

SURFACE WATER CONTROLS SUMMARY REPORT

PUYALLUP/KIT CORNER CUSTODIAL LANDFILL King County, Washington

Prepared for
King County Department of Natural Resources
Solid Waste Division

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Woodward-Clyde



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In early 1996, Woodward-Clyde Consultants was contracted by the King County Solid Waste Division to conduct remedial work at the Puyallup/Kit Corner Custodial Landfill. The scope of work includes evaluating surface water, groundwater, and landfill gas (LFG) conditions at the landfill. Landfill gas conditions were evaluated and a landfill gas control system master plan has been prepared and submitted to King County. In addition, Woodward-Clyde has been contracted to design landfill gas system improvements, including expansion of the existing southern perimeter gas system to include the eastern and western perimeter of the landfill. It is anticipated that design of this system will be complete in early 1997 and the system expansion will be built during the late spring and early summer of 1997.

Additional groundwater monitoring wells have been installed and groundwater conditions are currently being evaluated by Woodward-Clyde. This evaluation includes ongoing quarterly monitoring of wells. A summary report describing the results of this evaluation is scheduled for completion by late spring 1997.

The effects of surface water were evaluated by investigating the performance of the landfill cover, the extent of the refuse, refuse geometry, and the leachate conditions in the landfill; and by studying the interaction between the landfill, surface water bodies, and shallow groundwater on the east side and beneath the site. This evaluation included shallow groundwater because of the interaction between surface water and groundwater, to the extent needed to understand surface water or landfill conditions. This evaluation will complement the groundwater summary report described above, but is not considered to be a thorough analysis of groundwater conditions. This summary report presents the results of the surface water controls evaluation for the site.

The report is organized into ten sections. The remainder of section one provides the introduction and background information on the site and site conditions. Section two describes surface features and hydrology associated with the landfill. Section three describes the culvert passing through the landfill and the qualitative evaluation of the condition of the culvert. The evaluation of the landfill cover is provided in Section four. Section five describes the investigation of the interior landfill conditions, especially the presence of landfill leachate. Section six provides an analysis of shallow groundwater conditions adjacent to the landfill and interactions among surface water, landfill leachate, and shallow groundwater. Section seven provides a semi-quantitative hydrologic water balance of the landfill. Section eight presents the results of geographic surveying of exploration locations associated with this investigation. The results and recommendations are summarized in Section nine. Section ten provides a list of references.

1.1 PHYSICAL SETTING

The Puyallup/Kit Corner Custodial landfill is located in western Washington in the Puget Sound lowlands approximately 4 miles southeast of Puget Sound. The landfill is located near the city of Federal Way in southern King County, just southeast of the Interstate 5 (I-5) and State Highway 18 (SR-18) interchange (Figure 1-1). Interstate 5 is located approximately 250 feet west of the landfill and SR-18 is located approximately one-quarter mile north of the landfill. The landfill is separated from these highways by wooded areas. Single family and multi-family residential developments have recently been constructed on the east and south sides of the landfill.

The landfill area covers approximately 20 acres in a mound which ranges from 10 to 40 feet above the surrounding grade. The maximum elevation is approximately 364 feet above mean sea

level (msl). An underground gas pipeline and paved access road run generally north-south just west of the landfill, and a water supply line runs along the landfill's northern border. Ditches lie along the northern border and along the access road. A perimeter road provides access around the landfill, except along the northeast area where the fence line cuts the road off for a short distance. Dirt roads criss-cross the landfill surface. A stream and two stormwater detention ponds lie to the east of the landfill. The stream flows southward along the east side of the landfill and then through a culvert beneath the southeastern portion of the landfill. The stream exits the culvert along the south side of the landfill and continues flowing southward. Although the site is fenced and the gate across the access road remains locked, the site has experienced trespassing and some vandalism to the existing LFG extraction system.

The landfill mound is vegetated with grasses, Scotch broom, and blackberries. Some alder and Douglas fir trees can be found in the central and southeastern portions of the landfill, and around much of the landfill's perimeter. Some areas of the landfill cover are cracked and uneven, displaying surface depressions from differential compaction and settling of the underlying debris. The landfill cover was reportedly last graded in the 1970s (W. Kinney 1996). Depressions in the cover collect and pond water during the rainy season.

1.2 CLIMATE

The landfill is located in the Puget Lowlands, an area of moderate precipitation and temperatures. Precipitation in the area, virtually all of which occurs as rainfall, averages about 35 to 40 inches per year. The weather pattern is dominated by the Aleutian Low Pressure System during the winter, when average temperatures are in the low 40s (°F), and by the Pacific High Pressure System in the summer, when average temperatures are in the low-to-mid 60s (°F). The yearly mean temperature is about 53° F (NOAA 1991). The area averages about 228 days per year of cloudy skies, and approximately 85 percent of the precipitation occurs during the eight-month period between September and April (Liesch et al. 1963).

1.3 REGIONAL GEOLOGY AND HYDROGEOLOGY

The landfill is located within the southern portion of a generally north-south trending topographic and structural depression known as the Puget Sound Lowlands, which lies between the Olympic Mountains to the west and the Cascade Mountains to the east. The topography and sedimentary deposits of the lowlands were formed primarily by the erosional and depositional processes of advancing and retreating glaciers during the Pleistocene Period. Deposits in the southern lowlands are dominantly from the last of four major periods of glaciation in the area—the Fraser Glaciation. This period of glaciation was marked by two glacial advances, or stades—the Sumus stade and the earlier Vashon stade.

Deposits in the southern lowlands, referred to as the Des Moines Drift Plain, are from the Vashon stade. These glacial deposits include moraines, outwash gravels and sands, tills, and glaciofluvial deposits from rivers and lakes which formed as a result of glacial processes. These deposits are generally termed drift, and the glacial sedimentary sequence may be as much as 1,000 feet thick in areas of the lowlands. In some areas, more recent erosional and depositional processes of area rivers and streams have overprinted the glacial morphology and deposits. The recent fluvial

deposits and Pleistocene glacial sediments are underlain by Tertiary volcanic and sedimentary rocks.

The principal aquifers beneath the Des Moines Drift Plain occur within Vashon Advance Outwash deposits and the pre-Vashon Salmon Springs Drift (Luzier 1969). Federal Way Water District wells, located west of the landfill site, are likely completed within a Vashon Outwash aquifer. The Salmon Springs Drift occurs predominately as coarse sand and gravel. Much of the drift is densely consolidated and pore spaces are filled with fine material. Some of the drift deposits, however, are highly permeable zones of coarse sand and gravel capable of yielding thousands of gallons per minute to wells. Some water supply wells are completed in pre-Salmon Springs deposits; however, not much is known about the extent of these aquifers.

Groundwater flow below the southern lowlands is complex, and generally moves downward from one water-bearing zone to the next, as well as flowing laterally (Cline 1969). Groundwater in the Federal Way area flows generally southward within a channel of the Vashon Advance Outwash deposits (Robinson & Noble 1987).

1.4 PUYALLUP/KIT CORNER LANDFILL HISTORY

A 1936 aerial photograph indicates that the landfill site was undeveloped at that time, although the sparse vegetation visible on the photograph indicates that it had likely been logged prior to that time (Applied Geotechnology Inc. 1992). Sometime between 1936 and 1947 the site was reportedly developed as a gravel pit (N. Fujii 1992). Landfilling at the site began in 1947. No records exist of the volume or types of refuse placed in the landfill (D. Nyblom 1992). Landfilling began in the northeast and continued southward, with excavation of borrow material occurring along the south property line (W. Kinney 1996). In 1959, approximately 9.5 acres of the original 40-acre site was deeded to the State of Washington Department of Highways for construction of I-5, and some refuse was reportedly moved from the deeded area to active areas of the landfill.

By the early-to-mid 1960s, the Puyallup/Kit Corner landfill served as the principal municipal landfill for southwest King County. Aerial photographs indicate that the area used as landfill more than doubled between 1960 and 1965 (Applied Geotechnology Inc. 1992). In 1965, the gas pipeline along the western border of the landfill was installed at a depth of 3 to 5 feet. The pipeline trench did not include any barriers to liquid or gas migration from the landfill (AGI 1994b). Also during 1965, the stream along the east side of the landfill was re-routed into a culvert running southwest for approximately 600 feet beneath the southeast portion of the landfill. The stream exits the culvert along the south side of the landfill. Although the northern side of the landfill was the older fill area, it was raised and expanded in the later stages of the landfill operations. Younger refuse was also likely placed over older refuse in the central part of the landfill as it was expanded. The landfill ceased operation in 1967, with the total refuse thickness estimated at 30 to 40 feet (Seattle King County Department of Public Health 1985). The landfill was then covered by approximately four feet of locally derived soil (W. Kinney 1992).

2.1 TOPOGRAPHY

The landfill was constructed by mounding refuse prior to placing final cover soils. It occupies approximately 20 acres of land. The highest point on the landfill is at about 364 feet above msl and the lowest point underlain by refuse is in a depression in the southeast corner of the site (Southeast Depression) at about 316 feet above msl (Figure 2-1). The highest point of the main landfill mound is about 42 feet above the east perimeter road near monitoring well PKC-MW1. The south slope is the longest slope on the landfill with a total height of about 20 feet and inclined generally flatter than about 6 horizontal to 1 vertical (6H:1V). The east slope varies from about 3.5H:1V to 4H:1V at its steepest locations. The steepest slopes are on the north side of the site at 3.2H:1V. The west slopes vary greatly but are less than 10 feet in height and typically flatter than 6H:1V.

The topography immediately west of the site is relatively flat, with a high point on the northwest end which slopes gently down towards the southwest and then drops steeply down to I-5. To the north of the site, the ground surface slopes gently downward from west to east. The topography east of the site is relatively flat east of the East Stream. This area is occupied by a small intermittent stream (the East Stream), two detention ponds, and a wetland. The Southeast Depression area is at the bottom of a steep (2H:1V) slope that rises upward about 40 feet immediately to the south. Apartment buildings have been constructed south of the landfill near the top of this slope. Apartment buildings have also been constructed at elevations similar to the landfill site south of the landfill on the west side of the East Stream.

The landfill surface has a dense grass cover that is typically less than 12 inches high. Near the middle of the top platform, deciduous and conifer trees 20 to 40 feet tall exist with thick areas of Scotch broom on the east side. The perimeter of the landfill on the north, west, and east sides is densely vegetated with tall deciduous trees, brush, and blackberry bushes. The south side of the landfill also has dense vegetation, in patches, among the thick grasses. The undisturbed area north and west of the landfill site is forested, while the south side is developed with apartment buildings. The east side of the landfill is adjacent to a single family housing development, wetland, and two detention ponds. General vegetation patterns on the landfill site and other site features are shown on Figure 2-2.

2.2 SOUTHEAST DEPRESSION

A large surface depression in the southeast corner of the site occupies nearly one acre (320 feet above msl and below) and is approximately 5 feet deep at the lowest point (see Figure 2-3). The depression is bounded on the north by the perimeter road, on the west by the access road to well PKC-MW4, on the east by a steep 5- to 7-foot-high slope, and to the south by the 40-foot high 2H:1V slope. The limits of the depression are roughly defined by PKC-MW16, PKC-GP16, and PKC-GP17. The depression is underlain by refuse with thin cover soil. The refuse ranges in depth from about 18 feet (PKC-GP17) to 32 feet (EW-12D) below ground surface (bgs) on the west and east sides, respectively. Thus, refuse exists down to about 283 feet above msl in this area, and possibly even 5 to 10 feet lower.

According to King County Solid Waste Division, the Southeast Depression was excavated for cover soil for the main landfill and backfilled with refuse (W. Kinney 1996). The depression

appears to be isolated from the main body of the landfill by the south perimeter access road and culvert. The depression has formed over time due to settlement. Additional settlement on the order of 12 inches has occurred since the LFG extraction system on the south side of the landfill was initiated in 1994, and was attributed to the vacuum effect and surcharge that the LFG system has had on the unconsolidated, wet refuse. Most other settlement in this area can be attributed to consolidation of the refuse and should be expected to continue.

2.3 EAST STREAM

The East Stream begins just north of the northern detention pond, flows south along the east side of the landfill, and crosses the southeast corner of the landfill (See Figure 2-3). At the point where the stream crosses the landfill it enters a 36-inch diameter corrugated metal pipe (CMP) beginning about 40 feet east of PKC-MW1. The culvert is about 600 feet long and bisects the southeast corner of the landfill before exiting south of PKC-MW3. The stream usually goes dry in the late summer months (Applied Geotechnology Inc. 1992). The invert elevation at the outlet is at about 309.2 feet msl; the invert at the inlet is roughly 6 to 7 feet higher. The stream bed elevations near the north and south ends of the culvert are at about 315 and 308 feet msl, respectively (AGI 1994b). These elevations indicate that the average slope of the culvert between the north and south ends is approximately 1.0 to 1.17 percent.

Significant flows and flooding have occurred in the stream during heavy winter rainfall events, resulting in periodic flooding of the Southeast Depression. Recent flooding events are discussed in Section 4.3.

2.4 SMALL SURFACE DEPRESSIONS/PONDED AREAS

The surface of the landfill has numerous small depressions 0.5 to 2 feet deep that likely resulted from differential settlement of the underlying refuse. Most of the depressions are found on the west side of the landfill platform. Water temporarily ponds in these depressions during prolonged rainy periods (Figure 2-3). Depressions on the north, south and eastern sides of the landfill cover are typically shallow (less than 1 foot deep) and water ponded in these depressions appear to infiltrate soon after rainy weather stops. The depressions on the west side of the landfill platform tend to be larger (up to 40 feet in size and up to two feet deep) and hold water for longer periods of time. The longer duration appears to be due to a dense, low-permeability layer just below the landfill surface in this area (see Section 4.1). Two large ponded areas also were observed southwest of the landfill, south of PKC-MW2. This area was excavated in 1970 and the soil was used to regrade depressions which developed on the landfill (W. Kinney 1996).

Significant water ponding was observed along the east perimeter road and in ditches along the north perimeter road. These areas are affected by precipitation, and also are located in areas where seepage from the landfill has been observed.

2.5 SURFACE SEEPS

Seepage along the landfill perimeter was observed during the current field investigations and was investigated during previous studies at the landfill site. These investigations are discussed below.

2.5.1 Previous Investigations

In 1984 and 1985, the Seattle-King County Department of Public Health (1985) conducted a survey of 23 abandoned landfills in King County, including the Puyallup/Kit Corner Landfill site, to determine if any public health problems existed at the sites. A surface water evaluation was included in the study performed at the Puyallup/Kit Corner Landfill site. Two surface water samples were tested at the site and checked for leachate indicator parameters including pH, temperature, dissolved oxygen, conductivity and turbidity. One water sample was taken from the drainage conduit on the west side of the landfill which drains into a ditch along I-5 (the West Stream). A discoloration characteristic of leachate was observed in the water sample; however, testing did not indicate a leachate problem, although a pH of 5.3 was measured. The second sample was taken in the East Stream near the inlet to the CMP culvert that passes through the landfill. Testing indicated no leachate contamination in the East Stream at that time.

The Seattle-King County Department of Public Health (1986) conducted a toxicity/hazard assessment at the site in 1986. The Puyallup/Kit Corner Landfill was among six landfill sites that were further investigated to identify potential hazardous conditions to human health or safety, which included an evaluation of surface waters at the site. Three water samples (two in the East Stream and one in pool of water near EW1) and one discrete soil sample in the stained ditch on the north end of the landfill were tested. Samples were analyzed for U.S. Environmental Protection Agency (EPA) Hazardous Substance List organic chemicals, EPA Priority Pollutant metals and total cyanide, and characterized using Beckman's Microtox bioassay procedure. The analyses did not reveal any priority pollutant concentrations of concern and concluded that the site surface presents no public health risk beyond background levels.

In 1992, Converse Consultants Northwest performed an assessment of surface water for the Alder Glen Property located east of the landfill (CCN 1992). Three surface water samples were tested, two from the East Stream and one from a drainage swale adjacent to Lot 38. The samples were tested for analysis of priority pollutant organics and metals and Minimal Functional Standards for Solid Waste Handling monitoring requirements listed in WAC 173-304-490(2)(c). Converse Consultants Northwest concluded that "Water quality results do not indicate leachate-impacted surface water at the sample locations" (CCN 1992, page 8).

On April 27, 1992, the King County Solid Waste Division sampled and tested water which appeared to be a landfill seep from the north end of the landfill at the request of the Seattle-King County Department of Public Health. The sample was collected from the orange-stained area after sufficient rainfall produced enough water in the area for an adequate sample. Typical landfill leachate indicator parameters were found at relatively low concentrations, except manganese. Lead (less than 30 mg/L) was the only parameter possibly exceeding the sample hardness concentration. The King County Solid Waste Division did not find evidence of surface water impacts at that particular location based on the sample test results (King County Solid Waste Division 1992).

Surface water samples were collected and tested by AGI Technologies in 1993 from the East Stream and from a swale near the northeast corner of the landfill (AGI 1994b). The East Stream water samples were collected near the inlet and outlet of the CMP culvert that passes through the landfill, and the remaining sample was collected upstream of the landfill as a background sample. The three water samples collected from the East Stream and one from the northeast swale were

tested for volatile organic compounds, total dissolved oxygen, total suspended metals, chloride, sulfate, nitrate/nitrite and ammonia, chemical oxygen demand, and total organic carbon. In addition to analytical testing, the water samples were field screened for pH, temperature, and conductivity. AGI reported that all analytical test results "indicate the landfill is not impacting surface water quality in the East Stream" (AGI 1994b, page 6-1). In addition, several seeps around the landfill were also tested for conductivity. Results indicated conductivity of the sampled seepage water ranging from 20 to 450 $\mu\text{mho/cm}$.

2.5.2 Current Investigation

Seepage emanating from the landfill cover was observed at a number of locations around the landfill perimeter during the field investigation program (March and April 1996). On May 10, 1996, a survey of these seeps was performed and conductivity measurements were recorded at selected locations where pools of water were encountered. To help distinguish seepage areas from moist areas caused by rainfall, the survey was conducted after several days of dry weather, preceded by several days of only light precipitation. Orange to reddish-orange staining and/or an iridescent sheen were typically observed at the seepage locations. Generally, the seeps were observed on the inside of the perimeter road and at the toe of the landfill slope. The areas where seepage and staining were observed and the results of the conductivity measurements are shown on Figure 2-3.

The most significant area of seepage was found on the east side of the landfill along the perimeter road. Consistent seeps were observed from just north of PKC-MW1 to PKC-GP21, with the heaviest seepage occurring between PKC-MW1 and PKC-MW5. Orange and reddish-orange staining and the iridescent sheen were observed in pools of water, but mostly on the surface of the soil and ground cover. The ground surface was very moist or had ponded water along the entire length of this area. Conductivity measurements made in the pools of water ranged between 97 and 445 $\mu\text{mho/cm}$. These levels of specific conductance are extremely low and would not be considered an indication of typical landfill leachate; however, dilution from rainfall may have affected the results.

One long seepage zone was observed on the south side of the landfill near PKC-MW3. This zone extended from about 100 feet east of PKC-MW3 to 150 feet west of PKC-MW3. The pools of water were dried up at the time of our survey so conductivity couldn't be measured, but the soil along the toe of the slope in this area was moist, and staining of the soil and ground cover along the north side of the south perimeter road indicated seeps in this area.

Orange staining indicated seepage on the west side of the landfill. The staining was observed from about 50 feet south of PKC-GP19 to about 20 feet south of PKC-MW6.

On the north side of the landfill, a zone of heavy seepage was observed near PKC-GP20. This area was about 60 feet long, although a ditch conveyed stained water east from this area. Conductivity measurements were as high as 422 $\mu\text{mho/cm}$. A pool of water farther east, near PKC-MW7, had an iridescent sheen on it and a conductivity measurement of 221 $\mu\text{mho/cm}$ was recorded.

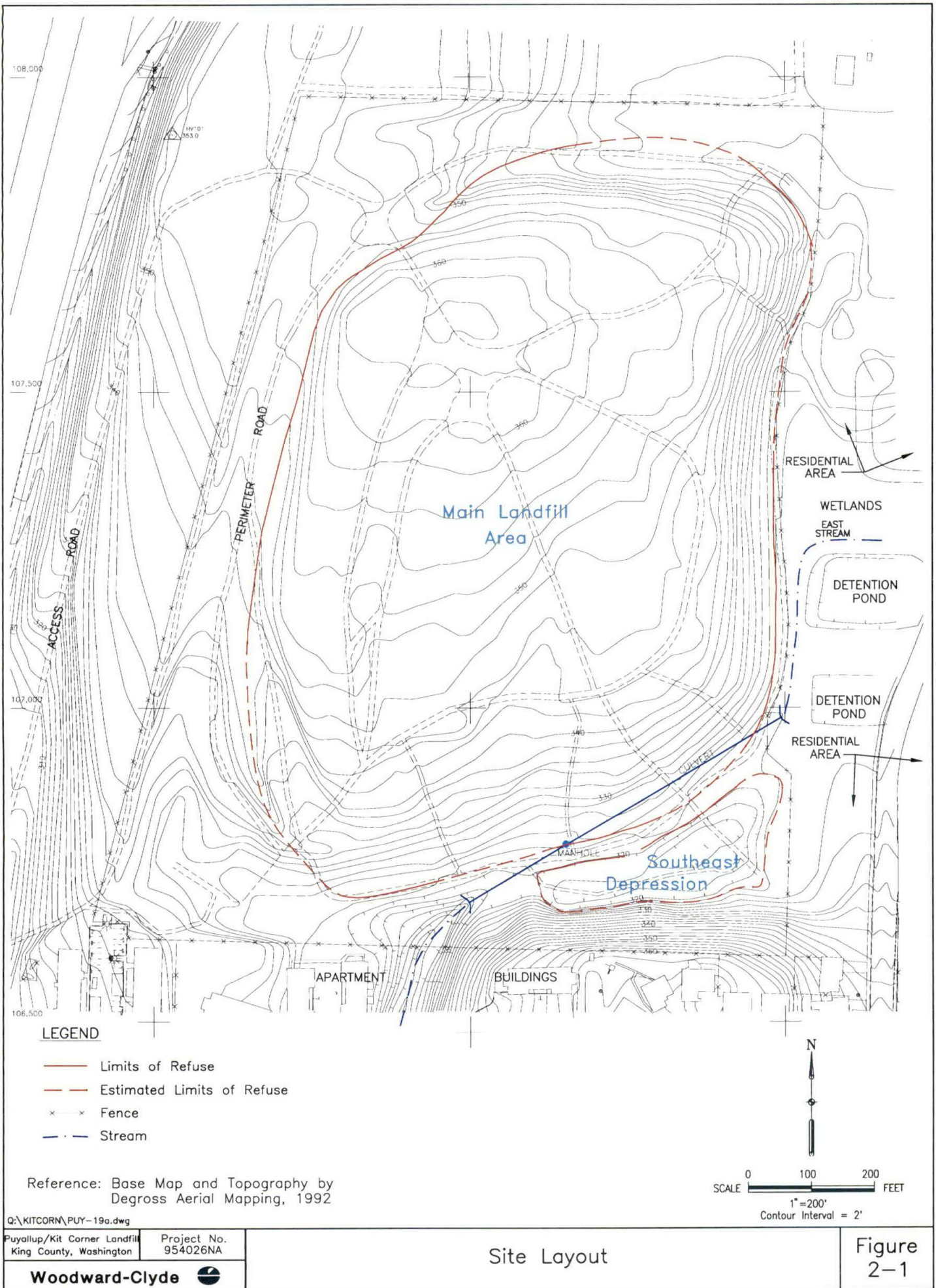
Orange staining was observed at a few spots on the landfill platform; however, the thick grasses prevented observations from being made in most areas.

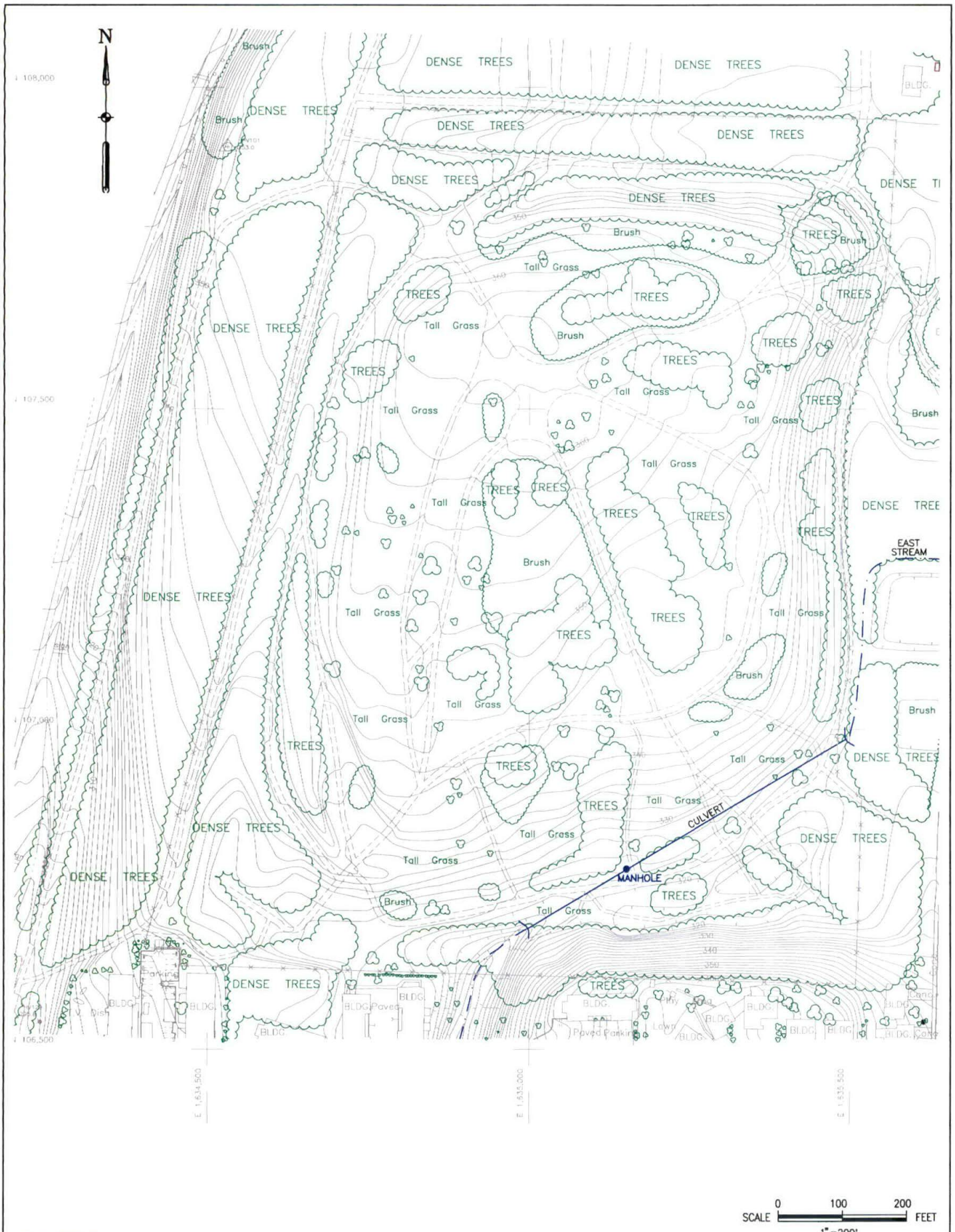
Conductivity measurements also were performed on water samples taken from the north side of the East Stream, at each end of the culvert. No staining was observed in these areas.

Conductivity measurements of 108 $\mu\text{mho/cm}$ and 117 $\mu\text{mho/cm}$ were recorded for the samples taken from the stream at the east (inlet) and west (outlet) ends of the culvert, respectively.

2.6 TENSION CRACKS

An area with extensive tension cracks was observed near the southwest corner of the landfill platform. The approximate locations of the tension cracks are shown on Figure 2-3. A depression has resulted in this area, apparently due to settlement of underlying refuse. It appears that 6 to 8 feet of settlement has occurred and long tension cracks have resulted along the east and west sides of the depression with shorter cracks to the south. The tension cracks are up to 150 feet long. Parts of the cracks have up to 12 inches of lateral offset. The shape of the depression indicates that a refuse geometry similar to the Southeast Depression may underlie this area, although Mr. Walt Kinney recalls refuse depths on the order of 10 to 15 feet in this area (W. Kinney 1996). The tension cracks were briefly described by Applied Geotechnology Inc. (1992).





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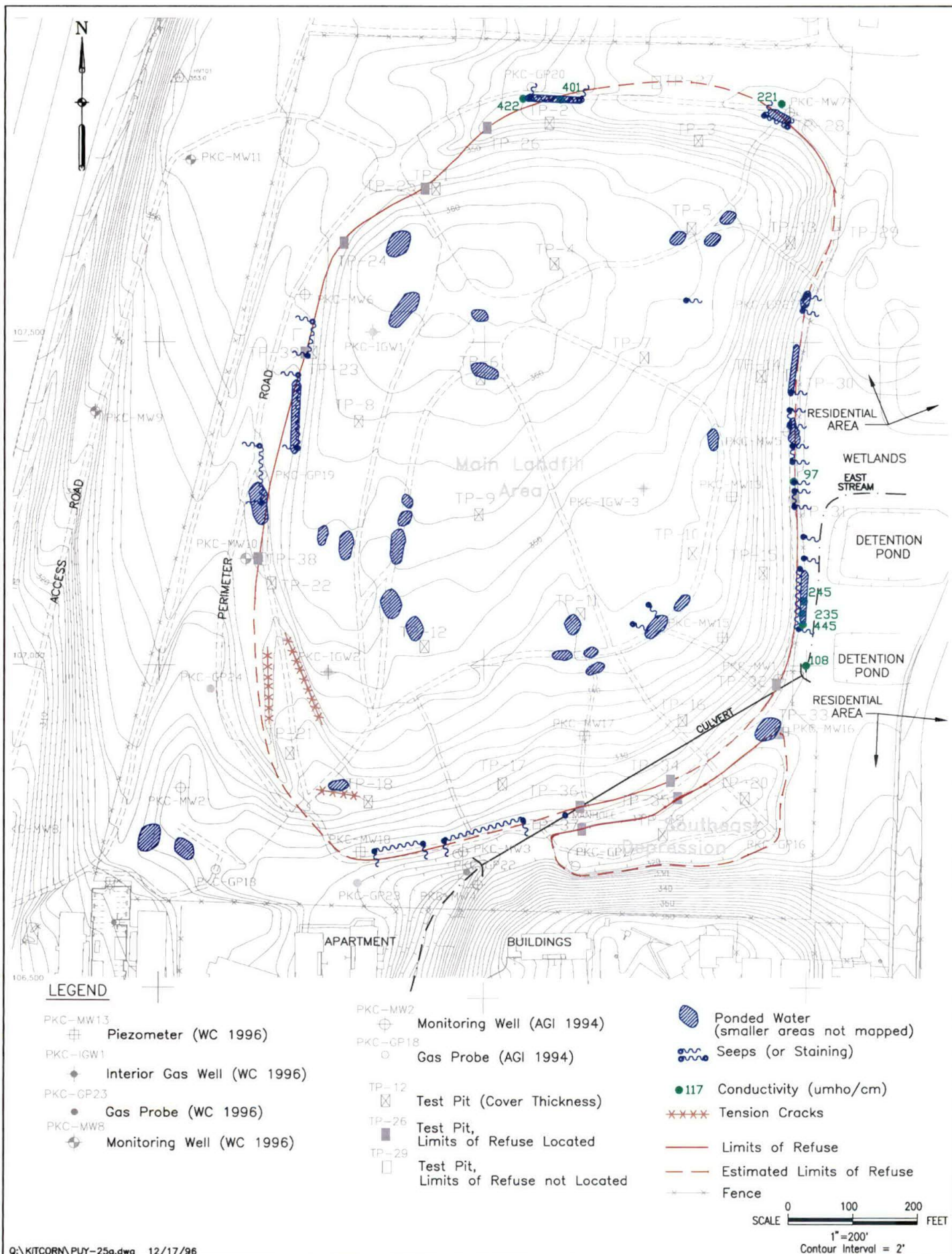
Puyallup/Kit Corner Landfill
Puyallup, Washington

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Site Plan

Figure
2-2



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Puyallup/Kit Corner Landfill
King County, Washington

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Landfill Cover Surface Water Features and Seeps

Figure
2-3

One objective of this study was to evaluate the culvert that passes through the landfill in order to determine the physical condition of the culvert and to estimate whether culvert leakage had the potential to generate significant quantities of landfill leachate. The 36-inch diameter culvert is about 600 feet long and is oriented in a west-southwest direction (Figure 2-2). The East Stream flows south along the eastern boundary of the landfill before entering the culvert about 40 feet east of PKC-MW1 and then discharging between PKC-MW3 and PKC-MW4. Both ends of the culvert are equipped with steel trash racks. On May 8, 1996, a geotechnical engineer from Woodward-Clyde visually evaluated the culvert, by viewing the interior at both the inlet and outlet, as well as inspecting the culvert at the manhole located about 180 feet from the outlet. The entire length of the culvert was not inspected.

The creek was about 12 inches deep just inside the east end of the pipe at the time of the observations. Both ends of the culvert appeared to be in very good condition and no debris was observed inside the culvert within visual range of the ends (about 50 to 75 feet). No rust, holes, or other signs of corrosion were observed at either end of the pipe. In addition, the pipe did not show any signs of deformation along the interior as far as was observed. The outer 3 feet at the outlet of the pipe did have several 1/4-inch diameter holes, which appeared to be punctures by a sharp object rather than corrosion. The holes were seen on the sides and top of the exposed end of the outlet and none were observed below the water surface. The holes likely occurred during or after installation of the culvert. No indications of unusual odors or landfill gas were noticed at the ends of the culvert or at the manhole during the observations.

The inside of the manhole was examined through the grate of the cover. The 2-foot diameter cover was corroded to the rim of the manhole and could not be removed without the risk of damaging the manhole itself. The manhole appears to be constructed out of brick and concrete mortar. The depth to the bottom of the manhole is about 11 feet. The top of the east inlet pipe is about 6.7 feet below the grate, which places the bottom of the pipe about 9.7 feet below the cover. The upper 5 feet of the manhole is about 2 feet in diameter and the lower 6 feet is 3.5 to 4 feet in diameter. The mortar between the bricks appears to be deteriorating or was poorly placed when the manhole was constructed. Several areas between bricks appeared to have no mortar and water likely can leak through the manhole in these areas. The bottom 12 to 18 inches of the manhole, below the CMP pipe ends, appears to be in native soil, although it was difficult to observe because of the flowing water.

This indicates about 1.3 feet of water swirls around in the bottom of the manhole before exiting. Both pipes appeared to be in good condition. The inlet pipe did have significant discoloration, but this appears to be due to rusting of the iron manhole step above the east inlet pipe which drips down and accumulates on top of the pipe. The west pipe appears to have much more rust and corrosion but the pipe did not appear to have any holes.

The 1986 report by the Seattle-King County Department of Public Health discussed a different manhole which collapsed just northeast of the outlet. The collapse resulted in a hole about 8 to 10 feet in diameter and about 10 feet deep. The stream was flowing at the bottom and fill strata was readily observed on the sides of the hole. During our site observations, this area had been repaired and appears to have been reconstructed by adding a new CMP pipe section to the culvert and placing small riprap over the pipe as backfill, east to the perimeter access road. No documents or discussions related to this work were available. It is also possible that this collapsed area may have been a collapsed section of the CMP culvert due to corrosion that may

have looked like a manhole. Observations made on the landfill surface above the alignment of the CMP culvert indicate localized settlement up to a few feet deep. This may indicate settlement of pipe backfill soils and/or corrosion of the pipe, piping of soil through the corroded areas, and subsequent settlement. This observation, in conjunction with repairs made to the outlet end of the culvert and possible rusting/corrosion at the manhole, suggests that the culvert may be in poor condition along some of the buried section. The ends of the culvert may be relatively new or less impacted to corrosive elements due to their position.

The results of our investigation indicate that the culvert was likely installed prior to placement of refuse in that area. The culvert is likely completely buried in native or fill soils and backfilled with clean soil. Refuse placed after installation of the culvert may be above or just north of the culvert alignment. The King County Solid Waste Division also confirmed that the culvert was installed in native soils in 1965 as the landfill operations progressed southward (W. Kinney 1996, AGI 1994b). Although the culvert appears to be in fair condition, leakage is expected at the existing manhole. This leakage, and possible other leakage from deteriorated sections of pipe, is considered significant when compared to the overall site water balance as further discussed in Section 7.

4.1 BACKHOE TEST PITS

The cover of the landfill was evaluated by excavating test pits at selected locations across the surface and collecting soil samples to be tested for grain size distribution. Thickness and grain size distribution of the cover soils were measured to characterize the site for evaluating the cover performance, for performing the Hydrologic Evaluation of Landfill Performance (HELP) modeling, and for the water balance analysis. In addition, test pits were excavated to determine the extent of refuse along sections of the landfill perimeter. The extent of refuse will be used during the design phase of the LFG system expansion and when evaluating the CMP culvert and Southeast Depression.

4.1.1 Cover Thickness

Twenty-three backhoe test pit locations (TP-1 through TP-23) were excavated to characterize the thickness and material types across the landfill surface. The test pits were selected to obtain a representative number of locations along the sideslopes, top platform, and in the Southeast Depression. Test pits were located in the field using nearby landforms and features such as existing well locations and access roads. Their locations are shown on Figure 4-1.

The test pits were excavated on March 11 and 12, 1996, under the direction of a geotechnical engineer or geologist from Woodward-Clyde. The test pits were excavated through the cover soils and about one foot into the refuse. The thickness of the cover soils varied from 1 foot near the west side of the landfill to about 8.5 feet near the middle of the landfill. The west and north sides of the landfill had the thinnest cover soils, varying from 1 to 3 feet thick. The cover along the east and northeast slopes varied from 4 to 6 feet thick, and the south slope had a relatively uniform 4-foot thickness. The thickness at the north end of the top platform ranged from 2.5 to 3.5 feet. The south end of the top platform was generally thicker than the north end, with the cover typically ranging from 3.5 to 6 feet thick, excluding Test Pit TP-9, which was 8.5 feet thick. The two test pits excavated in the Southeast Depression indicated that the cover was 1.5 and 3.5 feet thick. Field observations of the test pit excavations are summarized in Appendix A.

Cover soils were generally composed of poorly graded sand with silt and gravel, silty sand with gravel, or silty gravel with sand. Gravel and sand portions each generally made up about 40 to 50 percent of the sample, while the silt portion typically ranged from 5 to 20 percent. The gravel were typically subrounded, and some cobbles up to about 12 inches in diameter were observed. Laboratory tests consisting of grain size determinations were conducted on 11 composite samples obtained from the cover soils. The test is described and the grain size curves are presented in Appendix D.

The cover soils were generally easy to excavate, except for a very dense gray silty gravel with sand to silty sand, encountered on the south half of the top platform (test pits TP-10, TP-11, TP-12, and TP-22). This hard gray layer was typically about 1 foot thick and was generally encountered just above the refuse materials. This layer had the appearance of recompacted glacial till. Soil excavated from the Southeast Depression was used as cover soil for the refuse as the landfill progressed southward (W. Kinney 1996). Glacial till soils removed from the Southeast Depression were likely recompacted on the south end on the top platform, resulting in the dense, gray, till-like layer described above.

While excavating the test pits, a portable gas detector was used to monitor landfill gas levels by placing the instrument into the excavation near the top of the test pit. The primary purpose was to monitor for safety of the field personnel during exploration activities. Significant landfill gas levels, 22 and 40+ percent lower explosive limit (LEL), were recorded in test pits TP-5 and TP-7, respectively. Both test pits are located near the northeast corner of the landfill. Landfill gas was not detected in any of the other test pits. Landfill gas may have been present in other test pits, but was not detected when monitoring the air space for safety purposes. The measurements depended on the level of gas present, wind direction, and depth of the test pit. At no time did field personnel enter the test pits.

The refuse materials below the cover soils were observed and moisture content and degree of decomposition were visually estimated and recorded. Newspaper was generally the best indicator of the state of decomposition and amount of moisture. In general, refuse was composed of typical household waste materials, including plastic containers, plastic bags, newspaper, cardboard, clothing articles, glass, metal, wire, wood, and yard waste. Refuse materials encountered in the test pits are described in more detail in Appendix A.

Seepage within the cover soils was observed in several test pits. Seeps were generally observed on the central and south half of the top platform where the dense gray layer was encountered; however, seeps in test pits TP-7 and TP-17 were also observed. The seeps appear to be short-term features related to perched water from recent heavy precipitation and likely go dry once the rains stop for an extended period of time. This was evident in Test Pit TP-12, where significant seepage was observed on March 11 at a depth of 2 feet, while no seepage was observed in a hand-dug pit at the same location on May 8, 1996.

4.1.2 Refuse Limits

The extent of refuse along portions of the landfill perimeter were determined (1) for the design of the perimeter LFG collection system, and (2) to evaluate the relationship of the refuse with the CMP culvert and the north side of the Southeast Depression. Sixteen test pits (TP-24 through TP-39) were excavated to determine the limits of refuse. Refer to Figure 4-1 for test pit locations and estimated limits of refuse. The test pits were excavated on October 14 and 15, 1996, under the direction of a geologist from Woodward-Clyde. The purpose of these test pits was solely to determine the extent of refuse. No samples were obtained and no detailed descriptions of the refuse or soil types were made.

Landfill Perimeter

Test pits TP-24 through TP-32, TP-38, and TP-39 were excavated to aid in design of the perimeter LFG header pipe and condensate lines. Establishing the limits of refuse was important to design a collection system which would be installed beyond the refuse thereby reducing construction costs and settlement and long-term maintenance problems. The refuse limits identified in these test pits all occurred within the perimeter access road, except TP-27, TP-29, and TP-30. The limits of refuse was not determined at TP-27 because of difficulty in excavating the refuse into the wooded area north of the perimeter road. The limits of refuse on the east side of the landfill, south of about PKC-MW5, appear to terminate near the west side of the perimeter access road. North of PKC-MW5, the refuse limits were not determined in the test pits and

appear to extend east to or beyond the fence line approximately between test pits TP-29 and TP-30. However, according to Mr. John Komorita of the King County Solid Waste Division, King County personnel performed test explorations at the time the fence line was installed and that all refuse is within the fence line (J. Komorita 1996). On the west side of the landfill, north of the LFG treatment facility, the refuse appears to be east of PKC-MW10 and PKC-MW6.

Southeast Depression and CMP Culvert

Test pits TP-33 through TP-37 were excavated to determine the geometry of the refuse relative to the north side of the Southeast Depression and the CMP culvert. Test pit TP-32 was also used for this purpose. Test pits TP-32, TP-34, and TP-36 were excavated directly over the CMP culvert along the south edge of the main landfill slope. These test pits were excavated to determine if refuse was in contact or overlying the culvert. Based on the test pit results, it appears that the culvert was placed in native or fill soils and backfilled with granular soil. In all three test pits the bottom of the refuse was encountered above the culvert. In TP-36, the top of the culvert was estimated at about 8 feet deep and refuse was encountered between 2.5 and 4 feet below the ground surface (bgs). Refuse in TP-32 was encountered from 2.5 to 3 feet deep, while in TP-34 the refuse was encountered at about 4 feet deep and only about 0.5 feet thick. The culvert was not encountered in any of the test pits to avoid potential damage, since the bottom of the refuse appeared to be well above the crown of the pipe. Test pits TP-33, TP-35, and TP-37 were excavated along the north side of the Southeast Depression. The north end of the refuse limits were established in all three test pits. The northern extent of refuse was generally close to the top of the slope break, and refuse thickness increased rapidly to the south except in TP-37, in which only a thin stringer of refuse was found. Refuse was encountered 0.5, 2 and 1 foot bgs in test pits TP-33, TP-35, and TP-37, respectively.

All six test pits along this area encountered the edge of refuse for the main landfill or the Southeast Depression. The south perimeter access road appears to be underlain by fill soil with only minor and sporadic refuse mixed in. Results from the test pits also suggest that thin stringers of refuse may underlie the road in some areas, but in general the two refuse bodies appear to be separate from each other.

4.2 HELP MODEL

To aid in evaluating the water balance, a hydrologic evaluation of landfill performance (HELP) model was performed for the landfill cover. The results of the cover exploration program (including thickness of the cover materials, grain size distribution, and depth of vegetation) were used in the model to characterize the site. The detailed results of the analyses are presented in Appendix B and summarized below.

As shown on Figure B-1 in Appendix B, the landfill surface was divided into six sub-areas based on the slope of the landfill surface, landfill cover permeability, thickness of the cover, and vegetation patterns. To evaluate the permeability of the cover soils, grain size analysis were performed on test pit samples. The results of grain size analysis (see Appendix D) were evaluated using the program MVAKSF developed by Vukovic and Soro (1992) to estimate the permeability of the soil layers. The MVAKSF program calculates the hydraulic conductivity from grain size distribution using different empirical formulas proposed by ten researchers. Appendix B describes

the empirical formulas used and the MVAKSF program in more detail, and Table B-1 shows the results of the permeability analysis for the test pit samples. Based on their investigations, Vukovic and Soro suggest that the formulae proposed by Kruegerr and Zamarinu provide results which are most representative of field conditions. The average permeability of the sandy layer (layer 2) obtained from Kruegerr and Zamarinu's formulas were $1.41\text{E-}02$ cm/sec and $6.38\text{E-}03$ cm/sec, respectively (Vukovic and Soro 1992). The corresponding permeability estimates for the silty gravel layer (layer 3) were $3.78\text{E-}03$ cm/sec and $1.17\text{E-}03$ cm/sec.

A typical topsoil material with a permeability of $7.2\text{E-}04$ cm/sec (soil type #6 in the HELP model database) was assigned to the vegetative top soil layer (layer 1). A permeability of $5.8\text{E-}03$ cm/sec (soil type #2 in the HELP model database) was assigned to layer 2, as it represented permeability within the range obtained from Kruegerr's and Zamarinu's formulas. Field observations indicated that water ponded on top of the silty gravel layer, suggesting that the permeability of layer 3 was lower than those estimated by the MVAKSF program. Therefore, a soil type #9 in the HELP model database, representing a permeability of $1.9\text{E-}04$ cm/sec, was assigned to layer 3.

The results of the HELP analyses show no significant variation of results obtained from the HELP models between the six different sub-areas (Table B-3 in Appendix B). The results suggest that the presence of dense vegetation at the landfill and the coarse grain size distribution of the cover soils controls the infiltration rates by reducing runoff and increasing evapotranspiration. A weighted average based on area magnitudes was used to obtain the average infiltration rates for the entire landfill. The average percentage of precipitation infiltrating through the landfill cover was 58.9 percent (23.0 inches/year). This represents an infiltration of approximately 83,000 cubic feet per acre per year, or a total infiltration of 1,600,000 cubic feet (12 million gallons) per year for the entire landfill area.

4.3 SOUTHEAST DEPRESSION FLOODING

During our field exploration investigations at the site, a very heavy rainfall event occurred (reportedly about 2 inches in 24 hours) on April 23, 1996. A Woodward-Clyde geologist observed that the entire southeast depression was filled with water on April 24, 1996. The ponded area was reportedly about 5 feet deep and covered several of the extraction well heads. Observations the following day revealed that no water was ponded at this location and therefore had completely infiltrated into the refuse in one day. Later discussions with Ms. Anna Leake of King County Solid Waste Division also revealed that flooding of this area was suspected but never observed (A. Leake 1996). Ms. Leake did note that a similar flood event occurred between January 8 and 15, 1996. Ms. Leake mentioned that the event observed by the Woodward-Clyde geologist flooded about half way up the control panel located near the east end of the depression near extraction wells EW12S and EW12D. The control panel apparently shorted out and the condensate pump located bgs also became inoperative due to the flooding. The chain link fence around the control panel had weeds and branches several feet high tangled in the fencing. In addition, mud was present about halfway up the control panel. The bottom of the control panel is about 51 inches above the ground. The water depth in this area would have been about 57 inches deep (almost 5 feet deep).

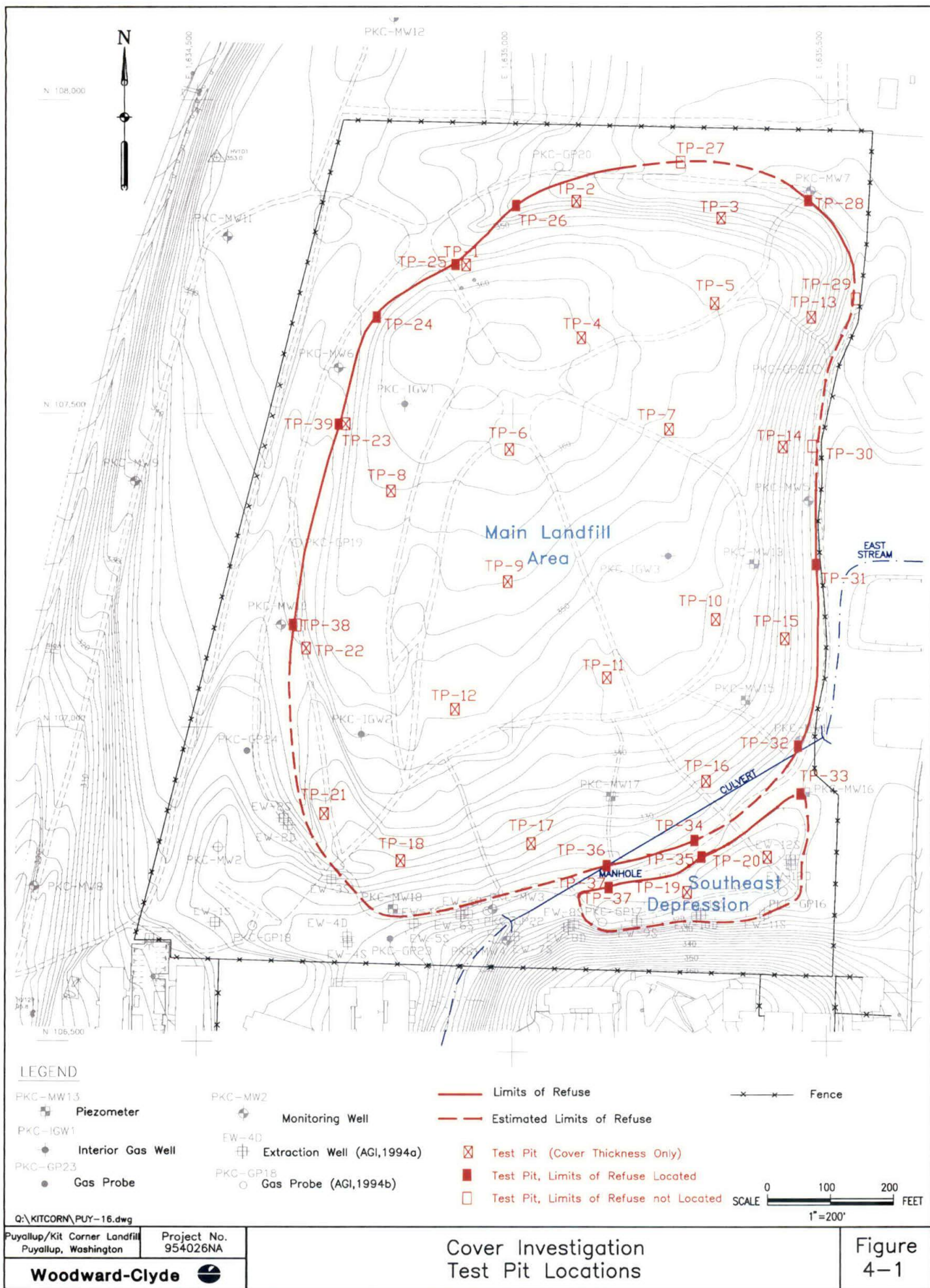
A section of the slope north of the control panel (approximately between EW12S and PKC-MW16) has eroded, exposing soil and gravel. Test pit TP-33, excavated in the eroded area, only had about 0.5 feet of cover over the refuse. This is the area where floodwaters enter the Southeast Depression after overtopping the inlet of the culvert. The access road on the west end of the depression is about 3.5 feet above the adjacent ground surface and about 4.5 to 5 feet above the ground surface at the control panel. The access road is covered with gravel fill and the west side has been protected with small riprap (up to 12 inches). The riprap extends from the west edge of the access road to the outlet of the culvert. Near the east end of the culvert, a significant buildup of sticks and other debris was found accumulated at the bottom of the fence. Other flood debris was seen south of the culvert within the trees.

Based on our observations and our discussions with Ms. Leake, it appears that the Southeast Depression flooded at least twice during January through April 1996. Flooding probably also occurred on February 8, 1996, during the heavy rains that flooded many rivers and streams in western Washington. The flooding may be due to inadequate size of the culvert, debris buildup on the trash rack, or downstream backwater effects, which flood the exit to the culvert. It appears that debris buildup within the trash rack may not be the main problem, but rather inadequate sizing and backwater effects from undersized culverts downstream may be the primary problems. Our observations after the April flood and Ms. Leake's observations after the January flood did not reveal any debris buildup at the inlet of the culvert. Backwater effects from the creek below the culvert may also be a significant problem during peak flow events. Discussions with King County Surface Water Management suggests that the culvert is likely undersized and that all culverts along this reach of the East Stream should be at least 48 inches in diameter (D. Althausen 1996). We understand that King County Solid Waste Division plans to relocate the control panel to higher ground so that it will not be affected by future flooding. According to King County Solid Waste Division, past flooding downstream of the landfill culvert caused backwater to flood as high as the top of the fence at the property line (W. Kinney 1996). This sort of flooding downstream of the culvert would inundate the outlet of the culvert.

Flood water overtops the east inlet pipe and appears to flow to the southwest through the fence near the gate across from PKC-MW1. The fence acts like a sieve and strains out the sticks and larger debris. Water flows southward about 20 feet west of PKC-MW16 before dumping into the Southeast Depression. The depression fills up with water until it overtops the west access road (to PKC-MW4), which acts as a small levee. The flooded water then reenters the stream by flowing across the small riprap and dumping into the creek at the outlet of the pipe. This would explain the fresh eroded area on the north slope of the depression near PKC-MW16 and the need to protect the west access road and the area above the culvert with gravel and small riprap. The riprap may also have been placed when the old collapsed manhole/pipe was repaired prior to this investigation.

The capacity of the depression is about 85,000 cubic feet (640,000 gallons). When compared to the volume of surface infiltration from precipitation through the entire 20-acre landfill, this represents an additional 5 percent of water infiltrating into the landfill per single flood event. If this occurs two to three times a year then 10 to 15 percent more water will be introduced into the refuse in addition to direct infiltration through the cover soil by normal rainfall. Because of the high permeability and relative thinness (1.5 to 3.5 feet) of the sandy cover soil over the refuse in the Southeast Depression, 5 feet of water in this area could completely infiltrate into the refuse

within about 24 hours, as was observed by Woodward-Clyde personnel. Water infiltrating before and during overtopping the access road was not accounted for; therefore, these volumes should be viewed as minimum estimated volumes of additional water infiltration. Actual infiltration volumes may be higher.



Three interior gas wells (PKC-IGW1 to PKC-IGW3) were installed in the refuse between March 15 and 19, 1996, to evaluate leachate conditions. The bottom of the landfill was identified to establish the thickness of refuse in the borings and to determine the soil materials below the landfill. The interior gas well borings were drilled using 13½-inch diameter hollow stem augers, and the well compilations consisted of 4-inch, SDR 11, high density polyethylene (HDPE) casing with ¼-inch machine slotted screened sections. In addition, as part of the shallow groundwater study, three piezometers (designated PKC-MW13, PKC-MW15, and PKC-MW17) were installed in refuse and PKC-MW18 also encountered refuse during drilling. The piezometers were installed between March 11 and 14, 1996. The borings were drilled using 8.5-inch outside diameter hollow stem augers and the piezometers consisted of 2-inch, schedule 40, polyvinyl chloride (PVC) casings and factory slotted (0.01 inch), 10-foot screen sections. Prior to constructing the wells, a bentonite seal was placed in the bottom of the borings up to approximately the bottom of the refuse.

The locations of the interior gas wells and shallow piezometers are shown on Figure 5-1. Summary boring logs with the completions are presented in Appendix C. Details of the drilling methods and monitoring completions also are presented in Appendix C.

5.1 SUBSURFACE CONDITIONS

The borings that penetrated refuse encountered three general material types: cover soil, refuse, and native soil. Table 5-1 summarizes the depths of the borings, thickness of materials encountered, screened intervals, and depth to water at time of drilling.

The cover soil materials were similar to those encountered in the cover evaluation and test pit program (Section 4.0). Cover soils in borings PKC-IGW1 and PKC-IGW3 consisted of silty gravel with sand (GM), while PKC-IGW2 consisted of poorly graded sand with silt and gravel (SP-SM).

Refuse materials were generally composed of varying amounts of paper, plastic, glass, metal, wire, rubber, cloth, and wood debris, with lesser quantities of various other materials. Little soil was observed among the refuse. The refuse appeared to have low to moderate decomposition (see Appendix A) with some yard debris in Boring PKC-IGW1 being highly decomposed. Cross-section A-A' (Figure 5-2) illustrates the general geometry of the refuse based on the limited borings. The location of cross-section A-A' is shown on Figure 5-1.

Native soils were encountered below the refuse materials in all three borings. The soils generally consisted of very dense silty sand with gravel (SM) to silty gravel with sand (GM). The native soils appeared to be glacial till. Typically, the sampler could not be driven to its full depth (blow counts for the final foot were in excess of 100 blows/foot). The glacial till was not fully penetrated in any of the interior gas wells or shallow piezometer borings. Moisture content tests and grain size analyses were performed on the native soils from each boring to characterize the material types. The test results are presented in Appendix D and the grain size curves are shown on Figure D-1.

5.2 LEACHATE

Leachate (defined here as liquid in the landfill in direct contact with refuse) was encountered in PKC-IGW1, PKC-IGW3, PKC-MW13, and PKC-MW18 at the time of drilling, as shown in Table 5-1 and on Figures 5-2, 5-3, and 5-4. These appear to be actual leachate levels in the refuse rather than perched leachate levels. The depths to leachate of 13, 18, and 17 feet for PKC-IGW1, PKC-IGW3, and PKC-MW13, respectively, indicate that approximately 5, 17, and 18 feet, respectively, of leachate existed in these borings at the time of drilling. No leachate was encountered in PKC-IGW2 or PKC-MW17 at the time of drilling. Well PKC-MW15 had approximately 2 feet of wet refuse (paper saturated but no free water) at the bottom, but no measurable leachate level has been recorded. Well PKC-MW18 encountered approximately 3 feet of saturated refuse.

Long-term monitoring of the leachate levels is presented in Appendix E. The data indicate that the leachate level has dropped during the spring and summer and appears to be directly related to the wet weather season or heavy rainfall events. Therefore, highest leachate levels are likely to occur near the end of the wet season (March to April), while the lowest leachate levels may occur at the end of the dry season (September to October). Leachate levels measured on August 19, 1996, indicated that PKC-IGW1 had dropped about 1.5 feet since the time of drilling, and PKC-IGW3 and PKC-MW13 had dropped about 8 to 10 feet. Wells PKC-IGW3 and PKC-MW13 have similar leachate conditions and refuse geometries, and both exhibited very similar responses to fluctuations in leachate levels.

The bottom of the landfill appears to have a slight bowl shape underlain by glacial till soils (see Figures 5-2, 5-3, and 5-4). The native soils may minimize vertical leachate migration beneath the main landfill. Based on the leachate conditions within the landfill and the observed seeps, it appears that leachate builds up within the landfill during the winter and spring and migrates east, where it daylight along the east perimeter road. Leachate also may migrate east beyond the perimeter road and seep directly into the East Stream, based on the gradient of the leachate and elevation of the stream bed. The eastward gradient appears to occur year-round, with the highest gradient occurring in the winter. The pool of leachate that may exist in the refuse is illustrated on Figure 5-5, which represents the highest observed leachate levels. Most of the saturated refuse is on the central and east side of the landfill. The pool of leachate has a downward gradient to the east and emanates from the east landfill slope in the form of seeps.

Leachate volumes appear to be directly related to rainfall amounts and infiltration into the landfill through the cover soils. Therefore, the rainy part of the season will produce most of the leachate within the landfill and little will be generated during the drier periods. The seasonal fluctuation in leachate generation will have at least three impacts to the site: (1) the highest leachate levels will probably be during mid-winter to late spring, (2) seeps emanating from the landfill cover will be most apparent during this same period and they may not appear at the surface during the summer and fall, and (3) potential leachate entering the stream would be greatest when leachate levels are higher, but the impact may not be measurable due to dilution because the stream flow would also be the greatest during this time. Previous water quality tests (AGI 1994b) may not show measurable leachate constituents in the stream due to the time of year samples were taken, leachate levels within the landfill, and the dilution effect the stream would have on the leachate. As discussed in Section 2.5, several past seepage studies at the landfill indicated that the sampled

SECTION FIVE

Landfill Leachate Conditions

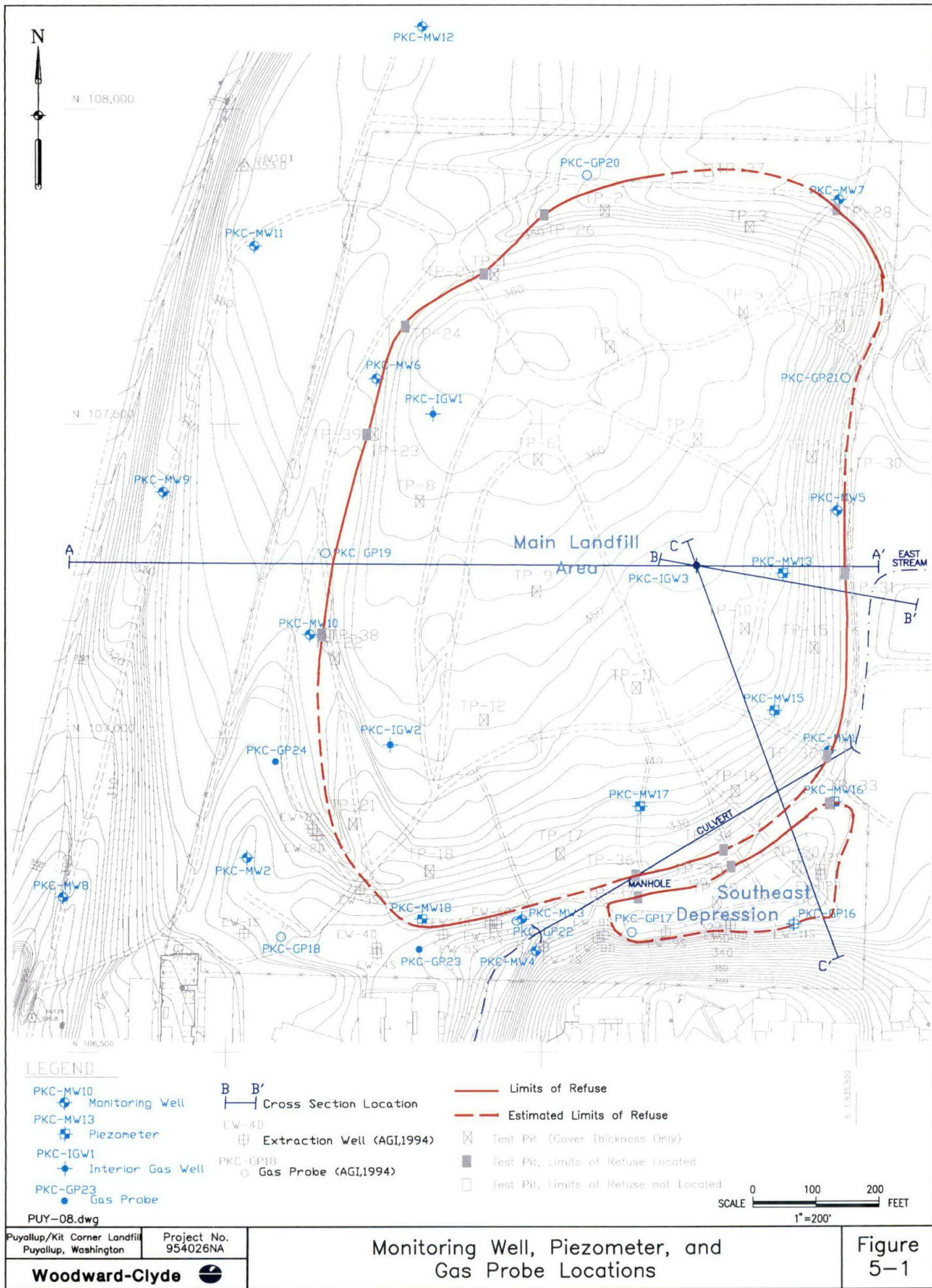
seeps presented no public health risk and analytical results did not indicate any priority pollutant concentrations of concern.

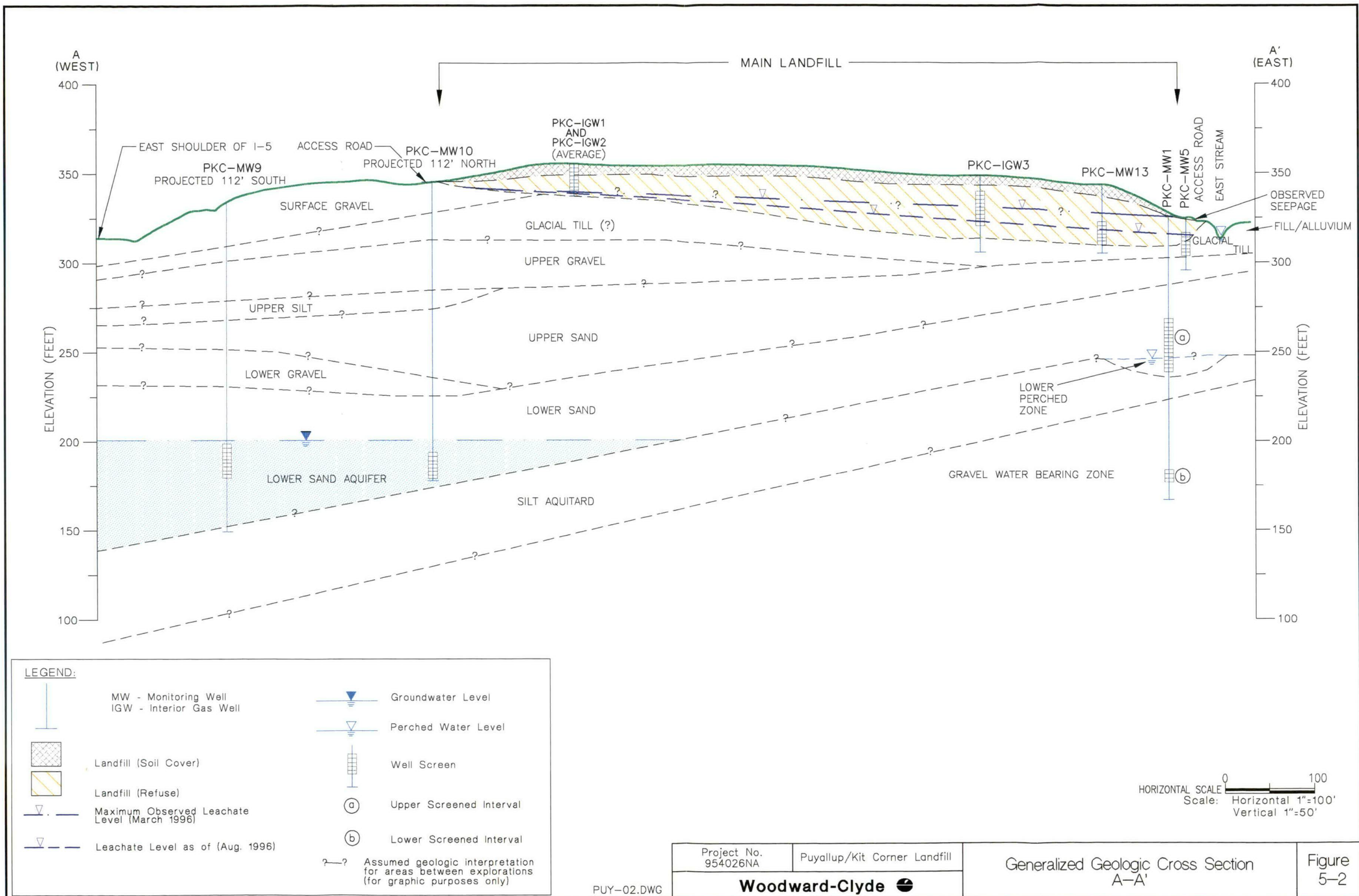
Occurrence of leachate in the Southeast Depression is discussed separately in Section 6.3.2.

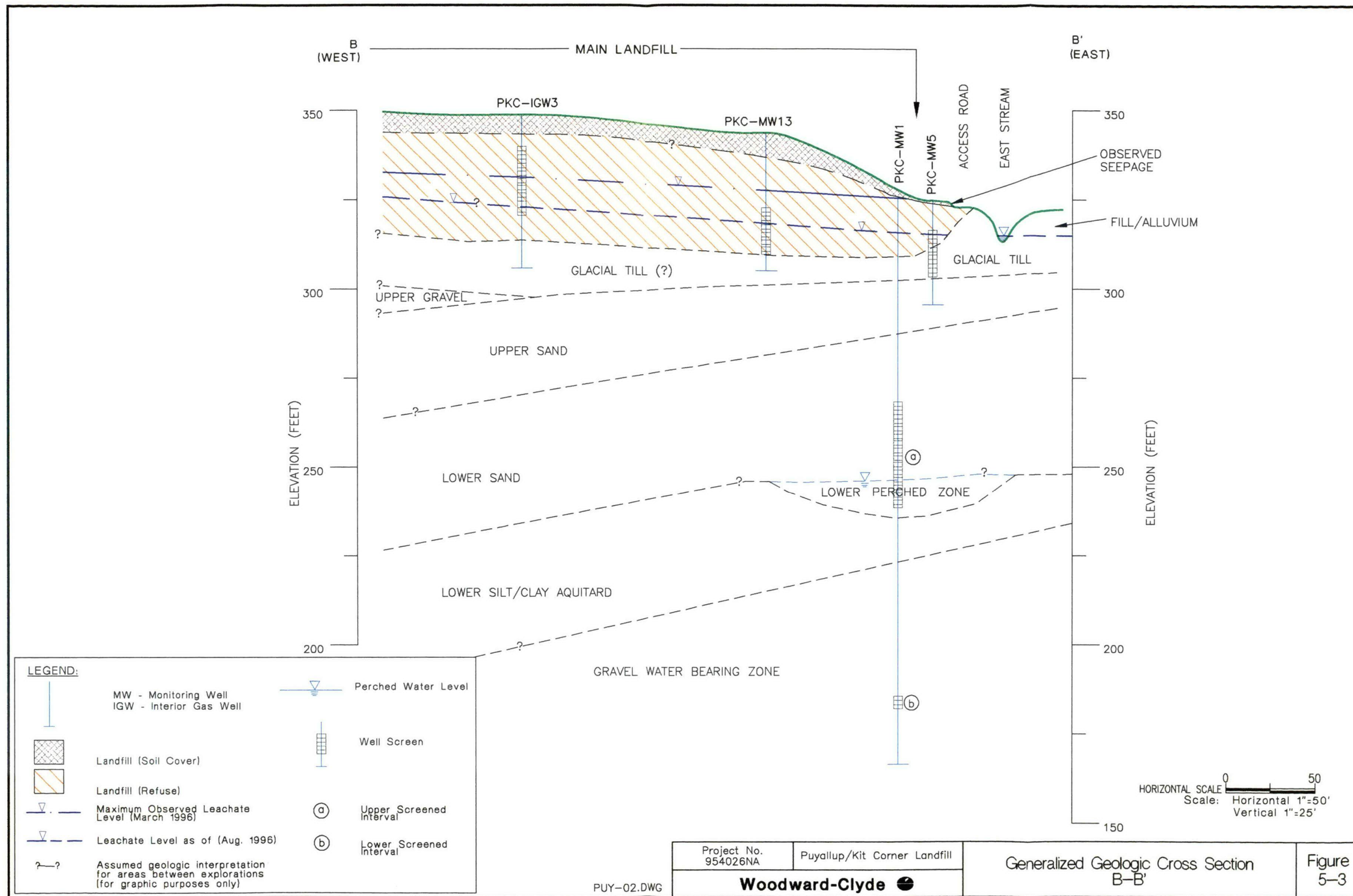
Table 5-1
SHALLOW WELL SUMMARY

BORING	TOTAL DEPTH DRILLED (ft)	COVER THICKNESS (ft)	REFUSE DEPTH (ft)	SCREENED INTERVAL (ft bgs)	DEPTH TO LEACHATE ^a (ft)
PKC-IGW1	26	3.5	3.5-18	10-18	13
PKC-IGW2	31.2	2	2-16	8.5-13.5	not encountered
PKC-IGW3	43.5	6	6-35	11.5-32	18
PKC-MW13	38.2	6.5	6.5-34	23-33	17
PKC-MW15	26	5	5-22	12-22	not encountered
PKC-MW16	26	none	none	12-22	not encountered
PKC-MW17	26.5	4	4-21.5	11-21	not encountered
PKC-MW18	26	3.8	3.8-7	13-23	3.8

Note: a. at time of drilling

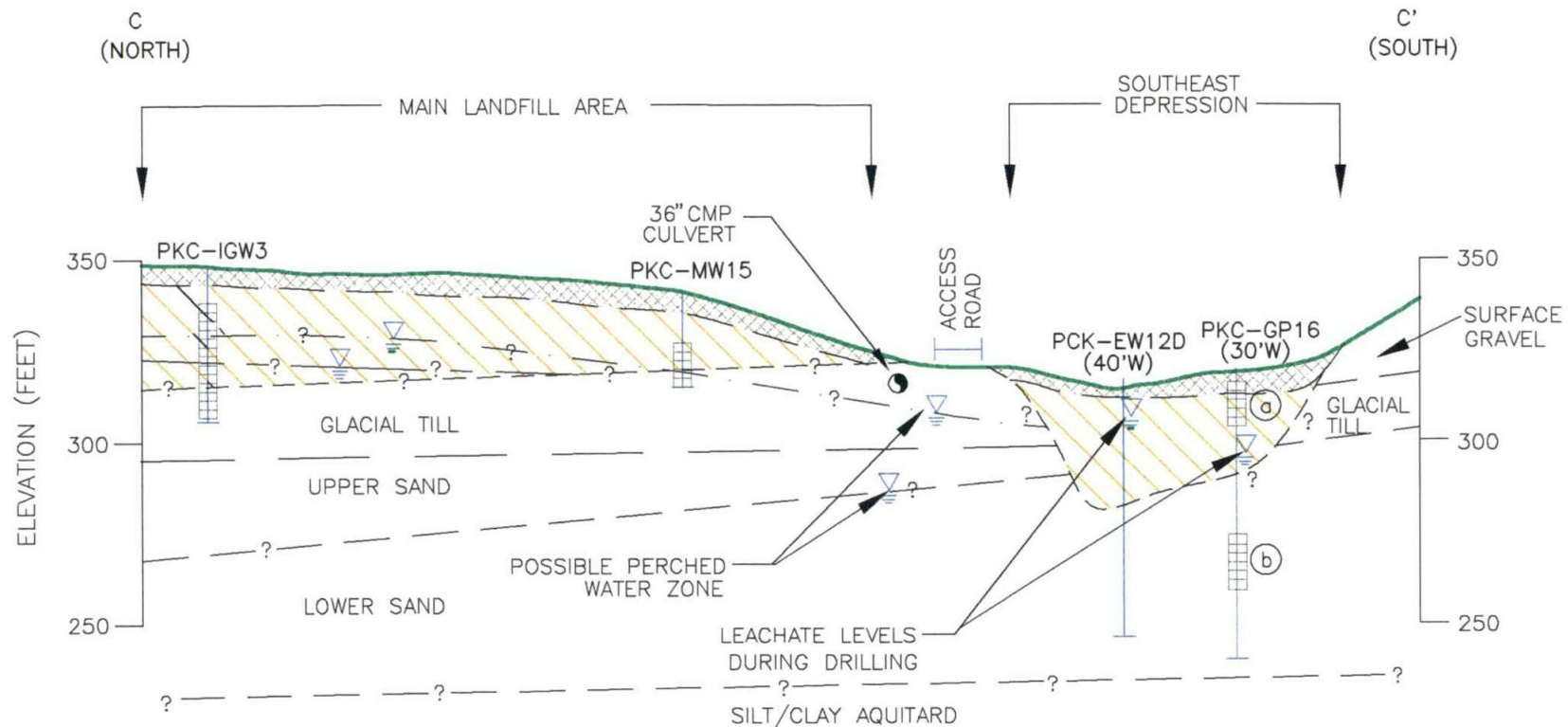






PUY-02.DWG

Project No. 954026NA	Puyallup/Kit Corner Landfill	Generalized Geologic Cross Section B-B'	Figure 5-3
Woodward-Clyde			



LEGEND:

PKC-IGW3

MW - Monitoring Well
IGW - Interior Gas Well
GP - Gas Probe
EW - Extraction Well
Bottom of Boring



Landfill (Soil Cover)



Landfill (Refuse)



Maximum Observed Leachate Level (March 1996)



Leachate Level as of August 1996



Assumed geologic interpretation for areas between explorations (for graphical purposes only)



Well Screen



Upper Screened Interval



Lower Screened Interval

PUY-02.DWG

Project No.
954026NA

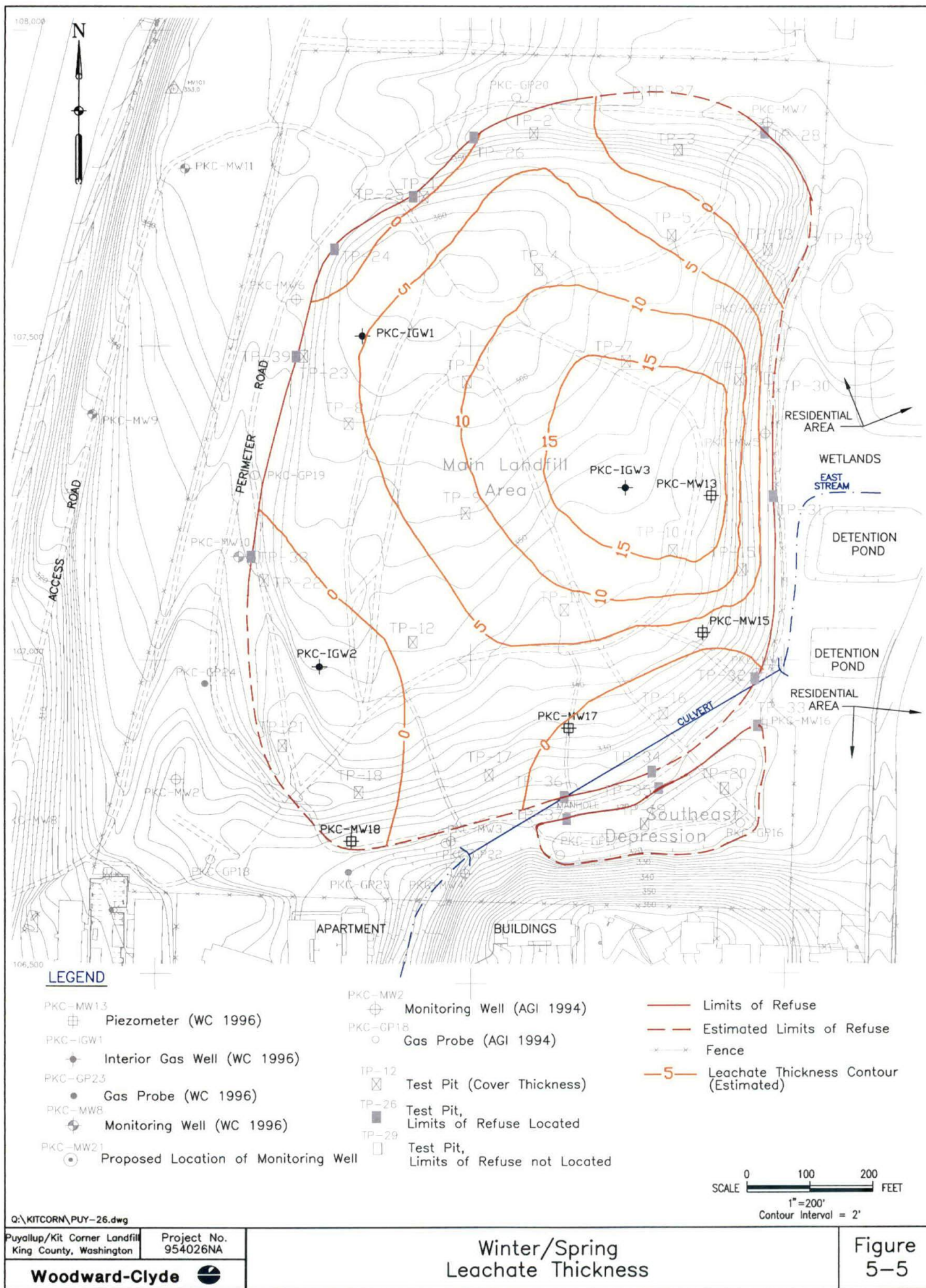
Puyallup/Kit Corner Landfill

Woodward-Clyde

HORIZONTAL SCALE 0 100 FEET
Scale: Horizontal 1"=100'
Vertical 1"=50'

Generalized Geologic Cross Section
C-C'

Figure
5-4



Shallow groundwater conditions on the east side of the landfill were assessed to determine the relationship between the leachate in the landfill, the East Stream, the detention ponds and wetland area, and possible shallow groundwater east of the landfill. This assessment included:

- Reviewing existing site hydrogeologic information
- Installing five new piezometers within and east of the landfill
- Collecting groundwater level measurements during April, May, June, August, and November 1996
- Making seepage observations
- Sampling and testing groundwater from new and existing monitoring wells
- Reviewing shallow groundwater and surface water quality data

In addition, information from the three interior gas wells was used for this assessment. Based on this information, possible interactions between leachate in the landfill and off-site surface water and shallow groundwater bodies were made. Estimates were made regarding potential leachate generation and possible leachate migrating off-site to the East Stream or shallow groundwater.

Groundwater quality data will be discussed under a separate Groundwater Summary Report, to be issued at a later date. Site hydrogeologic conditions and more detailed discussions of the deep monitoring wells will also be presented in the Groundwater Summary Report.

6.1 PIEZOMETERS INSTALLATIONS

Five piezometers (designated PKC-MW13 and PKC-MW15 to PKC-MW18) were installed at the site to aid in assessing the shallow groundwater conditions in the southeast area of the landfill and the leachate levels within the southeast side of the landfill. Three piezometers (PKC-MW13, PKC-MW15, and PKC-MW17) were installed within the landfill refuse to assess leachate conditions in conjunction with the three interior gas wells (Section 5.0). Two other shallow piezometers, PKC-MW16 and PKC-MW18, were installed along the southeast and south margins of the landfill, respectively, to assess shallow groundwater conditions within the native soils.

Well PKC-MW14 was not drilled or installed because it was to be located on King County Surface Water Management property between the two detention ponds. It was delayed for permitting reasons, and while waiting, it was determined that sufficient information was gathered from the other five piezometers to assess the shallow groundwater conditions. The locations of the shallow piezometers are shown on Figure 5-1. Summary boring logs, piezometer completions and details of the drilling methods are presented in Appendix C.

6.2 SUBSURFACE CONDITIONS

The three borings drilled within the refuse (PKC-MW13, PKC-MW15, and PKC-MW17) as well as PKC-MW18, encountered three general materials: cover soil, refuse, and native soils. Well PKC-MW16 was drilled entirely within native soils. Table 5-1 summarizes the depths of the borings, thickness of materials encountered, screened intervals, and water conditions present at the time of drilling.

Cross-section A-A' (Figure 5-2) characterizes the general geologic conditions below the site in an east-west direction. Subsurface information obtained while installing deep monitoring wells and deep gas probes at the site during the recent study by Woodward-Clyde, as well as previous borings (AGI 1994a and 1994b), also were used to generate this cross-section. The summary boring logs for the deep monitoring wells and deep gas probes installed by Woodward-Clyde are included in Appendix C and their locations are shown on Figure 5-1.

Cover soils and refuse materials encountered in these borings are similar to those encountered in the test pits (Section 4.0) and interior gas wells (Section 5.0), and therefore will not be described in this section. The native soils encountered in PKC-MW16 generally consisted of very dense, poorly graded sand with varying amounts of gravel, minor silt, and gravel layers. The native soils encountered below the refuse in the other four shallow piezometer borings generally consisted of till-like material composed of very dense, silty sand, silty sand with gravel, or poorly graded sand with silt and gravel. The upper portions of PKC-MW16 had somewhat of a till-like appearance, but most of the soils appeared to be of glacial outwash origin. A few grain-size analyses and moisture content tests were performed to characterize the soil types, and the results are presented in Appendix D.

As shown in Table 5-1, water was initially encountered in PKC-MW18, but has since gone dry (See Appendix E). Water measured in PKC-MW18 likely accumulated during drilling operations and may not be shallow groundwater. No groundwater was encountered in PKC-MW16; however, a piezometer was installed across zones which exhibited wet soil conditions in an attempt to measure shallow groundwater or perched water at that location. Leachate was only encountered in PKC-MW13. A wet zone was encountered near the bottom of the refuse in PKC-MW15; however, no standing leachate has been measured in the piezometer. No wet or saturated refuse was encountered in PKC-MW17 and the piezometer has been dry since installation. Approximately 17 feet of saturated refuse was encountered in PKC-MW13. The leachate and refuse geometry in PKC-MW13 was similar to PKC-IGW3, which was installed about 150 feet to the west.

6.3 SHALLOW HYDROGEOLOGIC CONDITIONS

The shallow groundwater conditions on the east side of the site were evaluated. This evaluation included assessing the results from the interior gas well and shallow piezometer installations, seepage survey, geometry of refuse, and proximity to the East Stream, culvert, detention ponds, and wetland area. Elevations of water levels or leachate at the time of drilling and through November 19, 1996 are summarized in Table 6-1.

6.3.1 East Stream Area

Geometry

Potential impacts to the East Stream from the landfill were addressed by evaluating water elevations of the East Stream, refuse zone and leachate levels, and observed seeps. Cross-section B-B' (Figure 5-3) illustrates the shallow groundwater, surface water, and leachate conditions that exist on the east side of the landfill. As shown, refuse was encountered in borings PKC-IGW3 and PKC-MW13 between 310 to 343 feet above msl, and leachate was encountered between 310

and 331 feet above msl. Seepage was observed on the east side of the landfill between 322 and 325 feet above msl. The bottom of the East Stream near the inlet to the culvert was surveyed at 315.1 feet above msl (AGI 1994b).

The geometry of the landfill in relation to the East Stream indicates that the bottom of the landfill (310 feet above msl) is at least 5 feet below the bottom of the stream (315 feet above msl).

Refuse along the east side of the landfill appears to be saturated with a pool of leachate up to 17 feet deep (PKC-IGW3) and about 16 feet above the stream bottom. As shown on Figure 5-2, the leachate level measured on August 19, 1996, had dropped about 9 to 10 feet from the level on March 1 and was approaching the water level in the East Stream.

Shallow Groundwater

Three borings were drilled near the east side of the landfill. During drilling, wet native soils were encountered in all three borings: PKC-MW1 (304–309 feet), PKC-MW5 (302–314 feet), and PKC-MW16 (about 301–302 feet). Wells PKC-MW1 and PKC-MW16 were drilled entirely within native soils, while PKC-MW5 was drilled through refuse materials. The well installed in PKC-MW5 was screened partially within refuse. Borings for wells PKC-MW3, PKC-MW4, and PKC-GP-22, which were drilled on the south side of the landfill, encountered wet soil zones during drilling (AGI 1994b). Soil in Boring PKC-MW3 was very wet between elevations 265 and 305 feet, while PKC-MW4 encountered wet soil between elevation 307 and the bottom of the hole at elevation 305 feet, and GP-22 encountered saturated soil between elevations 291 and 305 feet. These borings, in conjunction with the borings drilled on the east side of the landfill and Boring PKC-MW18 (299–305 feet) drilled on the south side, suggest that there is a seasonal perched shallow groundwater zone between approximately elevations 299 and 309 feet.

Wells PKC-MW1 and PKC-MW5 were drilled at the toe of the landfill slope between the stream and the landfill (AGI 1994b), while PKC-MW16 was drilled to the south of the culvert inlet. No shallow groundwater well was installed in PKC-MW1. Well PKC-MW16 has not had a measurable water level since construction. Well PKC-MW5 was screened below and within the bottom portion of the refuse and therefore water level measurements may be directly impacted by leachate within the refuse. Borings PKC-MW3, PKC-MW4, and PKC-GP22 were drilled on the south side of the landfill in the vicinity of the CMP culvert outlet.

It appears that the "Upper Perched Zone" of shallow groundwater, as described by AGI (1994b), does exist along the eastern and southeastern margins of the landfill immediately adjacent to the East Stream, as shown on Figure 6-1. However, based on the drilling logs and observed water levels, this shallow perched groundwater zone appears to fluctuate seasonally and may be very discontinuous. Discontinuity occurs due to more permeable geologic materials interspersed among less permeable materials. Recharge to the zone probably occurs by infiltration of water from several sources: direct precipitation, wetland area, East Stream, and perched leachate within the main landfill area. Leakage into the shallow groundwater zone likely occurs from the base of the stream, from the wetland and stormwater detention ponds, and from saturated refuse. This perched zone appears to diminish during dry months, especially after the base flow of the East Stream is gone. As shown in the water level data in Appendix E, well PKC-MW4, which is screened in this perched zone, is periodically dry when measured. All other wells screened in the shallow perched groundwater zone have not recorded measurable groundwater levels, although

wet or saturated soil zones were encountered during drilling (PKC-MW5, PKC-MW16, PKC-MW18). Well PKC-MW5, which was screened across refuse, has continually had high water level readings above the well screen and in the refuse zone. These readings suggest that the well is directly impacted by leachate within the refuse. The water level in PKC-MW5 has been systematically dropping with the drier weather conditions from April to November 1996. This systematic water level drop coincides with decreasing perched leachate levels within the refuse. It is apparent that PKC-MW5 water level measurements reflect perched leachate levels rather than perched shallow groundwater zones associated with the East Stream. Water movement within this Upper Perched Zone is likely to be primarily vertical, with lateral spreading occurring during the winter months as the rate of recharge exceeds the vertical discharge capacity.

The Upper Perched Zone appears to be in direct hydraulic connection with leachate observed within the landfill. Water levels suggest that lateral flow from the refuse provides a portion of the recharge to this zone. Consequently, the water quality within this zone has been affected, as will be discussed in the subsequent Groundwater Summary Report.

6.3.2 Southeast Depression

The Southeast Depression is underlain by at least 32 feet and possibly up to 40 feet of refuse and thin cover soil. Based on borings drilled by AGI (1994a and 1994b) estimated refuse thickness contours can be drawn for the Southeast Depression as shown in Figure 6-2. Refuse margins for this area were based on the settlement patterns and on the extent of refuse test pits performed on the north side. Approximately 25,000 to 30,000 cubic yards of refuse exists in the Southeast Depression, based on the estimated refuse geometry. A profile of this area is shown in Cross-section C-C' (Figure 5-4). As shown, the bottom of the refuse under the main landfill to the north is at approximately 313 feet msl. The south edge of the main landfill appears to terminate near the culvert and the north side of the perimeter access road. Within the Southeast Depression, the refuse appears to be directly underlain by the lower sand unit. Gas probe PKC-GP16 (AGI 1994b) and gas extraction wells EW10D and EW12D (AGI 1994a), installed by AGI, all penetrated into the lower sand unit immediately below refuse. Although this condition was encountered, the occurrence or potential impacts were not discussed. Leachate was observed within the refuse while drilling PKC-GP16 and PKC-GP17 (AGI 1994b). Twenty-two feet of wet to saturated refuse was observed while drilling PKC-GP16 (elevations 290 to 312), and about 6 feet was encountered at the bottom of PKC-GP17 (elevations 299 to 305). Measured water levels in PKC-GP16a and PKC-GP17a (AGI 1994b) indicated leachate levels in the refuse at about elevation 300 feet. Thus, leachate level within the refuse is generally at similar elevations as the surrounding shallow perched groundwater level in the native soils (elevations 299 to 309). These elevations suggest that there is a hydraulic connection between the perched shallow groundwater zone and the leachate in the refuse.

The refuse within the Southeast Depression is almost entirely below the elevation of the stream bed. There should not be a concern of leachate seeping from the Southeast Depression into the stream, except possibly into the west end of the stream. At the west end of the culvert the stream bed is at about 308 feet above msl, which is about 4 to 5 feet below the top of the refuse within the depression, but about 3 feet above the highest observed leachate level within the refuse. Based on the elevation differences, water could enter the Southeast Depression refuse from the

culvert or the stream; however, the primary source of recharge for the Southeast Depression is likely direct precipitation or flooding due to overtopping of the East Stream.

Rather than leachate from the Southeast Depression impacting the stream, the concern is that water from the stream, especially on the east and south sides, may flow into the Southeast Depression. The Southeast Depression may act as a "sink" to perched shallow groundwater as well as the surface water from precipitation and flooding. Depending on the subsurface geometry, the Southeast Depression may draw down the shallow groundwater table in its vicinity.

Conversations with King County Solid Waste Division indicate that several gas extraction wells and gas probes in the Southeast Depression perform erratically sometimes in the winter months (A. Leake and M. Mendenhall 1996). In fact, PKC-GP16 sometimes does not function due to inundation by water. These observations suggest that the Southeast Depression is periodically impacted by high leachate levels, which fluctuate significantly during wet periods. Flooding would certainly be one cause of high leachate levels, and potential increased shallow groundwater flow may also impact the wells and probes.

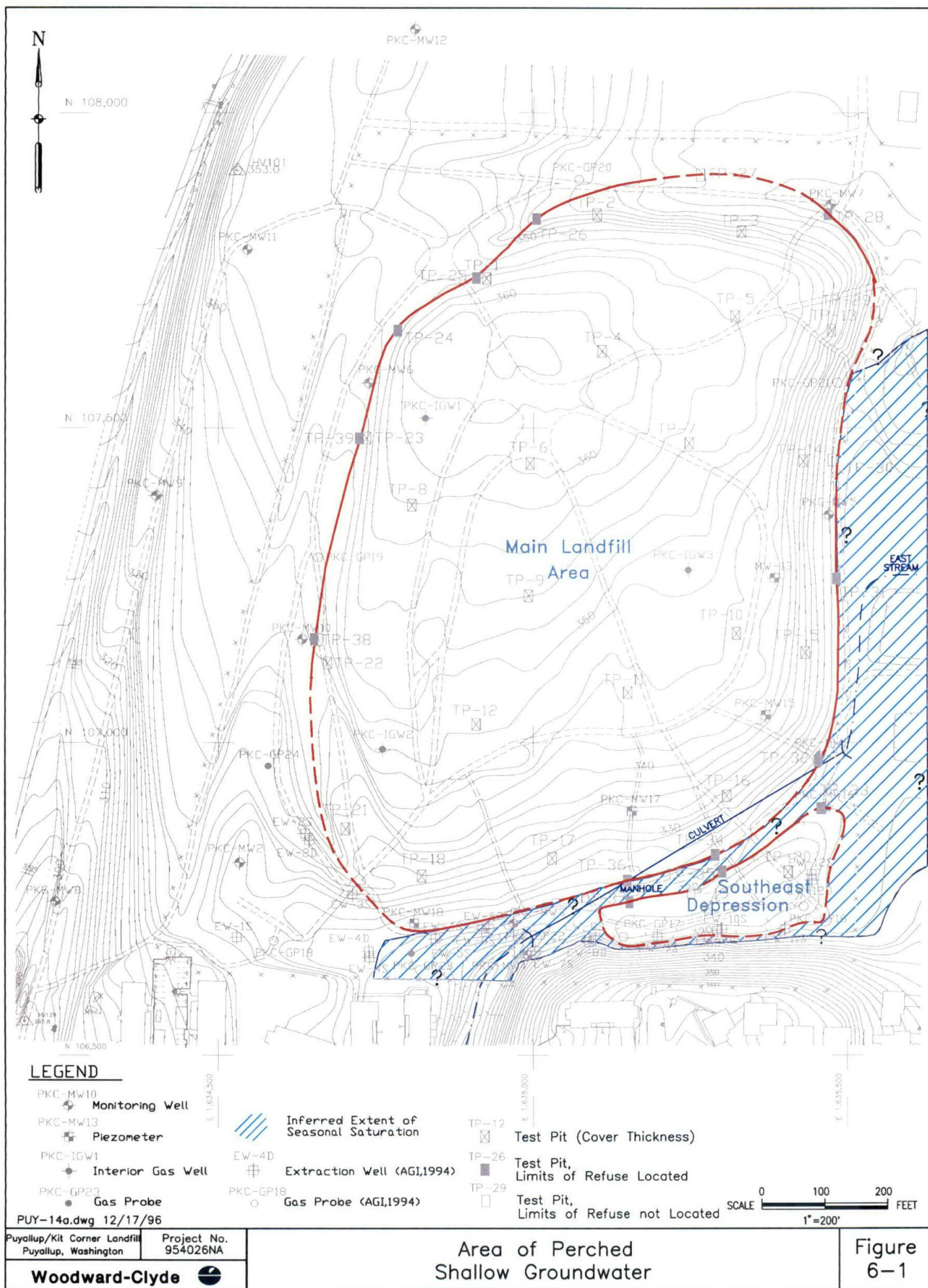
The primary concern with respect to the leachate within the Southeast Depression is the direct contact between the refuse and the Lower Sand Aquifer. As discussed previously, this depression not only is impacted by surface water infiltration and surface run-on from the slope to the south, but it is also impacted by flooding, which adds significant quantities of water to the refuse. In addition, if the culvert is leaking at the manhole, water may migrate into the Southeast Depression refuse, thereby generating additional leachate. Any leachate which is generated in this refuse could migrate into the Lower Sand Unit.

Table 6-1
**SUMMARY OF GROUNDWATER, SURFACE WATER,
 AND LEACHATE ELEVATIONS**
 (ft msl)

LOCATION	SURFACE ELEVATION	WATER ELEVATION ^a 8/19/96	REFUSE INTERVAL	LEACHATE ZONE
PKC-IGW1	360.6	347.6–346.3	342.6–357.1	342.6–347.6
PKC-IGW2	348.6	None	332.6–346.6	None
PKC-IGW3	348.8	330.8–322.5	313.8–342.6	313.8–330.8
PKC-MW1 ^b	322	wet to sat: 304–309	None	None
PKC-MW5 ^b	325	wet to sat: 302–314	314–319	302–323.7
PKC-MW13	344.0	327–320.5	310–337.5	310–327
PKC-MW15	340.6	None	318.6–335.6	wet: 318.6–322.6
PKC-MW16 ^b	321.8	None (wet: 301.3)	None	None
PKC-MW17	334.3	None	312.8–330.3	None
PKC-MW18	323.7	None	316.7–319.9	316.7–319.9
Creek Bed (E. of CMP)	315.1	-	-	-
Creek Bed (W. of CMP)	308.1	-	-	-
Seeps (E. side)	-	-	-	322–325
Seeps (S. side)	-	-	-	322
Southeast Depression	315–318	-	283–314	283–285

Notes:

- a. Ranges of water levels, leachate, or wet zones encountered between time of drilling and 8/19/96.
 b. Shallow groundwater zones as shown on AGI (1994) boring logs.



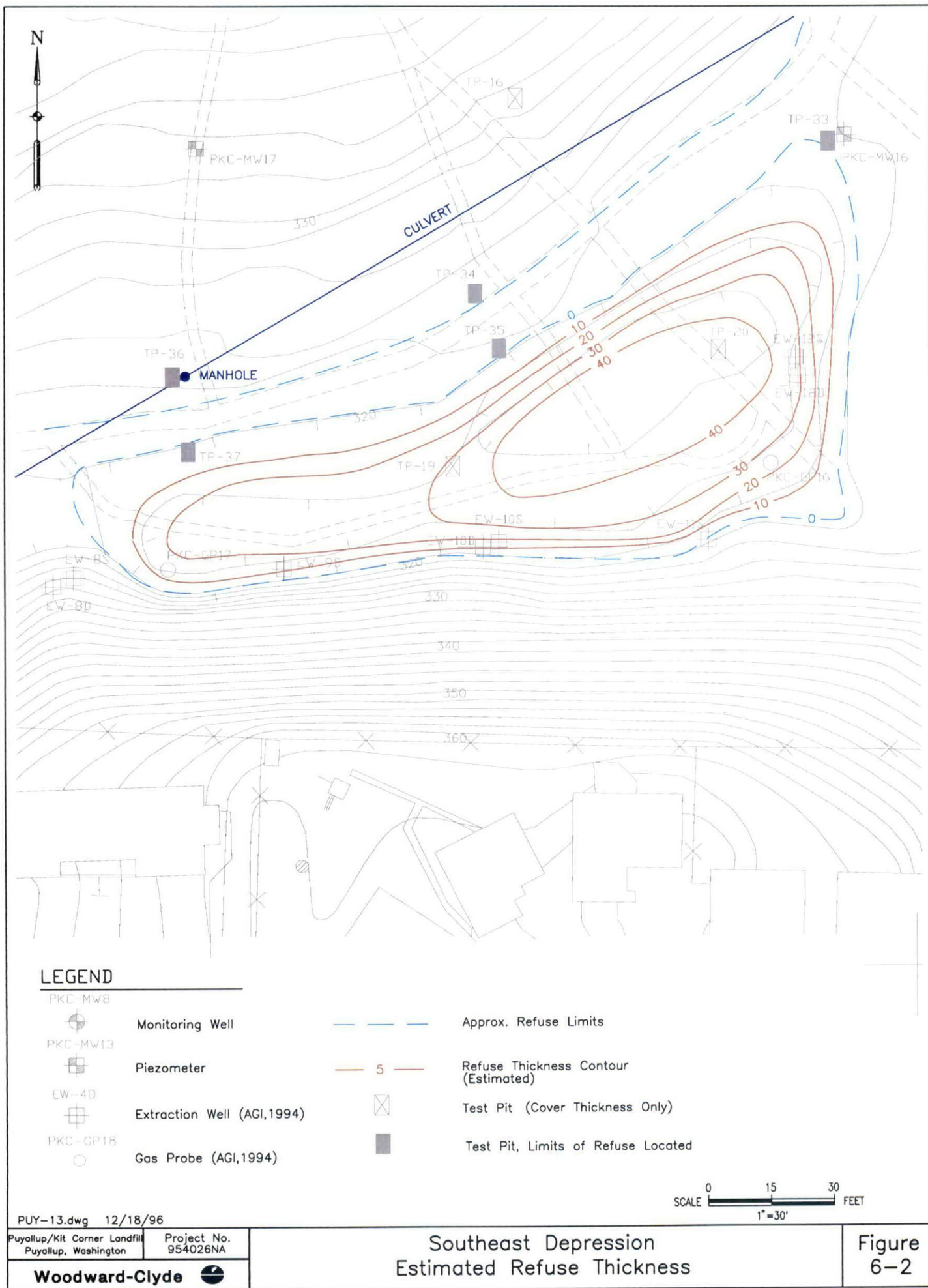


Figure
6-2

PUY-13.dwg 12/18/96

Puyallup/Kit Corner Landfill
Puyallup, Washington

Project No.
954026NA

Woodward-Clyde

7.1 GENERAL

A water balance analysis was performed for the landfill using general water balance equations. The landfill was divided and analyzed in two general areas: the main landfill area and the Southeast Depression. Estimates of the following parameters were components of the water balance analysis:

- Infiltration - calculated from the HELP model analyses
- Flow rates for the underlying foundation soils
- Leakage quantities for the culvert
- Volume of water due to flooding of the Southeast Depression
- Surface water runoff from the south slope into the Southeast Depression

7.2 MAIN LANDFILL AREA

Water inflow into the main area of the landfill occurs primarily due to infiltration of precipitation which falls directly onto the cover of the landfill. Surface water runoff onto the landfill is not a factor since the landfill is sloped down to the adjacent ground in all directions and surface water is generally directed away from the landfill. Because the invert of the culvert is below the bottom of the main landfill, leakage from water flowing through the culvert and manhole would not affect the main landfill area.

Interaction between the landfill and the East Stream appear to be seasonal. The stream bed is higher than the bottom of the refuse in the landfill, which implies possible leakage from the stream into the refuse in this area. However, winter and summer-time leachate levels in the refuse (PKC-IGW1, PKC-IGW3, PKC-MW5, and PKC-MW13), indicate that there is a eastward gradient of the leachate and that the leachate elevations are above the water level in the stream (Figure 5-3). Hydraulic connection between the landfill leachate and East Stream through perched water levels is expected during winter wet conditions. As the perched zones dry out in the summer, this connection does not exist and primary leakage from the landfill would be vertical. Since the leachate levels are higher than the stream water level, and the leachate appears to have an eastern gradient, the impact of the stream on the main landfill was ignored in the water balance analyses.

The main landfill area occupies 19 of the 20 acres of land underlain by refuse. The HELP model results (Section 4.2) indicate about 12 million gallons of rainfall infiltrates into the landfill each year. Flows through the underlying glacial till were calculated for both summer and winter leachate levels, due to the seasonal fluctuations. Flow through the glacial till depends on the thickness of the till, permeability, and head of leachate. Estimates based on the field exploration programs suggest that the glacial till averages about 20 feet thick under the main portion of the landfill. Leachate measurements in PKC-IGW3 and PKC-MW13 indicate winter leachate thicknesses of about 17 feet and summer thicknesses of about 9 feet.

Coupled with an estimated average hydraulic conductivity for the till of 5×10^{-7} cm/s (typically 1×10^{-4} to 1×10^{-10} cm/s, [Freeze and Cherry 1979]), these parameters indicate that 5 to 7 million gallons of water can flow vertically through the glacial till below the landfill each year. Therefore,

it is estimated that approximately one-half of the infiltration into the landfill predicted by the HELP model can migrate vertically. The other estimated 5 to 7 million gallons must move laterally and either discharge to the East Stream or discharge vertically through zones where the till is absent or exhibits a much higher permeability. Although the leachate measurements and thickness data used in this calculation are generally accurate, the hydraulic conductivity that was used is only an estimate based on general experience with glacial till in the area. The hydraulic conductivity could be much higher (i.e., 1×10^{-4} cm/s) if silt percentages are much lower than seen in the borings or if outwash deposits overlie the glacial till in areas below the refuse. The extent of the upper outwash deposits are not fully known and may impact vertical migration rates of leachate where present.

7.3 SOUTHEAST DEPRESSION

The Southeast Depression was analyzed separately for several reasons: (1) the refuse appears to be isolated from the main landfill area, (2) the top of the refuse is at a lower elevation than the bottom of the refuse in the main landfill area, (3) glacial till or high fines content glacial deposits are absent from below a portion of the refuse, (4) the area is impacted by flooding of the East Stream (5) surface water impacts from the slope to the south of the depression, and (6) possible impacts from leakage from the culvert or shallow groundwater flow from the East Stream.

Infiltration into the refuse in this area, based on the results of the HELP model, may generate approximately 500,000 gallons of leachate annually. In addition, surface water runoff from the steep slope south of the depression would account for about 140,000 gallons of water per year. If 59 percent actually of surface runoff infiltrates into the refuse, then more than 80,000 gallons of leachate could be generated from the steep slope.

Flooding in the Southeast Depression was documented at least twice this past winter season. If flooding is assumed to occur twice every year, and all water ponded within the depression infiltrates directly into the underlying refuse, then 1,265,000 gallons of leachate may be generated. This does not include water infiltrating into the refuse before or during overtopping of the access road to PKC-MW4, while the flooding is occurring. (Thus, this is a conservative estimate.)

Leakage through culvert joints and the manhole is likely to impact the refuse in the Southeast Depression due to the elevation of the refuse with respect to the invert elevation of the culvert. Flow rates through the culvert were calculated from the Watershed Data Management file compiled for the Hylebos Creek Basin study supplied by King County Surface Water Management. The King County program modeled the East Stream down through the Evergreen Vale Apartments and southward for upgrading of the culverts along that stretch of the stream. Due to the proximity of the 36-inch culvert on the landfill property, the program should provide a good approximation of the flow rates. The program modeled daily rainfall totals from 1949 to 1995 and the results indicate that an average annual volume of 2.55 cubic feet per second of water flows through the culvert. This amounts to 601,517,664 gallons/yr. Most of this flow occurs between October and March. Therefore, if it is assumed that 80 percent of the flow occurs in the winter months and 20 percent in the summer, and 0.5 percent leakage occurs in the winter and 1 percent in the summer, then about 2,400,000 and 1,200,000 gallons leak through the culvert each year in the winter and summer, respectively.

Summing up all the estimated impacts to the Southeast Depression indicates about 5,550,000 gallons of leachate per year may be generated by water infiltrating into the refuse in this area. Of this total, about 90 percent is due to flooding events and possible leakage through the culvert. If it is assumed that no leakage occurs through the culvert and manhole, flooding would account for about 68 percent of the total leachate generated in the Southeast Depression. The Southeast Depression occupies less than one acre of the landfill (less than 5 percent of the area), but may account for up to 32 percent of the potential leachate generation. These calculations do not include possible leachate generation due to inflow of shallow groundwater from the Upper Perched Zone.

Extraction wells EW10D and EW12D and gas probe PKC-GP16, drilled by AGI (1994a), penetrated unsaturated sand of the Sand Aquifer directly below the refuse in the Southeast Depression. The lower permeability glacial till unit underlying the main area of the landfill appears to have been removed during excavation activities in the Southeast Depression and refuse was placed directly in contact with the sand unit. Water which infiltrates into the refuse in the Southeast Depression can migrate vertically downward, generating leachate, and pass directly into the sand unit. The water quality impacts from leachate generation in this area will be summarized in the groundwater report for the site. A report is scheduled for completion by May 1997.

Surveys were performed to determine the vertical and horizontal controls of all the test pits, monitoring wells, interior gas wells, piezometers, and gas probes which were installed during this phase of work. Stakes which identified the extent of refuse in test pits TP-24 to TP-39 were included in the surveys. The surveys were performed by Symonds Consulting Engineers and were tied into the existing surveys performed at the site. Horizontal and vertical positioning were determined for all exploration locations. The vertical position for the test pits was the disturbed surface of the backfilled excavation. Vertical control for the borings and completions included (1) the top of the casings, (2) the top of the monument rim, and (3) the adjacent ground surface. The deep groundwater monitoring wells have dedicated groundwater pumps installed in them with a thin metal plate secured to the top of the casings. For these five wells, the top of the metal plates were surveyed rather than the top of the casings. The results of the surveys are presented in Appendix F.

Settlement of the landfill may affect survey data for all wells or piezometers located within the refuse limits. Not only will the ground surface and protective monuments settle, but there is a possibility that the casings will also settle, although to a lesser degree.

Our investigations at the site identified several areas of concern which should be addressed. In addition, we have provided recommendations to improve the performance of the cover and mitigate possible impacts to nearby water bodies.

9.1 KEY FINDINGS

There are three primary concerns with respect to the performance of the cover system and potential generation of leachate at the site: (1) flooding of Southeast Depression, (2) "windows" or openings in the Glacial Till and refuse in direct contact with the Lower Sand under the Southeast Depression, and (3) leachate generation and seeps.

9.1.1 Southeast Depression - Flooding of the Area

Flooding of the Southeast Depression occurred at least twice in early 1996 and likely caused a significant increase of water infiltration into the refuse, generating leachate. Conservative estimates indicate that at least 5 percent of the estimated annual leachate volume is generated with each flood event (excluding leakage from the culvert). Thus, taking into consideration the two flooding events in addition to the other leachate generated by this area, the Southeast Depression generated over 32 percent of the annual landfill leachate, although it occupies less than 5 percent of the landfill area. This does not include infiltration of water during flooding or potential shallow groundwater impacts. If all factors are considered, the Southeast Depression may account for up to 40 percent of all leachate generation at the site during 1996.

Flooding has also damaged existing improvements to the site. The control box for the landfill gas system and the condensate pump have both been inoperative due to flooding. Future damage to other components of the landfill gas system also may occur if flooding continues. Flooding also causes increased erosion to the landfill surface. No refuse has been exposed to date, but a significant flood event could scour the thin landfill cover and expose refuse. Only about 0.5 feet of cover soil exists over refuse in the northeast area of the Southeast Depression.

Flooding of the Southeast Depression also likely affects the performance of the landfill gas collection system, making it less efficient and possibly generating much more condensate due to increased water in the refuse.

9.1.2 Southeast Depression - Refuse in Immediate Contact with Lower Sand Unit

One of the most important observations made at the site was that Glacial Till is not consistently present below refuse below the Southeast Depression, and refuse is in immediate contact with the Lower Sand Unit. This is important for two reasons: leachate within the refuse can migrate directly into the Lower Sand Unit, and no natural barrier exists under the refuse in this portion of the landfill. This area is most likely a significant contributor to leachate and contaminant migration below the landfill.

9.1.3 Leachate Generation and Seeps

As discussed previously, the HELP model results showed that about 60 percent of precipitation at the site will infiltrate through the cover and into the refuse. Rainfall alone will produce about 12 million gallons of leachate annually. This figure does not include a minimum of 1.3 million gallons of leachate which may be generated in the Southeast Depression for two flood events per year, 3.6 million gallons due to a leaky culvert, 140,000 gallons due to runoff from the south off-site slope, or impacts by shallow groundwater. Not only will the leachate potentially impact the lower sand aquifer across the site, but it likely has a direct impact immediately below the Southeast Depression area.

Significant seepage observed around the landfill perimeter, especially the east slope, suggests that large quantities of leachate within the refuse are migrating toward the landfill margins. The seeps appear to be most significant during the winter and spring seasons, when leachate within the landfill is at its maximum elevation. Leachate gradients on the east side of the landfill indicate that leachate could migrate under the east perimeter road and enter the East Stream. Potential leachate entering the East Stream may be greatest during the winter and spring, but high flows in the stream likely dilute the leachate constituents to undetectable levels. Insufficient information was available to determine how much seepage from the main landfill may be migrating into the Southeast Depression refuse.

9.2 RECOMMENDATIONS

Our investigations have identified areas for potential improvement which should be addressed and some conditions which should be better defined. The following additional work should be performed at the site.

9.2.1 Recommendations for Additional Investigation

Southwest Area Investigation

Settlement of the landfill surface in the southwest portion of the landfill (Southwest Depression) exhibits characteristics similar to those seen in the Southeast Depression. The Southwest Depression has settled up to 10 feet relative to the surrounding landfill cover. Refuse underlying this area could be composed of very different materials prone to faster degradation rates and greater settlement, or the refuse could be much deeper at this location. In light of the Southeast Depression having very deep refuse in direct contact with the Lower Sand Unit, it is recommended that the Southwest Depression be evaluated further for possible similar conditions. Although it is anticipated that underlying glacial soils (till) are thicker to the west, potential past excavation operations may have removed some or all of the till. The settlement pattern and tension cracks suggest that this area has settled significantly and that the refuse bottom elevations are likely deeper than that encountered in PKC-IGW2. If refuse conditions in the Southwest Depression are similar to the Southeast Depression, refuse could be up to 30 to 40 feet thick. A single exploratory boring to a maximum estimated depth of about 40 feet is recommended to establish the refuse depth in this area.

Southeast Depression Investigation

To understand the refuse characteristics for possible mitigation purposes and more refined cost estimates, a single large test pit excavated in the refuse in the Southeast Depression is recommended. The test excavation should be at least 20 feet deep. This test excavation would allow for better observations on the potential excavation problems, leachate/water conditions in the refuse, and possible odor issues. All of these issues could significantly affect construction costs if not known during design.

Leachate Testing

Leachate generated in the Southeast Depression should be tested to determine the strength of the leachate and its potential impact to the Lower Sand Unit. The age of the refuse and the continued leaching of the refuse over time due to flooding and infiltration may have diminished the strength of the leachate. Analytical testing would determine the leachate current strength and potential impacts could be better ascertained. Leachate samples from the Southeast Depression can be obtained from gas probes PKC-GP16a and PKC-GP17a, and extraction wells EW-10S, EW-11S, and EW-12S. It is recommended that one round of leachate sampling and analytical testing be performed in these probes and wells during one of King County's regular groundwater sampling rounds. The results can be evaluated and incorporated into the Groundwater Summary Report or in a separate technical memorandum. After reviewing the leachate analytical results in conjunction with results from the groundwater study, determination of possible off-site groundwater wells south or southwest of the Southeast Depression can be evaluated.

It would also be beneficial to take leachate samples from the main landfill body at this time. Results from the main landfill would be useful in evaluating the potential reduction in or differences between the two refuse bodies. Samples within the main landfill body can be obtained from interior gas well PKC-IGW3 and monitoring well PKC-MW13. Samples have been taken from PKC-MW5 that indicate leachate parameters in the samples; however, this well is screened across refuse and the upper portion of the native soils below the refuse.

CMP Culvert/Manhole Investigation and Replacement

Based on the results of the culvert evaluation (Section 3), limit of refuse investigation (Section 4.1.2), and general site observations, it is apparent that the CMP culvert and manhole are subject to corrosion and leakage. Observations at the manhole indicated stream water in direct contact with native soil at all times when the stream is flowing and this condition is a definite source of leakage although the amount is unknown. The culvert itself appears to be in good conditions at the inlet and outlet ends, however, past collapses such as the one reported by the Seattle-King County Department of Public Health (1986) and depressions over the culvert alignment as observed during our investigation suggest that the integrity of the pipe is questionable in areas in closer proximity to the landfill. The depressions in the landfill surface over the culvert may be due to settlement of loose backfill soils and/or due to corrosion and subsequent erosion of soil into the pipe resulting in settlement at the landfill surface. The collapse reported by the Seattle-King County Department of Public Health was most likely associated with corrosion of the pipe and/or manhole or due to poor construction.

Based on these observations, it is recommended that test excavations be performed to expose the pipe in a few areas suspect to corrosion. The pipe should be exposed so that personnel can readily inspect the integrity of the pipe on top and the sides, and to see if leakage is occurring along the bottom. Test excavations would be significantly larger and deeper than the refuse limit test pits, which identified refuse depths down to about 4 feet bgs. The top of the pipe is likely 7 to 8 feet deep, making the bottom about 10 to 11 feet bgs.

Stream water in direct contact with the soil in the bottom of the manhole at all times when the stream is flowing may contribute significant leakage to the soil below. This condition should be terminated. In addition, the poor construction of the manhole sidewalls likely allow water to leak into surrounding soil. Therefore it is recommended that the entire manhole be replaced with a water-tight manhole design, if the culvert is to be used in the future. If an open channel design for the East Stream is desired to control flooding of the landfill and to stop likely leakage through the culvert, then the culvert can be abandoned in place or be removed entirely.

Gas Probe Abandonment

After the completion of leachate testing described above, we recommend that PKC-GP17a be abandoned. This gas probe has been screened across refuse materials and into the underlying unsaturated sand of the lower sand unit. This construction practice enables leachate within the refuse to be conveyed down through the monitoring casing and possibly migrate through more permeable zones in the native soils and contact shallow groundwater zones. Although sand around the probe is also likely quite permeable, the addition of the probe allows direct conveyance of potential leachate into this sand unit. This gas probe should be abandoned and does not need to be replaced, unless gas measurement within the refuse is important at this location.

9.2.2 Recommendations for Site Improvement

Southeast Depression - Flood and Leachate Control

The Southeast Depression has been identified as an area of concern. Flooding, leachate generation, and impact to the lower sand aquifer must be evaluated further. We suggest the following work be performed in the Southeast Depression area:

- **Mitigate flooding problem.** Flooding of this area should be stopped in order to (1) minimize generation of leachate, (2) avoid future damage to the landfill gas extraction system, and (3) avoid possible erosion of the landfill cover. This should be accomplished by one of the following:
 - Replacing the culvert and manhole with sizes that will convey all peak flows
 - Providing an overflow pipe or lined channel to convey overflow volumes during peak flows
 - Removing the culvert and manhole (or abandon the culvert and manhole in place) and replacing them with an open lined channel capable of conveying all peak flows

Alternatives should be evaluated fully to determine the appropriate pipe size or channel size to prevent future flooding. This would require a hydraulic analysis of the stream above the

culvert. The King County Surface Water Management model for the Hylebos Creek Basin could be used for this study and for design of a new channel or pipe. Alternatives should be designed to prevent infiltration of water into the refuse and possible surface erosion. Therefore, open channel designs may require a liner, and pipe designs should be water tight. Alternatives should also be capable of being incorporated with any future improvements to the landfill, such as a cap, or excavation of refuse in the Southeast Depression, so that unnecessary additional costs will be avoided. Additional factors, such as potential future flooding (i.e., if a larger culvert became blocked during a flood) should be considered.

- **Perimeter surface water control ditches.** The Southeast Depression should be bounded with perimeter surface water drainage ditches to prevent surface water from flowing into the depressed area, especially from the south slope. The ditch should be constructed along the south and east slopes, and along the south perimeter road. Water collected in the ditches should be conveyed away from and downgradient of the landfill.
- **Leachate control.** Future leachate generation from the refuse in the Southeast Depression should be prevented due to its proximity to the Lower Sand Aquifer. Flood prevention and eliminating potential leaks from the culvert/manhole would be a major step and surface water control will also help, but infiltration and subsequent leachate generation should be prevented also. This can be accomplished by capping the Southeast Depression area, or excavating and relocating the refuse materials.

Capping would likely involve a geomembrane, such as PVC, and would prevent nearly all water from infiltrating into the refuse from the surface, but the source would not be mitigated. Capping would not prevent possible lateral migration of water or leachate from the stream, culvert, shallow groundwater, or main landfill from impacting the Southeast Depression refuse. Capping would also require positive drainage measures be employed to direct surface water off-site.

Excavating and relocating the refuse would mitigate this particular source of potential leachate generation. However, possible leachate levels within the refuse may require special construction procedures (pumping and containment of leachate) beyond normal excavation and relocation. Also, there is some uncertainty as to what degree this would improve the overall groundwater conditions for the entire site. A suitable site for relocation of about 10,000 cubic yards of the excavated refuse may be the depressed area on the southwest corner of the landfill between test pits TP-21 and TP-22. The southwest corner of the landfill can be easily regraded and filled with refuse. Additional refuse can be placed on the west side of the landfill platform to regrade low spots; however, the surface may have to be raised several feet to bury the remaining refuse. In addition to removing all the refuse from this area, the filled depression would provide a suitable place for an open channel design for the East Stream if the culvert is to be replaced by an open channel.

After removal of refuse from the Southeast Depression, the bottom should be sealed with a low-permeability soil to prevent potential future leachate from the main landfill area from entering the Lower Sand Aquifer. General fill could then be placed up to the stream level. Fill necessary to backfill the refuse excavation could be obtained from King County's property on the north side of the landfill or other areas on-site, or imported from off-site.

Landfill Cover Evaluation

We recommend that all the data gathered at the site and potential implications be evaluated to determine whether the landfill cover should be modified. Considerations for a cap should be deferred until future remedial work, such as the expansion of the landfill gas extraction system along the east and west sides of the landfill (scheduled for the spring of 1997), is completed. These measures may be effective in minimizing site contamination migration from the main landfill. The high infiltration and leachate generation quantities warrant additional ongoing monitoring to determine the need and effectiveness of a cap for the site in the future. Although we recommend that the Southeast Depression be capped or removed entirely at this time, we recommend that the main landfill be evaluated after current work is completed and the effectiveness can be more fully evaluated. Future studies may include determining the need for a cap, as well as costs for construction, long-term operational costs, and possibly end uses of the site such as open space or a park due to the proximity to residential neighborhoods.

9.2.3 Recommendations for Site Monitoring

Continued monitoring and additional monitoring should be performed to better understand the characteristics of the landfill and to provide information for the most suitable mitigation measures, if required in the future. The following monitoring activities are recommended:

- **Leachate and shallow groundwater.** Long-term monitoring of shallow groundwater around the landfill and leachate levels within the landfill should continue. Monitoring leachate levels within the refuse could be important in further evaluating leachate generation rates and trends with respect to the time of year and precipitation events. Monitoring should be performed at least on a bimonthly basis.
- **Southeast Depression - leachate levels.** Potential leachate within the Southeast Depression refuse should be monitored. Monthly monitoring of leachate levels in this area through the coming winter could establish trends which would be important to evaluate the effectiveness of possible future mitigation measures. Monitoring can be accomplished at gas probes PKC-GP16a and PKC-GP17a, and possibly in extraction wells EW10S, EW11S, and EW12S.
- **PKC-MW3A.** Shallow groundwater levels have been recorded in the past in PKC-MW3a. Monitoring of shallow ground should be continued and included in the monitoring events at the site.

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The landfill cover explorations consisted of excavating and sampling 23 shallow test pits (TP-1 to TP-23) at selected locations across the landfill cover. The test pits were excavated on March 11 and March 12, 1996. The approximate locations of the test pits are shown on Figure 4-1.

The test pits were excavated under the full-time observation of a geotechnical engineer or geologist from Woodward-Clyde Consultants. The excavation equipment consisted of a Case 580 backhoe with a 24-inch bucket, operated by personnel from Tacoma Pump & Drilling, Inc. of Graham, Washington. When refuse was encountered, the excavations were terminated about 1 foot into the refuse. The depth of the cover soils varied from 1 to 8.5 feet, depending on the location. Disturbed soil samples were obtained from the cover soils in each test pit excavation, sealed in plastic bags, and returned to our office for further examination. Selected samples were sent to a laboratory for determination of the grain size distributions.

Field personnel recorded pertinent information for each test pit, cover material type, depth to refuse, depth to seeps (if any), and composition of refuse, including estimation of moisture and decomposition. The following moisture and decomposition categories were used when describing the refuse materials.

Moisture Content Scale

Dry Refuse: Rock, dirt, etc., no trace of moisture, paper will be fuzzed up

Normal: Newspaper, etc. still not noticeably wet, but normal moisture

Damp: Paper shows dampness. Lawn clippings, tree branches stiff and hold together

Wet: Paper saturated but no free water, just getting sloppy

Saturated: Mud or free water present

Decomposition Scale

Little: Newspaper readable, refuse looks new

Some: Newspaper readable, refuse intact but weathered

Moderate: Newspaper not legible, branches intact

Much: Newspaper not legible, branches had to crumble

Severe: Newspaper not legible, branches crumble easily

The cover soils were classified in general accordance with ASTM D 2487 and/or D 2488. The refuse depths described on the following test pit summaries represent the approximate boundaries between the cover material and refuse. The soil cover thickness and seepage conditions depicted are only for the specific dates and locations reported, and therefore do not necessarily represent other locations and times.

Sixteen additional test pits (TP-24 to TP-39) were excavated to determine the limits of refuse along the east, west, and north sides of the landfill, and along the perimeter road between the main landfill and the Southeast Depression. The results from these test pits are discussed in Section 4.1.2.

TP-1 (Elevation 355.9 feet)

Depth (feet)	Description	% LEL
0-1.5	Brown, moist, poorly graded SAND with gravel. $\pm 30\%$ gravel.	-
1.5-2	Refuse: Green carpet (yarns pull apart easy, backing falling off), plastic bags, newspaper (dated Oct. 2, 1966). Paper is damp with some decomposition. Paper has black edges but interior is legible. Cardboard is legible (has plastic coating).	0
2-3	Gray, moist, poorly graded sand with gravel.	-
No seepage encountered. Sample obtained from cover soil.		

TP-2 (Elevation 349.3 feet)

Depth (feet)	Description	% LEL
0-2.5	Gray, moist, poorly graded SAND with silt and gravel. $\pm 30\%$ gravel.	-
2.5+	Refuse: All refuse is very rust colored. Paper is damp and moderately decomposed. Paper is stained throughout, but some of interior is legible. Plastic toys, bags, handbags. Broken glass. Rusted cans, but still legible.	0
No seepage encountered. Sample obtained from cover soil.		

TP-3 (Elevation 343.1 feet)

Depth (feet)	Description	% LEL
0-5	Gray, moist, poorly graded SAND with gravel and some silt. $\pm 20-30\%$ gravel.	-
5+	Refuse: Paper is wet and moderately decomposed. Paper is saturated throughout and illegible, except large clump which was legible inside (dated Oct. 8, 1965), outside is brown and illegible. Lots of plastic bags, liquid soap bottles.	0
No seepage encountered. Sample obtained from cover soil.		

TP-4 (Elevation 356.9 feet)

Depth (feet)	Description	% LEL
0-0.5	Brown, moist, poorly graded SAND with silt and $\pm 10\%$ gravel.	-
0.5-3.5	Gray, moist, poorly graded Sand with $\pm 10\%$ gravel.	-
3.5+	Refuse: Paper is damp with some decomposition. Paper is brown and saturated on outside, inside is very legible, moist. Plastic bags, broken glass, antlers. Wood pieces are soft, splintered (like mulch).	0
No seepage encountered. Sample obtained from 0.5 to 3.5 feet.		

TP-5 (Elevation 354.1 feet)

Depth (feet)	Description	% LEL
0-0.5	Brown, moist, poorly graded SAND with silt and gravel. $\pm 40\%$ gravel.	-
0.5-2.5	Gray, moist, poorly graded SAND with silt and gravel. $\pm 40\%$ gravel.	-
2.5+	Refuse: Paper is wet and moderately decomposed. Paper edges brown and illegible, inside is saturated but legible. Plastic coated jacket in good condition, wood soft but intact.	22 (OVA 0.7-1.2 ppm)
No seepage encountered (some ponding on surface nearby). Sample obtained from 0.5 to 2.5 feet.		

APPENDIX A

Landfill Cover Investigation

TP-6 (Elevation 360.4 feet)

Depth (feet)	Description	% LEL
0-1.5	Brown/gray, moist, poorly graded SAND with silt and gravel to silty GRAVEL with sand.	-
1.5-2.5	Gray, moist, poorly graded SAND with silt and gravel to silty GRAVEL with sand. (Moderately difficult to excavate this layer).	-
2.5+	Refuse: Paper is wet with some decomposition. Paper inside is legible. Plastic bags, rusted cans, wire, rusted metal tools.	0
No seepage encountered. Sample obtained from 0 to 1.5 feet.		

TP-7 (Elevation 355.7 feet)

Depth (feet)	Description	% LEL
0-0.5	Brown, moist, poorly graded SAND with silt and gravel to silty GRAVEL with sand.	-
1.5-3	Gray, moist, poorly graded SAND with silt and gravel. (Moderately difficult to excavate this layer).	-
3+	Refuse: Paper is wet and moderately decomposed. Paper is brown and illegible outside, inside is legible. Lots of intact wood, glass, rubber sole of shoe.	40+
Seepage encountered at 0.5 feet (ponded water on surface nearby). Sample obtained from 0.5 to 1.5 feet.		

TP-8 (Elevation 355.4 feet)

Depth (feet)	Description	% LEL
0-3	Gray and light brown alternating layers, moist, silty SAND with gravel to silty GRAVEL with sand. 0-0.5 (lt brn), 0.5-1.5 (gray), 1.5-2.5 (lt brn), 2.5-3 (gray).	-
3+	Refuse: Paper is wet with some decomposition. Paper inside is legible, but falls apart easily. Plastic toys, bags, pens. Wood wet and intact. Carpet falls apart along yarns - no backing left.	0
Seepage encountered 1.5 feet below ground surface (ponded water on surface nearby). Sample obtained from 1.5 to 3 feet.		

TP-9 (Elevation 350.1 feet)

Depth (feet)	Description	% LEL
0-8.5	Brown, moist, silty GRAVEL with sand. Gray layer from 1.5 to 2.5 feet. Seepage emanating below gray layer.	-
8.5+	Refuse: Paper is wet with moderate decomposition. Paper inside is illegible. Wood intact but soft. Metal cans rusted with holes. Plastic torn apart.	0
Heavy seepage at 2.5 feet (rapidly fills test pit). Sample obtained from cover soil.		

TP-10 (Elevation 345.0 feet)

Depth (feet)	Description	% LEL
0-3	Brown, moist, silty SAND with gravel to silty GRAVEL with sand.	-
3-5	Gray, moist, silty SAND with gravel to silty GRAVEL with sand.	-
5+	Refuse: Rusted tin cans, rubber tire, cloth bags. Refuse is wet with some decomposition.	0
Seepage encountered at 3 feet. Sample obtained from 3 to 5 feet.		

TP-11 (Elevation 343.5 feet)

Depth (feet)	Description	% LEL
0-2	Brown, moist, silty SAND with gravel.	-
2-5	Gray, moist, silty GRAVEL with sand. (very hard to excavate this layer).	-
5+	Refuse: Paper is wet and moderately decomposed. Paper is brown and illegible outside, inside is partially legible. Wood partially decayed, metal is very rusted. Plastic is worn.	0
Minor seepage encountered at 2 feet (large ponded area on surface adjacent to test pit). Sample obtained from 2-5 feet.		

TP-12 (Elevation 349.5 feet)

Depth (feet)	Description	% LEL
0-2	Brown, moist, silty SAND with gravel ($\pm 40\%$ gravel). Grass roots typically down to 10 to 12 inches deep.	-
2-3.5	Gray, moist, silty GRAVEL with sand (very hard to excavate this layer).	-
3.5+	Refuse: Paper (phone book) is wet with some decomposition. Phone book is legible inside, but falls apart easily. Wood looks good, clothes look almost new, plastic falls apart easily.	0
Seepage encountered at 2 feet (ponded water on surface nearby). Sample 12a obtained from 0 to 2 feet, 12b from 2 to 2.5 feet.		

TP-13 (Elevation 342.8 feet)

Depth (feet)	Description	% LEL
0-4	Brown and gray, moist, poorly graded SAND with silt and gravel. $\pm 40\%$ gravel. Gray layer from 0.5 to 1.5 feet.	-
4+	Refuse: Paper is wet/saturated with moderate to much decomposition. Paper is illegible outside, and nearly illegible even inside. Thick cotton cloth falls apart easily. Intact plastic trash and apple bags. Copper wire.	0
No seepage encountered. Sample obtained from cover soil.		

TP-14 (Elevation 335.3 feet)

Depth (feet)	Description	% LEL
0-5.5	Gray, moist, poorly graded SAND with silt and gravel. $\pm 40-50\%$ gravel.	-
5.5+	Refuse: Paper is damp to wet with some decomposition. Paper is easily legible when parted. Rusty tin cans, tire chains. Unbroken glass bottles.	0
No seepage encountered. Sample obtained from cover soil.		

TP-15 (Elevation 334.8 feet)

Depth (feet)	Description	% LEL
0-6	Gray, moist, poorly graded SAND with gravel. ± 10 to 20% gravel. Extremely rapid caving of sidewalls.	-
6+	Refuse: Damp with some to moderate decomposition. Heavily rusted tin cans and wire. Plastic bags.	0
No seepage encountered. Sample obtained from cover soil.		

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TP-16 (Elevation 334.8 feet)

Depth (feet)	Description	% LEL
0-4	Gray, moist, poorly graded SAND with gravel. ± 10 % gravel. Caving of test pit sidewalls.	-
4+	Refuse: Damp with some decomposition. Wire, green rubber hose. Plastic garbage.	0
No seepage encountered. Sample obtained from cover soil.		

TP-17 (Elevation 331.9 feet)

Depth (feet)	Description	% LEL
0-4	Brown, moist, poorly graded SAND with silt and gravel. ± 30 to 40% gravel.	-
4+	Refuse: Paper is wet/saturated with some decomposition. Paper is illegible outside with moderate decomposition, but inside is easily readable, although falls apart easily. Rusty tin cans. Glass bottles. Plastic is good condition.	0
Moderate seepage encountered 1 foot below surface. Sample obtained from cover soil.		

TP-18 (Elevation 331.1 feet)

Depth (feet)	Description	% LEL
0-4	Brown, moist, poorly graded SAND with silt and gravel. ± 35 to 45% gravel.	-
4+	Refuse: Paper is wet/saturated with some to moderate decomposition. Paper is illegible outside with moderate decomposition, but inside is easily readable, although falls apart easily (dated Aug. 14, 1966). Very rusty tin cans. Glass bottles. Plastic is in fair condition. Wire.	0
No seepage encountered. Sample obtained from cover soil.		

TP-19 (Elevation 316.9 feet)

Depth (feet)	Description	% LEL
0-1.5	Gray and brown, moist, poorly graded GRAVEL with silt and sand. Gray layer from 0.5 to 1.5 feet.	-
1.5+	Refuse: Refuse is wet. Plywood is soft. Very rusty metal and wire. Glass bottles and plastic bags. Little to no paper.	0
No seepage encountered. Sample obtained from cover soil.		

TP-20 (Elevation 315.5 feet)

Depth (feet)	Description	% LEL
0-3.5	Gray and brown, moist, poorly graded GRAVEL with silt and sand. Gray layer from 1 to 2 feet.	-
3.5+	Refuse: Refuse is very wet with moderate decomposition. Most of refuse appears black (looks burnt, but is not). Very strong oil odor. Very rusty metal and wire. Glass bottles. Paper is slightly legible on inside when pulled apart.	0
No seepage encountered. Sample obtained from cover soil.		

TP-21 (Elevation 337.7 feet)

Depth (feet)	Description	% LEL
0-2	Brown, dry to moist, silty GRAVEL with sand. Gray layer from 1 to 2 feet (hard to excavate - on old access road).	-
2	Refuse: Paper and cardboard has normal moisture with only some decomposition. Easily read print on paper (dated 1965). Wood branches not decomposed. Plastic.	0
No seepage encountered. Sample obtained from cover soil.		

TP-22 (Elevation 345.9 feet)

Depth (feet)	Description	% LEL
0-3	Brown and gray, moist, silty GRAVEL with sand. Gray layer from 2 to 3 feet (hard to excavate in gray layer).	-
3	Refuse: Paper damp to wet with some to moderate decomposition. Some paper is very decomposed while some is very legible. Olympia beer can rusted at seams. Wire, plastic.	0
Heavy seepage encountered at 1.5 feet. Sample obtained from cover soil.		

TP-23 (Elevation 350.0 feet)

Depth (feet)	Description	% LEL
0-1	Gray, moist, silty GRAVEL with sand.	-
1	Refuse: Paper and cardboard is wet to saturated with some to moderate decomposition. Can read some print on paper (Jan. 2, 1966 date). Tin cans very rusted with many holes.	0
No seepage encountered. Sample obtained from cover soil.		

B.1 MODEL DESCRIPTION

The U.S. Environmental Protection Agency (EPA) Hydrologic Evaluation of Landfill Performance (HELP) model was selected to model infiltration through the landfill. This appendix presents a description of the hydrologic model, the model methodology, simplifying assumptions inherent in using the HELP model, the data requirements, and the model application. For a detailed discussion of the theory, the reader is referred to the model documentation (EPA 1994).

B.1.1 Hydrologic Model

This hydrologic model is based on the relationship between precipitation, evapotranspiration, surface runoff, and soil moisture storage. The water added by precipitation will either evaporate directly back to the atmosphere from the soil surface, be utilized by plants through transpiration, wet a dried soil to field capacity, drain through surface runoff, or infiltrate into the subsurface. (Field capacity is the maximum moisture content which a soil or solid waste can retain in a gravitational field without producing continuous downward percolation.) A brief description of these processes and the factors that influence them is provided below.

B.1.1.1 Infiltration

A fraction of the precipitation will infiltrate into the soil. Infiltration rate depends on soil type, vegetation cover and slope. It is also affected by climatic factors that affect soil moisture content (e.g., precipitation, temperature, and humidity).

The infiltration fraction of precipitation is the principle contributor to leachate generation for a landfill. Other contributors include the water of decomposition, the initial moisture content of the solid waste and contact with the groundwater table. All of these parameters/contributors are assumed to be negligible compared to the infiltration fraction of precipitation. It is reasonable and appropriate to not consider water of decomposition and initial moisture content of the solid waste when estimating the percolation rates. This analysis approximates vertical percolation through the landfill and does not account for groundwater intrusion into the waste material.

B.1.1.2 Evapotranspiration

Evapotranspiration, the combined evaporation from soil surfaces and transpiration from plants, represents the transport of water from the soil to the atmosphere. The amount of available water present in the soil that is lost to the atmosphere depends on soil type and vegetation. It is also affected by climatic factors that affect soil moisture content (e.g., precipitation, temperature and humidity).

B.1.1.3 Surface Runoff

Surface runoff represents the fraction of precipitation that flows off the area of concern. The amount of surface runoff will depend upon many factors, including the intensity and duration of the storm, the antecedent soil moisture condition, the permeability and infiltration capacity of the cover soil, the slope of the potential runoff surfaces, and the amount and type of vegetation cover.

B.1.1.4 Soil Moisture Storage

Soil moisture storage capacity represents water that can be held in the soil. Soil moisture storage depends on soil type, soil structure, field capacity and depth of the soil layer. The total amount of water stored in the soil at field capacity consists of two components. First, hygroscopic water is water tightly bound to the soil particles that cannot be removed by plants. It is synonymous to the water content below the wilting point. Second, available water is water that can be removed by evapotranspiration and it is synonymous to the water content that is above the wilting point and below field capacity.

B.1.1.5 Percolation

Percolation represents water that exceeds the soil's storage capacity and flows to the water table. When the water content is above the field capacity, percolation results. The amount of percolation is determined by soil moisture.

B.1.2 Model Methodology

The HELP program models the effects of hydrologic processes including precipitation, surface storage, runoff, infiltration, percolation, evapotranspiration, soil-moisture storage and lateral drainage using a quasi-two-dimensional deterministic model. Section B.1.2.1 briefly describes the equations and methods used to calculate each of these processes. A discussion of the mathematical representation of each of these processes is beyond the scope of this document. The data required to model these processes are presented in Section B.1.2.2.

B.1.2.1 Model Assumptions

The HELP model computes runoff by the Soil Conservation Service (SCS) runoff curve number method. Evapotranspiration is computed by a modified Penman method. Percolation is determined by applying Darcy's Law for saturated flow with modifications for unsaturated conditions. Lateral drainage is computed analytically from a linearized Boussinesq equation which is corrected to agree with the range of design specifications used for hazardous waste landfills. The model performs sequential daily analysis to determine runoff, evapotranspiration, percolation and lateral drainage, and calculates the daily, monthly and annual water budget. This model will not account for lateral inflow and surface run-on.

B.1.2.2 Data Requirements

The HELP model requires climatic data, soil characteristics, and design specifications. Climatic input data consists of daily precipitation, mean monthly temperatures, mean monthly solar radiation values, leaf area indices, evaporative zone depth and winter cover factors. Soil characteristics include porosity, field capacity, wilting point, hydraulic conductivity, water transmissivity evaporation coefficients, and SCS runoff curve number. Design specifications consist of the number of layers and their descriptions including layer type, thickness, slope and lateral distance to a collection drain. It allows for synthetic membranes to be used as a cover and/or liner.

B.1.3 Model Application

The HELP model (Version 3.01) was used to estimate the infiltration rate through the Puyallup/Kit Corner Landfill cover system. The climatic data, soil characteristics and design assumptions used in the HELP model are presented in Section B.1.3.1. The model results are presented in Section B.1.3.2.

B.1.3.1 Site-Specific Characteristics and Assumptions

To account for variation in vegetation, cover slope, and soil cover materials at the site, the landfill was divided into 6 areas as shown in Figure B-1. The HELP analysis was performed for each area separately. The results of all the areas were used to get an estimate of the rate infiltration into the landfill cover at the site.

The number and type of soil layers representing the cover section for HELP model analysis were estimated from the results of the test pits and laboratory analysis of soil samples. Field observations indicated that the landfill cover consists of a 1-foot-thick vegetative soil layer (layer 1) overlying a sandy layer (layer 2). Test pit observations in areas A-3 and A-4 indicated presence of a very hard, gray, silty gravel layer (layer 3) underlying the sandy layer.

To evaluate the permeability of the sandy layer and silty gravel layer, grain size analysis were performed on test pit samples. The results of grain size analysis were evaluated using the program MVAKSF developed by Vuković and Soro (1992) to estimate the permeability of the soil layers. The program MVAKSF calculates the hydraulic conductivity from grain size distribution using difference empirical formulae proposed by ten different researchers. Based on their investigations, Vuković and Soro suggest that the formulae proposed by Krueger and Zamarinu provide results which are most representative of field conditions. Table B-1 shows the results of the permeability analysis on test pit samples. The average permeabilities of sandy layer (layer 2) obtained from Krueger and Zamarinu's formulae were $1.41\text{E-}04$ m./sec ($1.41\text{E-}02$ cm/sec) and $6.38\text{E-}05$ m/sec ($6.38\text{E-}03$ cm/sec), respectively. The corresponding permeability estimates for the silty gravel layer (layer 3) were $3.78\text{E-}05$ m/sec ($3.78\text{E-}03$ cm/sec) and $1.17\text{E-}05$ m/sec ($1.17\text{E-}03$ cm/sec).

The HELP model database provided default soil type data providing information about field capacity, wilting point, and permeability required for the HELP analysis. A default soil type was chosen for each layer in the cover system using the test pit observations and the results of permeability analysis. A soil type #6 in the HELP model database, representing typical top soil material with a permeability of $7.2\text{E-}04$ cm/sec, was assigned to the vegetative top soil layer. A soil type #2 in HELP model database, with a permeability of $5.8\text{E-}03$ cm/sec, was assigned to layer 2, as it represented permeability within range obtained from Krueger and Zamarinu's formulae. Field observations indicated that water ponded on top of the silty gravel layer, suggesting that the permeability of layer 3 was lower than those obtained from MVAKSF program. Therefore, a soil type #9 in the HELP model database, representing a permeability of $1.9\text{E-}04$ cm/sec, was assigned to layer 3.

The thickness of the soil layers was estimated by averaging the observed thickness in test pits located in each area. Vegetation in the area was considered dense and consisted of tall grass or trees. An evapotranspiration depth of 18 inches was assigned to areas with tall grass and an

evapotranspiration depth of 24 inches was assigned to the areas with trees. The slope of the landfill length of surface drainage path were estimated from topographic map of the landfill (Figure 2-1). Table B-2 provides a summary of the assumptions used in the HELP model for each designated area.

The HELP model contains extensive weather information data from weather stations throughout the United States. Weather data from the Olympia, Washington weather station was most applicable for this analysis and was used in the HELP modeling. The precipitation data of Olympia was scaled to represent the 39 inches of precipitation observed at the Puyallup/Kit Corner Landfill area (Applied Geotechnology Inc. 1992).

B.1.3.2 Model Results

The results of the HELP analyses are presented in Table B-3. As seen from the table, there is no significant variation of results obtained from the HELP models for different areas. The results suggests that the presence of dense vegetation at the landfill controls the infiltration rates by reducing runoff and increasing evapotranspiration. A weighted average based on area magnitudes was used to obtain the average infiltration rates for the entire landfill. As seen from Table B-3, the average percentage of precipitation infiltrating through the landfill cover was 58.86% (22.96 in/year). This represents an infiltration of 83,000 cf/acre/year, or a total infiltration of 1,600,000 cf/year for the entire landfill area.

Table B-1
PUYALLUP KIT CORNER LANDFILL
PERMEABILITY ESTIMATED FROM GRAIN SIZE DISTRIBUTION DATE

Case	Test Pits	USC'S Classification*	D10 mm	D60 mm	Coeff. of Uniformity	Permeability (m/sec)**									
						HAZEN	SLICHTER	TERZAGHI	BEYER	SAUERBREI	KRUEGERR	KOZENY	ZUNKER	ZAMARINI	USBR
Layer -1 (Sand layer)															
1	TP-1, TP-2, TP-3	SP-SM	0.110	2.483	22.57	6.17E-05	1.22E-05	1.77E-05	7.28E-05	5.18E-05	1.36E-04	5.52E-06	1.14E-05	5.32E-05	1.71E-04
2	TP-4, TP-5, TP-7	SP-SM	0.040	4.750	118.25	7.91E-06	1.56E-06	2.22E-06	4.52E-06	2.98E-05	1.00E-04	3.12E-06	6.82E-06	3.49E-05	1.49E-04
3	TP-6, TP-8, TP-23	GM	0.018	5.850	329.56	1.55E-06	3.04E-07	4.33E-07	2.55E-07	4.72E-06	6.24E-05	1.62E-06	3.64E-06	2.01E-05	3.87E-05
4	TP-9, TP-10	GM	0.032	7.870	242.56	5.16E-06	1.01E-06	1.45E-06	1.48E-06	2.25E-05	9.69E-05	2.72E-06	6.05E-06	3.23E-05	1.49E-04
5	TP-11, TP-12	SM	0.018	4.750	267.60	1.55E-06	3.04E-07	4.33E-07	3.83E-07	4.72E-06	6.09E-05	1.61E-06	3.61E-06	1.97E-05	3.62E-05
6	TP-13, TP-14	SP-SM	0.052	5.650	109.28	1.31E-05	2.58E-06	3.67E-06	7.90E-06	3.49E-05	1.18E-04	3.71E-06	8.09E-06	4.12E-05	1.73E-04
7	TP-15, TP-16	SP	0.160	0.784	4.91	2.60E-04	7.45E-05	1.28E-04	2.29E-04	2.32E-04	4.12E-04	7.25E-05	9.19E-05	2.86E-04	1.79E-04
8	TP-17, TP-18	SP-SM	0.070	5.033	71.90	2.40E-05	4.72E-06	6.73E-06	1.85E-05	4.77E-05	1.30E-04	4.40E-06	9.50E-06	4.71E-05	1.82E-04
9	TP-19, TP-20	GP-GM	0.130	8.872	68.44	8.24E-05	1.62E-05	2.31E-05	6.49E-05	8.23E-05	1.99E-04	6.85E-06	1.47E-05	7.24E-05	3.05E-04
10	TP-21, TP-22	GM	0.032	6.467	199.32	5.16E-06	1.01E-06	1.45E-06	1.88E-06	1.86E-05	9.12E-05	2.69E-06	5.93E-06	3.11E-05	8.69E-05
Average						4.63E-05	1.14E-05	1.85E-05	4.02E-05	5.29E-05	1.41E-04	1.05E-05	1.62E-05	6.38E-05	1.47E-04
Layer -2 (Silty gravel Layer)															
11	TP-12B	GM	0.0106	9.98	937.52	5.56E-07	1.09E-07	1.56E-07	-1.38E-07	8.30E-07	3.78E-05	9.00E-07	2.05E-06	1.17E-05	2.93E-06

* Based on soil lab classification

** Permeability values calculated using MVASKE program (Vukovic and Soro, 1992)

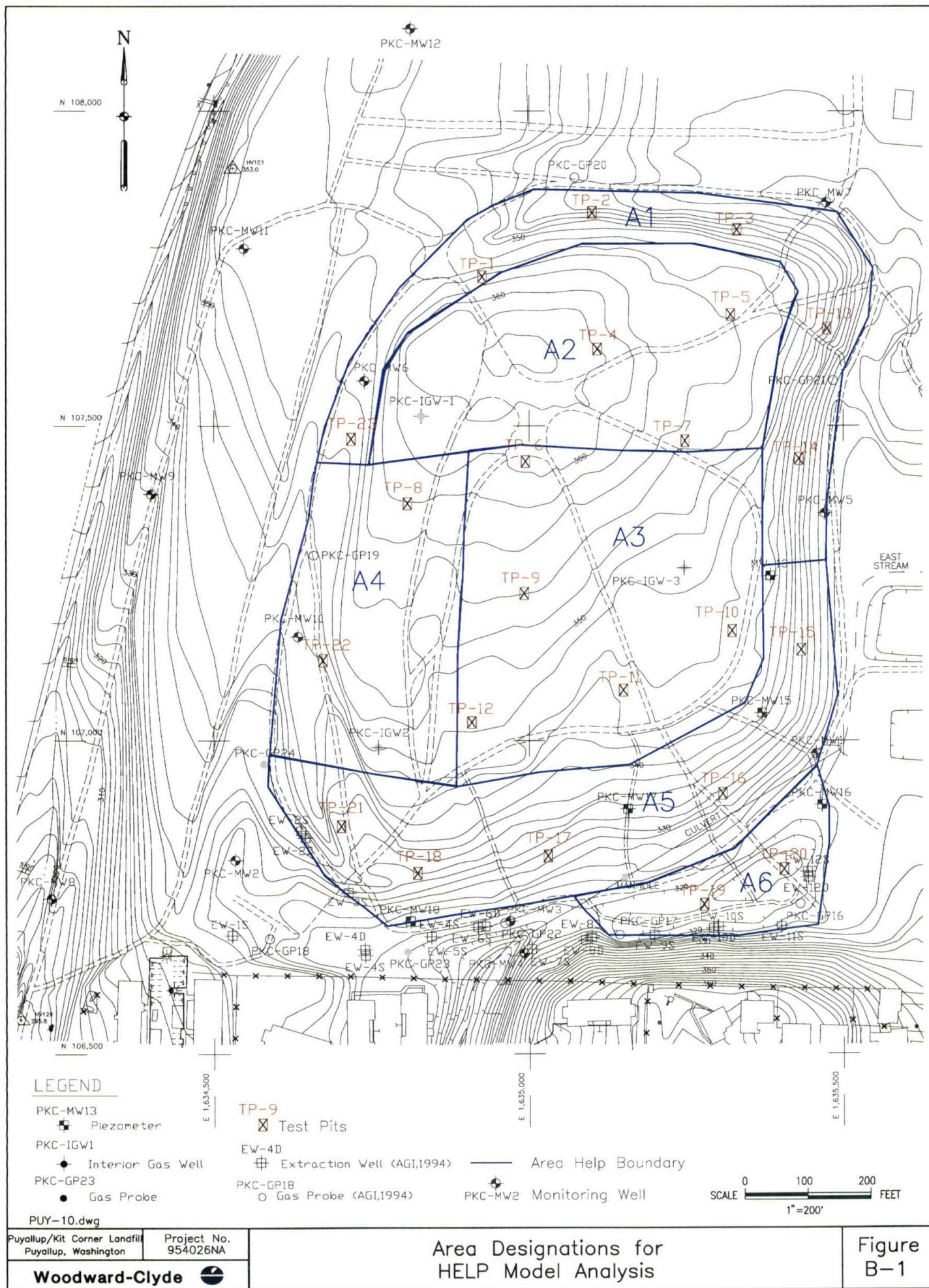
Table B-2
HELP MODEL ASSUMPTIONS FOR PUYALLUP KIT CORNER LANDFILL

No.	Area (acres)	Test pits	Average Total Depth (in)	Average Depth to Seepage layer (ft)	Layer 1 - k = 7.2E-04 cm/sec	Layer 2 - k = 5.8E-03cm/sec	Layer 3 - k = 1.9E-04	Vegetation (Root Depth)	Surface Slope	Drainage Length (ft)
						Thickness (ft)	Thickness (ft)			
A-1	3	TP-1, TP-2, TP-3, TP-23	30	-	12	18	0	Trees (24")	20.0%	50
A-2	4	TP-4, TP-5, TP-7	36	-	12	24	0	Tall Grass (18")	3.5%	200
A-3	5	TP-6, TP-9, TP-10, TP-11, TP-12	59	34	12	22	25	Trees (24")	3.5%	200
A-4	3	TP-8, TP-22	36	18	12	6	18	Tall grass (18")	3.5%	100
A-5	4	TP-15, TP-16, TP-17, TP-18, TP-21	48	-	12	36	0	Tall Grass (18")	15.0%	50
A-6	1	TP-19, TP-20	30	-	12	18	0	Tall Grass (18")	3.0%	50

Table B-3
RESULTS OF HELP MODEL ANALYSES FOR PUYALLUP KIT CORNER LANDFILL

No.	Area (acres)	Total Precipitation		Run-Off		Evapotranspiration		Infiltration	
		inches	%	inches	%	inches	%	inches	%
A-1	3	39.00	100.00%	0.01	0.02%	16.14	41.39%	22.83	58.54%
A-2	4	39.00	100.00%	0.01	0.01%	15.93	40.84%	23.03	59.06%
A-3	5	39.00	100.00%	0.00	0.00%	16.14	41.39%	22.84	58.57%
A-4	3	39.00	100.00%	0.01	0.02%	15.89	40.75%	23.09	59.21%
A-5	4	39.00	100.00%	0.01	0.04%	15.93	40.84%	23.00	58.97%
A-6	1	39.00	100.00%	0.01	0.03%	15.93	40.84%	23.04	59.07%
Total*	20	39.00	100.00%	0.01	0.02%	16.01	41.05%	22.96	58.86%

* Weighted total based on area magnitudes



Page 1 of 3

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

STATION LATITUDE = 47.50 DEGREES

PERCOLATION/LEAKAGE THROUGH 22.83360 (4.34924) 82885.969 58.54393
FROM LAYER 2
CHANGE IN WATER STORAGE 0.019 (0.8147) 68.04 0.048

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1971 THROUGH 1990

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.38 0.54	4.82 0.77	3.56 1.48	2.77 3.69	1.39 5.86	0.93 6.79
STD. DEVIATIONS	1.91 0.48	1.64 0.47	1.13 0.90	0.75 1.29	0.77 2.29	0.51 1.90
RUNOFF						
TOTALS	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.007	0.000 0.000
STD. DEVIATIONS	0.000 0.000	0.001 0.000	0.000 0.000	0.000 0.000	0.000 0.031	0.000 0.000
EVAPOTRANSPIRATION						
TOTALS	0.918 0.559	1.147 0.694	2.181 1.257	3.211 1.330	1.829 0.918	1.315 0.785
STD. DEVIATIONS	0.109 0.512	0.136 0.391	0.240 0.611	0.418 0.276	0.547 0.088	0.664 0.080
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	5.5530 0.0576	4.1610 0.0314	1.9955 0.0215	0.9283 0.1200	0.4514 3.7600	0.2056 5.5484
STD. DEVIATIONS	1.5181 0.0097	1.3261 0.0046	0.9076 0.0036	0.5441 0.2745	0.1569 2.3456	0.0418 1.5850

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1971 THROUGH 1990

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.00 (5.058)	141579.1	100.00
RUNOFF	0.007 (0.0305)	25.83	0.018
EVAPOTRANSPIRATION	16.143 (1.4141)	58599.22	41.390

PEAK DAILY VALUES FOR YEARS 1971 THROUGH 1990

	(INCHES)	(CU. FT.)
PRECIPITATION	2.48	9002.400
RUNOFF	0.134	487.9757
PERCOLATION/LEAKAGE THROUGH LAYER 2	1.536051	5575.86377
SNOW WATER	2.65	9621.7881
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2602
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0480

FINAL WATER STORAGE AT END OF YEAR 1990

LAYER	(INCHES)	(VOL/VOL)
1	2.7093	0.2258
2	3.3615	0.1868
SNOW WATER	0.000	

 HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
 HELP MODEL VERSION 3.01 (14 OCTOBER 1994)
 DEVELOPED BY ENVIRONMENTAL LABORATORY
 USAE WATERWAYS EXPERIMENT STATION
 FOR USEPA RISK REDUCTION ENGINEERING LABORATORY

PRECIPITATION DATA FILE: C:\HELP3\PYLP.D4
 TEMPERATURE DATA FILE: C:\HELP3\PYLP.D7
 SOLAR RADIATION DATA FILE: C:\HELP3\PYLP.D13
 EVAPOTRANSPIRATION DATA: C:\HELP3\PYLP.D11
 SOIL AND DESIGN DATA FILE: C:\HELP3\PY2.D10
 OUTPUT DATA FILE: C:\HELP3\PY2.0UT

TIME: 13:18 DATE: 5/29/1996

 TITLE: Puyallup Kit Corner Landfill *Area A-2*

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
 COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
 MATERIAL TEXTURE NUMBER 6

THICKNESS = 12.00 INCHES
 POROSITY = 0.4530 VOL/VOL
 FIELD CAPACITY = 0.1900 VOL/VOL
 WILTING POINT = 0.0850 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.2250 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.720000011000E-03 CM/SEC
 NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.90
 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
 MATERIAL TEXTURE NUMBER 2

PY2.0UT 5-29-96 1:19p

THICKNESS = 24.00 INCHES
 POROSITY = 0.4370 VOL/VOL
 FIELD CAPACITY = 0.0620 VOL/VOL
 WILTING POINT = 0.0240 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.1743 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
 SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A
 GOOD STAND OF GRASS, A SURFACE SLOPE OF 3%
 AND A SLOPE LENGTH OF 200. FEET.

SCS RUNOFF CURVE NUMBER = 62.40
 FRACTION OF AREA ALLOWING RUNOFF = 90.0 PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE = 1.000 ACRES
 EVAPORATIVE ZONE DEPTH = 18.0 INCHES
 INITIAL WATER IN EVAPORATIVE ZONE = 3.697 INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE = 8.058 INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE = 1.164 INCHES
 INITIAL SNOW WATER = 0.000 INCHES
 INITIAL WATER IN LAYER MATERIALS = 6.884 INCHES
 TOTAL INITIAL WATER = 6.884 INCHES
 TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
 SEATTLE WASHINGTON

MAXIMUM LEAF AREA INDEX = 4.00
 START OF GROWING SEASON (JULIAN DATE) = 126
 END OF GROWING SEASON (JULIAN DATE) = 287
 AVERAGE ANNUAL WIND SPEED = 9.10 MPH
 AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 75.00 %
 AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 69.00 %
 AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 70.00 %
 AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 79.00 %

NOTE: PRECIPITATION DATA FOR SEATTLE WASHINGTON
 WAS ENTERED FROM AN ASCII DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
 COEFFICIENTS FOR SEATTLE WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.10	42.80	44.20	48.70	55.00	60.20
64.80	64.10	60.00	52.50	44.80	41.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

STATION LATITUDE = 47.50 DEGREES

PERCOLATION/LEAKAGE THROUGH 23.03335 (4.35046) 83611.055 59.05606
FROM LAYER 2
CHANGE IN WATER STORAGE 0.035 (0.9034) 126.85 0.090

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1971 THROUGH 1990

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.38 0.54	4.82 0.77	3.56 1.48	2.77 3.69	1.39 5.86	0.93 6.79
STD. DEVIATIONS	1.91 0.48	1.64 0.47	1.13 0.90	0.75 1.29	0.77 2.29	0.51 1.90
RUNOFF						
TOTALS	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.005	0.000 0.000
STD. DEVIATIONS	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.021	0.000 0.000
EVAPOTRANSPIRATION						
TOTALS	0.911 0.583	1.139 0.562	2.175 1.388	3.220 1.294	1.662 0.900	1.319 0.777
STD. DEVIATIONS	0.109 0.539	0.135 0.317	0.218 0.728	0.414 0.301	0.543 0.092	0.725 0.079
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	5.5570 0.1035	4.2243 0.0690	2.0719 0.0499	0.9668 0.1415	0.4152 3.7395	0.1793 5.5154
STD. DEVIATIONS	1.4533 0.0179	1.3298 0.0083	0.9503 0.0048	0.5937 0.2635	0.1654 2.3539	0.0481 1.5628

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1971 THROUGH 1990

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.00 (5.058)	141579.1	100.00
RUNOFF	0.005 (0.0213)	17.53	0.012
EVAPOTRANSPIRATION	15.929 (1.4156)	57823.64	40.842

PY2.OUT 5-29-96 1:19p

PEAK DAILY VALUES FOR YEARS 1971 THROUGH 1990

	(INCHES)	(CU. FT.)
PRECIPITATION	2.48	9002.400
RUNOFF	0.095	344.8818
PERCOLATION/LEAKAGE THROUGH LAYER 2	1.783633	6474.58643
SNOW WATER	2.65	9621.7881
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2926
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0565

FINAL WATER STORAGE AT END OF YEAR 1990

LAYER	(INCHES)	(VOL/VOL)
1	2.8320	0.2360
2	4.7506	0.1979
SNOW WATER	0.000	

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HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
 HELP MODEL VERSION 3.01 (14 OCTOBER 1994)
 DEVELOPED BY ENVIRONMENTAL LABORATORY
 USAE WATERWAYS EXPERIMENT STATION
 FOR USEPA RISK REDUCTION ENGINEERING LABORATORY

PRECIPITATION DATA FILE: C:\HELP3\pylp2.D4
 TEMPERATURE DATA FILE: C:\HELP3\pylp2.D7
 SOLAR RADIATION DATA FILE: C:\HELP3\pylp2.D13
 EVAPOTRANSPIRATION DATA: C:\HELP3\pylp2.D11
 SOIL AND DESIGN DATA FILE: C:\HELP3\py3.D10
 OUTPUT DATA FILE: C:\HELP3\py3.OUT

TIME: 16: 7 DATE: 5/29/1996

TITLE: Puyallup Kit Corner Landfill Area A-3

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
 COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
 MATERIAL TEXTURE NUMBER 6
 THICKNESS = 12.00 INCHES
 POROSITY = 0.4530 VOL/VOL
 FIELD CAPACITY = 0.1900 VOL/VOL
 WILTING POINT = 0.0850 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.2156 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.720000011000E-03 CM/SEC
 NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
 MATERIAL TEXTURE NUMBER 2

py3.OUT 5-29-96 4:08p

THICKNESS = 22.00 INCHES
 POROSITY = 0.4370 VOL/VOL
 FIELD CAPACITY = 0.0620 VOL/VOL
 WILTING POINT = 0.0240 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.1211 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC

LAYER 3

TYPE 3 - BARRIER SOIL LINER
 MATERIAL TEXTURE NUMBER 9

THICKNESS = 25.00 INCHES
 POROSITY = 0.5010 VOL/VOL
 FIELD CAPACITY = 0.2840 VOL/VOL
 WILTING POINT = 0.1350 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.5010 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.190000006000E-03 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
 SOIL DATA BASE USING SOIL TEXTURE # 6 WITH AN
 EXCELLENT STAND OF GRASS, A SURFACE SLOPE OF 3.1%
 AND A SLOPE LENGTH OF 200. FEET.

SCS RUNOFF CURVE NUMBER = 57.90
 FRACTION OF AREA ALLOWING RUNOFF = 90.0 PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE = 1.000 ACRES
 EVAPORATIVE ZONE DEPTH = 24.0 INCHES
 INITIAL WATER IN EVAPORATIVE ZONE = 4.631 INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE = 10.680 INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE = 1.308 INCHES
 INITIAL SNOW WATER = 0.000 INCHES
 INITIAL WATER IN LAYER MATERIALS = 17.776 INCHES
 TOTAL INITIAL WATER = 17.776 INCHES
 TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
 SEATTLE WASHINGTON

MAXIMUM LEAF AREA INDEX = 5.00
 START OF GROWING SEASON (JULIAN DATE) = 126
 END OF GROWING SEASON (JULIAN DATE) = 287
 AVERAGE ANNUAL WIND SPEED = 9.10 MPH
 AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 75.00 %
 AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 69.00 %
 AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 70.00 %
 AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 79.00 %

NOTE: PRECIPITATION DATA FOR SEATTLE
WAS ENTERED FROM AN ASCII DATA FILE.

WASHINGTON

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.10	42.80	44.20	48.70	55.00	60.20
64.80	64.10	60.00	52.50	44.80	41.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

STATION LATITUDE = 47.50 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1971 THROUGH 1990

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.38 0.54	4.82 0.77	3.56 1.48	2.77 3.69	1.39 5.86	0.93 6.79
STD. DEVIATIONS	1.91 0.48	1.64 0.47	1.13 0.90	0.75 1.29	0.77 2.29	0.51 1.90
RUNOFF						
TOTALS	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.001	0.000 0.000
STD. DEVIATIONS	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.006	0.000 0.000
EVAPOTRANSPIRATION						
TOTALS	0.918 0.559	1.147 0.694	2.181 1.257	3.211 1.330	1.829 0.918	1.315 0.785
STD. DEVIATIONS	0.109 0.512	0.136 0.391	0.240 0.611	0.418 0.276	0.547 0.088	0.664 0.080
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	5.5172 0.0033	4.1237 0.0040	1.9439 0.0120	0.8381 0.2437	0.3959 4.0860	0.0689 5.6089
STD. DEVIATIONS	1.5466 0.0113	1.3349 0.0088	0.8917 0.0151	0.4763 0.4248	0.1939 2.3579	0.0594 1.5829

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	0.0565 0.0000	0.0468 0.0000	0.0191 0.0002	0.0087 0.0024	0.0039 0.0434	0.0007 0.0582
STD. DEVIATIONS	0.0169 0.0001	0.0173 0.0001	0.0088 0.0002	0.0050 0.0037	0.0020 0.0253	0.0006 0.0171

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1971 THROUGH 1990

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.00 (5.058)	141579.1	100.00
RUNOFF	0.001 (0.0063)	5.13	0.004
EVAPOTRANSPIRATION	16.143 (1.4141)	58599.22	41.390
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	22.84549 (4.38918)	82929.109	58.57440
AVERAGE HEAD ACROSS TOP OF LAYER 3	0.020 (0.004)		
CHANGE IN WATER STORAGE	0.013 (0.7536)	45.61	0.032

PEAK DAILY VALUES FOR YEARS 1971 THROUGH 1990

	(INCHES)	(CU. FT.)
PRECIPITATION	2.48	9002.400
RUNOFF	0.028	102.5380
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.092966	7597.46777
AVERAGE HEAD ACROSS LAYER 3	0.629	
SNOW WATER	2.65	9621.7881
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2617
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0480

FINAL WATER STORAGE AT END OF YEAR 1990

LAYER	(INCHES)	(VOL/VOL)
1	2.7093	0.2258
2	2.7927	0.1269
3	12.5250	0.5010
SNOW WATER	0.000	

NOTE: PRECIPITATION DATA FOR SEATTLE
WAS ENTERED FROM AN ASCII DATA FILE.

WASHINGTON

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.10	42.80	44.20	48.70	55.00	60.20
64.80	64.10	60.00	52.50	44.80	41.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

STATION LATITUDE = 47.50 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1971 THROUGH 1990

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.38 0.54	4.82 0.77	3.56 1.48	2.77 3.69	1.39 5.86	0.93 6.79
STD. DEVIATIONS	1.91 0.48	1.64 0.47	1.13 0.90	0.75 1.29	0.77 2.29	0.51 1.90
RUNOFF						
TOTALS	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.006	0.000 0.000
STD. DEVIATIONS	0.000 0.000	0.001 0.000	0.000 0.000	0.000 0.000	0.000 0.029	0.000 0.000
EVAPOTRANSPIRATION						
TOTALS	0.912 0.584	1.141 0.563	2.175 1.396	3.198 1.304	1.593 0.903	1.344 0.778
STD. DEVIATIONS	0.110 0.540	0.136 0.321	0.222 0.732	0.423 0.305	0.527 0.091	0.727 0.079
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	5.4961 0.0000	4.0335 0.0000	1.8190 0.0000	0.5006 0.7120	0.0813 4.7020	0.0098 5.7371
STD. DEVIATIONS	1.5913 0.0000	1.3947 0.0000	0.8602 0.0000	0.3428 0.9090	0.1206 2.3812	0.0440 1.6106

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	0.0566 0.0000	0.0469 0.0000	0.0192 0.0000	0.0056 0.0074	0.0008 0.0513	0.0001 0.0609
STD. DEVIATIONS	0.0149 0.0000	0.0161 0.0000	0.0093 0.0000	0.0039 0.0094	0.0012 0.0238	0.0004 0.0185

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1971 THROUGH 1990

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.00 (5.058)	141579.1	100.00
RUNOFF	0.007 (0.0288)	24.47	0.017
EVAPOTRANSPIRATION	15.892 (1.4180)	57688.57	40.747
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	23.09146 (4.40416)	83821.984	59.20505
AVERAGE HEAD ACROSS TOP OF LAYER 3	0.021 (0.004)		
CHANGE IN WATER STORAGE	0.012 (0.6592)	44.03	0.031

PEAK DAILY VALUES FOR YEARS 1971 THROUGH 1990

	(INCHES)	(CU. FT.)
PRECIPITATION	2.48	9002.400
RUNOFF	0.126	456.3805
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.282994	8287.26855
AVERAGE HEAD ACROSS LAYER 3	0.597	
SNOW WATER	2.65	9621.7881
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2796
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0577

FINAL WATER STORAGE AT END OF YEAR 1990

LAYER	(INCHES)	(VOL/VOL)
1	2.8321	0.2360
2	0.8136	0.1356
3	9.0180	0.5010
SNOW WATER	0.000	

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NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

STATION LATITUDE = 47.50 DEGREES

PERCOLATION/LEAKAGE THROUGH 23.00009 (4.29799) 83490.312 58.97078
FROM LAYER 2

CHANGE IN WATER STORAGE 0.059 (1.1056) 213.78 0.151

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1971 THROUGH 1990

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.38 0.54	4.82 0.77	3.56 1.48	2.77 3.69	1.39 5.86	0.93 6.79
STD. DEVIATIONS	1.91 0.48	1.64 0.47	1.13 0.90	0.75 1.29	0.77 2.29	0.51 1.90
RUNOFF						
TOTALS	0.000 0.000	0.002 0.000	0.000 0.000	0.000 0.000	0.000 0.012	0.000 0.000
STD. DEVIATIONS	0.000 0.000	0.007 0.000	0.000 0.000	0.000 0.000	0.000 0.054	0.000 0.000
EVAPOTRANSPIRATION						
TOTALS	0.911 0.583	1.139 0.562	2.175 1.388	3.220 1.294	1.662 0.900	1.319 0.777
STD. DEVIATIONS	0.109 0.539	0.135 0.317	0.218 0.728	0.414 0.301	0.543 0.092	0.725 0.079
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	5.6170 0.1795	4.3056 0.1228	2.2878 0.0886	1.1018 0.0910	0.5188 3.0472	0.2845 5.3553
STD. DEVIATIONS	1.3748 0.0284	1.3664 0.0150	1.0160 0.0088	0.5890 0.0821	0.2026 2.3455	0.0712 1.5856

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1971 THROUGH 1990

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.00 (5.058)	141579.1	100.00
RUNOFF	0.014 (0.0540)	51.34	0.036
EVAPOTRANSPIRATION	15.929 (1.4156)	57823.64	40.842

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PEAK DAILY VALUES FOR YEARS 1971 THROUGH 1990

	(INCHES)	(CU. FT.)
PRECIPITATION	2.48	9002.400
RUNOFF	0.217	787.2486
PERCOLATION/LEAKAGE THROUGH LAYER 2	2.195793	7970.72852
SNOW WATER	2.65	9621.7881
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2894
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0565

FINAL WATER STORAGE AT END OF YEAR 1990

LAYER	(INCHES)	(VOL/VOL)
1	2.8320	0.2360
2	7.4271	0.2063
SNOW WATER	0.000	

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SEATTLE WASHINGTON

STATION LATITUDE = 47.50 DEGREES

PERCOLATION/LEAKAGE THROUGH 23.03842 (4.35443) 83629.461 59.06907
FROM LAYER 2

CHANGE IN WATER STORAGE 0.025 (0.8303) 90.35 0.064

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1971 THROUGH 1990

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.38 0.54	4.82 0.77	3.56 1.48	2.77 3.69	1.39 5.86	0.93 6.79
STD. DEVIATIONS	1.91 0.48	1.64 0.47	1.13 0.90	0.75 1.29	0.77 2.29	0.51 1.90
RUNOFF						
TOTALS	0.000 0.000	0.001 0.000	0.000 0.000	0.000 0.000	0.000 0.009	0.000 0.000
STD. DEVIATIONS	0.000 0.000	0.004 0.000	0.000 0.000	0.000 0.000	0.000 0.040	0.000 0.000
EVAPOTRANSPIRATION						
TOTALS	0.911 0.583	1.139 0.562	2.175 1.388	3.220 1.294	1.662 0.900	1.319 0.777
STD. DEVIATIONS	0.109 0.539	0.135 0.317	0.218 0.728	0.414 0.301	0.543 0.092	0.725 0.079
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	5.5326 0.0709	4.1773 0.0459	1.9792 0.0331	0.8782 0.2207	0.3470 4.0407	0.1298 5.5831
STD. DEVIATIONS	1.5026 0.0151	1.3272 0.0064	0.9141 0.0038	0.5481 0.3905	0.1586 2.3379	0.0407 1.5603

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1971 THROUGH 1990

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.00 (5.058)	141579.1	100.00
RUNOFF	0.010 (0.0401)	35.61	0.025
EVAPOTRANSPIRATION	15.929 (1.4156)	57823.64	40.842

 PEAK DAILY VALUES FOR YEARS 1971 THROUGH 1990

	(INCHES)	(CU. FT.)
PRECIPITATION	2.48	9002.400
RUNOFF	0.168	609.3522
PERCOLATION/LEAKAGE THROUGH LAYER 2	1.681919	6105.36523
SNOW WATER	2.65	9621.7881
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2906
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0565

 FINAL WATER STORAGE AT END OF YEAR 1990

LAYER	(INCHES)	(VOL/VOL)
1	2.8320	0.2360
2	3.4574	0.1921
SNOW WATER	0.000	

The field exploration program consisted of drilling and installing five deep groundwater wells (PKC-MW8 through PKC-MW12), two deep multilevel gas monitoring probes (PKC-GP23 and PKC-GP24), five shallow piezometers (PKC-MW13, PKC-MW15 through PKC-MW18), and three interior gas monitoring wells (PKC-IGW1 through PKC-IGW3). The exploration locations are shown on the Site and Exploration Plan (Figure 5-1). The explorations were advanced and the wells and probes installed under the direction of a geotechnical engineer and/or geologist from Woodward-Clyde Consultants. All drilling and installation services were performed by Tacoma Pump & Drilling Company, Inc. of Graham, Washington, under subcontract to Woodward-Clyde Consultants between March 11 and April 12, 1996. The borings were located approximately in the field by pacing/taping distances from nearby surface features. The explorations were later surveyed by Symonds Consulting Engineers using traditional and GPS survey equipment. The survey data is summarized in Appendix F.

At each boring location, sampling was performed using a 2-inch outside diameter split-spoon sampler driven with a standard 140-pound hammer. A 3-1/2 inch O.D. split-spoon California sampler was typically used in an attempt to obtain larger samples when drilling through coarse-grained soils such as gravel. The larger shoe opening would allow more gravel to pass into the sampler. Samples were obtained by driving the sampler 18 inches into the soil with a hammer free-falling 30 inches. The number of blows required for each 6 inches of penetration is recorded. This resistance or blows for the last 12 inches (blows per foot) provides a measure of the relative density of granular soils and the relative consistency of cohesive soils. If the high penetration resistance encountered in the very dense soils precluded driving the total 18-inch sample interval, the penetration resistance for the partial penetration is entered on logs as follows: if the penetration is greater than 6 inches and less than 18 inches, then the number of blows is recorded over the number of inches driven; 30 blows for 6 inches and 50 for 3 inches, for instance, would be recorded as 80/9". The blow counts are shown on the boring logs at the respective sample depths.

The soils encountered during drilling were visually classified in the field by the engineer or geologist in general accordance with the Unified Soil Classification System (USCS). The soil samples were collected by the Woodward-Clyde engineer or geologist, placed in plastic bags, and transported for observation and laboratory testing. The field classifications were checked in our office after laboratory testing had been completed. The laboratory test results are summarized in Appendix D.

In addition, pertinent information including soil sample depths, stratigraphy, and groundwater occurrence were recorded. The drilling operation was also monitored for indication of various drilling conditions, such as hard drilling and soft drilling. Sample rods were monitored for indications of groundwater. Groundwater was accurately measured in all three borings while hollow stem auger techniques were used. Drilling stopped for a short time until water levels stabilized and then they were measured. Methane and hydrogen sulfide were also monitored during drilling activities.

A key to the symbols and terms used on the boring logs is included on Figure C-1. Summary boring logs are presented on Figures C-2 through C-16. The stratigraphic contacts shown on the individual boring logs represent the approximate boundaries between soil types. The actual transitions between soil units may be more gradual or abrupt. The soil and groundwater

conditions depicted are only for the specific dates and locations reported, and therefore are not necessarily representative of other locations and times.

The following sections summarize information and equipment used for the different explorations.

Deep Monitoring Wells

The monitoring wells were constructed in accordance with the regulations described in WAC 173-160, *Minimum Standards for Construction and Maintenance of Wells*. The borings were drilled between March 21 and April 15, 1996, and the monitoring wells were installed between March 25 and April 12, 1996.

The borings were advanced using a Foremost DR24 air rotary drill rig which advanced 8-inch diameter steel casing by rotation methods. The drill bit consisted of a 7-7/8 inch tricone button bit equipped with 2-inch hole for inhole sampling purposes. A 7-7/8 inch drag bit with 3-inch inhole sampling capabilities was also used to expedite 3-inch sampling requirements. The five deep groundwater monitoring wells were advanced to depths between 128 and 196.5 feet below the ground surface (bgs).

The monitoring wells were installed using a cable tool drill rig. The wells were constructed using new flush-threaded, 4-inch, schedule 80 PVC casings and screens. The well screen consisted of factory-slotted (0.020-inch) pipe designed specifically for use in groundwater monitoring wells. A threaded end cap was attached to the bottom of each well screen, and the pipe was placed into the boring through the inside of the casing. No glues, chemical cements or solvents were used to assemble the well construction materials. A clean, nongraded sand filter pack was placed into the annular space around the well screen from the bottom of the boring to approximately 2 to 4 feet above the top of the screened interval. A bentonite plug (3/8-inch chips) of at least 3 feet in thickness was placed above the sand pack, and a seal of bentonite-cement grout was installed from the top of the bentonite plug to grade level (concrete at surface). Flush-to-grade well monuments were used along the paved access road for PKC-MW8, PKC-MW9, and PKC-MW11. Wells PKC-MW10 and PKC-MW12 were constructed with 8-inch diameter steel standpipe monuments protected by three 3-inch bollards. All monuments were cemented in place.

Following construction, the monitoring wells were developed by surging and overpumping. Approximately ten well volumes of fluids and sediment were bailed from each well. Waters produced during well development were placed into DOT-approved-55 gallon closed-top steel drums (17H). The development water was transported to the central staging area on the north side of the landfill within the fenced boundary.

The boring logs for the deep monitoring wells are presented on Figures C-2 through C-6. Following each boring log is a monitoring well construction log summarizing the details of each well completion.

Shallow Piezometers

The borings were drilled and shallow piezometers installed between March 11 and 14, 1996. The borings were advanced using a Mobile B-61 HDX hollow stem auger drill rig equipped with 4-1/4 inch I.D. auger and an 8-1/2 inch carbide bullet with spade drill bit. The five shallow piezometers were advanced to depths between 26 and 38.2 feet bgs. Borings PKC-MW13, PKC-MW15,

PKC-MW17, and PKC-MW18 were drilled through refuse. Boring PKC-MW16 was the only shallow piezometer boring not drilled through refuse. No boring was performed for PKC-MW14.

The shallow piezometers were constructed using new flush-threaded, 2-inch, schedule 40 PVC casings and screens. The well screen consisted of factory-slotted (0.010-inch) pipe designed specifically for use in groundwater monitoring wells. A threaded end cap was attached to the bottom of each well screen, and the pipe was placed into the boring through the inside of the hollow stem augers. No glues, chemical cements or solvents were used to assemble the well construction materials. A 2 to 4 foot bentonite plug (3/8-inch chips) was placed at the bottom of all the borings prior to constructing the piezometers. A clean filter pack composed of 10/20 silica sand was placed into the annular space around the piezometer screen from about 0.5 to 1 foot below the bottom of the casing to approximately 2 to 3 feet above the top of the screened interval. A bentonite seal (3/8-inch chips) was installed from the top of the sand pack to grade level (concrete at surface). All of the shallow piezometers were constructed with 8-inch diameter steel standpipe monuments, locked, and protected by three 3-inch bollards. All monuments were cemented in place. Compression caps (J-plugs) were installed on all the piezometer casings. The casing were later fitted with slip caps and labcocks for gas monitoring purposes.

The boring logs for the shallow piezometers are presented on Figures C-7 through C-11.

Multi-level Gas Probes

The deep multi-level gas probe borings were drilled from March 11 to 15, 1996 and the probes were installed between March 18 and 21, 1996. Drilling, sampling, and installing of the deep multi-level gas probes utilized the same drill and installation rigs and sampling equipment as described above for the deep groundwater wells. The multi-level gas probes were drilled to depths of 124.5 and 124 feet, for PKC-GP23 and PKC-GP24, respectively.

Five gas probes were installed in each boring, with each probe having a specific screened interval. The probes are labeled A through E, with A being the shallowest screened interval and E being the deepest screened interval. The multi-level gas probes were constructed using new flush-threaded, 3/4-inch, schedule 80 PVC casings and screens. The screen consisted of factory-slotted (0.020-inch) pipe. A threaded end cap was attached to the bottom of each gas collection screen, and the pipes were installed into the boring through the inside of the casing. No glues, chemical cements or solvents were used to assemble the probe construction materials. A clean filter pack consisting of pea gravel was placed into the annular space around the probe screen from about one foot below each screened interval to about 2 feet above each screened interval. A bentonite plug (3/8-inch chips) of about 5 feet in thickness was placed above and below each screened interval within the boring. The multi-level gas probes were completed by attaching a labcock to the top of each probe, identifying each probe, and installing a 12-inch diameter steel standpipe monuments protected by three 3-inch bollards. Both monuments were cemented in place and locked for protection.

The boring logs for the multi-level gas probes are presented on Figures C-12 and C-13.

Interior Gas Wells

The three interior gas wells were drilled and installed within reuse of the main landfill body between March 15 and 19, 1996. The borings were advanced using a Mobile B-61 HDX hollow stem auger drill rig equipped with an 8-1/2 inch I.D. augers and a 13-1/2 inch carbide bullet drill bit. The three interior gas wells were advanced to depths between 26 and 43.5 feet bgs. All three borings were drilled through refuse.

The interior gas wells were constructed using new butt fusion welded 4-inch, SDR 11, HDPE casings and screens. The well screen consisted of machined 1/4-inch pipe designed specifically for the gas collection within the refuse. An end cap was butt-fusion welded to the bottom of each well screen, and the pipe was placed into the boring through the inside of the hollow stem augers. No glues, chemical cements or solvents were used to assemble the well construction materials. At least 7 feet of bentonite plug (3/8-inch chips) was placed at the bottom of the borings prior to constructing the interior gas wells. A clean filter pack composed of 1/2-inch gravel was placed into the annular space around the well screen from about 0.5 feet below the bottom of the casing to approximately one foot above the top of the screened interval. A bentonite seal (3/8-inch chips) was installed from the top of the gravel pack to grade level (concrete at surface). All of the shallow piezometers were constructed with 8-inch diameter steel standpipe monuments, locked, and protected by three 3-inch bollards. All monuments were cemented in place. Compression caps (J-plugs) were installed on all the interior gas well casings. The casing were later fitted with slip caps and labcocks for gas monitoring purposes.

The boring logs for the interior gas wells are presented on Figures C-14 through C-16.

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Key to Log of Boring

Sheet 1 of 3

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
							Dense, moist, brown, SILTY SAND (SM).			PID = 0 ppm.
							[solid line denotes observed contact between strata or abrupt change in soil type] [dashed line denotes inferred contact between strata or gradational change in soil type]			
			1	90	34		Sample collected in 3-inch-diameter California split-spoon sampler.	16		LL=45, PI=10 MC=22 SA=32
			2	85	37		Sample collected in 2-inch-diameter Standard Penetration Test (SPT) split-barrel sampler.	70		
			3	100	Push		Sample collected in Shelby tube.	7		Hard drilling.
			4				Grab sample.	50		
			5	0	50/6"		Grab sample collected where there was no recovery from driven sampler.	0		
							Perched water ▽ Groundwater level measured during drilling ▽			
1	2	3	4	5	6	7	8	9	10	11

COLUMN DESCRIPTIONS

- | | | |
|----|------------------------------|---|
| 1 | Elevation: | Elevation (in feet) referenced to Mean Sea Level (MSL). |
| 2 | Depth: | Distance (in feet) below the ground surface. |
| 3 | Sample Type: | Type of soil sample collected at depth interval depicted; symbols explained above. |
| 4 | Sample Number: | Sample identification number. |
| 5 | Percent Recovery: | Percentage of sample recovered for given sample interval; blank if not recorded. |
| 6 | Sample Blows/foot: | Number of blows required to advance driven sampler 1 foot, or distance indicated, using a 140-lb hammer with a 30-inch drop. " * " indicates blow count for initial 6-inch seating interval of sampling only. |
| 7 | Graphic Log: | Graphic depiction of subsurface material encountered; symbols explained on Sheet 2 of Key. |
| 8 | Material Description: | Description of subsurface material encountered, including USCS soil designation. |
| 9 | % LEL: | Percentage Lower Explosive Limit (LEL). |
| 10 | Well Completion Log: | Graphic depiction of well construction; symbols explained on Sheet 3 of Key. |
| 11 | Remarks and Tests: | Comments or observations regarding drilling/sampling made by driller or Woodward-Clyde Consultants' field personnel. Field and lab test results are presented in abbreviated format; see Sheet 2 of Key for abbreviations used. |

GENERAL NOTES

- Soil classifications are based on the Unified Soil Classification System (USCS) and include consistency or relative density (where standard blow count correlation is possible), moisture, and color. Field descriptions may have been modified to reflect results of laboratory tests.
- Descriptions on these boring logs apply only at the specific boring locations and at the time the borings were advanced. They are not warranted to be representative of subsurface conditions at other locations or times.

Figure C-1

Project: Puyallup / Kit Corner Landfill
Project Location: King County, Washington
Project Number: 954026NA

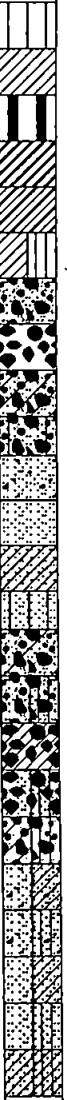
Key to Log of Boring

Sheet 2 of 3

ABBREVIATIONS FOR TEST RESULTS LISTED IN "REMARKS AND FIELD / LAB TESTS" COLUMN

MC=22 Moisture content, test result in percent
DD=105 Dry density, test result in pcf
LL=45 Liquid limit, test result in percent
PI=22 Plasticity index, test result in percent
SA=32 Sieve analysis, percent passing No. 200 sieve
WA=99 Wash analysis, percent passing No. 200 sieve
HYD Hydrometer analysis
PERM Permeability or flexible-wall hydraulic conductivity test, test result (k) in cm/sec
PID=0 Photoionization Detector reading, in parts per million

UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL VERSUS CORRESPONDING GRAPHIC LOG



SILT - ML
Lean (low-plasticity) CLAY - CL
Elastic SILT - MH
Fat (high-plasticity) CLAY - CH
Lean to fat CLAY - CL/CH
SILTY CLAY - CL-ML
Well-graded GRAVEL - GW
Poorly graded GRAVEL - GP
CLAYEY GRAVEL - GC
SILTY GRAVEL - GM
Well-graded SAND - SW
Poorly graded SAND - SP
CLAYEY SAND - SC
SILTY SAND - SM
Well-graded GRAVEL with CLAY - GW-GC
Well-graded GRAVEL with SILT - GW-GM
Poorly graded GRAVEL with CLAY - GP-GC
Poorly graded GRAVEL with SILT - GP-GM
SILTY, CLAYEY GRAVEL - GC-GM
Well-graded SAND with CLAY - SW-SC
Well-graded SAND with SILT - SW-SM
Poorly graded SAND with CLAY - SP-SC
Poorly graded SAND with SILT - SP-SM
SILTY, CLAYEY SAND - SC-SM

Figure C-1

Project: Puyallup / Kit Corner Landfill
Project Location: King County, Washington
Project Number: 954026NA

Key to Log of Boring

Sheet 3 of 3

SYMBOLS USED IN WELL COMPLETION LOG

CONCRETE

BENTONITE-CEMENT GROUT

BENTONITE CHIPS

BENTONITE PELLETS

SAND PACK

PEA GRAVEL

SLOTTED PIPE IN SAND PACK

PIPE END CAP

SLOUGH



Figure C-1

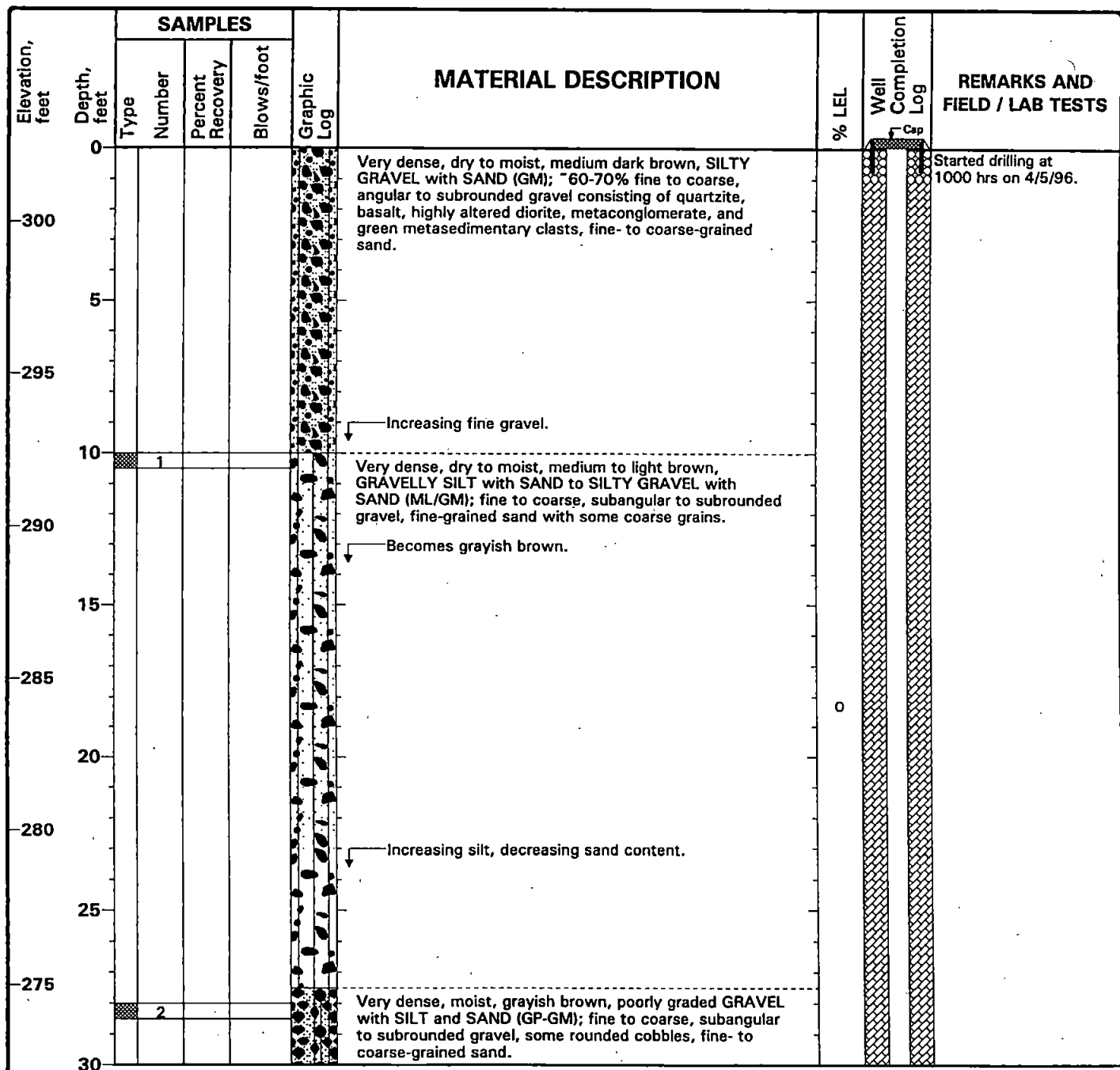


Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 8

Sheet 1 of 4

Date(s) Drilled4/5/96 and 4/8/96				Logged ByJ. McKenna		Checked ByD. Haddock	
Drilling MethodAir Rotary				Drill Bit Size/Type7-7/8-inch tricone button bit		Surface Elevation (feet)302.4	
Drill Rig TypeForemost DR24				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)128.0	
Depth to Ground-water (feet, bgs)		First106.5	Completion100.4	24 Hours99.6		Hammer Weight/Drop (lbs/in.)140 / 30	
Diameter of Hole (inches)8		Diameter of Well (inches)4		Type of Well CasingSchedule 80 PVC		Sampler TypeSPT	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 103.9-96.7 ft, bentonite-cement grout 96.7-1 ft, concrete 1 ft to surface			
CommentsFrontage Road							



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 8

Sheet 2 of 4

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
30						Very dense, moist, grayish brown, SILTY GRAVEL with SAND (GM); fine to coarse, subangular to subrounded gravel, some rounded cobbles, fine- to coarse-grained sand.			
270									
35						Increasing sand content.			Perched water table measured at 34 ft at 1255 hrs on 4/5/96 after sitting for 2 hrs.
265						Very dense, moist to wet, brown, poorly graded GRAVEL with SAND (GP); ~90% fine, subrounded to rounded gravel, coarse-grained sand with some medium grains, trace silt.			Driller pulled drill stem out -- very wet, muddy.
40		3				Very dense, wet, brown, SILTY GRAVEL with SAND (GM); fine, subrounded to rounded gravel, coarse-grained sand.			
260						Very dense, wet, brown, poorly graded GRAVEL (GP); ~99% fine to coarse, subangular to rounded gravel consisting of diorite, granite, andesite, basalt, schist, and marble(?), trace medium- to coarse-grained sand, trace silt.			
45									
255		4	0	100/2**		Very dense, moist to wet, brown SILT (ML), with ~10% coarse-grained sand to fine gravel; occasional lenses of brown and gray, medium- to coarse-grained sand.			Water coming out of cyclone; intact silt chunks in cyclone are only slightly moist inside.
			0	75/1**					
50		5	100	100/4*		Very dense, moist, orange, SILTY GRAVEL with SAND (GM); ~60% fine gravel, with some coarse gravel and coarse-grained sand.			~40% of sample slough; silt around most sand grains and gravel; dry inside intact silt chunks. Very slow drilling 50-55 ft.
250						Becomes light brown; increasing sand content, fine- to coarse-grained.			
55						Very dense, moist, brown, poorly-graded GRAVEL with SILT and SAND (GP-GM); ~60-95% fine to coarse, subrounded to rounded gravel, medium- to coarse-grained sand with trace fine grains; varying proportions of coarse-grained sand and fine gravel.	0		
245									
60									
240									
65									
235									
70									

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 8

Sheet 3 of 4

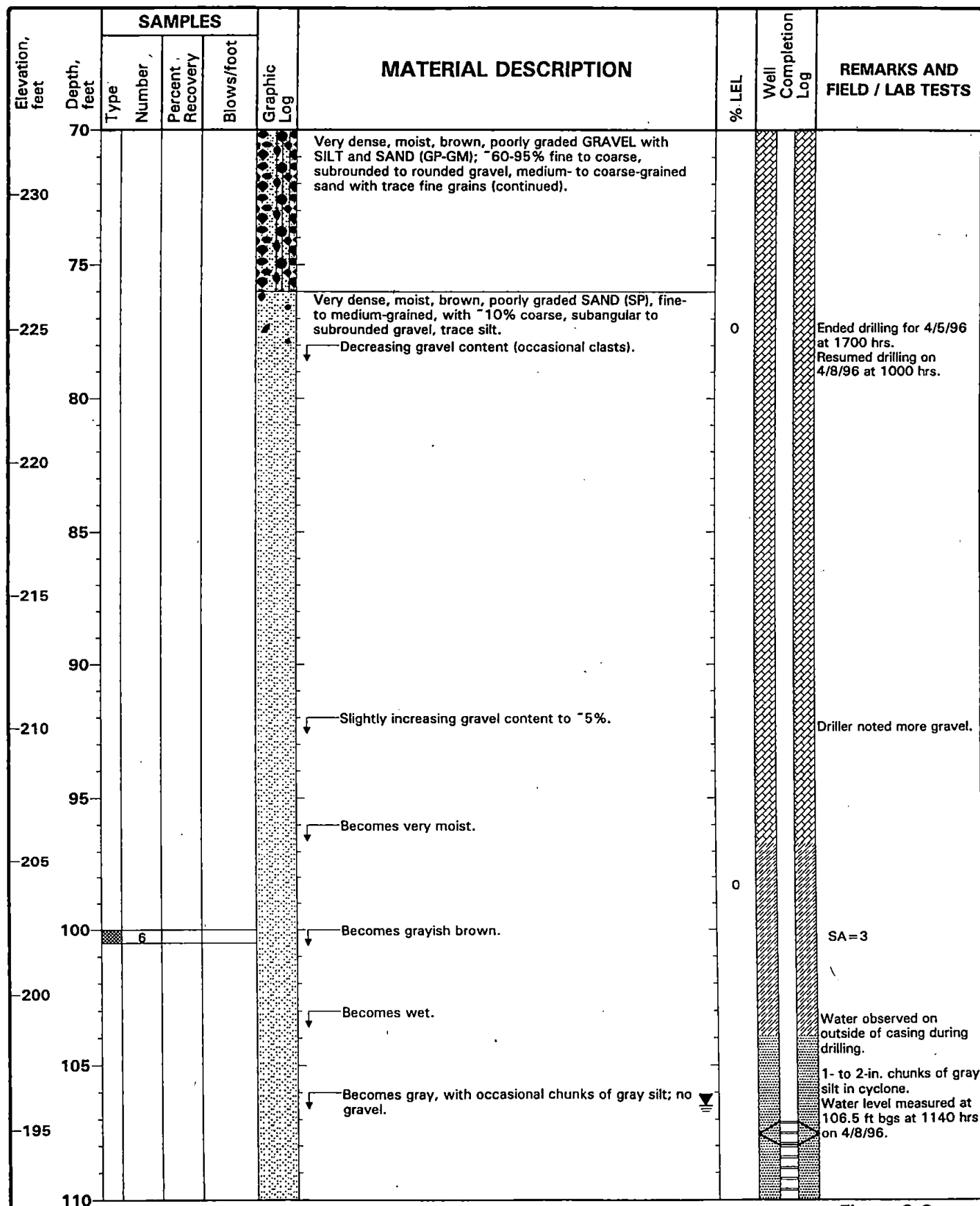
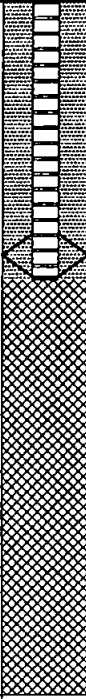


Figure C-2

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 8

Sheet 4 of 4

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
110						Very dense, wet, gray, poorly graded SAND (SP), fine- to medium-grained; occasional chunks of gray silt (continued).			
190									
115									
185							0		
120									
180									
125									
175									
130									
170									
135						Bottom of boring at 128.0 feet.			Finished drilling at 1400 hrs on 4/8/96.
165									
140									
160									
145									
155									
150									

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

CONSTRUCTION LOG FOR MONITORING WELL IN BORING PKC-MW 8

Location	Cable tool rig, using tremie pipe		Date(s) Installed	4/12/96
Installed By	Tacoma Pump & Drilling	Observed By	J. McKenna	Total Depth (ft bgs) 128.0
Method of Installation	Cable-tool rig, using tremie pipe			
Screened Interval	185.3 - 195.3 ft MSL	Completion Zone	Sand Aquifer	
Remarks	Metal plate mounted to top of riser pipe for groundwater sampling purposes.			

NOTE: DIAGRAM IS NOT TO SCALE

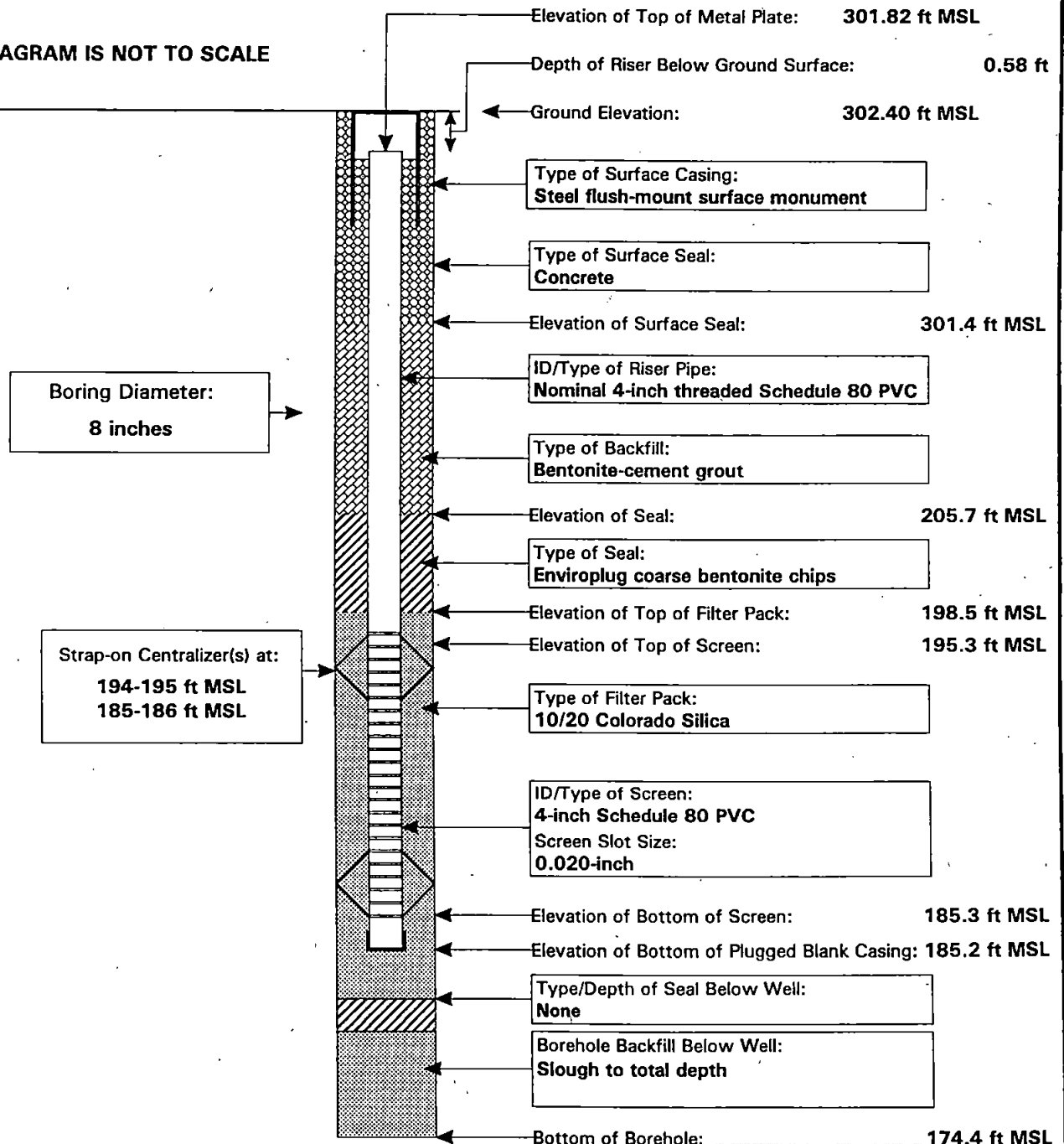


Figure C-2

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 9

Sheet 1 of 5

Date(s) Drilled	4/1/96 - 4/4/96			Logged By	J. McKenna	Checked By	D. Haddock
Drilling Method	Air Rotary			Drill Bit Size/Type	7-7/8-inch spade bit (4 teeth)	Surface Elevation (feet)	334.9
Drill Rig Type	Foremost DR24			Drilled By	Tacoma Pump & Drilling	Total Depth Drilled (feet)	186.0
Depth to Ground-water (feet, bgs)	First 132.5	Completion --	24 Hours --	Hammer Weight/ Drop (lbs/in.)	140 / 30	Sampler Type	SPT and California
Diameter of Hole (inches)	8	Diameter of Well (inches)	4	Type of Well Casing	Schedule 80 PVC	Screen Perforation	0.020-inch slot
Type of Sand Pack	10/20 Colorado Silica			Type of Seal(s)	Bentonite chips 182.2-180 ft, 172-167.6 ft, 135.5-130.5 ft; bentonite-cement grout 130.5-1 ft; concrete 1 ft to surface		
Comments	Frontage Road, 400 ft south of PKC-MW11						

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
0	0							Cap	Started drilling on 4/1/96.
-330	5		1						
-325	10		2	0	50/0.5"				4- to 7-in. intact clumps of sandy silt in cyclone. No clay according to field hydrometer test; water clear after 10 min.
-320	15		3						Proportions of silt and gravel vary.
-315	20		4	0	80/4"				
-310	25		5						Very difficult drilling 25-29 ft; abundant rocks. Silt blowing profusely out of cyclone.
-305	30								

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 9

Sheet 2 of 5

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
30			6	0	80/1**		Very dense, moist, light brown, SILTY GRAVEL to GRAVELLY SILT (GM/ML) (continued).			
300	35		7							
							Very dense, moist, orange-brown, poorly graded GRAVEL with SAND (GP); ~70% fine to coarse, subrounded to rounded gravel (consisting of ~60% basalt and andesite clasts), fine- to medium-grained sand, trace silt.	0		Ended drilling for 4/1/96 at 1615 hrs. Resumed drilling on 4/3/96 at 0850 hrs.
295	40		8	0	50/1.5*					
290	45		9				Gravel becomes angular to subrounded.			Possibly more gravel; difficult to determine in cyclone.
285	50		10	40	70		Very dense, moist, orange-brown, SILTY GRAVEL with SAND (GM); fine to coarse, subangular gravel.			Very fast, easy drilling to about 80 ft.
280	55		11				Very dense, moist, orange-brown, GRAVELLY SILT with SAND (ML), ~10-20% fine to coarse, subangular to subrounded gravel, fine- to medium-grained sand.			
275	60		12	0	50/2*					
270	65		13				Very dense, moist, brown, poorly graded SAND with GRAVEL (SP); medium- to coarse-grained sand, ~20% fine to coarse, subangular to subrounded gravel, trace silt.			
265	70		14				Very dense, moist, brown, poorly graded SAND (SP), fine- to medium-grained, with occasional gravel.	0		



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 9

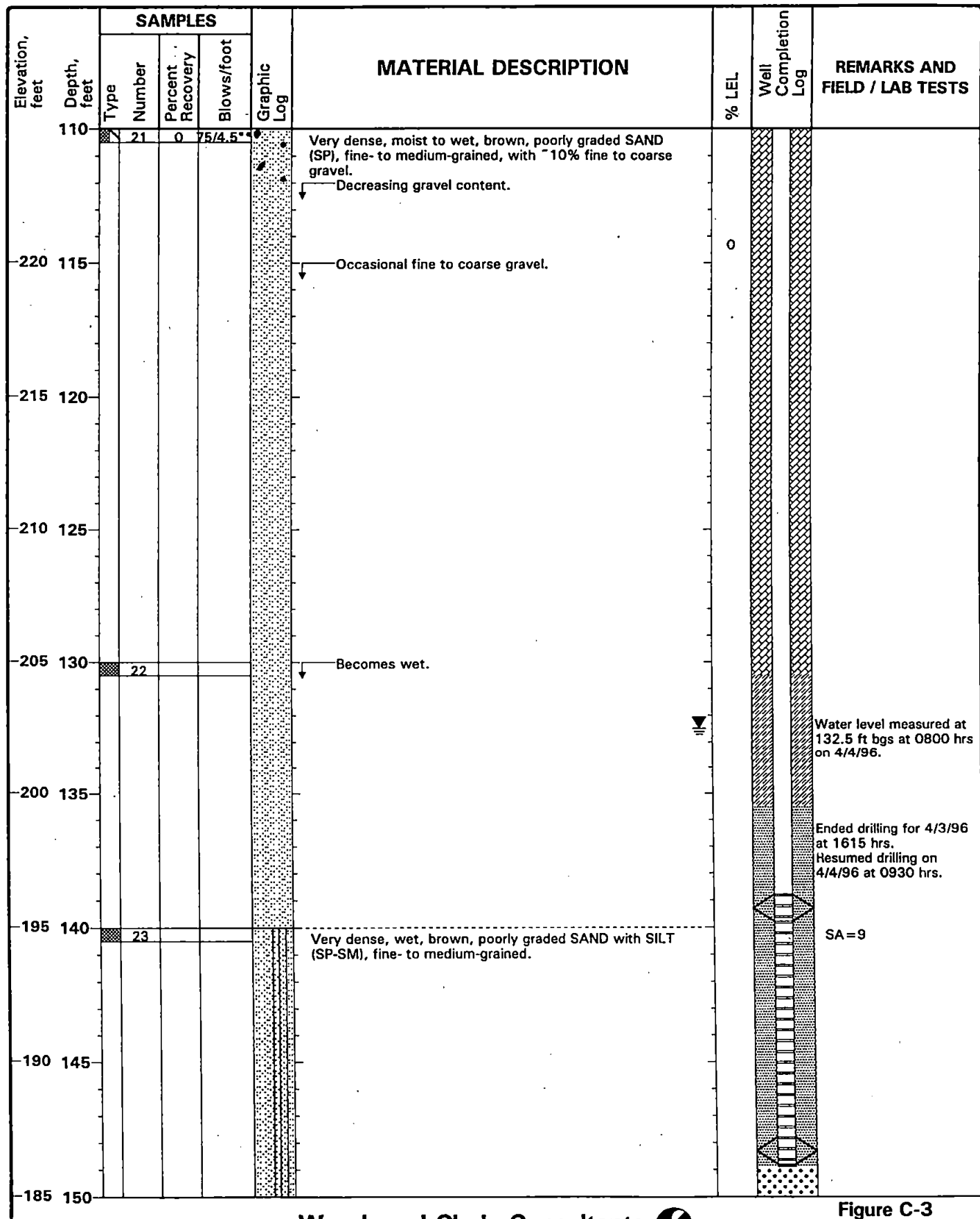
Sheet 3 of 5

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
70		15	10	80/0**			Very dense, moist, brown, poorly graded SAND (SP), fine- to medium-grained, with occasional gravel (continued).			
260	75									
255	80	16	0	75/5**			Very dense, moist, brown, poorly graded SAND with GRAVEL (SP); fine- to medium-grained sand with occasional coarse grains, ~30% mostly fine, subangular to subrounded gravel, trace silt.			
250	85	17					Very dense, moist, brown, poorly graded GRAVEL with SAND (GP); ~50% mostly fine, subrounded to rounded gravel consisting of roughly equal proportions of basalt, diorite, granite, and green sedimentary clasts, fine- to medium-grained sand, trace silt. Becomes ~80% fine to coarse, subangular to subrounded gravel, with fine-grained sand and silt; trace medium- to coarse-grained sand. Becomes moist to wet.			Hard, slow drilling.
245	90	18	0	50/1*			Becomes ~90% mostly fine gravel, occasional cobbles, coarse-grained sand.			
240	95	19					Very dense, moist to wet, brown, poorly graded SAND with GRAVEL (SP); coarse-grained sand, ~30% gravel. Very dense, moist to wet, brown, poorly graded GRAVEL with SAND (GP); ~60% gravel, medium- to coarse-grained sand, trace silt.	0		
235	100		0	75/6**			Decreasing gravel content.			One cobble-size andesite clast recovered in sampler.
230	105	20					Very dense, moist to wet, brown, poorly graded SAND with GRAVEL (SP); fine- to medium-grained sand, ~40% fine, subrounded to rounded gravel.			Driller noted abrupt change to very easy drilling.
225	110									

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 9

Sheet 4 of 5



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW 9

Sheet 5 of 5

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
150						Very dense, saturated, brown, poorly graded SAND with SILT (SP-SM), fine- to medium-grained (continued).			
180	155		24			Very dense, wet, gray, poorly graded SAND (SP), fine- to medium-grained.	0		Sand is denser; color change very abrupt, distinct.
175	160					Occasional soft, gray silt chunks, 0.5 to 1 inch diameter.			Occasional small (0.5- to 1.5-in.) chunks of stiff, dry, gray silt with sand observed 160-175 ft.
170	165		25						
165	170								
160	175						0		
155	180					Abundant 1- to 2-inch lengths of wood. More abundant, larger pieces of wood. Abundant chunks of hard, gray clay, 1 to 5 inches diameter.			Driller noted drilling as if through gravel, but only wood in cyclone.
150	185		26 27 28	100 100 100	40/6" 85/10" Push	Hard, wet, gray CLAY (CH).			SPT at 182 ft not collected; sloughing sand in sampler. Finished drilling at 1230 hrs on 4/4/96. Re-entered borehole on 4/5/96 to collect Shelby tube sample. MC=31 WA=99 PERM k=1E-08
						Bottom of boring at 186.0 feet.			
145	190								

Project: Puyallup / Kit Corner Landfill
Project Location: King County, Washington
Project Number: 954026NA

CONSTRUCTION LOG FOR MONITORING WELL IN BORING PKC-MW 9

Location	Cable tool rig, using tremie pipe		Date(s) Installed		4/5/96 and 4/9/96	
Installed By	Tacoma Pump & Drilling		Observed By	J. McKenna	Total Depth (ft bgs)	186.0
Method of Installation	Cable-tool rig, using tremie pipe					
Screened Interval	186.1 - 196.1 ft MSL		Completion Zone	Sand Aquifer		
Remarks	Metal plate mounted to top of riser pipe for groundwater sampling purposes.					

NOTE: DIAGRAM IS NOT TO SCALE

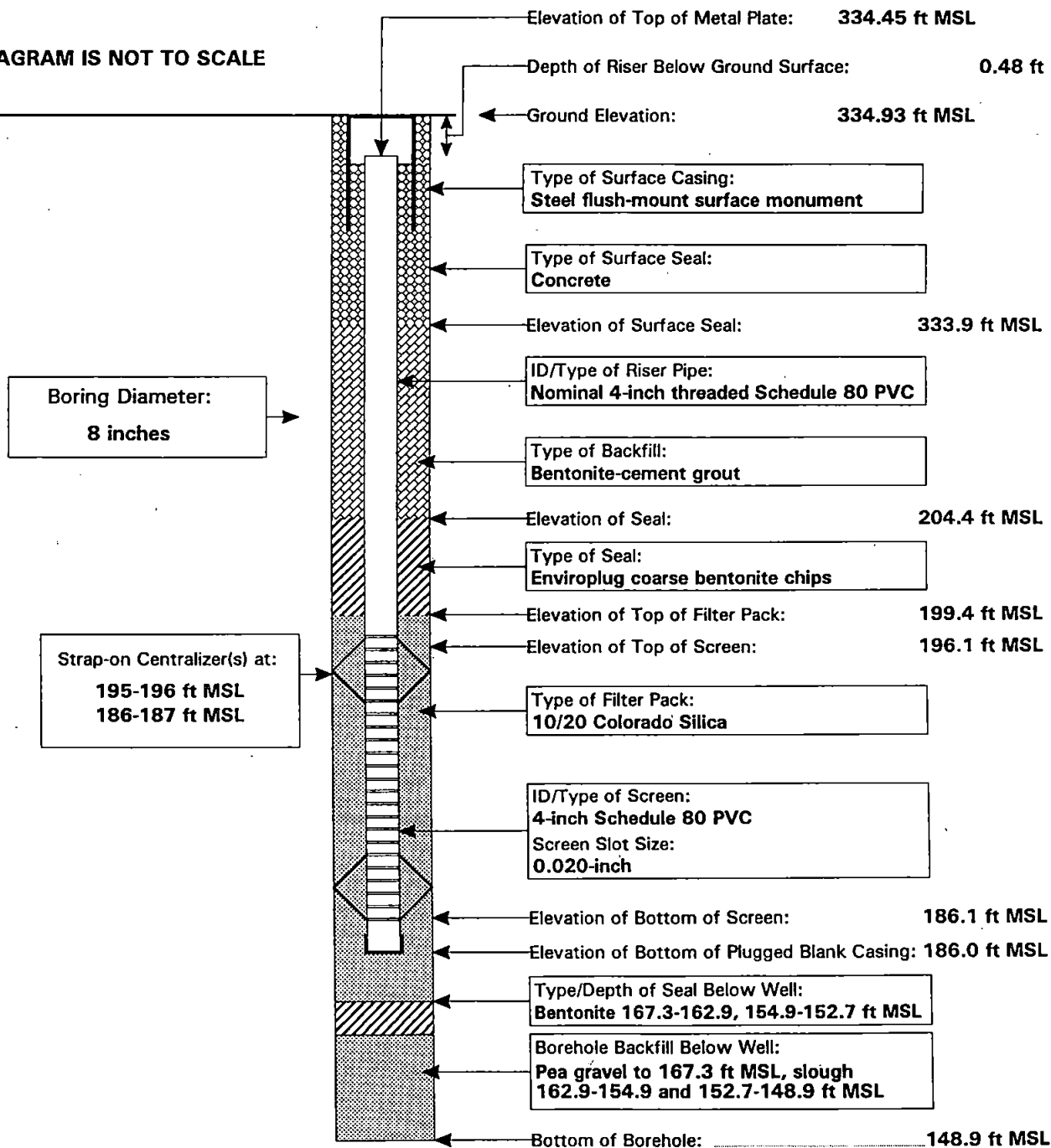


Figure C-3

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW10

Sheet 1 of 5

Date(s) Drilled3/21/96 - 3/22/96				Logged ByJ. McKenna		Checked ByD. Haddock	
Drilling MethodAir Rotary				Drill Bit Size/Type7-7/8-inch drag bit		Surface Elevation (feet)345.1	
Drill Rig TypeForemost DR24				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)166.5	
Depth to Ground-water (feet, bgs)		First144.0	Completion--	24 Hours--		Hammer Weight/Drop (lbs/in.)140 / 30	
Diameter of Hole (inches)8		Diameter of Well (inches)4		Type of Well CasingSchedule 80 PVC		Sampler TypeSPT and California	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 149.6-146 ft, bentonite-cement grout 146-1 ft, concrete 1 ft to surface			
CommentsWest-central edge of landfill							

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
345	0						Very dense, moist, gray to brown, SILTY SAND with GRAVEL (SM); medium- to coarse-grained sand, ~20% coarse gravel consisting of basalt and biotite-bearing granite.			Started drilling at 0815 hrs on 3/21/96.
340	5		1	0	75/4**			0		PID = 0.0 ppm
335	10		2	0	55/5**		Sand becomes coarse-grained; ~25% fine gravel with some coarse clasts.	0		PID = 0.0 ppm
			3							
330	15		4	40	100/8"		Sand becomes medium-grained with some coarse grains; decreasing gravel content to ~10%, consisting mostly of basalt with few granitic clasts.	0		PID = 0.0 ppm
							Sand becomes fine- to medium-grained; increasing gravel content to ~40%, some cobbles, consisting mostly of andesite and basalt with some granitic clasts.			
325	20		5	0	100/2**		Very dense, moist, gray to brown, SILTY SAND with GRAVEL to poorly graded SAND with SILT and GRAVEL (SM/SP-SM); fine- to medium-grained sand, ~40% coarse, subangular to subrounded gravel consisting mostly of basalt with some diorite.	0		PID = 0.0 ppm
							Decreasing gravel content to ~25%.			Driller noted easy drilling.
320	25		6	0	100/2.5**					
							Very dense, moist to wet, gray to brown, SILTY SAND (SM), fine to coarse-grained, with fine to coarse gravel consisting of andesite, diorite, and basalt.			
30										

Figure C-4

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW10

Sheet 2 of 5

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
315	30		7	0	100/ 0.5**		Very dense, moist to wet, brown, poorly graded GRAVEL with SAND (GP); fine to coarse, subrounded gravel and cobbles consisting of quartzite, basalt and andesite, trace silt.	0		PID = 0.0 ppm Slow, hard drilling.
310	35		8 9		100/0**			0		Sample 9 is single cobble; andesite with hornblende, plagioclase, and altered green mineral.
305	40		10	0	100/ 1.5**		Gravel becomes mostly fine, subangular to subrounded; no cobbles.	0		No cobbles, but noticeable grinding during drilling, abundant rock shards. PID = 0.0 ppm
300	45		11 12	50	50/6"		Very dense, moist to wet, brown, well-graded GRAVEL (GW); ~95% fine to coarse, angular to subangular gravel and cobbles, trace medium- to coarse-grained sand.			Lack of recovery suggests many cobble-size clasts.
295	50		13 14	25	100/6**		Decreasing gravel to ~75%, fine (subrounded) to coarse (angular) clasts; increasing fine- to coarse-grained sand, with trace silt. Increasing gravel content to ~80-100%.	0		PID = 0.0 ppm Sample 14 is single cobble with fresh surfaces; sand likely washed out of sampler.
290	55		15				Very dense, moist to wet, brown, poorly graded GRAVEL with SAND (GP); ~60% mostly fine gravel, fine- to coarse-grained sand, trace silt.	0		Gravel observed to have clean, fresh surfaces.
285	60		16	0	100/3**		Very dense, moist to wet, brown, SILTY SAND with GRAVEL to SANDY SILT with GRAVEL (SM/ML); fine-grained sand, ~30% fine gravel. SILT (ML), with occasional coarse-grained sand to fine gravel.			4- to 5-in. cohesive silt chunks coming out of cyclone.
280	65						Very dense, moist to wet, brown, SILTY SAND (SM), fine-grained, with ~10% coarse-grained sand to fine gravel.			
70							Very dense, moist to wet, brown, poorly graded SAND with GRAVEL (SP); coarse-grained sand with some medium grains, ~30% fine, subrounded gravel, trace silt.			

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW10

Sheet 3 of 5

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
275	70	17	0	100/4**			Very dense, moist to wet, brown, poorly graded SAND with GRAVEL (SP); coarse-grained sand with some medium grains, ~30% fine, subrounded gravel, trace silt (continued).			Sand in cyclone (inferred from characteristic sound).
270	75	18					Becomes moist, with decreasing gravel content.	0		Easy drilling.
265	80	19	40	100			Very dense, moist, brown, poorly graded SAND (SP), medium- to coarse-grained, with occasional fine to coarse, subrounded gravel, trace silt. Becomes coarse-grained.			
260	85	20					No gravel.			SA = 4
255	90	21	25	50/4*			Tan clay grading into to gray clay (CL).			Occasional gray clay chunks in cyclone.
250	95	22					Becomes grayish brown, medium- to coarse-grained, with occasional fine to coarse gravel.			Driller reported characteristic "sound" of gravel. Ended drilling for 3/21/96 at 1430 hrs. Resumed drilling on 3/22/96 at 0900 hrs. Two broken rocks in sampler.
245	100	23	0	70/3.5*			Very dense, moist, grayish brown, well-graded SAND with SILT and GRAVEL (SW-SM); ~40% mostly fine, subrounded gravel with occasional coarse, subangular to subrounded clasts up to 1-1/2 inches.			Composite Sample MW10-23 + 24: SA = 6
240	105	24					Coarse-grained sand and fine gravel become angular.			Very difficult drilling.
110										Driller reported slightly easier drilling.

Figure C-4

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW10

Sheet 4 of 5

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
-235	110	25	0	50/2**			Very dense, moist, grayish brown, poorly graded SAND with GRAVEL (SP); coarse-grained sand, ~40% fine to coarse, subangular to subrounded gravel, trace silt.	0		PID = 0.0 ppm
-230	115	26					Very dense, moist, grayish brown, poorly graded GRAVEL with SAND (GP); ~70% fine to coarse, subangular to subrounded gravel, medium to coarse-grained sand.			
-225	120	27	40	75/6*			Gravel becomes coarser, more rounded, with occasional cobbles, consisting of diorite, quartzite, and basalt with altered green rind.			Trace to no fine sand observed.
-220	125						Very dense, moist, grayish brown, poorly graded SAND (SP), medium- to coarse-grained, with occasional coarse gravel, trace silt.			
-215	130	28	25	90/11*			Very occasional gravel, no silt.			Two clasts in sampler: diorite, basalt.
-210	135	29					No gravel.			
-205	140	30	50	60			Very dense, moist to wet, grayish brown, poorly graded SAND with SILT (SP-SM), fine- to medium-grained.			SA=6
-200	145						Becomes gray.			Water table at 144 ft at 1230 hrs on 3/22/96.
150							Becomes dense, wet.			

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW10

Sheet 5 of 5

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
-195	150		31		40		Dense, wet, grayish brown, poorly graded SAND with SILT (SP-SM), fine- to medium-grained (continued).			Sampler saturated.
-190	155							0		PID = 0.0 ppm
-185	160		32				Dense, wet, grayish brown, poorly graded SAND (SP), fine- to medium-grained, with trace silt.			Very clean sand observed in cyclone. SA=1
-180	165		33	50	13		↓ Becomes medium dense.			
							Bottom of boring at 166.5 feet.			Finished drilling on 3/22/96.
-175	170									
-170	175									
-165	180									
-160	185									
-155	190									

Woodward Clyde Consultants

Figure C-4



Project: Puyallup / Kit Corner Landfill
Project Location: King County, Washington
Project Number: 954026NA

CONSTRUCTION LOG FOR MONITORING WELL IN BORING PKC-MW10

Location	Cable tool rig, using tremie pipe		Date(s) Installed	3/25/96
Installed By	Tacoma Pump & Drilling	Observed By	M. Sydow	Total Depth (ft bgs) 166.5
Method of Installation	Cable-tool rig, using tremie pipe			
Screened Interval	183.2 - 193.2 ft MSL	Completion Zone	Sand Aquifer	
Remarks	Metal plate mounted to top of riser pipe for groundwater sampling purposes.			

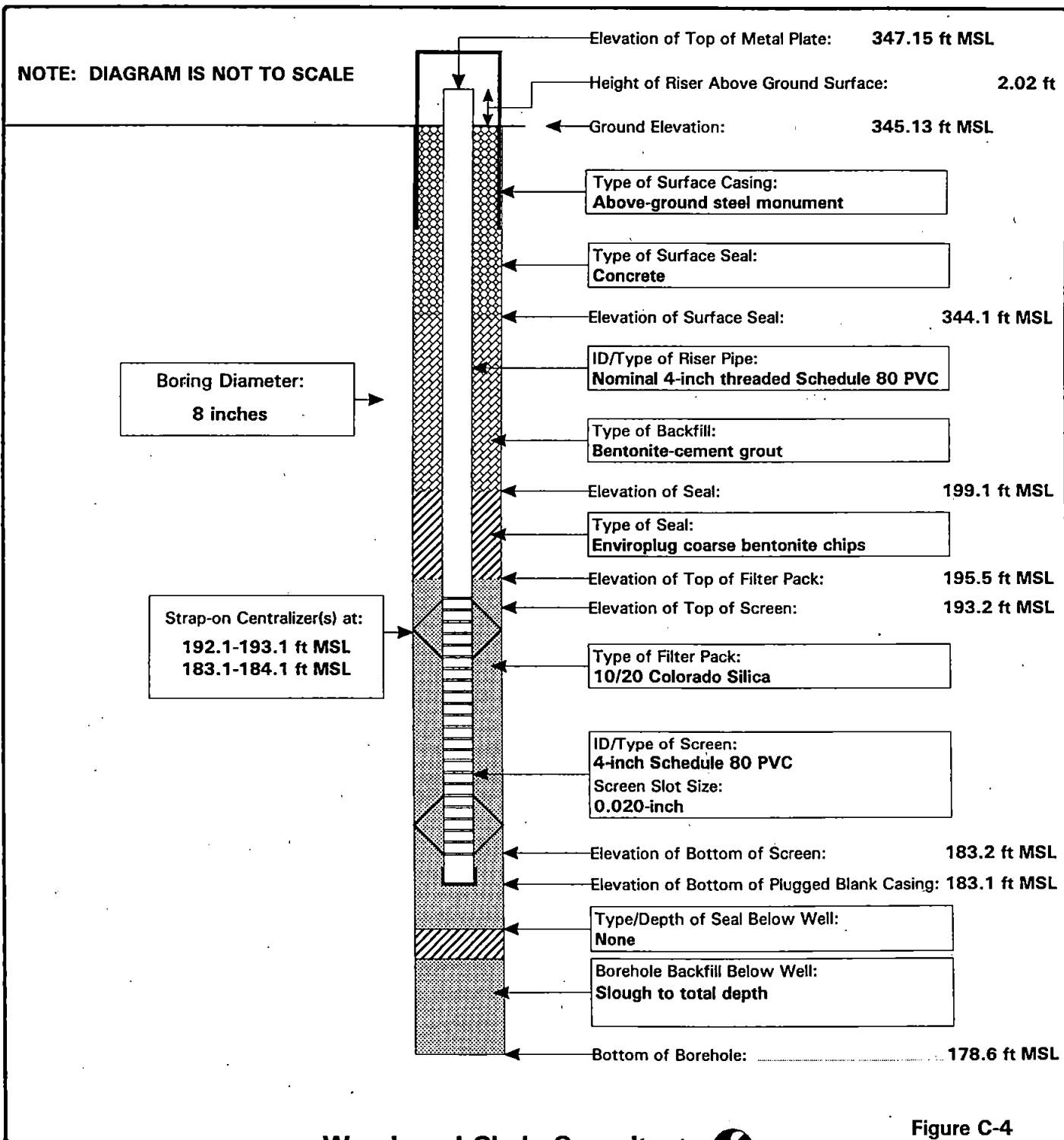


Figure C-4

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW11

Sheet 1 of 5

Date(s) Drilled3/25/96 - 3/26/96				Logged ByJ. McKenna		Checked ByD. Haddock	
Drilling MethodAir Rotary				Drill Bit Size/Type7-7/8-inch drag bit		Surface Elevation (feet)354.2	
Drill Rig TypeForemost DR24				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)171.0	
Depth to Ground-water (feet, bgs)		First152.5	Completion--	24 Hours--	Hammer Weight/Drop (lbs/in.)140 / 30		Sampler TypeSPT
Diameter of Hole (inches)8		Diameter of Well (inches)4		Type of Well CasingSchedule 80 PVC		Screen Perforation0.020-inch slot	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 154.4-147.5 ft and 3-1 ft, bentonite-cement grout 147.5-3 ft; concrete 1-0 ft			
CommentsEast side of Frontage Road, near fire hydrant							

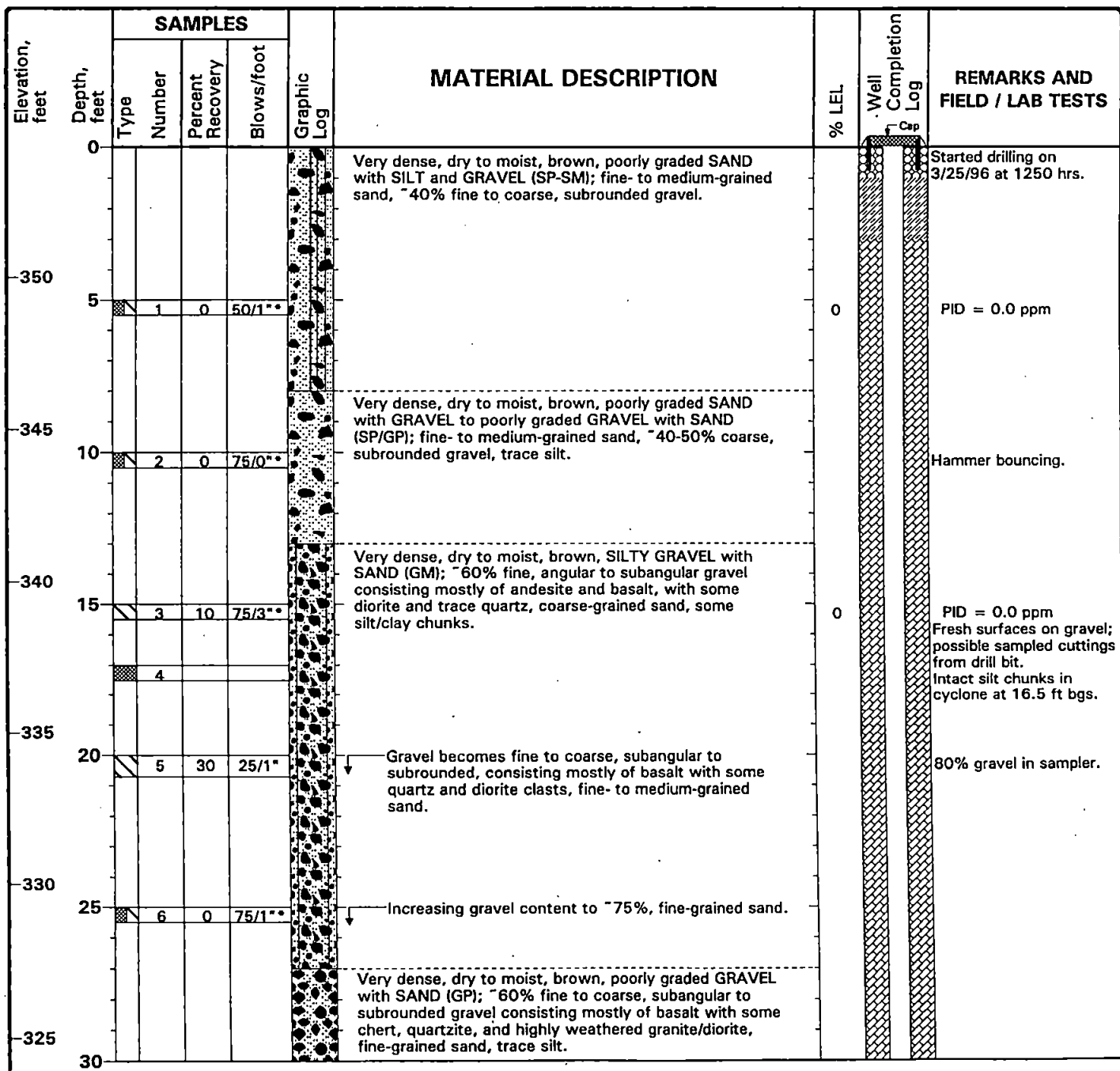


Figure C-5

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW11

Sheet 2 of 5

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
30		7	25	75/5**		Very dense, dry to moist, brown, poorly graded GRAVEL with SAND (GP); ~60% fine to coarse, subangular to subrounded, fine to coarse gravel consisting mostly of basalt with some chert, quartzite, and highly weathered granite/diorite, fine-grained sand, trace silt (continued).			
320	35	8	25	75/5**		Gravel becomes finer, angular, with some weathered andesite clasts, fine- to medium-grained sand.	0		PID = 0.0 ppm
315	40	9	0	75/1**		Very dense, dry to moist, brown, poorly graded SAND with GRAVEL (SP); fine- to medium-grained sand, fine, angular gravel, trace silt.			
310	45	10	10	75/3**		Very dense, dry to moist, brown, well-graded GRAVEL with SAND (GW); fine to coarse, subangular to subrounded gravel, fine- to medium-grained sand.			
305	50	11	15	75/5**		Very dense, dry to moist, brown, SILTY GRAVEL with SAND (GM); fine gravel, fine-grained sand.			
300	55	12				Very dense, moist, brown, poorly graded SAND (SP), medium-grained, with occasional gravel.			
						Very dense, moist, brown, SILTY SAND (SM), fine-grained, with occasional gravel.	0		PID = 0.0 ppm Ended drilling for 3/25/96 at 1715 hrs. Resumed drilling on 3/26/96 at 0915 hrs.
295	60	13	20	75/3**		Increasing gravel content. Becomes fine- to medium-grained.			Gravel content undetermined due to grinding by bit.
290	65	14				Decreasing gravel content.			Driller noted easy drilling.
285	70					Very dense, moist, brown, SILTY SAND to SANDY SILT (SM/ML), fine-grained sand with some coarse grains, some clay, occasional gravel.			

Figure C-5

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW11

Sheet 3 of 5

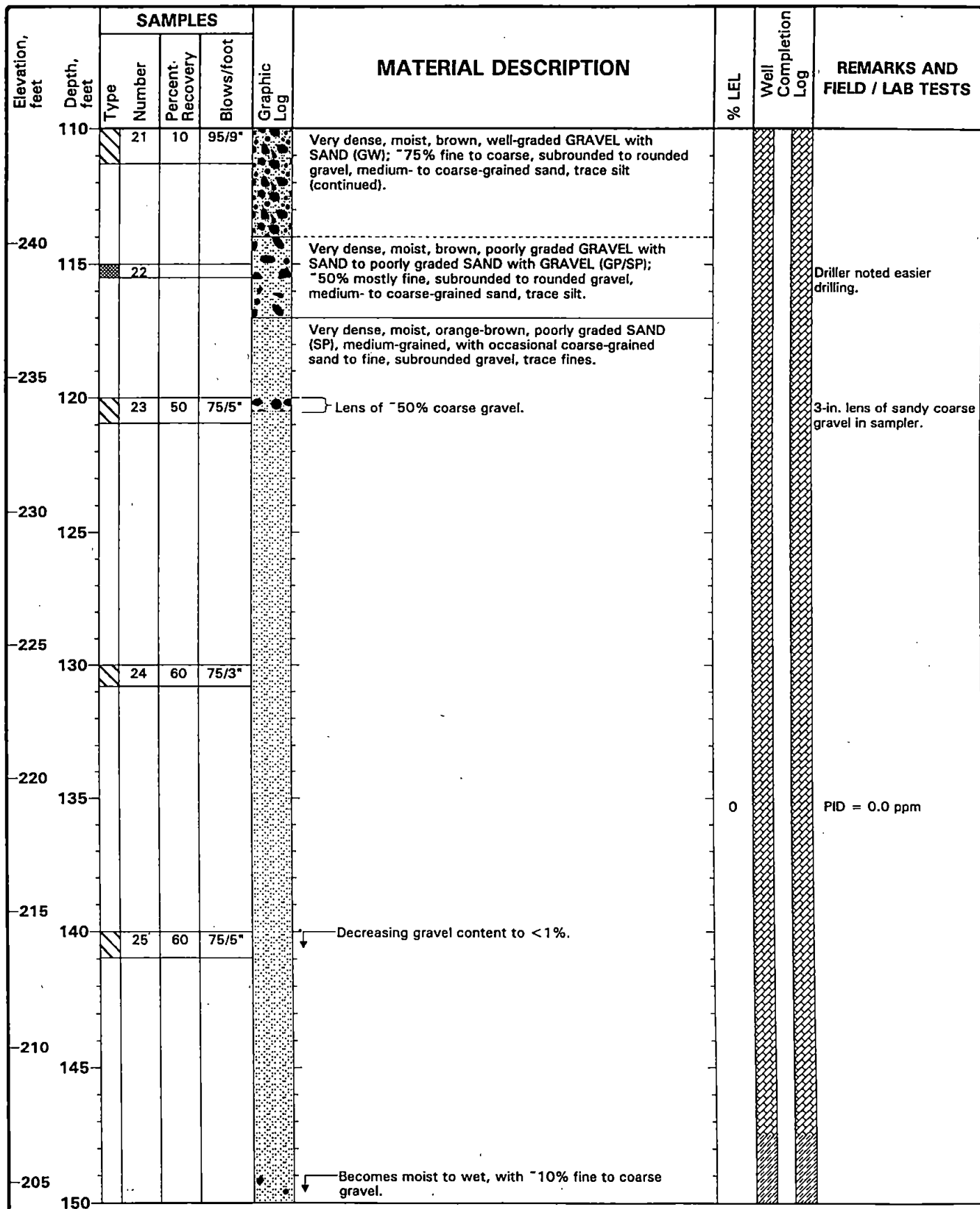
Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
70							Very dense, moist, SILTY SAND to SANDY SILT (SM/ML), fine-grained sand with some coarse grains, some clay, occasional gravel (continued). SILTY SAND (SM).			
280							SILTY GRAVEL (GM).			Intact chunks of clayey silt in cyclone.
75	15						Very dense, wet, brown, poorly graded SAND (SP), medium- to coarse-grained, with occasional fine gravel, trace silt. CLAY to SILT (CL/ML). Poorly graded SAND with SILT and GRAVEL (SP-SM).	0		PID = 0.0 ppm
275							Increasing gravel content to ~10-20%, consisting of diorite and basalt.			Coarse gravel and cobbles in cyclone; possible gravel lens.
80	16	30	80/8"				Decreasing gravel to ~10%, fine to coarse, subrounded to rounded clasts.			
270							With clay chunks, 1 to 2 inches diameter.			Driller noted soft drilling, abundant clay chunks in cyclone; possible clay layer.
265										Driller noted hard drilling.
90	17	60	75/4"							
260										
95	18									
255							Very dense, moist, brown, well-graded GRAVEL with SAND (GW); ~75% fine to coarse, subrounded to rounded gravel, medium- to coarse-grained sand, trace silt.	0		Hard drilling.
100	19	20	50/2"							PID = 0.0 ppm
250							Very dense, moist, brown, poorly graded GRAVEL with SAND (GP); ~75% mostly fine, subrounded to rounded gravel, medium- to coarse-grained sand, trace silt.	0		PID = 0.0 ppm
105	20									
245							Very dense, moist, brown, well-graded GRAVEL with SAND (GW); ~75% fine to coarse, subrounded to rounded gravel, medium- to coarse-grained sand, trace silt.			
110										

Figure C-5

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW11

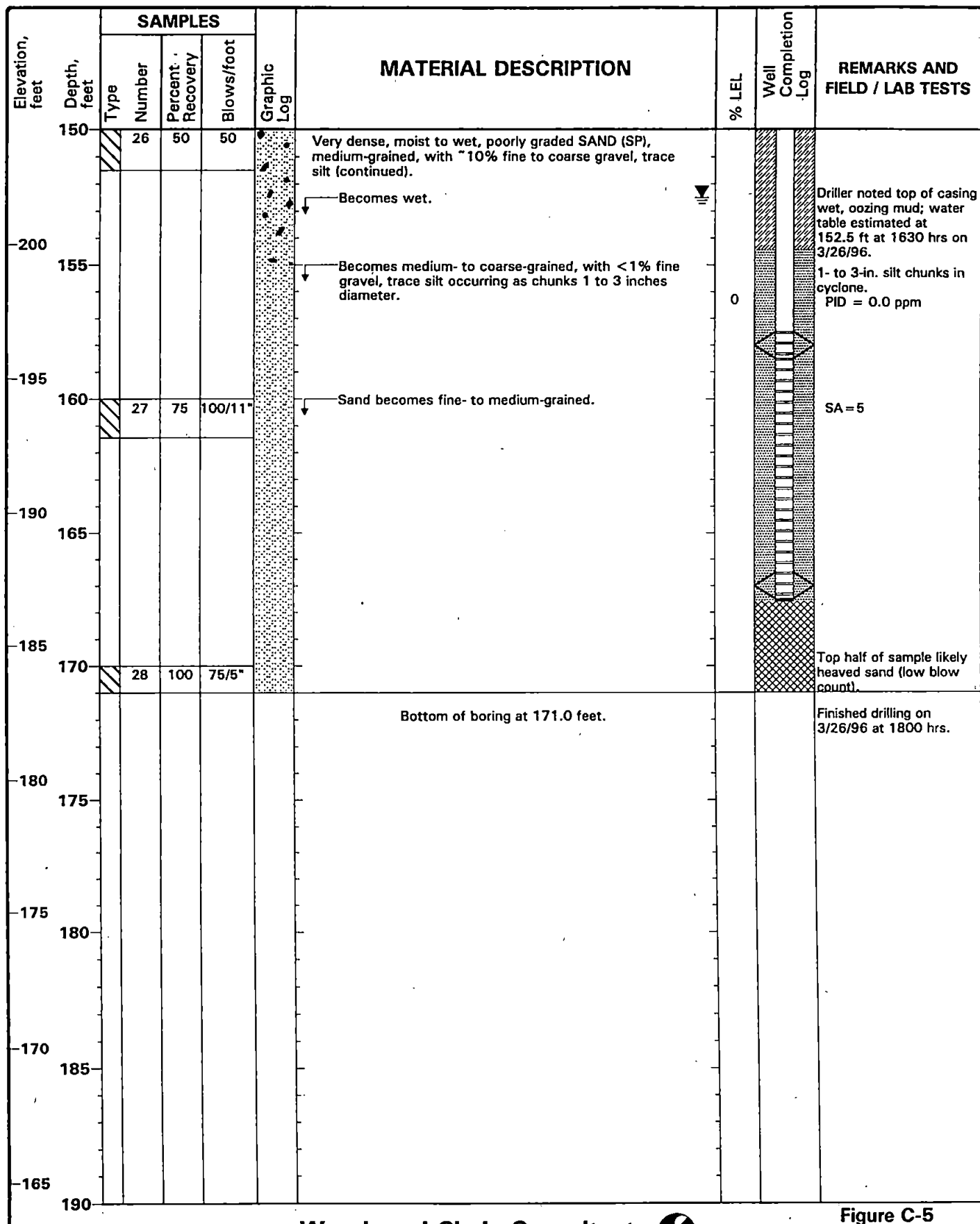
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Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW11

Sheet 5 of 5



Project: Puyallup / Kit Corner Landfill
Project Location: King County, Washington
Project Number: 954026NA

CONSTRUCTION LOG FOR MONITORING WELL IN BORING PKC-MW11

Location	Cable tool rig, using tremie pipe		Date(s) Installed	4/2/96 - 4/3/96	
Installed By	Tacoma Pump & Drilling	Observed By	J. McKenna	Total Depth (ft bgs)	171.0
Method of Installation	Cable-tool rig, using tremie pipe				
Screened Interval	186.7 - 196.7 ft MSL		Completion Zone	Sand Aquifer	
Remarks	Metal plate mounted to top of riser pipe for groundwater sampling purposes.				

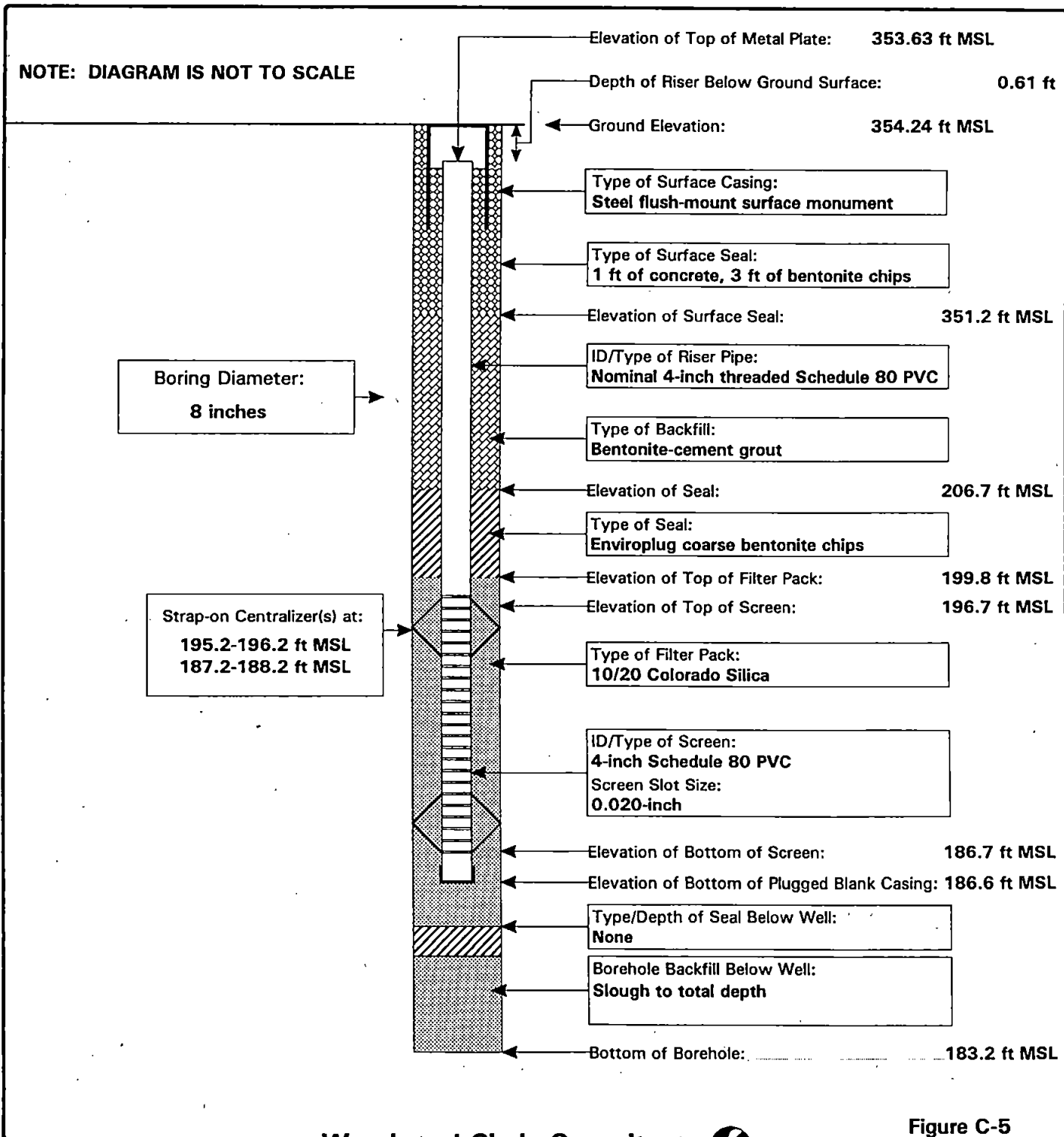


Figure C-5

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW12

Sheet 1 of 6

Date(s) Drilled3/27/96 - 3/29/96				Logged ByJ. McKenna		Checked ByD. Haddock	
Drilling MethodAir Rotary				Drill Bit Size/Type7-7/8-inch tricone button bit		Surface Elevation (feet)357.8	
Drill Rig TypeForemost DR24				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)196.5	
Depth to Ground-water (feet, bgs)		First156.1	Completion--	24 Hours--	Hammer Weight/ Drop (lbs/in.)140 / 30		Sampler TypeSPT
Diameter of Hole (inches)8		Diameter of Well (inches)4		Type of Well CasingSchedule 80 PVC		Screen Perforation0.020-inch slot	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 192-184.6 ft, 175-169.1 ft, 154.9-148.3 ft, 22-1 ft; bentonite-cement grout 148.3-22 ft; concrete 1-0 ft			
CommentsNorthwest of landfill, 330 ft north of Access Road							

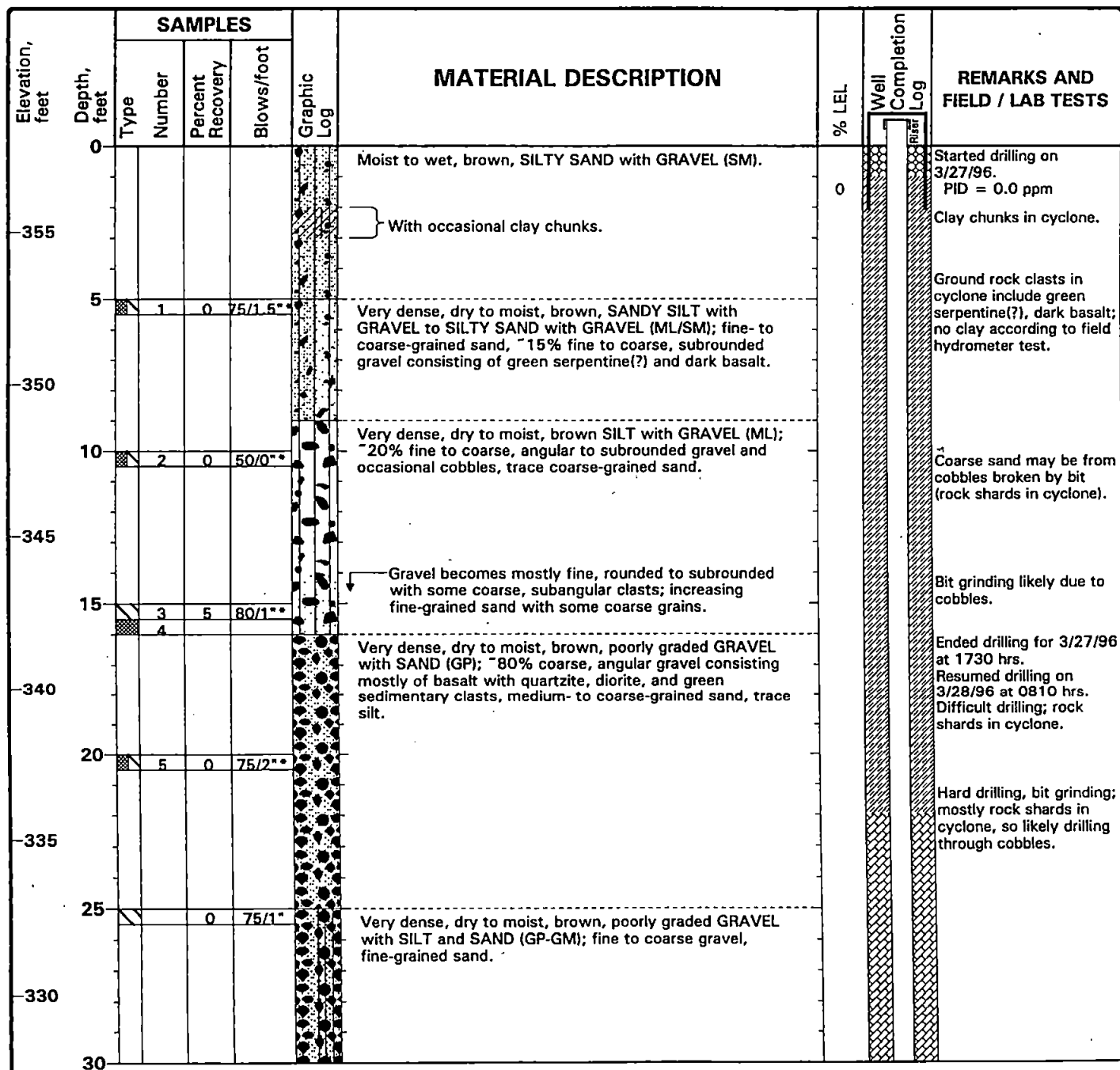


Figure C-6

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW12

Sheet 2 of 6

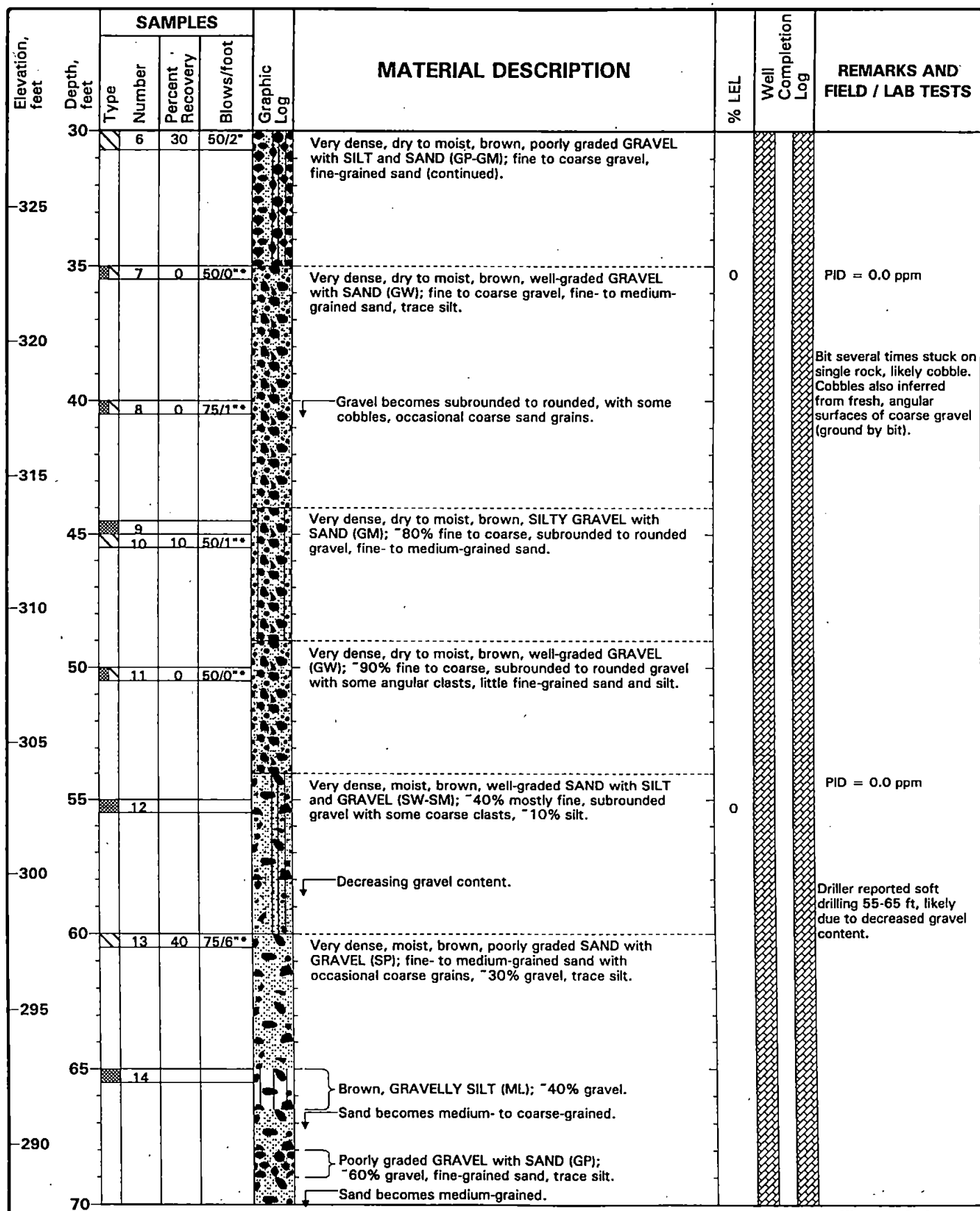


Figure C-6

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW12

Sheet 3 of 6

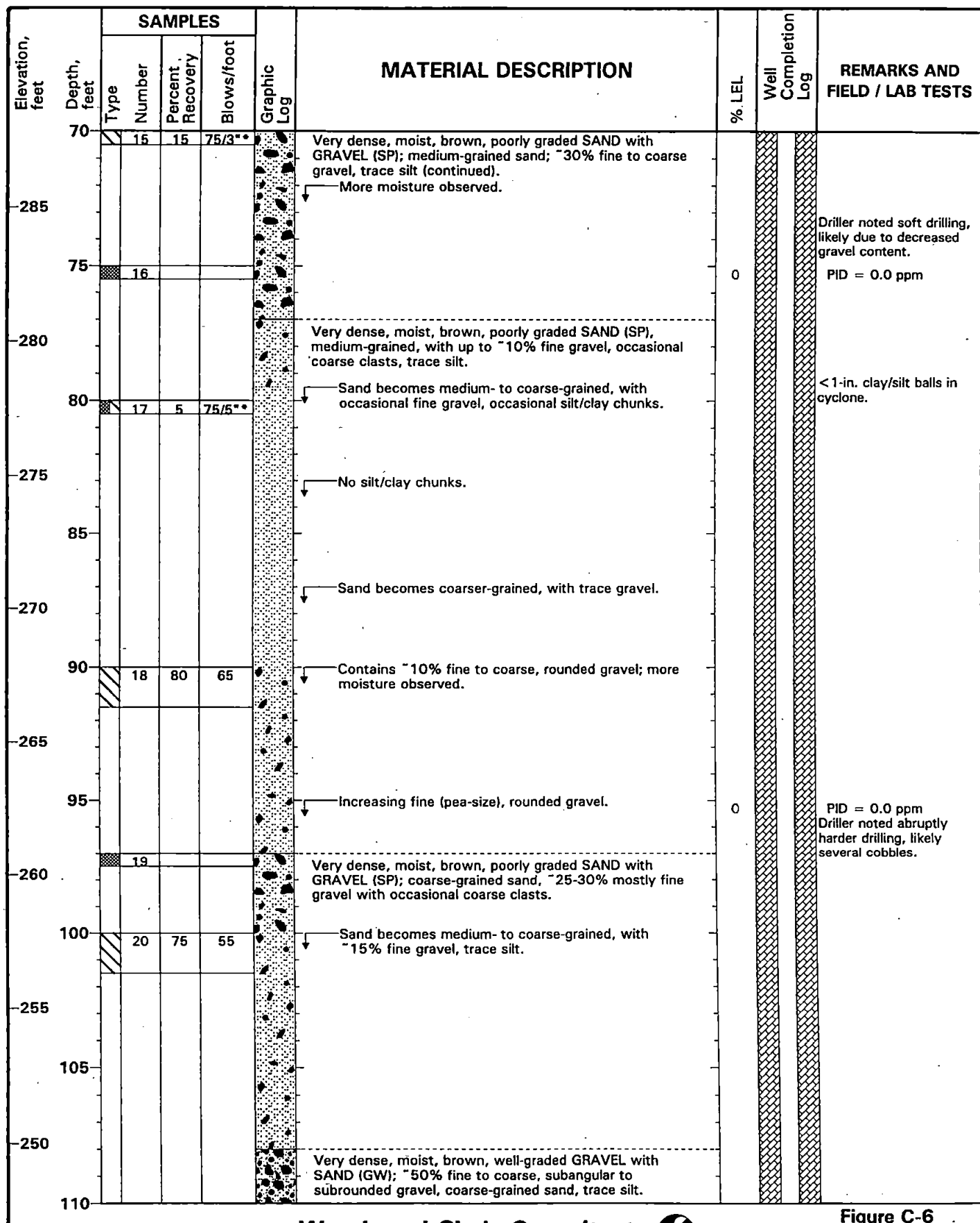
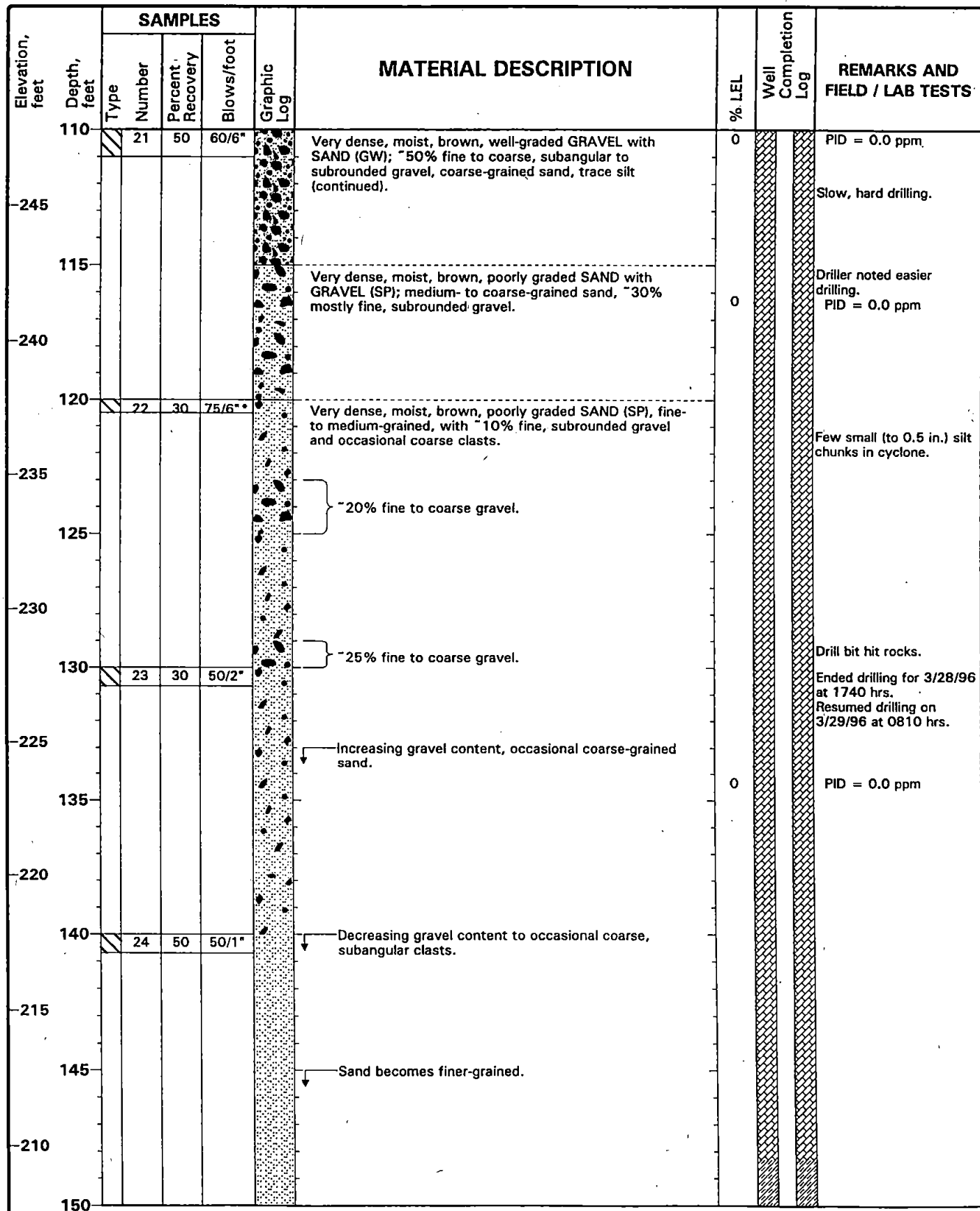


Figure C-6

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW12

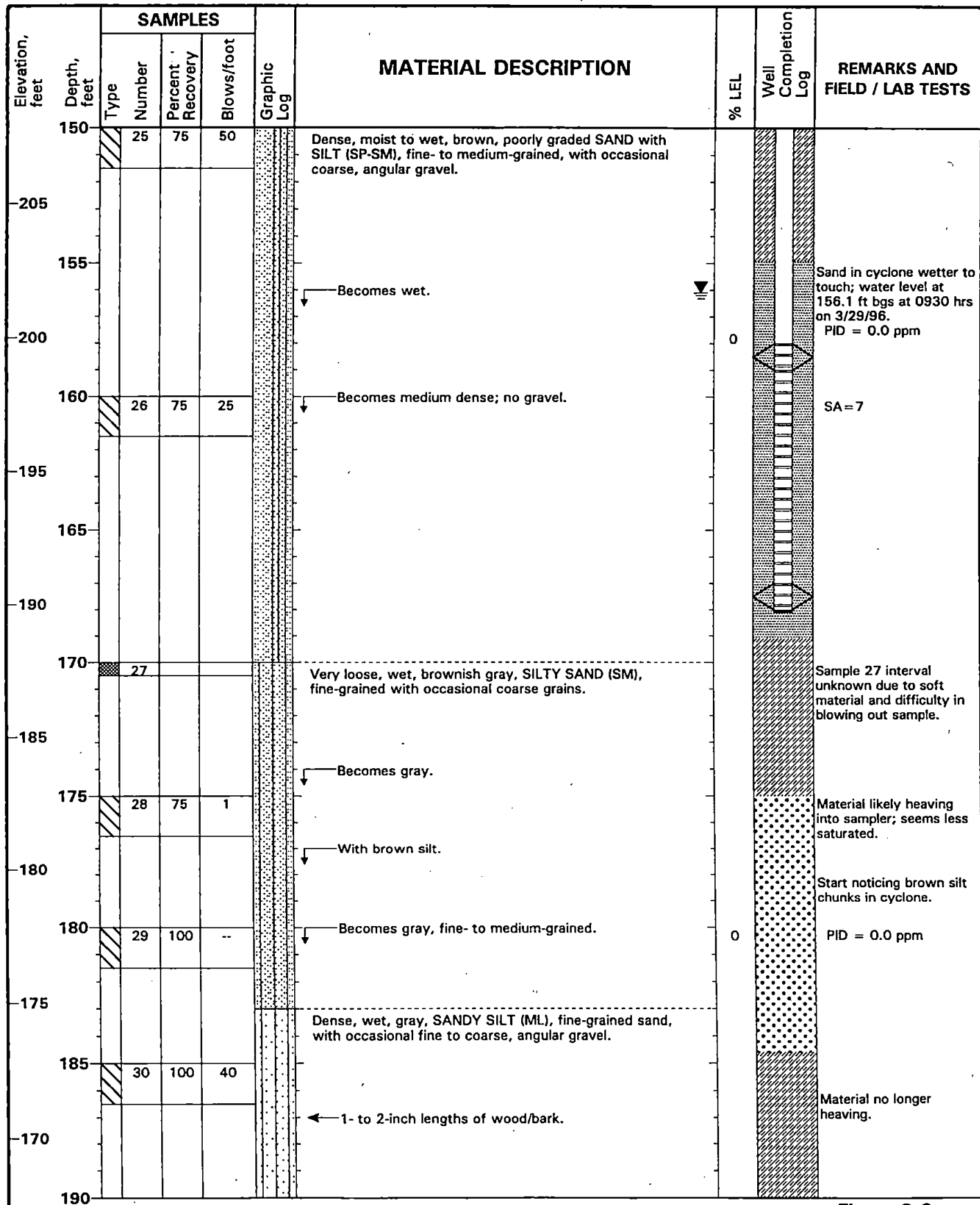
Sheet 4 of 6



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW12

Sheet 5 of 6



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW12

Sheet 6 of 6

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
190			31	100	19		Medium dense, wet, gray, SANDY SILT to SILTY SAND (ML/SM), fine-grained sand.			Silt/clay chunks in cyclone.
165							Medium dense, wet, gray, SANDY SILT (ML), fine-grained sand.			
195			32	100	13					
160							Bottom of boring at 196.5 feet.			Finished drilling at 1700 hrs on 3/29/96.
200										
155										
205										
150										
210										
145										
215										
140										
220										
135										
225										
130										
230										

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

CONSTRUCTION LOG FOR MONITORING WELL IN BORING PKC-MW12

Location	Cable tool rig, using tremie pipe	Date(s) Installed	4/3/96 - 4/5/96
Installed By	Tacoma Pump & Drilling	Observed By	M. Sydow
		Total Depth (ft bgs)	196.5
Method of Installation	Cable-tool rig, using tremie pipe		
Screened Interval	189.8 - 199.8 ft MSL	Completion Zone	Sand Aquifer
Remarks	Metal plate mounted to top of riser pipe for groundwater sampling purposes.		

NOTE: DIAGRAM IS NOT TO SCALE

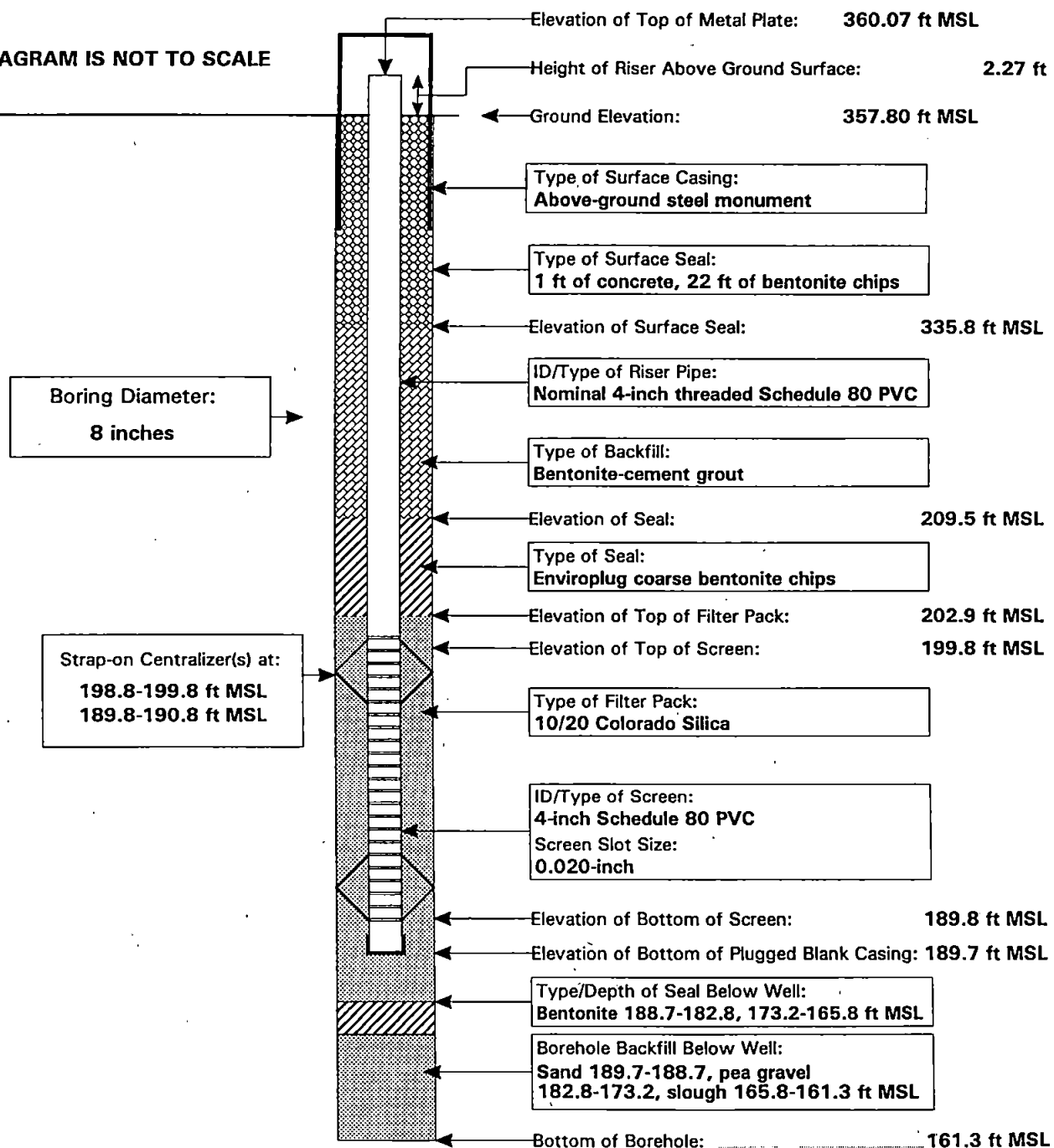


Figure C-6



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW13

Sheet 1 of 2

Date(s) Drilled3/12/96				Logged ByB. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (4-1/4-inch-ID)				Drill Bit Size/Type8-1/2-inch carbide bullet with spade		Surface Elevation (feet)344.0	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)38.2	
Depth to Ground-water (feet, bgs)		First17.0	Completion19.7	24 Hours—	Hammer Weight/Drop (lbs/in.)140 / 30		Sampler TypeCalifornia
Diameter of Hole (inches)8-1/2		Diameter of Well (inches)2		Type of Well CasingSchedule 40 PVC		Screen Perforation0.010-inch slot	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 38.2-34 ft and 20-1 ft, concrete 1 ft to surface			
Comments							

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
0							COVER SOIL Moist, brown, SILTY GRAVEL with SAND (GM), subrounded gravel up to 2 inches, medium-grained sand.	0		Started drilling at 1030 hrs.
340			1		—			0		
5			2	0	57			0		Sampler probably pushing on a cobble. Driller noted difference in drilling about 6.5 ft (top of refuse?).
335			3	33	39		REFUSE: Moist to wet; plastic bags, hard plastic, rusted tin can, cloth (releases water when squeezed); some to moderate decomposition.	0		PID = 3.5 ppm H2S = 0 ppm
10										
330			4	60	110/7*		Wet refuse; plastic bags, hard plastic, bottle cap, wire, cloth, string; moderate to much decomposition.	0		PID = 16.1 ppm H2S = 0 ppm
325							Saturated refuse; more malodorous than other, drier samples.			Softer drilling at 17 ft (possibly saturated refuse).
20			5A 5B	75	23		← Saturated refuse (Sample 5A). ← Wet refuse (Sample 5B); wood chunk and black substance; moderate decomposition; in matrix of SILTY SAND (SM), fine-grained.	0		PID = 16.9 ppm H2S = 0 ppm
320			6	33	55		Saturated, dark gray refuse; paper, cloth, plastic, metal; moderate to much deposition; odor.	112 146		PID = 4.8 ppm H2S = 0 ppm
25			7	33	20		Saturated, dark gray refuse; slightly decomposed wood, plastic bag, blue plastic cap, metal.	—		
315			8	20	28		Saturated, dark gray refuse; thin wood pieces (somewhat strong, some decomposition); odor.	165		No sample retained. PID = 3.1 ppm H2S = 0 ppm
30										

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW13

Sheet 2 of 2

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot				
30						REFUSE in little soil matrix, saturated, dark gray (continued).			
			9	33	50/5*	Saturated, dark gray refuse; plastic bags; greatly increased soil matrix.	26		Harder drilling at 32.5 ft. PID = 0.7 ppm H2S = 0 ppm
310									
	35		10	90	5/5.5**	Very dense, wet, dark gray, SILTY SAND with GRAVEL (SM), gravel up to 3 inches.	23		PID = 0.0 ppm H2S = 0 ppm
			11	20	50/1.5*		2		PID = 0.0 ppm H2S = 0 ppm
305						Bottom of boring at 38.2 feet.			Finished drilling at 1345 hrs.
40									
300									
45									
295									
50									
290									
55									
285									
60									
280									
65									
275									
70									

Figure C-7

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW15

Sheet 1 of 1

Date(s) Drilled3/11/96				Logged ByM. Craig / B. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (4-1/4-inch-ID)				Drill Bit Size/Type8-1/2-inch carbide bullet with spade		Surface Elevation (feet)340.6	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)26.0	
Depth to Ground-water (feet, bgs)		First Dry	Completion Dry	24 Hours Dry	Hammer Weight/Drop (lbs/in.)140 / 30		Sampler TypeCalifornia
Diameter of Hole (inches)8-1/2		Diameter of Well (inches)2		Type of Well CasingSchedule 40-PVC		Screen Perforation0.010-inch slot	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 26-23 ft and 9-2 ft, concrete 2 ft to surface			
Comments							

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot					
340	0						COVER SOIL Moist, brown, poorly graded SAND with SILT and GRAVEL to SILTY SAND with GRAVEL (SP-SM/SM).			
335	5		1	5	22		REFUSE: Damp; metal debris (not corroded), hard plastic fragments.			
330	10						Rubber debris, plastic. Coarse gravel. Soil matrix consists of moist, black, SILT with SAND and GRAVEL (ML); moderately decomposed plastic.			
325	15						Becomes damp to moist.	0		PID = 0.0 ppm
320	20						Mostly soil matrix consisting of wet, gray, SILTY SAND (SM), fine- to medium-grained, with occasional fine gravel; occasional plastic and metal debris.	0		PID = 0.0 ppm
315	25		2	30	50/3*		Very dense, moist, brown, poorly graded SAND with SILT and GRAVEL (SP-SM), medium- to coarse-grained sand, fine gravel.	0		Hard drilling at 22 ft. PID = 0.0 ppm
							Bottom of boring at 26.0 feet.			Terminated drilling at 1415 hrs due to refusal.
	30									

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW16

Sheet 1 of 1

Date(s) Drilled3/13/96				Logged ByB. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (4-1/4-inch-ID)				Drill Bit Size/Type8-1/2-inch carbide bullet with spade		Surface Elevation (feet)321.8	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)26.0	
Depth to Ground-water (feet, bgs)		First Dry	Completion Dry	24 Hours Dry	Hammer Weight/Drop (lbs/in.)140 / 30		Sampler TypeCalifornia
Diameter of Hole (inches)8-1/2		Diameter of Well (inches)2		Type of Well CasingSchedule 40 PVC		Screen Perforation0.010-inch slot	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 26-23 ft and 10-1 ft, concrete 1 ft to surface			
Comments							

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
0									Started drilling at 0930 hrs.
-320									Hard drilling, rig chatter at 3 ft.
	5		1	100	50/5.5"		0		PID = 0.4 ppm H2S = 0 ppm Equipment broke at 0945 hrs; resumed drilling at 1015 hrs.
-315									
	10		2	80	50/3.5"		0		Harder drilling at 10 ft. PID = 0.7 ppm H2S = 0 ppm
-310									
	15		3	75	85/11.5"		0		Much easier drilling at 15.2 ft. H2S = 0 ppm MC=14 SA=5
-305									
	20		4	100	130/11"		0		PID = 0.0 ppm H2S = 0 ppm
-300									
	25		5A 5B	60	85/6"		0		PID = 0.0 ppm H2S = 0 ppm
-295									Finished drilling at 1200 hrs.
	30								



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW17

Sheet 1 of 1

Date(s) Drilled3/12/96				Logged ByB. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (4-1/4-inch-ID)				Drill Bit Size/Type8-1/2-inch carbide bullet with spade		Surface Elevation (feet)334.3	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)26.5	
Depth to Ground-water (feet, bgs)	First Dry	Completion Dry	24 Hours Dry	Hammer Weight/ Drop (lbs/in.)140 / 30		Sampler Type	California
Diameter of Hole (inches)8-1/2		Diameter of Well (inches)2		Type of Well CasingSchedule 40 PVC		Screen Perforation0.010-inch slot	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 26.5-21.5 ft and 8-1 ft, concrete 1 ft to surface			
Comments							

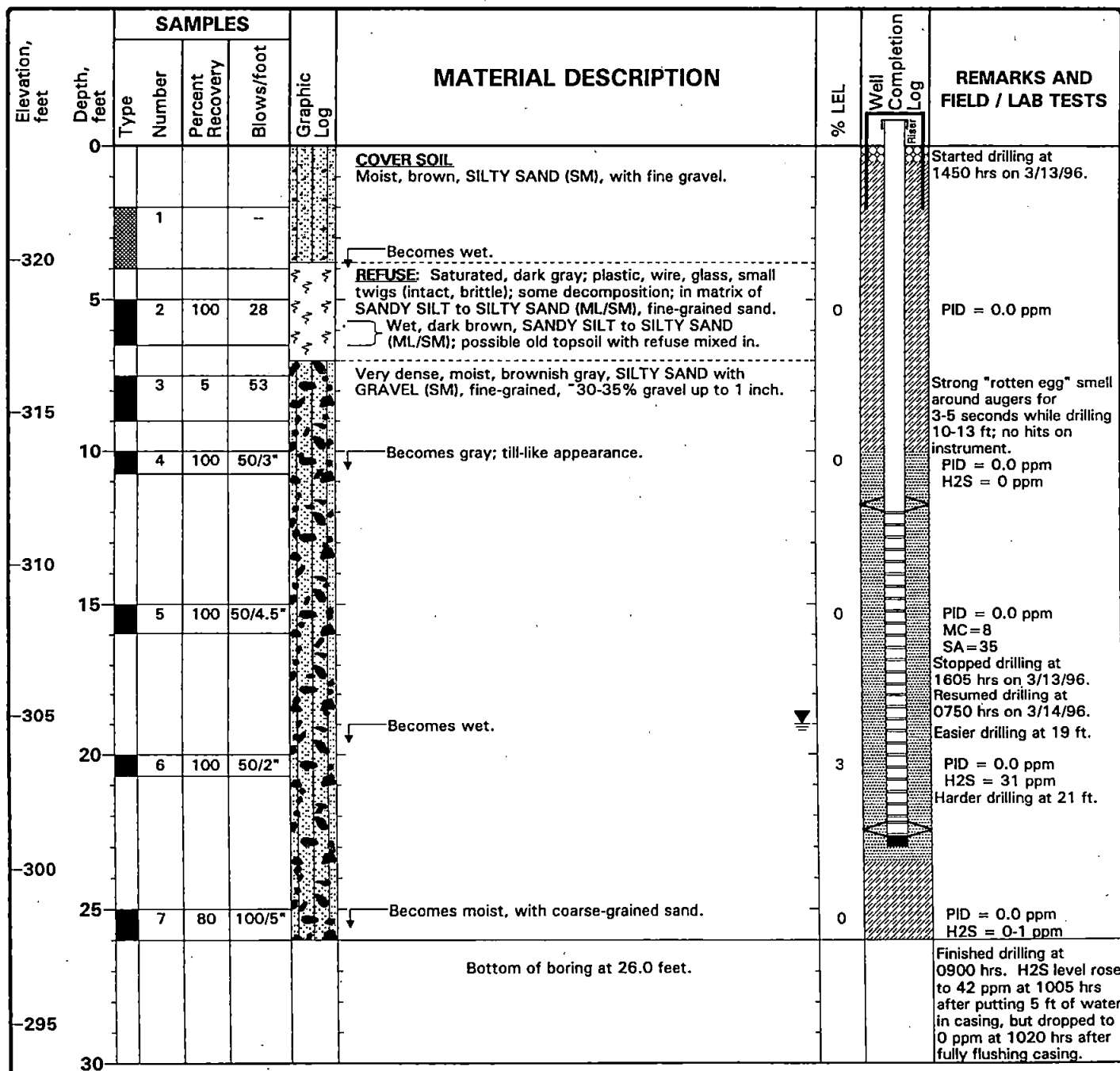
Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
0	0								Started drilling at 1530 hrs.
			1						Composite Sample TP17 + TP18 + MW17-1: SA=10
-330	5		2	0	35/10"		0		Driller noted easy drilling at 4 ft; refuse observed on auger flights. No recovery; sampler bouncing on hard material. PID = 0.3 ppm H2S = 0 ppm
-325	10		3	50	21		0		PID = 0.0 ppm H2S = 0 ppm
-320	15		4	100	88		0		PID = 0.0 ppm H2S = 0 ppm
-315	20		5	100	50/1.5"		-		
			6	100	50/5"		0		Harder drilling at 22 ft. PID = 0.0 ppm
-310	25		7A 7B	100	100/11"		0		PID = 0.1 ppm MC=8 SA=17
-305	30								Finished drilling and started well installation at 1730 hrs.

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-MW18

Sheet 1 of 1

Date(s) Drilled3/13/96 - 3/14/96				Logged ByB. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (4-1/4-inch-ID)				Drill Bit Size/Type8-1/2-inch carbide bullet with spade		Surface Elevation (feet)323.7	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)26.0	
Depth to Ground-water (feet, bgs)	First19.0	Completion-	24 Hours-	Hammer Weight/Drop (lbs/in.)140 / 30		Sampler Type	California
Diameter of Hole (inches)8-1/2		Diameter of Well (inches)2		Type of Well CasingSchedule 40 PVC		Screen Perforation0.010-inch slot	
Type of Sand Pack10/20 Colorado Silica				Type of Seal(s)Bentonite chips 26-23.5 ft and 10-0.5 ft, concrete 0.5 ft to surface			
Comments							



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP23

Sheet 1 of 4

Date(s) Drilled3/11/96 - 3/13/96				Logged ByM. Craig		Checked ByD. Haddock	
Drilling MethodAir Rotary with Casing				Drill Bit Size/Type7-7/8-inch tricone bit		Surface Elevation (feet)322.1	
Drill Rig TypeDR 24 (Foremost)				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)124.5	
Depth to Ground-water (feet, bgs)		First--	Completion--	24 Hours--		Hammer Weight/Drop (lbs/in.)140 / 30	
Diameter of Hole (inches)8-3/4		Diameter of Well (inches)3/4 (5x)		Type of Well CasingSchedule 80 PVC		Screen Perforation0.020-inch slot	
Type of Sand PackPea gravel				Type of Seal(s)Bentonite chips 124.5-118.2 ft, 84.8-80.1 ft, 64.9-58.9 ft, 44.9-40 ft, 24.9-20.2 ft, 7-2.5 ft; concrete 2.5-0 ft			
CommentsGas probes labeled A to E, shallowest to deepest; probes equipped with labcock protected by locking standpipe.							

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Probe Completion Log					REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log		E	D	C	B	A	
0													Started drilling at 1630 hrs on 3/11/96.
320			1		--		0						PID = 0.0 ppm
315	5		2	30	65								Very dense, dry to moist, gray, poorly graded SAND with SILT (SP-SM), medium- to coarse-grained, with fine gravel. Brown SILT (ML) lens, 2 to 3 inches thick.
													Very dense, wet, brown, SILTY SAND (SM), fine- to medium-grained, with occasional fine gravel.
310	10		3	5	50/4"		0						Very dense, dry to moist, gray, poorly graded SAND (SP), fine- to medium-grained, with occasional fine to coarse gravel.
			4	0	90/1"								Very dense, moist, gray, SILTY SAND with GRAVEL (SM), fine- to medium-grained sand, fine to coarse gravel.
305	15		5	60	135		0						Very dense, moist to wet, gray, poorly graded SAND with SILT (SP-SM), fine- to medium-grained.
			6		--								Very dense, wet, gray, poorly graded GRAVEL with SILT and SAND (GP-GM), fine to coarse gravel, fine-grained sand.
300	20		7	5	80/4"								Drilling through gravel at 19 ft.
													Material in sampler is moist.
			8		--								Very dense, wet, gray, SILTY SAND (SM), fine- to medium-grained, with occasional fine to coarse gravel (Till?).
295	25		9	20	50/1"								Becomes moist.
													Becomes wet.
			10		--								Becomes dry to moist, with increasing coarse-grained sand and gravel content.
300	30												Driller reported possible cobbles at 27 ft.

Figure C-12

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP23

Sheet 2 of 4

Elevation, feet	Depth, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Probe Completion Log					REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot				E	D	C	B	A	
30				0	100/2**		Very dense, dry to moist, gray, SILTY SAND (SM), fine- to medium-grained, with coarse-grained sand and fine to coarse gravel [Till?] (continued). Becomes moist; increasing silt content.							Fine gravel in sampler shoe.
290														
			11		--									
35			12	60	90/6*			0						Moist in top of barrel, damp in sampler shoe. PID = 0.0 ppm
285														
			13		--		Increasing coarse-grained sand, decreasing gravel content.							
40				0	80/2**									
280			14		--		Very dense, moist, gray, poorly graded SAND with SILT (SP-SM), fine- to medium-grained, with occasional fine gravel.							
45			15	60	56		Very dense, moist, gray, SILTY SAND (SM), fine- to medium-grained, with occasional fine gravel.	0						PID = 0.0 ppm
275														
50			16	40	100/7.5*		Very dense, moist, brown, poorly graded SAND (SP), fine- to medium-grained, with trace silt, occasional fine gravel.							
270							No gravel.							
55				0	90/9*			0						PID = 0.0 ppm
265			17	60	75/6*		Becomes wet.							
							Becomes moist.							
			18		--									
60			19	5	80/4.5*		With occasional cobbles.							Cobble in sampler shoe.
260							With some fine- to coarse gravel.							
65			20	60	100/9*		With occasional coarse-grained sand and fine gravel.							
255														
			21		--		Very dense, moist, brown, poorly graded SAND with GRAVEL (SP), fine- to medium-grained with trace coarse-grained sand, ~25-30% fine to coarse gravel, trace silt.							
70														

Figure C-12

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP23

Sheet 3 of 4

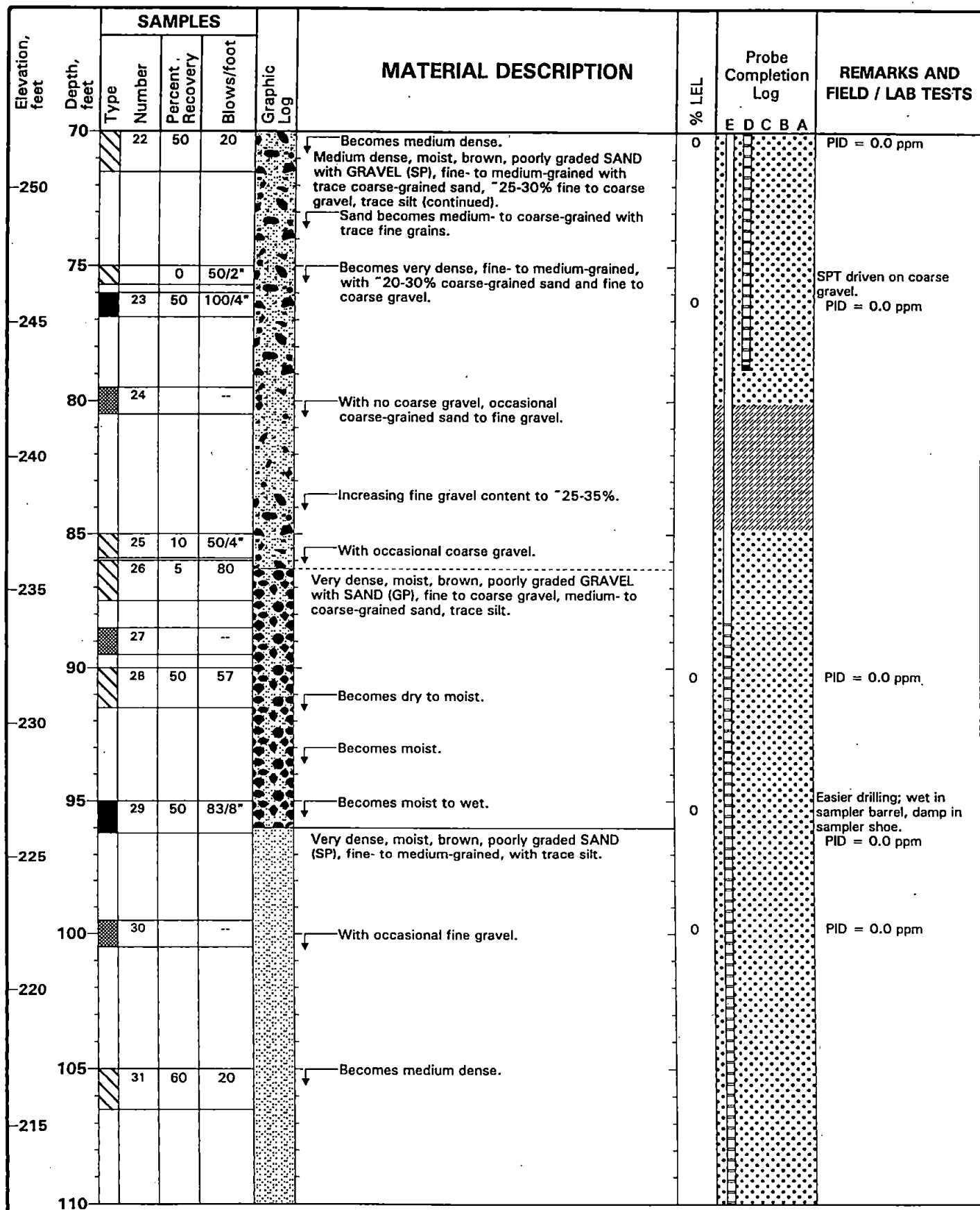


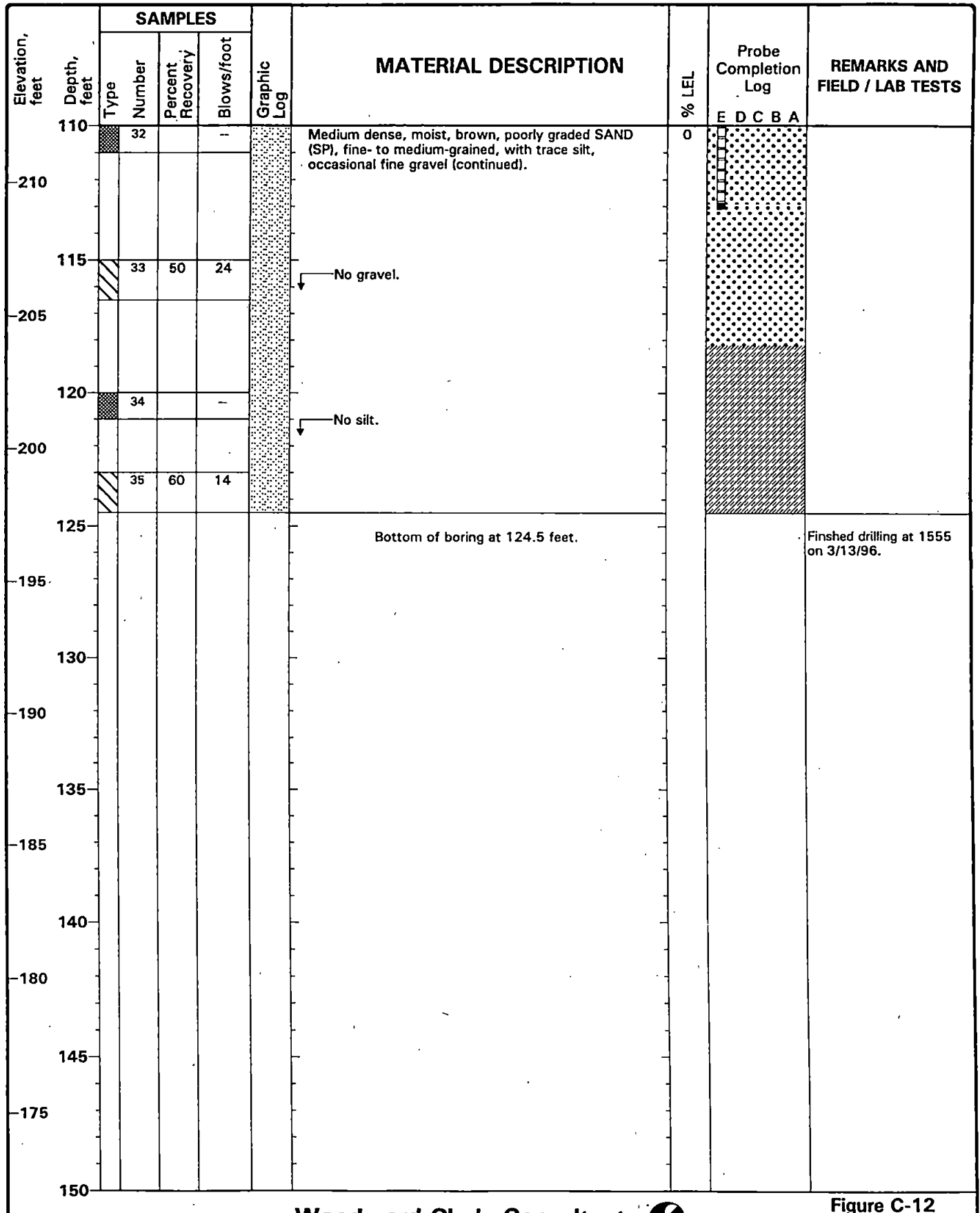
Figure C-12



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP23

Sheet 4 of 4

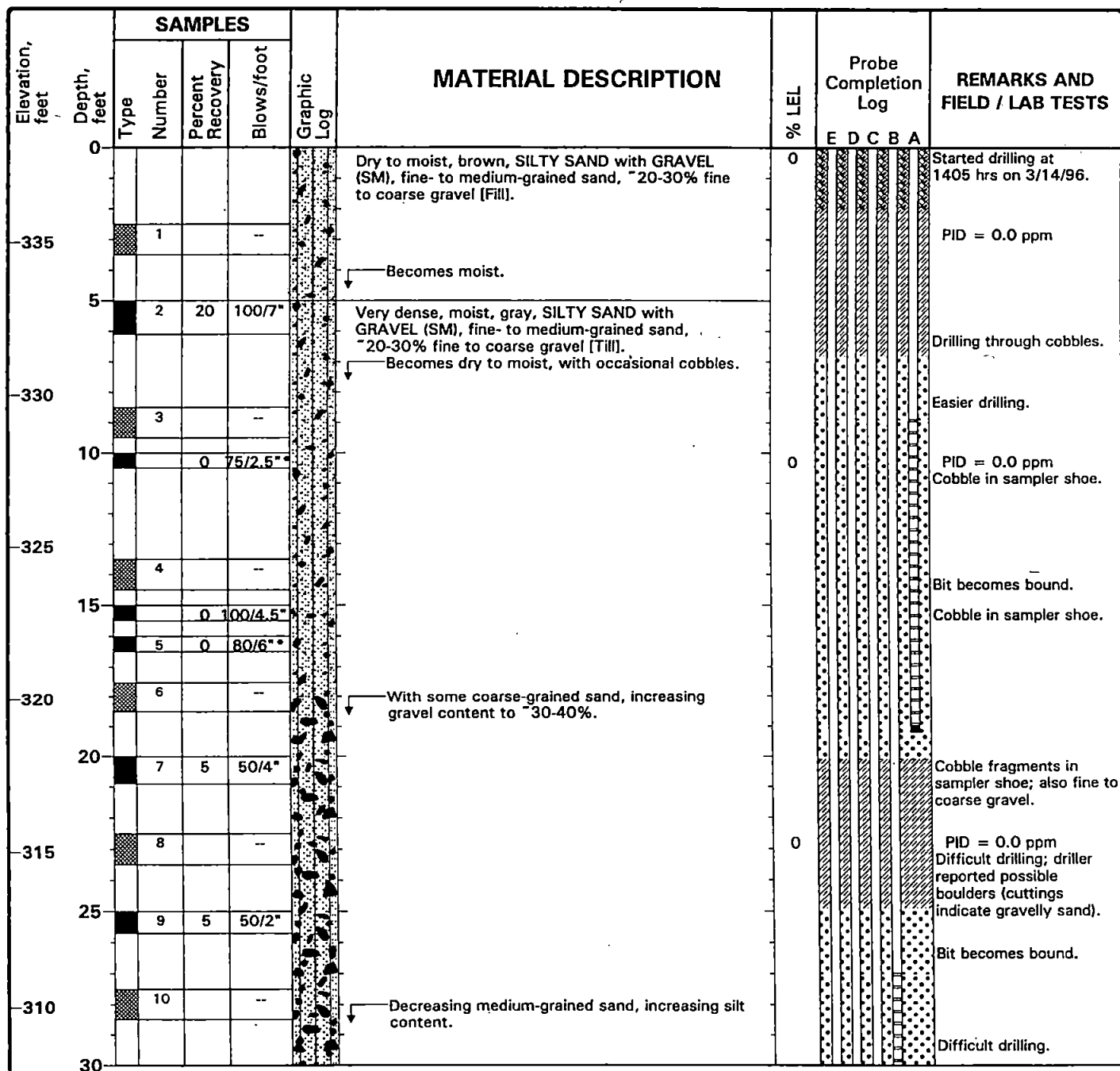


Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP24

Sheet 1 of 4

Date(s) Drilled	3/14/96 - 3/15/96			Logged By	M. Craig	Checked By	D. Haddock
Drilling Method	Air Rotary with Casing			Drill Bit Size/Type	7-7/8-inch tricone bit	Surface Elevation (feet)	338.1
Drill Rig Type	DR 24 (Foremost)			Drilled By	Tacoma Pump & Drilling	Total Depth Drilled (feet)	124.0
Depth to Ground-water (feet, bgs)	First --	Completion --	24 Hours --	Hammer Weight/Drop (lbs/in.)	140 / 30	Sampler Type	SPT, California
Diameter of Hole (inches)	8-3/4	Diameter of Well (inches)	3/4 (5x)	Type of Well Casing	Schedule 80 PVC	Screen Perforation	0.020-inch slot
Type of Sand Pack	Pea gravel			Type of Seal(s)	Bentonite chips 124-118.2 ft, 84.9-80.1 ft, 64.9-60.1 ft, 44.8-40.1 ft, 24.9-20.1 ft, 6.8-2 ft; concrete 2-0 ft		
Comments	Gas probes labeled A to E, shallowest to deepest; probes equipped with labcock protected by locking standpipe.						



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP24

Sheet 2 of 4

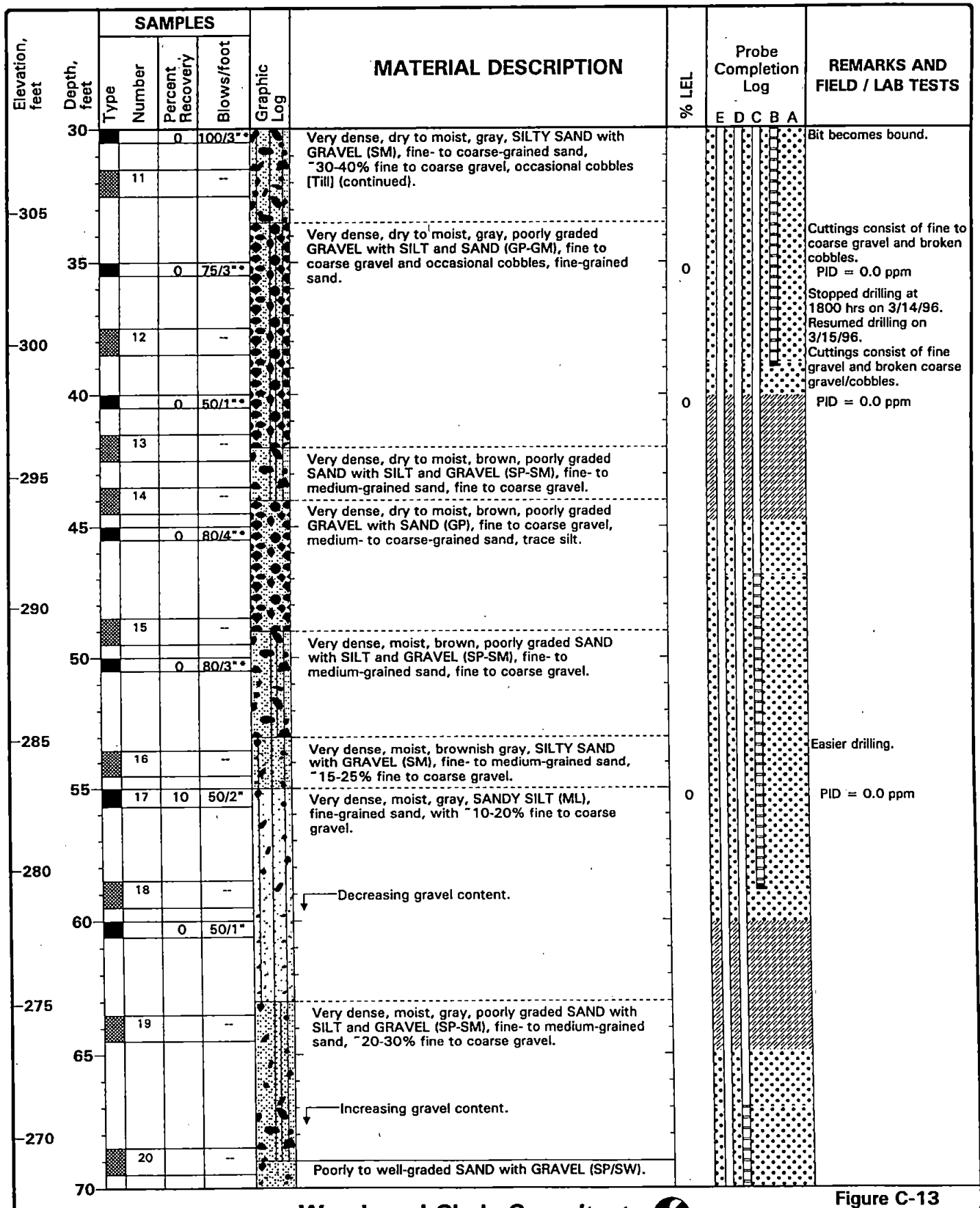


Figure C-13

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP24

Sheet 3 of 4

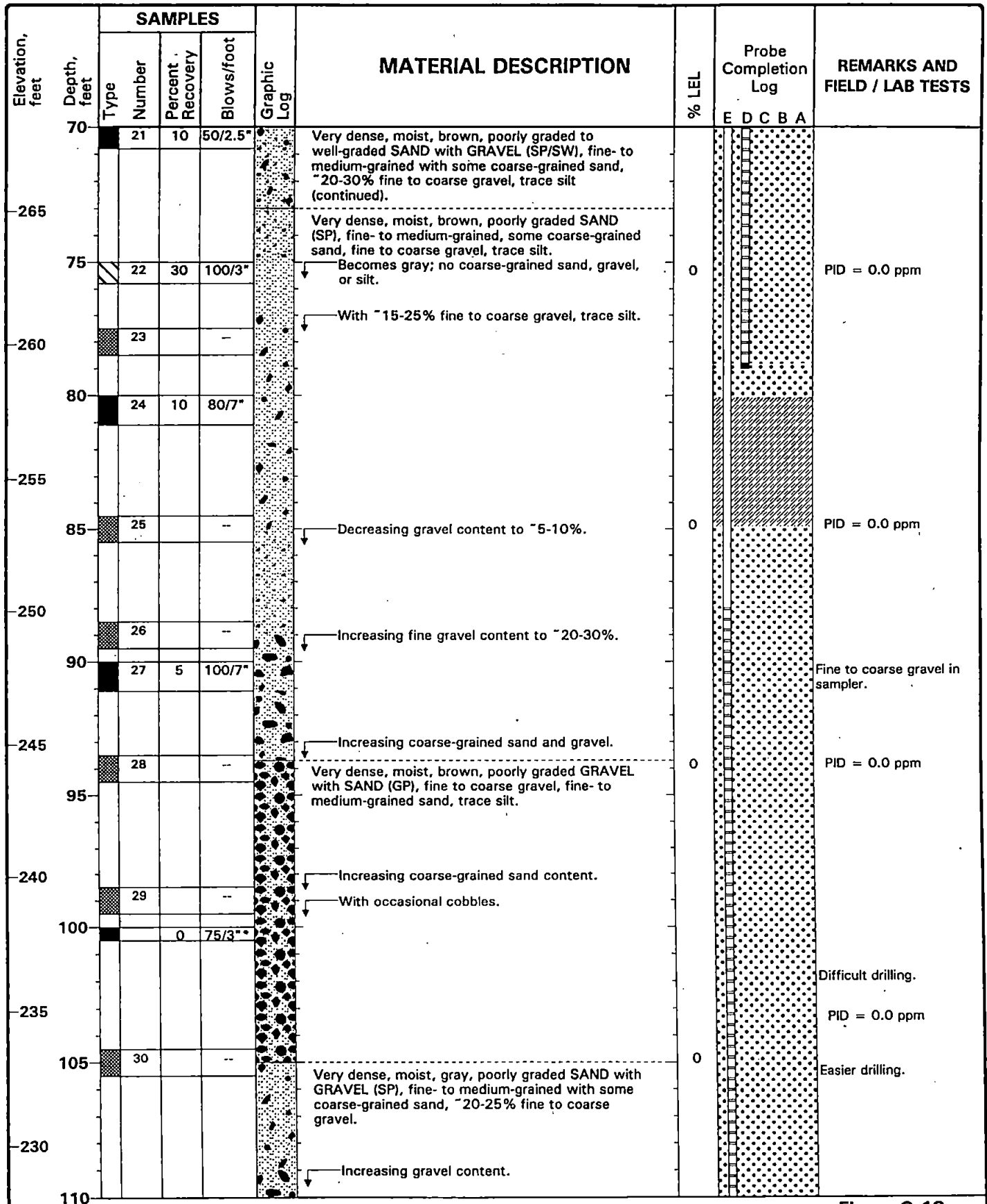


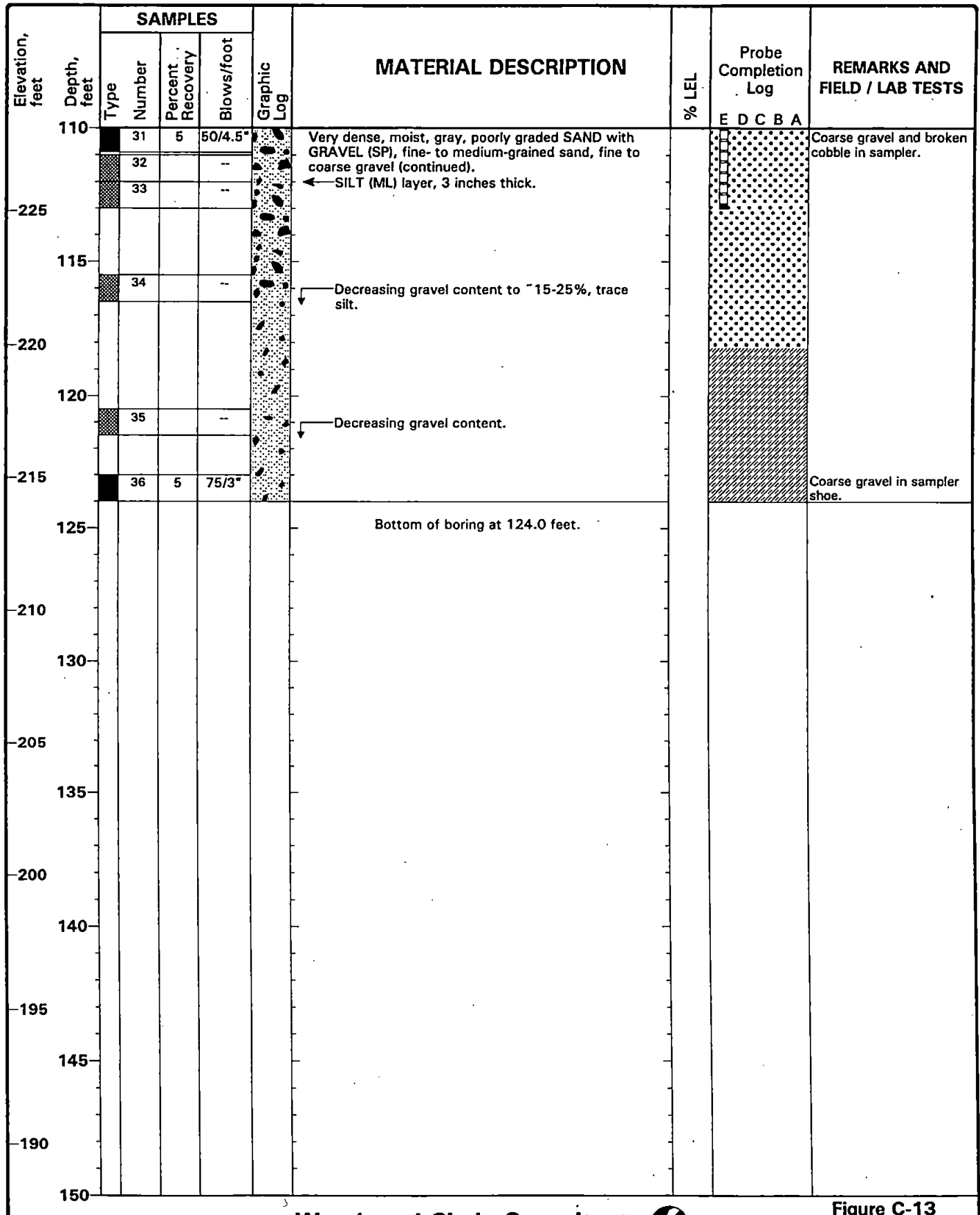
Figure C-13



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-GP24

Sheet 4 of 4



Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-IGW1

Sheet 1 of 1

Date(s) Drilled3/15/96				Logged ByB. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (8-1/4-inch-ID)				Drill Bit Size/Type13-1/2-inch carbide bullet bit		Surface Elevation (feet)360.6	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)26.0	
Depth to Ground-water (feet, bgs)		First13.0	Completion--	24 Hours--		Hammer Weight/Drop (lbs/in.)140 / 30	
Diameter of Hole (inches)13-1/2		Diameter of Well (inches)4		Type of Well CasingHDPE SDR 11		Sampler TypeCalifornia	
Type of Sand Pack3/8- to 3/4-inch gravel				Type of Seal(s)Bentonite chips 26-19 ft and 8.5-1 ft, concrete 1 ft to surface			
Comments							

Elevation, feet	SAMPLES				Graphic Log	MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
	Type	Number	Percent Recovery	Blows/foot					
360		1				COVER SOIL Moist, brown, SILTY GRAVEL with SAND (GM).			Started drilling at 0820 hrs. Composite Sample TP6 + TP8 + TP23 + IGW1-1: SA = 17
355		2	33	21		REFUSE Damp refuse; paper, plastic, glass; some to moderate decomposition (paper is moderately decomposed and not readable on outside, but print on inside is readable); in matrix of dark gray, SILTY SAND to SANDY SILT (SM/ML).	0		Driller reported easy drilling at 3.5 ft. PID = 0.4 ppm H2S = 0-1 ppm
350		3	50	70/8"		Wire, glass, abundant metal.	0		PID = 1.3 ppm H2S = 0-1 ppm
345		4	50	17		Possibly perched water. Saturated refuse; abundant plastic trash bags, new-looking Rainbow Bread bags. Abundant paper, plastic, glass; paper is damp to wet inside, wet to saturated outside. Refuse becomes saturated; includes highly decomposed yard debris (grass and other vegetation).	0		PID = 0.0 ppm H2S = 0-1 ppm
340		5	100	50/3"		Very dense, moist, gray, SILTY GRAVEL with SAND (GM), gravel up to 1-1/2 inches, fine-grained sand; material looks like glacial till.	0		Hard drilling 17-18 ft. Composite Sample IGW1-5 + 6 + 7: SA = 31
		6	100	100/5"			0		Hard drilling at 20 ft. PID = 0.3 ppm H2S = 0-1 ppm MC = 8
335		7	75	50/4"		Increasing gravel content.	0		PID = 0.0 ppm H2S = 0-1 ppm
						Bottom of boring at 26.0 feet.			
330									

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-IGW2

Sheet 1 of 2

Date(s) Drilled3/18/96				Logged ByB. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (8-1/4-inch-ID)				Drill Bit Size/Type13-1/2-inch carbide bullet bit		Surface Elevation (feet)348.6	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)31.2	
Depth to Ground-water (feet, bgs)		First--	Completion--	24 Hours--	Hammer Weight/Drop (lbs/in.)140 / 30		Sampler TypeCalifornia
Diameter of Hole (inches)13-1/2		Diameter of Well (inches)4		Type of Well CasingHDPE SDR 11		Screen Perforation1/4-inch slot	
Type of Sand Pack3/8- to 3/4-inch gravel				Type of Seal(s)Bentonite chips 31.2-14.5 ft and 7.5-0.5 ft, concrete 0.5 ft to surface			
Comments							

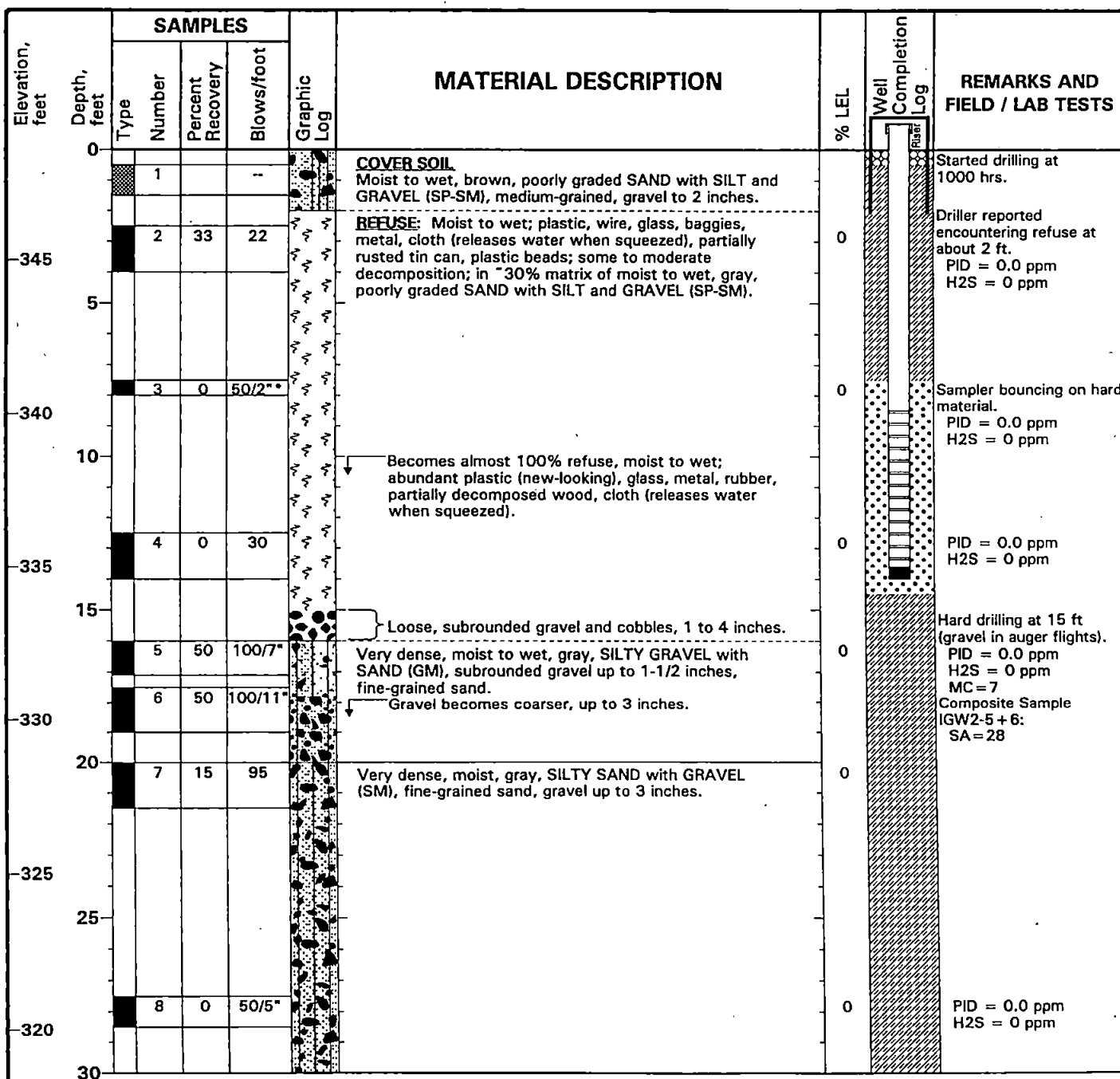


Figure C-15

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-IGW2

Sheet 2 of 2

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
30			9	50	100/8"		Very dense, moist, gray, SILTY SAND with GRAVEL (SM), fine-grained sand, gravel up to 3 inches (continued).		
							Bottom of boring at 31.2 feet.		Finished drilling at 1310 hrs.
315									
35									
310									
40									
305									
45									
300									
50									
295									
55									
290									
60									
285									
65									
280									
70									

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-IGW3

Sheet 1 of 2

Date(s) Drilled3/18/96 - 3/19/96				Logged ByB. Metcalfe		Checked ByD. Haddock	
Drilling MethodHollow-Stem Auger (8-1/4-inch-ID)				Drill Bit Size/Type13-1/2-inch carbide bullet bit		Surface Elevation (feet)348.8	
Drill Rig TypeMobile B-61 HDX				Drilled ByTacoma Pump & Drilling		Total Depth Drilled (feet)43.5	
Depth to Ground-water (feet, bgs)		First 18	Completion 26.4	24 Hours 18.8		Hammer Weight/Drop (lbs/in.)140 / 30	
Diameter of Hole (inches)13-1/2		Diameter of Well (inches)4		Type of Well CasingHDPE SDR 11		Sampler TypeCalifornia	
Type of Sand Pack3/8- to 3/4-inch gravel		Type of Seal(s)Bentonite chips 43.5-33 ft and 10-0.5 ft, concrete 0.5 ft to surface					
Comments							

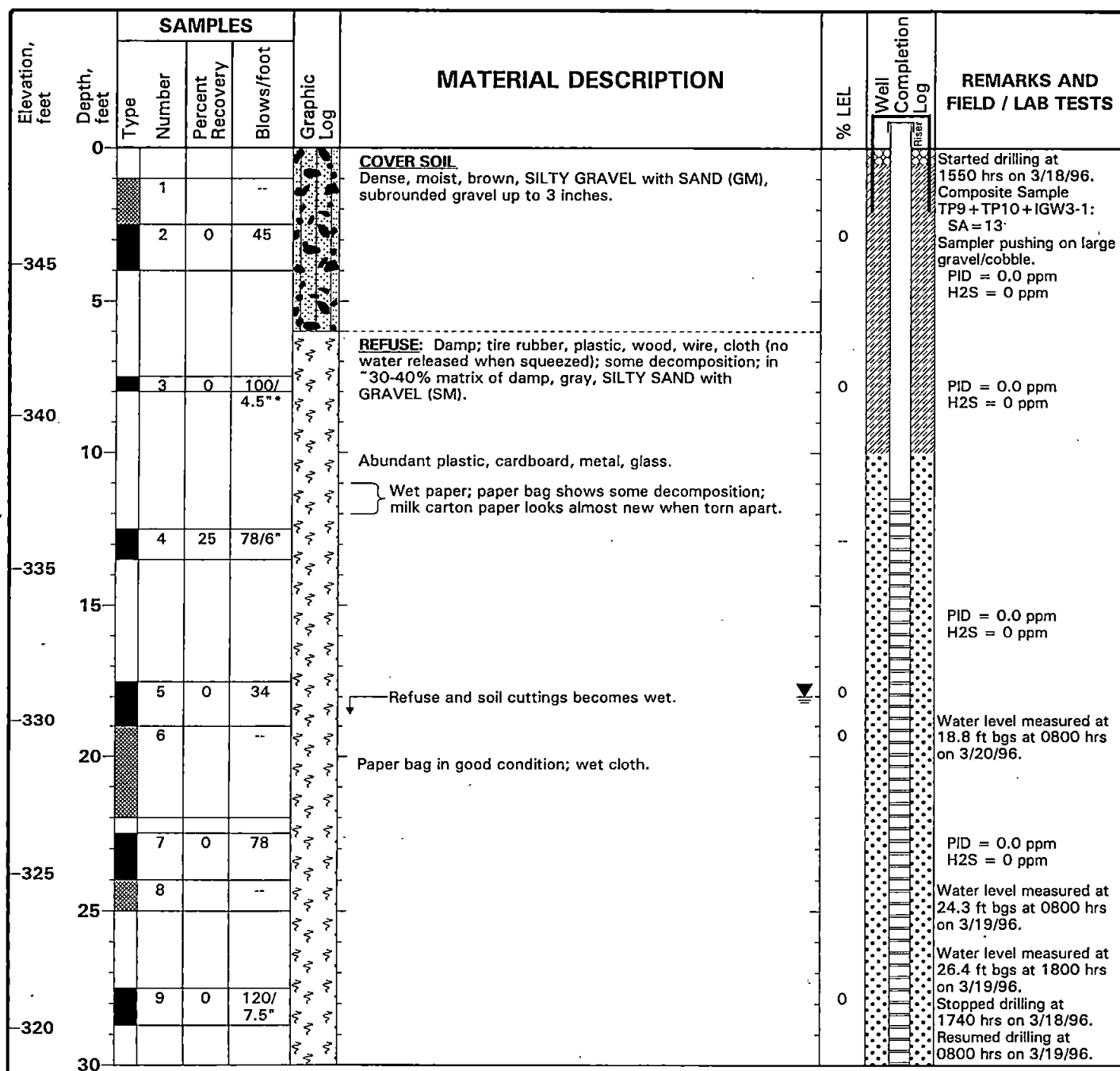


Figure C-16

Project: Puyallup / Kit Corner Landfill
 Project Location: King County, Washington
 Project Number: 954026NA

Log of Boring PKC-IGW3

Sheet 2 of 2

Elevation, feet	Depth, feet	SAMPLES				MATERIAL DESCRIPTION	% LEL	Well Completion Log	REMARKS AND FIELD / LAB TESTS
		Type	Number	Percent Recovery	Blows/foot	Graphic Log			
30						REFUSE in soil matrix, wet (continued). Refuse becomes saturated; moderately decomposed newspaper (easily readable when parted along pages).	0		PID = 0.0 ppm H2S = 0 ppm
315			10	0	55				
35						Very dense, moist, gray, SILTY SAND with GRAVEL (SM), fine-grained sand, ~ 25% gravel up to 1 inch.			Driller noted harder/firmer drilling at 35 ft.
310			11	75	165/8*				Very hard drilling 38-41 ft. MC = 10
40									Composite Sample IGW3-11 + 12: SA = 23
305			12	100	150/4*	Becomes grayish brown.	0		PID = 0.0 ppm H2S = 0 ppm
45						Bottom of boring at 43.5 feet.			Finished drilling at 1045 hrs on 3/19/96.
300									
50									
295									
55									
290									
60									
285									
65									
280									
70									

Figure C-16

Woodward-Clyde delivered selected soil samples to Soil Technology Inc. of Bainbridge Island to perform the laboratory testing. The tests were performed in general accordance with test methods of the American Society for Testing and Materials (ASTM) or other applicable procedures. Selected soil samples were tested for in-place moisture content, percent passing No. 200 sieve, grain size distribution, and permeability.

The results of the laboratory tests are presented on Table D-1 and Figures D-1 through D-5. The moisture content test results and percent passing the No. 200 sieve are also presented on the boring logs in Appendix C.

Water Content Determinations

Water contents were determined in general accordance with ASTM D 2216 for seven of the samples obtained from the borings. The results of these tests are presented on the boring logs at the respective sample depth. Table D-1 summarizes the test results.

Percent Passing U.S. No. 200 Sieve

Sample PKC-MW9-28, which was tested for hydraulic conductivity, was also evaluated for the percentage of sample passing the U.S. No. 200 sieve. The sample was obtained from a depth of 185.4 to 185.7 feet bgs. The sample was "washed" through the No. 200 mesh sieve to determine the relative percentages of coarse and fine-grained particles in the soil. The percent passing value represents the percentage by weight of the sample finer than the U.S. No. 200 sieve. This test was conducted to verify field descriptions and to determine the fines content for evaluation purposes. The test was conducted in accordance with ASTM D 1140, and the results indicated that 99 percent of the sample passed the U.S. No. 200 sieve.

Grain Size Analysis

Grain size analyses were performed on representative samples in general accordance with ASTM D 422. The wet sieve analysis method was used to determine the percentage of soil greater than the U.S. No. 200 mesh sieve. The results of the grain size analyses were plotted, classified in general accordance with USCS, and are presented on Figures D-1 through D-5.

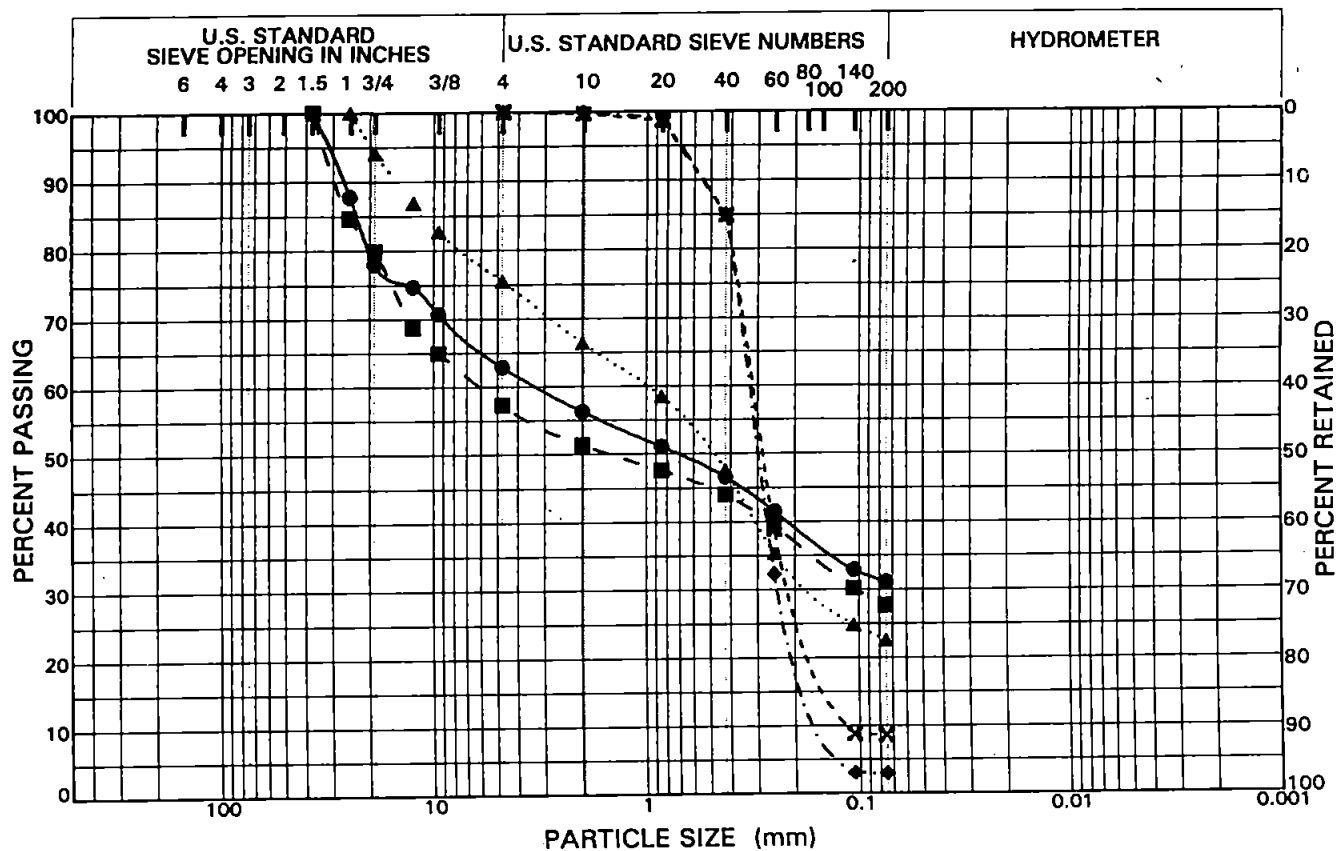
Hydraulic Conductivity

A flexible wall hydraulic conductivity test was conducted on a relatively undisturbed soil sample obtained using a Shelby tube. The sample (no. 28) was taken from the silt aquitard while drilling Monitoring Well PKC-MW9. The tests were conducted in general accordance with ASTM D 5084. The test was run by extruding the sample from the Shelby tube. The sample which was tested was obtained from a depth of about 185.4 to 185.7 feet bgs. The test results indicated that the sample had a hydraulic conductivity of 1×10^{-8} cm/sec. In addition, the results of the test indicated a moisture content of 31 percent and a wet density of 31 pounds per cubic foot prior to initiating the test.

Table D-1
MOISTURE CONTENT TEST RESULTS

SAMPLE NO.	SAMPLE DEPTH (feet)	MOISTURE CONTENT (percent)
PKC-MW9-28	185.4–185.7	31
PKC-IGW1-5	20–21	8
PKC-IGW2-5	16–17	7
PKC-IGW3-11	37.5–38.5	10
PKC-MW16-3	15–16.5	14
PKC-MW17-7a	25–25.5	8
PKC-MW18-5	15–16	8

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Boring Number	Sample Number	Depth (feet)	Symbol	LL	PI	Classification
PKC-IGW1	5 + 6 + 7	20-26	●			Silty Gravel with Sand (GM)
PKC-IGW2	5 + 6	16-19	■			Silty Gravel with Sand (GM)
PKC-IGW3	11 + 12	37.5-43	▲			Silty Sand with Gravel (SM)
PKC-MW 8	6	100	◆			Poorly graded Sand (SP)
PKC-MW 9	23	140	×			Poorly graded Sand with Silt (SP-SM)

Project: Puyallup / Kit Corner Landfill
King County, Washington
Project Number: 954026NA

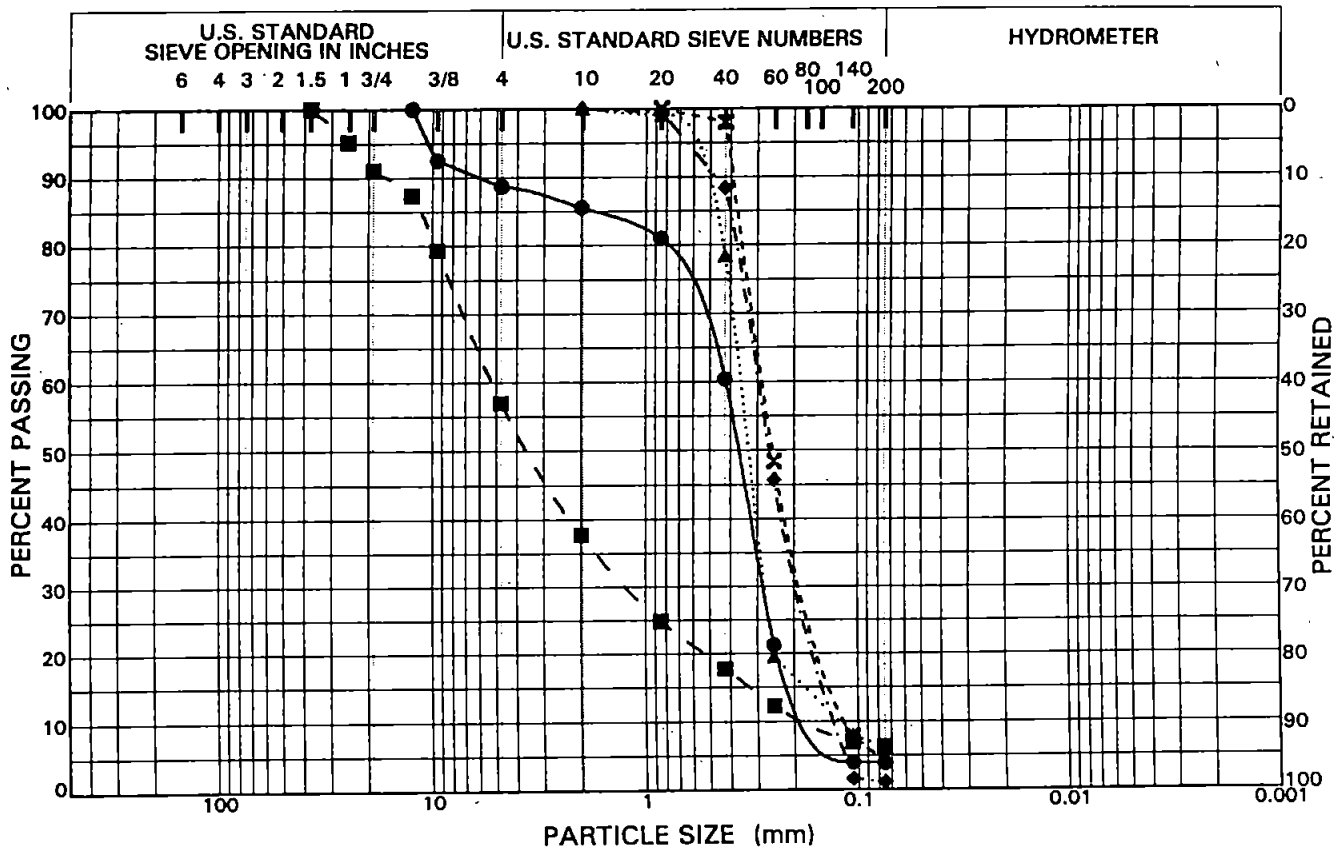
PARTICLE SIZE DISTRIBUTION CURVES

Gas Well and Monitoring Well Samples

Figure D-1



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine.	



Boring Number	Sample Number	Depth (feet)	Symbol	LL	PI	Classification
PKC-MW10	20	85	●			Poorly graded Sand (SP)
PKC-MW10	23 + 24	100-105	■			Well-graded Sand with Silt and Gravel (SW-SM)
PKC-MW10	30	140	▲			Poorly graded Sand with Silt (SP-SM)
PKC-MW10	32	160	◆			Poorly graded Sand (SP)
PKC-MW11	27	160	×			Poorly graded Sand (SP)

Project: Puyallup / Kit Corner Landfill
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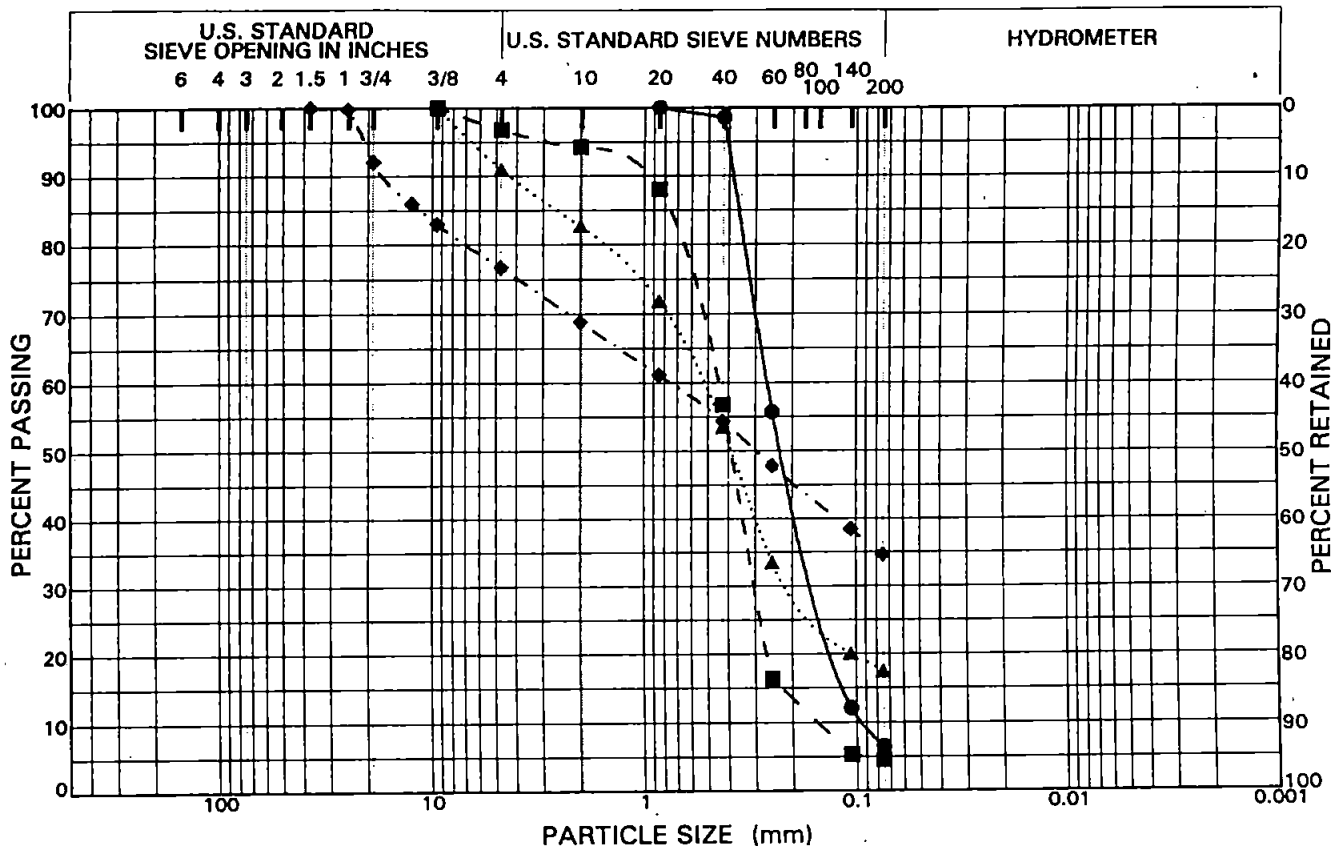
PARTICLE SIZE DISTRIBUTION CURVES

Gas Well and Monitoring Well Samples

Figure D-2

Woodward-Clyde Consultants

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Boring Number	Sample Number	Depth (feet)	Symbol	LL	PI	Classification
PKC-MW12	26	160	●			Poorly graded Sand with Silt (SP-SM)
PKC-MW16	3	15	■			Poorly graded Sand (SP)
PKC-MW17	7a	25	▲			Silty Sand (SM)
PKC-MW18	5	15	◆			Silty Sand with Gravel (SM)

Project: Puyallup / Kit Corner Landfill
King County, Washington

Project Number: 954026NA

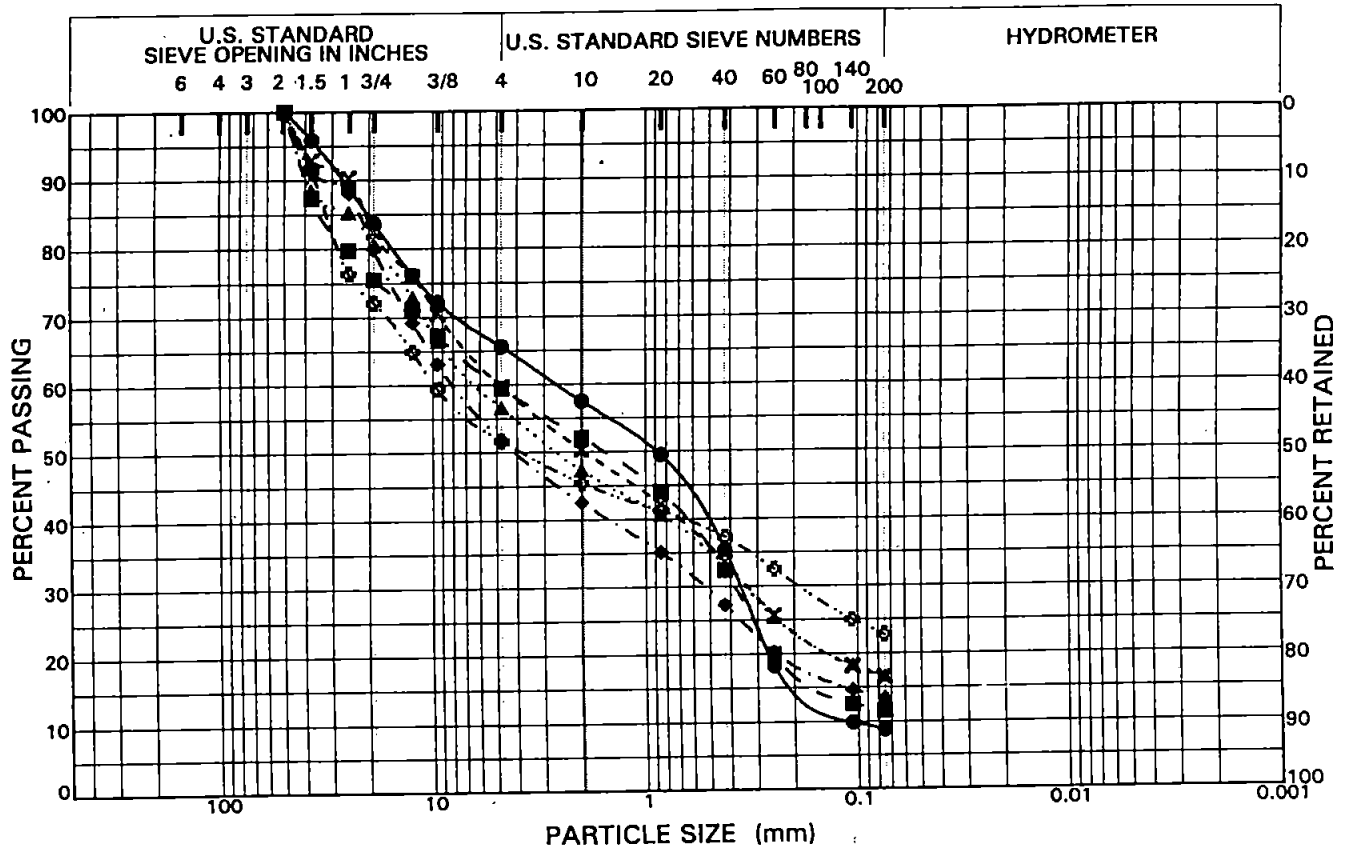
PARTICLE SIZE DISTRIBUTION CURVES

Gas Well and Monitoring Well Samples

Figure D-3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Sample Identification	Symbol	LL	PI	Classification
TP1 + TP2 + TP3	●			Poorly graded Sand with Silt and Gravel (SP-SM)
TP4 + TP5 + TP7	■			Poorly graded Sand with Silt and Gravel (SP-SM)
TP6 + TP8 + TP23 + IGW1-1 (1 ft)	▲			Silty Gravel with Sand (GM)
TP9 + TP10 + IGW3-1 (1 ft)	◆			Silty Gravel with Sand (GM)
TP11 + TP12a	×			Silty Sand with Gravel (SM)
TP12b (2-2.5 ft)	◊			Silty Gravel with Sand (GM)

Project: Puyallup / Kit Corner Landfill
King County, Washington

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PARTICLE SIZE DISTRIBUTION CURVES

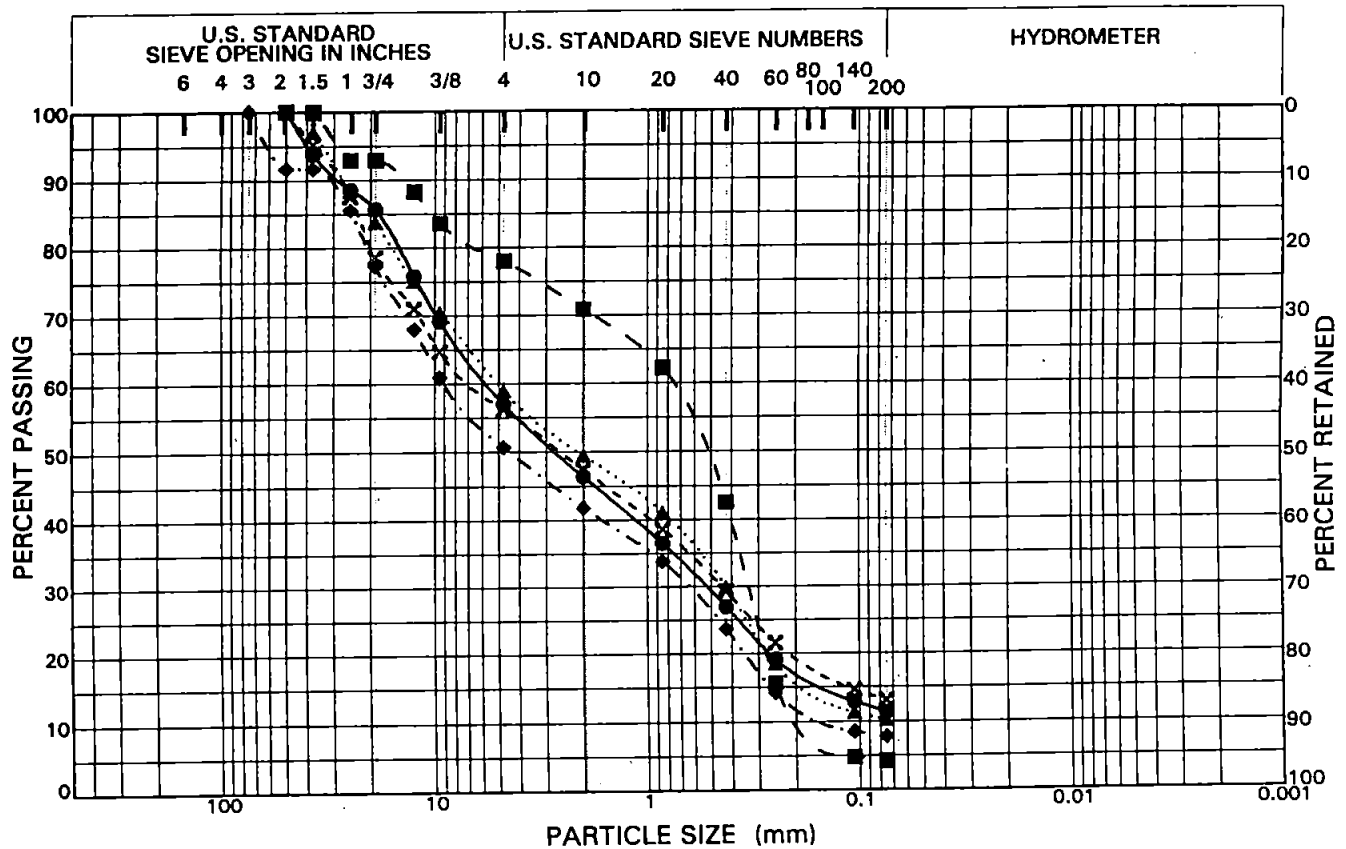
Composite Near-Surface Samples

Figure D-4

Woodward-Clyde Consultants



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Sample Identification	Symbol	LL	PI	Classification
TP13 + TP14	●			Poorly graded Sand with Silt and Gravel (SP-SM)
TP15 + TP16	■			Poorly graded Sand with Gravel (SP)
TP17 + TP18 + MW17-1 (2 ft)	▲			Poorly graded Sand with Silt and Gravel (SP-SM)
TP19 + TP20	◆			Poorly graded Gravel with Silt and Sand (GP-GM)
TP21 + TP22	×			Silty Gravel with Sand (GM)

Project: Puyallup / Kit Corner Landfill
King County, Washington
Project Number: 954026NA

PARTICLE SIZE DISTRIBUTION CURVES

Composite Near-Surface Samples

Figure D-5

APPENDIX E

Groundwater Potentiometric Surface Data

**GROUNDWATER POTENTIOMETRIC SURFACE DATA
PUYALLUP/KIT CORNER LANDFILL, KING COUNTY, WASHINGTON**

Well Location	Top of Casing ^a Elevation (ft msl)	Depth to Groundwater (ft btoc) ^a								Groundwater Elevation (ft msl)							
		4/25/93 ^b	3/26/96 ^c	3/29/96 ^d	4/24/96 ^d	5/26/96 ^d	6/19/96 ^d	8/19/96 ^d	11/7/1996 ^d	4/25/93 ^b	3/26/96	3/29/96	4/24/96	5/26/96	6/19/96	8/19/96	11/7/96
MW-1a	323.68	76.70	70.81	71.04	72.76	74.02	74.64	78.18	81.26	246.98	252.87	252.64	250.92	249.66	249.04	245.50	242.42
MW-1b	323.54	102.54	93.77	93.99	94.19	94.21	94.11	95.05	98.06	221.00	229.77	229.55	229.35	229.33	229.43	228.49	225.48
MW-2	330.10	129.79	127.68	127.62	126.44	125.52	125.06	125.66	126.99	200.31	202.42	202.48	203.66	204.58	205.04	204.44	203.11
MW-3b	322.50	117.88	110.28	110.45	111.09	110.93	110.45	111.65	114.26	204.62	212.22	212.05	211.41	211.57	212.05	210.85	208.24
MW-4	323.37	16.33		DRY	DRY	16.74	DRY	DRY	DRY	307.04		DRY	DRY	306.63	DRY	DRY	DRY
MW-5 ^e	326.59	2.84	2.95	3.09	2.67	3.08	4.27	6.54	6.85	323.75	323.64	323.50	323.92	323.51	322.32	320.05	319.74
MW-6	354.25	152.54	150.94	150.93	149.80	148.55	148.06	148.61	149.73	201.71	203.31	203.32	204.45	205.70	206.19	205.64	204.52
MW-7	334.37	DRY			DRY	114.93	114.95	DRY	115.20	DRY			DRY	219.44	219.42	DRY	219.17
MW-8	301.82				99.46	98.31	97.72	97.62	99.98	301.82			202.36	203.51	204.10	204.20	201.84
MW-9	334.45				130.65	129.29	128.81	129.77	131.08				203.80	205.16	205.64	204.68	203.37
MW-10	347.15			144.14	143.30	142.04	141.44	142.08	143.62			203.01	203.85	205.11	205.71	205.07	203.53
MW-11	353.63				149.22	147.82	147.37	148.16	149.20				204.41	205.81	206.26	205.47	204.43
MW-12	360.07				154.97	153.68	153.09	153.11	154.18				205.10	206.39	206.98	206.96	205.89
MW-13 ^e	346.34			22.34		22.35	23.48	25.83	27.10			324.00		323.99	322.86	320.51	319.24
MW-15 ^e	342.84			DRY		DRY	DRY	DRY	DRY			DRY		DRY	DRY	DRY	DRY
MW-16	324.44			DRY		DRY	DRY	DRY	24.20(?)			DRY		DRY	DRY	DRY	(DRY)?
MW-17 ^e	336.53			DRY		DRY	DRY	DRY	DRY			DRY		DRY	DRY	DRY	DRY
MW-18 ^f	326.28			23.42		21.48	DRY	DRY	DRY			302.86		304.80	DRY	DRY	DRY
IGW-1 ^e	362.63					15.32	15.85	16.29	15.27					347.31	346.78	346.34	347.36
IGW-2 ^e	350.91					DRY	DRY	DRY	DRY					DRY	DRY	DRY	
IGW-3 ^e	351.44					24.70	25.96	28.92	30.65					326.74	325.48	322.52	320.79

Notes:

btoc = below top of casing

msl = mean sea level

a: elevation or measuring point at top of metal plate if Well Wizard pump installed
or at top of PVC casing if no pump installed

b: elevations obtained from AGI, July 1994

c: measured by King County field personnel

d: measured by Woodward-Clyde field personnel

e: measured depth to water is level of water within landfill refuse (leachate)

f: water likely a result of drilling activities and not actual shallow groundwater

Symonds Consulting Engineers conducted a survey of all the wells, gas probes, piezometers, and test pits which were performed as part of this investigation. The survey was completed after all the field explorations were completed and monuments constructed. The test pits were marked in the field using wood stakes with the appropriate identification number. The survey results are provided on the attached pages.

May 22, 1996

Bob Metcalfe
Woodward-Clyde Consultants
1501 4th Ave. Suite 1500
Seattle, Washington

SYMONDS

CONSULTING ENGINEERS

Puyallup/Kit Corner Landfill
Monitoring Well and Test Pit Elevations

NAME	NORTHING	EASTING	ELEV.	DESCRIPTION
MW-8	106748.5	1634243.9	302.50 301.82 302.40	TOP OF METAL RIM TOP OF METAL PLATE GROUND ASPHALT
MW-9	107391.4	1634401.9	334.98 334.45 334.93	TOP OF METAL RIM TOP OF METAL PLATE GROUND ASPHALT
MW-10	107164.6	1634632.4	347.85 347.15 345.13	TOP OF MONUMENT TOP OF METAL PLATE ADJACENT GROUND
MW-11	107782.6	1634545.3	354.38 353.63 354.24	TOP OF METAL RIM TOP OF METAL PLATE GROUND ASPHALT
MW-12	108130.6	1634810.6	360.97 360.07 357.80	TOP OF MONUMENT TOP OF METAL PLATE ADJACENT GROUND
MW-13	107260.7	1635383.6	346.91 346.34 344.02	TOP OF MONUMENT TOP OF 2" PVC ADJACENT GROUND
MW-15	107045.2	1635370.4	343.45 342.84 340.56	TOP OF METAL CASING TOP OF 2" PVC ADJACENT GROUND
MW-16	106897.4	1635466.1	324.95 324.44 321.81	TOP OF METAL CASING TOP OF 2" PVC ADJACENT GROUND
MW-17	106890.4	1635156.5	337.24 336.53 334.25	TOP OF MONUMENT TOP OF 2" PVC ADJACENT GROUND

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MW-18	106712.6	1634810.0	326.83 326.28 323.73	TOP OF MONUMENT TOP OF 2" PVC ADJACENT GROUND
TP-1	107736.7	1634924.9	355.87	STAKE IN GROUND
TP-2	107809.1	1635094.3	349.27	STAKE IN GROUND
TP-3	107812.4	1635357.2	343.10	STAKE IN GROUND
TP-4	107755.9	1635093.8	356.86	STAKE IN GROUND
TP-5	107736.3	1635368.1	354.12	STAKE IN GROUND
TP-6	107443.2	1634994.1	360.37	STAKE IN GROUND
TP-7	107501.5	1635231.0	355.74	STAKE IN GROUND
TP-8	107308.1	1634793.6	355.40	STAKE IN GROUND
TP-9	107132.7	1634949.3	350.13	STAKE IN GROUND
TP-10	107173.3	1635323.2	345.03	STAKE IN GROUND
TP-11	107080.1	1635150.1	343.46	STAKE IN GROUND
TP-12	107033.0	1634866.5	349.45	STAKE IN GROUND
TP-13	107653.5	1635474.2	342.84	STAKE IN GROUND
TP-14	107447.2	1635429.3	335.33	STAKE IN GROUND
TP-15	107143.0	1635432.9	334.82	STAKE IN GROUND
TP-16	106939.8	1635288.7	334.82	STAKE IN GROUND
TP-17	106832.9	1635014.3	331.93	STAKE IN GROUND
TP-18	106767.0	1634807.2	331.13	STAKE IN GROUND
TP-19	106725.7	1635265.1	316.87	STAKE IN GROUND
TP-20	106759.0	1635394.2	315.48	STAKE IN GROUND
TP-21	106863.5	1634700.9	337.70	STAKE IN GROUND
TP-22	107127.2	1634672.2	345.91	STAKE IN GROUND
TP-23	107460.5	1634717.5	349.98	STAKE IN GROUND
IGW-1	107515.6	1634827.5	363.74 362.63 360.60	TOP OF MONUMENT TOP OF 4" PVC ADJACENT GROUND

IGW-2	106989.2	1634759.5	351.15 350.91 348.58	TOP OF MONUMENT TOP OF 4" PVC ADJACENT GROUND
IGW-3	107273.4	1635246.7	351.77 351.44 348.76	TOP OF MONUMENT TOP OF 4" PVC ADJACENT GROUND
GP-23	106663.6	1634805.3	324.97 322.12	TOP OF MONUMENT ADJACENT GROUND
A-19			324.59	TOP OF PETCOCK VALVE
E-113			324.51	TOP OF PETCOCK VALVE
D-79			324.58	TOP OF PETCOCK VALVE
C-59			324.52	TOP OF PETCOCK VALVE
B-39			324.59	TOP OF PETCOCK VALVE
GP-24	106962.6	1634578.3	340.88 338.05	TOP OF MONUMENT ADJACENT GROUND
E-113			340.51	TOP OF PETCOCK VALVE
B-39			340.59	TOP OF PETCOCK VALVE
A-19			340.57	TOP OF PETCOCK VALVE
C-59			340.52	TOP OF PETCOCK VALVE
D-79			340.43	TOP OF PETCOCK VALVE

Date surveyed: May 8, 1996

Bench mark: Top of the brass cap of the centerline monument at the intersection of 25th PL South & S 357th ST. Elevavtion of monument 344.638 feet.

Puyallup/Kit Corner Landfill
Test Pits - Extent of Refuse Survey

NAME	NORTHING	EASTING	ELEVATION	DESCRIPTION
TP-24	107652.0	1634783.1	355.0	Stake in Ground
TP-25	107737.3	1634906.5	355.6	Stake in Ground
TP-26	107831.8	1635004.7	346.6	Stake in Ground
TP-27	107901.2	1635265.5	334.9	Stake in Ground
TP-28	107839.8	1635469.8	332.8	Stake in Ground
TP-29	107682.0	1635544.9	328.5	Stake in Ground
TP-30	107445.9	1635478.6	326.1	Stake in Ground
TP-31	107259.4	1635482.2	325.5	Stake in Ground
TP-32	106970.0	1635455.7	321.9	Stake in Ground
TP-33	106894.5	1635458.5	322.1	Stake in Ground
TP-34	106821.6	1635290.3	323.0	Stake in Ground
TP-35	106795.0	1635301.5	323.1	Stake in Ground
TP-36	106781.3	1635150.4	322.7	Stake in Ground
TP-37	106746.5	1635154.0	321.4	Stake in Ground
TP-38	107165.1	1634652.4	347.3	Stake in Ground
TP-39	107482.5	1634723.2	351.1	Stake in Ground