Operation and Maintenance Costs					
Activity		Average Annual Cost	Length of Operation		PW[1] Project Lifetime
Groundwater Monitoring (Biannual)	$	24,000	5 years	$	107,000
Groundwater Monitoring (Annual)	$	12,000	25 years	$	154,000
Groundwater Monitoring Reports	$	5,000	30 years	$	86,000
Monitoring Well Maintenance	$	2,000	30 years	$	35,000
Quarterly Product Recovery and Disposal	$	8,000	10 years	$	65,000
Annual Cap Inspection and Maintenance	$	1,000	30 years	$	17,000
Cap Resurfacing (Years 15 and 30)	$	135,000	NA	$	117,000
			O&M Costs Subtotal	**$**	**581,000**
			O&M Cost Contingency (20 %)	$	120,000
			Subtotal	**$**	**700,000**
			Taxes (7.2%)	$	50,000
TOTAL ESTIMATED O&M PRESENT WORTH COST (1996 DOLLARS)				**$**	**750,000**
TOTAL ESTIMATED CONSTRUCTION PRESENT WORTH COST (1996 DOLLARS)				**$**	**1,910,000**
TOTAL ESTIMATED ALTERNATIVE 4 PRESENT WORTH COST (1996 DOLLARS)				**$**	**2,660,000**

[1] PW = present worth, calculated assuming a 4% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = annual cost
i = discount rate
n = number of years

For comparison purposes, the non-discounted O & M costs were also calculated using the same 30-year operational time frame as for the present worth calculations.

The estimated non-discounted O & M cost for this alternative is:	$	1,300,000
The total estimated cost for this alternative (construction plus non-discounted O & M) is:	$	3,210,000

Table 6-5

Construction and Operation and Maintenance Costs
Alternative 6 - Hot Spot Soil Removal and Stabilization, Asphalt Cap, Vertical Containment, and Groundwater Monitoring

Construction Costs					
	ITEM	UNIT COST	UNITS	QUANTITY	COST
1	**Site Facilities and Preparation**	$75,000	LS	1	**$75,000**
2	**Foundation Demolition and Disposal**				
	(see Alternative 2)	$47,000.00	LS	1	**$47,000**
3	**Hot Spot Soil Excavation**				
	a. Sheet Piling	$12.00	SF	60,000	$720,000
	b. Excavate/Haul Unsaturated Hot Spot Soil	$5.00	CY	7,880	$39,400
	c. Excavate/Haul Saturated Hot Spot Soil	$8.00	CY	12,450	$99,600
	d. Excavate Non-Hot Spot Soil (Overburden)	$5.00	CY	5,000	$25,000
	e. Screen Excavated Soils	$15.00	CY	5,000	$75,000
	Subtotal				**$959,000**
4	**Silt Stabilization (Blow Pit Area Only)**				
	a. Extraction Well Installation and Testing	$150,000	LS	1	$150,000
	b. Groundwater Extraction and Discharge	$100,000	LS	1	$100,000
	Subtotal				**$250,000**
5	**Excavation Dewatering (Upper Sand)**				
	a. Water Treatment Equipment	$300,000	LS	1	$300,000
	b. Water Treatment	$0.10	Gal	1,000,000	$100,000
	Subtotal				**$400,000**
6	**Stabilize Excavated Hot Spot Soil**	$200	CY	18,000	**$3,600,000**
7	**Soil Replacement and Compaction**				
	a. Imported Fill to High Water Elevation	$7.35	CY	12450	$92,000
	b. Replace Stabilized Soil	$2.00	CY	25,200	$50,000
	Subtotal				**$142,000**
8	**Asphalt Cap**				
	a. Finish Grade Areas	$0.45	SY	36,700	$16,515
	b. Asphalt Treated Base (4")	$9.00	SY	36,700	$330,300
	c. Petromat with Tackcoat	$1.35	SY	36,700	$49,545
	d. Asphalt Wearing Course (2")	$6.00	SY	36,700	$220,200
	Subtotal				**$616,560**
9	**Analytical Support**	$250,000	LS	1	**$250,000**
10	**Abandon/Replace Monitoring Wells**				
	(See Alternative 1; two fewer shallow wells)	$46,000	LS	1	**$46,000**

Construction Cost Subtotal	**$**	**6,390,000**
Engineering (5%)	$	319,500
Construction Cost Contingency (20 %)	$	1,278,000
Subtotal	**$**	**7,990,000**
Taxes (7.2%)	$	575,000
Estimated Total Construction Costs	**$**	**8,570,000**

Table 6-5

Construction and Operation and Maintenance Costs
Alternative 6 - Hot Spot Soil Removal and Stabilization, Asphalt Cap, Vertical Containment, and Groundwater Monitoring

Operation and Maintenance Costs					
Activity		**Average Annual Cost**	**Length of Operation**		**PW[1] Project Lifetime**
Groundwater Monitoring (Biannual)	$	24,000	5 years	$	107,000
Groundwater Monitoring (Annual)	$	12,000	25 years	$	154,000
Groundwater Monitoring Reports	$	5,000	30 years	$	86,000
Monitoring Well Maintenance	$	2,000	30 years	$	35,000
Annual Cap Inspection and Maintenance	$	1,000	30 years	$	17,000
Cap Resurfacing (Years 15 and 30)	$	230,000	NA	$	199,000
			O&M Costs Subtotal	**$**	**600,000**
			O&M Cost Contingency (20 %)	$	120,000
			Subtotal	**$**	**720,000**
			Taxes (7.2%)	$	52,000
TOTAL ESTIMATED O&M PRESENT WORTH COST (1996 DOLLARS)				**$**	**772,000**
TOTAL ESTIMATED CONSTRUCTION PRESENT WORTH COST (1996 DOLLARS)				**$**	**8,570,000**
TOTAL ESTIMATED ALTERNATIVE 6 PRESENT WORTH COST (1996 DOLLARS)				**$**	**9,340,000**

[1] PW = present worth, calculated assuming a 4% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = annual cost
i = discount rate
n = number of years

For comparison purposes, the non-discounted O & M costs were also calculated using the same 30-year operational time frame as for the present worth calculations.

The estimated non-discounted O & M cost for this alternative is:	$	**1,440,000**
The total estimated cost for this alternative (construction plus non-discounted O & M) is:	$	**10,010,000**

Table 6-6

Construction and Operation and Maintenance Costs
Alternative 7 - Excavate and Stabilize all Impacted Soil and Groundwater Monitoring

Construction Costs					
ITEM		UNIT COST	UNITS	QUANTITY	COST
1	**Site Facilities and Preparation**	$75,000	LS	1	**$75,000**
2	**Foundation Demolition and Disposal**				
	(see Alternative 2)	$47,000.00	LS	1	$47,000
	Subtotal				**$47,000**
3	**Soil Excavation**				
	a. Sheet Piling	$12.00	SF	60,000	$720,000
	b. Excavate/Haul Unsaturated Hot Spot Soil	$5.00	CY	31,450	$157,250
	c. Excavate/Haul Saturated Hot Spot Soil	$8.00	CY	12,450	$99,600
	d. Excavate Non-Hot Spot Soil (Overburden)	$5.00	CY	5,000	$25,000
	e. Screen Excavated Soils	$15.00	CY	14,900	$223,500
	Subtotal				**$1,230,000**
4	**Silt Stabilization (Blow Pit Area Only)**				
	a. Extraction Well Installation and Testing	$150,000	LS	1	$150,000
	b. Groundwater Extraction and Discharge	$100,000	LS	1	$100,000
	Subtotal				**$250,000**
5	**Excavation Dewatering (Upper Sand)**				
	a. Water Treatment Equipment	$300,000	LS	1	$300,000
	b. Water Treatment	$0.10	Gal	1,000,000	$100,000
	Subtotal				**$400,000**
6	**Stabilize Excavated Soil**	$200	CY	36,450	**$7,290,000**
7	**Soil Replacement and Compaction**				
	a. Imported Fill to High Water Elevation	$7.35	CY	12,450	$92,000
	b. Replace Stabilized Soil	$2.00	CY	51,030	$102,000
	Subtotal				**$194,000**
8	**Analytical Support**	$300,000	LS	1	**$300,000**
9	**Abandon/Replace Monitoring Wells**				
	(See Alternative 1; two fewer shallow wells)	$46,000	LS	1	**$46,000**
				Construction Cost Subtotal	**$ 9,790,000**
				Engineering (5%)	$ 489,500
				Construction Cost Contingency (20 %)	$ 1,958,000
				Subtotal	**$ 12,240,000**
				Taxes (7.2%)	$ 881,000
				Estimated Total Construction Costs	**$ 13,120,000**

Table 6-6

Construction and Operation and Maintenance Costs
Alternative 7 - Excavate and Stabilize all Impacted Soil and Groundwater Monitoring

Operation and Maintenance Costs					
Activity		**Average Annual Cost**	**Length of Operation**		**PW[1] Project Lifetime**
Groundwater Monitoring (Biannual)	$	24,000	5 years	$	107,000
Groundwater Monitoring (Annual)	$	12,000	25 years	$	154,000
Groundwater Monitoring Reports	$	5,000	30 years	$	86,000
Monitoring Well Maintenance	$	2,000	30 years	$	35,000
			O&M Costs Subtotal	**$**	**382,000**
			O&M Cost Contingency (20 %)	$	80,000
			Subtotal	**$**	**462,000**
			Taxes (7.2%)	$	33,000
TOTAL ESTIMATED O&M PRESENT WORTH COST (1996 DOLLARS)				**$**	**495,000**
TOTAL ESTIMATED CONSTRUCTION PRESENT WORTH COST (1996 DOLLARS)				**$**	**13,120,000**
TOTAL ESTIMATED ALTERNATIVE 7 PRESENT WORTH COST (1996 DOLLARS)				**$**	**13,620,000**

[1] PW = present worth, calculated assuming a 4% discount rate using the average annual cost and years of operation indicated in the following formula:

$$PW = A\frac{(1+i)^n - 1}{i(1+i)^n}$$

where A = annual cost
i = discount rate
n = number of years

For comparison purposes, the non-discounted O & M costs were also calculated using the same 30-year operational time frame as for the present worth calculations.

The estimated non-discounted O & M cost for this alternative is:	**$**	**820,000**
The total estimated cost for this alternative (construction plus non-discounted O & M) is:	**$**	**13,940,000**

FIGURES

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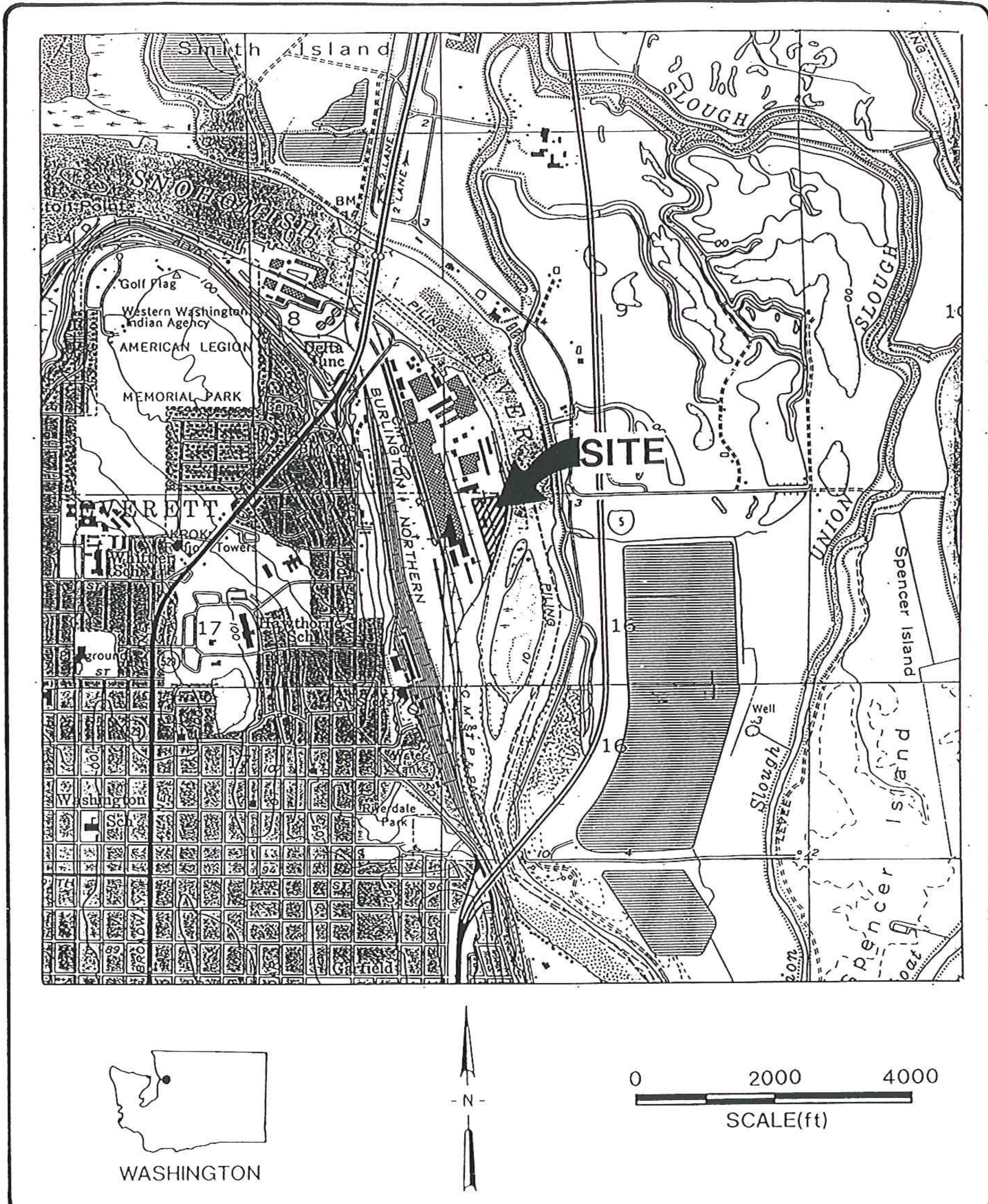

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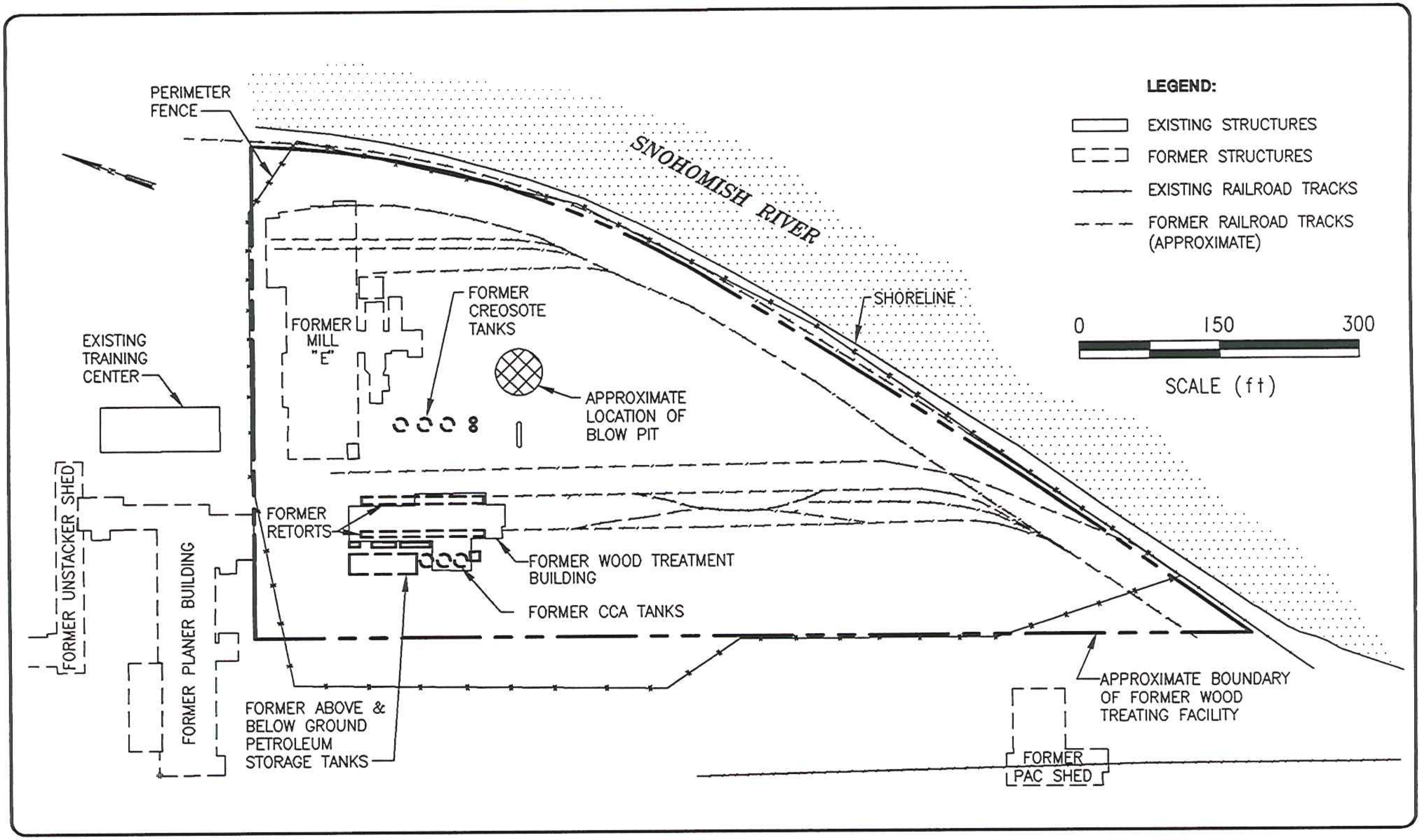
Figure 2-1
WEYERHAEUSER COMPANY
FORMER MILL E / KOPPERS FACILITY
EVERETT, WASHINGTON

SITE LOCATION MAP



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PROJECT NO.
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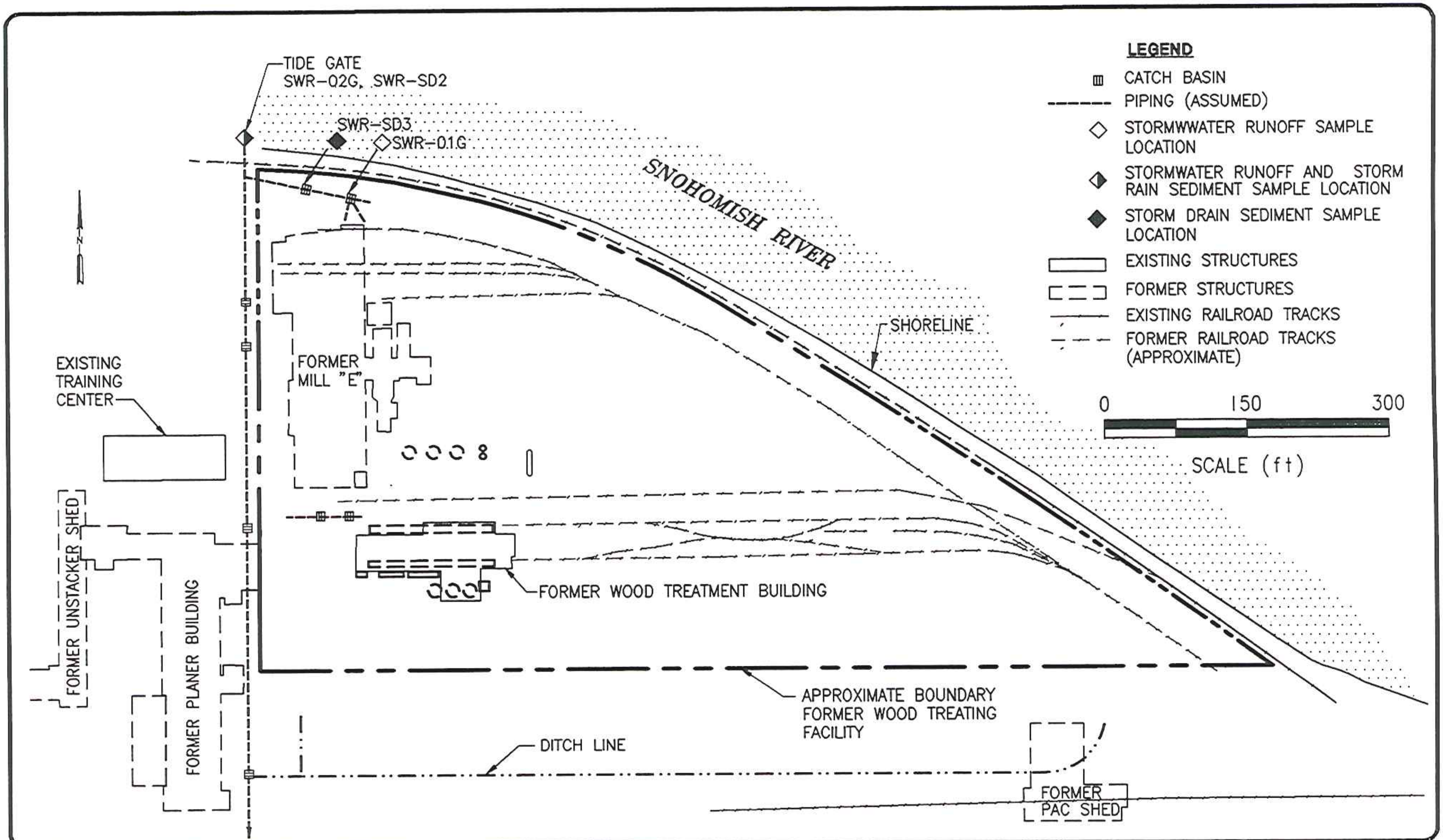
Figure 2-2
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

SITE MAP

1= 150 01-07-97 G:\DWG\40141037\BO109N15



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40141-037.109

Figure 2-3
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
STORMWATER CONVEYANCE STRUCTURES AND SAMPLING LOCATIONS

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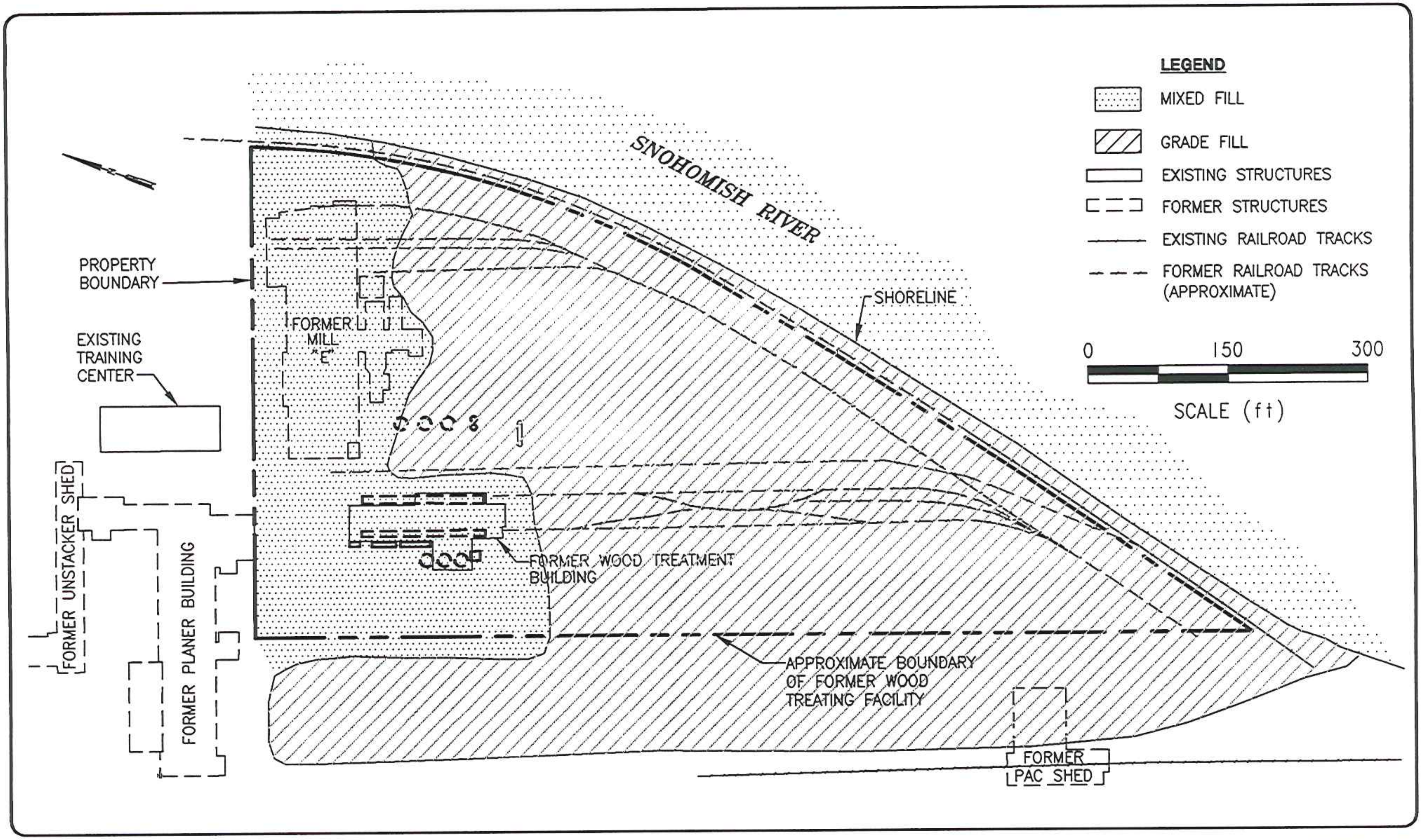

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Figure 2-4
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

EXTENT OF GRADE FILL AND MIXED FILL

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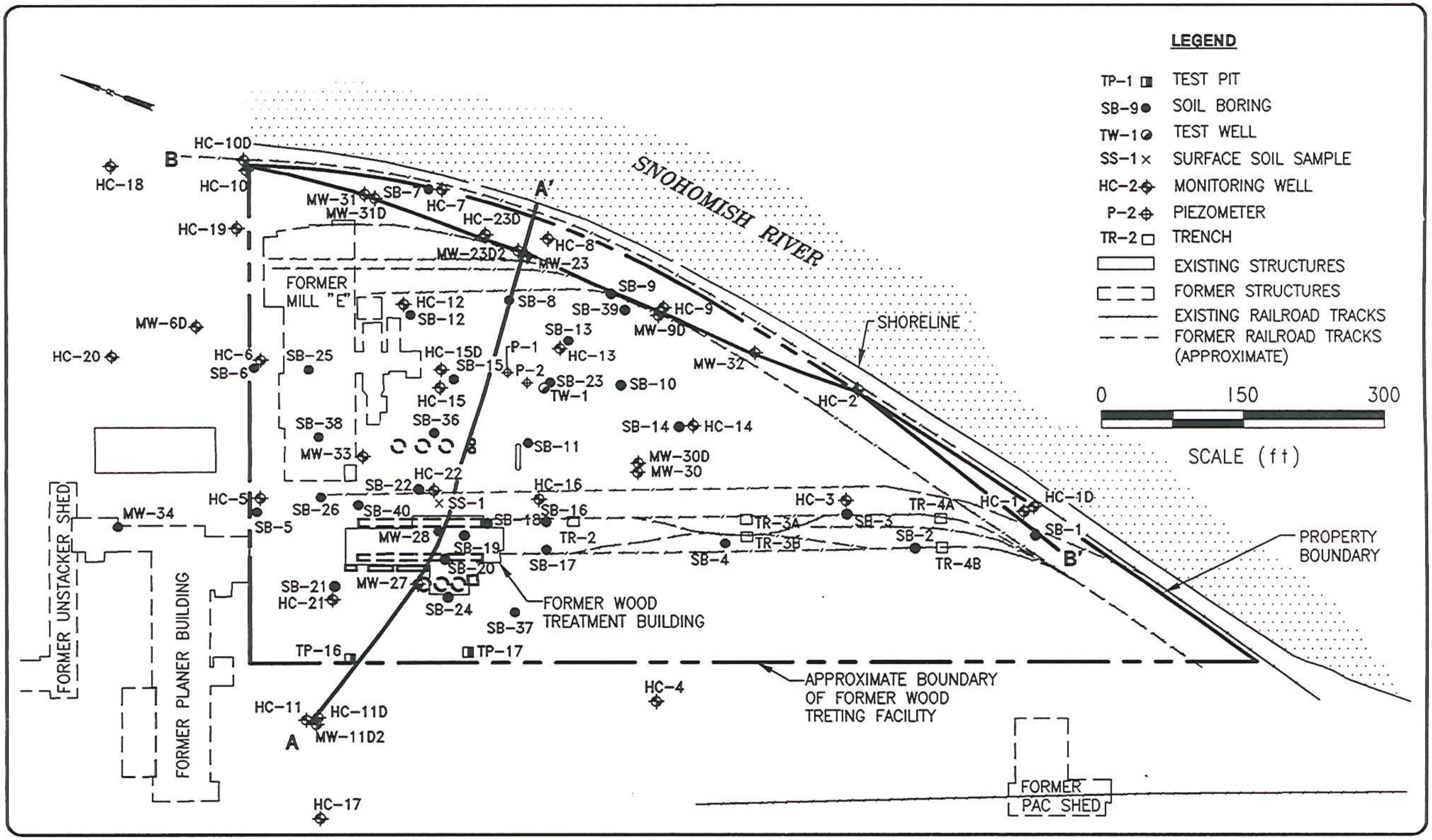

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Figure 2-5
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

CROSS SECTION LOCATION MAP

1= 150 01-07-96 G:\DWG\40141037\B0109N22

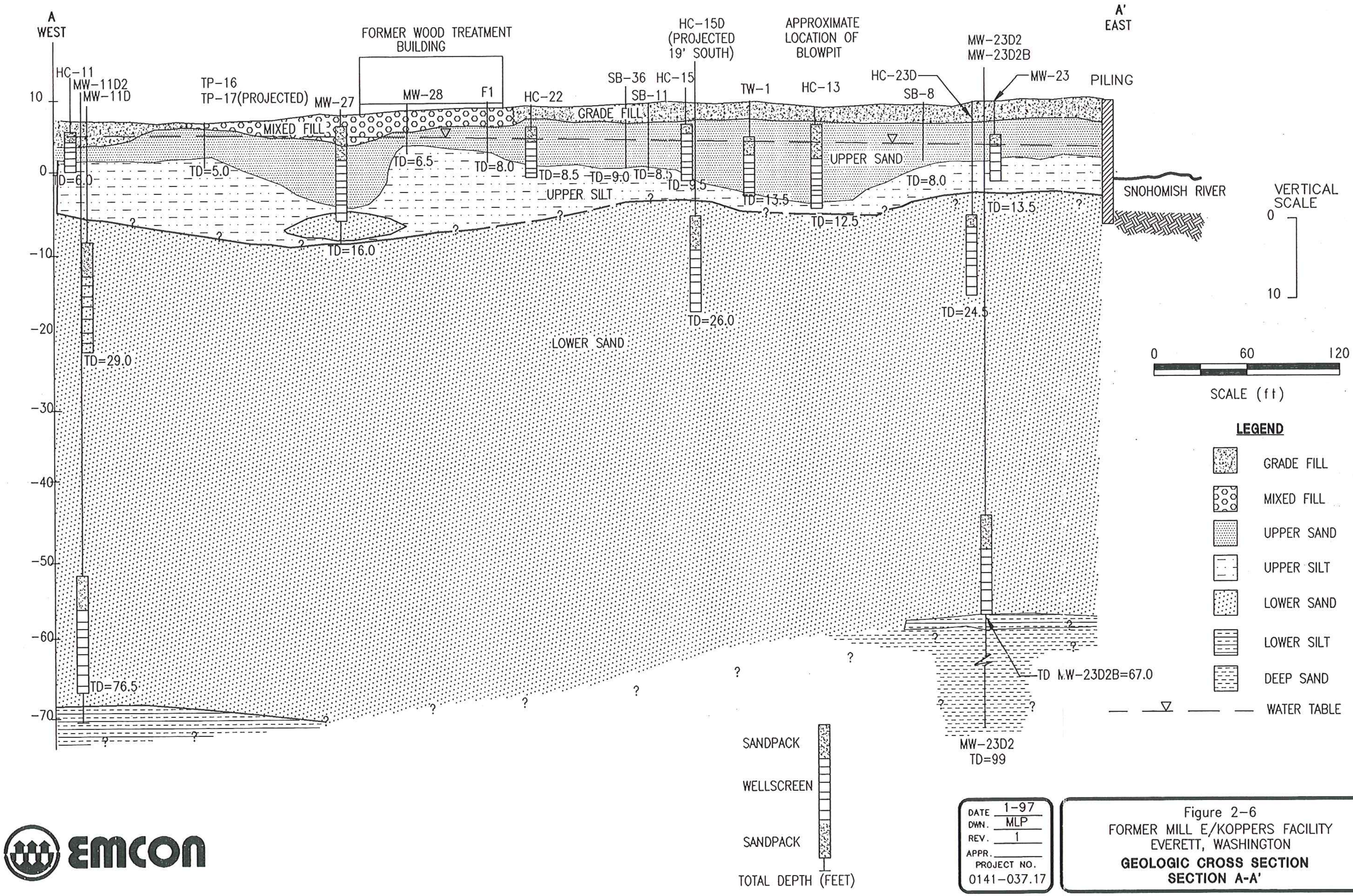

Figure 2-6
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
GEOLOGIC CROSS SECTION
SECTION A-A'

1= 60 5-17-94 g:\dwg\40141037\B0109N27

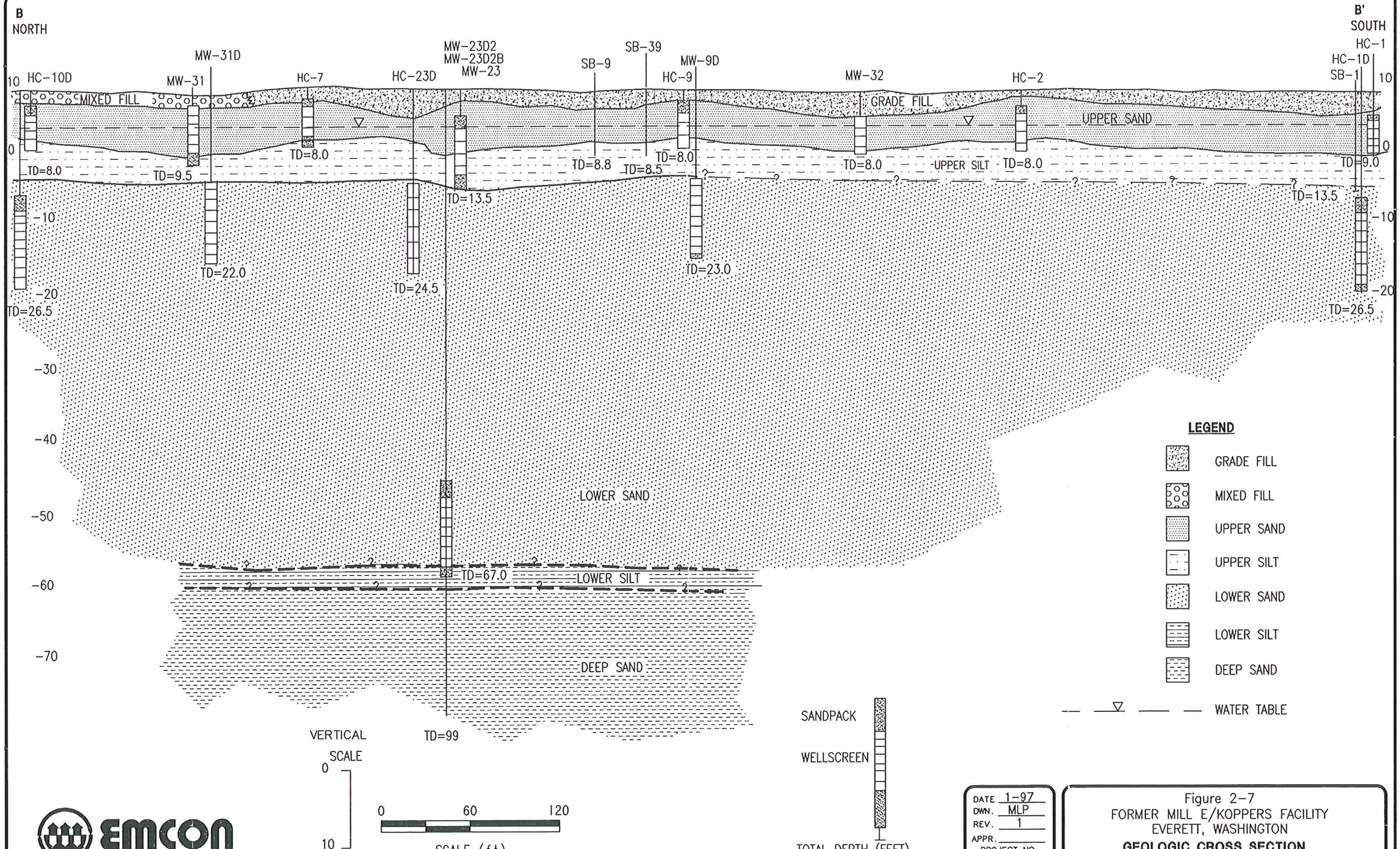

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Figure 2-7
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
GEOLOGIC CROSS SECTION
SECTION B-B'

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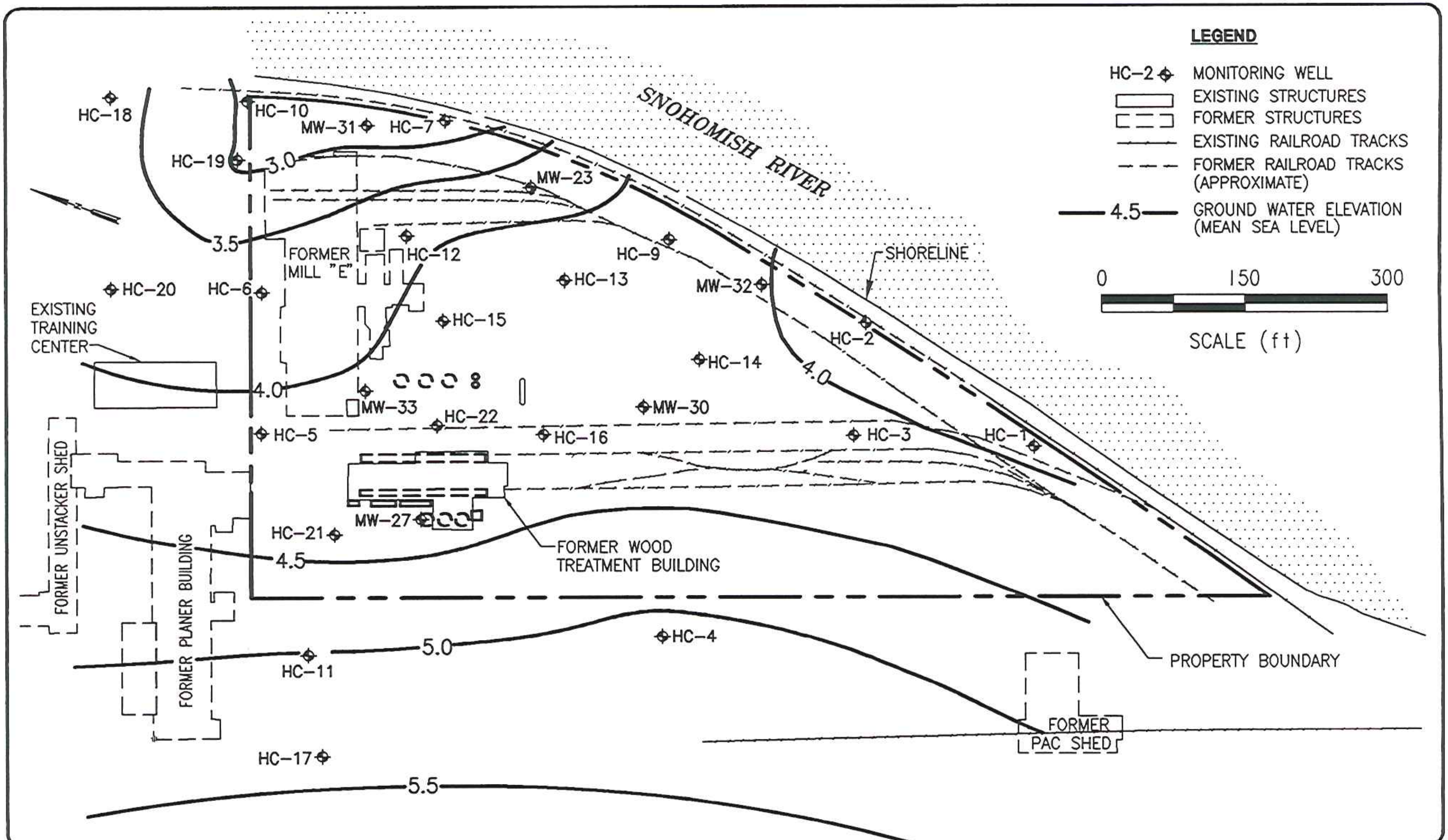

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Figure 2-8
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

GROUNDWATER ELEVATIONS
UPPER SAND AQUIFER - JULY 1992

1= 150 01-07-96 G:\DWG\0141037\B0109N21

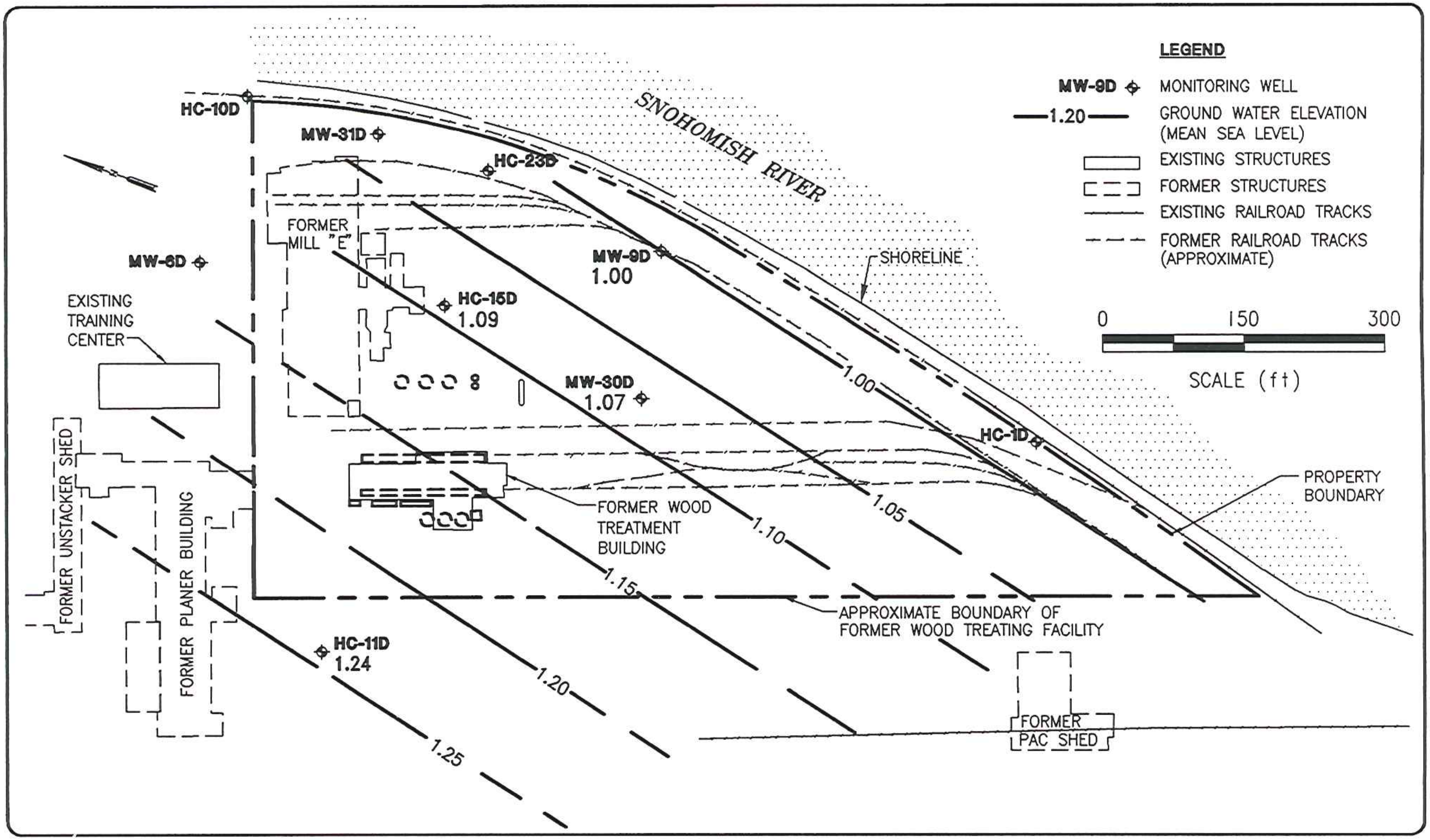

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Figure 2-9
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
GROUNDWATER ELEVATIONS-LOWER SAND AQUIFER
NOVEMBER 1992
NET ELEVATIONS CORRECTED FOR TIDAL INFLUENCE

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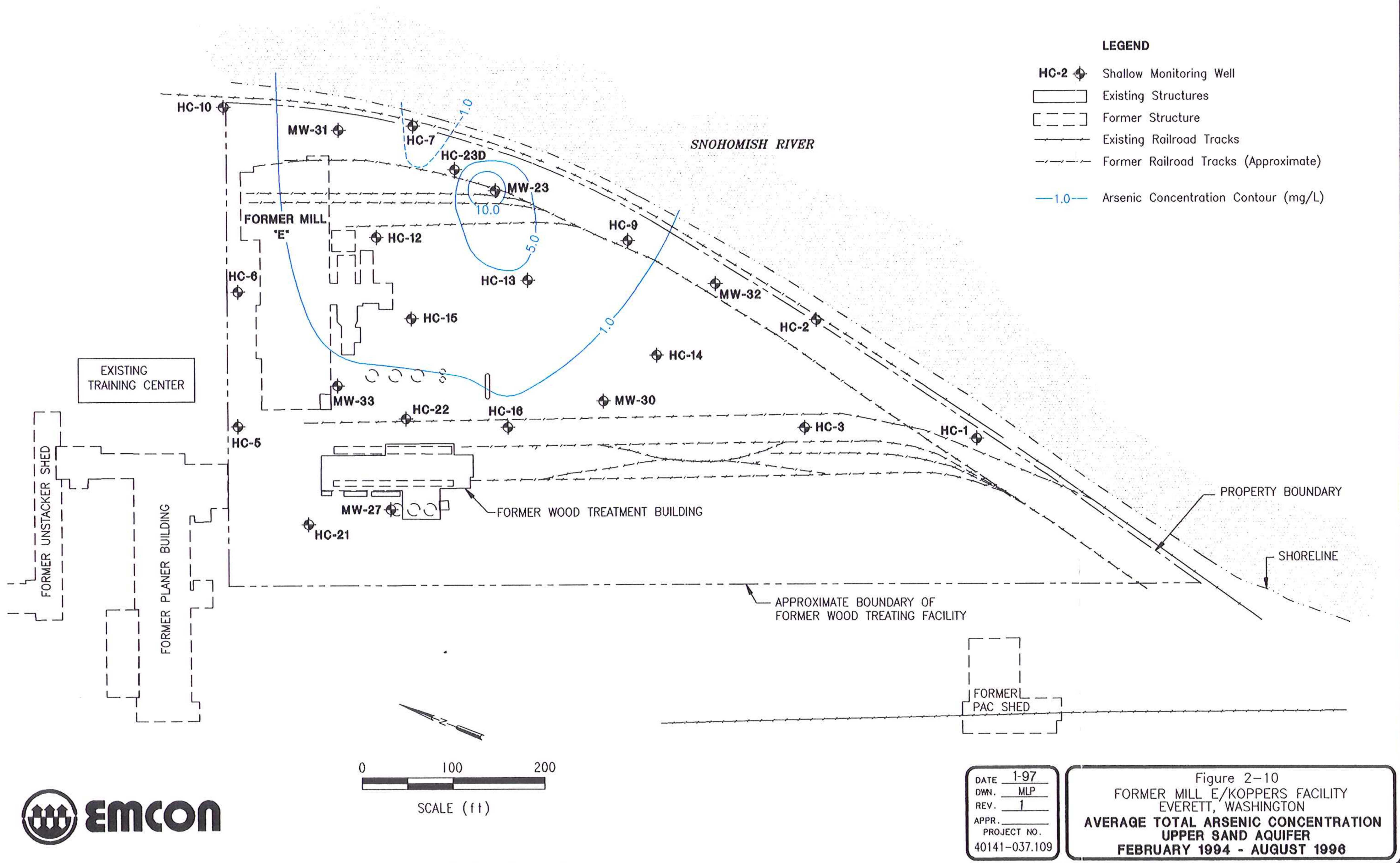

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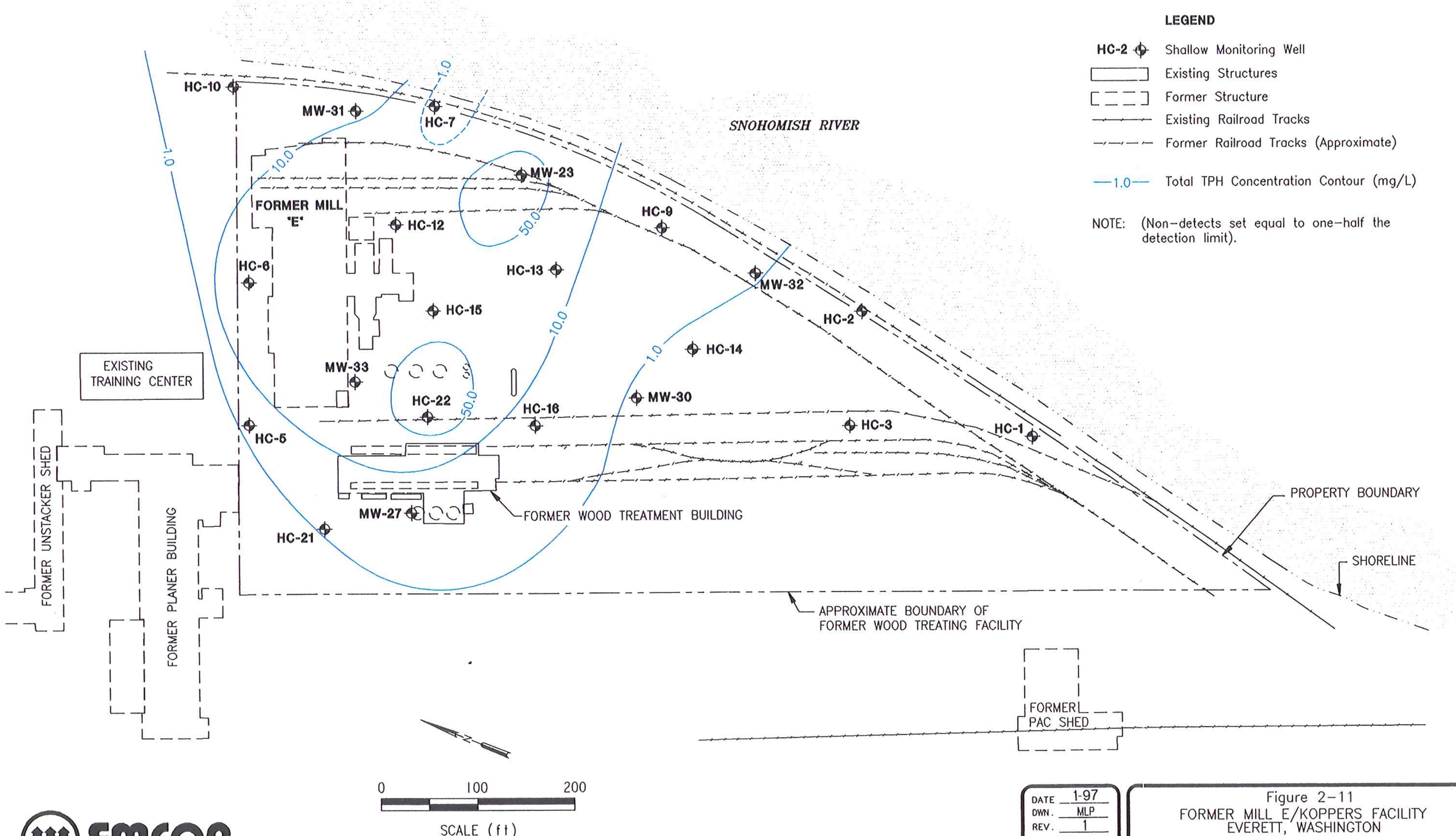
Figure 2-10
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

AVERAGE TOTAL ARSENIC CONCENTRATION
UPPER SAND AQUIFER
FEBRUARY 1994 - AUGUST 1996

1= 100 11-18-96 G:\DWG\40141037\BO109N05



EMCON

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Figure 2-11
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
AVERAGE TOTAL TPH CONCENTRATION
UPPER SAND AQUIFER
FEBRUARY 1994 - AUGUST 1996

1= 100 11-18-96 G:\DWG\40141037\B0109N04

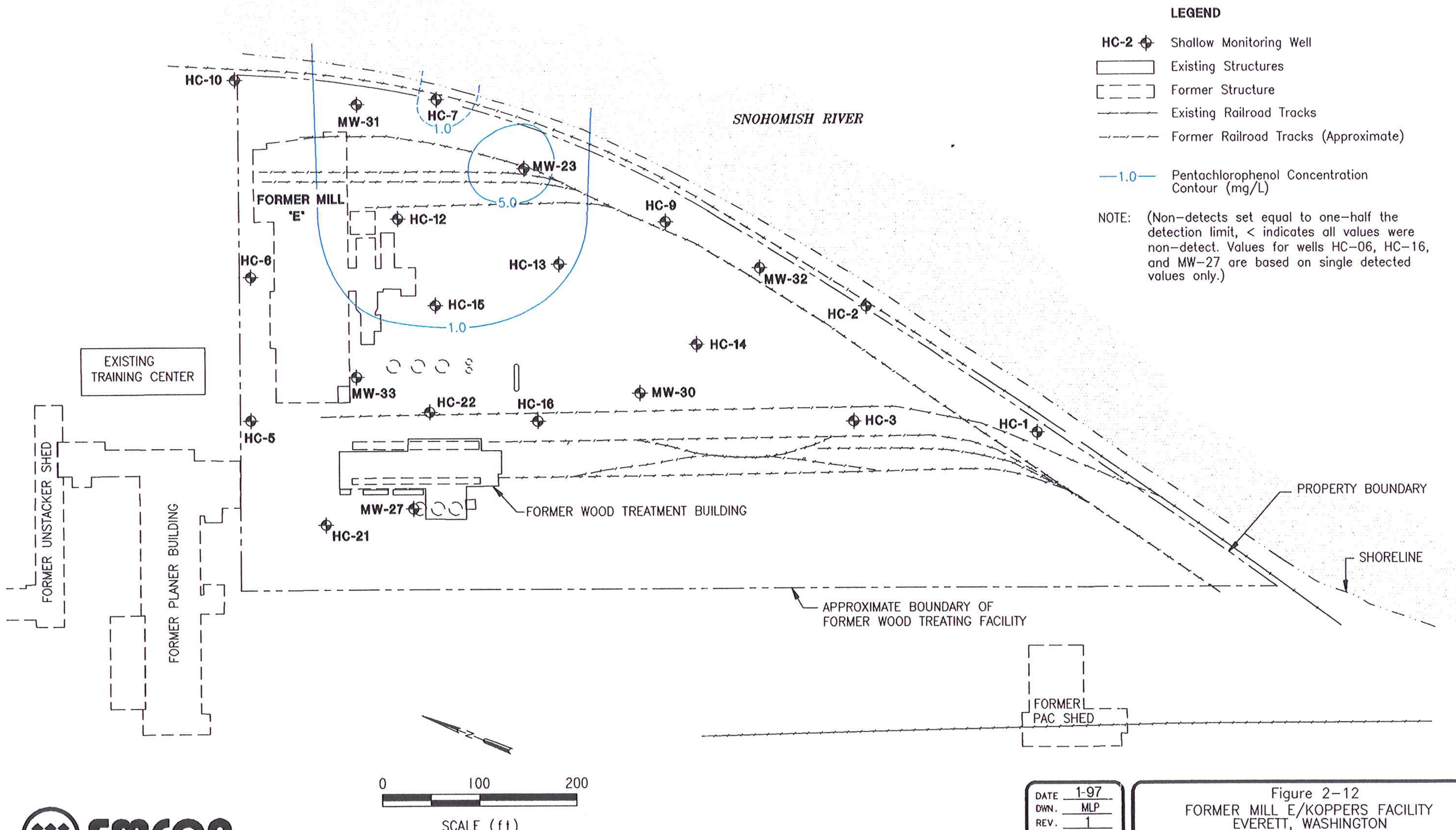

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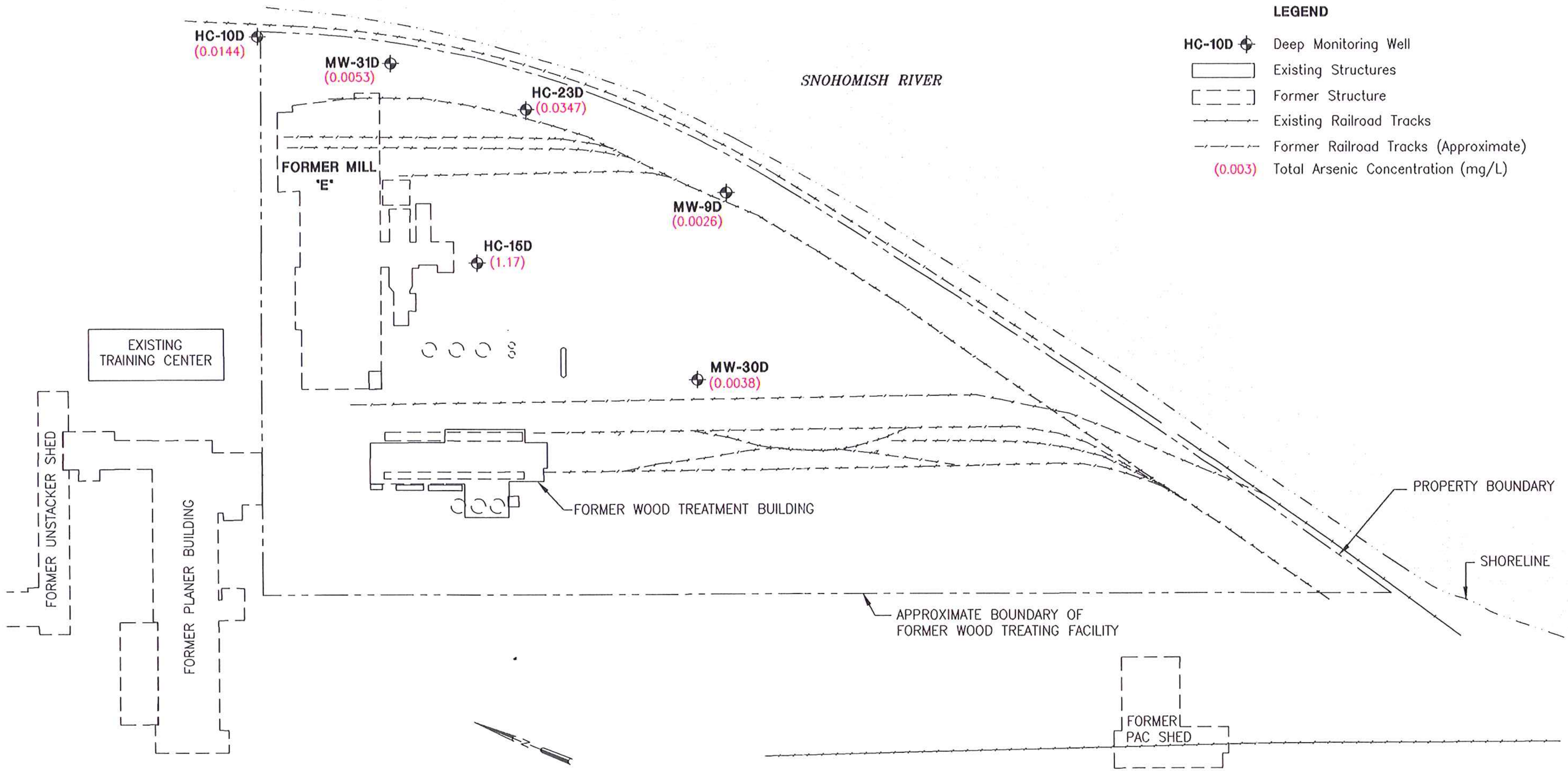
Figure 2-12
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
AVERAGE PENTACHLOROPHENOL CONCENTRATION
UPPER SAND AQUIFER
FEBRUARY 1994 - AUGUST 1996

1= 100 11-18-96 G:\DWG\40141037\B0109N07



0 100 200

SCALE (ft)

EMCON

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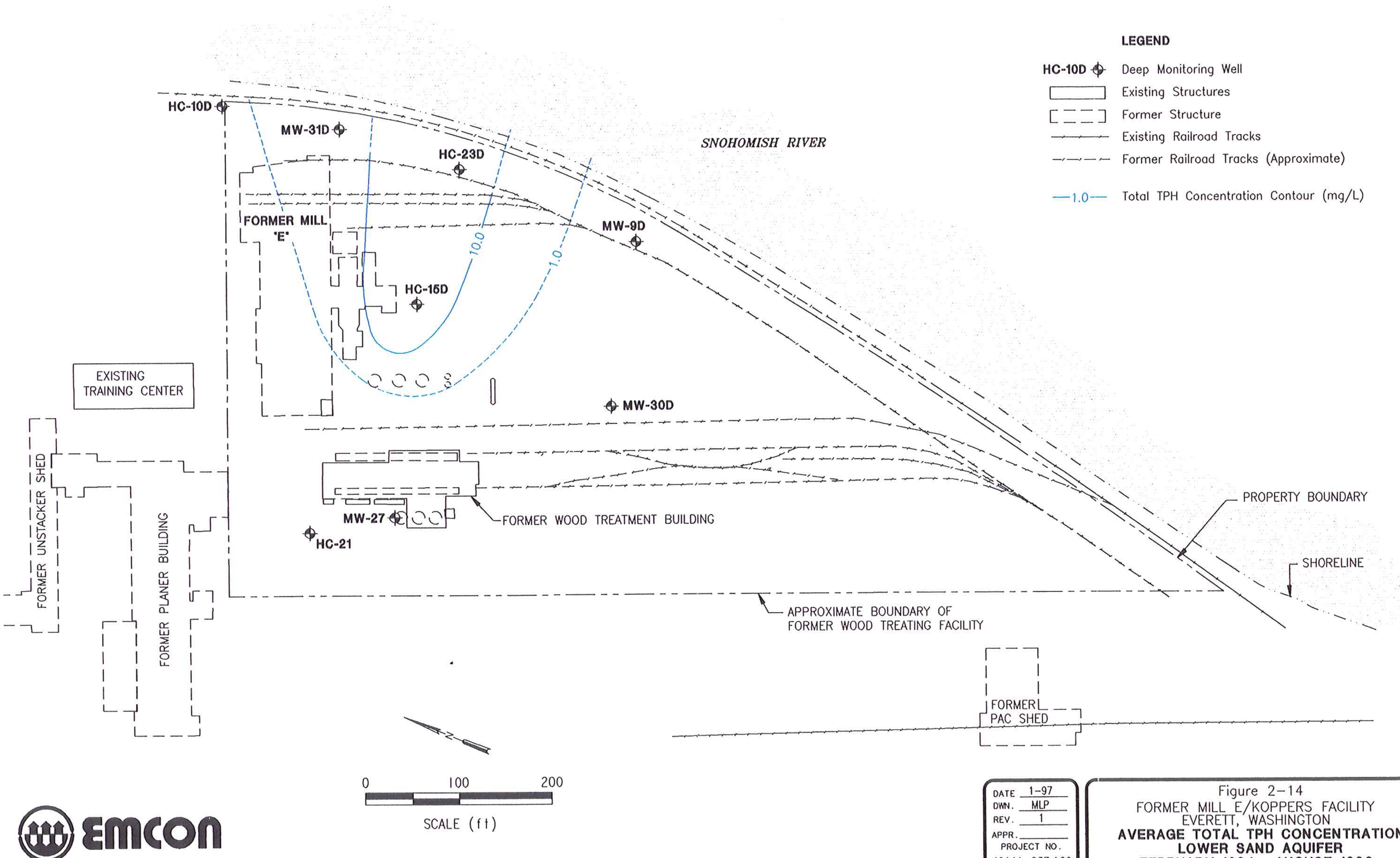
Figure 2-13
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
AVERAGE TOTAL ARSENIC CONCENTRATIONS
LOWER SAND AQUIFER
FEBRUARY 1994 - AUGUST 1996

1= 100 2-21-97 G:\DWG\40141037\B0109N08



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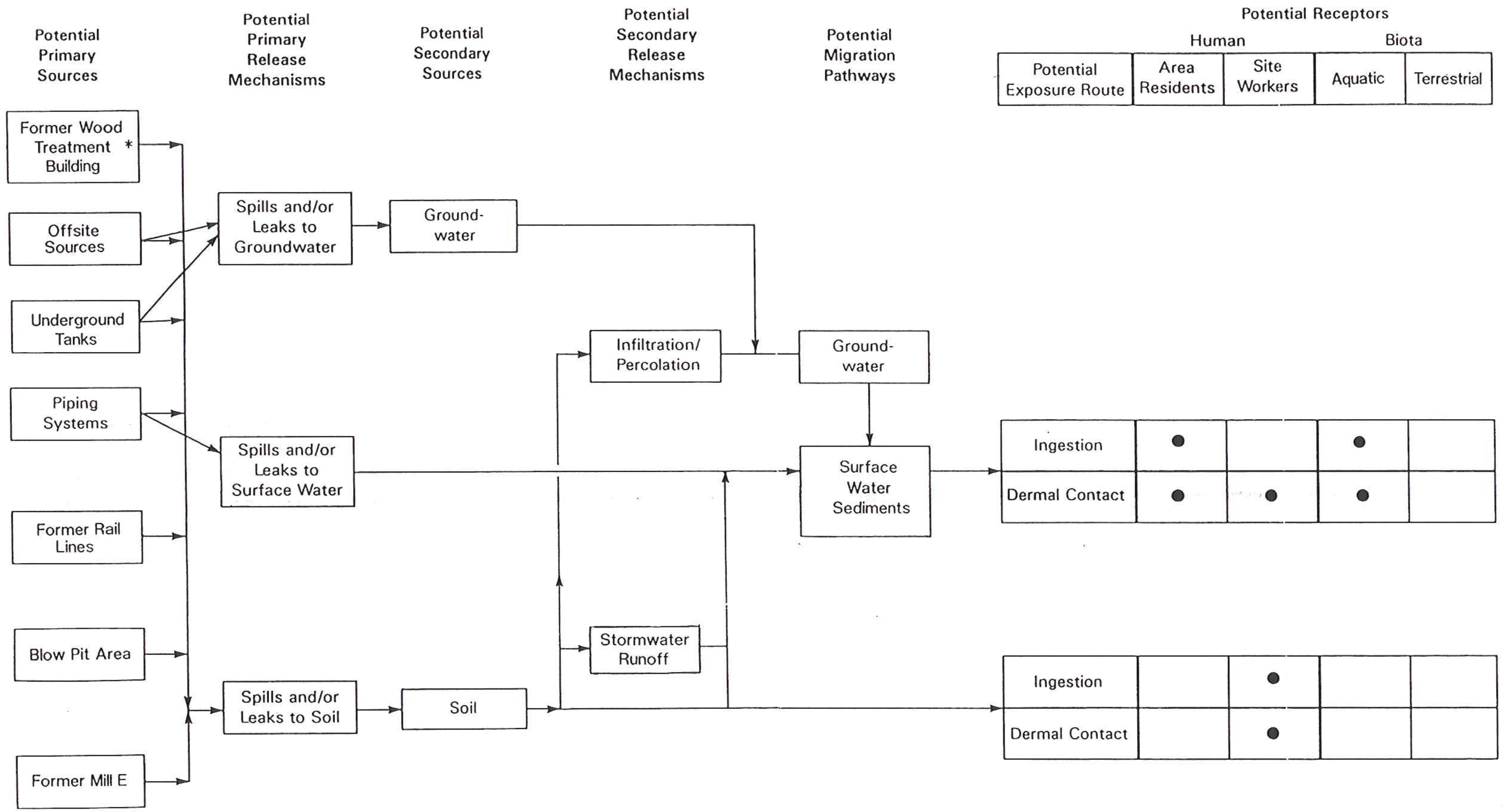
PROJECT NO.
40141-037.109

Figure 2-14
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
AVERAGE TOTAL TPH CONCENTRATION
LOWER SAND AQUIFER
FEBRUARY 1994 - AUGUST 1996

1= 100 11-18-96 G:\DWG\40141037\B0109N06



* Includes Retorts and Aboveground Tanks

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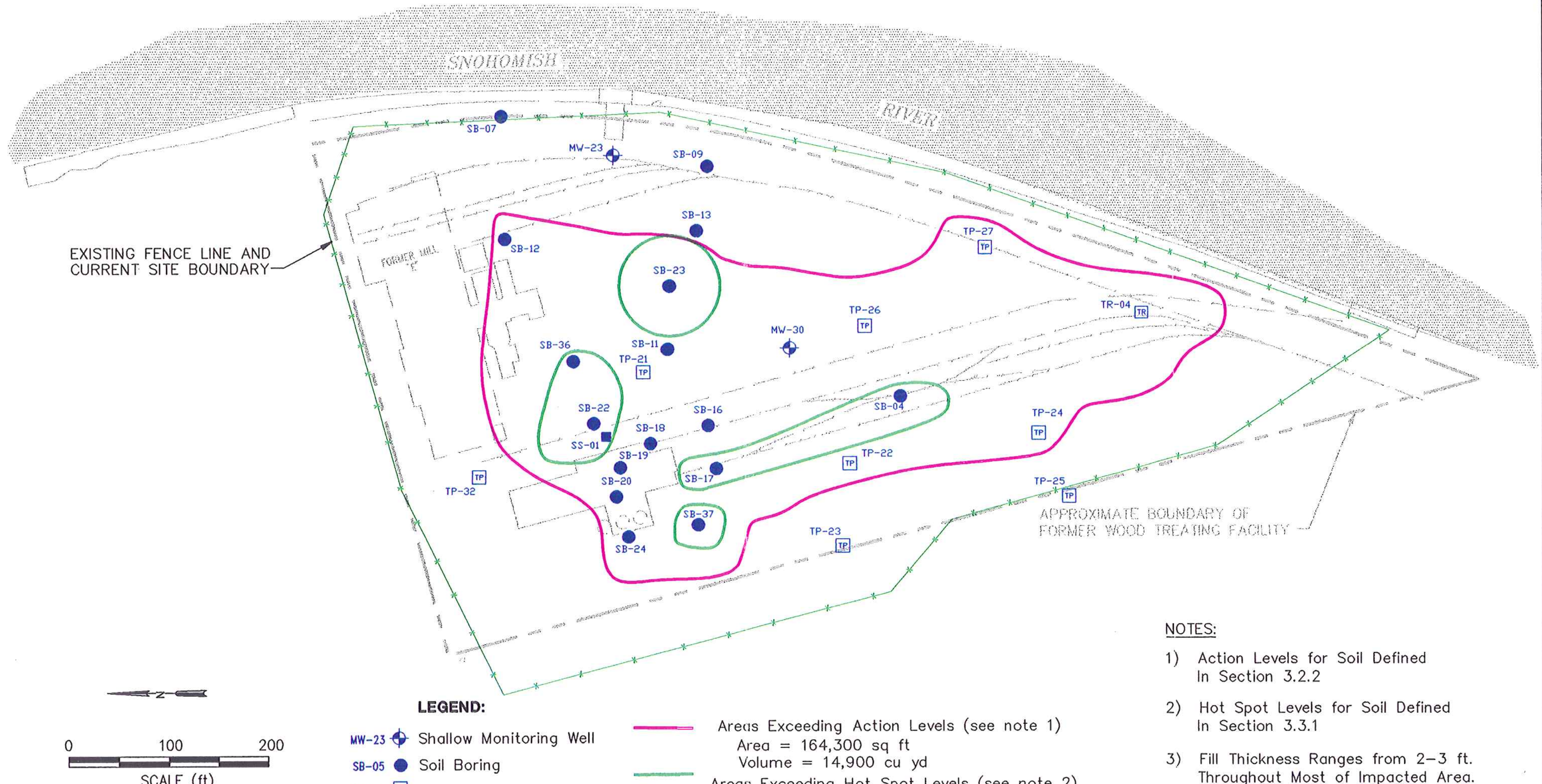
Figure 2-15
FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
CONCEPTUAL SITE MODEL



LEGEND:

- MW-23 Shallow Monitoring Well
- SB-05 Soil Boring
- TP-10 Test Pit
- TR-01 Trench
- HA-01 Hand Auger
- SS-01 Surface Soil Sample

Areas Exceeding Action Levels (see note 1)
Area = 164,300 sq ft
Volume = 14,900 cu yd

Areas Exceeding Hot Spot Levels (see note 2)
Area = 26,900 sq ft
Volume = 5,000 cu yd

NOTES:

1) Action Levels for Soil Defined In Section 3.2.2

2) Hot Spot Levels for Soil Defined In Section 3.3.1

3) Fill Thickness Ranges from 2–3 ft. Throughout Most of Impacted Area.

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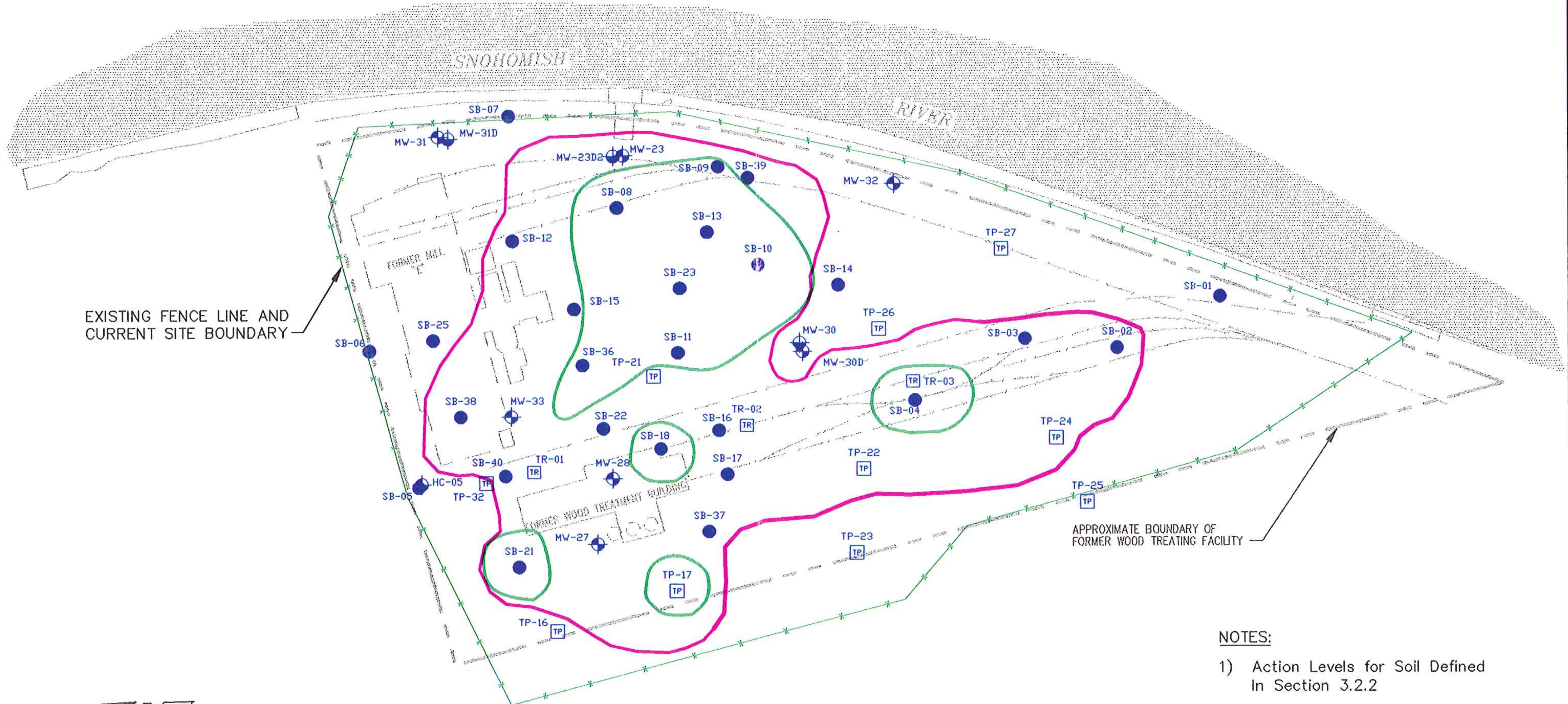
Figure 3-1
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
AREAS EXCEEDING ACTION LEVELS AND HOT SPOT LEVELS FILL

SCALE: 1=100 11-15-96 G:\DWG\40141037\B0109N16



0 100 200

SCALE (ft)

LEGEND:

MW-23	Shallow Monitoring Well
MW-23D	Deep Monitoring Well
SB-05	Soil Boring
TP-10	Test Pit
TR-01	Trench
HA-01	Hand Auger
SS-01	Surface Soil Sample

Areas Exceeding Action Levels (see note 1)
Area = 190,000 sq ft
Volume = 16550 cu yd

Areas Exceeding Hot Spot Levels (see note 2)
Area = 55,000 sq ft
Volume = 2880 cu yd

NOTES:

1) Action Levels for Soil Defined In Section 3.2.2

2) Hot Spot Levels for Soil Defined In Section 3.3.1

3) Unsaturated Upper Sand Thickness Ranges from 2–2.5 ft. Throughout Most of Impacted Area.

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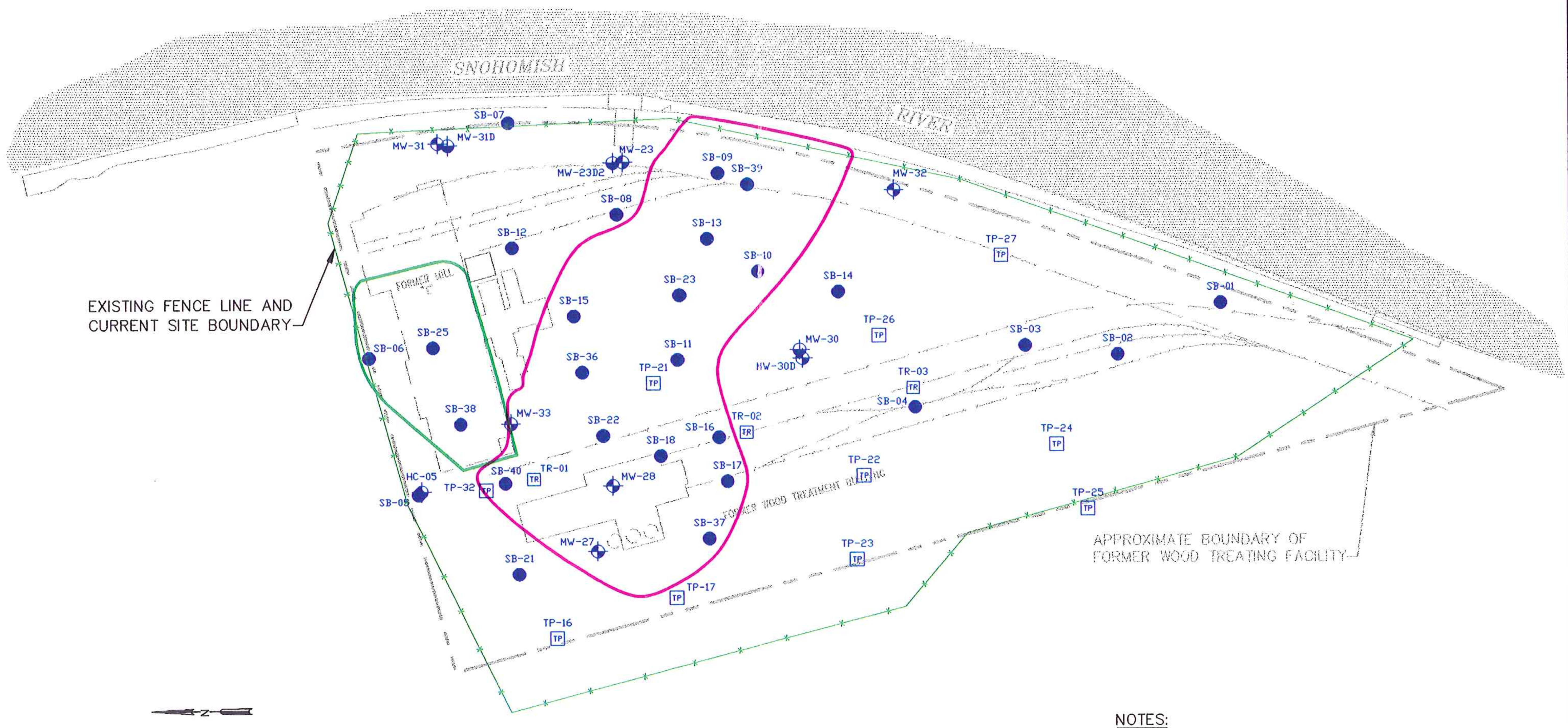
Figure 3–2
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
AREAS EXCEEDING ACTION LEVELS AND HOT SPOT LEVELS UNSATURATED UPPER SAND

SCALE: 1=100 11-15-96 G:\DWG\40141037\BO109N17



0 100 200
SCALE (ft)

LEGEND:

- MW-23 Shallow Monitoring Well
- MW-23D Deep Monitoring Well
- SB-05 Soil Boring
- TP-10 Test Pit
- TR-01 Trench
- HA-01 Hand Auger
- SS-01 Surface Soil Sample

Area "A"
Area = 93,140 sq ft
Volume = 11,300 cu yd

Area "B"
Area = 21,000 sq ft
Volume = 1150 cu yd

NOTES:

1) Hot Spots for Saturated Upper Sand Defined in Section 3.3.1

2) Saturated Upper Sand Thickness Ranges From 2–6 ft. Throughout Hot Spot Areas.

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Figure 3–3
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
HOT SPOT
SATURATED UPPER SAND

SCALE: 1=100 11-18-96 G:\DWG\40141037\B0109N19

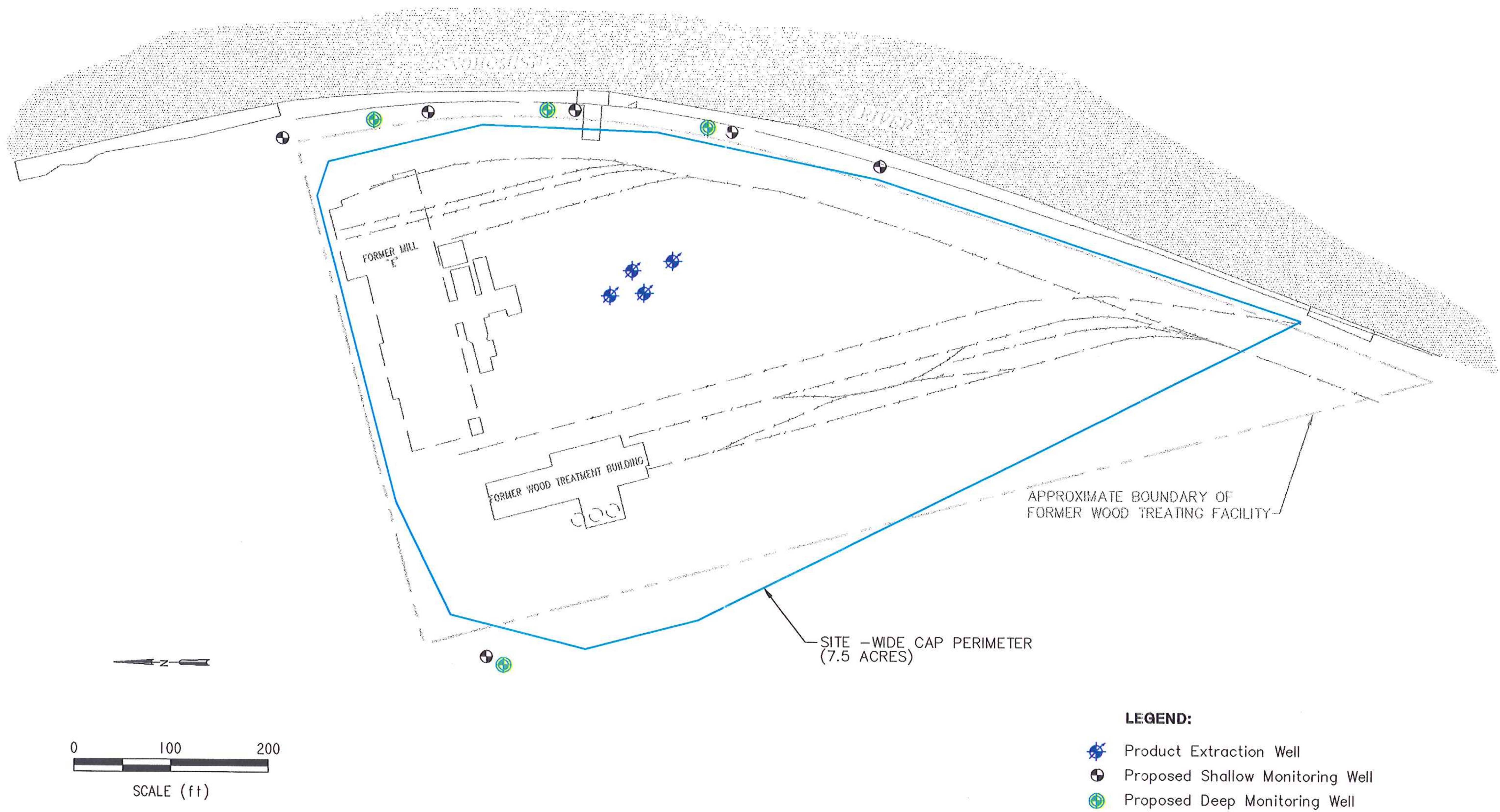

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Figure 6-1
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

ALTERNATIVE 2

SCALE: 1=100 2-20-97 G:\DWG\40141037\B0109N09

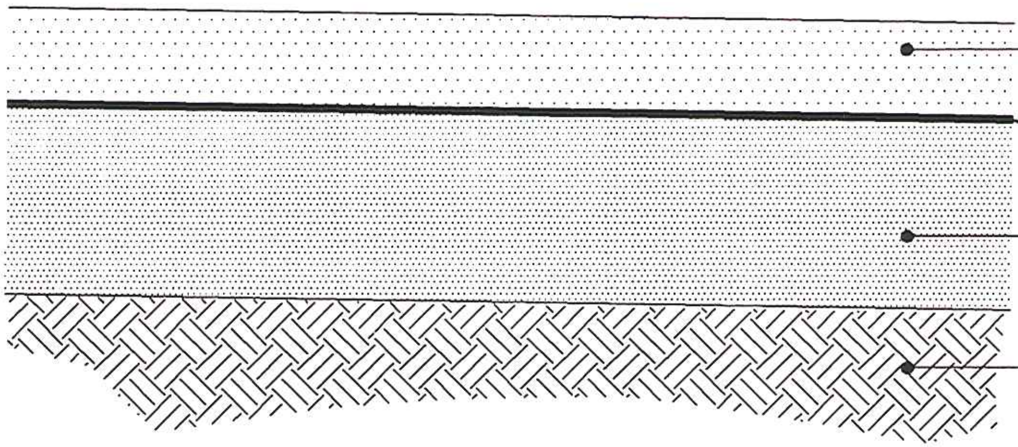

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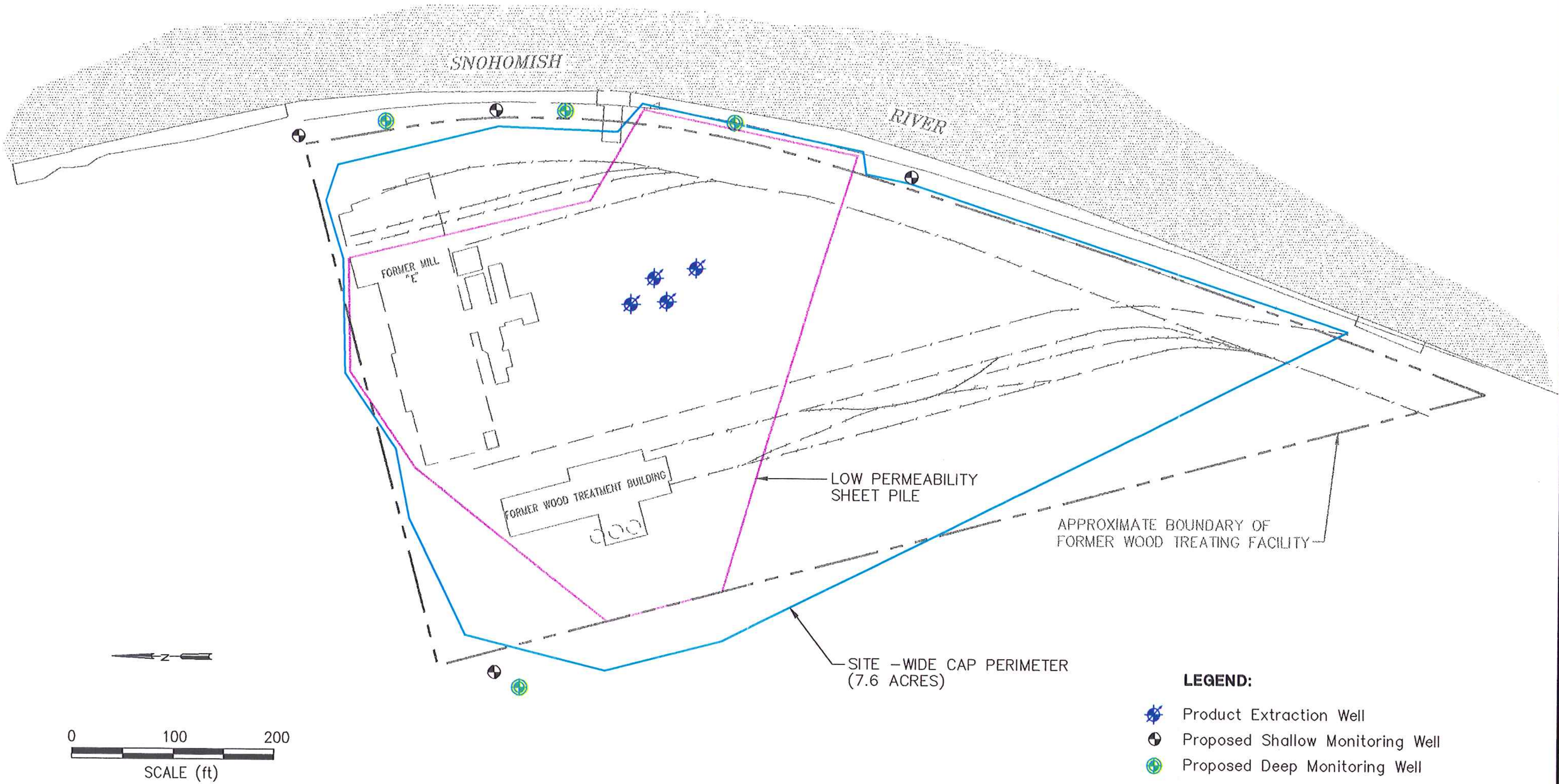
Figure 6-2
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

ALTERNATIVE 2
ASPHALT CAP SECTION

1= 1 11-15-96 G: \DWG\40141037\B0109N14



LEGEND:

- Product Extraction Well
- Proposed Shallow Monitoring Well
- Proposed Deep Monitoring Well

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Figure 6-3

WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

ALTERNATIVE 3

SCALE: 1=100 11-21-96 G:\DWG\40141037\BO109N10

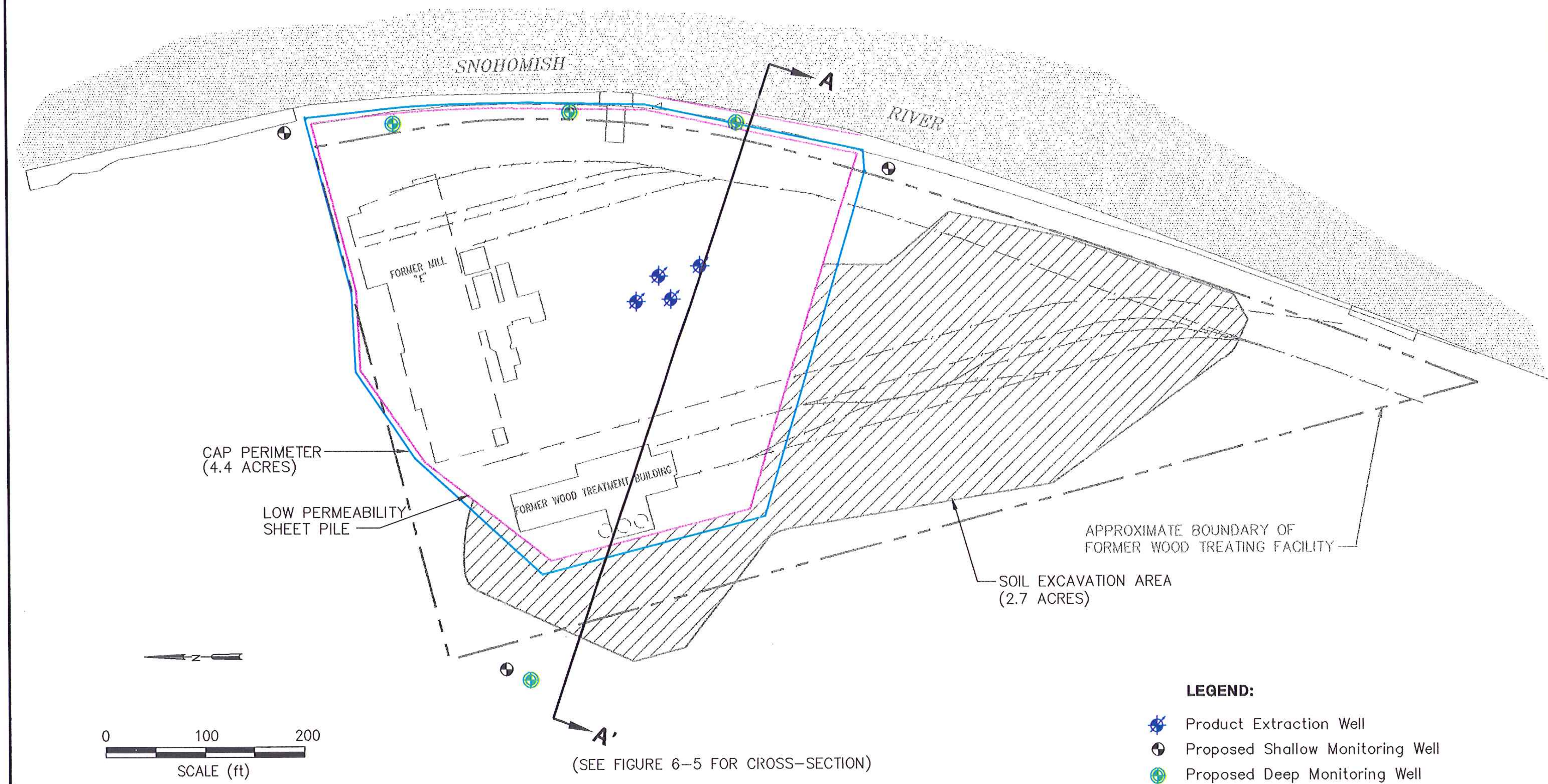

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Figure 6–4
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

ALTERNATIVE 4

SCALE: 1=100 11–21–96 G:\DWG\40141037\B0109N20

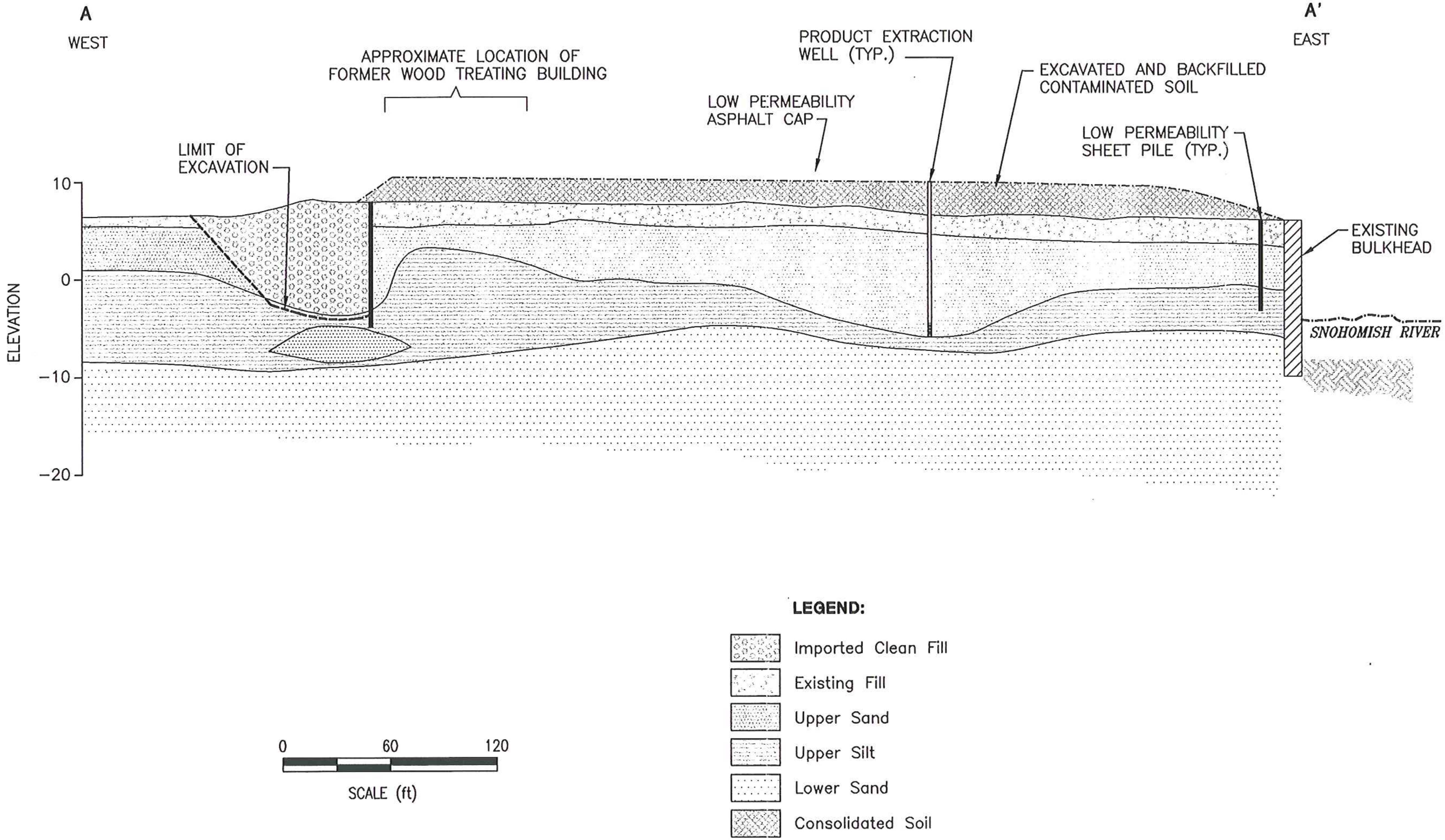

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Figure 6–5
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON
REMEDIAL ALTERNATIVE 4
CROSS SECTION A-A'

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Figure 6-6
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

ALTERNATIVE 6

SCALE: 1=100 11-20-96 G:\DWG\40141037\BO109N12

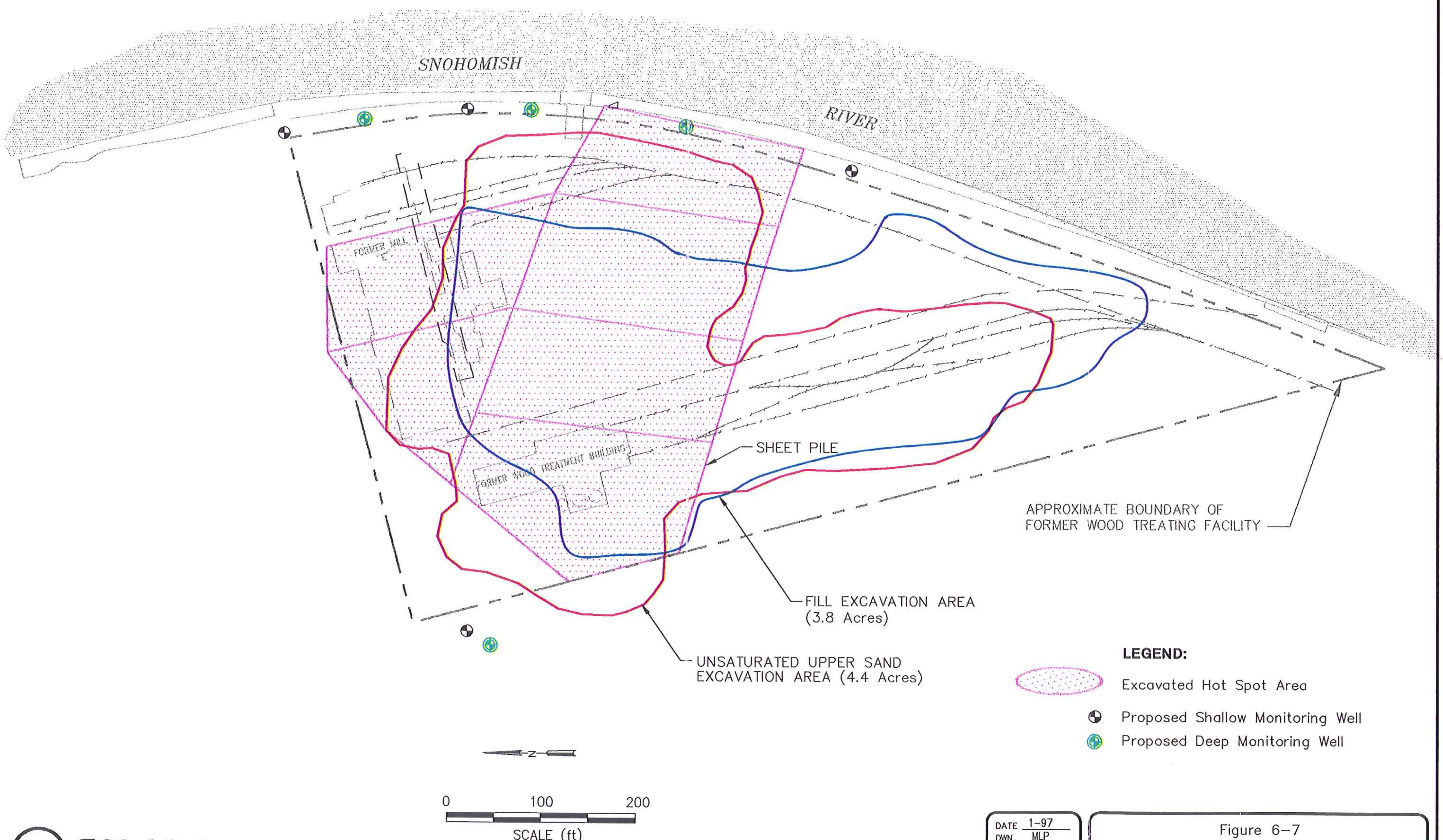

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Figure 6-7
WEYERHAEUSER FORMER MILL E/KOPPERS FACILITY
EVERETT, WASHINGTON

ALTERNATIVE 7

SCALE: 1=100 2-21-97 G:\DWG\40141037\B0109N13

APPENDIX A

COMPARISON OF GROUNDWATER DATA TO POTENTIALLY APPLICABLE SURFACE WATER STANDARDS

Appendix A

Comparison of Groundwater Data to Potential Surface Water Standards
(concentrations in ug/L)

Chemical	PQL[1]	C SW[2]	SFW[3]	SMW[3]	HHO[4]	FFW[5]	FMW[5]	Upper Sand UCL95[6]	Lower Sand UCL95[6]
TPH	200	–	–	–	–	–	–	80,000	22,500
Benzene	10.0	1,070	–	–	710 a,c	–	–	2,800	320
Toluene	10.0	121,000	–	–	2,000,000 a	–	–	5,000	21
Ethylbenzene	10.0	17,300	–	–	290,000 a	–	–	260	150
Xylenes, Total	10.0	–	–	–	–	–	–	1,400	45
Acenaphthene	10.0	1,610	–	–	110,000 a	–	–	190	82
Bis(2-ethylhexyl)phthalate	10.0	89	–	–	59 a,c	–		39	96
Carbazole	10.0	–	–	–	–	–	–	150	77
2,4-Dichlorophenol	10.0	478	–	–	7,900	–	–	38	ND-
2,4-Dimethylphenol	10.0	1,380	–	–	–	–	–	93	21
Dibenzofuran	10.0	–	–	–	–	–	–	67	49
Fluorene	10.0	8,640	–	–	14,000 a	–	–	64	52
2-Methylnaphthalene	10.0	–	–	–	–	–	–	830	810
2-Methylphenol	10.0	–	–	–	–	–	–	210	ND
4-Methylphenol	10.0	–	–	–	–	–	–	650	ND
Naphthalene	10.0	24,700	–	–	–	–	–	11,000	5,500
Pentachlorophenol	10.0	123	v,d	7.9 d	82 a,c,j	13***	7.9	9,300	ND
Phenanthrene	10.0	–	–	–	–	–	–	22	7
Phenol	10.0	2,780,000	–	–	46,000,000 a,j	–	–	190	10
2,4,5-Trichlorophenol	10.0	–	–	–	–	–	–	170	ND
Arsenic	5.0	2.46	190 d	36 d,cc	1.4 a,b,c	190	36	14,300	27.8
Chromium (tri/ hex)	7.0	405,000/2,030	207 n,d,gg /11d	–, gg/50 d	n/n	210/11	–/50	92	8.7
Copper	7.0	2,660	10.2 p,d	–	–	12	2.9	14.6	3.9
Lead	6.0	–	2.2 r,d,dd	5.8 d,dd	n	3.2+	5.6	4.1	1.8

NOTE:

-- = no criterion.

1 = From Weyerhaueser laboratory

2 = Method C surface water formula values from Ecology's Cleanup Levels and Risk Calculations (CLARC II) Table, February 1996; 1x10^{-6} risk level

Appendix A

Comparison of Groundwater Data to Potential Surface Water Standards (concentrations in ug/L)

Chemical	PQL[1]	C SW[2]	SFW[3]	SMW[3]	HHO[4]	FFW[5]	FMW[5]	Upper Sand UCL95[6]	Lower Sand UCL95[6]

3 = Water Quality Standards for surface waters of the State of Washington, WAC 173-201A-040 Toxic Substances; freshwater chronic (SFW) and marine water chronic (SMW).

d = a 4-day average concentration not to be exceeded more than once every three years on the average

j = $\leq (0.865)(e^{(0.7852[\ln(\text{hardness})]-3.490)})$, calculated using hardness = 100 mg/L

n = $\leq e^{(0.8190[\ln(\text{hardness})]+1.561)}$, calculated using hardness = 100 mg/L

p = $\leq (0.862)(e^{(0.8545[\ln(\text{hardness})]-1.465)})$, calculated using hardness = 100 mg/L

r = $\leq (0.687)(e^{(1.273[\ln(\text{hardness})]-4.705)})$, calculated using hardness = 100 mg/L

s = if the four-day average chronic concentration is exceeded more than once in a three-year period, the edible portion of the consumed species should be analyzed. Said edible tissue concentrations shall not be allowed to exceed 1.0 mg/kg of methylmercury.

v = $\leq e^{(1.005(\text{pH})-5.290)}$

bb = $\leq (0.891)(e^{(0.8473[\ln(\text{hardness})]+0.7614)})$, calculated using hardness = 100 mg/L

cc = Nonlethal effects (growth, C-14 uptake, and chlorophyll production) to diatom (*Thalassiosira aestivalis* and *Skeletonema costatum*) which are common to Washington's waters have been noted at levels below the established criteria. The importance of these effects to the diatom populations and the aquatic system is sufficiently in question to persuade the state to adopt the USEPA National Criteria value (36 ug/L) as the state threshold criteria, however, wherever practical the ambient concentrations should not be allowed to exceed a chronic marine concentration of 21 ug/L.

dd = these ambient criteria are based on the dissolved fraction (for cyanide criteria using the weak and dissociable method) of the metal. The department shall apply the criteria as total recoverable values to calculate effluent limits unless data is made available to the department clearly demonstrating the seasonal partitioning of the dissolved metal in the ambient water in relation to an effluent discharge. Metals criteria may be adjusted on a site-specific basis when data is made available to the department clearly demonstrating the effective use of the water effects ratio approach established by USEPA, as generally guided by the procedures in *Water Quality Handbook*, December 1983, as supplemented or replaced. Information which is used to develop effluent limits based on applying metals partitioning studies or the water effects ratio approach shall be identified in the permit fact sheet developed pursuant to WAC 173-220-060 or 173-226-110, as appropriate, and shall be made available for the public comment period required pursuant to WAC 173-220-050 or 173-226-130(3), as appropriate.

ff = these criteria are based on the total-recoverable fraction of the metal.

gg = where methods to measure trivalent chromium are unavailable, these criteria are to be represented by total-recoverable chromium.

4 = Water Quality Standards; Numeric Criteria for Priority Toxic Pollutants; 40 CFR 131; for human health, consumption of water and organisms (HHWO) and organisms (HHO).

a = criteria revised to reflect current agency q_1* or RfD, as contained in the Integrated Risk Information System (IRIS). The fish tissue bioconcentration factor (BCF) from the 1980 criteria documents was retained in all cases.

Appendix A

Comparison of Groundwater Data to Potential Surface Water Standards
(concentrations in ug/L)

Chemical	PQL[1]	C SW[2]	SFW[3]	SMW[3]	HHO[4]	FFW[5]	FMW[5]	Upper Sand UCL95[6]	Lower Sand UCL95[6]

b = the criteria refer to the inorganic form only.

c = criteria in the matrix based on carcinogenicity (10^{-5} risk).

n = EPA is not promulgating human health criteria for this contaminant. However, permit authorities should address this contaminant in NPDES permit actions using the State's existing narrative criteria for toxics.

j = no criteria for protection of human health from consumption of aquatic organisms (excluding water) was presented in the 1980 criteria document or in the 1986 Quality Criteria for Water. Nevertheless, sufficient information was presented in the 1980 document to allow a calculation of a criterion, even though the results of such a calculation were not shown in the document.

5 = Federal Water Quality Criteria, freshwater chronic (FFW) and marine chronic (FMW); from *Quality Criteria for Water 1986,* as amended, USEPA 440/5-86-001.

+ = hardness-dependent criteria (100 mg/L $CaC0_3$ used).

*** = pH dependent criteria (7.8 pH used).

6 = Values shown are the 95 percent upper confidence limit on the mean (or the maximum detected value if indicated by the MTCA statistical guidance) of the groundwater monitoring data from the perimeter monitoring wells in the upper and lower sand aquifers. Data used was from February 1994 through August 1996. Only compounds with a frequency of detection greater than 5 percent were evaluated.

APPENDIX B

TREATABILITY STUDIES

APPENDIX B

TREATABILITY STUDIES

Soil

Part of the FS included conducting a series of treatability studies to evaluate the potential applicability and effectiveness of three treatment technologies. These technologies were bioremediation, soil washing, and solidification/stabilization. Approximately 30 remediation technologies were initially screened and reduced to 12 potentially applicable technologies. Based on information concerning their general effectiveness and implementability, these 12 technologies were all considered potentially applicable. Six of the twelve (four containment technologies, rotary kiln incineration, and off-site landfill) did not require any additional information to incorporate them into remedial action alternatives.

The remaining six technologies required obtaining additional information on their potential effectiveness through treatability studies. Table B-1 lists the 12 technologies and their associated treatability study requirements. The six technologies for which treatability studies were recommended can be divided into three general categories:

- Soil washing
- Solidification/stabilization
- Bioremediation

Bench-scale treatability studies for these three technologies were conducted in accordance with EMCON's Proposal for Treatability Study Program at the Former Mill E/Koppers Facility, May 1993. Results are summarized below. The treatability studies are described in detail in the Treatability Study Summary Report (EMCON, 1994b).

The bioremediation study was performed by EMCON at its Environmental Technologies Laboratory in Bothell, Washington. An 8-week slurry-phase study was performed to evaluate three different treatments: an inorganic-amended nutrient slurry, a slurry supplemented with native bacteria from the site, and a slurry supplemented with commercial strains of bacteria. Only one of the three treatments (the native bacteria slurry) showed significant contaminant reduction. Total PAH concentrations were reduced by approximately 90 percent, and TPH levels were reduced by approximately 50 percent. There was no conclusive evidence that PCP or arsenic levels were reduced.

The soil washing study was conducted by BioGenesis Enterprises, Inc. (BioGenesis), of Fairfax Station, Virginia. BioGenesis tested five separate soil washing solutions or combinations of solutions in their laboratory. The first four wash solutions tested resulted in greater than 98 percent reductions in all organic contaminants in the soil, but only a 55 percent reduction in the arsenic concentrations. The fifth test, which was specially designed to enhance arsenic removal, resulted in greater than 80 percent reduction in arsenic, while maintaining greater than 98 percent removal of the organics.

The solidification/stabilization study was conducted by Silicate Technology Corporation (STC) of Scottsdale, Arizona. This study was conducted in two phases. In the first phase, STC tested two different blends of treatment chemicals (proprietary cementitious mixtures) on soil samples from the site. The leachability of the organic contaminants and arsenic from the solidified soil was then evaluated using the TCLP. The chemical mixture providing the most promising results was then further evaluated in Phase 2. This consisted of applying different ratios of the chemical mixture to the soil. TCLP analysis of a solidified soil sample indicated the leachability of arsenic and most organics was reduced by 90 percent or more. In addition, an unconfined compressive strength of 300 pounds per square inch was achieved with only a moderate increase in the volume of treated soil.

Results from these treatability studies are summarized in Table B-2. They demonstrate that soil washing appears to be a promising treatment technology for the Site. One potential problem contaminant is arsenic, which was only reduced by 89 percent. This removal efficiency would not likely achieve arsenic cleanup standards for the most contaminated soil. It also appears that solidification/stabilization may significantly reduce the leachability of contaminants from the soil. Bioremediation does not appear to be a viable treatment alternative for the site due to its limited ability to degrade all the organic contaminants of concern.

No further bench-scale or pilot-scale testing of these or other technologies were required to support completion of the FS. Pilot-scale testing in the field will likely be required at a future date if soil washing or solidification/stabilization is selected for full-scale implementation at the site.

Groundwater

Contaminated groundwater from on-site pump tests and well purging was collected for use in simple bench-scale treatability tests. These tests provided information that was used to design an on-site pilot-scale treatment system which treated approximately 40,000 gallons of groundwater. The purpose of these tests was to determine the effectiveness of specific technologies in removing contaminants present in the groundwater.

Bench-scale tests focused on the characterization and removal of arsenic from the groundwater. An assumption was made that granular activated carbon would successfully remove soluble organic contaminants and carbon was therefore not tested at the bench-scale level. Before bench testing, analytic tests were used to determine the relative concentrations of trivalent and pentavalent arsenic as well as quantifying dissolved versus total filterable arsenic. Three test treatments were designed based on the most successful arsenic treatment methods described in the USEPA Treatability Manual (USEPA, 1991). These were:

- Pre-oxidation with sodium hypochlorite, addition of ferric sulfate, addition of sodium hydroxide to adjust pH to 8.0, and anionic polymer followed by gravity settling.

- Addition of ferric sulfate, addition of sodium hydroxide to adjust pH to 8.0, and anionic polymer followed by gravity settling.

- Addition of ferric chloride, addition of sodium hydroxide to adjust pH to 8.0, and anionic polymer followed by gravity settling.

Test results demonstrated that all three treatments were effective in removing arsenic to acceptable levels. The process using ferric chloride was selected for pilot-scale testing because of ease of chemical handling (ferric chloride is available in concentrated liquid form which dissolves rapidly and completely in water).

Pilot-scale testing consisted of two batch treatments of site groundwater of approximately 20,000 gallons each. Ferric chloride (150 mg/L) was added first as an arsenic coprecipitant, followed by sodium hydroxide for pH control (to pH 8.0) and heavy metal and iron hydroxide formation. An anionic flocculant was added (5 mg/L) as a gravity settling aid. After settling, the clarified supernatant was pumped through two, 200-pound granular activated carbon units (in series) at the maximum rated flow capacity of 10 gallons per minute (gpm). The treated water was collected in another 20,000 gallon tank and tested.

Significant reductions in contaminant concentrations were achieved by the treatment as shown in Table B-3.

Table B-1
Treatability Study Requirements - Soil

Process Option	Bench-Scale	Pilot-Scale	Comments
Asphalt/Concrete Cap	No	No	Treatability studies not required for containment technologies.
Soil Cap	No	No	Treatability studies not required for containment technologies.
Geomembrane Cap	No	No	Treatability studies not required for containment technologies.
Composite Cap (e.g., RCRA cap)	No	No	Treatability studies not required for containment technologies.
In Situ Soil Washing/Flushing	No	Yes	Bench-scale testing conducted for *ex situ* soil washing will be adequate. If bench-scale test are positive, pilot-scale field testing would be required to assess applicability.
In Situ Bioremediation	No	Yes	Bench-scale testing (e.g., flask studies) conducted for *ex situ* bioremediation will provide initial screening information. If bench-scale tests are very positive, pilot-scale field testing would be required to assess applicability.
Landfarming	Yes	Yes	Pilot-scale field tests conducted if bench-scale test identify one or more promising methods of solid-phase soil treatment.
Slurry-Phase Reactor	Yes	No	
Rotary Kiln Incineration	No	No	Technology's effectiveness well established; treatability test not required.
Soil Washing	Yes	No	Pilot-scale tests not required to scale-up technology from bench test results.
Solidification/Stabilization	Yes	No	Pilot-scale tests not required to scale-up technology from bench test results.
Off-site Landfill	No	No	Not applicable.

Table B-2
Treatability Study Summary

	Biotreatability	Soil Washing	Solidification/Stabilization
Treatment Efficiency (percent reduction)			
CPAHs	62[a]	98[f]	NC[h]
Total PAHs	91[a]	99[f]	>90[i]
Pentachlorophenol	NC[b]	99[f]	>90[i]
TPH-Diesel	35[a]	98[f]	>92[i]
TPH-Gasoline	NA[c]	99[f]	NC
Arsenic	8[d]	89[g]	85[i]
Dioxins/furans	48[e]	98[f]	NC
Additional treatability studies recommended?	No. Initial study results do not indicate that bioremediation will be completely effective in reducing key contaminant concentrations.	Not at this time. The initial study provided the information needed to evaluate the technology at the feasibility study level. Additional pilot-scale testing may be appropriate if this technology is eventually selected for site remediation.	Not at this time. The initial study provided the information needed to evaluate the technology at the feasibility study level. Additional pilot-scale testing may be appropriate if this technology is eventually selected for site remediation.
Technology recommended for use in feasibility study for remedial alternative development?	No. Does not appear to adequately address several major site contaminants, while other technologies (e.g., soil washing) appear feasible.	Yes. Site soils appear suitable for this technology, and study results indicate that adequate contaminant removal may be achieved.	Yes. The technology appears relatively effective at reducing leachability of site contaminants.

NOTE: NC = Not calculated.
NA = Not applicable.

[a] Based on a comparison of samples collected at 0 and 4 weeks from native culture amendment test run.

[b] Variability in pentachlorophenol data precludes calculation of percent reduction.

[c] Due to volitalization that occurred during the slurry test, there were no TPH-G compounds detected in any of the samples.

[d] As expected, there was no reduction in arsenic concentrations. The value reported represents laboratory variability.

[e] Percent reduction based on two samples (i.e., control and active treatments). Ninety-five percent of the reduction observed was in the hepta- and octa- dioxin congeners.

[f] Average reduction efficiency of all treatment runs.

[g] Arsenic reduction based on results of special arsenic wash.

[h] Reduction in CPAH leachability not calculable, because no CPAH compounds were detected in TCLP extract in both the pre- and post-treatment samples.

[i] Results represent reduction in contaminant leachability based on optimized treatment blend.

Table B-3
Groundwater Pilot-Scale Treatability Results

Analyte	Before Treatment (mg/L)	After Treatment (mg/L)	Percent Reduction (%)
Chemical Oxygen Demand	237	5	98
Total Suspended Solids	40	<5	>88
Arsenic	9.35	0.045	99.5
Chromium	0.122	<0.005	>96
Naphthalene	7.30	<0.005	>99.9
2-Methylnaphthalene	2.00	<0.005	>99.8
Acenaphthalene	1.10	<0.005	>99.6
Phenanthrene	1.80	<0.005	>99.7
Pentachlorophenol	12.0	<0.030	>99.8