S.R.
6/26/91

HARTCROWSER

Earth and Environmental Technologies

Phase Ic Site Characterization Report
Weyerhaeuser-Everett Mill E Site
Everett, Washington

Prepared for
Weyerhaeuser Corporation

March 26, 1991
J-2395-06

RECEIVED
MAY 30 1991
DEPT. OF ECOLOGY

CONTENTS

CONTENTS (continued)

FIGURES

PHASE Ic SITE CHARACTERIZATION REPORT
WEYERHAEUSER-EVERETT MILL E SITE
EVERETT, WASHINGTON

INTRODUCTION

This report summarizes the results of the Phase Ic Site Characterization work completed at the Weyerhaeuser Mill E site located in Everett, Washington. The location of our study area is shown on Figure 1.

The purpose of the Phase Ic efforts was to provide data necessary to substantially complete the characterization of residual hazardous wastes present in soil and shallow groundwater at the Mill E site. The investigations build directly on site characterization activities previously performed at the facility (Hart Crowser, 1989a and 1989b). The aggregate Mill E site characterization efforts (i.e., Phases Ia through Ic) were performed consistent with the proposed Washington State Model Toxics Control Act (MTCA) guidelines, and will ultimately permit the selection and design of appropriate remedial actions at the facility.

Specific objectives of the Phase Ic site characterization efforts were as follows:

- Assessment of the extent of soil contamination around and beneath the Old Machine Shop area;
- Assessment of seasonal flow and contaminant concentration variations in the shallow groundwater zone present at the facility (Upper Sand);
- Assessment of possible upgradient contributions of arsenic to shallow groundwaters at Mill E;
- Determination of potential contaminant migration to the deeper (Lower Sand) groundwater zone as a result of groundwater leakage from the Upper Sand; and
- Preliminary assessment of overall risks to human health and the environment posed by chemicals present at Mill E, consistent with risk evaluation methodologies of the MTCA.

The following discussions present the results and assess the significance of the Phase Ic efforts. Interpretations of the data presented herein build upon previous findings, as described in our earlier reports. However, when the Phase Ic data indicate that refinements to the conceptual model of the Mill E site (Hart Crowser, 1989b) are warranted, more detailed discussions are presented. A complete discussion of site history and previous analyses is presented in the Hart Crowser report dated October 27, 1989.

Site Location and Description

This site characterization focuses on the former Mill E, a portion of the Weyerhaeuser-Everett Facility located along the western bank of the Snohomish River (Figure 1). Access to the Mill E area is restricted by Weyerhaeuser security at all times. The perimeters of the site are patrolled regularly, and because the site is open, relatively flat, and cleared of most vegetation, surveillance is generally unobstructed.

A majority of the former Mill E facilities have been decommissioned, leaving just two buildings standing at the present time. These buildings include the Old Machine Shop in the central portion of the site and the Training Building located near the northern boundary. Foundation pads from the former mill, a j-bar sorter, and numerous smaller buildings are also present.

Phase Ic Project Scope

Hart Crowser completed the Phase Ic field explorations between May and August 1990 in accordance with our proposal dated May 4, 1990.

We completed the following tasks under this agreement:

- Drilled five soil borings around the perimeter of the Old Machine Shop and one soil boring through the floor of the building, and submitted the soil samples from each boring for laboratory analyses;
- Assessed wet weather conditions in the Upper Sand by performing one round of wet-weather groundwater elevation measurements and collecting six groundwater quality samples;

- Analyzed five bulkhead seep samples collected from a series of small rivulets flowing into the Snohomish River during low tide;
- Installed, developed, and sampled four shallow monitoring wells to assess the distribution of arsenic in groundwater upgradient of the Mill E site;
- Installed two Lower Sand monitoring wells using the cable tool method to assess groundwater quality downgradient of the Old Machine Shop; and
- Directed the survey of all wells and borings installed during the Phase Ic characterization.

SUMMARY

Soil Quality

Soils encountered in borings advanced in the Old Machine Shop Area contained elevated concentrations of hydrocarbons, including benzene, toluene, ethylbenzene, and xylene (BTEX), low molecular weight polycyclic aromatic hydrocarbons (LPAHs), and potentially carcinogenic PAHs (cPAHs). Based on the aggregate soil quality data collected at the site to date, soil quality within the Old Machine Shop Area appears to be generally similar to that in the adjacent East Shop Area. These data likely reflect similar or related contaminant releases within the general vicinity.

Upper Sand Groundwater Quality

Groundwater quality conditions within the Upper Sand groundwater zone which underlies the site were monitored during a relatively "wet season" condition in May 1990. The concentration distribution of contaminants within this groundwater zone was very similar to conditions encountered during our previous "dry season" sampling in August 1989. Although overall groundwater elevations within this zone were approximately 0.5 to 1 foot higher than during the previous sampling, groundwater flow directions were relatively unchanged.

The primary contaminants identified in Upper Sand groundwater at the Mill E site include arsenic, BTEX, LPAHs, cPAHs, and pentachlorophenol (PCP). The area of the site exhibiting groundwater contamination is consistent with the location of soils exceeding groundwater protection criteria, as discussed above.

Groundwater quality data collected to date reveal a local elevation of arsenic concentrations to 16.9 parts per million (ppm). The presence of locally elevated arsenic onsite is consistent with prior releases from former wood treating operations. However, arsenic concentrations above the Washington State background concentration of 0.005 ppm also occur upgradient of Mill E, at locations removed from site influence. The average arsenic concentration observed in upgradient wells is approximately 0.55 ppm. The source of the upgradient arsenic has not been identified, but could include potential fill associated with a former smelting facility which operated in the site vicinity near the turn of the century.

Lower Sand Groundwater Quality

Hydrogeologic data collected during this study and during previous site characterization efforts reveal that a predominant discharge pathway for Upper Sand groundwater is via leakage to the underlying Lower Sand groundwater zone. Although a silt layer is present across most of the site which separates these two groundwater zones, the thickness of the silt is variable, and ranges from less than 1 to 9 feet. Based on water balance estimates, substantial leakage through the silt occurs, particularly in those locations where the silt has been eroded or altered by prior site development. A major zone of leakage was previously identified near well HC-5; this condition was also observed during the more recent monitoring.

Considering these hydrogeologic data, and the presence of elevated chemical concentrations within the Upper Sand, contamination of the Lower Sand groundwater zone due to leakage was considered likely. Furthermore, the available soil data indicated that the vertical extent of detectable soil contamination could extend into the Lower Sand, resulting in a residual contaminant "source" to this lower groundwater zone.

Groundwater quality data collected from the Lower Sand confirmed the presence of contaminants within this zone. Overall, the types of contaminants and the concentrations encountered in the Lower Sand were very similar to conditions within the overlying Upper Sand. The most prevalent chemicals detected included arsenic, BTEX, LPAHs, and PCP. As discussed above, these data are consistent with leakage of shallow contaminated groundwater through the silt and/or release of the contaminants from a residual soil source within the Lower Sand zone. The relative importance of these two potential migration scenarios can not be reliably distinguished at this time.

Groundwater contamination of the Lower Sand zone which is attributable to site releases appears to be restricted to an area within approximately 300 feet of the Snohomish River. However, the available data are not sufficient to reliably determine the extent of such contamination. Based on regional information, the Lower Sand zone at Mill E may be approximately 50 feet thick.

Preliminary Risk Evaluation

The aggregate site characterization data collected to date at Mill E were evaluated using a preliminary risk assessment methodology defined by the MTCA. The intent of this risk evaluation was to provide a preliminary characterization of potential hazards to human health and the environment which may be posed by chemical contaminants at Mill E. The risk evaluation considered continued industrial use of the property and the release of chemicals to the Snohomish River. All exposure parameters and toxicity evaluations were based on risk assessment methodologies presented in the MTCA.

More than 99 percent of the total potential risk at the Mill E site is attributable to the eight chemicals or chemical groups: arsenic, chromium, benzene, xylene, PCP, naphthalene, cPAHs, and tetrachlorodibenzodioxin (TCDD). Accordingly, site risk evaluations were based on these "indicator" chemicals, consistent with MTCA regulations.

Based on this preliminary risk evaluation, no non-carcinogenic risk (i.e., no toxicity) to human health is expected as a result of reasonable maximum exposure (RME) conditions at the Mill E site.

Potential lifetime cancer risks due to RME conditions at the Mill E site ranged from 4 x 10^{-8} (1 in 25 million) due to consumption of contaminated fish from the Snohomish River to 6 x 10^{-5} (1 in 17,000) due to on-site soil contact exposures. Only the on-site direct soil contact exposure pathway exceeded the overall MTCA lifetime cancer risk target of 1 x 10^{-6} (1 in 1 million). (The MTCA also defines a higher target risk for industrial sites of 1 x 10^{-5} [1 in 100,000]. Most of the potential direct soil contact cancer risk was associated with cPAHs, with a smaller risk posed by arsenic and TCDD.

Off-site ecological impacts were assessed relative to both water and sediment quality conditions in the groundwater seepage area immediately adjacent to Mill E. The primary identified pathway of site chemicals discharged to the Snohomish River is via seep EV-4, located downgradient of the principal areas of on-site groundwater contamination. Measured chemical concentrations at EV-4 exceeded marine aquatic life chronic and acute water quality criteria for both arsenic and naphthalene. A localized area of toxicity to sensitive aquatic life may exist within the immediate vicinity of the groundwater seep zones. Because of the relatively high river flows, the seeps are rapidly diluted within nearshore areas of the Snohomish River.

Maximum concentrations of arsenic and several LPAHs (including naphthalene) detected in nearshore sediments immediately adjacent to Mill E exceeded marine chemical criteria levels specified in the state Sediment Management Standards (WAC 173-304). Minimum cleanup levels defined under WAC 173-304 were also exceeded for these chemicals at individual locations. Based on this comparison, a localized area of toxicity to sensitive aquatic life is possible in sediments immediately adjacent to Mill E.

SITE GEOLOGY

Subsurface explorations encountered a sequence of fill and native deposits in the upper 30 feet of soil beneath the former Mill E facilities. Our interpretation of these soils consists of four primary geologic units, including:

- Grade Fill Material

- Upper Sand (Dredge Fill Sand)
- Silt (Natural Wetland Silt), and
- Lower Sand (Alluvial Deposit).

These four geologic units are consistent with the stratigraphic sequence encountered by Sweet-Edwards in the Kraft Mill area (Figure 1, about 3,000 feet to the north, also along the western bank of the Snohomish River). The correlation between the two areas indicates that the sequence of alluvial deposition followed by filling activities may be consistent across the Weyerhaeuser-Everett facilities.

Our geologic interpretation is based on data collected from 37 soil borings, which ranged in depth from about 8 to 30 feet. The locations of these borings are shown on Figure 2 and geologic logs for each are presented in Appendix A.

We use two geologic cross sections to show the occurrence of these geologic units with depth beneath the site. These cross sections are drawn parallel and perpendicular to the Snohomish River (as shown on Figure 2) and they are presented on Figure 3. The following discussion provides additional detail on each geologic unit, including specific characteristics of each.

Grade Fill Material

We encountered grade fill material at the surface in each exploration. This material, used to create a working surface at the site, consists of asphalt, crushed rock ballast, and bark. Thickness of the fill material was variable, ranging from about 1 foot near the machine shop to 3 feet in the east shop area.

Upper Sand

Site history indicates that a layer of dredge sands was deposited on the Snohomish River floodplain, including the area where Mill E was located. We encountered these sands below the Grade Fill in each exploration and have denoted these deposits the Upper Sand for discussion purposes.

The Upper Sand consists primarily of gray, medium to coarse sand. Only minor variations in color and gravel content were noted. Because the soil was deposited as fill, variability within the unit is likely to be random. Gravel content varied from approximately 0 to 15 percent, with the amount estimated at less than 5 percent in most borings. While primarily gray in color, brown and gray-brown sands were also noted.

While the thickness is variable, the unit appears to be continuous beneath the entire site. In addition, we encountered the same stratigraphic sequence in three borings (HC-24, HC-25, and HC-26) advanced 200 to 300 feet west of the Mill E area. The Upper Sand is typically 5 to 6 feet thick, with a range of 1.5 (Boring HC-11) to 10.5 feet (Boring HC-13). In general, the thicknesses increase toward the Snohomish River.

Silt Layer

We encountered a Silt Layer below the Upper Sand in most of the explorations. Local history indicates that the silt was deposited in natural wetlands along the Snohomish River floodplain prior to placement of the fill.

The Silt Layer is composed primarily of very soft, gray silt with abundant organic fragments (including wood, peat, and roots). Along the river margin and east of the training building, we often observed the presence of fine sandy layers in the upper 1 to 2 feet of the silt. Beneath the remainder of the site, we observed little sand within the silt.

We estimate that the Silt Layer is typically 3 to 10 feet thick below the Mill E site with localized thinning in some areas. The cross sections indicate that the greatest Silt Layer thicknesses (7 to 10 feet) are generally encountered west of the machine shop and that thickness tends to decrease (3 to 5 feet) toward the Snohomish River. Soil boring locations characterized by minimal silt thicknesses (i.e., less than 1-foot-thick) include HC-5 (0 foot), HC-8 (0.4 foot), and HC-15D (0.5 foot).

Lower Sand

Below the Silt Layer, we encountered sand and gravelly sand in each of the deeper borings. Based on uniformity of grain size and stratigraphic position, we have denoted this unit as the Lower Sand. We interpret this unit as a portion of the Snohomish River alluvial sequence, which may be up to several hundred feet thick according to an earlier study (Sweet-Edwards, 1988).

The Lower Sand consists of gray, loose to medium dense, slightly gravelly sand with wood fragments. The Lower Sand typically contains 5 to 10 percent gravel, and visually appears coarser than the Upper Sand. The coarsest material was encountered in the lowermost 4 feet of HC-10D, where the gravel content increased to about 70 percent of the sample.

Geology in Cross Section

The relationship of the geologic units discussed above is presented in cross sections on Figure 3. The locations of these cross sections are shown on Figure 2.

As shown on Cross Sections A-A' and B-B', the geologic units are generally continuous beneath the site, with the exception of local breaches in the Silt Layer. Cross Section A-A' indicates that the base of the Upper Sand generally slopes toward the Snohomish River as the unit thickness increases. The cross section also shows that the Silt Layer thins toward the river, with localized thinning of this unit shown at several locations in both of the cross sections.

SITE HYDROGEOLOGY

Our explorations and subsequent monitoring indicate that two water-bearing horizons are present within the upper 30 feet beneath the site. These horizons include an unconfined (water table) system within the Upper Sand and conditions that vary from confined to unconfined within the Lower Sand. These two water-bearing horizons are separated by the Silt Layer, an aquitard that limits hydraulic connection between the two units.

To assess this hydrologic system with two water bearing units, we have completed a field monitoring and testing program that includes:

- Monitoring water levels in both the Upper and Lower Sand units (Table 1);
- Measuring the tidal response in both hydrologic units and the Snohomish River; and
- Assessing the hydraulic conductivity of the Upper Sand, Silt Layer, and Lower Sand using a combination of field methods and laboratory testing.

Complete discussions of the methods used in these tasks are presented in Hart Crowser (1989b). The following discussion draws on data collected during earlier study, assessing groundwater occurrence and movement beneath the site.

Upper Sand

Drilling and subsequent monitoring indicate that the shallowest water-bearing horizon beneath Mill E is within the dredge sands, which we have termed the Upper Sand unit. Groundwater is typically encountered within this unit at a depth of about 3 to 4 feet below grade, with the saturated thickness of the horizon averaging 3 to 5 feet. The base of this unit is defined by its point of contact with the underlying Silt Layer.

Groundwater Levels and Flow

Groundwater flow in the Upper Sand is primarily toward the Snohomish River. The groundwater elevation contour maps presented on Figure 4 (Spring) and Figure 5 (Fall) indicate that the hydraulic head distribution changes in elevation seasonally (0.5 to 1 foot), but that little variation in flow direction is observed. In addition, the relative distribution of hydraulic gradients across the site is consistent between these measurements.

One primary deviation from the eastern flow direction is the presence of a sink in the groundwater surface south of the Training Building. Our water level measurements have consistently indicated the presence of a groundwater-low in this area. We attribute this to a localized thinning in the Silt Layer (near HC-5), which increases the rate of groundwater flow into the underlying water-bearing zone (which is consistent with our geologic observations in HC-5, where no silt was encountered).

Tidal Fluctuation

Continuous water level monitoring indicates that groundwater in the Upper Sand exhibits only a minor response to tidal fluctuation in the Snohomish River (Figure 6). Monitoring over a 72-hour period, we measured tidal-induced water level fluctuations of 0.2 to 0.5 foot in the Upper Sand (a 13.2-foot fluctuation was measured in the Snohomish River over the same period). This fluctuation created short-term gradient reversals along the river margin, but the net gradient across the site was toward the river throughout the monitoring period.

Hydraulic Conductivity

We estimate that the hydraulic conductivity of the Upper Sand is approximately 0.001 to 0.01 cm/sec based primarily on our slug test data. These data are considered the best estimate because they provide an *in situ* measurement, while estimates from grain size are dependent upon an empirical relationship designed for well-graded sand samples. The indicated range is consistent with testing of dredge fill materials in other areas within the Port of Everett and the Puget Sound region.

Silt Layer

Exclusive of the few sandy stringers encountered, we did not note the presence of free water within the Silt Layer during drilling. No monitoring wells have been completed within this unit to date.

We have estimated the vertical hydraulic conductivity of this unit using laboratory testing methods. Testing conducted on an undisturbed shelby tube sample provides an estimated permeability of 3×10^{-7} cm/sec. Because the soil type was fairly uniform across the site, we interpret this as a representative value. Sweet-Edwards conducted four similar tests at the Kraft Mill and estimated permeabilities of 2×10^{-8} to 2×10^{-7} cm/sec.

Lower Sand

The deepest water-bearing unit identified in studies to date is within the alluvial Lower Sand unit. The present monitoring system screens the upper 15 feet of this unit. Monitoring indicates that groundwater conditions within this aquifer range from confined to unconfined, based on tidal phase. During periods of high tide, the unit becomes fully saturated and the resulting pressure head rises above the top of the Lower Sand unit. In contrast, at low tide the upper portion of this unit will become unsaturated.

Groundwater Levels and Flow

Our water level monitoring data are used to compare groundwater elevation within the Lower Sand with the overlying hydrogeologic units. Data from the highest tidal-phase monitored (Table 1, August 31, 1990) indicate that the pressure head within the Lower Sand can rise five feet above the base of the Silt Layer and one to four feet above the base of the Upper Sand. At low tide, our data indicate that the upper one to two feet of the Lower Sand unit becomes unsaturated.

Groundwater flow within the Lower Sand is dependent upon tidal phase. The net direction of groundwater flow in this unit is toward the Snohomish River, as shown on Figure 7. However, at high tide a reversal in gradients has been observed beneath the site (Figure 8). We estimate the duration of the reversal at 6 to 8 hours per day. Calculations indicate that the net flow direction is toward the river, with an average gradient of approximately 0.02.

Tidal Fluctuation

The groundwater flow conditions within the Lower Sand vary throughout the day based on tidal phase (Figure 9). Using continuous monitoring data, we recorded a 7- to 9-foot fluctuation in groundwater elevation over individual tidal cycles. We measured a corresponding change of 13.2 feet in the Snohomish River. These monitoring data support the reversals in gradient noted during our periodic rounds of water level measurements.

Hydraulic Conductivity

Using field testing and observation, we estimate the hydraulic conductivity of the Lower Sand to range from 0.001 to 0.1 cm/sec, based primarily on the soil type encountered. The higher permeability estimates are associated with an increase in gravel content in the aquifer. Because of rapid water level response to tidal influences, we were not able to analyze *in situ* testing data. Therefore, our estimate is based primarily on grain size measurements, published ranges for this soil type, and comparison with data from the Upper Sand.

Sweet-Edwards estimated a permeability of 0.001 cm/sec based on one test that they conducted in this unit. Their estimate is comparable with our low-end estimate, which is consistent with the lack of gravelly soil encountered in their boring.

Flow through the Groundwater System

The primary direction of groundwater flow beneath the Mill E site is from west to east in both of the water-bearing units. However, groundwater elevations are consistently higher in the Upper Sand than they are in the Lower Sand. The presence of this downward vertical gradient (which averages 0.75) induces groundwater flow between the two water-bearing zones.

The following discussion focuses on the fate of groundwater flowing within the Upper Sand. The methods of estimating groundwater discharge rates are discussed in detail in our previous characterization reports, and are not repeated herein. The seasonal variability of the system is assessed using data from August 1989 and May 1990, the two monitoring periods with the greatest contrast in groundwater levels.

Groundwater Receptors

Monitoring indicates that the Snohomish River and the Lower Sand are the two primary receptors of Upper Sand groundwater. We have identified three pathways for discharge, including horizontal flow into the river channel (in the form of seeps), downward flow through the Silt Layer, and leakage through windows in the silt. Our estimates of seasonal flow through each of these pathways is discussed below.

Seepage to River. During low tide, we have observed seepage from the site bulkhead into the river channel. The major seep locations are presented on Figures 4 and 5. The observation of seeps in this area is consistent with the groundwater elevation data. These data indicate that groundwater discharge from the Upper Sand is concentrated in the area between monitoring wells HC-9 and HC-10. We observed little or no seepage along the bulkhead south of HC-9.

The estimated volume of water being discharged through the seeps varies seasonally. Using data collected during August 1989, we estimated that an average of 1.5 gpm was being discharged. In contrast, we estimate an average discharge of 3 gpm using May 1990 data. Saturated thickness of the Upper Sand ranged from 1 to 2 feet in August to 1.5 to 3 feet in May, and hydraulic gradients averaged 0.01 and 0.02, respectively.

Flow through Silt. Downward vertical gradients indicate that groundwater will flow from the Upper Sand, through the Silt Layer, into the Lower Sand. Using the laboratory-measured silt permeability and average vertical gradients (over the tidal cycle), we have estimated the rate of flow through a 500,000-square-foot area (that encompasses a majority of the Mill E facilities). These calculations indicate that groundwater flowed through the Silt Layer at an average rate of about 1.5 to 2 gpm in August 1989 and increased to about 2 to 2.5 gpm in May 1990.

Leakage through Silt Windows. Geologic data and water level monitoring support the presence of a window in the Silt Layer in the vicinity of HC-5. Using local hydraulic permeabilities and the induced gradients in the depressed area, we have estimated flow through this window. Using data from August 1989, we estimate an average flow of about 0.5 gpm, increasing to about 1 gpm using May 1990 data.

SOIL AND GROUNDWATER SAMPLING PLAN

Previous Phase I Mill E investigations detected the presence of various metal and organic chemical contaminants in both soil and groundwater samples collected from the site. The chemicals of potential concern identified from these investigations (and from associated preliminary risk assessments) include arsenic and chromium, benzene, toluene, ethylbenzene and xylene (BTEX), polycyclic aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), chlorinated dibenzofuran and dibenzodioxin compounds, and petroleum hydrocarbons. Previous releases of these chemicals to site soils appears to have been related to former wood treating operations at and adjacent to the present Old Machine Shop building.

Consistent with the location of the former wood treating operations, the highest concentrations of the identified chemicals of potential concern have been previously encountered in soil and groundwater collected from locations east of the Old Machine Shop (Figure 2). Concentrations declined rapidly to the south, west, and north of this area. Migration of these chemicals in site groundwaters appears to be occurring in a predominantly easterly direction, toward the Snohomish River.

With the exception of arsenic, none of the identified chemicals were detected at levels of concern upgradient (i.e., west) of the Old Machine Shop. Although the concentrations of dissolved arsenic in monitoring wells also declined upgradient of the East Shop Area, arsenic levels in these "boundary" wells still exceeded the federal drinking water standard (0.05 ppm) and Washington State background levels (0.005 ppm). Based on these data, and the finding of similarly elevated arsenic concentrations in other local shallow groundwaters (e.g., upgradient of Mill B and the Kraft Mill), an off-site groundwater source of arsenic to Mill E was considered likely.

In order to support the development of an appropriate remedial action plan for the Mill E site, we identified several additional data needs in our previous Site Characterization Report (Hart Crowser, 1989b). Specific data requirements included the following:

- Assessment of soil quality beneath the Machine Shop;
- Characterization of the vertical extent of soil contamination and the potential for groundwater quality impacts in the Lower Sand unit;
- Identification and water quality characterization of local seeps flowing through the bulkhead located along the Snohomish River;

- Assessment of seasonal variability of groundwater quality through resampling of existing wells; and
- Definition of upgradient groundwater arsenic area background (or reference) concentrations by installing and sampling monitoring wells screened in the Upper Sand upgradient of the Mill E site.

The sampling and analysis plan discussed below was designed to address these additional site characterization requirements.

Soil Sampling Plan

Old Machine Shop Soil Borings. We collected a total of 19 soil samples (including one duplicate sample) from the six soil borings (A-1 through F-1) installed in the vicinity of the Old Machine Shop (Figure 2). Sample collection procedures are described in Appendix A. Samples were collected at depths ranging from 2.5 to 11.5 feet below ground surface. Eighteen of the samples were submitted to Weyerhaeuser's analytical laboratory for chemical analysis of the following parameters:

- Total Metals (including arsenic, chromium, and copper);
- Volatile Organics (EPA method 8240);
- Phenols (modified EPA method 8270);
- Polycyclic Aromatic Hydrocarbons (modified EPA method 8270); and
- Total Solids.

Arsenic Reference Samples. Nine of the soil samples (including one duplicate sample) collected from the four arsenic reference borings (HC-24 through HC-26 and WP-1) were analyzed for total arsenic. Arsenic reference boring locations are shown on Figure 1. Samples were selected for analysis based on sample depth, lithology, visual evidence of contamination, and sample recovery.

Groundwater Sampling Plan

Upper Sand Wells. Six monitoring wells (HC-5, HC-6, HC-7, HC-9, HC-12, and HC-16) completed in the Upper Sand unit were resampled in May 1990 to evaluate "wet season" groundwater quality. Wells were selected for resampling based on the distribution of chemical concentrations determined during the previous 1989 (dry season) sampling event. We had initially intended to sample those wells in the East Machine Shop Area which contained the highest chemical concentrations. However, monitoring wells HC-13, HC-15, and HC-22, which had previously exhibited elevated constituent levels, could not be reliably sampled in May 1990 because to the presence of floating free product in the well. The product layer could not be suitably separated from the underlying water at the time of sampling.

Upper Sand groundwater samples were analyzed for the following parameters:

- Dissolved Priority Pollutant Metals;
- Volatile Organics (EPA method 8240);
- Phenols (modified EPA method 8270); and
- Polycyclic Aromatic Hydrocarbons (modified EPA method 8270).

Metal sample filtration was performed in the field, as described in Appendix A. Groundwater temperature, pH, specific conductivity, and dissolved oxygen were also determined in the field.

Lower Sand Groundwater. Three existing wells (HC-1D, HC-10D, and HC-11D) and two newly installed wells (HC-15D and HC-23D) were sampled for the same parameters as Upper Sand groundwater samples. In addition, Lower Sand groundwater samples were analyzed for total dissolved solids to evaluate river-groundwater interaction.

Seeps. Five bulkhead seeps (Seep-1 through Seep-4 and Seep EV-4) located along the Snohomish River were identified and sampled using procedures described in Appendix A. Locations of the seeps are shown on Figure 2. Seep samples were analyzed for the following parameters:

- Dissolved priority pollutant metals;
- Total priority pollutant metals;
- Volatile organics (EPA method 8240);
- Phenols (modified EPA method 8270);
- PCBs (modified EPA method 8270); and
- Total suspended solids.

Metal sample filtration was performed in the field, as described in Appendix A. Temperature, pH, specific conductivity, and dissolved oxygen measurements were also obtained in the field for Seep-1 through Seep-4 water samples. For comparison, we measured the same field parameters in a water sample collected from the Snohomish River.

SOIL AND GROUNDWATER QUALITY

The following sections discuss the results of soil and groundwater quality analyses performed at the Mill E site. We first present the results from this Phase Ic scope of work, and then combine these data into an overall soil and groundwater characterization of the Mill E site, utilizing all available information (Hart Crowser, 1989a and 1989b).

Soil and groundwater quality data generated by this work were reviewed by an environmental geochemist to determine the validity of the data based on general quality control criteria. Based on this review, the analytical results were deemed acceptable for the purposes of this work. For reference, our data validation report and laboratory certificates are included in Appendix B (Appendix B is produced under separate cover). All soil analysis results were reported by the analytical laboratory on an as-received (wet weight) basis. Based on our experience with similar soil quality investigations, subsurface soil results reported on an as-received basis are typically 10 to 30 percent lower than concentrations reported on a dry weight basis.

Soil Quality

Old Machine Shop Borings

Metals. Soils collected from the Old Machine Shop area exhibited arsenic concentrations ranging from 6 to 114 ppm, chromium concentrations from 20 to 132 ppm, and copper from 6 to 34 ppm (Table 2). Metal concentrations were generally highest in samples collected from 2.5 to 4.0 feet below ground surface, immediately below the gravel ballast material. Overall, no distinct areal distribution of metal concentrations was evident in this area.

Hydrocarbons. Elevated concentrations of volatile organic hydrocarbons (BTEX compounds) and polycyclic aromatic hydrocarbons (PAHs) were detected in samples collected from each of the six soil borings (Table 2). Volatile hydrocarbons appeared to be distributed through the depth of the soil borings. However, the highest PAH concentrations were commonly detected at deeper depths (5 to 12 feet). Sample F-1/S-3, which contained the highest PAH concentrations detected during this study, also exhibited a strong hydrocarbon odor and sheen. Boring F-1 was installed inside of the Old Machine Shop adjacent to the location of a former hydraulic pit and wood treating retort. The high concentration of dibenzofuran (120 ppm), a major component of creosote, and the distribution of PAH compounds observed in sample F-1/S-3, suggest that this sample probably contained a mixture of hydrocarbon products including creosote.

Volatile Organics. Methylene chloride, acetone, and methyl ethyl ketone (MEK) were also detected in several of the soil borings at low levels (less than 0.3 ppm). These volatile organic compounds were also detected at similar levels in soil samples collected during the initial environmental assessment (Hart Crowser, 1989a) and site characterization (Hart Crowser, 1989b). Although these chemicals are common laboratory contaminants, they were not generally detected in the laboratory or field blanks associated with these samples and were thus not qualified during the data review.

Other Constituents of Concern. Pentachlorophenol (PCP) was detected only in borings C-1 (maximum concentration of 1.7 ppm) and F-1 (6.5 ppm).

Arsenic Reference Borings

Arsenic concentrations in soil samples collected from borings HC-24, HC-25, and HC-26 were all within expected regional background concentrations of approximately 1 to 20 ppm (Tables 3 and 4). However, elevated arsenic concentrations were detected in boring WP-1 samples 2A (125 ppm) and 2B (7,940 ppm). Extraction procedure toxicity (EP Tox) and toxicity characteristic leaching procedure (TCLP) tests conducted as part of the Mill B site characterization study (Hart Crowser, 1990) indicated that the arsenic was not readily leachable in these two samples.

As discussed in the draft Mill B Site Characterization Report (Hart Crowser, 1990), a metal (primarily lead) smelting plant operated near the southern boundary of the Mill B site in the early 1890s to 1914. Evidence of smelting activities include the presence of a slag outcrop located along the current Kraft Mill entrance ramp as well as gravel-size fragments encountered in surface and subsurface soil samples obtained in the area. Although slag-like materials were not evident in the HC-24 through HC-26 borings, it is nevertheless possible that slag or associated materials were used as fill in other areas in the vicinity of Mills B and E.

Groundwater Quality

Upper Sand

As discussed previously, a total of six wells (HC-5, HC-6, HC-7, HC-9, HC-12, and HC-16) were resampled in May 1990 to evaluate seasonal variability in Upper Sand groundwater quality. A summary of these results is presented in Tables 5 and 6. In general, the results were similar to the previous (dry season) data -- results were not consistently higher or lower. The spatial distribution of selected parameters (including arsenic, BTEXs, PCP, and PAHs) are shown on Figure 10 for Upper Sand and Seep samples collected as part of this work. A more detailed discussion of Upper Sand groundwater quality is discussed below.

Free Product. Free-phase floating product was detected in May 1990 in wells HC-13, HC-15, and HC-22. Free product was not detected in these wells during the previous dry season sampling (1989), though hydrocarbon sheens were observed at that time. Apparent free-phase product thicknesses are presented on Figure 10, and ranged from 0.01 foot (HC-22) to 0.9 foot (HC-13).

During our sampling efforts, we were able to recover a sufficient volume (one liter) of the free-product present in well HC-13 to perform a fuel screening analysis. The product appeared to be viscous. Weyerhaeuser's laboratory identified the product as creosote.

Dissolved Metals. All of the nine metals analyzed were detected in at least one groundwater sample collected from the Upper Sand. Arsenic, chromium, and zinc were detected in all samples, at concentrations ranging from 0.128 to 8.68 ppm (arsenic), 0.002 to 0.052 ppm (chromium), and 0.003 to 0.006 ppm (zinc). The highest overall concentrations of all metals were detected in well HC-9, located southeast of the Shop (Figure 10).

Both the Washington State background groundwater concentration of 0.005 ppm (WAC 173-340-720(2) and the existing drinking water maximum contaminant level (MCL) of 0.05 ppm were exceeded throughout the site, and during both sampling events. The maximum arsenic concentration measured during the most recent sampling was 8.68 ppm (HC-9). Previous sampling of HC-13, however, revealed a somewhat higher maximum concentration of 16.9 ppm. The distribution of arsenic in the Upper Sand is depicted on Figure 11.

Based on the distribution of arsenic concentrations (Figure 11) and site historical data, the primary source of arsenic to site groundwaters appears to have been releases associated with the use of arsenic-based wood preservatives such as Chromated Copper Arsenate (CCA). However, although arsenic concentrations declined upgradient of the former wood treating area, the concentrations in upgradient wells were still above the proposed MTCA compliance cleanup standard. Measured dissolved arsenic concentrations in the arsenic reference groundwater samples, as shown in Table 7, ranged from 0.01 ppm (HC-25) to 1.2 ppm (WP-1).

Considering the nearly ubiquitous distribution of arsenic in Upper Sand groundwater, as depicted on Figure 11, it is apparent that there is a regional source of arsenic in the Weyerhaeuser Everett Facilities area, possibly related to the historic smelting operations and fill activities discussed previously. Based on limited geologic information, we believe that the Upper Sand unit may be hydraulically connected to the upper water-bearing unit encountered in the Slag Area of Mill B.

Volatile Organics. BTEX compounds, styrene, and 1,2-dichloroethane were the only volatile organic compounds detected in groundwater samples collected from the Upper Sand during the May 1990 sampling. BTEX compounds and styrene were also detected during the previous sampling round.

The highest volatile organic compound concentrations detected during both sampling rounds occurred in groundwater collected from the East Machine Shop Area, and in wells HC-6 and HC-9. Benzene concentrations in many of these wells exceeded the existing MCL of 0.005 ppm (Table 5). The primary sources of BTEX compounds appears to be from hydrocarbon products including gasoline encountered in soil borings in the East Machine Shop Area and adjacent to the Old Machine Shop.

The source of 1,2-dichloroethane, a cleaning solvent, and styrene, commonly associated with plastics, are unknown. A low concentration (0.009 ppm) of 1,2-dichloroethane was detected during the May 1990 sampling of well HC-6, but was not detected during the previous (1989) sampling round. The existing MCL for 1,2-dichloroethane is 0.005 ppm. The only other well exhibiting detectable concentrations of this chemical was HC-23D (0.001 ppm; Lower Sand completion; see below).

The maximum styrene concentrations detected during the recent (May 1990) sampling was 0.017 ppm in well HC-9. However, during the previous (1989) sampling round, styrene concentrations were present at higher concentrations of 0.2 ppm (HC-13) and 0.44 ppm (HC-15). Wells HC-13 and HC-15 were not sampled during the May 1990 event.

PAHs. PAHs were detected in all six of the wet season groundwater samples. Naphthalene was the predominant PAH compound observed in Upper Sand groundwater, and was detected at concentrations ranging from less than 0.0002 ppm (HC-7) to 2.1 ppm (HC-6). Naphthalene is generally the most soluble and mobile of the PAH compounds and is probably derived from hydrocarbon products encountered in the East Machine Shop and Old Machine Shop areas.

Potentially carcinogenic PAHs (cPAHs) such as benzo(a)anthracene, benzo(a)pyrene, and chrysene were detected in several Upper Sand groundwater samples collected during both the August 1989 and May 1990 sampling rounds. Detectable cPAH concentrations were at or below approximately 0.0002 ppm.

PCP. Pentachlorophenol was detected in four of the six wells sampled during May 1990, and at concentrations ranging from 0.0026 ppm (HC-12) to 6.6 ppm (HC-9). The highest PCP concentration detected during both rounds of sampling was 60 ppm, measured in a sample collected from well HC-13. As discussed above, the PCP present in site groundwaters was probably derived from historical wood treating operations conducted in the East Machine Shop and Old Machine Shop areas.

Seeps

We sampled a total of five seeps in conjunction with the wet weather assessment of Upper Sand groundwater quality. Seep quality results are presented in Tables 8 and 9. The spatial distribution of selected parameters are shown on Figure 10. Seep-1 through Seep-4 were sampled at low tide on May 29, 1990. Seep EV-04, which was first sampled by Weyerhaeuser in the summer of 1989, was resampled at low tide on June 22, 1990. Results were consistent between the two rounds of sampling.

Unlike Seep EV-4, which exhibits consistent discharge, Seep-1 through Seep-4 appear to flow only intermittently and may not be significant groundwater discharge points. Water flow in Seep-1 through Seep-4 was highest as the river receded during low tide. Flows decreased rapidly with time and eventually stopped flowing near the end of low tide. Based on these observations, and also considering the specific conductance data (high conductance relative to groundwater and river water at low tide), we believe that these seeps consist primarily of river water which flows into void spaces behind the bulkhead during high tide and then flows back out of the bulkhead into the river during low tide. Therefore, water quality in Seep-1 through Seep-4 may not be representative of site groundwater discharges to the Snohomish River.

Metals. Arsenic and zinc were detected in all of the seep samples, at concentrations ranging from 0.003 to 0.158 ppm (arsenic) and 0.01 to

0.069 ppm (zinc). Total lead was detected in Seep-1 at a concentration of 0.011 ppm. However, lead was not detected in the filtered sample collected from Seep-1 (less than 0.002 ppm). Since Seep-1 also exhibited the highest total suspended solids concentration (110 ppm), the detected total lead concentration at this site is likely simply an artifact of particulates introduced into the sample during collection. The dissolved lead concentration is thus more representative of the discharge (and bioavailable) concentration.

Organics. Naphthalene, which was detected in Seep-1 at a concentration of 0.0009 ppm, was the only organic compound detected in Seep-1 through Seep-4 samples. However, seep EV-4 contained a considerably larger number of organic chemicals. Seep EV-4 contained detectable BTEX compounds (0.02 to 0.23 ppm), naphthalene (6 ppm), 2-methylnaphthalene (1 ppm), and acenaphthene (0.22 ppm).

Lower Sand

As part of this work, we sampled groundwater from two newly installed wells (HC-15D and HC-23D) and three existing wells (HC-1D, HC-10D, and HC-11D) completed in the Lower Sand unit. Results are summarized in Table 10. Wells HC-1D, HC-10D, and HC-11D were first sampled in the summer of 1989. Groundwater quality observed in these wells was consistent between the two sampling rounds.

Dissolved Metals. With the exception of antimony, cadmium, and lead, most of the metals analyzed were detected in the Lower Sand groundwater samples. The highest metal concentrations within the Lower Sand were detected in well HC-15D, located in the East Machine Shop area. The dissolved arsenic concentration in this well was detected at 3.08 ppm. For comparison, the dissolved arsenic concentration in the upgradient well HC-11D was less than 0.002 ppm.

Volatile Organics. BTEX compounds and 1,2-dichloroethane were the only volatile organic compounds detected in the Lower Sand groundwater samples. As discussed above, these compounds were also detected in the Upper Sand groundwater. No volatile organics were detected in wells HC-1D, HC-10D, and HC-11D. The highest BTEX concentrations were detected in well HC-15D (0.32 to 3.4 ppm). Benzene (0.064 ppm) and ethylbenzene (0.029 ppm) were also detected in HC-23D.

PAHs. PAH compounds were detected in three Lower Sand unit wells (HC-10D, HC-15D, and HC-23D). Naphthalene exhibited the highest concentrations of the PAH detected, ranging from less than 0.0002 to 28 ppm (HC-15D). A strong hydrocarbon-like odor and sheen was observed in well HC-15D during sampling activities. No cPAHs were detected in any of the groundwater samples collected from the Lower Sand.

Phenols. Low levels of phenol (0.0012 to 0.002 ppm) and 2-chlorophenol (0.0002 to 0.0003 ppm) were detected in wells HC-1D, HC-10D, and HC-11D. Pentachlorophenol (PCP) was detected at its highest concentration in well HC-15D (9.7 ppm). PCP was not detected in any of the other Lower Sand unit wells.

Comparison to Upper Sand Groundwater Quality. At a given location on the site, chemical concentrations are generally similar between the Lower Sand and Upper Sand units, particularly within the affected area of the site. This general condition if evident in the groundwater quality contour maps presented on Figures 11, 12, and 13. Based on the limited number of Lower Sand sampling locations, the spatial distribution of BTEX and PAH concentrations in Lower Sand groundwater generally corresponds with concentrations detected in Upper Sand groundwater. The highest concentrations of arsenic, BTEX, PAH, and PCP within both units were detected in the East Machine Shop area, and at similar levels.

Potential Sources of Contamination to the Lower Sand. Based on the groundwater quality data collected in wells HC-15D and HC-23D, it appears that the inorganic and organic chemicals of potential concern present in the Upper Sand and also present within the Lower Sand groundwater zone. Potential sources of contaminants to this deeper zone include:

- Downward migration of contaminated groundwater from the Upper Sand, through breeches in the silt aquitard, and into the Lower Sand; and

- Lateral migration of contaminants from a residual source located within the Lower Sand, which could potentially be located in the vicinity of the Old Machine Shop.

Based on the available data, vertical migration of contaminants from the Upper Sand to the Lower Sand is likely. This conclusion is supported by the downward hydraulic gradient between these zone, the lack of continuity observed in the Silt aquitard, and the similarity of water quality between the zones. Downward migration of groundwater is particularly likely in the vicinity of well HC-5, which appears as a local "sink" on the groundwater flow maps (Figures 4 and 5), consistent with the minimal Silt Layer thickness at this location. Additional breaches or "thinning" of the Silt Layer are likely around former foundation pilings and site features that required excavation beyond depths of 5 to 8 feet.

Determination of the predominant pathways contributing to contamination of the Lower Sand groundwater may be important in the assessment of potential remediation options at the Mill E site. For example, if the primary contaminant transport pathway to the Lower Sand is via downward migration (i.e., leakage) of Upper Sand groundwaters, then cleanup of the Upper Sand will directly improve future groundwater quality in the Lower Sand. However, if there is a substantial residual source of contaminants within the Lower Sand (e.g., due to possible prior vertical migration of creosote materials), then remediation of the Upper Sand alone may not readily achieve cleanup within the Lower Sand.

Data collected during our Phase I investigations suggests that both of the migration processes outlined above may be affecting groundwater quality in the Lower Sand unit. Field observations indicate that contaminant sources may be in direct contact with the Lower Sand. The presence of a sheen in HC-15D indicates that free-phase or residual product (probably a diesel/creosote mixture) may be present in the Lower Sand. Based on our understanding of the former site facilities, some of the retorts, underground storage tanks, and associated piping could have been in direct contact with the Lower Sand. The significance of potential residual contaminant sources within the Lower Sand may need to be addressed to assure the effectiveness of remediation at Mill E within the Lower Sand.

Preliminary Risk Evaluation

The aggregate site characterization data presented above and in previous reports (Hart Crowser, 1989a and 1989b) will ultimately form the basis to determine the need for and scope of remedial actions at

Mill E. A statistical summary of selected (see below) soil data collected from the East Machine Shop and Machine Shop areas of the site which have exhibited the highest chemical concentrations is presented in Table 11. A similar summary of water quality conditions near the Snohomish River is presented in Table 12. In order to provide a preliminary evaluation of the magnitude of site risks posed by these chemical concentrations, the risk assessment methodology defined in the MTCA cleanup standards regulation (WAC 173-340) was applied to Mill E.

Prior to performing the risk analysis, chemicals of potential concern were identified from the list of all chemicals detected at Mill E. Based on the preliminary risk evaluation discussed below, those chemicals which contributed to more than 99 percent of the total site risk at the site were identified. These "indicator" chemicals included arsenic, chromium, benzene, xylene, PCP, naphthalene, cPAHs, and TCDD. The eight indicator chemicals or chemical groupings form the basis for quantitative assessments of site hazards and cleanup requirements, consistent with state and federal hazardous waste guidelines.

Consistent with WAC 173-340 and federal Superfund guidelines, the human health risk assessment was based on the reasonable maximum exposure (RME) expected to occur at the site, based on current and projected future site use conditions. The RME scenario considered the following:

- **Direct Soil Contact.** Under current and projected industrial site use conditions (consistent with WAC 173-340 industrial use criteria), workers at Mill E may come in direct contact with near-surface (0 to 15 feet) soils at Mill E as a result of trenching or other earth-moving operations. Soil contact exposures under this condition are assessed by considering incidental soil ingestion rates which may result from these activities. The soil concentration used in this assessment was defined by the upper 95th percentile tolerance limit of all area soils to a depth of 15 feet (Table 11). Exposure assumptions defined in WAC 173-340 are summarized in Table 13.

- **Air Inhalation.** Inhalation of chemicals present in soils at Mill W may occur via two processes: volatilization and fugitive dust suspension. Volatilization of chemicals was assessed by applying soil concentrations summarized in Table 11 to the EPA's vapor release model discussed in Hart Crowser (1989b). A one-foot cover thickness (representing existing ballast material) was assumed to occur over the contaminated soils. Potential dust generation resulting from disturbance of contaminated soils (e.g., due to earth-moving activities) was also addressed, based on fugitive dust emission and dispersion models described in the EPA Exposure Assessment Manual (1988). Under worst-case site conditions, the average annual concentration of site soils released into the local air environment (represented by the total suspended particulate [TSP] level) is calculated at approximately 1 $\mu g/m^3$. Chemical concentrations of the TSP attributable to site dust releases were assumed to be represented by the Table 11 soil data. Local air concentrations attributable to site vapor and dust releases are summarized in Table 14. Exposure assumptions defined in WAC 173-340 are also summarized in Table 14.

- **Fish and Shellfish Consumption.** As discussed in Hart Crowser (1989b), discharge of contaminated groundwaters to the Snohomish River may lead to bioconcentration in edible fish tissue in the estuary, which may represent a potential human health risk. The magnitude of such risks was estimated in this evaluation using the 95 percent tolerance limit of chemical concentrations detected in groundwaters near the Snohomish River (Table 12). Based on an upper-bound estimate of the total site groundwater discharge of 20 gpm (considering uncertainties in the site groundwater flow estimates discussed previously), and the estimated 7-day, 10-year low-flow within the local estuary of approximately 1,400 cubic feet per second, the worst-case groundwater dilution in the Snohomish River is approximately 1×10^{-6} (1 in 1 million). Site groundwater concentrations were assumed to be diluted in the river and then concentrated in edible fish and shellfish tissue, based on bioconcentration factors used by EPA to develop water quality criteria (Clean Water Act; Section 304). Exposure assumptions defined in WAC 173-340 are summarized in Table 15.

Toxicity and/or suspected carcinogenicity criteria of the indicator chemicals at Mill E are applied to the exposure assessment summarized above to estimate the magnitude of human health and ecological risks. For this assessment, toxicity criteria were largely obtained from a recent (March 1991) retrieval from EPA's Integrated Risk Information System (IRIS). Brief toxicologic profiles of the indicator chemicals are presented below.

Arsenic

Acute and chronic exposure to inorganic arsenic via ingestion and inhalation can result in a variety of toxic effects, especially to moist tissues such as the eyes and respiratory system. A chronic oral reference dose of 1 x 10^{-3} mg/kg-day is established by the EPA based on heratosis and hyperpigmentation effects observed for exposed humans. The uncertainty factor used to derive the criteria is 1, indicating a high degree of confidence in the study used to establish the criteria.

Arsenic is classified by the EPA as a group A human carcinogen. The EPA inhalation slope factor is 50 $(mg/kg\text{-}day)^{-1}$, based on respiratory tract tumors in exposed humans. For oral exposures a slope factor of 1.75 $(mg/kg\text{-}day)^{-1}$ has been proposed by the EPA based on skin tumors in exposed humans.

Chromium

EPA has established an oral reference dose (RfD) for Cr(III) of 1 mg/kg-day, based on chronic rat feeding study. EPA reports a low degree of confidence in the value due to inexplicit description of study protocol and results, lack of high dose information, and lock of an observed effect level.

Although inhalation of chromium dust is considered by EPA to be potentially carcinogenic, the soluble salts which likely characterize oral exposures are not presently identified as carcinogenic. EPA has established an oral reference dose (RfD) for Cr(VI) of 0.005 mg/kg-day, based on a chronic rat drinking study. EPA reports a low degree of confidence in the value due to the small number of animals tested, the small number of parameters measured, and the lack of toxic effects at the highest tested dose.

EPA has classified Cr(VI) as a Group A (known human) carcinogen via the inhalation route, and based on dose-response relationships has characterized the inhalation potency slope as 41 $(mg/kg\text{-}day)^{-1}$.

Benzene

Benzene is classified as a group A carcinogen based on several occupational studies which observed increased incidence of leukemia in exposed workers. The EPA slope factor for both oral and inhalation exposures is 2.9×10^{-2} $(mg/kg\text{-}day)^{-1}$.

Xylene

Xylene vapor may cause irritation of the eyes, nose, and throat. Acute exposure to xylene vapor may cause central nervous system depression. The acute inhalation reference dose established by the EPA is 8.6×10^{-2} mg/kg-day, based on central nervous system effects and nose and throat irritation in exposed humans. The acute oral reference dose established by the EPA is 5.7×10^{-1} mg/kg-day, based on hyperactivity, decreased body weight and increased mortality in exposed rats. Uncertainty factors of 100 are used to derive both criteria.

Naphthalene

Naphthalene is included among a class of compounds collectively referred to as polycyclic aromatic hydrocarbons. For non-carcinogenic PAHs, naphthalene is considered to be the most toxic.

An oral reference dose of 4×10^{-3} mg/kg-day for chronic exposure to naphthalene has been established based on ocular and internal lesions observed in exposed rats. An uncertainty factor of 10,000 is used to derive the criteria. Such a large uncertainty factor indicates extremely low confidence in the available toxicological criteria, and the need to apply this criteria with caution.

Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)

PAHs are large group of structurally related organic compounds consisting of annealed aromatic (benzene) rings. The toxicity of different PAH compounds has been shown to be related to the chemical structure of the compound. Of the 13 PAHs listed as priority pollutants, sufficient data exists to allow classification by the EPA of seven high molecular weight PAH compounds (HPAHs) as probable (Group B2) carcinogens: benzo(a) anthracene, chrysene, benzo (b) fluoranthene, benzo (k) fluoranthene benzo(a)pyrene, dibenzo(a,h,i)anthracene, and ideno(1,2,3-cd)pyrene.
Because benzo(a)pyrene(B(a)P) is considered to be the most potent and most common occurring of the carcinogenic PAHs, a conservative method for evaluating the effects of carcinogenic PAHs is to use

benzo(a)pyrene as a surrogate and assume that all other carcinogenic PAHs are equally toxic. This approach is necessary because there is not information of sufficient quality for all carcinogenic PAHs to allow a quantitative evaluation of each compound.

The EPA classifies benzo(a)pyrene as a B2 probable human carcinogen, based on sufficient evidence of carcinogenicity in all nine species of experimental animals for which data are reported. Slope factors of 6.1 $(mg/kg\text{-}day)^{-1}$ for inhalation exposures, and 12 $(mg/kg\text{-}day)^{-1}$ for oral exposure have been proposed by the EPA. These values are currently being reviewed by the EPA, are not presently reported in IRIS or HEAST, and are not regarded as verified for use in quantitative risk assessments.

Pentachlorophenol (PCP)

A single study on the chronic oral toxicity of pentachlorophenol to rats observed liver and kidney effects. Based on this study an oral reference dose of 3×10^{-2} mg/kg-day is established by the EPA. An uncertainty factor of 100 is used to derive the oral reference dose based on intra- and interspecies variability in the toxicity of this chemical. Pentachlorophenol has also been classified as a B2, probable human carcinogen, based on multiple types of tumors observed in exposed mice, and evidence of mutagenicity in short-term bioassays. An oral slope factor of 1.2×10^{-1} $(mg/kg\text{-}day)^{-1}$ is established by the EPA.

Tetrachlorodibenzodioxin (TCDD)

Many isomeric forms of dioxin (dibenzo-p-dioxin) exist, with the toxicity of dioxin being dependant on the number and position of chlorine atoms attached to the basic polyaromatic ring structure. While several acute and chronic effects are attributed to dioxin exposure of humans, carcinogenic, teratogenic, and fetotoxic effects are of greatest concern. The most toxic isomer, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), is classified as a B2, probable human carcinogen, based on several tumors observed in rats exposed by gavage. Oral and inhalation slope factors for TCDD of 1.5×10^{-5} $(mg/kg\text{-}day)^{-1}$ are established by the EPA. The cummulative potencies of all dioxin and furan compounds were expressed as TCDD-equivalents using relative potency factors developed by EPA and NATO. Non-carcinogenic effects of TCDD were evaluated relative to an interim EPA oral reference dose of 1×10^{-9} mg/kg-day.

The results of the human health risk characterization are presented in Tables 13, 14, and 15. Based on this preliminary risk evaluation, no non-carcinogenic risk (i.e., no toxicity) to human health is expected as a result of reasonable maximum exposure (RME) conditions at the Mill E site. The cumulative Hazard Index considering all pathways of potential exposure was below 0.4, relative to a potential "threshold" toxicity value of 1.

Potential lifetime cancer risks due to RME conditions at the Mill E site ranged from 4 x 10^{-8} (1 in 25 million) due to consumption of contaminated fish from the Snohomish River (Table 15) to 6 x 10^{-5} (1 in 17,000) due to on-site soil contact exposures (Table 13). The potential cancer risk associated with site inhalation exposures was intermediate between this risk range at 1 x 10^{-6} (1 in 1 million; Table 14). Only the on-site direct soil contact exposure pathway exceeded the overall MTCA lifetime cancer risk target of 1 x 10^{-6} (1 in 1 million). (The MTCA also defines a higher target risk for industrial sites of 1 x 10^{-5} [1 in 100,000). Most of the potential direct soil contact cancer risk was associated with cPAHs, with a smaller risk posed by arsenic and TCDD.

Off-site ecological impacts were assessed relative to both water and sediment quality conditions in the groundwater seepage area immediately adjacent to Mill E. The primary identified pathway of site chemicals discharged to the Snohomish River is via seep EV-4, located downgradient of the principal areas of on-site groundwater contamination. Measured chemical concentrations at EV-4 exceeded marine aquatic life chronic and acute water quality criteria for both arsenic and naphthalene (Table 16). A localized area of arsenic and naphthalene toxicity to sensitive aquatic life thus may exist within the immediate vicinity of the groundwater seep zones. PCP concentrations in site groundwaters are also sufficiently greater than aquatic life criteria to indicate a potential ecological concern, though PCP has not been detected in any nearshore seep or sediment sample. (Biodegradation of PCP is known to occur readily in marine environments). In any event, because of the relatively high river flows, the seeps are rapidly diluted within nearshore areas of the Snohomish River.

Maximum concentrations of arsenic and several low molecular weight PAHs (including naphthalene) detected in nearshore sediments immediately adjacent to Mill E also exceeded marine chemical criteria levels specified in the state Sediment Management Standards (WAC

173-304; Table 16). Sediment concentrations adjacent to the groundwater (and seep) discharge area were also above minimum cleanup levels defined under WAC 173-304. Based on this comparison, a localized area of toxicity to sensitive aquatic life is possible in sediments immediately adjacent to Mill E.

LIMITATIONS

This work was performed and this report prepared in accordance with generally accepted professional practices for the nature of the work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Weyerhaeuser Company for specific application to the project site. This report is not meant to represent a legal opinion and no other warranty, express or implied, is made.

Sincerely,

HART CROWSER, INC.

DOUGLAS L. HILLMAN
Project Hydrogeologist

CLAYTON R. PATMONT
Principal

Table 1 - Well Completion and Groundwater Monitoring Data

Depth to Groundwater from Top of Casing in Feet

Well Number	Well Depth	Casing Stick-up	27/28-Jun 1989	9:00 AM 3-Jul 1989	12:00 PM 3-Jul 1989	10:00 AM 6-Jul 1989	2:00 PM 2-Aug 1989	1:00 PM 10-May 1990	9:00 AM 29-May 1990	9:00 AM 15-Jun 1990	5:00 PM 31-Aug 1990
River	NA	NA	NM	15.70	17.00	7.60	15.30	12.50	NM	NM	4.20
HC-1	8.0	2.5	6.72	6.67	NM	6.85	7.23	6.77	NM	NM	7.46
HC-1D	26.0	2.6	12.67	11.07	NM	9.88	14.34	14.23	NM	10.18	7.91
HC-2	8.0	2.7	7.51	7.46	7.50	7.51	7.79	7.20	NM	NM	7.77
HC-3	7.9	2.4	6.86	6.90	6.88	6.95	7.19	6.50	NM	NM	7.28
HC-4	5.5	2.8	5.33	5.40	5.41	5.47	5.75	5.35	NM	NM	6.10
HC-5	8.0	2.4	5.73	5.75	5.76	5.82	6.13	5.28	NM	NM	6.29
HC-6	7.5	2.4	6.43	6.43	6.47	6.48	6.79	6.04	NM	NM	6.99
HC-7	7.5	2.9	8.77	8.46	8.64	8.59	8.95	8.92	NM	NM	9.30
HC-8	6.5	1.8	8.33	8.32	8.33	8.33	Dry	8.39	NM	NM	Dry
HC-9	8.0	2.0	6.34	6.31	6.31	6.41	6.64	5.85	NM	NM	6.78
HC-10	8.0	2.4	7.13	6.98	NM	7.07	7.73	7.35	NM	NM	7.94
HC-10D	26.0	2.4	8.47	11.59	NM	9.72	14.34	14.15	NM	9.55	6.89
HC-11	6.0	2.5	4.05	4.24	NM	4.25	4.48	4.04	NM	NM	4.85
HC-11D	27.0	2.6	9.31	7.28	10.04	6.84	10.82	10.85	NM	7.90	6.73
HC-12	8.0	2.0	6.40	6.47	6.52	6.48	6.73	5.87	NM	NM	6.89
HC-13	12.5	1.7	5.97	5.98	5.98	6.06	6.30	Product	NM	NM	Product
HC-14	8.0	1.7	6.14	6.13	6.13	6.21	6.42	5.64	NM	NM	6.73
HC-15	9.5	2.4	6.65	6.73	6.78	6.68	7.00	Product	NM	NM	Product
HC-15D	25.5	2.0	---	---	---	---	---	---	---	9.23	7.02
HC-16	8.0	1.8	5.34	5.36	5.35	5.43	5.70	4.82	NM	NM	5.92
HC-17	7.5	2.6	---	---	---	---	5.21	4.72	NM	NM	5.43
HC-18	8.0	2.4	---	---	---	---	6.88	6.62	NM	NM	7.06
HC-19	9.0	-0.3	---	---	---	---	5.21	4.74	NM	NM	5.53
HC-20	9.0	-0.3	---	---	---	---	4.13	3.52	NM	NM	4.31
HC-21	7.5	2.5	---	---	---	---	6.24	5.64	NM	NM	6.68
HC-22	8.3	2.4	---	---	---	---	6.73	Product	NM	NM	Product
HC-23D	24.5	2.3	---	---	---	---	---	---	---	10.39	7.91
HC-24	7.0	2.1	---	---	---	---	---	---	2.91	NM	3.76
HC-25	7.0	2.0	---	---	---	---	---	---	2.75	NM	4.32
HC-26	7.5	2.1	---	---	---	---	---	---	3.87	NM	4.51
WP-1	10.5	1.8	---	---	---	---	---	---	5.30	NM	5.50

Groundwater Elevation in Feet (Mean Sea Level)

Well Number	T.O.C. Elevation	27/28-Jun 1989	9:00 AM 3-Jul 1989	12:00 PM 3-Jul 1989	10:00 AM 6-Jul 1989	2:00 PM 2-Aug 1989	1:00 PM 10-May 1990	9:00 AM 29-May 1990	9:00 AM 15-Jun 1990	5:00 PM 31-Aug 1990
River	9.90	NM	-5.80	-7.10	2.30	-5.40	-2.60	NM	NM	5.70
HC-1	10.85	4.13	4.18	NM	4.00	3.62	4.08	NM	NM	3.40
HC-1D	11.18	-1.49	0.11	NM	1.30	-3.16	-3.05	NM	1.00	3.27
HC-2	11.41	3.90	3.95	3.91	3.90	3.62	4.21	NM	NM	3.64
HC-3	11.08	4.22	4.18	4.20	4.13	3.89	4.58	NM	NM	3.80
HC-4	10.43	5.10	5.03	5.02	4.96	4.68	5.08	NM	NM	4.33
HC-5	9.08	3.35	3.33	3.32	3.26	2.95	3.80	NM	NM	2.79
HC-6	10.23	3.80	3.80	3.76	3.75	3.44	4.19	NM	NM	3.24
HC-7	11.38	2.61	2.92	2.74	2.79	2.43	2.46	NM	NM	2.08
HC-8	11.51	3.18	3.19	3.18	3.18	Dry	3.12	NM	NM	Dry
HC-9	10.46	4.12	4.15	4.15	4.05	3.82	4.61	NM	NM	3.68
HC-10	10.22	3.09	3.24	NM	3.15	2.49	2.87	NM	NM	2.28
HC-10D	10.47	2.00	-1.12	NM	0.75	-3.87	-3.68	NM	0.92	3.58
HC-11	9.08	5.03	4.84	NM	4.83	4.60	5.04	NM	NM	4.23
HC-11D	9.23	-0.08	1.95	-0.81	2.39	-1.59	-1.62	NM	1.33	2.50
HC-12	10.42	4.02	3.95	3.90	3.94	3.69	4.55	NM	NM	3.53
HC-13	10.08	4.11	4.10	4.10	4.02	3.78	Product	NM	NM	Product
HC-14	10.26	4.12	4.13	4.13	4.05	3.84	4.62	NM	NM	3.53
HC-15	10.75	4.10	4.02	3.97	4.07	3.75	Product	NM	NM	Product
HC-15D	10.22	---	---	---	---	---	---	NM	0.99	3.20
HC-16	9.52	4.18	4.16	4.17	4.09	3.82	4.70	NM	NM	3.60
HC-17	10.00	---	---	---	---	4.79	5.28	NM	NM	4.57
HC-18	10.37	---	---	---	---	3.49	3.75	NM	NM	3.31
HC-19	7.87	---	---	---	---	2.66	3.13	NM	NM	2.34
HC-20	7.54	---	---	---	---	3.41	4.02	NM	NM	3.23
HC-21	10.01	---	---	---	---	3.77	4.37	NM	NM	3.33
HC-22	10.55	---	---	---	---	3.82	Product	NM	NM	Product
HC-23D	11.36	---	---	---	---	---	---	---	0.97	3.45
HC-24	8.39	---	---	---	---	---	---	5.48	NM	4.64
HC-25	8.56	---	---	---	---	---	---	5.81	NM	4.24
HC-26	9.50	---	---	---	---	---	---	5.63	NM	4.99
WP-1	16.77	---	---	---	---	---	---	11.47	NM	11.27

---	Monitoring well not completed at time of measurement
NM	Completed well not monitored
Dry	No groundwater in monitoring well
Product	Free-phase hydrocarbon present in monitoring well

Table 2 - Summary of Machine Shop Soil Quality Data (Page 1 of 3)

Boring/Sample Number: Sample Depth in feet:	A-1/S-1 2.5-4.0	A-2/S-2 5.0-6.5	A-3/S-3 7.5-9.0	A-4/S-4 10.0-11.5	B-1/S-1 2.5-4.0	B-2/S-2 5.0-6.5
Total Metals in mg/kg (ppm)						
Arsenic	60	7	7	7	49	38
Chromium	24	22	20	20	32	20
Copper	22	18	16	17	18	16
Solids in %	93.2	85.3	82.0	72.2	92.6	85.6
Volatile Organic Compounds in mg/kg (ppm)						
Methylene Chloride	0.014	0.017	0.065	0.025 U	0.63 U	0.63 U
Acetone	0.031	0.012	0.025	0.061	1.3 U	1.3 U
2-butanone (MEK)	0.01 U	0.01 U	0.008 J	0.05 U	1.3 U	1.3 U
Benzene	0.005 U	0.005 U	0.012	0.47	0.63 U	0.63 U
Toluene	0.006	0.005 U	0.022	0.64	13	9.6
Ethylbenzene	0.005 U	0.005 U	0.005 J	0.39	5.1	5.8
Styrene	0.005 U	0.005 U	0.005 U	0.1	0.63 U	0.63 U
Xylenes	0.014	0.005 U	0.042	1.3	67	75
Semivolatile Organic Compounds in mg/kg (ppm)						
Phenol	0.66 U	0.67 U	0.66 U	33 U	0.66 U	0.66 U
4-methylphenol	0.66 U	0.67 U	0.66 U	33 U	0.66 U	0.66 U
Naphthalene	0.67	0.41 J	2.2	170	2.7	8.8
2-methylnaphthalene	0.1 J	0.34 J	2	64	3	9
Acenaphthene	0.66 U	0.35 J	2.6	54	0.34 J	0.83
Dibenzofuran	0.66 U	0.29 J	1.5	34	0.66 U	0.49 J
Fluorene	0.66 U	0.53 J	3	45	0.34 J	0.81
Pentachlorophenol	0.66 U	0.67 U	0.66 U	33 U	0.66 U	0.66 U
Phenanthrene	0.66 U	1.8	4.9	120	0.94	2.2
Anthracene	0.66 U	1.1	0.54 J	11 J	0.23 J	0.43 J
Fluoranthene	0.66 U	1.4	1.2	40	0.78	2
Pyrene	0.66 U	1.2	0.85	38	0.37 J	0.85
Benzo(a)anthracene	0.66 U	0.23 J	0.66 U	6.1 J	0.17 J	0.3 J
Chrysene	0.66 U	0.15 J	0.66 U	33 U	0.19 J	0.66 U
Benzo(b)fluoranthene	0.66 U	0.67 U	0.66 U	33 U	0.14 J	0.66 U
Benzo(k)fluoranthene	0.66 U	0.67 U	0.66 U	33 U	0.66 U	0.27 J

Notes:
All results are presented on an as- received basis.
U Not detected at indicated detection limit.
J Estimated value.

Table 2 - Summary of Machine Shop Soil Quality Data (Page 2 of 3)

Boring/Sample Number: Sample Depth in feet:	B-3/S-3 7.5-9.0	C-1/S-1 2.5-4.0	C-2/S-2 5.0-6.5	C-3/S-3 (S-2 Dup)	D-1/S-1A 2.5-3.25	D-2/S-2A 5.0-5.75
Total Metals in mg/kg (ppm)						
Arsenic	6	114	7	13	28	74
Chromium	35	70	38	29	21	24
Copper	34	12	24	6	15	14
Solids in %	67.8	89.0	62.3	66.3	89.4	76.6
Volatile Organic Compounds in mg/kg (ppm)						
Methylene Chloride	0.1	0.025 U	0.058	0.12	0.63 U	0.22
Acetone	0.043	0.05 U	0.19	1.3 U	1.3 U	0.073
2-butanone (MEK)	0.01 U	0.05 U	0.06	0.053	1.3 U	0.05 U
Benzene	0.35	0.035	0.13	0.1	0.63 U	0.11
Toluene	0.1	1.4 J	0.04	0.077	4.7	0.5
Ethylbenzene	0.057	2.5 J	0.15	0.19	9.9	0.18
Styrene	0.005 U	0.025 U	0.025 U	0.005 U	0.63 U	0.025 U
Xylenes	0.92	18 J	4.4	2.7	83	2.4
Semivolatile Organic Compounds in mg/kg (ppm)						
Phenol	0.66 U	0.65 U	0.33 U	0.033 U	3.3 U	0.65 U
4-methylphenol	0.66 U	0.65 U	0.33 U	0.033 U	3.3 U	0.65 U
Naphthalene	3.6	2.4	0.25 J	0.19	15	0.4 J
2-methylnaphthalene	0.46 J	3.7	0.099 J	0.064	17	0.26 J
Acenaphthene	0.32 J	0.41 J	0.33 U	0.033 U	1 J	0.14 J
Dibenzofuran	0.66 U	0.2 J	0.33 U	0.033 U	0.4 J	0.068 J
Fluorene	0.66 U	0.32 J	0.33 U	0.033 U	0.72 J	0.65 U
Pentachlorophenol	0.66 U	1.7	0.33 U	0.033 U	3.3 U	0.65 U
Phenanthrene	0.8	0.87	0.33 U	0.043	2.5 J	0.3 J
Anthracene	0.66 U	0.23 J	0.035 J	0.033 U	3.3 U	0.65 U
Fluoranthene	0.43 J	1.3	0.33 U	0.033 U	2.2 J	0.14 J
Pyrene	0.31 J	1.3	0.33 U	0.033 U	2.2 J	0.12 J
Benzo(a)anthracene	0.66 U	0.13 J	0.33 U	0.033 U	3.3 U	0.65 U
Chrysene	0.66 U	0.65 U	0.33 U	0.033 U	3.3 U	0.65 U
Benzo(b)fluoranthene	0.66 U	0.65 U	0.33 U	0.033 U	3.3 U	0.65 U
Benzo(k)fluoranthene	0.66 U	0.65 U	0.33 U	0.033 U	3.3 U	0.65 U

Notes:
All results are presented on an as-
U Not detected at indicated dete
J Estimated value.

Notes:
All results are presented on an as-received basis.
U Not detected at indicated detection limit.
J Estimated value.

Table 2 - Summary of Machine Shop Soil Quality Data (Page 3 of 3)

Boring/Sample Number: Sample Depth in feet:	D-2/S-2B 5.75-6.5	E-1/S-1 2.5-4.0	E-2/S-2 5.0-6.5	F-1/S-1 2.5-4.0	F-2/S-2 5.0-6.5	F-3/S-3 7.5-8.0
Total Metals in mg/kg (ppm)						
Arsenic	10	100	94	12	14	25
Chromium	40	65	132	23	37	46
Copper	29	15	26	24	15	24
Solids in %	60.8	88.2	58.5	72.2	74.2	77.9
Volatile Organic Compounds in mg/kg (ppm)						
Methylene Chloride	0.63 U	0.63 U	0.11	0.005 U	0.63 U	0.63 U
Acetone	1.3 U	1.3 U	0.29	0.011	1.3 U	1.3 U
2-butanone (MEK)	1.3 U	1.3 U	0.03	0.01 U	1.3 U	1.3 U
Benzene	0.63 U	0.63 U	0.07	0.005 U	0.63 U	0.63 U
Toluene	0.39 J	7.4	0.08	0.005 U	0.63 U	0.44 J
Ethylbenzene	0.34 J	7	0.05	0.005 U	0.63 U	1.1
Styrene	0.63 U	0.63 U	0.00 U	0.005 U	0.63 U	0.9
Xylenes	3.5	80	0.3	0.005 U	0.66	5.2
Semivolatile Organic Compounds in mg/kg (ppm)						
Phenol	0.033 U	1.3 U	0.03 U	0.033 U	33 U	30 J
4-methylphenol	0.033 U	1.3 U	0.03 U	0.033 U	33 U	23 J
Naphthalene	0.12	12	0.13	0.033 U	120	530
2-methylnaphthalene	0.036	18.079	0.33	0.033 U	73	260
Acenaphthene	0.033 U	0.46 J	0.04	0.033 U	51	180
Dibenzofuran	0.033 U	0.29 J	0.03 U	0.033 U	35	120
Fluorene	0.033 U	0.52 J	0.03 U	0.033 U	48	180
Pentachlorophenol	0.033 U	1.3 U	0.03 U	0.033 U	6.5 J	66 U
Phenanthrene	0.033 U	1.5	0.05	0.069	130	430
Anthracene	0.033 U	0.22 J	0.03 U	0.033 U	40	280
Fluoranthene	0.033 U	0.95 J	0.03 U	0.089	42	130
Pyrene	0.033 U	0.7 J	0.03 U	0.14	34	99
Benzo(a)anthracene	0.033 U	0.14 J	0.03 U	0.033 U	6.8 J	19 J
Chrysene	0.033 U	0.18 J	0.03 U	0.054	7.1 J	19 J
Benzo(b)fluoranthene	0.033 U	1.3 U	0.03 U	0.033 U	33 U	66 U
Benzo(k)fluoranthene	0.033 U	1.3 U	0.03 U	0.033 U	33 U	66 U

Notes:
All results are presented on an as-
U Not detected at indicated dete
J Estimated value.

Notes:
All results are presented on an as-received basis.
U Not detected at indicated detection limit.
J Estimated value.

Table 3 - Subsurface Soil Total Metals Background Reference

Total Metals in mg/kg (ppm)	Puget Sound Mean Soil Background(a)	Western U.S. Mean Soil Background(b)	Pilchuck Farm Median Soil Background(c)
Arsenic	<100 U	5.5	13.4
Cadmium	<7 U	----	0.3
Chromium	80	41	47
Copper	20	21	13.2
Lead	15	17	25.4
Mercury	----	0.05	0.14
Nickel	80	15	42.4
Zinc	80	55	56

NOTES:

U Indicates analyte was not detected

(a) Pevear, D., Geology Department, Western Washington University, unpublished data cited in Dexter et al., 1981.

(b) Shacklette and Boerngen, 1984.

(c) Harper-Owes, 1985.

Table 4 – Summary of Arsenic Background Soil Concentrations

Boring/Sample Number:	Sample Depth in Feet	Total Arsenic in mg/kg (ppm)	TCLP Arsenic in mg/L (ppm)	EP Toxicity Arsenic in mg/L (ppm)
HC-24/S-1	2.5 - 4.0	17.0	NA	NA
HC-24/S-3	7.5 - 9.0	10.2	NA	NA
HC-25/S-1	2.5 - 4.0	4.8	NA	NA
HC-25/S-4	6.5 - 8.0	11.7	NA	NA
HC-26/S-1	2.5 - 4.0	16.1	NA	NA
HC-26/S-4	6.5 - 8.0	8.9	NA	NA
WP-1/S-2A	5.0 - 5.75	115	0.2 U	0.2 U
WP-1/S-2B	5.75 - 6.5	7940	0.2 U	0.2 U
WP-1/S-3 (S-2A)	5.0 - 5.75	134	0.2 U	0.2 U

Notes:
NA Not analyzed.
U Not detected at indicated detection limit.

Table 5 - Summary of Organic Compound Concentrations in Upper Sand Groundwater

Well Number:	HC-5	HC-6	HC-7	HC-9	HC-92	HC-12	HC-16	HC-CRB	HC-5FB
					HC-9 Replicate			Rinseate Blank	Field Blank
Date Collected:	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90
Volatile Organics in mg/L (ppm)									
Methylene Chloride	0.007 U	0.012 U	0.005 U	0.005 U	0.012 U	0.007 U	0.05 U	0.005 U	0.033
Acetone	0.006 UJ	0.027 U	0.01 U	0.026 U	0.044 U	0.01 U	0.1 U	0.01 U	0.11
1,2,-Dichloroethane	0.005 U	0.009	0.005 U	0.005 U	0.005 U	0.005 U	0.05 U	0.005 U	0.005 U
Benzene	0.005 U	0.46	0.005 U	0.16	0.17	0.003 J	0.077	0.005 U	0.005 U
Toluene	0.005 U	0.72 J	0.005 U	0.059	0.061	0.017	0.57	0.005 U	0.005 U
Ethylbenzene	0.005 U	0.082	0.005 U	0.022	0.025	0.002 J	0.48	0.005 U	0.005 U
Xylenes	0.005 U	0.44	0.005 U	0.099	0.11	0.005	7.8	0.005 U	0.005 U
Styrene	0.005 U	0.005 U	0.005 U	0.016	0.017	0.005 U	0.05 U	0.005 U	0.005 U

Notes:

NA	Not analyzed.
U	Not detected at indicated detection limit.
J	Estimated value.

Table 5 - Summary of Organic Compound Concentrations in Upper Sand Groundwater

Well Number:	HC-5	HC-6	HC-7	HC-9	HC-92	HC-12	HC-16	HC-CRB	HC-5FB
					HC-9 Replicate			Rinseate Blank	Field Blank
Date Collected:	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90
Semivolatile Organics in mg/L (ppm)									
Phenol	0.0002 UJ	0.01 U	0.0003 J	0.27	0.011 U	0.0005 J	0.01 U	0.0005 J	0.0002 UJ
2-Chlorophenol	0.0002 J	0.01 U	0.0003 J	0.01 U	0.011 U	0.0002 J	0.01 U	0.0003 J	0.0002 UJ
2-Methylphenol	0.0002 UJ	0.015	0.0002 U	0.27	0.084	0.0012 J	0.01 U	0.0002 UJ	0.0002 UJ
4-Methylphenol	0.0002 UJ	0.067	0.0002 U	0.73	0.71	0.0011 J	0.03	0.0002 UJ	0.0002 UJ
2,4-Dimethylphenol	0.0002 UJ	0.018	0.0002 U	0.14	0.2	0.016 J	0.01 U	0.0002 UJ	0.0002 UJ
4-Chloro-3-methylphenol	0.0002 UJ	0.01 U	0.0002 U	0.01 U	0.011 U	0.0003 J	0.01 U	0.0002 UJ	0.0002 UJ
2,4,6-Trichlorophenol	0.0002 UJ	0.01 U	0.0002 U	0.01 U	0.003 J	0.0002 UJ	0.01 U	0.0002 UJ	0.0002 UJ
2,4,5-Trichlorophenol	0.001 UJ	0.052 U	0.001 U	0.17	0.15	0.001 UJ	0.052 U	0.001 UJ	0.001 UJ
Pentachlorophenol	0.001 UJ	0.071	0.001 U	6.3	6.8	0.0026 J	0.01 J	0.001 UJ	0.001 UJ
Benzoic Acid	NA	0.052 U	NA	0.017 J	0.023 J	NA	0.052 U	NA	NA
Naphthalene	0.0006 J	2.1	0.0002 U	1.8	1.8	0.068 J	0.61	0.0002 UJ	0.0002 UJ
2-Methylnaphthalene	0.0002 UJ	0.26	0.0002 U	0.23	0.22	0.006 J	0.21	0.0004 J	0.0002 UJ
Acenaphthlyene	0.0002 UJ	0.01 U	0.0002 U	0.01 U	0.011 U	0.0003 J	0.01 U	0.0002 UJ	0.0002 UJ
Acenaphthene	0.0046 J	0.057	0.0003 J	0.07	0.011 U	0.0021 J	0.021	0.0003 J	0.0002 UJ
Fluorene	0.0009 J	0.01 U	0.0002 U	0.01 U	0.026	0.001 J	0.012	0.0002 UJ	0.0002 UJ
Phenanthrene	0.0002 UJ	0.01 U	0.0002 U	0.01 U	0.014	0.0028 J	0.016	0.0002 UJ	0.0002 UJ
Anthracene	0.0002 UJ	0.01 U	0.0002 U	0.01 U	0.003 J	0.0007 J	0.003 J	0.0002 UJ	0.0002 UJ
Fluoranthene	0.0002 UJ	0.01 U	0.0002 U	0.01 U	0.011 U	0.0003 J	0.009 J	0.0002 UJ	0.0002 UJ
Pyrene	0.0002 UJ	0.01 U	0.0002 J	0.01 U	0.011 U	0.0004 J	0.008 J	0.0002 UJ	0.0002 UJ
Benzo(a)anthracene	0.0002 J	0.01 U	0.0002 U	0.01 U	0.011 U	0.0002 UJ	0.01 U	0.0002 UJ	0.0002 UJ
Dibenzofuran	NA	0.01 U	NA	0.01 U	0.011 U	NA	0.008 J	NA	NA

239506T5.WK1

Table 6 - Summary of Trace Metal Concentrations in Upper Sand Groundwater

Well Number:	HC-5	HC-6	HC-7	HC-9	HC-92	HC-12	HC-16	HC-CRB	HC-5FB
					HC-9 Replicate			Rinseate Blank	Field Blank
Date Collected:	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90	5/16/90
Dissolved Metals in mg/L (ppm)									
Antimony	0.005 U	0.005 U	0.005 U	0.012	0.009	0.005 U	0.005	0.009	0.005 U
Arsenic	0.128	0.497	0.617	8.42	8.68	3.94	2.63	0.005	0.016
Cadmium	0.001 U	0.002	0.002	0.036	0.036	0.015	0.011	0.001 U	0.001 U
Chromium	0.002	0.002	0.002	0.05	0.052	0.019	0.01	0.001	0.001 U
Copper	0.001	0.001 U	0.001	0.002	0.001	0.001 U	0.003	0.002	0.001 U
Lead	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.005	0.002 U	0.002 U
Nickel	0.003 U	0.003 U	0.003 U	0.008	0.009	0.003 U	0.003 U	0.003 U	0.003 U
Silver	0.001 U	0.002	0.001	0.006	0.006	0.002	0.002	0.001 U	0.001 U
Zinc	0.006	0.004	0.003	0.003	0.003	0.003	0.003	0.001	0.001
Field Parameters									
pH	6.9	6.5	6.9	6.8	NA	6.8	6.6	NA	NA
Specific Conductivity in µmhos/cm	720	460	1,250	1,660	NA	340	310	NA	NA
Temperature in °C	12.7	14.9	12.7	12.7	NA	12.8	13.6	NA	NA
Dissolved Oxygen in mg/L (ppm)	1.0	1.6	1.2	1.4	NA	1.4	1.3	NA	NA

Notes:
NA Not analyzed.
U Not detected at indicated detection limit.
J Estimated value.

239506T6.WK1

Table 7 – Summary of Arsenic Concentrations in Background Wells

Well Number: Date Collected:	HC-24 5/29/90	HC-25 5/29/90	HC-26 5/29/90	HC-62 (HC-26 dup) 5/29/90	WP-1 5/29/90
Arsenic in mg/L (ppm)	0.382	0.01	0.611	0.607	1.2
Field Parameters					
pH	6.1	6.2	7.0	NA	7.2
Specific Conductivity in µmhos/cm	270	410	570	NA	430
Temperature in °C	14.8	14.2	15.0	NA	13.2
Dissolved Oxygen in mg/L (ppm)	1.4	1.2	1.2	NA	1.4

Notes:

NA	Not analyzed.
U	Not detected at indicated detection limit.
J	Estimated value.

239506T7

Table 8 – Summary of Trace Metal Concentrations in Seep Samples

	Concentration in mg/L (ppm)				
Seep Number:	Seep–1	Seep–2	Seep–3	Seep–4	Seep EV–04
Date Collected:	5/30/90	5/30/90	5/30/90	5/30/90	6/22/90
Total Metals					
Arsenic	0.158	0.006	0.004	0.012	0.144
Cadmium	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U
Chromium	0.028	0.001 U	0.002	0.01	0.009
Copper	0.045	0.001 U	0.003	0.016	0.008
Lead	0.011	0.002 U	0.002 U	0.002 U	0.002 U
Nickel	0.023	0.003 U	0.003 U	0.007	0.005
Selenium	0.002	0.002	0.002 U	0.002 U	0.002
Silver	0.002	0.001 U	0.001 U	0.001 U	0.001
Zinc	0.069	0.029	0.015	0.028	0.014
Dissolved Metals					
Arsenic	0.118	0.006	0.004	0.003	0.039
Cadmium	0.001 U	0.001 U	0.001 U	0.001 U	0.003
Chromium	0.002	0.001 U	0.002	0.002	0.003
Copper	0.002	0.007	0.007	0.001	0.004
Lead	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Nickel	0.003 U	0.003	0.003 U	0.003 U	0.003 U
Selenium	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Silver	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U
Zinc	0.018	0.032	0.016	0.01	0.026
Total Suspended Solids	110	5 U	7	98	70

Notes:

NA Not analyzed.

U Not detected at indicated detection limit.

J Estimated value.

23950618.wk1

Table 9 – Summary of Organic Compound Concentrations in Seep Samples

Seep Number: Date Collected:	Seep 1 5/29/90	Seep 2 5/29/90	Seep 3 5/29/90	Seep 4 5/29/90	Seep EV-04 6/22/90	Trip Blank 5/30/90
Volatile Organics in mg/L (ppm)						
Benzene	0.001 U	0.001 U	0.001 U	0.001 U	0.14	0.001 U
Toluene	0.001 U	0.001 U	0.001 U	0.001 U	0.02	0.001 U
Ethylbenzene	0.001 U	0.001 U	0.001 U	0.001 U	0.05	0.001 U
Xylenes	0.001 U	0.001 U	0.001 U	0.001 U	0.23	0.001 U
Semivolatile Organics in mg/L (ppm)						
Naphthalene	0.0009 J	0.0002 UJ	0.0002 UJ	0.0002 UJ	6 J	NA
2-methylnaphthalene	0.0002 UJ	0.0002 UJ	0.0002 UJ	0.0002 UJ	1 J	NA
Acenaphthene	0.0002 UJ	0.0002 UJ	0.0002 UJ	0.0002 UJ	0.22 J	NA
Field Parameters						
pH	6.8	6.9	6.9	6.9	NA	NA
Specific Conductivity in μmhos/cm	4,500	7,600	4,900	3,300	NA	NA
Temperature in °C	11.3	11.8	11.8	11.4	NA	NA
Dissolved Oxygen in mg/L (ppm)	3.3	8.1	3.9	3.0	NA	NA

Notes:

NA Not analyzed.

U Not detected at indicated detection limit.

J Estimated value.

239506T9

Table 10 - Summary of Groundwater Quality in Lower Sand Unit Wells

Well Number:	HC-1D		HC-10D		HC-11D		HC-15D		HC-23D		HC-28R (HC-23D Replicate)		Trip Blank	
Date Collected:	6/15/90		6/15/90		6/15/90		6/15/90		6/15/90		6/15/90		6/15/90	
Dissolved Metals in mg/L (ppm)														
Antimony	0.005	U	0.005	U	0.005	U	0.007		0.005	U	0.005	U	NA	
Arsenic	0.039		0.012		0.002	U	3.08		0.029		0.023		NA	
Cadmium	0.001	U	0.001	U	0.001	U	0.011		0.001	U	0.001	U	NA	
Chromium	0.004		0.002		0.003		0.05		0.002		0.002		NA	
Copper	0.002		0.002		0.003		0.003		0.002		0.002		NA	
Lead	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	NA	
Selenium	0.002		0.003		0.003		0.002	U	0.002		0.002		NA	
Silver	0.006		0.002		0.002		0.001		0.003		0.004		NA	
Zinc	0.006		0.003		0.009		0.006		0.009		0.009		NA	
Volatile Organics in mg/L (ppm)														
Benzene	0.001	U	0.001	U	0.001	U	1.9		0.064		0.058		0.001	U
Toluene	0.001	U	0.001	U	0.001	U	3.4		0.005	U	0.003		0.001	U
Ethylbenzene	0.001	U	0.001	U	0.001	U	0.32		0.029		0.027		0.001	U
Xylenes	0.001	U	0.001	U	0.001	U	1.4		0.019		0.017		0.001	U
1,2,-Dichloroethane	0.001	U	0.001	U	0.001	U	0.1	U	0.005	U	0.001		0.001	U

Notes:

NA	Not analyzed.
U	Not detected at indicated detection limit.
J	Estimated value.

Table 10 - Summary of Groundwater Quality in Lower Sand Unit Wells

Well Number:	HC-1D	HC-10D	HC-11D	HC-15D	HC-23D	HC-28R (HC-23D Replicate)	Trip Blank
Date Collected:	6/15/90	6/15/90	6/15/90	6/15/90	6/15/90	6/15/90	6/15/90
Semivolatile Organics in mg/L (ppm)							
Phenol	0.0012 J	0.0019 J	0.002 J	0.021 UJ	0.021 U	0.01 UJ	NA
2-Chlorophenol	0.0002 J	0.0003 J	0.0003 J	0.021 UJ	0.021 U	0.01 UJ	NA
4-Methylphenol	0.0002 UJ	0.0002 UJ	0.0002 UJ	0.0421 J	0.021 U	0.01 UJ	NA
Pentachlorophenol	0.0011 UJ	0.0011 UJ	0.0011 UJ	9.7 J	0.1 U	0.053 UJ	NA
Naphthalene	0.0002 UJ	0.0002 UJ	0.0002 UJ	28 J	7.4 J	9.8 J	NA
2-methylnaphthalene	0.0002 UJ	0.0002 UJ	0.0002 UJ	1.4 J	1.6 J	2.2 J	NA
Acenaphthene	0.0002 UJ	0.0014 J	0.0002 UJ	0.3 J	0.31 J	0.42 J	NA
Fluorene	0.0002 UJ	0.0002 UJ	0.0002 UJ	0.083 J	0.021 U	0.02 J	NA
Phenanthrene	0.0002 UJ	0.0002 UJ	0.0002 UJ	0.18 J	0.021 U	0.01 UJ	NA
Total Dissolved Solids in mg/L (ppm)	680	340	670	400	660	680	NA
Field Parameters							
pH	6.6	6.7	6.9	7.1	6.6	NA	NA
Specific Conductivity in µmhos/cm	1,030	540	1,060	430	1,030	NA	NA
Temperature in °C	12.8	13.0	13.0	15.7	14.0	NA	NA
Dissolved Oxygen in mg/L (ppm)	2.6	1.7	4.0	0.6	1.9	NA	NA

Table 11 – Summary of East Machine Shop/Machine Shop Soil Quality Data

	Concentration in mg/kg (ppm)							
Sample Location	Arsenic	Chromium	Benzene	Xylene	Naphthalene	PCP	TCDD-eq	cPAH
TP-4-6'	20	34	–	–	31.0	3.30	–	5.20
TP-12-5'	340	–	1.200 U	1.200 U	1,000.0	100.00	–	138.20
TP-15-2'	130	–	–	–	5.3	0.35 U	–	0.26
HC-12-3'	98	31	0.001 N	0.006 N	1.5 N	1.00 U	–	1.21 N
HC-12-6'	–	–	0.002 N	0.005 U	1.0 U	1.00 U	–	20.10 N
HC-12-7'	19	43	0.001 U	0.005 U	1.1 N	1.00 U	–	3.06 N
HC-13-3'	–	–	0.002 N	0.015 N	1.2 N	3.20 N	0.0008 J	98.18 N
HC-13-6'	295	479	0.110 N	2.200 N	3.8 N	1.00 U	–	33.93 N
HC-13-7'	–	–	0.870 N	2.000 N	122.2 N	1.00 U	–	2.47 N
HC-13-9'	–	–	0.600 N	0.430 N	22.4 N	22.00 N	–	1.00 U
HC-13-10'	–	–	1.000 N	2.500 N	138.5 N	33.00 N	0.0001 U	6.41 N
HC-13-12'	–	–	1.000 N	0.870 N	80.0 N	13.00 N	–	1.00 U
HC-15-3'	–	–	0.007 N	0.520 N	51.0 N	21.00 N	0.0002 J	1.08 N
HC-15-6'	55	35	0.009 N	0.180 N	400.0 NJ	15.00 N	–	4.06 N
HC-15-7'	–	–	0.342 N	0.650 N	321.8 N	1.00 U	–	1.00 U
HC-15-9'	–	–	0.240 N	0.280 N	489.8 N	1.10 N	–	1.00 U
HC-16-3'	94	25	2.900 N	12.000 N	38.8 N	1.00 U	–	10.42 N
HC-16-6'	–	–	1.200 N	6.400 N	8.8 N	1.00 U	–	1.00 U
HC-16-7'	29	18	1.200 N	5.400 N	1.0 N	1.00 U	–	0.50 N
HC-16-7'(Dup)	–	–	0.650 N	2.400 N	0.2 N	1.00 U	–	0.19 N
HC-22-3'	47	39	2.554 N	2.658 N	222.0 N	39.00 N	–	372.80 N
HC-22-6'	–	–	2.404 N	3.015 N	250.0 N	27.00 N	–	107.90 N
HC-22-7'	–	–	0.242 N	1.512 N	193.0 N	11.00 N	–	38.80 N
A-1-3'	60	24	0.005 U	0.014	0.7	0.66 U	–	0.66 U
A-2-6'	7	22	0.005 U	0.005 U	0.4 J	0.67 U	–	0.38
A-3-8'	7	20	0.012	0.042	2.2	0.66 U	–	0.66 U
A-4-11'	7	20	0.470	1.300	170.0	33.00 U	–	6.10 J
B-1-3'	49	32	0.630 U	67.000	2.7	0.66 U	–	0.50 J
B-2-6'	38	20	0.630 U	75.000	8.8	0.66 U	–	0.57 J

Table 11 - Summary of East Machine Shop/Machine Shop Soil Quality Data

	Concentration in mg/kg (ppm)							
Sample Location	Arsenic	Chromium	Benzene	Xylene	Naphthalene	PCP	TCDD-eq	cPAH
B-3-8'	6	35	0.350	0.920	3.6	0.66 U	-	0.66 U
C-1-3'	114	70	0.035	18.000 J	2.4	1.70	-	0.13 J
C-2-6'	7	38	0.130	4.400	0.3 J	0.33 U	-	0.33 U
C-2-6'(Dup)	13	29	0.100	2.700	0.2	0.03 U	-	0.03 U
D-1-3'	28	21	0.630 U	83.000	15.0	3.30 U	-	3.30 U
D-2A-5'	74	24	0.110	2.400	0.4 J	0.65 U	-	0.65 U
D-2B-6'	10	40	0.630 U	3.500	0.1	0.03 U	-	0.03 U
E-1-3'	100	65	0.630 U	80.000	12.0	1.30 U	-	0.32 J
E-2-6'	94	132	0.070	0.300	0.1	0.03 U	-	0.03 U
F-1-3'	12	23	0.005 U	0.005 U	0.0 U	0.03 U	-	0.10 J
F-2-6'	14	37	0.630 U	0.660	120.0	6.50 J	-	13.90 J
F-3-8'	25	46	0.630 U	5.200	530.0	66.00 U	-	38.00 J
Number of Samples	28	26	39	39	41	41	3	41
Minimum Concentration	6	18	0.001	0.003	0.0	0.02	0.0001	0.02
Maximum Concentration	340	479	2.900	83.000	1,000.0	100.00	0.0008	372.80
Average Value	64	55	0.498	9.951	103.7	8.69	0.0003	22.21
Upper 95% Tolerance (a)	90	86	0.690	16.175	156.0	13.45	0.0010	39.05

Notes:

(a) The upper 95 percent confidence limit of the average value, assuming non-detects = 1/2 detection limit.

- Denotes that no analysis was performed for the chemical.

U Not detected at indicated detection limit

J Estimated Value

N Tentatively identified compound

Table 12 - Summary of Groundwater and Seep Water Quality Data Collected near the Snohomish River

		Concentration in mg/L (ppm)						
Sample Location	Sample Date	Dissolved Arsenic	Dissolved Chromium	Benzene	Xylene	Naphthalene	PCP	CPAH
HC-1	Aug-89	2.150	0.006	0.005 UJ	0.005 UJ	0.100 U	0.025 U	0.100 U
HC-2	Aug-89	0.091	0.005 U	0.005 UJ	0.005 UJ	0.100 U	0.025 U	0.100 U
HC-7	Aug-89	0.609	0.005 U	0.005 UJ	0.005 UJ	0.100 U	0.025 U	0.100 U
	May-90	0.617	0.002	0.005 U	0.005 U	0.000 U	0.001 U	0.000 U
HC-9	Aug-89	8.750	0.037	0.047 J	0.031 J	0.780	4.400 J	0.100 U
	May-90	8.420	0.050	0.160	0.099	1.800	6.300	0.010 U
	May-90(Dup)	8.680	0.052	0.170	0.017	1.800	6.800	0.011 U
HC-10	Aug-89	0.132	0.008	0.005 UJ	0.005 UJ	0.100 U	0.025 U	0.100 U
HC-1D	Aug-89	0.039	0.006	0.005 UJ	0.005 UJ	0.100 U	0.025 U	0.100 U
	May-90	0.039	0.004	0.001 U	0.001 U	0.000 UJ	0.001 UJ	0.000 UJ
HC-10D	Aug-89	0.013	0.005 U	0.005 UJ	0.005 UJ	0.100 U	0.025 U	0.100 U
	May-90	0.012	0.002	0.001 U	0.001 U	0.000 UJ	0.001 UJ	0.000 UJ
HC-23D	May-90	0.029	0.002	0.064	0.019	7.400 J	0.100 U	0.021 U
	May-90(Dup)	0.023	0.002	0.058	0.017	9.800 J	0.053 UJ	0.010 UJ
Seep EV-4	Jun-89	0.115	0.015	0.100	0.200	2.300	0.025 U	0.100 U
	Jun-90	0.039	0.003	0.140	0.230	6.000 J	0.001 U	0.010 U
Number of Samples		16	16	16	16	16	16	16
Minimum Concentration		0.012	0.002	0.001	0.001	0.000	0.001	0.000 U
Maximum Concentration		8.750	0.052	0.170	0.230	9.800	6.800	0.100 U
Average Value		1.860	0.012	0.047	0.039	1.886	1.104	0.000 U
Upper 95% Tolerance (a)		3.348	0.020	0.075	0.071	3.236	2.152	0.000 U

Notes:

(a) The upper 95 percent confidence limit of the average value, assuming non-detects = 1/2 detection limit.

U Not detected at indicated detection limit

J Estimated Value

Table 13 – Preliminary Human Health Risk Assessment – Direct Soil Contact Exposures, Industrial Site Use

Average Body Weight in kg:	70	70
Soil Ingestion Rate in mg/day:	50	50
Contact Frequency – %:	40	40
Duration of Exposure in yrs:		20
Lifetime in yrs:		75

CONTAMINANT	ON-SITE RME SOIL CONCENTRATION in ppm	ORAL RfD in mg/kg-day	ORAL CANCER POTENCY SLOPE in (mg/kg-day)-1	Hazard Index	Cancer Risk
METALS:					
Arsenic (and compounds)	90.1	1.0E-03	1.8E+00	0.0	1E-05
Chromium (and compounds)	86.0	5.0E-03		0.0	
VOLATILE COMPOUNDS:					
Benzene	0.7		2.9E-02		2E-09
Xylene	16.2	5.7E-01		0.0	
PHENOLS:					
Pentachlorophenol	13.5	3.0E-02	1.2E-01	0.0	1E-07
POLYNUCLEAR AROMATIC HYDROCARBONS:					
Naphthalene	156.0	4.0E-03		0.0	
Total Carcinogenic PAHs	39.1		1.2E+01		3E-05
TETRACHLORODIBENZODIOXIN:					
2,3,7,8-TCDD Equivalents	0.0010	1.0E-09	1.5E+05	0.3	1E-05
				0.3	6E-05

2395tb13.wk1

Table 14 – Preliminary Human Health Risk Assessment – Inhalation Exposures, Industrial Site Use

Average Body Weight in kg:	70	70
Breathing Rate in m3/day:	20	20
Contact Frequency – %:	100	100
Duration of Exposure in yrs:		30
Lifetime in yrs:		75

CONTAMINANT	(Cover = 2 ft) PREDICTED VAPOR CONCENTRATION in ug/m3	(TSP = 1 ug/m3) PREDICTED DUST CONCENTRATION in ug/m3	INHALATION RfD in mg/kg-day	INHALATION CANCER POTENCY SLOPE (mg/kg-day)-1	Hazard Quotient	Cancer Risk
METALS:						
Arsenic (and compounds)	0.0E+00	9.0E-05	1.0E-03	5.0E+01	0.00	5E-07
Chromium (and compounds)	0.0E+00	8.6E-05	5.0E-03	4.1E+01	0.00	4E-07
VOLATILE COMPOUNDS:						
Benzene	4.0E-05	6.9E-07		2.9E-02		1E-10
Xylene	9.5E-04	1.6E-05	8.6E-02		0.00	
PHENOLS:						
Pentachlorophenol	<1E-06	1.3E-05	3.0E-02	1.2E-01	0.00	2E-10
POLYNUCLEAR AROMATIC HYDROCARBONS:						
Naphthalene	<1E-05	1.6E-04	4.0E-03		0.00	
Total Carcinogenic PAHs	<1E-06	3.9E-05		6.1E+00		3E-08
TETRACHLORODIBENZODIOXIN:						
2,3,7,8-TCDD Equivalents	<1E-10	9.8E-10	1.0E-09	1.5E+05	0.00	2E-08
					0.00	1E-06

2395tb14.wk1

Hart Crowser
J-2395-06

Table 15 – Preliminary Human Health Risk Assessment – Fish/Shellfish Consumption Exposures

Average Body Weight in kg:	70	70
Fish Consumption Rate in gms/day:	54	54
Diet Fraction – %:	50	50
Duration of Exposure in yrs:		30
Lifetime in yrs:		75

CONTAMINANT	NEAR-RIVER RME GROUNDWATER/SEEP CONCENTRATION in mg/L	(Q=20 gpm) MINIMUM RIVER DILUTION	Fish/Shellfish Bioconcentration Factor	ORAL RfD n mg/kg-day	ORAL CANCER POTENCY SLOPE in (mg/kg-day)-1	Hazard Index	Cancer Risk
METALS:							
Arsenic (and compounds)	3.348	1E-06	44	1.0E-03	1.8E+00	0.00	4E-08
Chromium (and compounds)	0.020	1E-06	16	5.0E-03		0.00	
VOLATILE COMPOUNDS:							
Benzene	0.075	1E-06	5		2.9E-02		2E-12
Xylene	0.071	1E-06	11	5.7E-01		0.00	
PHENOLS:							
Pentachlorophenol	2.152	1E-06	11	3.0E-02	1.2E-01	0.00	4E-10
POLYNUCLEAR AROMATIC HYDROCARBONS:							
Naphthalene	3.236	1E-06	30	4.0E-03		0.00	
Total Carcinogenic PAHs	0.000	1E-06	30		1.2E+01		1E-11 U
TETRACHLORODIBENZODIOXIN:							
2,3,7,8-TCDD Equivalents	-	1E-06	-	1.0E-09	1.5E+05		
						0.00	4E-08

2395tb15.wk1

Table 16 – Preliminary Ecological Risk Assessment – Comparison of Nearshore Concentrations with Water and Sediment Quality Criteria

CONTAMINANT	NEAR-RIVER UPPER-BOUND GROUNDWATER CONCENTRATION in mg/L	SEEP EV-4 CONCENTRATION in mg/L	Marine Aquatic Life Water Quality Criteria in mg/L		NEARSHORE SURFACE SEDIMENT CONCENTRATION in mg/L (ppm) (a)	Marine Aquatic Life Sediment Quality Criteria in mg/L (ppm)	
			Chronic	Acute		LAET (b)	MCUL (c)
METALS:							
Arsenic (and compounds)	3.348	.115 – .144	0.013	0.069	10 – 460	57	93
Chromium (and compounds)	0.020	.015 – .039	0.050	1.100	30 – 60	260	270
VOLATILE COMPOUNDS:							
Benzene	0.075	.100 – .140	0.700	5.100	< 0.2 (d)	–	–
Xylene	0.071	.200 – .230	–	–	< 0.2 (d)	–	–
PHENOLS:							
Pentachlorophenol	2.152	< 0.001	0.008	0.013	< 3	0.36	0.69
POLYNUCLEAR AROMATIC HYDROCARBONS:							
Naphthalene	3.236	2.30 – 6.00	0.620	2.350	< 9 – 220 (d)	99 (d)	170 (d)
Total Carcinogenic PAHs	< 0.0002	< 0.01	–	0.300	< 20 (d)	110 (d)	270 (d)

NOTES:

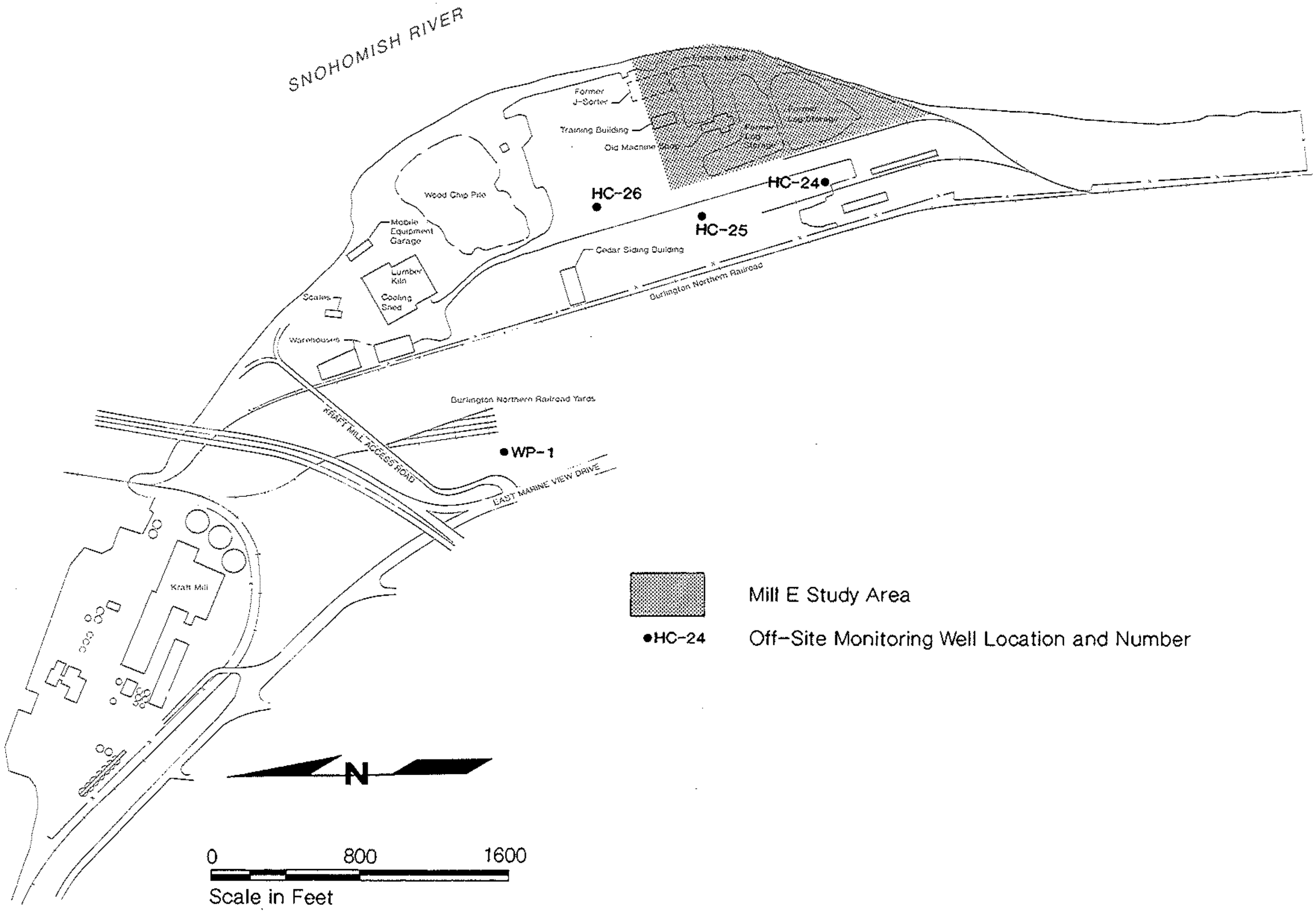
a) Based on surface sediment samples collected in the groundwater discharge zone (RS-2, RS-3, EV-3, RS-4, and RS-6).

b) Marine sediment chemical criteria from WAC 173-304; based on the Lowest Apparent Effects Threshold (LAET).

c) Minimum marine sediment cleanup level (MCUL) from WAC 173-304; based on the second-lowest AET.

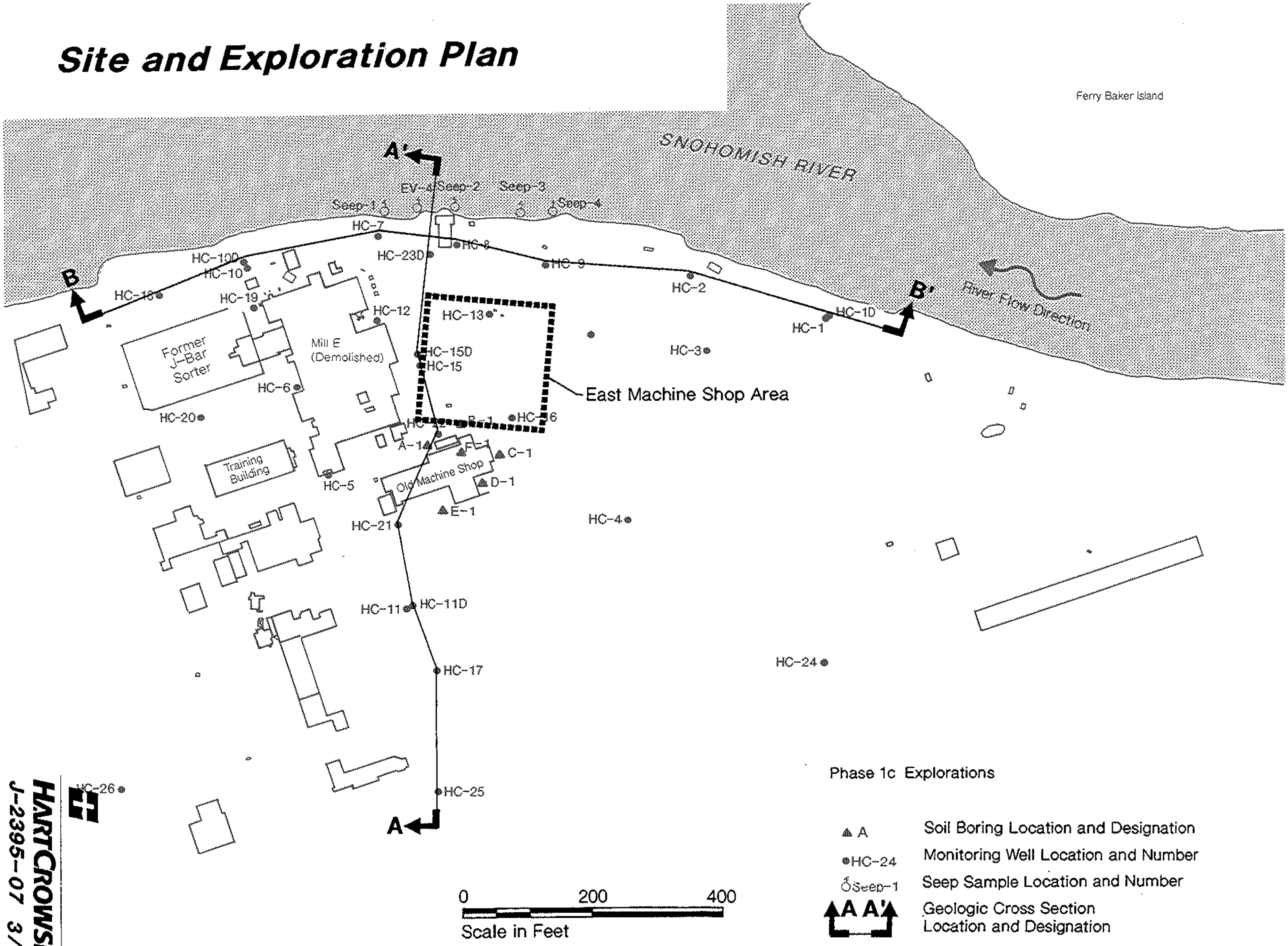
d) Concentration normalized to total organic carbon.

Weyerhaeuser Everett Facility Map
Mill E Study Area and Off-Site Well Locations



HARTCROWSER
J-2395-07 3/91
Figure 1

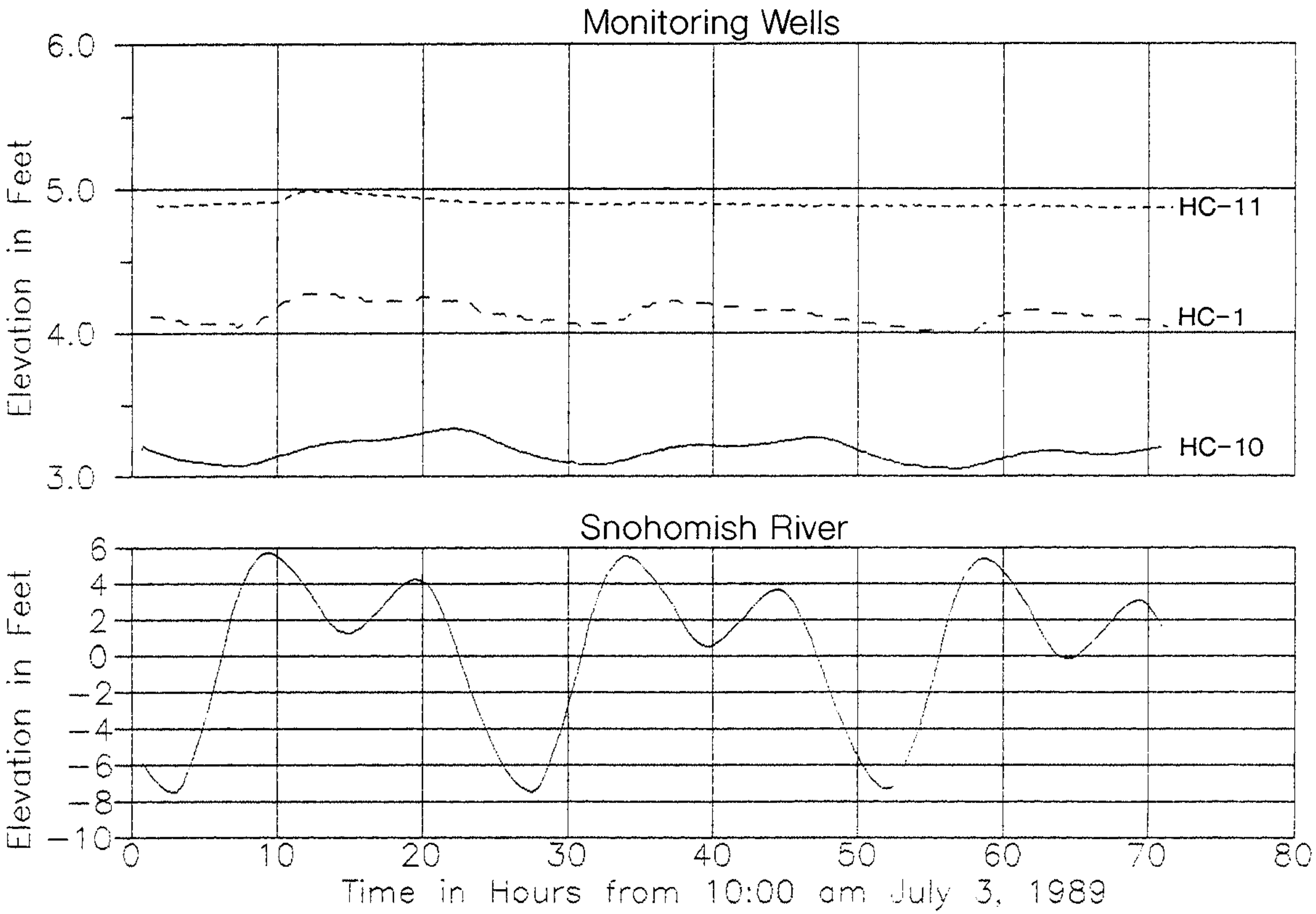
Site and Exploration Plan



HARTCROWSER
J-2395-07 3/91
Figure 2

Groundwater and Tidal Elevation with Time: Upper Sand

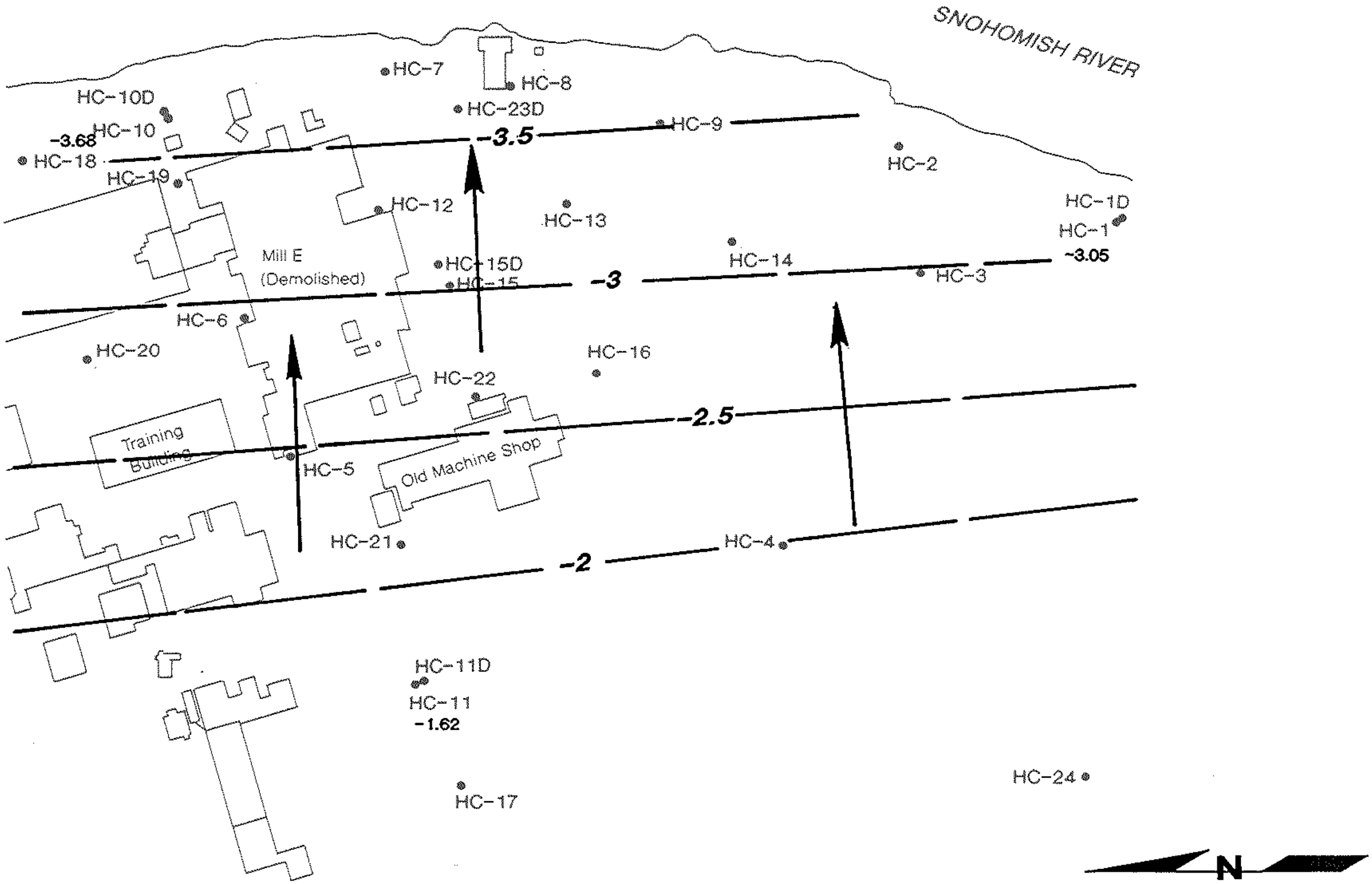
Monitoring Wells HC-1, HC-10 and HC-11, July 3 through July 6, 1989



HARTCROWSER
J-2395-07 3/91
Figure 6

Groundwater Elevation Contour Map

Lower Sand Unit – May 10, 1990



● HC-1 Monitoring Well Location and Number

1.62 Groundwater Elevation in Feet

— -3.5 — Groundwater Elevation Contour in Feet (above MSL)

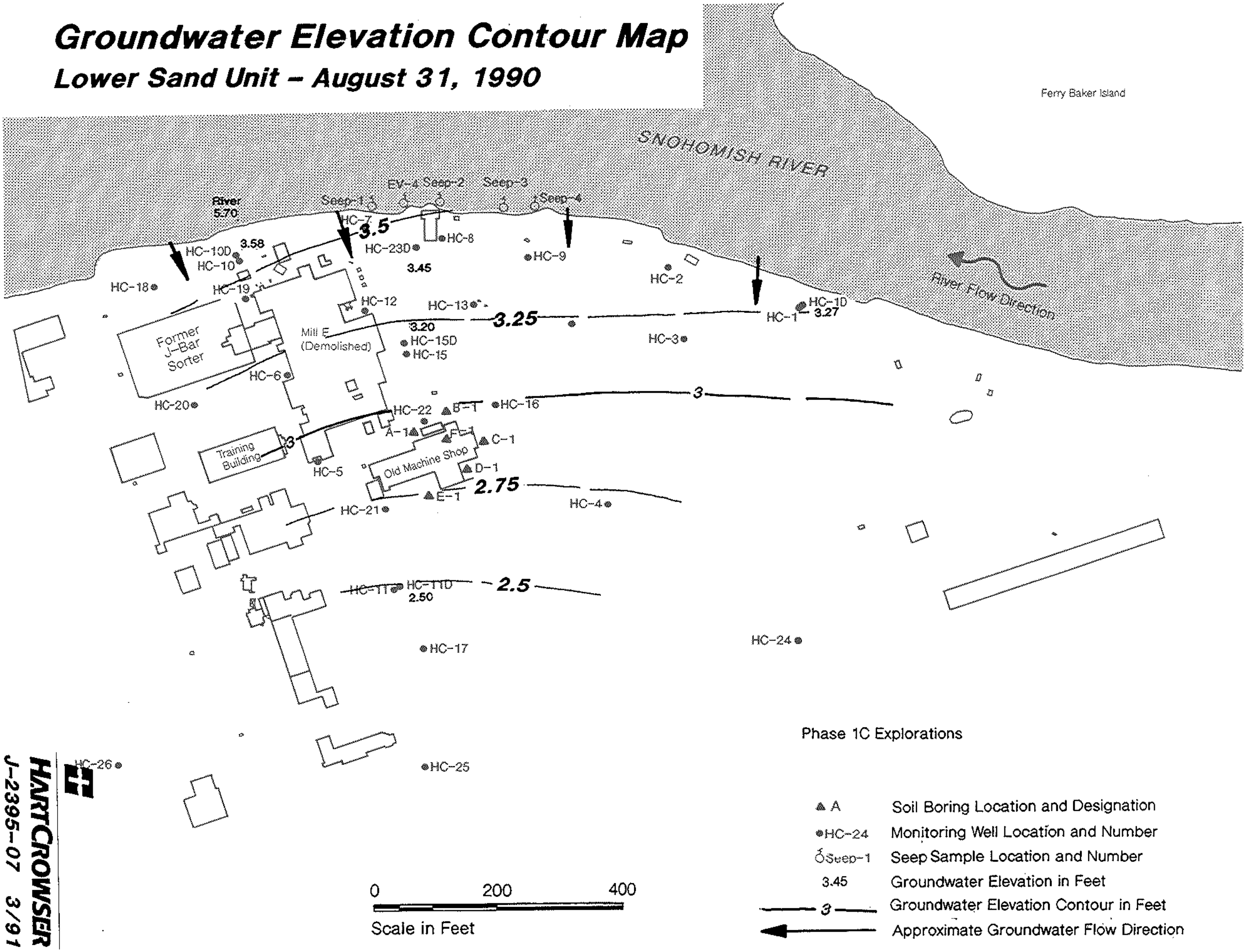
← Approximate Groundwater Flow Direction

0 150 300
Scale in Feet

HARTCROWSER
J-2395-07 3/91
Figure 7

Groundwater Elevation Contour Map

Lower Sand Unit – August 31, 1990



▲ A	Soil Boring Location and Designation
● HC-24	Monitoring Well Location and Number
Seep-1	Seep Sample Location and Number
3.45	Groundwater Elevation in Feet
— 3 —	Groundwater Elevation Contour in Feet
←	Approximate Groundwater Flow Direction

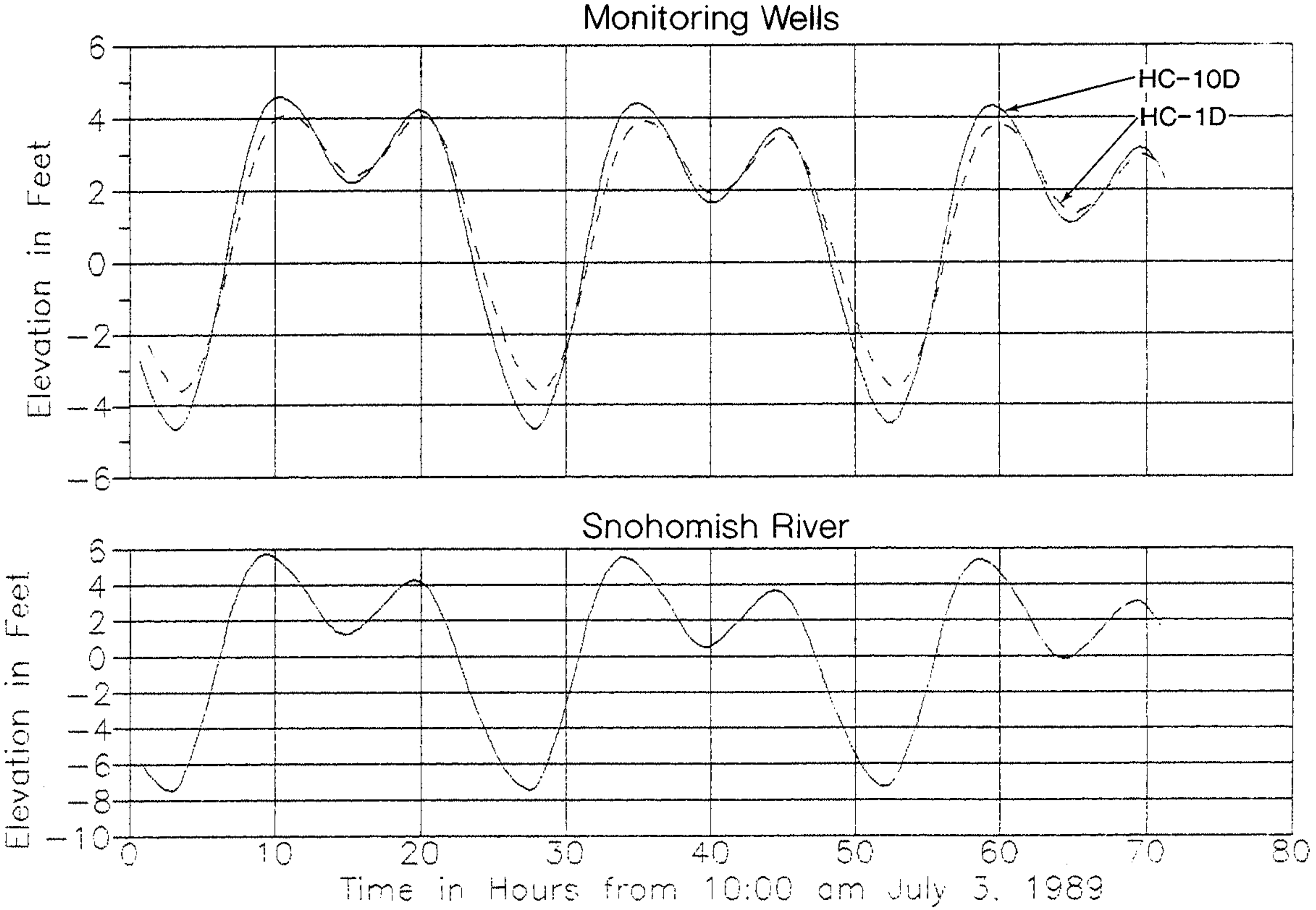
HARTCROWSER

J-2395-07 3/91

Figure 8

Groundwater and Tidal Elevation with Time: Lower Sand

Monitoring Wells HC-1D and HC-10D, July 3 through July 6, 1989

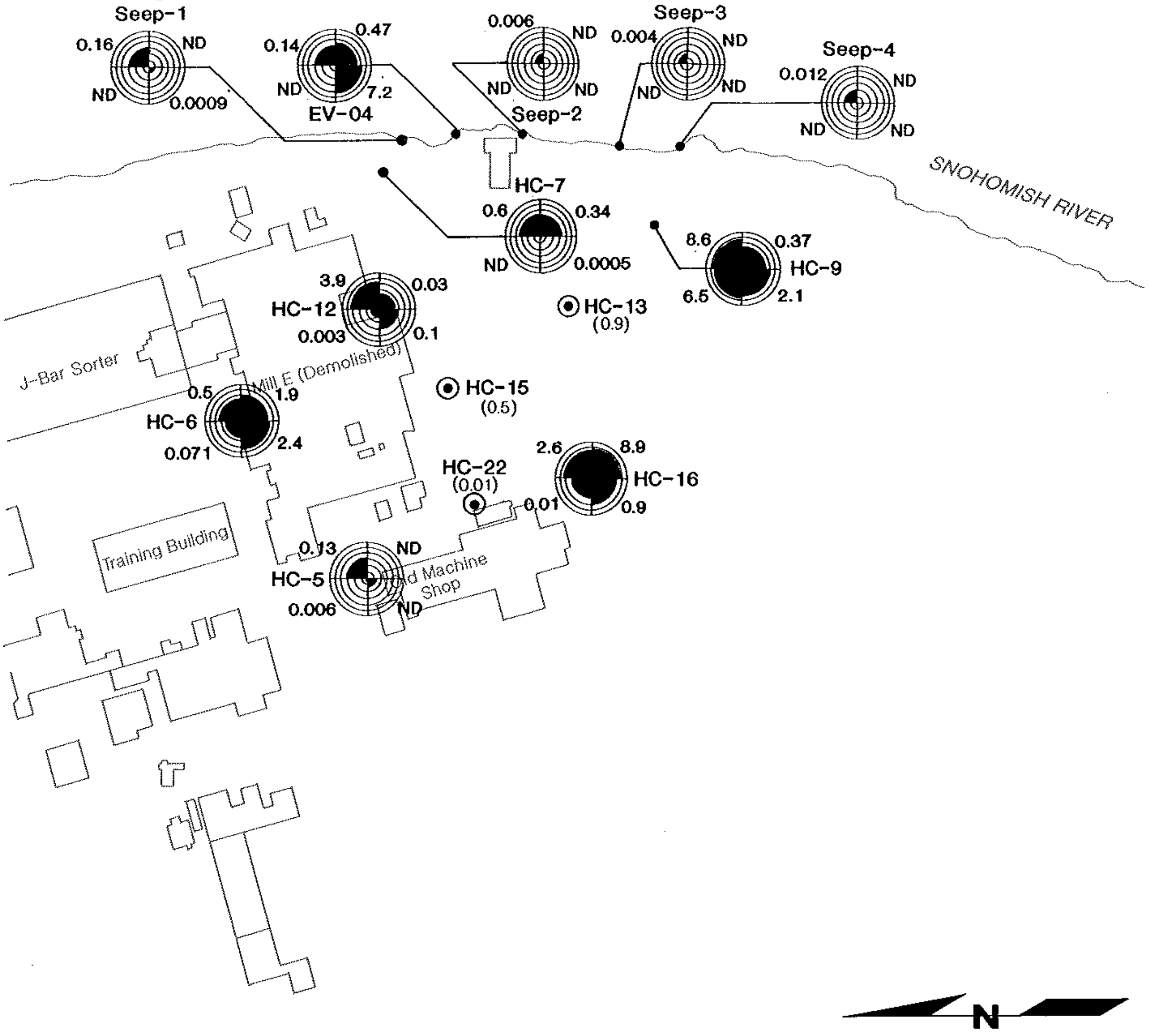


HARTCROWSER

J-2395-07 3/91

Figure 9

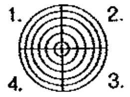
Summary of May 1990 Groundwater Sampling Results



HC-5	Monitoring Well Location and Number
Seep-1	Seep Location and Number
EV-4	Seep Location and Number

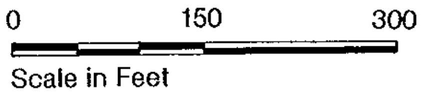
◉ Monitoring Well Containing Free Product

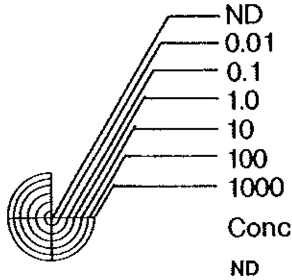
(0.5) Apparent Thickness of Free Product in Feet



1. Dissolved Arsenic
2. BTEX
3. PAHs
4. PCP

Note: Total PAHs and BETXs include detected values only.





Concentrations in ppm

ND Not Detected

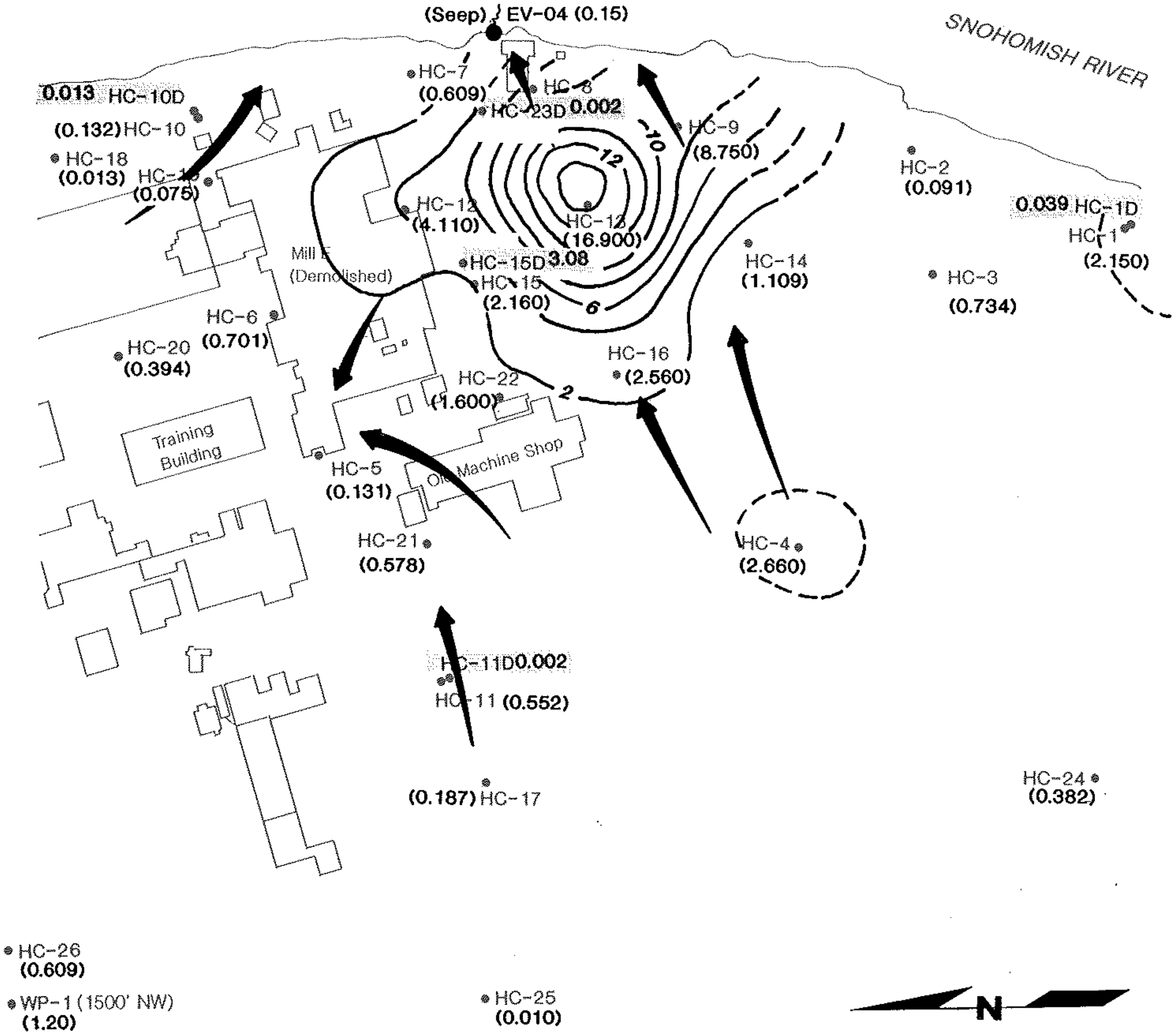
HARTCROWSER

J-2395-07 3/91

Figure 10

Dissolved Arsenic Concentration in Groundwater

Comparison between Lower Sand and Upper Sand Units



● HC-1	Monitoring Well Location and Number
(2.150)	Dissolved Arsenic Concentration in ppm – Upper Sand Unit
0.039	Dissolved Arsenic Concentration in ppm – Lower Sand Unit
— 6 —	Dissolved Arsenic Concentration Contour in ppm – Upper Sand Unit
ND	Not Detected
	Contour Interval 2 ppm
←	Upper Sand Groundwater Flow Direction–Low Tide, August 22, 1989

Note: Data used to contour Upper Sand unit concentrations were collected in June and August 1989. Lower Sand unit data were collected in June 1990.

0 150 300

Scale in Feet

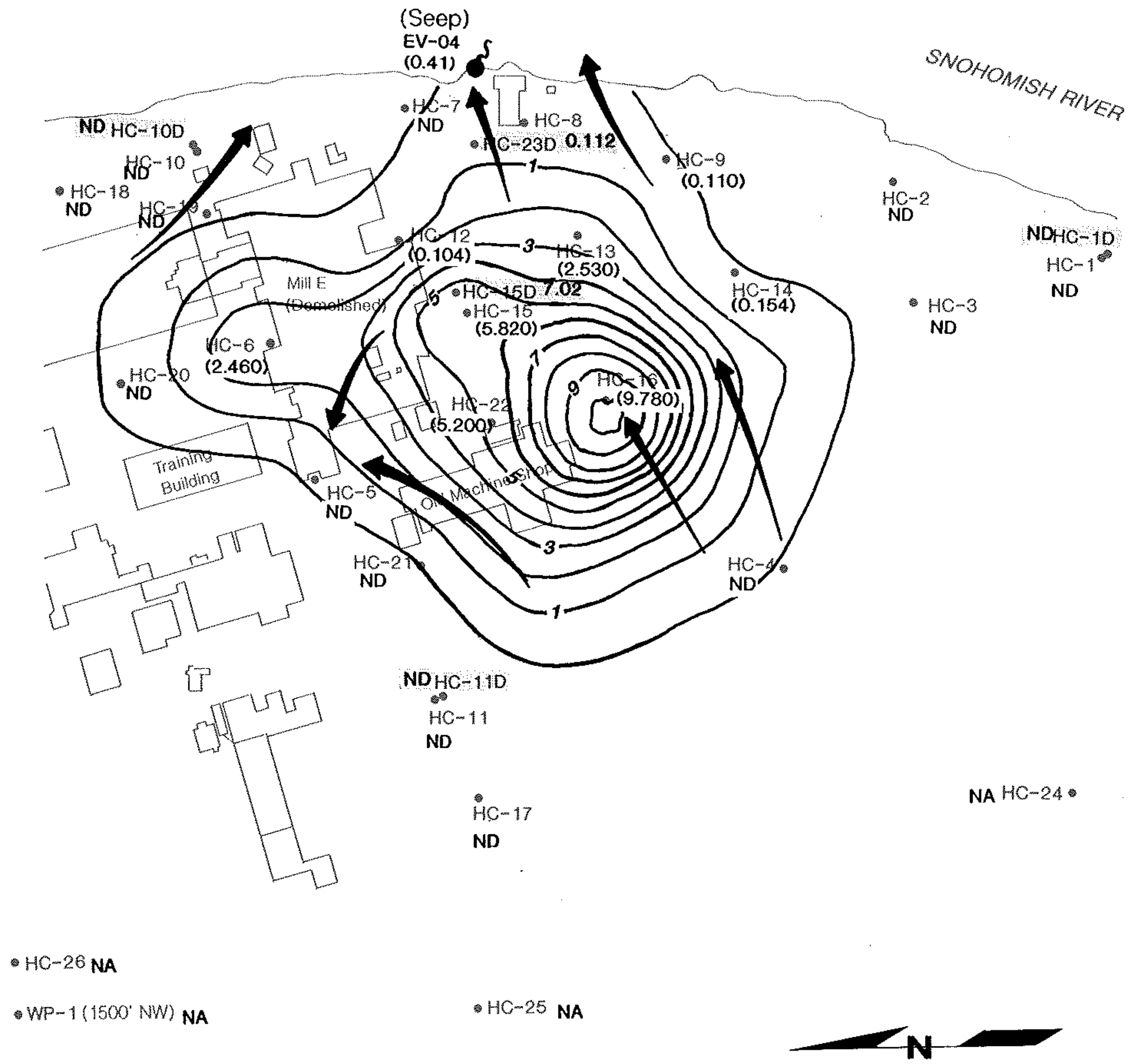
HARTCROWSER

J-2395-07 3/91

Figure 11

BETX Concentration in Groundwater

Comparison between Lower Sand and Upper Sand Units



● HC-1	Monitoring Well Location and Number
(2.460)	BETX Concentration in ppm – Upper Sand Unit
0.112	BETX Concentration in ppm – Lower Sand Unit
—3—	BETX Concentration Contour in ppm – Upper Sand Unit
ND	Not Detected
NA	Not Analyzed
	Contour Interval 1 ppm
←	Groundwater Flow Direction– Low Tide, August 22, 1989

Note: Data used to contour Upper Sand unit concentrations were collected in June and August 1989. Lower Sand unit data were collected in June 1990.

0 150 300

Scale in Feet

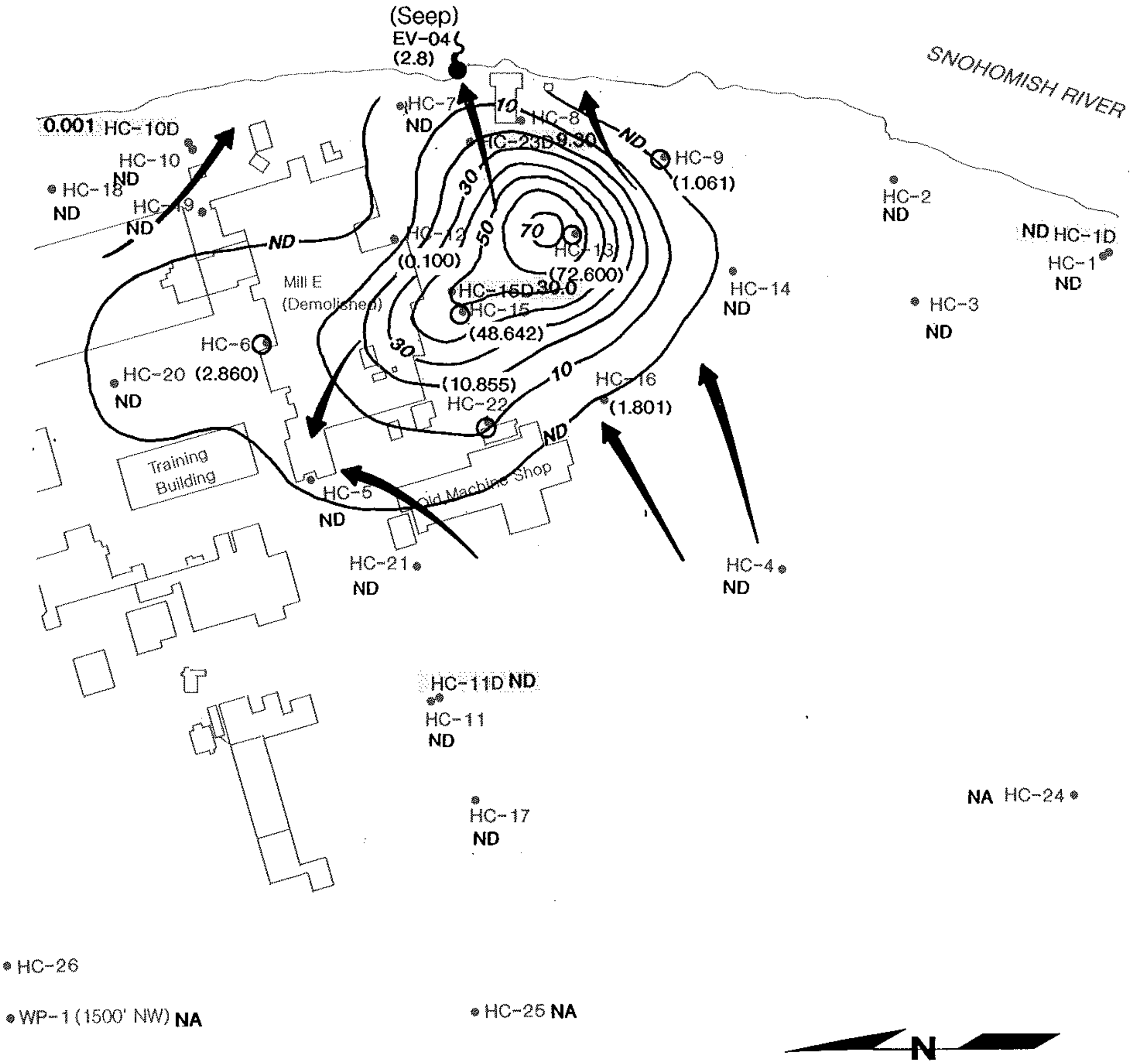
HARTCROWSER

J-2395-07 3/91

Figure 12

PAH Concentration in Groundwater

Comparison between Lower Sand and Upper Sand Units



Wells with PCP Detections

Well	PCP Concentration in ppm
HC-6	0.015J
HC-9	4.4J
HC-13	60J
HC-15	2.1
HC-15D	9.7J
HC-22	0.036J

J = Estimated Concentration

● HC-1	Monitoring Well Location and Number
(2.860)	PAH Concentration in ppm - Upper Sand Unit
0.001	PAH Concentration in ppm - Lower Sand Unit
—10—	PAH Concentration Contour in ppm - Upper Sand Unit Contour Interval 10 ppm
ND	Not Detected
NA	Not Analyzed
←	Groundwater Flow Direction - Low Tide, August 22, 1989

Note: Data used to contour Upper Sand unit concentrations were collected in June and August 1989. Lower Sand unit data were collected in June 1990.

0 150 300

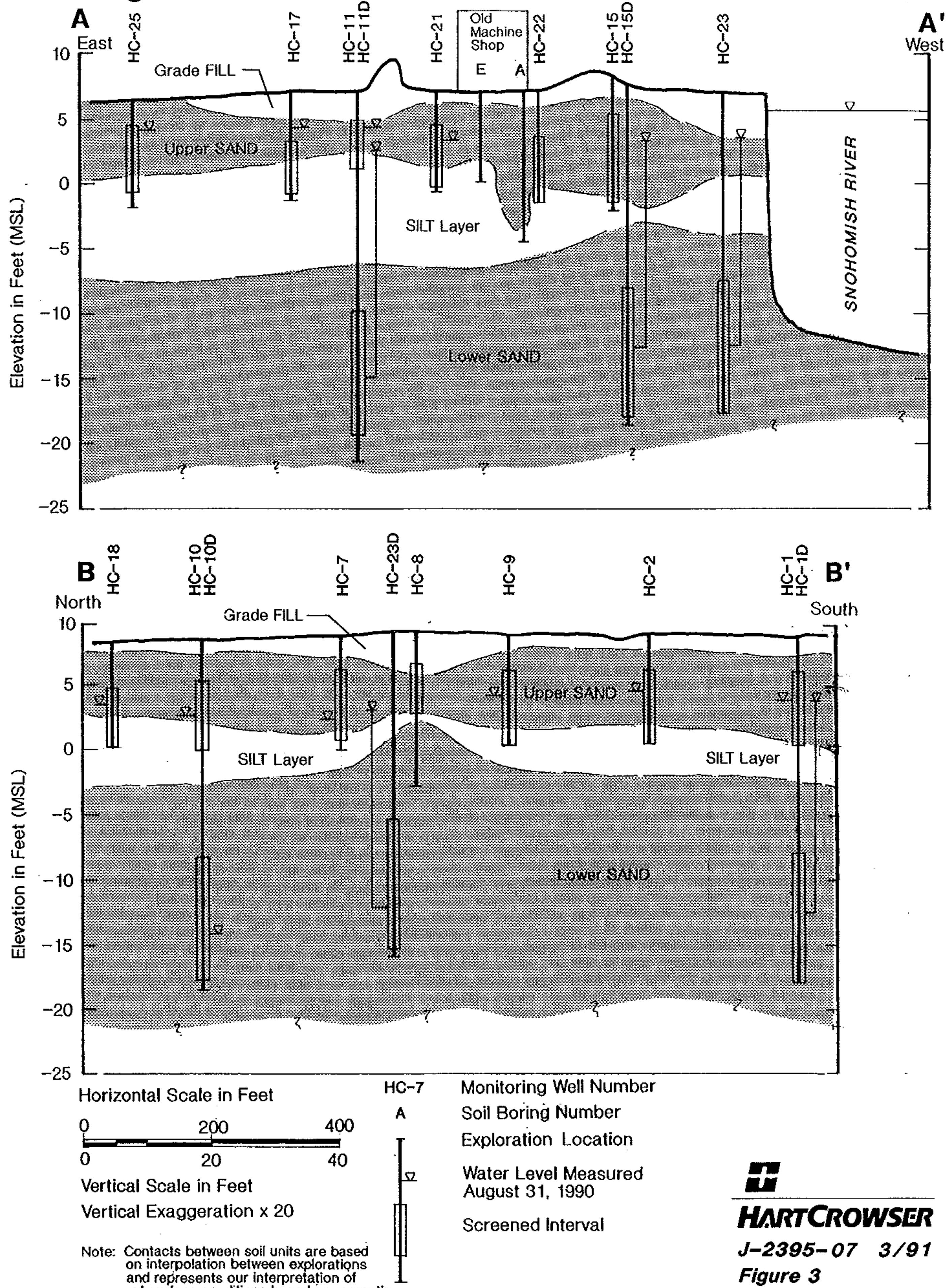
Scale in Feet

HARTCROWSER

J-2395-07 3/91

Figure 13

Geologic Cross Sections A–A' and B–B'



Note: Contacts between soil units are based on interpolation between explorations and represents our interpretation of subsurface conditions based on currently available data.

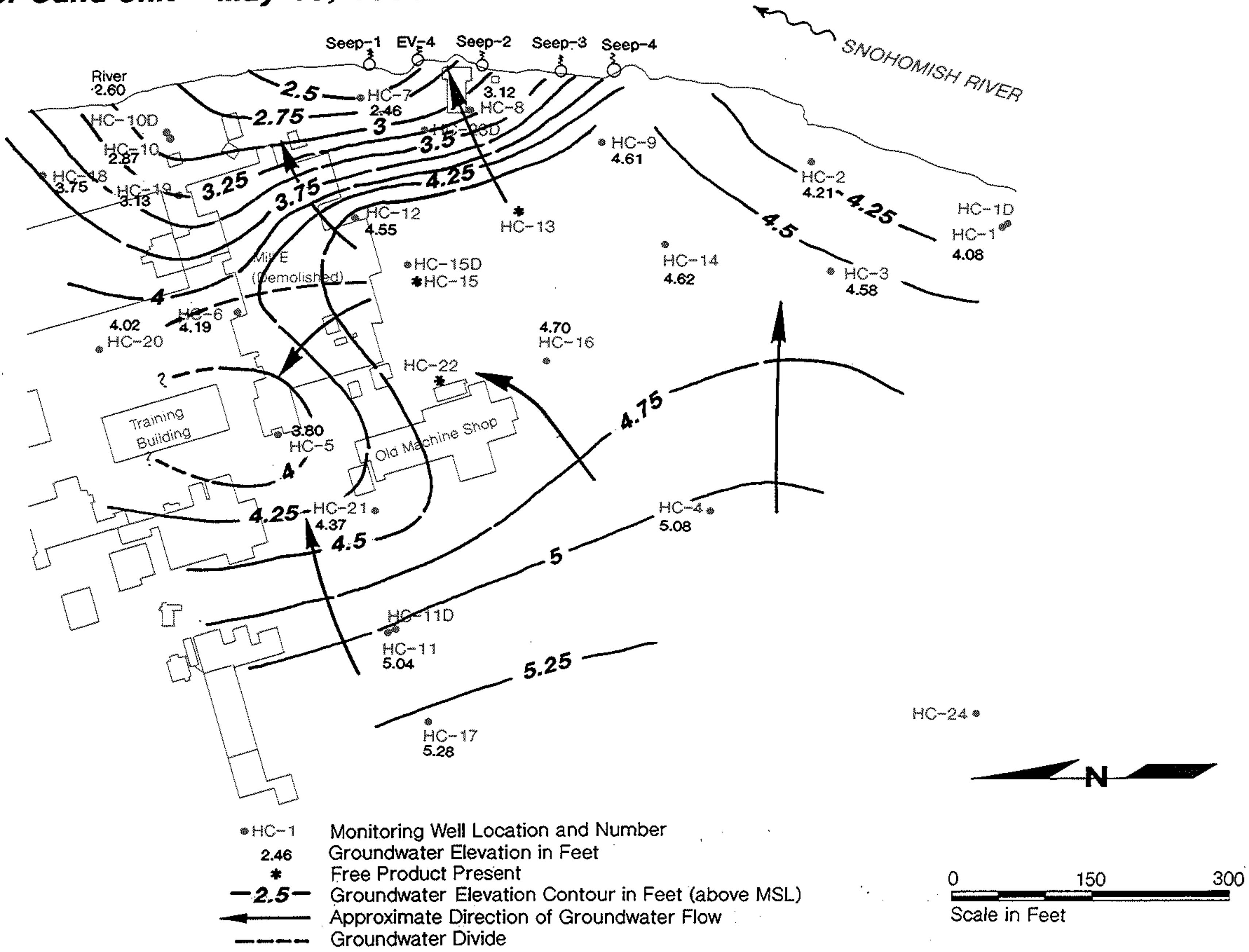
HARTCROWSER

J-2395-07 3/91

Figure 3

Groundwater Elevation Contour Map

Upper Sand Unit – May 10, 1990



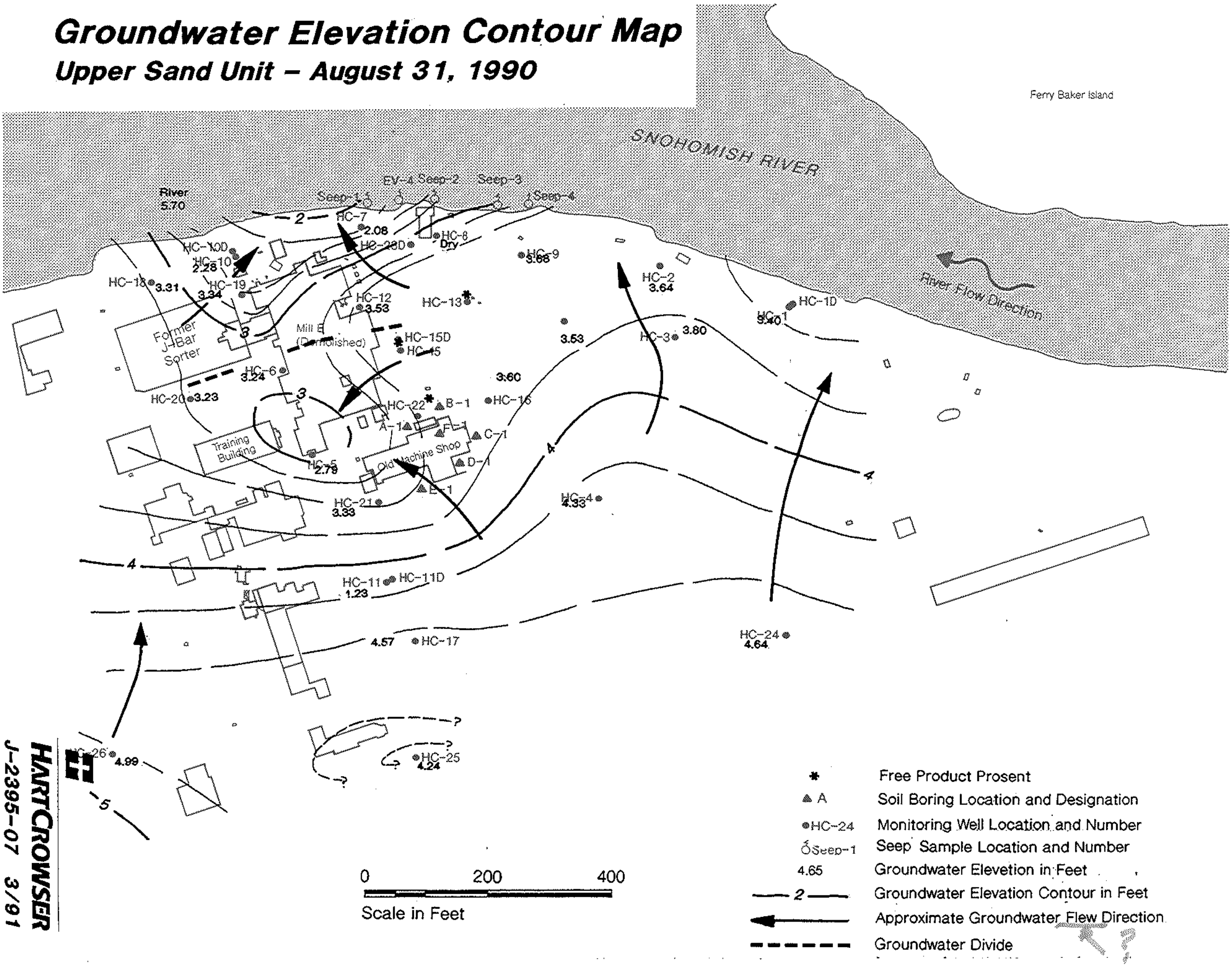
HARTCROWSER

J-2395-07 3/91

Figure 4

Groundwater Elevation Contour Map

Upper Sand Unit – August 31, 1990



HARTCROWSER
J-2395-07 3/91
Figure 5

APPENDIX A
FIELD METHODS

APPENDIX A
FIELD METHODS

INTRODUCTION

This appendix provides a description of the specific sampling and analysis procedures for data collection during the Phase Ic site characterization work at Mill E in Everett, Washington. Explorations completed during this phase of work included soil borings and monitoring well completions. Analyses and sampling included Upper and Lower Sand groundwater, subsurface product, former machine shop area soil, and bulkhead seeps.

DRILLING PROCEDURES

This section presents the methods we used to advance the soil borings and complete the monitoring wells associated with our Phase Ic work. We employed three different drilling techniques, including hollow-stem auger, solid-stem auger, and cable tool. Consistent well completion standards were used throughout.

Hollow-Stem Auger

GeoBoring, Inc., advanced nine soil borings using a truck-mounted hollow-stem auger (HSA) drilling rig (Mobile Drill B-61). Four of the borings (HC-24 through HC-26 and WP-1) were advanced on May 21, 1990, and completed as monitoring wells the same day. The remaining five borings (A-1 through E-1) were advanced and grouted on June 28, 1990.

Cable Tool Drilling

Holt Drilling, Inc., advanced two soil borings, completing a monitoring well in each, from June 7 through 11, 1990, using a cable tool drill rig (Bucyrus-Erie). The drilling was conducted through a series of steps designed to reduce the likelihood that contaminants from the Upper Sand could migrate into the Lower Sand during drilling. The method employed three casing sizes and required grouting a casing into the Silt

Layer before drilling through this unit. The following procedure was used:

- Drilling was initiated with 12-inch-diameter steel casing. This casing was advanced to the bottom of the Upper Sand and approximately 1 foot or less into the Silt Layer. The borehole was advanced by driving casing and bailing out the soil plug. Some water was required to remove the soil plug in the unsaturated zone; however, most of the added water was removed as the soil slurry was bailed from the casing.

- Once the Silt Layer was encountered and all soil was removed from the casing, a new 8-inch-diameter black steel casing was telescoped through the 12-inch casing and driven a few inches beyond the bottom of the hole. The 12-inch casing was then withdrawn as a cement-bentonite grout was tremied into the annular space, grouting the 8-inch casing into the Silt Layer.

- A grout pump, steam cleaning unit, and service truck with water tank was on the site for use. All grout was mixed and placed in accordance with Chapter 173-160 WAC. The 12-inch casing was reused, following steam-cleaning between holes.

All water and material produced from bailing during advance of the borehole were collected in 55-gallon drums.

Solid-Stem Auger

Pierson Drilling advanced one boring (F-1) through the floor of the Old Machine Shop using a Minute-Man Drill and solid-stem augers on July 9, 1990. The drilling method was employed because of the low clearance available within the building. The boring was grouted immediately following completion.

Monitoring Well Completion

Hart Crowser observed installation of the wells and prepared a field log for each. Interpretive logs and monitoring well construction diagrams are presented in this appendix on Figures A-2 through A-13. Figure A-1 contains an explanation of the terms and symbols used in these logs.

All monitoring wells were constructed with flush-threaded 2-inch-diameter PVC with 5- to 10-foot-long screens (0.020-inch slot). Casing and screen were installed through the hollow-stem augers or cable tool drill casing and Colorado 10/20 silica sand was poured slowly to form a sand pack around the screen. Sand packs were completed at a point 1 to 2 feet above the top of the well screens.

Each monitoring well was grouted from the top of the sand pack to ground surface using bentonite and concrete. As the augers and drill casing were removed, either a bentonite slurry (deep wells) or bentonite chips (shallow wells) filled the borehole void to a point 1 foot below ground surface. Each well was completed with a concrete surface seal and a 2- to 3-foot locking steel monument.

Soil Sampling

Soil samples were obtained from the auger explorations at 2.5-foot-depth intervals (or smaller) using the Standard Penetration Test procedure as described in ASTM D 1587. A 2-inch outside diameter, 18-inch-long split-spoon sampler was driven into the soil a distance of 18 inches using a 140-pound hammer, free-falling 30 inches. The number of blows required to drive the sample the last 12 inches is the Standard Penetration Resistance recorded at the respective depths on the boring logs. This resistance, or blow count, provides a measure of the relative density of granular soils and consistency of cohesive soils. Samples were recovered from the split-spoon samplers and described using the soil classification system presented on Figure A-1.

Soil samples were collected using two different methods during cable tool drilling. Near the Silt Layer, we collected soil samples using a 3-inch-diameter split-spoon sampler driven 18 inches ahead of the casing, using a set of slotted drilling jars. At other intervals, grab samples were obtained from the flap-valve bailer (used to clear the drill casing) for geologic classification.

Hart Crowser transferred soil from the sampler to new glass jars using a stainless steel spoon. Jars were sealed immediately, and held in a cooler with Blue Ice until delivered to the Hart Crowser mobile laboratory the same working day.

Drilling and sampling equipment were cleaned after the completion of each boring or sampling event to minimize the potential for cross contamination between soil borings or sample intervals. The augers were steam cleaned after each boring. Split-spoon samplers were cleaned between each sample run. Soil cuttings were collected in drums, labeled, and left on the site.

H-NU MEASUREMENTS

Sample jar headspace organic vapor measurements were made using an H-Nu photoionization detector to assess the possible presence of volatile hydrocarbons. Soil samples from the split-spoon sampler were collected in glass jars (filled half full), and covered with aluminum foil prior to capping. H-Nu measurements were made after the jar samples had sat for at least 15 to 20 minutes, by pushing the probe through the foil cover. The H-Nu measurements were made using a 10.2 eV probe. The H-Nu was calibrated using a manufacturer-supplied standard gas (isobutylene, equivalent to 34 ppm benzene) prior to making the measurements. H-Nu measurements are presented at their respective sample depth on the boring logs.

EQUIPMENT DECONTAMINATION

Before work began, all drill rigs and downhole equipment were steam cleaned. Between each boring, the following decontamination procedures were used for the drilling and downhole soil sampling equipment:

- Clean tap water was used for washing and steam cleaning of the equipment;

- Clean water was used to wash off soil and borehole cuttings. If any gross contamination was present, then a thorough wash with an Alconox solution and brushes was performed; and

- Steam water was used to wash off the equipment as the final decontamination.

All downhole sampling equipment was decontaminated using the following procedures before each sample was taken:

- The sampler was washed with clean water;
- The sampler was then washed in an Alconox solution; and
- The sampler was rinsed with tap water and deionized water.

GROUNDWATER MONITORING WELL DEVELOPMENT

Monitoring wells HC-24, HC-25, HC-25, and WP-1 were developed (before they were sampled) on May 25, 1990. Monitoring wells HC-15D and HC-23D were developed on June 11, 1990. The following procedure was used:

- A stainless steel, bottom-filling bailer was used to surge and remove the sediment in the screened section of the groundwater monitoring well;
- Hand bailing was continued until the groundwater became clear or when the turbidity content significantly decreased;
- At least ten casing volumes of groundwater were removed during development (if well was not bailed dry first);
- All equipment that was placed into the well was decontaminated before use by washing with successive rinses of alconox solution, tap water, and deionized water; and
- A new length of polyethylene rope was used for the bailer at each well site.

WATER LEVEL MEASUREMENTS

Water level measurements were made to a measured accuracy of about 0.05 foot with an Olympic Model 150 Electric Well Probe and a tape measure. The probe was lowered down the well casing until water was encountered. The tip of the well probe was routinely rinsed with deionized water between each well to avoid cross contamination.

GROUNDWATER SAMPLING

The following sections discuss the equipment and procedures used for sampling and handling of groundwater samples.

Equipment

The following equipment was used for groundwater sampling:

- pH, temperature, EC meter, dissolved oxygen meter;
- Electronic well sounder;
- Stainless steel, bottom-filling bailer;
- Portable photoionization detector equipped with a 10.2 eV lamp;
- New, clean polyethylene rope;
- Peristaltic pump;
- 0.45 mm disposable filters;
- Appropriate sampling containers;
- Ice and cooler; and
- Sample Custody Record.

Decontamination

The decontamination procedures described in the well development section were performed before each sample was taken.

Groundwater Sampling

In order to reduce potential cross contamination, groundwater samples were collected first from wells believed to contain background or low levels of contamination followed by wells suspected of containing higher levels of contamination.

Groundwater samples were collected by the following procedures:

- The well probe was rinsed with distilled water;

- The depth to water level from the top of casing was measured with an electronic well probe, to a precision of 0.05 foot and recorded;

- Prior to sampling, at least three casing volumes from each well were removed by bailing;

- Groundwater samples were collected with clean, decontaminated stainless steel bailers. New polyethylene rope was used for the bailer at each well;

- Sample containers were rinsed with the groundwater to be sampled. Groundwater retrieved from the monitoring well was poured into an appropriate container and capped. Samples for volatile analysis were collected first. Volatile sample containers were filled slowly with water, capped, inverted, and tapped to ensure no air bubbles remain. All sample containers were filled slowly to minimize turbulence. Samples analyzed for dissolved metals were filtered in the field using 0.45 μ filters. Preservatives were added to samples requiring preservation within 24 hours of sample collection. Field blanks were collected in a similar manner;

- Groundwater samples were immediately placed in a cooled ice chest. Samples collected for volatile analysis were placed in plastic sealable bags to minimize cross contamination. Samples suspected of containing high concentrations of volatile compounds were stored in a separate cooler;

- Field parameters (temperature, EC, dissolved oxygen, and pH) were measured and recorded;

- Groundwater sampling activities were documented on the Field Groundwater Sampling Data form; and

- Samples collected for chemical analysis were transported to Weyerhaeuser's laboratory using proper chain of custody procedures.

SEEP SAMPLING

We sampled a total of five different bulkhead seeps during two sampling rounds. We sampled four seeps (Seep-1 through Seep-4) on

May 29, 1990, and one seep (EV-4) on June 22, 1990. All seep samples were collected during low tide using stainless steel equipment (funnel and bowel) to direct seep water directly into bottles provided by the analytical laboratory.

In May we accessed the seeps using a small fishing boat. In June we accessed EV-4 using a hydraulic cherry-picker.

SAMPLE PROTOCOL

Appropriate sample containers provided by Weyerhaeuser's analytical laboratory were used. Time, date, initials of sampler, site location, and well name was recorded on all sample labels.

Samples were placed with appropriate packing in transport containers immediately after sampling. After sampling was completed and the samples were packed, the container was sealed and labeled with a custody seal.

A Sample Custody Record form was completed when samples were delivered to the laboratory. At a minimum the following was included:

- Client identification information;
- Name of person receiving the samples;
- Condition of transport and sample containers;
- Verification of sample containers and Chain of Custody Record;
- Time and date samples delivered to analytical laboratory;
- Allocation of samples; and
- Required sample analysis.

A copy of the Sample Custody Record was retained and provided to the appropriate QA officer.

Key to Exploration Logs

Sample Descriptions

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling

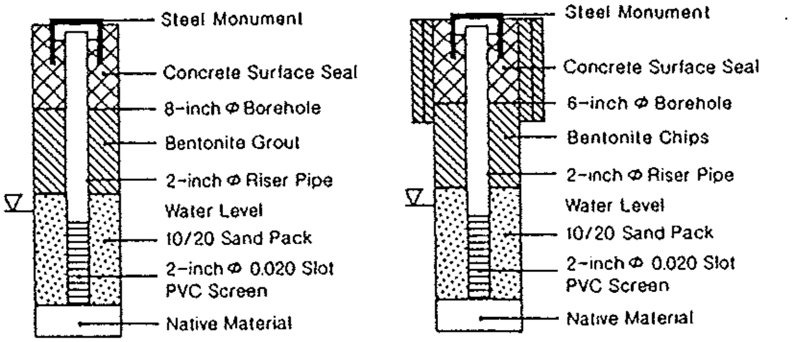
BORING SAMPLES

⊠	Split Spoon
⧄	Shelby Tube
▥	Cuttings
*	No Sample Recovery
P	Tube Pushed, Not Driven

Test Symbols

CA	Chemical Analysis
GS	Grain Size Classification

Monitoring Well Construction Details



Hollow-Stem Auger Method

Cable Tool Method
Intermediate Wells

HARTCROWSER

J-2395-06 7/90

Figure A-1

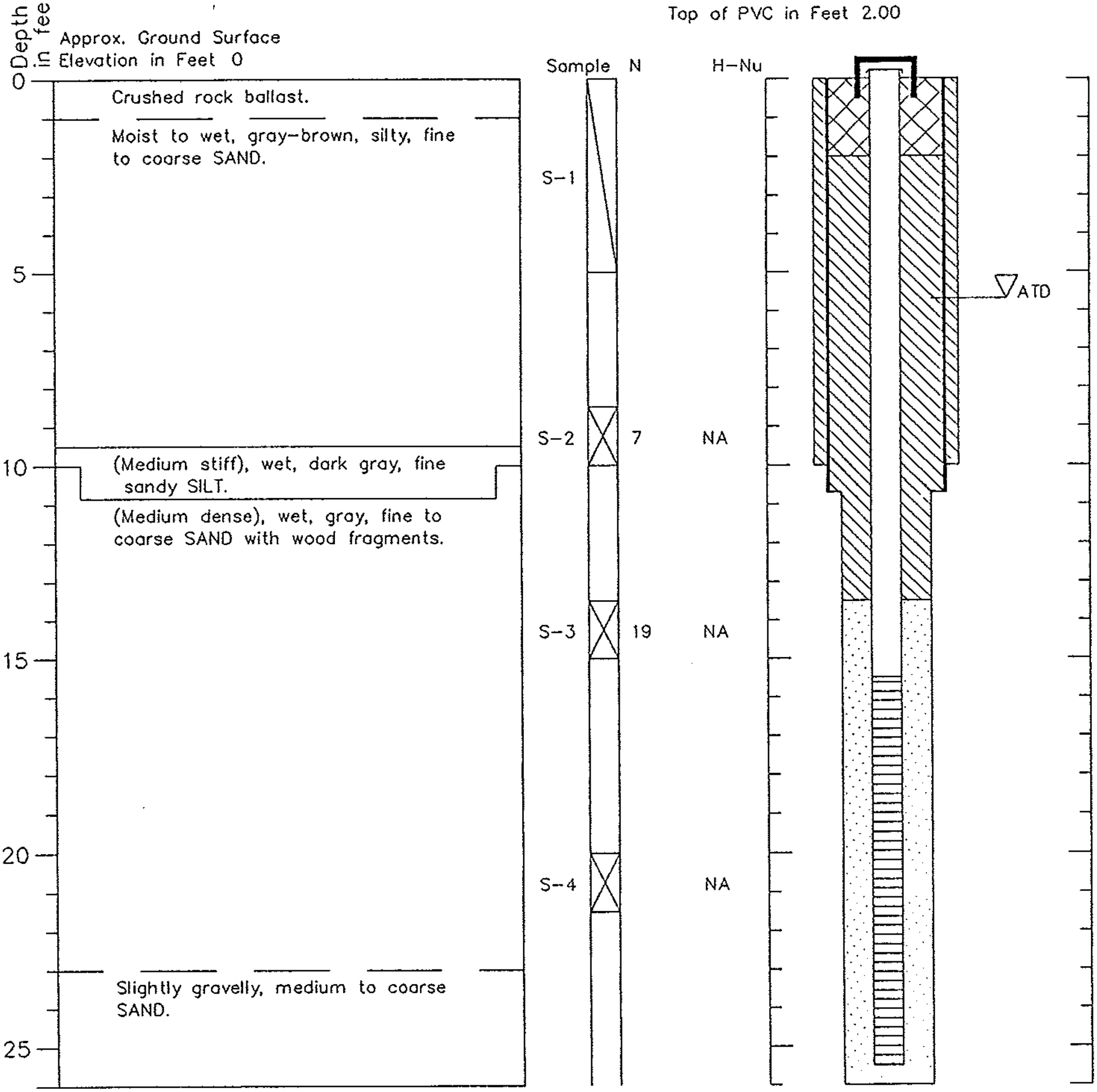
Boring Log and Construction Data for Monitoring Well HC-15D

Geologic Log

Monitoring Well Design

Casing Stickup in Feet 2.0
Top of PVC in Feet 2.00

Approx. Ground Surface Elevation in Feet 0



Crushed rock ballast.

Moist to wet, gray-brown, silty, fine to coarse SAND.

(Medium stiff), wet, dark gray, fine sandy SILT.

(Medium dense), wet, gray, fine to coarse SAND with wood fragments.

Slightly gravelly, medium to coarse SAND.

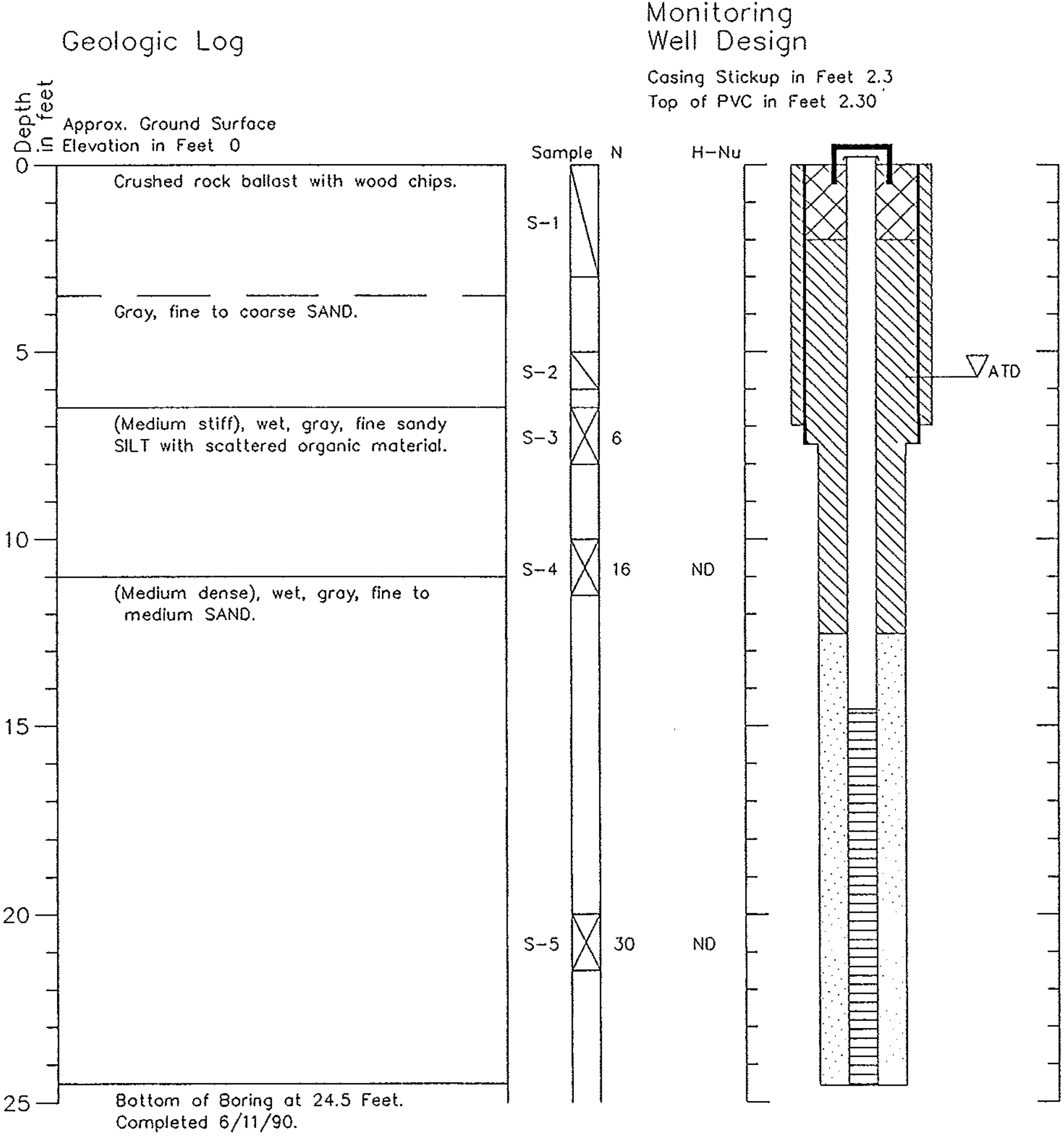
Bottom of Boring at 26.0 Feet.
Completed 6/8/90.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 6/90

Figure A-2

Boring Log and Construction Data for Monitoring Well HC-23D



Crushed rock ballast with wood chips.

Gray, fine to coarse SAND.

(Medium stiff), wet, gray, fine sandy SILT with scattered organic material.

(Medium dense), wet, gray, fine to medium SAND.

Bottom of Boring at 24.5 Feet.
Completed 6/11/90.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 6/90

Figure A-3

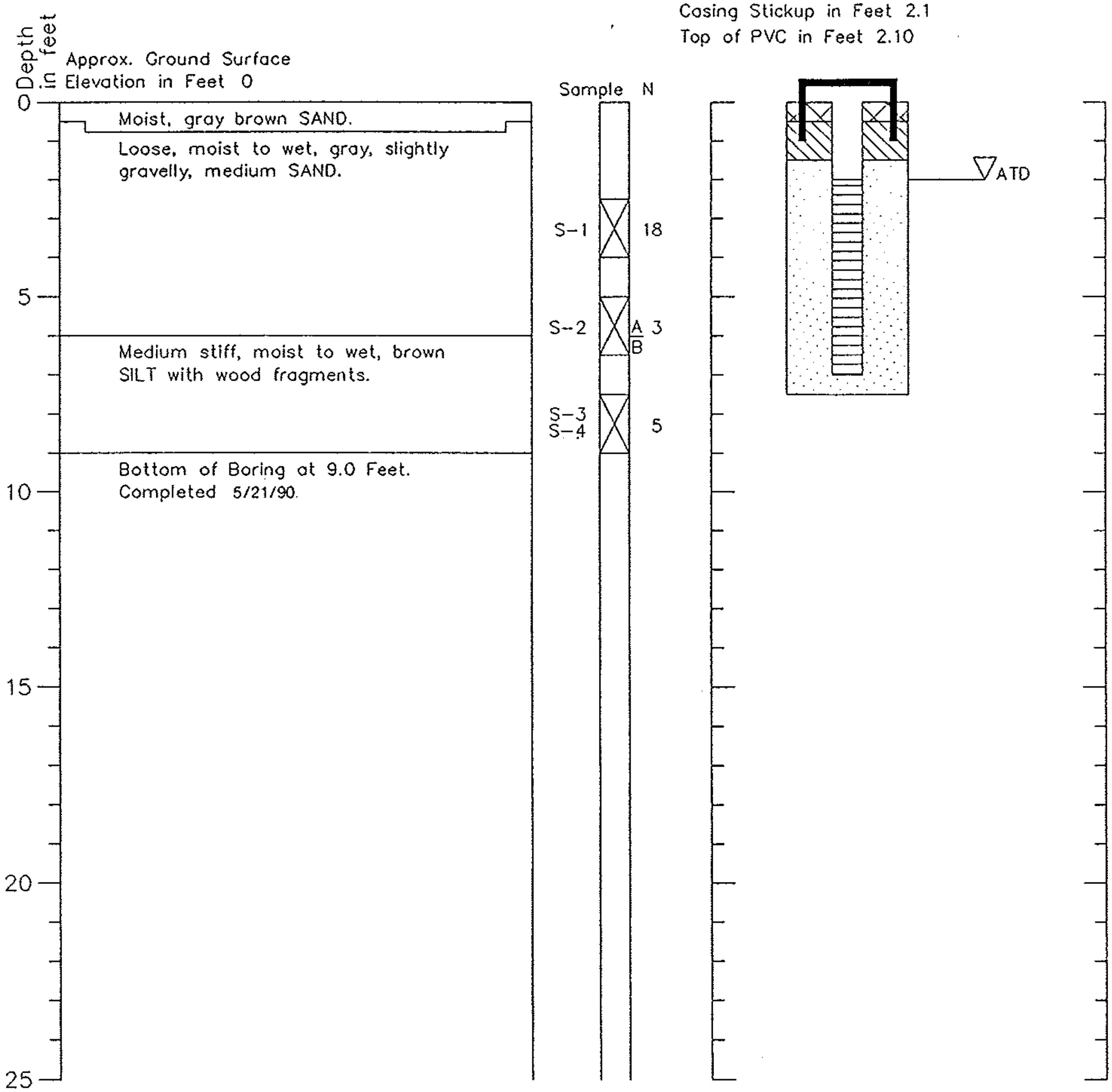
Boring Log and Construction Data for Monitoring Well HC-24

Geologic Log

Monitoring Well Design

Casing Stickup in Feet 2.1
Top of PVC in Feet 2.10

Approx. Ground Surface
Elevation in Feet 0



Moist, gray brown SAND.

Loose, moist to wet, gray, slightly gravelly, medium SAND.

Medium stiff, moist to wet, brown SILT with wood fragments.

Bottom of Boring at 9.0 Feet.
Completed 5/21/90.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 5/90

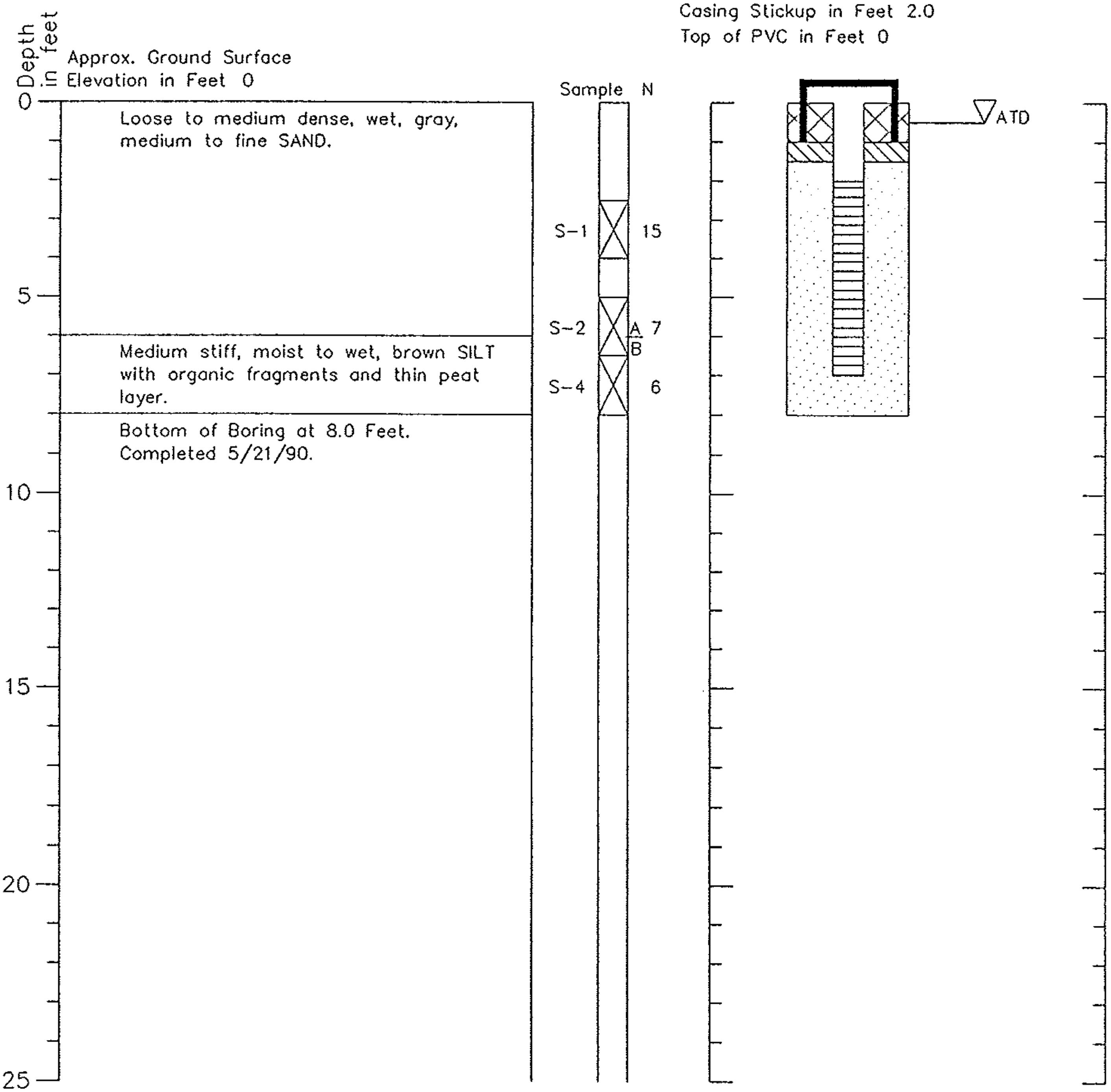
Figure A-4

Boring Log and Construction Data for Monitoring Well HC-25

Geologic Log

Monitoring Well Design

Casing Stickup in Feet 2.0
Top of PVC in Feet 0

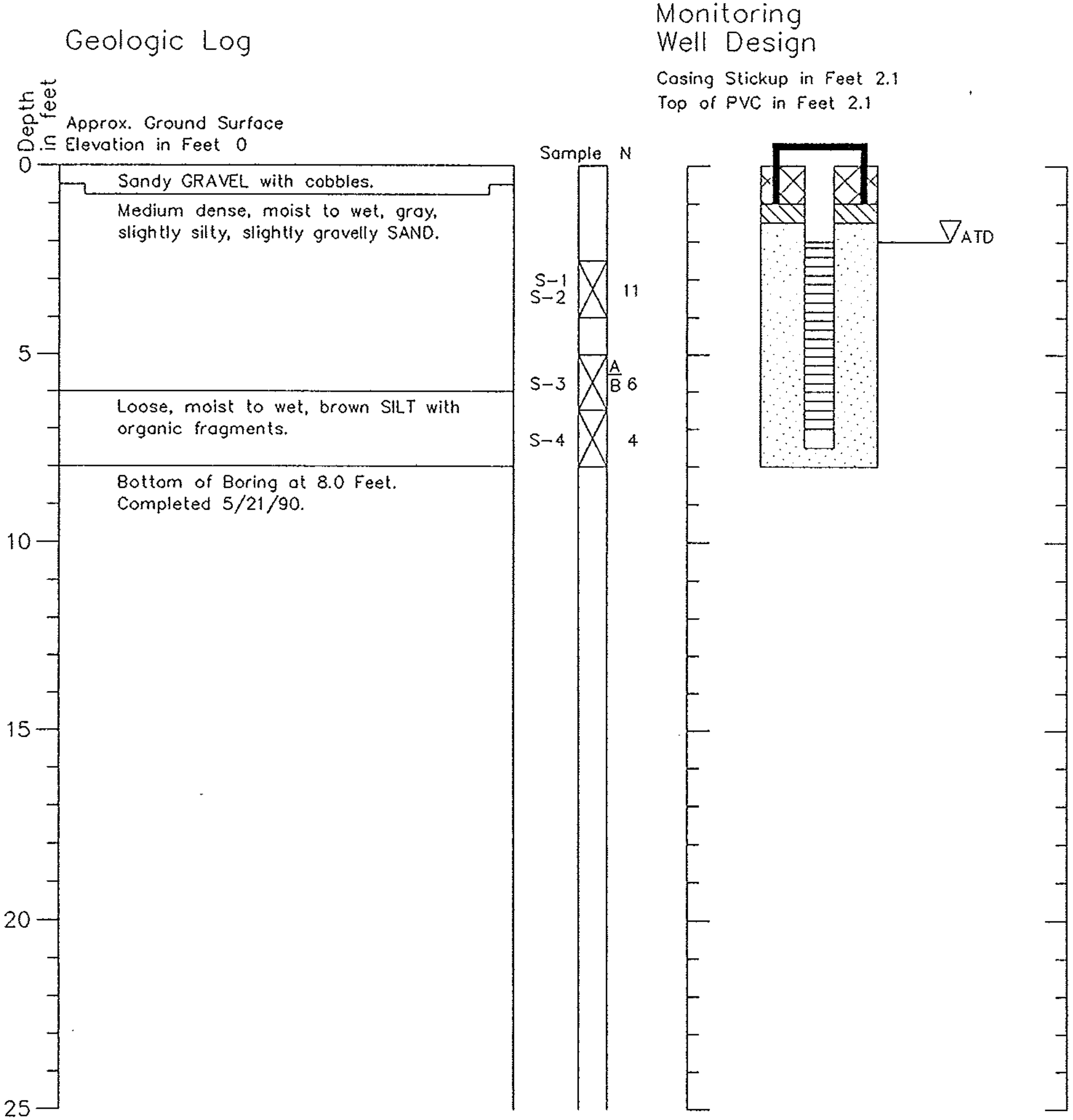


1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 5/90

Figure A-5

Boring Log and Construction Data for Monitoring Well HC-26



Sandy GRAVEL with cobbles.

Medium dense, moist to wet, gray, slightly silty, slightly gravelly SAND.

Loose, moist to wet, brown SILT with organic fragments.

Bottom of Boring at 8.0 Feet.
Completed 5/21/90.

1. Refer to Figure A–1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 5/90

Figure A–6

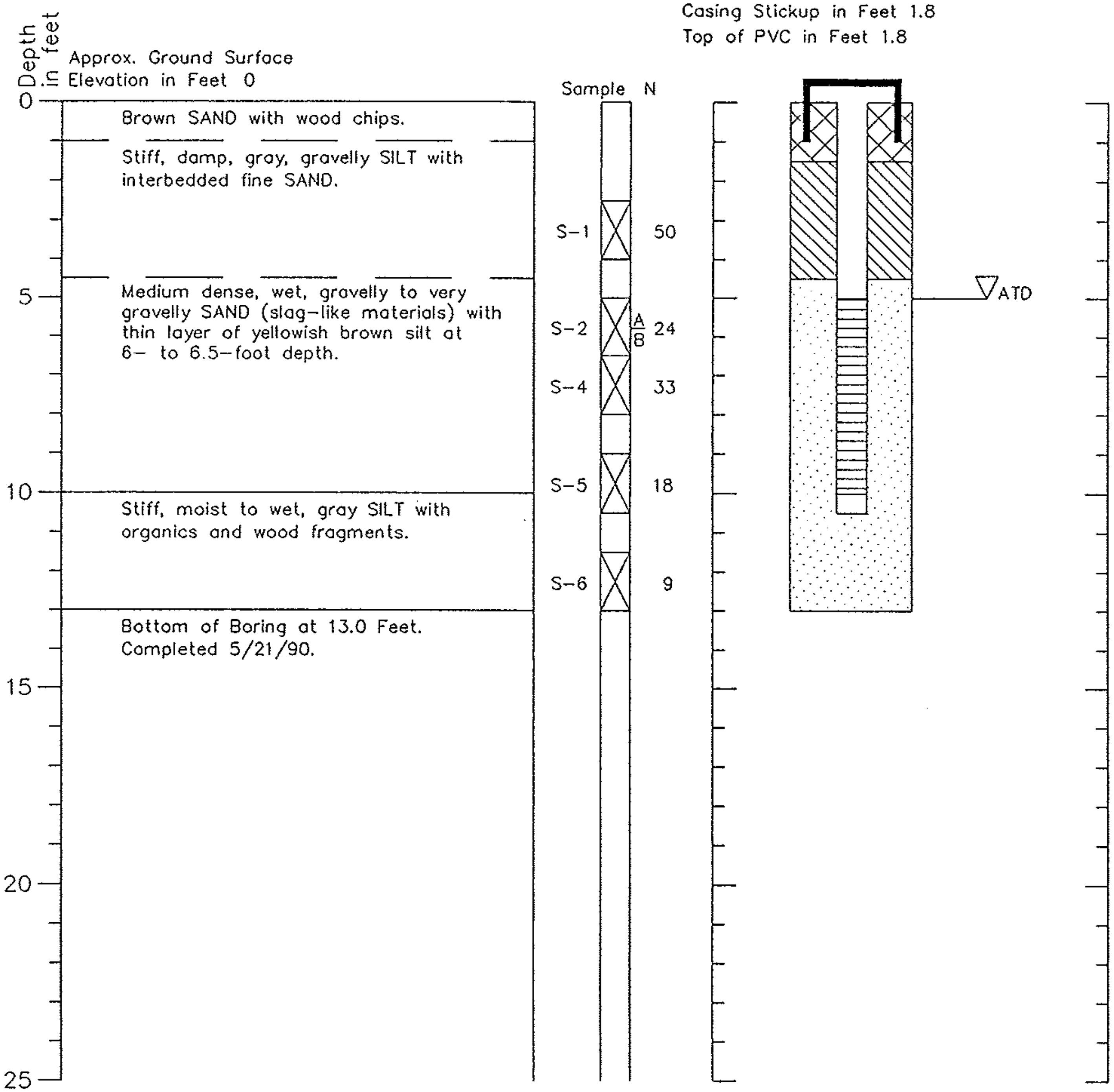
Boring Log and Construction Data for Monitoring Well WP-1

Geologic Log

Approx. Ground Surface Elevation in Feet 0

Monitoring Well Design

Casing Stickup in Feet 1.8
Top of PVC in Feet 1.8



Brown SAND with wood chips.

Stiff, damp, gray, gravelly SILT with interbedded fine SAND.

Medium dense, wet, gravelly to very gravelly SAND (slag-like materials) with thin layer of yellowish brown silt at 6- to 6.5-foot depth.

Stiff, moist to wet, gray SILT with organics and wood fragments.

Bottom of Boring at 13.0 Feet.
Completed 5/21/90.

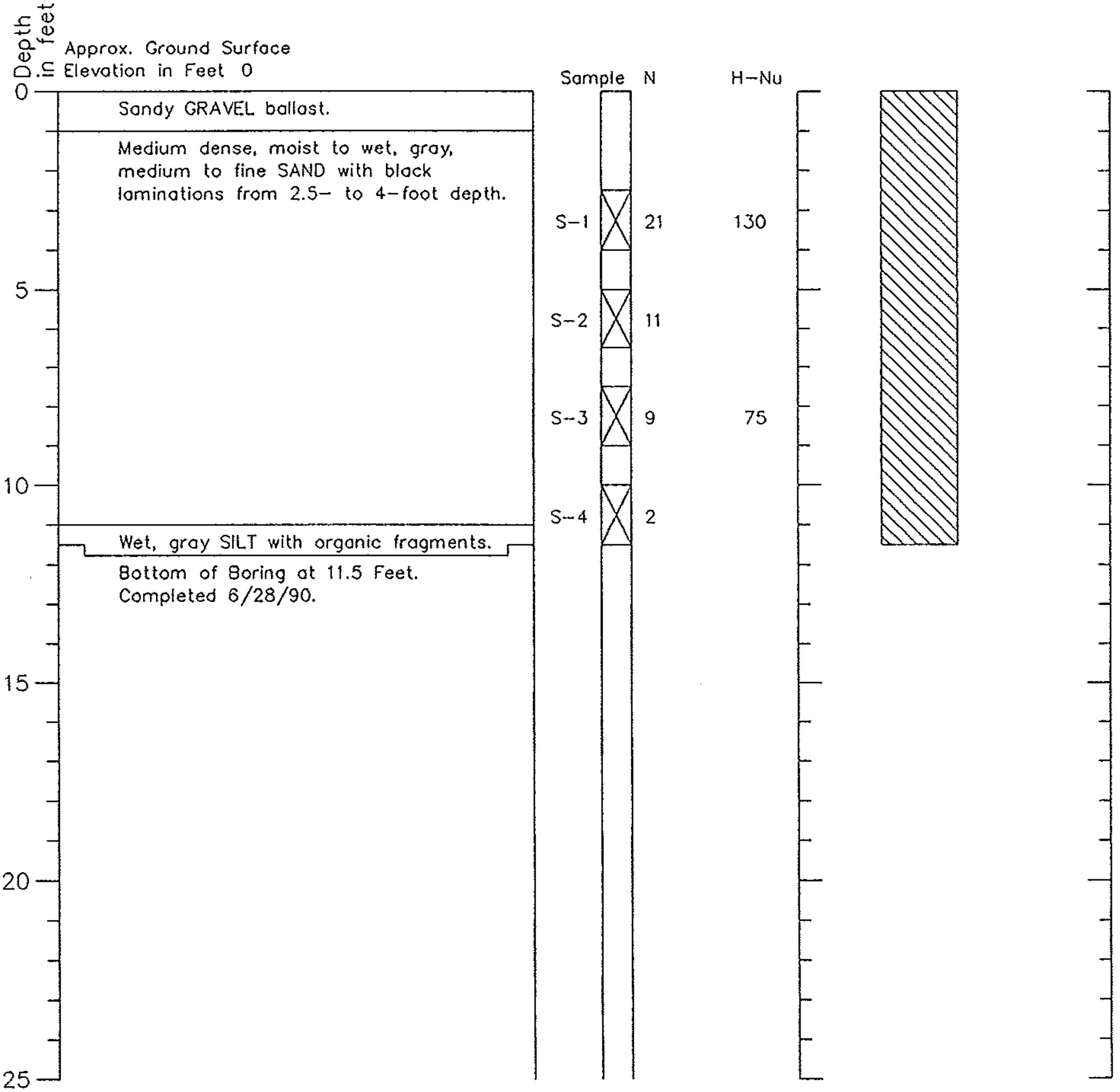
1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 5/90

Figure A-7

Boring Log A-1

Geologic Log



Approx. Ground Surface
Elevation in Feet 0

Sandy GRAVEL ballast.

Medium dense, moist to wet, gray, medium to fine SAND with black laminations from 2.5- to 4-foot depth.

Wet, gray SILT with organic fragments.

Bottom of Boring at 11.5 Feet.
Completed 6/28/90.

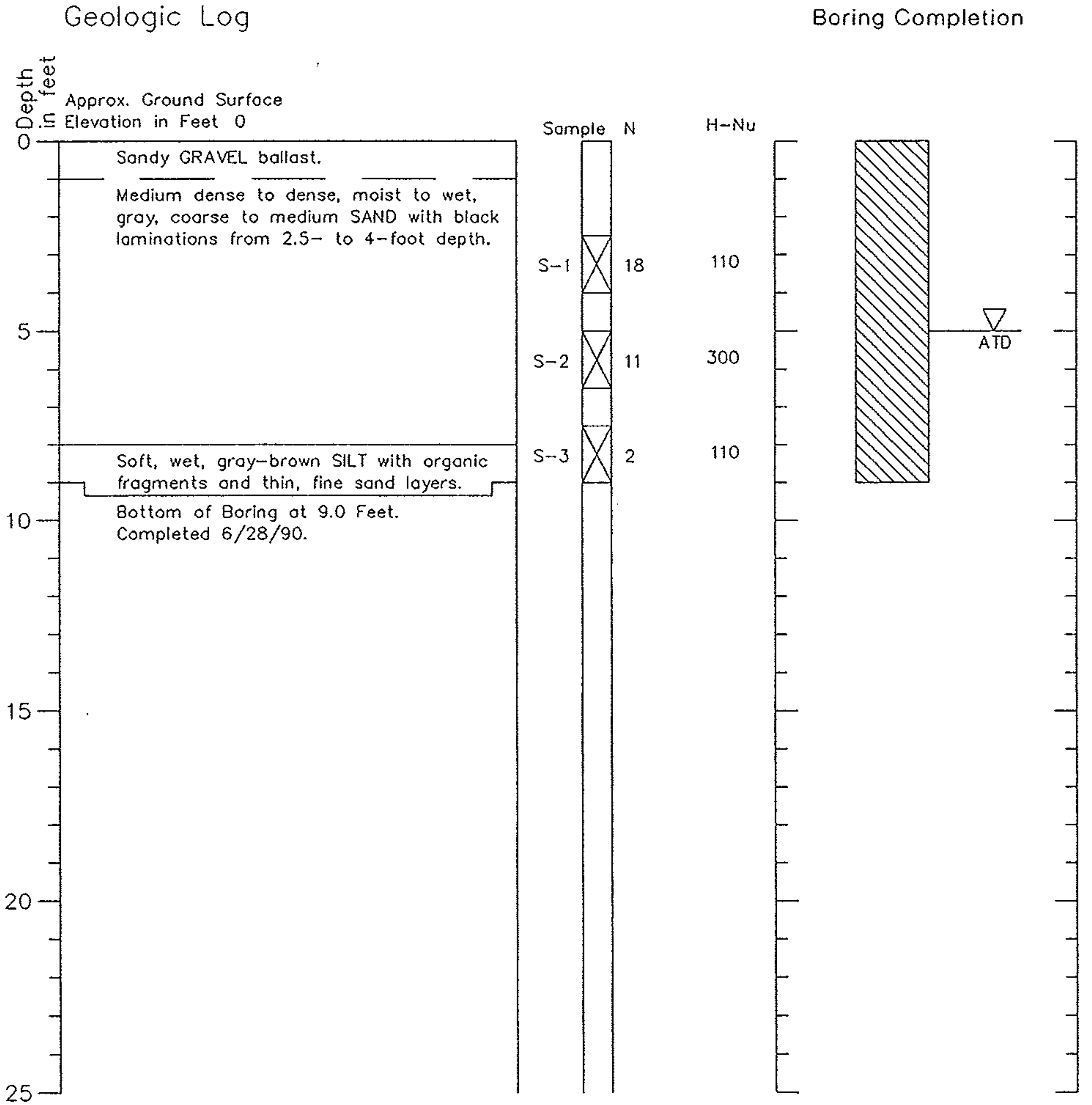
Sample	N	H-Nu
S-1	21	130
S-2	11	
S-3	9	75
S-4	2	

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 6/90

Figure A-8

Boring Log B-1



Sandy GRAVEL ballast.

Medium dense to dense, moist to wet, gray, coarse to medium SAND with black laminations from 2.5- to 4-foot depth.

Soft, wet, gray-brown SILT with organic fragments and thin, fine sand layers.

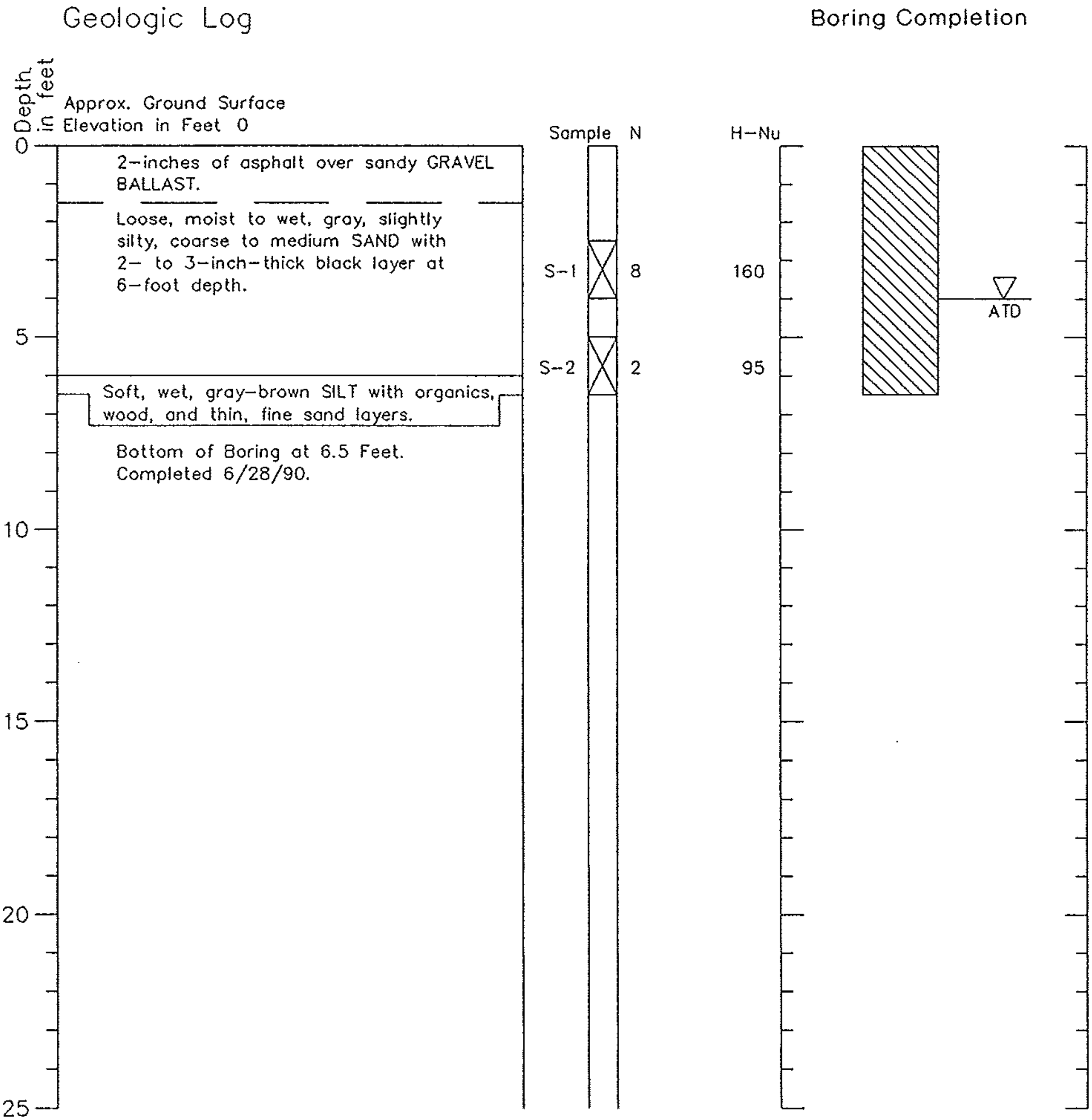
Bottom of Boring at 9.0 Feet.
Completed 6/28/90.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-2395-06 6/90

Figure A-9

Boring Log C-1



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

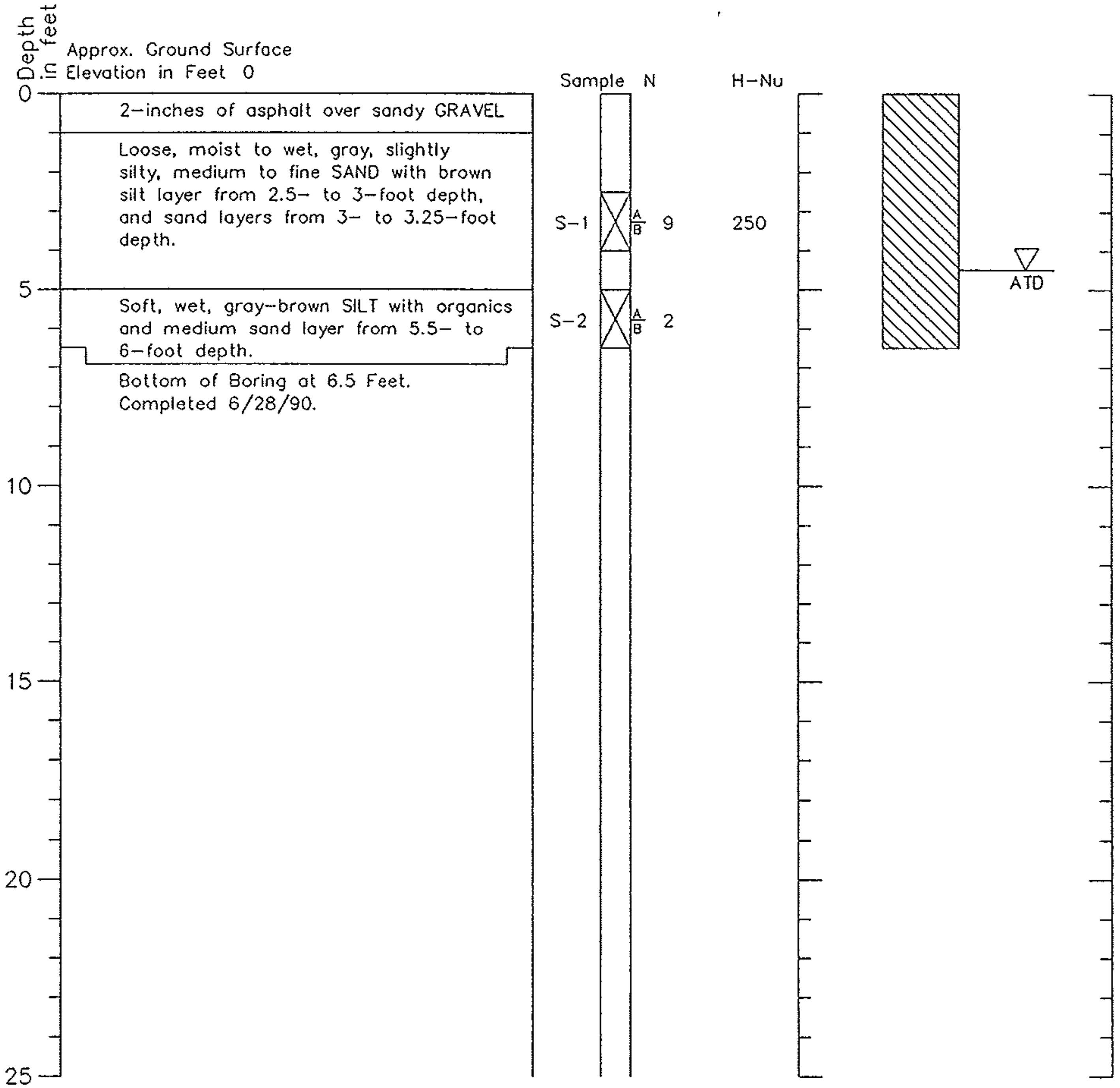
J-2395-06 6/90

Figure A-10

Boring Log D-1

Geologic Log

Boring Completion



2-inches of asphalt over sandy GRAVEL

Loose, moist to wet, gray, slightly silty, medium to fine SAND with brown silt layer from 2.5- to 3-foot depth, and sand layers from 3- to 3.25-foot depth.

Soft, wet, gray-brown SILT with organics and medium sand layer from 5.5- to 6-foot depth.

Bottom of Boring at 6.5 Feet.
Completed 6/28/90.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

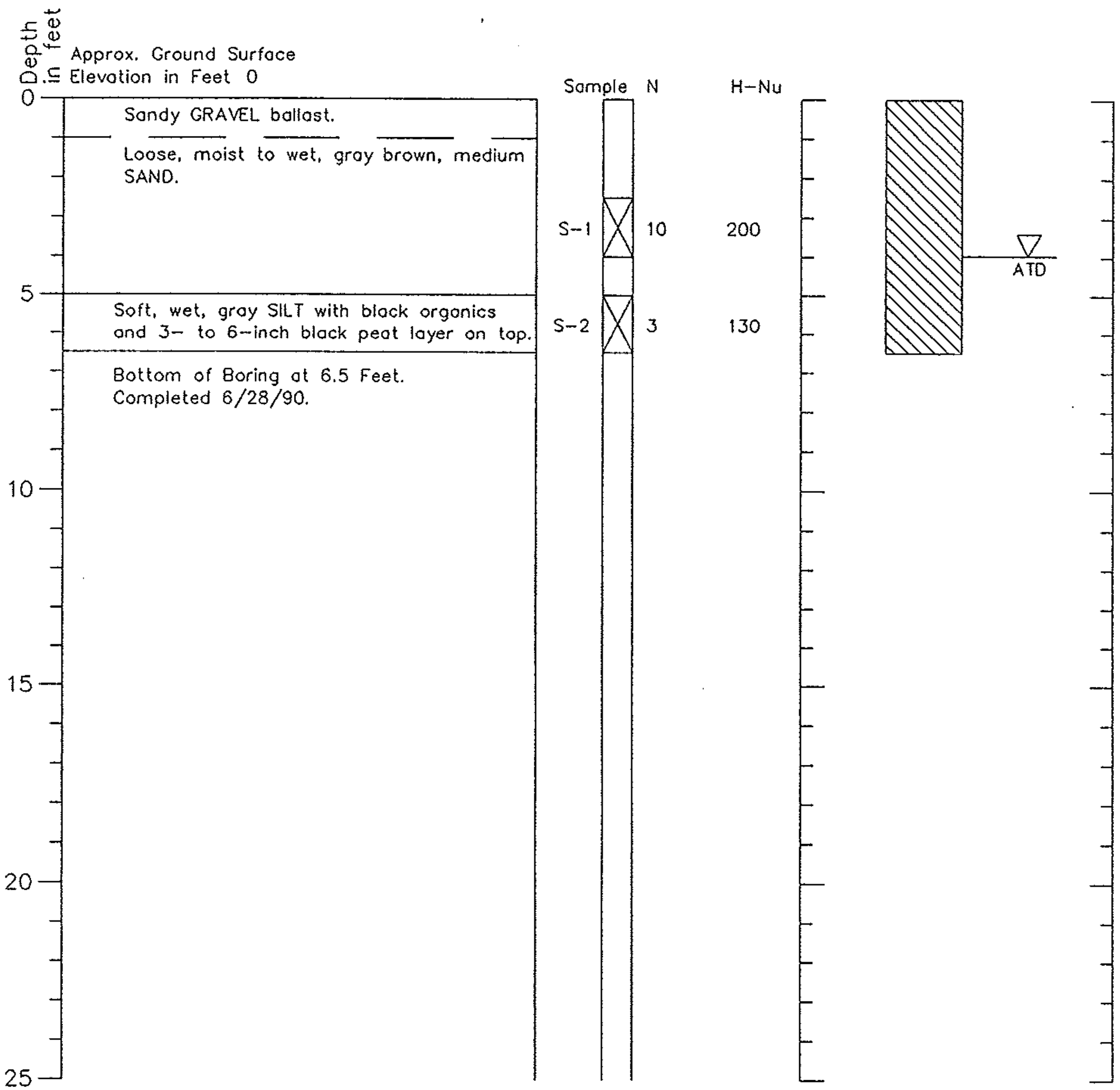
J-2395-06 6/90

Figure A-11

Boring Log E-1

Geologic Log

Boring Completion



Sandy GRAVEL ballast.

Loose, moist to wet, gray brown, medium SAND.

Soft, wet, gray SILT with black organics and 3- to 6-inch black peat layer on top.

Bottom of Boring at 6.5 Feet.
Completed 6/28/90.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

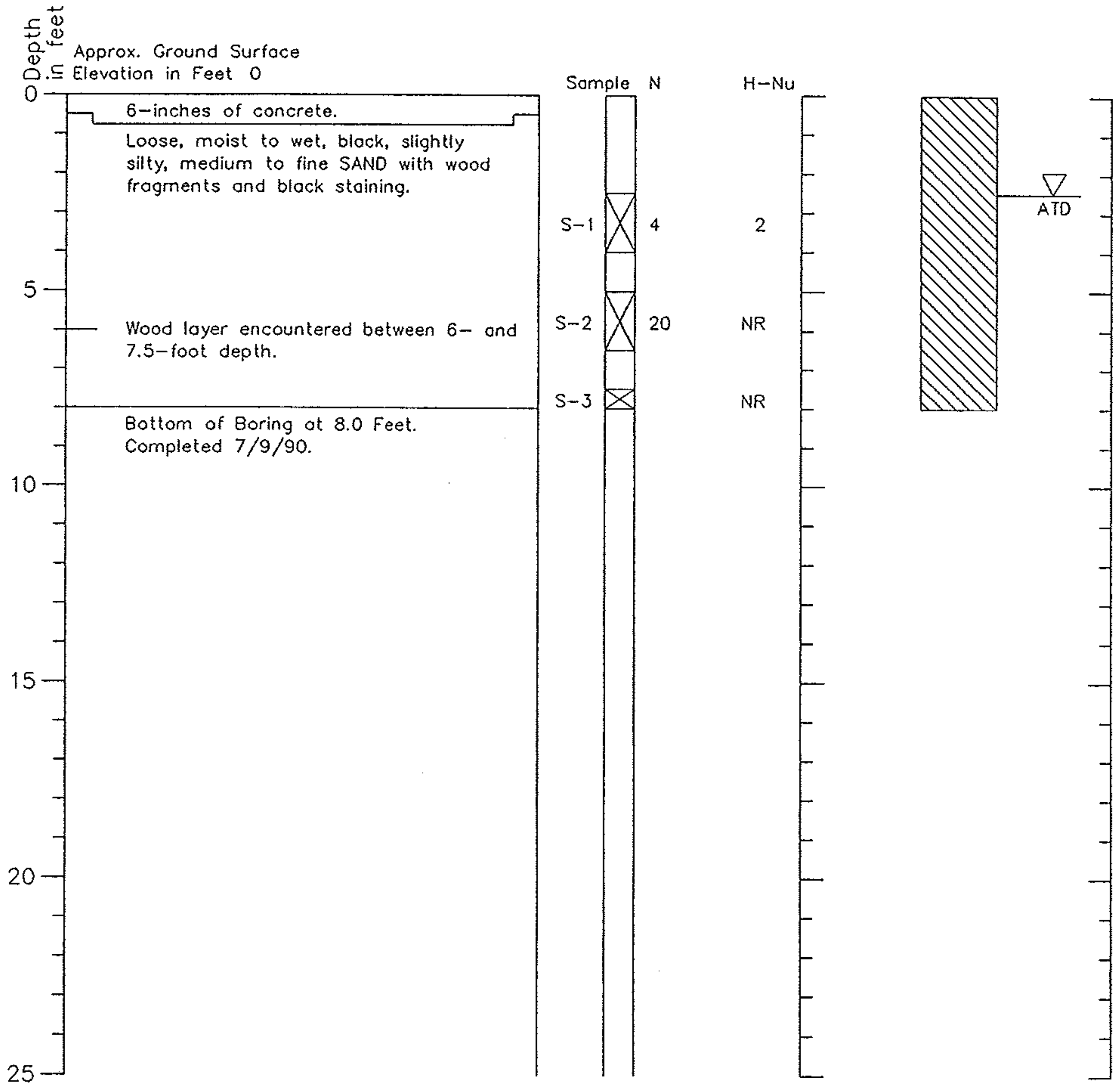
HARTCROWSER

J-2395-06 *6/90*

Figure A-12

Boring Log F-1

Geologic Log



6-inches of concrete.

Loose, moist to wet, black, slightly silty, medium to fine SAND with wood fragments and black staining.

Wood layer encountered between 6- and 7.5-foot depth.

Bottom of Boring at 8.0 Feet. Completed 7/9/90.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

J-2395-06 7/90

Figure A-13