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Hydrogeologic and Geotechnical Assessment

Newcastle Landfill

King County, Washington

J-1523-02
April 11, 1986

HART
CROWSER &
associates inc.
GEOTECHNICAL & HYDROGEOLOGIC CONSULTANTS

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Prepared for

Coal Creek Development Company and
Parametrix, Inc.

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HYDROGEOLOGIC AND GEOTECHNICAL ASSESSMENT
NEWCASTLE LANDFILL
KING COUNTY, WASHINGTON

INTRODUCTION

This is our assessment of hydrogeologic and geotechnical aspects of the Newcastle Landfill site and vicinity in east central King County, Washington (Figure 1). The purpose of our work is to assist the Coal Creek Development Company (CCDC) and Parametrix, Inc. in preparing a development and closure plan for the landfill, as well as an environmental impact statement on that plan.

The Newcastle Landfill is an active unclassified demolition waste landfill which has been in operation for a number of years. The current permitted landfill covers an area of approximately 70 acres (Figure 2) and generally ranges in elevation from approximately 865 to 910 feet as of the end of 1985. Landfilling has also extended over an approximate 10 to 15 acre area west of the permitted area which is reported to have occurred prior to operations by CCDC. Soil has been removed from some additional area in preparation for filling and/or to provide cover material, as shown on Figure 2.

We understand proposed landfilling is planned to continue operation over the next 5 to 10 years. The permitted area would be expanded to include land west of the existing permit boundary, much of which already contains waste as noted above. Continued operation for a 10-year-period would approximately double the volume of waste on the site.

Final grade elevations are projected to generally range between elevations 740 and 925 feet based on preliminary grading plans. Fill thicknesses would increase on the average by about 10 to 25 feet over about the western 60 percent of the existing permit area. Within the eastern and southeastern portions of the existing permit area, fill thicknesses are expected to increase by 20 to 100 feet. Landfilling within the proposed expanded permit area would increase fill thickness by 10 to 30 feet.

Work accomplished by Hart-Crowser & Associates for this study included:

- o Compiling and reviewing readily available data on the geology, hydrology, and mine workings in the area.
- o Conducting a geologic field reconnaissance and field well inventory with selective water sampling and chemical analyses.
- o Observation of backhoe test pits to assess soil conditions.
- o Completing selected laboratory testing of site soils.

Information sources used to prepare this report included: the Unclassified Use Permit Application filed by Parametrix, Inc. for the Coal Creek Development Co. to the City of Seattle for the operating year of 1986; files of Parametrix, the U.S. Environmental Protection Agency, Washington State Department of Natural Resources, Department of Ecology, and Hart-Crowser & Associates, Inc. These sources were supplemented with data obtained from interviews with landfill and regulatory agency employees, geologic field reconnaissance, and a field inventory of the wells in the area. A list of references is included at the end of this report.

This report has been prepared for the exclusive use of the Coal Creek Development Company, Inc. and their consultant, Parametrix, Inc. for specific application to the site and project described, in accordance with generally accepted geologic and engineering practices. No other warranty, expressed or implied, is made.

FINDINGS

The following section presents our findings and recommendations. The body of this report should be consulted for supporting data and analyses.

Geology

- The project area is underlain by two general types of geologic materials, shown schematically on Figure 3.
    - Surficial deposits (clays, silts, sands and gravels) of alluvium, glacial drift, and weathered residual soils locally overlie bedrock. These soils have been stripped from a portion of the proposed expanded permit area.
    - Bedrock consisting of folded weathered and unweathered sandstone and siltstone of the Tukwila and coal bearing Renton formations, and Oligocene Marine rocks (sandstone and shale).
- The northern side of the landfill is classified by King County as a Class III Seismic Hazard, apparently because slopes exceed 15 percent. This classification means King County will consider seismic aspects

during review of land use plans, but this classification will likely not unduly restrict use of the site.

Mining Activities

- Extensive coal mining has occurred in the area. Landfilling has been conducted over portions of at least four coal seams and has covered some of the previously recorded mine openings and subsidence features.

- Subsidence is anticipated to continue at the site, whether or not landfill operations continue, however, the magnitude and extent of surface settlement cannot be estimated. It appears likely that some of the mine workings contain refuse as a result of past landfill operations and/or subsidence.

- There is some potential risk that decay or combustion of existing refuse could lead to a fire and/or methane explosion in the old mine workings. This risk would be reduced by "good housekeeping" in future landfill operations and by final closure with a soil cover. Future subsidence may disturb the soil cover, and provision for future site caretaking is recommended.

Groundwater

- A shallow flow system occurs discontinuously within saturated portions of surficial sand and gravel deposits which overlie bedrock. Field observations, as well as mine records, indicate there is not a shallow soil aquifer beneath the landfill.

- The primary groundwater flow system in the area occurs within the bedrock units. Outside of the mine area, groundwater flows through fractures in the bedrock. Within the mined area, the mine shafts, tunnels and associated workings provide additional avenues of groundwater flow.

- The water table below the landfill lies at a depth of several hundred feet. Groundwater in the area generally flows towards the landfill from the east and northeast, and flows away from the landfill in a westerly direction towards the Richmond Tunnel.

- Most of the wells in the area obtain water from the bedrock units. The majority of wells completed in bedrock are located upgradient northeast of the landfill. Two wells (Wells 27E1 and 27F3) are located 3000 to 4000 feet downgradient (west) of the landfill and obtain water from the mines (well locations are shown on Figure 4).

- Two wells (Wells 26K3 and 26K5), located within 3000 feet of the landfill obtain water from a surficial groundwater system.

- Water quality varies widely in the area depending on well depth, bedrock unit penetrated, and proximity to the mined areas. Available data indicate that mining activities have affected groundwater quality. No evidence has been found that the existing landfill has produced leachate which has contaminated groundwater or off-site surface water.

- Possible leachate migration pathways to groundwater include:

  - Surface runoff and infiltration which may flow to the shallow groundwater system, and

  - Migration through mine openings, subsidence areas and/or fractures in bedrock.

Impacts of Continued Landfilling

- Continued use of current operating practices, including runoff control, grading and placement of soil capping material over the landfill will reduce the potential for groundwater contamination and refuse coal seam fires.

- Long-term subsidence is anticipated regardless of whether or not additional landfilling occurs.

- Proper closure of existing mine openings in the permit area and proposed expanded permit area would substantially reduce a safety hazard and potential for leachate migration to groundwater, and reduce the risk of mine fires and explosions.

- Continued operation of the landfill would provide a revenue base for future mitigation which may be required to deal with subsidence hazards.

- The potential for continued use of the landfill to adversely effect wells in the area is low. Most wells are located upgradient of the landfill and are not within leachate migration pathways.

- Two wells (27E1 and 27F3), which tap the flooded portions of the abandoned mine workings, are located 3000 to 4000 feet downgradient of the landfill. Water quality observations indicate that the existing landfill has not adversely affected these wells. With proper operation of the landfill, the possibility that these wells will be adversely affected is low.

RECOMMENDATIONS

- The current groundwater monitoring system included in UUP 127-85-U should be continued. This system includes:
  - Obtaining water samples from the Richmond Tunnel, Coal Creek Parkway underpass at I-405 and at the water source for King County Water District No. 117.
  - Collecting the samples 3 times per year.
  - Analyzing the water samples for:

    - pH
    - specific conductivity
    - hardness
    - chloride
    - total dissolved solids
    - total organic carbon

- Measurement of flow from the Richmond Tunnel at the time of sample collection.

- Design of the final cover system should anticipate future subsidence. The potential for subsidence should also be considered in planning for the final use of the site.

REGIONAL GEOLOGY

This section discusses bedrock and soil materials within an area roughly one mile around the existing landfill.

Bedrock Formations

Bedrock in the project area is divided into three major geologic formations including the Tukwila, Renton and an unnamed sequence of Oligocene-Miocene marine rocks (Figures 5 and 6) which have been folded and faulted to varying degrees. A regional geologic cross section showing the general bedrock relationships is shown on Figure 6.

South of the landfill, approximately 0.5 miles (1 kilometer), interbedded sedimentary and volcanic rocks of the middle Eocene (approximately 50 million years old) Tukwila Formation outcrop (noted as "TtK" on figures). These rocks form a long east-west-trending ridge and consist of siltstone, sandstone, conglomerate, and welded tuff.

North and stratigraphically above the Tukwila Formation, and underlying the landfill, are a thick sequence of sandstone and siltstone beds that contain numerous coal seams of varying thicknesses. These units belong to the middle to late Eocene (approximately 45 million years old) Renton Formation (noted as "Tr" on figures). Some of the coal seams have been extensively mined (see Mining Activities section). Renton Formation units in the landfill area trend to the west northwest and dip, or are inclined, to the northeast from 30 to 50 degrees (Figures 5 and 6).

The youngest bedrock formation in the area (approximately 35 millions years old) is the Oligocene-Miocene age Marine Rocks (noted as "Tom" on figures) that overlie the coal-bearing Renton Formation. These beds consist of marine sandstone, shale, and minor amounts of conglomerate which form the deep groundwater aquifer used by many single and multi-family wells in the area.

Surficial Units

Overlying bedrock units throughout the area are surficial units of varying age and lithologies (noted as "Qu" on Figure 5). The oldest mapped surficial unit is glacial drift. Glacial drift deposits include advance and recessional outwash deposits of sand and gravel and clay/silt-rich till. At least two different ages of drift occur in the area; a pre-Vashon, gravelly sand (probably outwash) and Vashon age advance and recessional outwash and till. The older units are of limited extent in the landfill area.

Vashon till, the predominant surficial unit, occurs as a blanket over most of the area, especially on hills. The till consists of unsorted, unstratified mixture of cobbles, gravel, sand, silt, and clay. The till is very compact and can be difficult to excavate. Water tends to perch on flat areas covered by till and generally can not be recovered in sufficient quantities for wells to be used for domestic supplies.

Advance and recessional outwash consisting of poorly sorted to well sorted gravel and sand with minor amounts of silt and clay occur in areas along stream bed side slopes and in the broad valley to the east of Lake Boren. Some outwash deposits may be easily excavated due to the lack of compaction and coarseness of the materials. Some outwash deposits provide water supply in the form of shallow wells and springs.

Throughout the area, residual soils up to a few feet in thickness have developed on top of the bedrock, till, and outwash deposits. These residual soils contain abundant organic material mixed with weathered sand, gravel, silt, and/or clay. The bedrock sandstones and siltstones exhibit gradational weathering from soil at the surface to hard, dense rock at depth. Residual soils developed from till and outwash weathering are similar in appearance, and tend to be more gravelly than those that develop on bedrock.

Other surficial units, referred to as alluvium and colluvium, and localized landslide debris were also observed. These deposits usually consist of loose clay, silt, sand, gravel, and/or cobbles that are unsorted and poorly stratified. In addition, there is an extensive area of coal preparation plant waste along the banks of Coal Creek, north of the landfill site. Skelly and Loy (1985) reported this material to be 30 to 50 feet in thickness, and to extend over approximately 15 acres.

EARTHQUAKE CONSIDERATIONS

The Puget Sound area is considered to be susceptible to earthquake activity, and has been treated as such in development of some local land use planning guidelines and in structural design for some facilties. The 1980 King County Sensitive Areas Map Folio shows unincorporated areas of land, within the county, which are considered to be Class III Seismic Hazards. These areas which are identified as a "local subzone" of U.S. Geological Survey seismic risk zone 3.

The Class III areas are identified as "those areas of King County which are subject to the most severe level of earthquake response". This category appears to include a limited area of the northern part of the landfill site. King County Ordinance 4365 establishes a process for regulating development within seismic hazard areas, as well as within areas of abandoned mines and other types of "natural hazard" areas.

The Map Folio text describes the designation of seismic hazard Class III areas as being based on the "presence of poorly drained to impervious alluvium and organic soils which are usually saturated and characterized by low density, and all other soil types located on slopes steeper than 15 percent." The practical effect of the seismic hazard designation is to indicate that potential seismic problems will be considered in the site plan review by the King County Building and Land Development Division. Seismic hazards which are typically a concern to King County include liquefaction and slope instability. In addition to these potential concerns, the effect of an earthquake on anticipated subsidence is likely to be assessed in a permit review for the Newcastle Landfill.

Previous geologic studies in the project area have not located any faults which are considered to be a potential earthquake source. A number of minor faults crossing the coal beds are shown on some of the old mine maps from the Newcastle area, however, the data indicate that these features are shallow and limited in extent and are interpreted to have occurred during the structural folding of the Renton Formation rocks which resulted in the present northern dip of these strata. Seismic studies in the Puget Sound area indicate that local earthquakes of significant magnitude typically originate at depths on the order of 40 to 70 kilometers. On this basis, it appears extremely unlikely that any past or future earthquake activity would be associated with the relatively near-surface faults which intersect the Newcastle area mine workings.

The observed soil conditions do not indicate that liquefaction due to seismic shaking would be a problem at the site. Liquefaction typically is considered to be a potential problem in saturated sands which are initially in a loose to moderately dense condition. Test pits excavated in the vicinity of the landfill for this study generally encountered very dense glacially overridden soils and weathered bedrock, which were locally mantled by relatively looser surficial soils on the order of a few feet in thickness. Although occasional minor seepage and/or surface ponding was noted in a few areas, the relatively loose surficial soils generally appeared to be well drained.

Slope stability problems within the landfill, should they occur, are not anticipated to pose much risk to the general public so long as access to the landfill is controlled. Seismic shaking may result in instability of cut or fill slopes that otherwise appear to be stable prior to an earthquake. Engineering analyses are available to assess the risk of such instability, and would typically be utilized in areas where slope failure could result in risk to human life or significant property damage. Perimeter slopes in refuse fills, along the proposed access road adjacent to the Newcastle Coal Creek Road, or in other areas where there is risk of slope movements affecting off-site areas, should be designed or assessed for potential instability, in accordance with typical engineering practices.

Generally speaking, it appears likely that subsidence will continue to occur in the vicinity of the landfill with or without continued landfilling operations or earthquakes, and the occurrence of earthquakes may impact the rate but not the degree of subsidence. Several previous studies have considered the potential for adverse earthquake effects on underground tunnels. Engineering literature reviewed for this study did not identify any examples of mine subsidence resulting from earthquakes, although there is potential that such may occur under some circumstances. Potential for seismically induced collapse of underground openings has been extensively studied in connection with design of facilities such as subways and nuclear waste repositories. While it may be hypothesized that superposition of seismic loads on existing gravity loads could aggrevate subsidence at the landfill, engineering literature includes relatively few examples of adverse effects on underground openings.

SITE FEATURES

Hart-Crowser personnel conducted surficial geologic reconnaissance and test pit excavations in and adjacent to the permit area (Figure 2). The site reconnaissance was accomplished to locate: springs, seeps and ponds; surface depressions, mine-openings, or other geologic hazards; and to determine the general properties of soils in the permit and expansion areas. Results of the test pit excavations and laboratory test results are shown in Appendices A and B, respectively. Figures 2, 3 and 4 show the results of the site reconnaissance.

Landfilling Observations

The extent of landfilling and the limits of topsoil stripped at the time of our observations are shown on Figures 2 and 5. Fill thicknesses reportedly range between 15 and 50 feet.

Some landfilling has occurred west of the existing permit area, within the eastern portion of the 75 acre area owned by CCDC. We understand that this filling was completed by the previous operators. Fill has been placed over approximately 20 percent of the CCDC property, within the proposed expanded permit area, and is estimated to range in thickness from approximately 5 to 20 feet.

Two man-made ponds occur within the permitted area. A small retention pond located near the junction of the haul road and Newcastle Coal Creek Road collects runoff from the northeastern portion of the permit area. Discharge is into the roadside drainage ditch. Another small retention pond near the junction between the main haul road and the exit lane from the top of the landfill collects runoff from the east central landfill area.

Near-Surface Soil and Rock

Twenty-seven test pits were excavated at the locations shown on Figure 2. The logs of these explorations are presented in Appendix A.

Within the northeastern portion of the permit area glacial deposits (till and outwash deposits) were encountered, ranging in thickness from three to greater than ten feet. Underlying the glacial deposits the Renton Formation (sandstone and siltstone) was observed. The top one to six feet of bedrock has weathered to a silty sand which grades into unweathered material with depth. Backhoe excavation was successfully completed within the weathered bedrock materials but could not be completed in unweathered bedrock.

Test pits excavated in August, 1985 in the southern portion of the permit boundary, prior to filling, indicate generally similar stratigraphy as that noted within the northeastern portion of the permit area. A coal seam was encountered in test pit TP-2. Residual soils were much thicker in this area than to the northeast and the till was highly oxidized and stained a brownish-red. We understand that prior to filling the surficial soils were removed from this area and used to construct a portion of the perimeter berms.

Soils and weathered bedrock have been stripped for use as cover material over an irregular area (Figure 2) adjacent to the western portion of the landfill, leaving stumps and small mounds of soil (approximately three feet high) in-place. A thin, poorly developed soil profile was observed within this stripped area. Test pits indicated bedrock at or near the surface.

North of the permit area boundary several small landslides were noted. Maximum observed slide size was 75 feet by 50 feet. No active seeps or springs were observed in this area, although some vegetation ("devils club" and "vinemaple") suggest water may be near the surface during a portion of the year.

Outside of the stripped area to the west of the existing landfill, the soils consist of forest litter and residual soils generally up to about three feet thick, overlying glacial drift and/or bedrock. Glacial drift ranges in thickness from 0 to about 15 feet. Nine test pits, and exposures in stream channels, roadcuts, and mine openings indicate that bedrock is generally at shallow depth throughout this portion of the study area. The predominant glacial unit in this area, till, is dense and poorly sorted. Several wet areas occur in the project area indicating that surface water does not readily percolate downward. The till deposits appear to be thickest in the southern portion of the area owned by CCDC, west of the existing landfill.

Forest litter, residual soil, and glacial drift overlie sandstone, siltstone, and minor coal seams of the Renton Formation in the area to the south of the landfill. Alluvial and colluvial soils are present in and adjacent to China Creek, which is the drainage for the southwestern portion of the landfill area. The upper reaches of China Creek were observed to be dry down to an elevation of about 700 feet, during our field reconnaissance. No mine openings or surface depressions indicative of subsidence were observed in this area.

Laboratory grain size and permeability tests were accomplished to determine engineering characteristics of the different soils observed in the test pits. The laboratory test methods and results are discussed in Appendix B.

Observed Surficial Mine Features

Evidence of past mining around the landfill site is available from numerous published reports as well as recent observations. Some mine openings have been fenced, others are open and visible, and some are well hidden by foliage. Several of these features were observed for stratigraphic information and the presence of water. No water was found in any of the openings down to depths of about 35 feet (the maximum measured depth).

Ecology and Environments, Inc's. (1983) inventory of mines potentially used as hazardous waste dumps found no evidence of substantial dumping in local mine openings, however, observations by Skelly and Loy (1985) as well as prior work by Hart-Crowser & Associates, Inc. indicate refuse has been dumped in several mine openings in the area.

Numerous surface depressions, apparently related to subsidence of old mine workings and an open shaft were observed north of the landfill between roughly the 730 and 775-foot contour interval. The depressions are linear, elongated, shallow features which trend west-northwest, are a few feet deep and wide, and roughly 20 to 50 feet long. Several cone-shaped depressions were also observed, northeast and northwest of the site. Some of the depressions were shallow, and others were 15 to 20 feet deep and 20 to 30 feet in diamter.

MINING

Background

Background information on the abandoned coal mines in the Newcastle-Coal Creek area is available from a variety of previous studies from the early 1900's to the present. Sources of information used in preparing this report include maps prepared by the old Washington Geological Survey and current Department of Natural Resources (DNR), the U.S. Bureau of Mines, the U.S. Office of Surface Mining (OSM), and previous studies in the area by Hart-Crowser & Associates, Inc. and others.

Mining beneath the landfill apparently began around the turn of the century. The coal seams in the project area are oriented as a series of inclined, tabular beds (Figure 5) and mining followed the inclination of the coal seams, which trend (strike) west to east . Typically, a relatively flat tunnel, referred to as a "gangway" or "level", was driven horizontally along the strike of the seam and coal was extracted by working up the dip of the seam above the gangway. The southerly (and upward) extent of the older workings from each gangway, where recorded, was typically on the order of 200 to 400 feet. Barrier pillars of coal initially left between working levels and along haulage ways were typically excavated ("robbed") by more recent miners.

The extent of recorded mine workings under the existing landfill is indicated on Figure 7. The mine workings under the landfill extend to the north, east and west, and connect to other mine workings which extend over an area of more than 700 acres.

Landfilling has occurred over portions of at least four coal seams known to have been mined: Muldoon, May Creek, Bagley No. 3 and possibly the No. 4 seams (Figures 5 and 6). Landfilling may also have covered additional thin "stringers" or "interbeds", which were not mined. No record of mining was found for the project area south of the Muldoon subcrop line (a subcrop in the line where the top of a coal seam meets the overlying soil or fill).

The original depth of soil cover over the top of the dipping coal seams, within the landfill boundaries, is not known. The soil was removed from part of the landfill area during strip mining on the Muldoon Seam (Figure 2 and 5), however, the extent of the earth moving is not known.

Figure 5 shows the subcrop lines for the seams mined beneath the landfill area. Location of the subcrop line is important, as this is the most likely locations for mine entries and airways, considering the mine layout known to be used in this area. A recent study for the OSM by Skelly and Loy, 1985, found recorded evidence of 14 mine openings to underground mine workings within the landfill area, and was able to document by visual observation 7 of these.

The locations of mine workings and related features (e.g., the coal seam subcrop lines) shown on the figures in this report are estimated to be accurate to within roughly 100 to 200 feet, based on our present information as well as previous work in the area. Greater accuracy in locating specific seams would require subsurface borings and surveying.

Evans, 1912, describes the mining methods which were used in this area. Pillars were left along the haulage ways and in the section above the gangway until a level was entirely developed, then most of the pillars were extracted on retreat. The Pacific Coast Coal Company (the major mining entity in the area) reportedly left the pillars along the gangways and at the top of each level of workings to provide support, but allowed the intervening sections (between levels) to collapse if they would. Later operations in this area (i.e., the "gypos" around the 1940s) resulted in additional pillar robbing, in many cases mining the pillars along the margins of the older workings, and in particular the near-surface coal that had been left at the top of the first level of workings.

Contemporary mining records, and more recent anecdotal information from some of the area's retired miners, indicates roof stability and the need for pillars and/or other supports, varied from seam to seam, as well as locally within different seams. Landes and Ruddy, 1902, describe use of the "breast and pillar" system of mining where roof conditions were bad, and use of the "panel system" where conditions were good. Some areas of the workings apparently caved while active mining was underway in the same vicinity, other areas are believed to have stayed open much longer. Observations in the area indicate many of the old entryways are still open to considerable depth.

Interconnection of mine workings is evident from mining activity descriptions (such as Ash, 1921), and as shown on old mine maps. Most of the coal mine workings in the Newcastle-Coal Creek area were interconnected. Initially, this interconnection was done deliberately to provide efficiencies in haulage from underground, both within particular coal beds, and through "rock tunnels" which were driven to connect workings in adjacent coal seams. Drain holes were drilled between adjacent sections of workings to protect miners in newer workings from mine flooding.

Considering the degree to which different mined areas were deliberately interconnected, as well as the effect of collapse between different levels as described by Ash, 1921, water in the abandoned mines in this vicinity can be considered as a single "mine pool." This interpretation is supported by records such as the 1929 Map of Newcastle-Issaquah Mines, by Pacific Coast Coal Company, which shows (for example) the Second Level on the Muldoon Seam extending from roughly a half mile west of the landfill to more than a mile and a half to the east of the landfill.

Subsidence

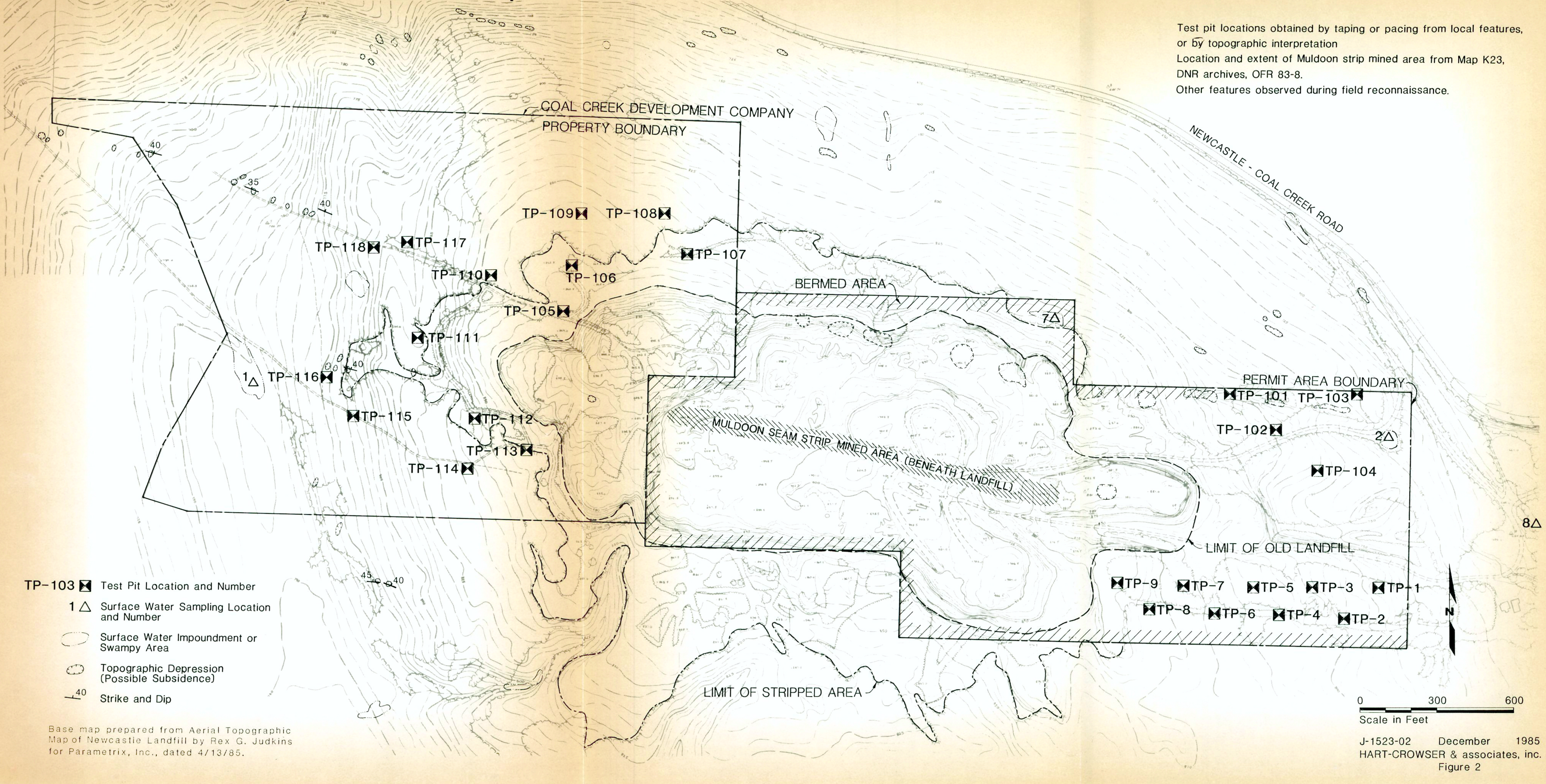
Subsidence is defined herein as differential settlement of the ground surface. The rate and magnitude of subsidence may be affected by a number of factors, but in general the process occurs due to collapse ("caving") of overlying rock strata into the mined voids. Subsidence of the ground surface has occurred and is likely to continue in the vicinity of the Newcastle Landfill area, since most of it is undermined by one or more levels of mine workings.

Stresses in the ground cause subsidence to result from movements initiated through failure of the roof or floor of the mine workings, and/or in pillars of coal or other supports which may have been used. The load, or stress from the overburden (including loads applied at the surface) is one of several factors which affect the collapse process. Although direct information on the present condition of the mine workings at depth is not available, there are indirect indications that caving has initially occured near the surface, but not necessarily at depth. Such indications include observation of subsidence features above relatively shallow workings, but not above adjacent deeper workings; observation of mine entries which are open to great depth (as indicated by the sound of rocks dropped down these entries); and the reported absence of evidence of large scale downwarping on air photos of the area. These indications suggest that overburden load, or stress is not a main factor in the subsidence process observed in the Newcastle vicinity, and therefore that past or future landfill operations likley do not have a significant effect on the occurrence of subsidence.

Although there is some potential for future discovery of currently unavailable mine records and/or unrecorded ("gypo") mine workings within the landfill, the extent of known and inferred mining within this area is such that discovery of additional mining would not materially change the extent of anticipated subsidence. Available information indicates the entire site has been undermined except for a relatively thin band south of the Muldoon crop line, along the southern border of the site, as shown on Figure 5.

Observed subsidence in the vicinity of the landfill has resulted in surface discontinuities ("sink holes," scarps and hummocky ground), with local relief on the order of several feet or more. The same degree of ground movements probably have occurred within the landfill, as well. Studies in other areas of the U.S. indicate subsidence over coal mines may not be significant until 50 to 100 years after abandonment, thus observation of

Site Reconnaissance and Explorations Location Map



Test pit locations obtained by taping or pacing from local features, or by topographic interpretation
Location and extent of Muldoon strip mined area from Map K23, DNR archives, OFR 83-8.
Other features observed during field reconnaissance.

TP-103 ⧓ Test Pit Location and Number
1 △ Surface Water Sampling Location and Number
Surface Water Impoundment or Swampy Area
Topographic Depression (Possible Subsidence)
40 Strike and Dip

Base map prepared from Aerial Topographic Map of Newcastle Landfill by Rex G. Judkins for Parametrix, Inc., dated 4/13/85.

J-1523-02 December 1985
HART-CROWSER & associates, inc.
Figure 2

prior ground movements in the Newcastle area may not be a reliale indication of the magnitude of future subsidence.

Apparent subsidence has already occurred within the landfill permit area as indicated in the cross sections in the 1986 Unclassified Use Permit drawings prepared by Parametrix, as well as on the Abandoned Coal Mine Survey map prepared by Skelly and Loy for OSM, dated February, 1985. Subsidence features may presently be observed in close proximity adjacent to the landfill, and it is likely that landfill operations have covered other evidence of subsidence. The extent (magnitude and location) of future subsidence will depend essentially on the degree to which the mined voids have filled with material from previous caving. No information is available on the degree of caving which may already have occurred in the workings under the landfill.

Considering available information for the landfill area as well as from other sites, planning for future use of the landfill should consider the potential for future subsidence to be of greater magnitude and/or at increased rates than previously observed. Prevention of subsidence is generally considered impractical due to cost, except where mine workings are readily accessible. Where subsidence prevention has been considered necessary to protect surface facilities at other sites, it has been accomplished (at considerable cost) by backfilling with relatively incompressible material. This is not likely to be cost-effective for the Newcastle Landfill site considering present and anticipated future use of the site, and the relative complexity and inaccessability of the mine workings.

Future subsidence resulting in differential ground movements is likely to impair the integrity of any type of landfill cover, and/or any barrier placed between the refuse and underlying natural ground. We anticipate long-term caretaker status will be appropriate unless the site is closed to access, as there is presently no means of determining the rate or extent of future ground movements at the site. Considering foundation problems which may be anticipated due to either continued mine subsidence or differential settlement of the refuse already on-site, future use of the site for structures may be considered impractical, and utilization as "open space" such as the proposed golf course may be quite practical. From the standpoint of risk arising from future subsidence, evalution of the site as either a landfill or for other purposes should consider the following:

- Risk to the public will be minimized by controlling access, limiting the density of use, and by allowing transient rather than continuous occupancy,
- Risk to persons in the area will be reduced by providing for high visibility open space, which is inspected and maintained on a regular basis,
- Ongoing revenue generation may be necessary to assure a financial basis for mitigating future subsidence related hazards which could develop.

Mine Fire Potential

For the unmined coal covered by the landfill, as with any coal seam, there is potential danger of a fire burning within the seam at or below the ground surface. This is a significant problem in some areas, but has been reported in Washington only a few times. The risk of a coal fire beneath the Newcastle Landfill could be increased if subsidence resulted in burning refuse being brought into contact with the underlying coal. A somewhat related potential problem involves the risk that methane in the mine workings, above the water table, could be present in the mine atmosphere in such proportions as to present an explosion hazard.

No information indicating any problem with past methane explosions in the area was found during this study. The air in coal mines commonly contains some amount of methane along with other gases, but the relative proportions and consequent hazard are variable from one location to another depending on the nature of the coal and adjacent strata, and the degree of ventilation. Potential for methane explosions being initiated by burning refuse would be reduced as mine openings are closed, but future subsidence could create new openings.

Bulletin 590, by the U.S. Bureau of Mines, 1960, specifically warns against "garbage or trash...dump areas over or near a surface exposure of a mined coalbed." This is because accumulation of heat from decay of organic material may lead to ignition of the coal. Although the ignition temperature of coal is on the order of 800 to 900 degrees fahrenheit, the ignition process may begin at temperatures as low as 200 degrees and proceed spontaneously due to the heat of oxidation. In addition to such bacteriological/chemical sources, other possible sources of ignition include fires accidently or deliberately set in the refuse, as well as the spread of off-site fires such as slash burns.

Good housekeeping practices at the landfill will reduce the likelihood of fires in the refuse, but it is not considered possible to completely eliminate the risk of ignition of the undelying coal so long as organic or combustible material is present in the refuse. Segregation of future refuse such that organic or combustible materials are surrounded by noncombustible materials, will reduce the risk of spreading potential combustion. This isolation may not be effective if large scale subsidence occurred. Similarly, the risk of fire would be reduced to the extent the decay of organic material produced anaerobic conditions within the landfill, as oxygen needs to be present to support combustion.

Fires were a danger during operation of coal mines in the Newcastle area, as they are in coal mines in other areas. Published information describes at least one major mine in the immediate vicinity of the landfill which caught fire and was abandoned and allowed to flood, and reported anecdotal accounts indicate other mine fires may also have occurred in the area. We understand there have been relatively recent reports of smoke observed at the landfill, but whether this indicates burning of the refuse or the underlying coal, is not known. Mist unrelated to combustion may also vent from mine openings under some atmospheric conditions, and this may possibly have been identified as smoke. It may be possible to determine whether there is presently a fire in the abandoned mine workings, and/or whether methane is present in explosive proportions, by monitoring the mine atmosphere through boreholes from the surface.

In the event that unmined coal beneath the landfill were to catch fire, it is possible that this could accelerate subsidence, and that subsidence could greatly increase the difficulty in controlling the fire. Subsurface coal fires can sometimes be extinguished by placement of soil cover to exclude oxygen, but a coal fire in the Newcastle area would be difficult or impossible to control in this manner due to the extensive old mine workings and subsidence features which could supply air. Control of a coal fire can also be accomplished by excavation of cutoffs and/or excavation to remove the burning material, but this may be impractical due to the steep pitch of the coal seams. Control of a coal fire beneath the Newcastle Landfill site would likely be accomplished by a combination of these techniques.

Closure of Mine Shafts

Planning for future site use should consider the potential need for remedial work to close shafts (as well as other subsidence holes) which may open. Shaft sealing techniques have been developed by the U.S. Bureau of Mines and others, and the Office of Surface Mining (OSM) can provide technical support for mitigating such hazards. In some cases, OSM may accomplish shaft closure work, however, the availability of funds for doing this is constrained by policy to certain types of sites.

Good shaft sealing techniques generally involve use of concrete and steel caps which are securely founded in bedrock, and closing an opening which extends through soil and/or landfill materials would likely require excavating around the opening to reach bedrock. Accordingly, it would likely be more cost-effective in the long run to do a good job of shaft closure prior to landfill placement, than to use expedient means and possibly have to reconstruct a shaft closure later. For shafts which have already been covered by the landfill, there may be no good way to address this concern, however, for any remaining mine openings on the landfill property or in the proposed expanded permit area, we recommend that permanent shaft closures be constructed.

GROUNDWATER FLOW SYSTEM

The groundwater flow system analysis was completed using existing available data (both published and unpublished). This data was supplemented by data collected during a field well inventory which was completed in November and December, 1985 within an area of about 1000 feet of the landfill and in selected areas at greater distance (based on well density and groundwater flow directions). During this inventory, well owners were contacted, well construction details were recorded, and where possible, well water levels and field measurements for pH and specific conductivity were made. A listing of the identified wells is contained in Table 1.

Groundwater in the area originates as precipitation that infiltrates the ground and migrates to the water table. A portion of the recharge will migrate within soil pores of the shallow soils. The remaining portion of the recharge migrates into bedrock and flow will occur within fractures, or mined areas.

Groundwater in the area generally migrates from high elevation areas to lower elevation areas. Discharge occurs either as base flow into drainage channels such as Coal Creek, or as underflow into Lake Washington.

There are two primary groundwater flow systems in the vicinity of the Newcastle Landfill. A shallow groundwater system which occurs within surficial soil units and a deeper groundwater flow system within the underlying bedrock units. The mines are a special part of the deeper bedrock groundwater system.

Shallow Groundwater Flow System

In the lower elevation areas (ditches, gullies, and Coal and China Creeks) surrounding the landfill (below approximately 850 feet), and along the sides of the off-site drainage channels, water bearing, shallow surficial soil deposits are present. In some locations these deposits are saturated year-round and provide groundwater to shallow wells suitable for domestic purposes.

The surficial groundwater flow system apparently is not present beneath and in the immediate vicinity of the landfill. This is evidenced by tests pits excavated within 600 to 1200 feet of the landfill which generally showed the surficial deposits to be thin and unsaturated. The "water level" indicated on the old mine maps is well below the top of bedrock.

The locations of known wells in the area are shown on Figure 4. Wells (27F1-F2, 27F4-F5, 26K3, 26K5, and 27M1) are shallow dug wells that tap the surficial soil deposits.

The shallow groundwater system is likely hydraulically connected to the surface water drainage system in the area and to the deep groundwater flow system. Groundwater flow in the shallow deposits will generally flow along the slope of the land surface topography with the primary flow being toward Coal Creek, China Creek, and other drainages.

Deep Groundwater Flow System

The primary groundwater flow system (and aquifer) in the vicinity of the landfill is within the underlying bedrock units. Flow within these units occurs within fractures or the abandoned mine workings.

The majority of wells which tap bedrock are located to the northeast of the landfill and are drilled in the non-coal bearing Oligocene-Miocene Marine Rock unit (Tom), outside of the general area where mining occurred. These wells vary in depth from 55 to 510 feet (well elevations are listed in Table 1) and water elevations are generally above elevation 700 feet.

Groundwater beneath the landfill lies within the coal bearing Renton Formation and is as much as several hundred feet deep beneath the landfill. Water levels measured in the wells and mine openings in the surrounding area indicate that the water level elevation beneath the landfill is within the range of 450 to 650 feet.

Several wells located to the northwest of the landfill are finished in the Renton Formation (Wells 26K1, 26K2, and 26K4). The logs of these wells indicate that they vary in depth from 113 to 141 feet and tap fractures within the unit.

Three to four thousand feet to the west of the landfill the available data and well inventory indicate that two wells domestic water supply systems tap the mine workings. Well 27E1 is drilled to tap into a flooded mine working while the water supply for 27F3 consists of piping placed through an existing mine shaft. The water level in wells 27E1 is estimated to lie at an approximate elevation of 425 feet. The water level elevation in the mine opening at 27F3 is lower than 470 feet. The actual water level could not be measured at the time of our field work.

Groundwater generally flows from areas of high water elevations to areas of low water elevation. As shown on Figure 4 water level elevations are highest to the northeast of the landfill and are lowest elevation to the west of the landfill. The data indicate that groundwater flows generally in a southwesterly direction towards the landfill and mining area and then flows in a westerly direction (along the coal seam trend). Discharge from the mine workings into a tributary of Coal Creek occurs at the Richmond Tunnel, approximately one mile west of the landfill.

The pattern of local groundwater flow may be altered by a plan that is being studied by OSM. A portion of the flow in Coal Creek, upstream of the landfill, flows seasonally into, and out of, a mine entrance known as the Ford Slope. OSM is evaluating the possibility of closing this mine opening and diverting the flows along surface water drainages. Diversion of this water from the mines may effect water levels within the mines and would likely reduce flows from the Richmond Tunnel. It is very unlikely that the regional groundwater flow patterns would be substantially altered, however, we understand OSM will assess such impacts prior to accomplishing the Ford Slope closure.

Existing Water Quality

Conductivity and pH measurements taken in the field (Table 1) on domestic wells show conductivity values generally less than 150 umhos/cm and pH values in the range of 5.5 to 6.5 pH units within the shallow groundwater system. The deeper groundwater system shows a greater variation in the tested water quality parameters (pH and specific conductivity).

Conductivity values in the range of 100 to 300 umhos/cm and pH values in the range of 5.7 to 8.6 pH units were in wells upgradient of the landfill which top the fractured rock aquifer. Higher conductivity values (greater than 500 umhos/cm) and pH values in the range of 6.3 to 6.6 pH units were measured in three locations downgradient of the landfill. These locations are the outflow from the Richmond tunnel and two wells which pump water directly from the mines (Lee-27F3 and Baima-27E1 wells).

Water quality data have been collected for the past five years at the Richmond Tunnel and from Coal Creek at a station located near the Parkway underpass. A water sample was also taken from the Lee well (27F3) in 1981 and analyzed for selected water quality parameters. The analytical results for a recent Richmond Tunnel sample and the Lee well sample are listed in Table 2.

Table 2 - Water Chemistry Comparison

	Richmond Tunnel June, 1985	Lee Well (27F3) September, 1981)
Conductivity (umhos/cm)	1050	950
Chloride (mg/L)	<1.0	5.5
Sulfate (mg/L)	163	231
Hardness (mg/L)	360	410
Chromium (mg/L)	0.0017	0.0007
Cadmium (mg/L)	0.0003	0.0007
Iron (mg/L)	0.13	0.17
Lead (mg/L)	<0.001	<0.001
Manganese (mg/L)	0.05	0.05
Mercury (mg/L)	0.0004	<0.0002
Selenium (mg/L)	<0.005	0.002
Silver (mg/L)	<0.0003	0.0014
Zinc (mg/L)	<0.001	0.212

The available data indicate that the mine water samples meet Washington State Drinking water standards except for specific conductivity. The higher specific conductivity values are most likely the result of the measured sulfate concentrations and water hardness which are higher than what is generally measured in other groundwater samples obtained in southwestern King County (Luzier, 1969).

Principal Pathways for Leachate Transport to Groundwater

When water comes in contact with landfill materials leachate can be generated. Leachate characteristics will vary depending on the material placed in the landfill. The Newcastle landfill is a demolition waste landfill that accepts mostly materials that will not create leachate (such as concrete rubble, glass and other largely inert material). Construction of a landfill cover and grading are directed towards minimizing the amount of water that comes in contact with the fill, further reducing the possibility of leachate generation.

If leachate were generated it would migrate out of the landfill to groundwater in several ways:

- subsurface interflow along the bedrock/soil interface and flow to and within the shallow groundwater system;
- flow to and within the deep groundwater system.

Rainfall that infiltrates the landfill cover system will follow two primary patterns. Water will flow along the bedrock/soil interface (interflow) and become part of a shallow groundwater system at lower elevations or could infiltrate the bedrock and migrate downward through fracture zones, mine openings, and subsidence areas, and become part of the deeper groundwater system.

Migration within the shallow system will generally follow the land surface contours. Once the deeper groundwater system is reached, migration will generally be toward the Richmond Tunnel.

Impacts on Existing Wells

Our review of the Department of Ecology well log records and well inventory identified as wells located on Figure 4 and listed in Table 1. Three principal types of water sources that were identified based on the type of groundwater system tapped by the wells in the area. These include:

- wells tapping shallow water within the surficial deposits;
- wells tapping fractured zones within bedrock;
- wells that tap directly into the mine openings.

No evidence exists that the existing wells have been effected by the landfill. The higher, specific conductivity values (as compared with upgradient wells), and higher concentrations of sulfate and hardness (as compared with typical groundwaters in southwestern King County) downgradient of the landfill are likely the result of contact with the mines rather than an indicator of leachate contamination from the landfill.

Conversations with Tim Walsh of the Washington State Department of Natural Resources indicate that elevated concentrations of sulfate and hardnes would be expected from the type of coal in the area. Other indicators of leachate contamination, such as chloride, are low in concentration and are within the typical range for groundwater in Western Washington (Luzier, 1969).

Wells tapping the bedrock aquifer to the east and northeast of the landfill should not be adversely effected by the landfill. These wells are located upgradient of the landfill.

Wells 27E1 and 27F3 obtain water from the mine workings and are downgradient from the landfill. As discussed above, the available data indicate that these wells have not been contaminated by landfill leachate. Based on this finding, the type of waste deposited at the landfill (demolition waste), the age of the landfill, and the wells distance from the landfill, the potential for continued landfill operation to adversely effect the water quality of these wells is very low.

Sincerely,

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Table 1 Well Data

Sheet 1 of 3

SECTION WELL NUMBER ①	OWNER	GROUND SURFACE ELEVATION IN FEET ②	WELL DEPTH IN FEET	WATER LEVEL ELEVATION IN FEET ③	WATER QUALITY PARAMETERS ④		
					pH	ELECTRICAL CONDUCTIVITY IN µMHOS	TEMPERATURE IN DEGREES C
23C1*	Hilltop Community	790	312	750	--	--	--
23E1*	Horizon View	975	353	845	8R	320R	12.7R
23K1	Peltola	910	36	885	--	--	--
23R1	Reasoner	875	149	772	--	--	--
24J1	Lilleskare	1000	78	960	--	--	--
24K1	Roush	1025	450	970	--	--	--
24K2	Henderson	1025	190	890	--	--	--
24K3	Williams	1070	85	--	--	--	--
24N1	Beauclair	1000	200	885	--	--	--
24N2	Paschal	1085	550	1008	--	--	--
24N3	Carpenter	1035	500	--	--	--	--
24N4	Newton	975	220	943	--	--	--
24N5	Cole	1000	160	957	--	--	--
24N6	Justad	1025	120	993	--	--	--
24P1	Leber	1150	127	1037	--	--	--
24P2	Erickson	1150	263	1005	--	--	--
24P3	Doig	1175	328	1140	--	--	--
24P4	Hallock	1300	320	--	--	--	--
24P5	Cougar Glen Water Assn	1110	275	980	6.7	150	7
24P6	Winikoff	1215	319	985	--	--	--
24Q1	Dowling	1010	101	990	--	--	--
24Q2	Price	1050	203	1000	--	--	--
24Q3	Lennox	1300	Shallow	--	--	--	--
24Q4	Connor	1060	450	995	--	--	--
24Q5	Foster	1000	55	965	--	--	--
24Q6	Wilson	1300	230	1250	--	--	--
24Q7	Currie	1125	398	1040	--	--	--
24Q8	Kimm Jr.	1120	170	974	--	--	--
24R1	Schendel	900	70	865	--	--	--
24R2	Russell	1150	265	1163	--	--	--
25B1	Clark	1450	510	1431	--	--	--
25B2	Sparks	1470	525	970	--	--	--
25D1	Beauregard	1130	300	980	--	--	--

Table 1 Well Data

Sheet 2 of 3

SECTION WELL NUMBER ①	OWNER	GROUND SURFACE ELEVATION IN FEET ②	WELL DEPTH IN FEET	WATER LEVEL ELEVATION IN FEET ③	WATER QUALITY PARAMETERS ④		
					pH	ELECTRICAL CONDUCTIVITY IN µMHOS	TEMPERATURE IN DEGREES C
25D2	Lyons	1050	135	944	--	--	--
25D3	Burbridge	970	240	924	6.8	165	6.5
25D4	Smith	1100	260	870	--	--	--
25D5	Roberts	1010	24	1000	5	75	8
25D6	Leland	1010	18	1000	5	70	7.5
26B1	Longfellow	750	412	680	8.6	250	9
26B2	Hoover	750	47	750	7	155	7.5
26K1	Miller	680	141	644	6.1	230	8
26K2	Penton	680	120	615	6.6	340	10
26K3	Swanson	690	11	680	--	135	12
26K4	Swanson	690	113	660	5.7	200	11.5
26K5	Swanson	560	5	560	5.3	115	9
27E1	Baima	500	75 to mines	425	6.5	890	18
27F1	Winston	450	10	443	5.8	115	7.8
27F2	Lee	520	11	515	5.7	160	9
27F3	Lee	520	taps mine openings	<470	6.3	600	8.5
27F4	Lee	520	4	515	5.7	230	10
27F5	Koler	530	8	525	5.7	160	9
27M1	Pedeferri	460	8	455	5.3	120	9
34C1	Damm	510	72	506	5.8	145	10
34C2	Stubbs	520	78	483	5.9	140	9.5
34G2	Winters	600	--	--	6	180	9.5
34J1	King	520	210	371	--	--	--
SAMPLING NUMBER	LOCATION						
1	West Pond	750	--	750	5.2	65	--
2	Retention Pond	720	--	720	6.5	700	3
3	China Creek @ 136th SE	500	--	500	5.8	70	5
4	Ford Slope	640	--	640	5.8	68	9.5
5	Primrose Tunnel	620	--	620	5.6	490	10
6	Richmond Tunnel	412	--	412	6.6	700	12
7	Pond at Berm	840	--	840	5.6	1500	3
8	East Pond	680	--	680	6.0	130	3

Table 1 Well Data

Sheet 3 of 3

1. The well numbering system is based on the system used by the Geological Survey in the State of Washington which is based on the township, range, section number, 40 acre tract within the section, and a serial number. All wells and sampling points are located in Township 24 North, Range 5 East. Wells with * are not included on Regional Well Location Map, Figure 4 because they are outside of map area.

2. Ground surface elevation is estimated from topography on the USGS Quadrangle map after roughly locating the well or sampling location or was measured using an altimeter during the field inventory and should be considered approximate only.

3. Water level elevation is based on the estimate of the ground surface elevation and either a measured (November, 1985 or Fall, 1981) or reported depth to water level and should be considered approximate only.

4. The water quality parameters were measured in the field using a YSI Model 33 S-C-T meter to measure temperature and conductivity and a SSE 209B pH meter. R indicates values that were reported and not specifically measured in the field.

5. Field measurements and inventory were conducted during December, 1985.

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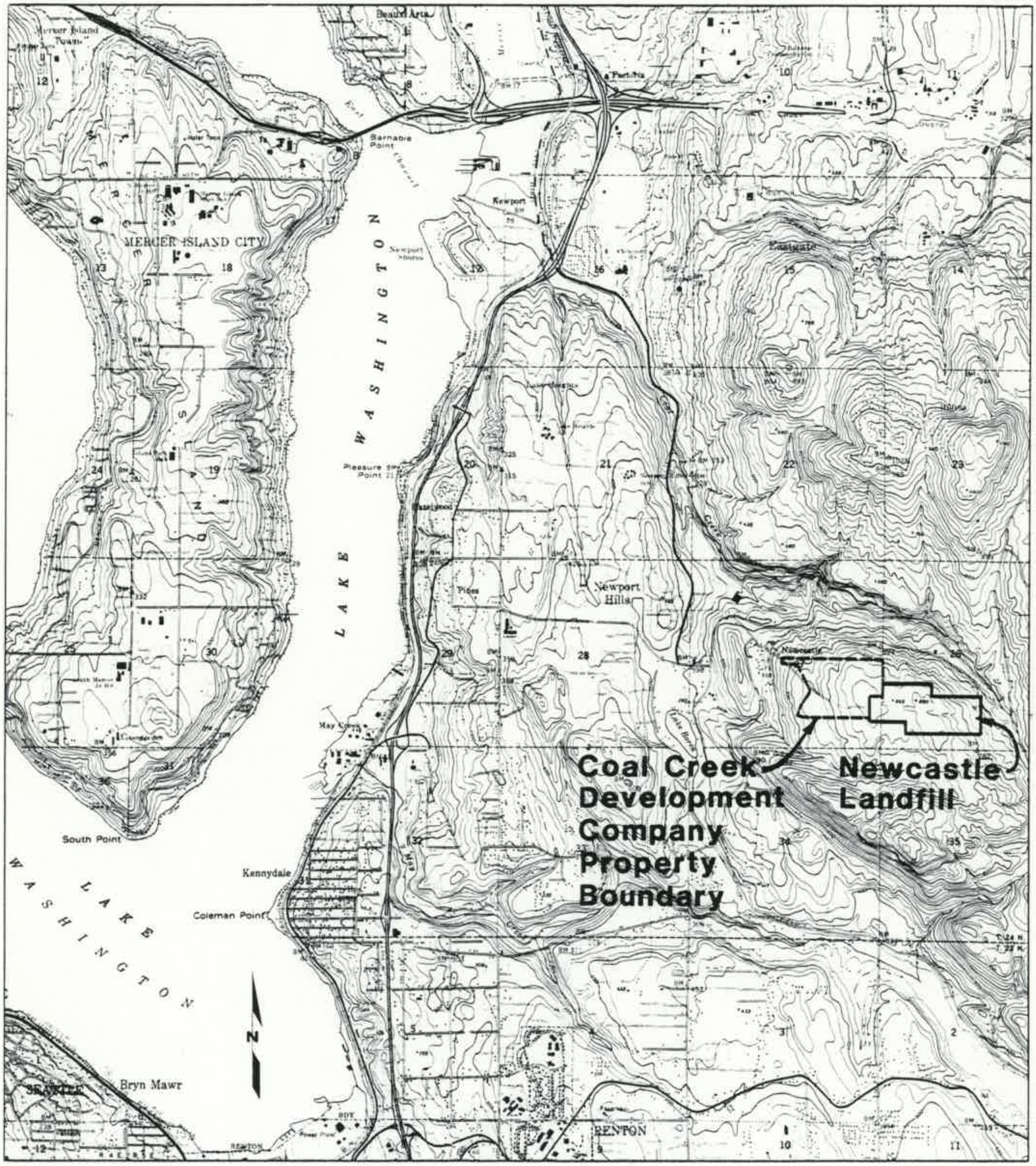
Vicinity Map



0 4000 8000

Scale in Feet

Base map prepared from 7-1/2 min. Quadrangle of Mercer Island, Washington.

J-1523-02 December 1985
HART-CROWSER & associates inc.
Figure 1

APPENDIX A
FIELD EXPLORATIONS

The program of subsurface explorations for this project included completion of twenty seven test pits excavated in two stages. Nine test pits were dug in August 1985; the remainder were dug in November 1985. The results of our exploration program are presented on the exploration logs within this Appendix A. The exploration logs are a representation of our interpretation of the excavation, sampling, and testing information. The depth where the soils or characteristics of the soils changed is noted. The change may be gradual. Soil samples recovered in the explorations were visually classified in the field in general accordance with the method presented on Figure A-1. A legend for the field exploration logs defining symbols and abbreviations utilized is also presented on Figure A-1.

Test Pits

A series of 27 test pits, designated TP-1 through TP-9 and TP-101 through TP-118, were excavated across the site utilizing a backhoe. Test pits allow direct visual observation of the subgrade soils on the sides of an excavated trench. The test pits were located by and excavated under the direction of an engineering geologist from our firm. Descriptive logs were developed in the field by observation of the soil disclosed in the test pits. Representative samples of soil types encountered were placed in plastic jars or bags and taken to our laboratory for further observation and testing. Ground water levels or seepage encountered during excavation were also noted. The density/consistency of the soil is based on visual observation and is not measured with a quantitative test during the excavation of the pits. The density/consistency is presented parenthetically on the test pit logs to indicate the value is estimated. The depth at which continued excavation was not readily possible using the backhoe was noted as the depth of refusal. The test pit logs are presented on Figures A-2 through A-15.

Key to Exploration Logs

Sample Descriptions

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

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

Density/Consistency

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

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

Moisture

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

Minor Constituents

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

Legends

Sampling

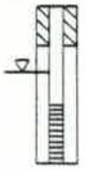
BORING SAMPLES

☒	Split Spoon
⧅	Shelby Tube
▥	Cuttings
◫	Core Run
*	No Sample Recovery
P	Tube Pushed, Not Driven

TEST PIT SAMPLES

☒	Grab (Jar)
⧄	Bag
⧅	Shelby Tube

Ground Water Observations



Surface Seal

Ground Water Level on Date (ATD) At Time of Drilling

Observation Well Tip or Slotted Section

♀ Ground Water Seepage (Test Pits)

Test Symbols

GS	Grain Size Classification
CN	Consolidation
TUU	Triaxial Unconsolidated Undrained
TCU	Triaxial Consolidated Undrained
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Curve
AL	Atterberg Limits

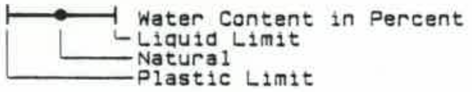


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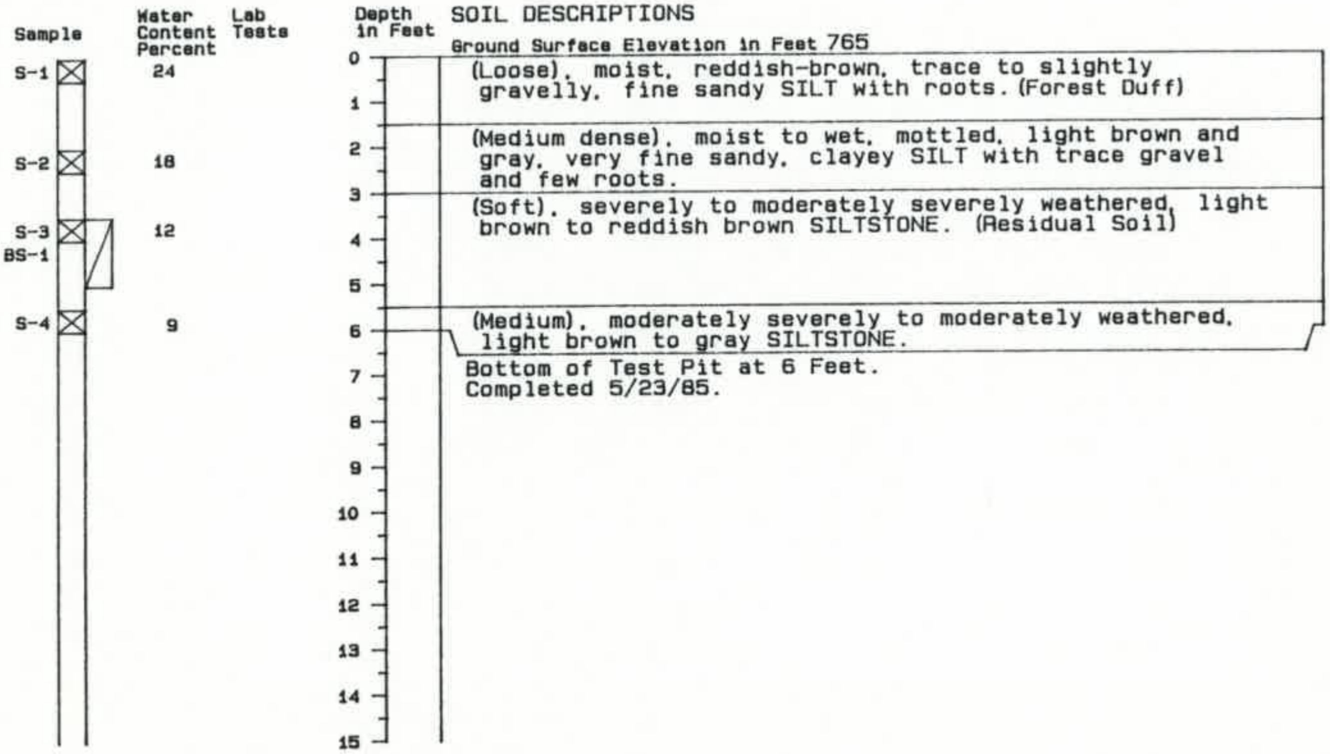
Figure A-1

Test Pit Log TP-1



Sample	Water Content Percent	Lab Tests
S-1	24	
S-2	18	
S-3	12	
BS-1		
S-4	9	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 765

(Loose), moist, reddish-brown, trace to slightly gravelly, fine sandy SILT with roots. (Forest Duff)

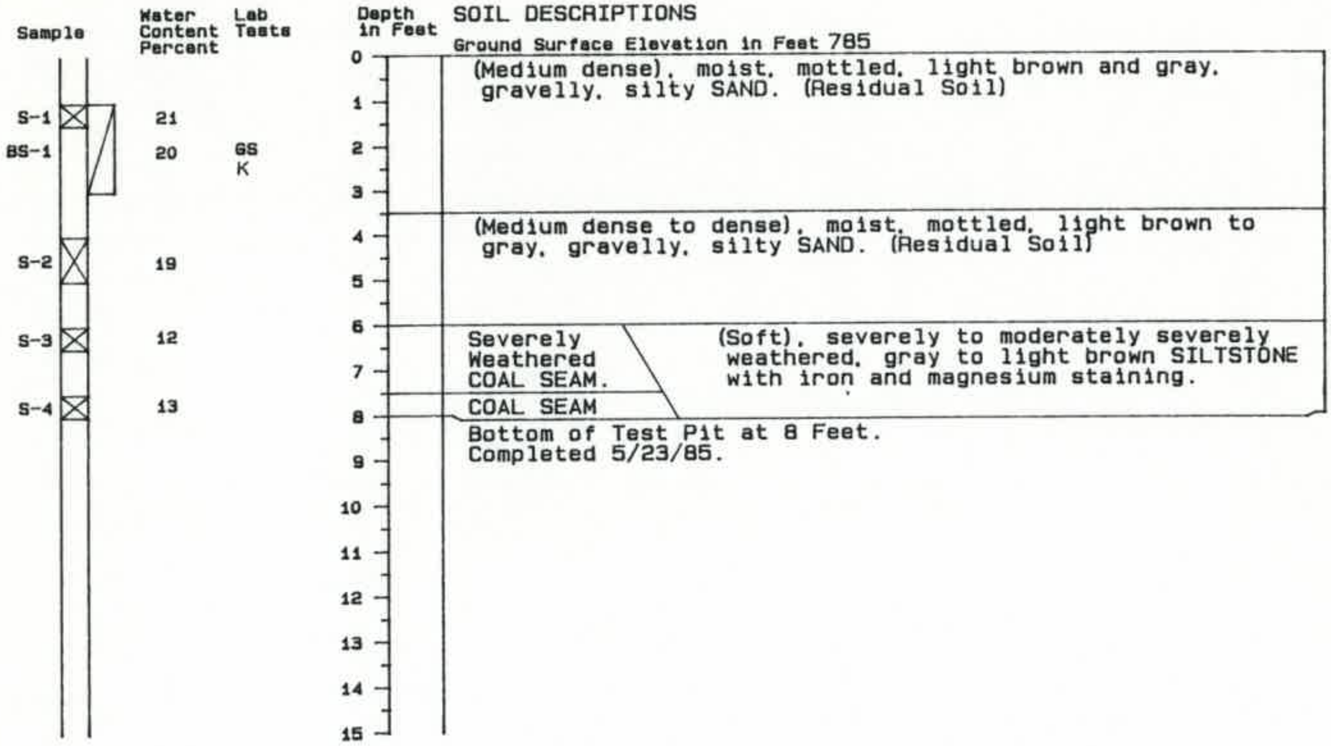
(Medium dense), moist to wet, mottled, light brown and gray, very fine sandy, clayey SILT with trace gravel and few roots.

(Soft), severely to moderately severely weathered, light brown to reddish brown SILTSTONE. (Residual Soil)

(Medium), moderately severely to moderately weathered, light brown to gray SILTSTONE.

Bottom of Test Pit at 6 Feet.
Completed 5/23/85.

Test Pit Log TP-2



Sample	Water Content Percent	Lab Tests
S-1	21	
BS-1	20	GS K
S-2	19	
S-3	12	
S-4	13	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 785

(Medium dense), moist, mottled, light brown and gray, gravelly, silty SAND. (Residual Soil)

(Medium dense to dense), moist, mottled, light brown to gray, gravelly, silty SAND. (Residual Soil)

Severely Weathered COAL SEAM.

COAL SEAM

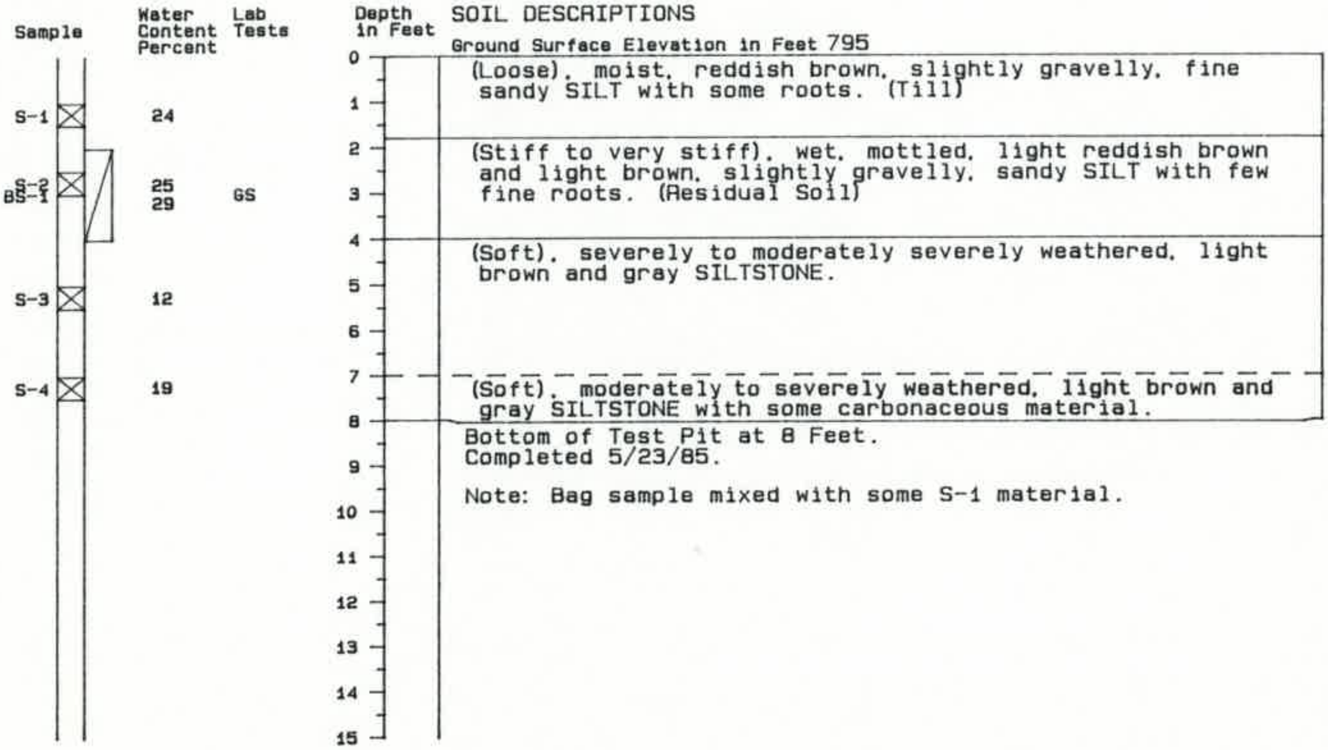
(Soft), severely to moderately severely weathered, gray to light brown SILTSTONE with iron and magnesium staining.

Bottom of Test Pit at 8 Feet.
Completed 5/23/85.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

J-1523-01 March 1985
HART-CROWSER & associates, inc.
Figure A-2

Test Pit Log TP-3



Sample	Water Content Percent	Lab Tests
S-1	24	
S-2	25	
BS-1	29	GS
S-3	12	
S-4	19	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 795

(Loose), moist, reddish brown, slightly gravelly, fine sandy SILT with some roots. (Till)

(Stiff to very stiff), wet, mottled, light reddish brown and light brown, slightly gravelly, sandy SILT with few fine roots. (Residual Soil)

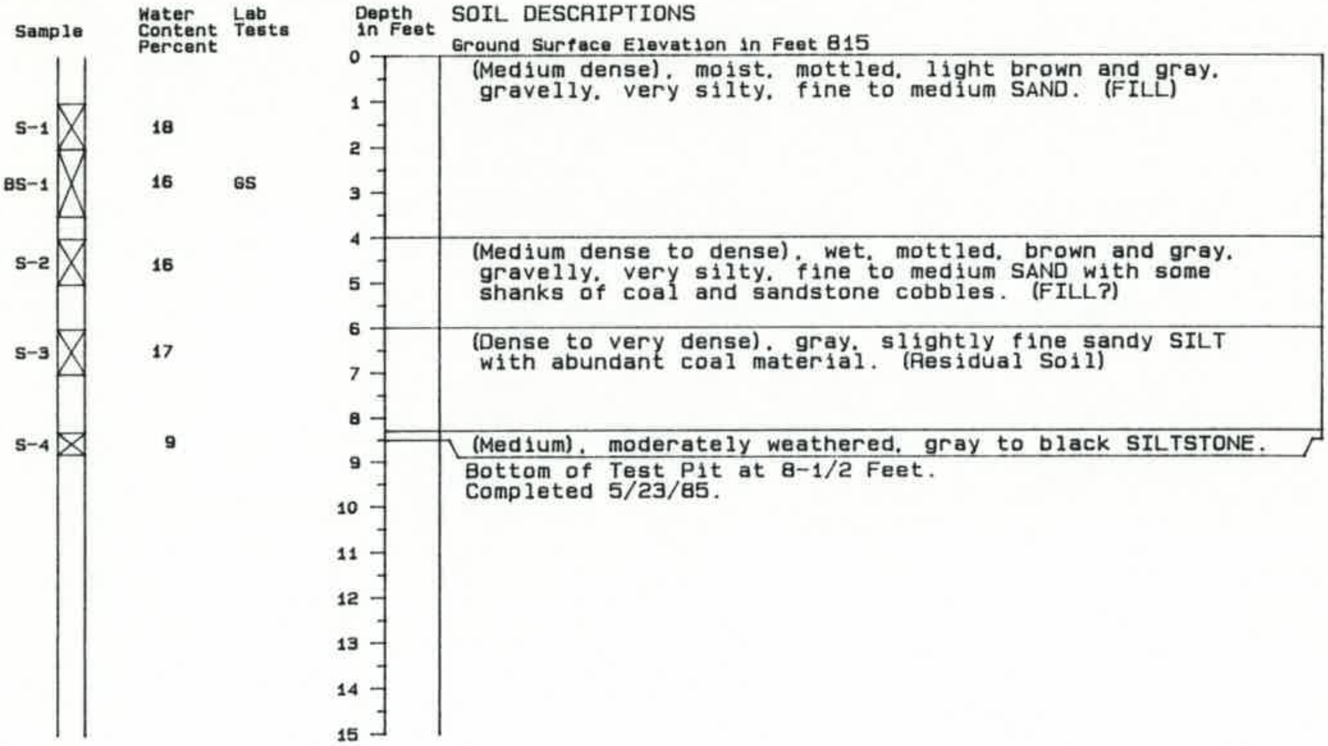
(Soft), severely to moderately severely weathered, light brown and gray SILTSTONE.

(Soft), moderately to severely weathered, light brown and gray SILTSTONE with some carbonaceous material.

Bottom of Test Pit at 8 Feet.
Completed 5/23/85.

Note: Bag sample mixed with some S-1 material.

Test Pit Log TP-4



Sample	Water Content Percent	Lab Tests
S-1	18	
BS-1	16	GS
S-2	16	
S-3	17	
S-4	9	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 815

(Medium dense), moist, mottled, light brown and gray, gravelly, very silty, fine to medium SAND. (FILL)

(Medium dense to dense), wet, mottled, brown and gray, gravelly, very silty, fine to medium SAND with some shanks of coal and sandstone cobbles. (FILL?)

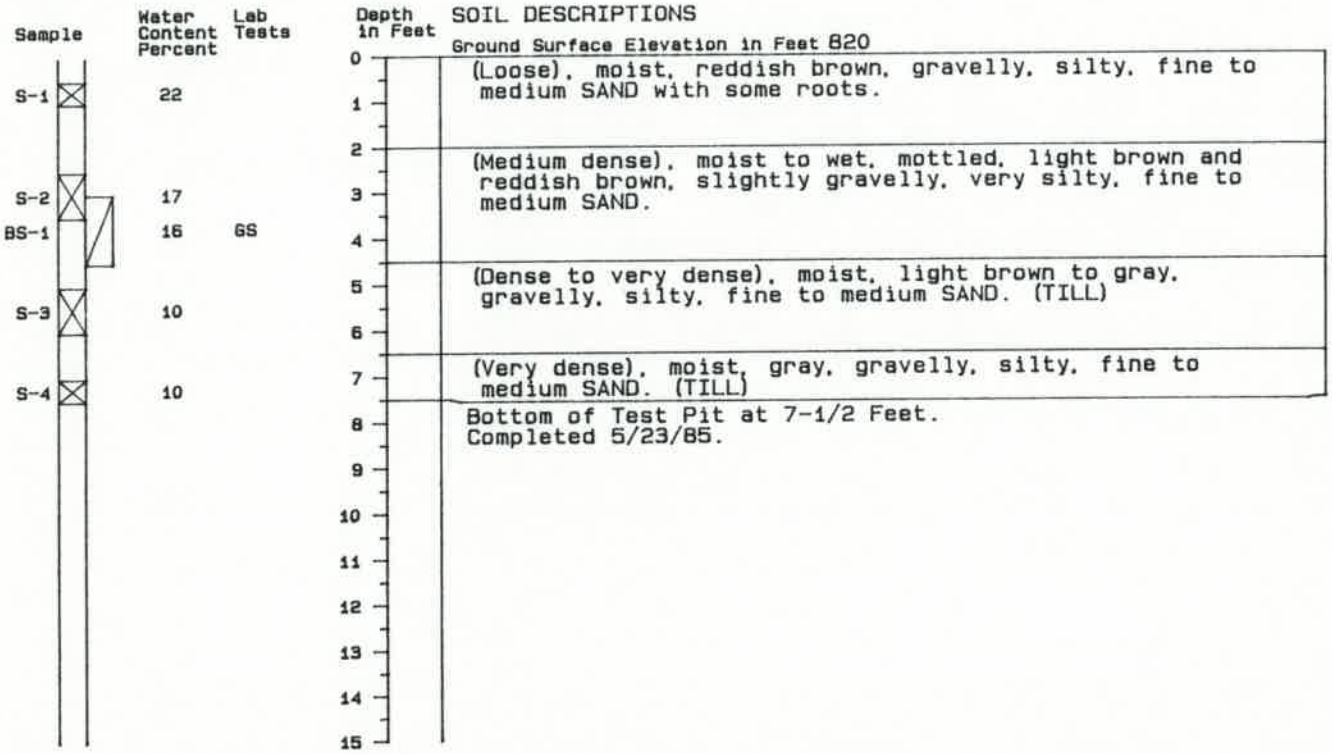
(Dense to very dense), gray, slightly fine sandy SILT with abundant coal material. (Residual Soil)

(Medium), moderately weathered, gray to black SILTSTONE.

Bottom of Test Pit at 8-1/2 Feet.
Completed 5/23/85.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

Test Pit Log TP-5



SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 820

(Loose), moist, reddish brown, gravelly, silty, fine to medium SAND with some roots.

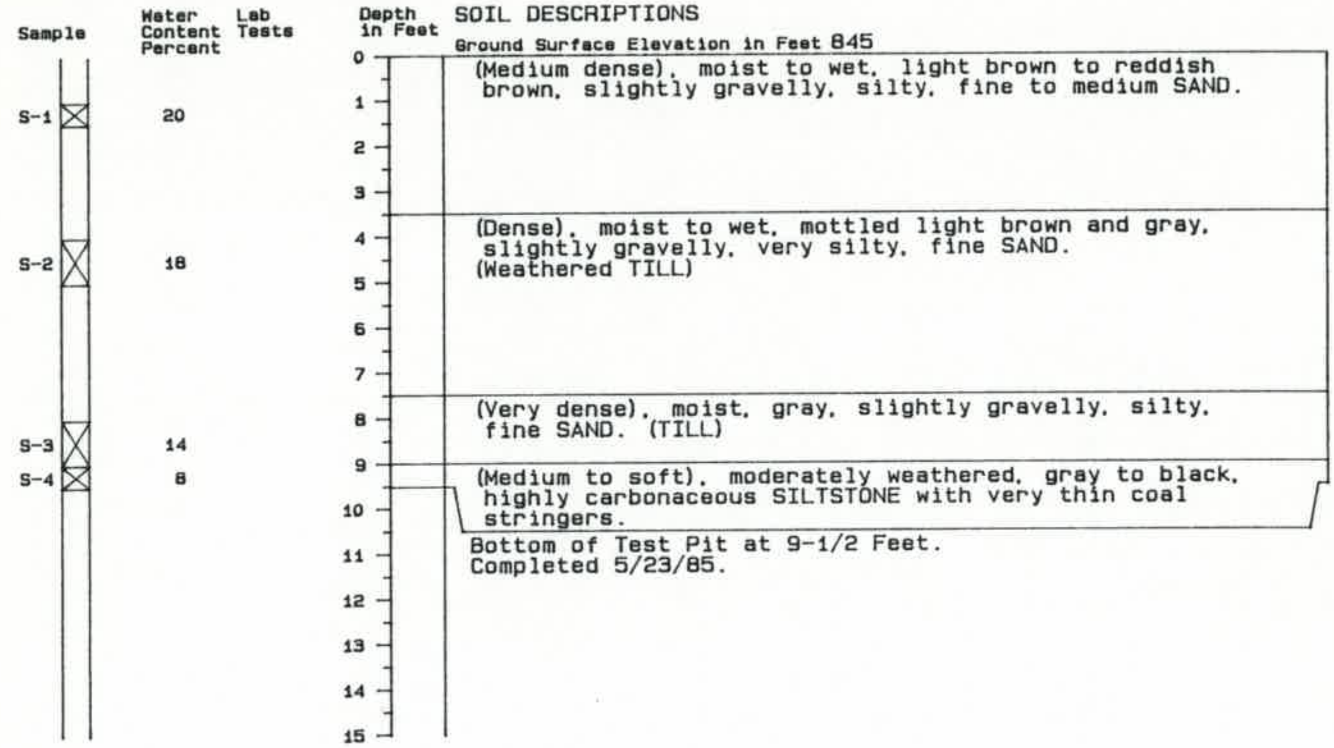
(Medium dense), moist to wet, mottled, light brown and reddish brown, slightly gravelly, very silty, fine to medium SAND.

(Dense to very dense), moist, light brown to gray, gravelly, silty, fine to medium SAND. (TILL)

(Very dense), moist, gray, gravelly, silty, fine to medium SAND. (TILL)

Bottom of Test Pit at 7-1/2 Feet.
Completed 5/23/85.

Test Pit Log TP-6



SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 845

(Medium dense), moist to wet, light brown to reddish brown, slightly gravelly, silty, fine to medium SAND.

(Dense), moist to wet, mottled light brown and gray, slightly gravelly, very silty, fine SAND. (Weathered TILL)

(Very dense), moist, gray, slightly gravelly, silty, fine SAND. (TILL)

(Medium to soft), moderately weathered, gray to black, highly carbonaceous SILTSTONE with very thin coal stringers.

Bottom of Test Pit at 9-1/2 Feet.
Completed 5/23/85.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

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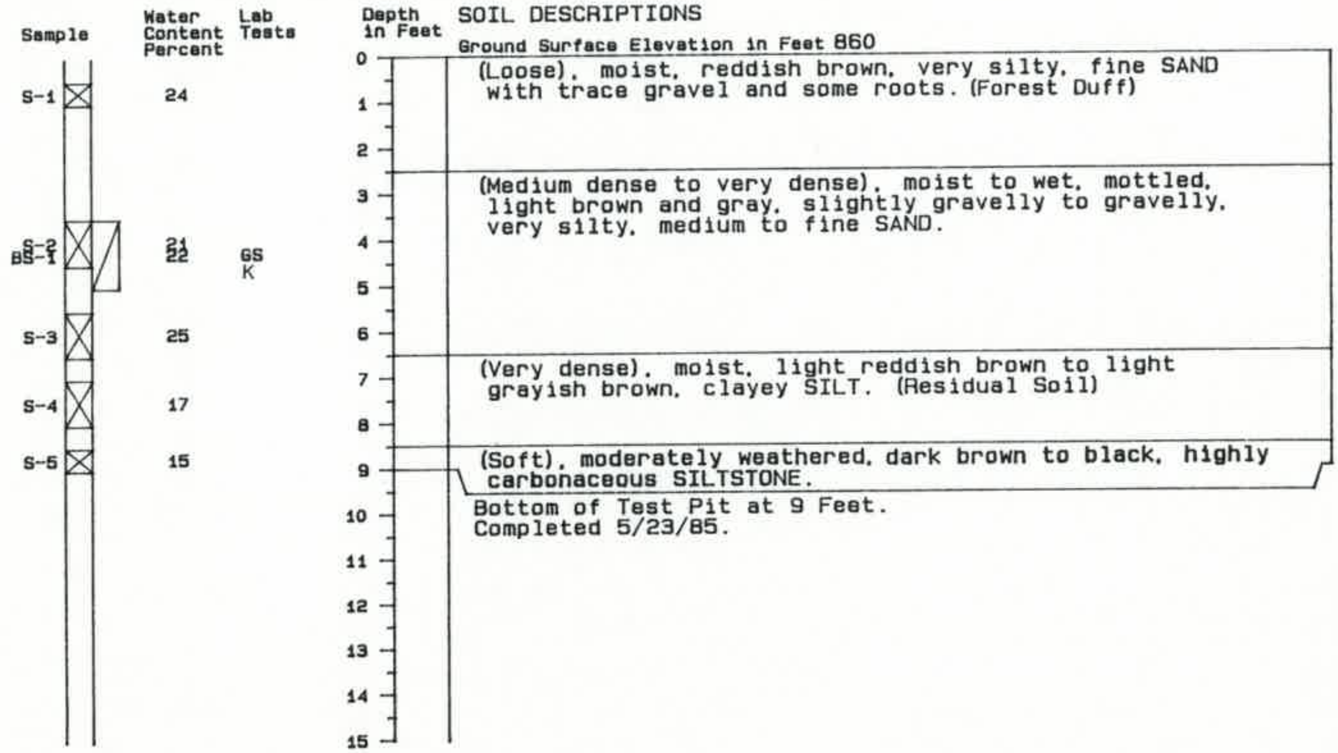
HART-CROWSER & associates, inc.
Figure A-4

Test Pit Log TP-7



Sample	Water Content Percent	Lab Tests
S-1	24	
S-2	21	
BS-1	22	GS K
S-3	25	
S-4	17	
S-5	15	

Depth in Feet

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 860

(Loose), moist, reddish brown, very silty, fine SAND with trace gravel and some roots. (Forest Duff)

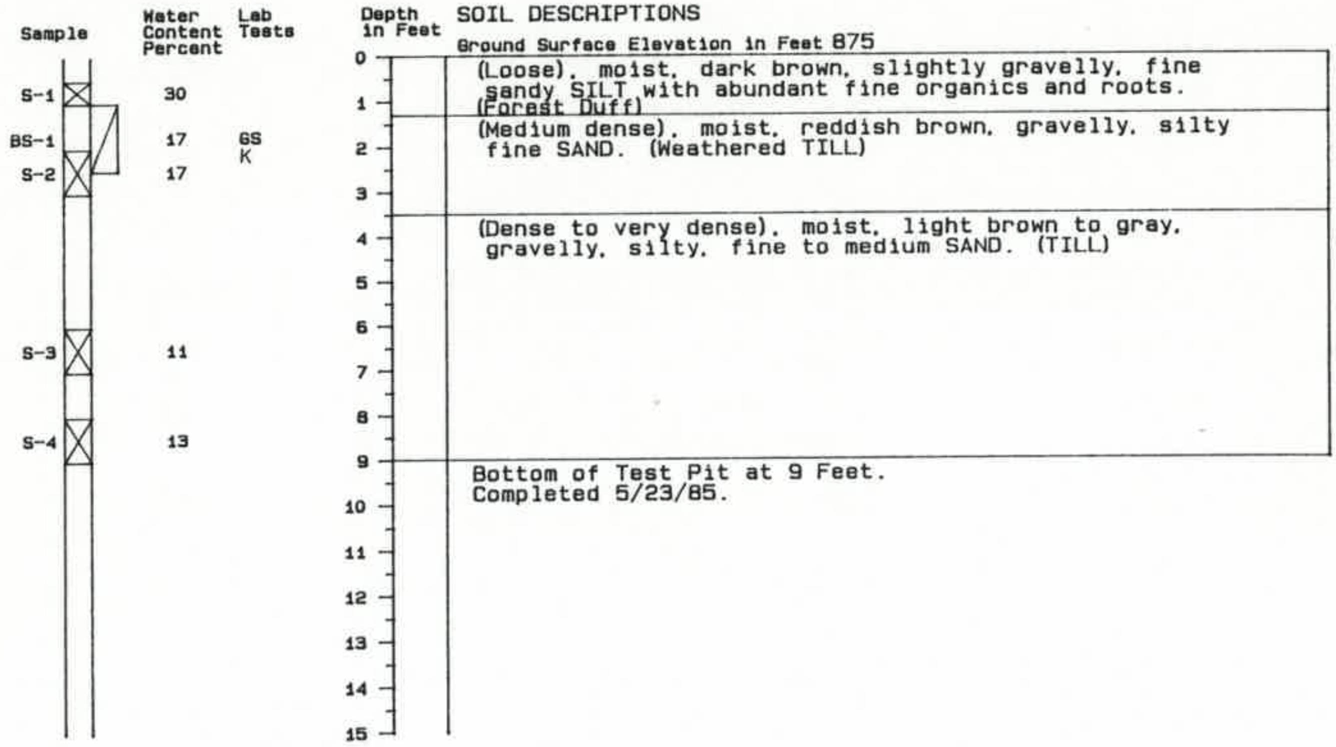
(Medium dense to very dense), moist to wet, mottled, light brown and gray, slightly gravelly to gravelly, very silty, medium to fine SAND.

(Very dense), moist, light reddish brown to light grayish brown, clayey SILT. (Residual Soil)

(Soft), moderately weathered, dark brown to black, highly carbonaceous SILTSTONE.

Bottom of Test Pit at 9 Feet.
Completed 5/23/85.

Test Pit Log TP-8



Sample	Water Content Percent	Lab Tests
S-1	30	
BS-1	17	GS K
S-2	17	
S-3	11	
S-4	13	

Depth in Feet

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 875

(Loose), moist, dark brown, slightly gravelly, fine sandy SILT with abundant fine organics and roots. (Forest Duff)

(Medium dense), moist, reddish brown, gravelly, silty fine SAND. (Weathered TILL)

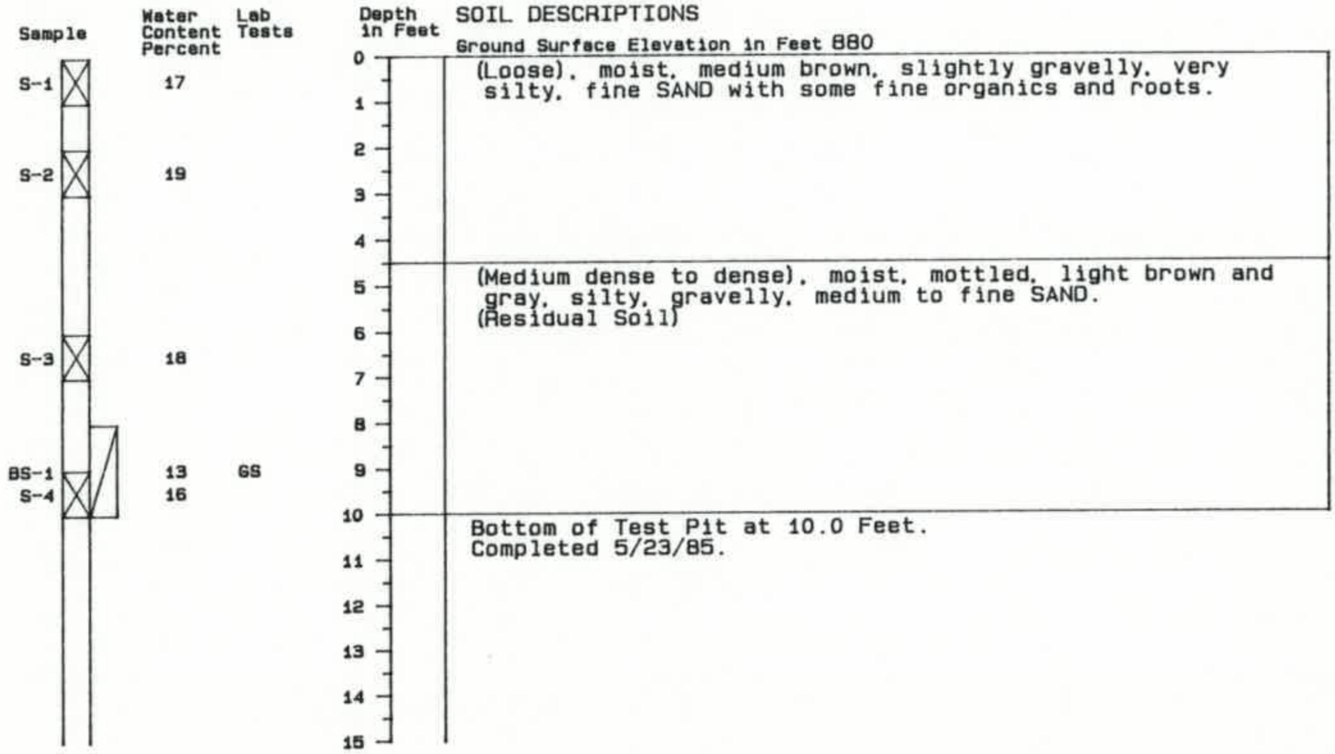
(Dense to very dense), moist, light brown to gray, gravelly, silty, fine to medium SAND. (TILL)

Bottom of Test Pit at 9 Feet.
Completed 5/23/85.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

Figure A-5

Test Pit Log TP-9



Sample	Water Content Percent	Lab Tests
S-1	17	
S-2	19	
S-3	18	
BS-1	13	GS
S-4	16	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 880

(Loose), moist, medium brown, slightly gravelly, very silty, fine SAND with some fine organics and roots.

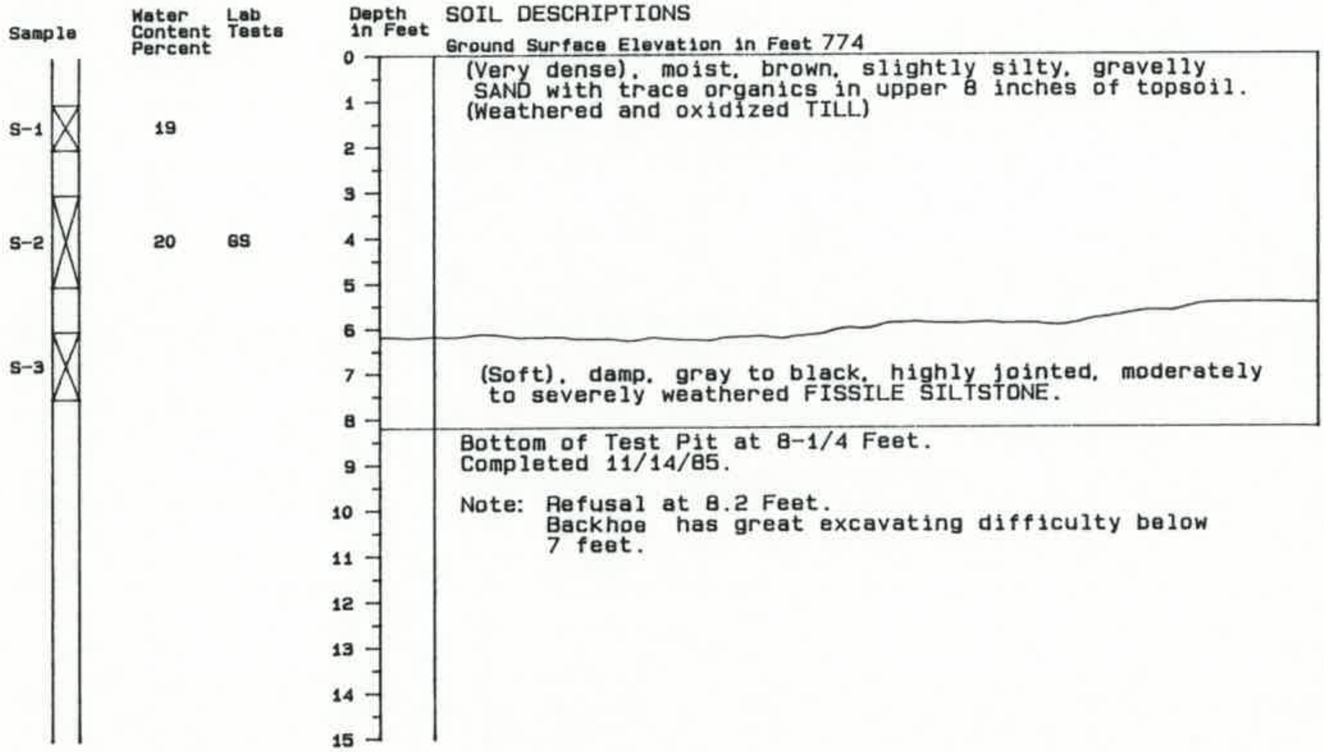
(Medium dense to dense), moist, mottled, light brown and gray, silty, gravelly, medium to fine SAND. (Residual Soil)

Bottom of Test Pit at 10.0 Feet.
Completed 5/23/85.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

J-1523-01 March 1985
HART-CROWSER & associates, inc.
Figure A-6

Test Pit Log TP-101



Sample	Water Content Percent	Lab Tests
S-1	19	
S-2	20	GS
S-3		

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 774

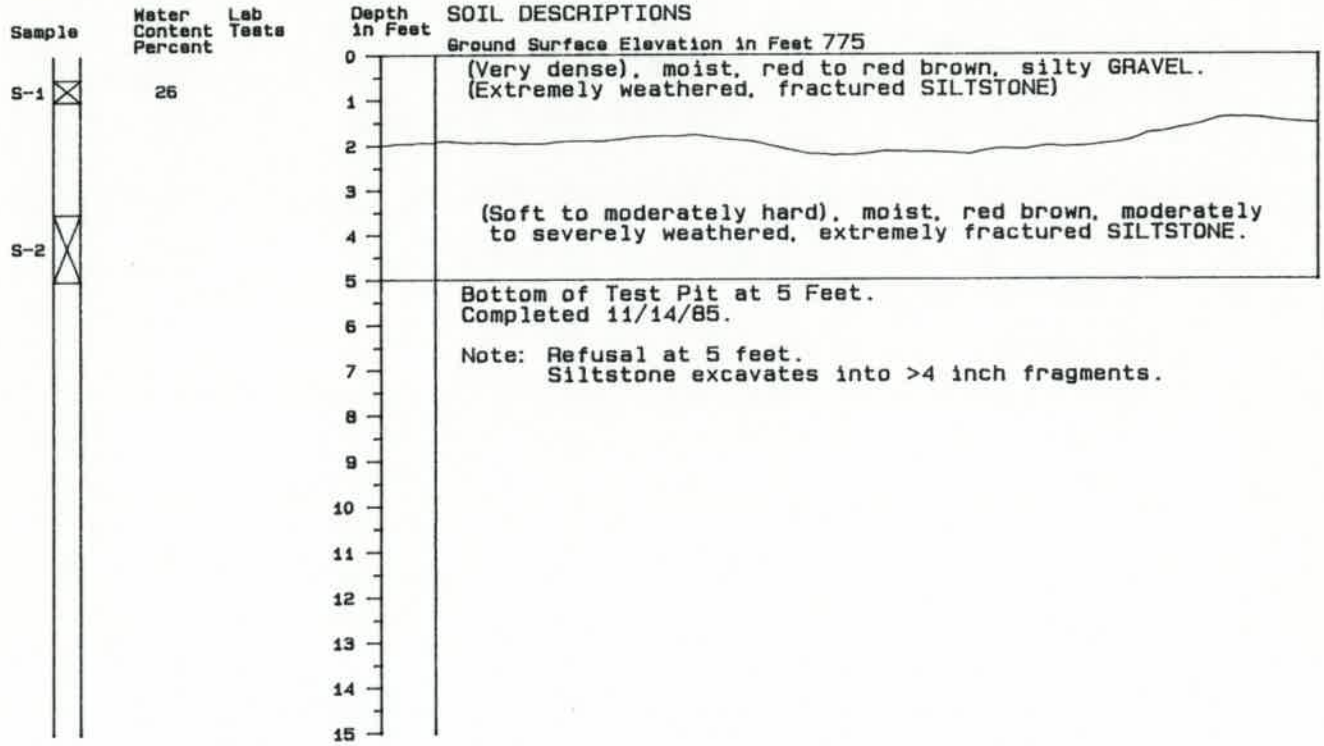
(Very dense), moist, brown, slightly silty, gravelly SAND with trace organics in upper 8 inches of topsoil. (Weathered and oxidized TILL)

(Soft), damp, gray to black, highly jointed, moderately to severely weathered FISSILE SILTSTONE.

Bottom of Test Pit at 8-1/4 Feet.
Completed 11/14/85.

Note: Refusal at 8.2 Feet.
Backhoe has great excavating difficulty below 7 feet.

Test Pit Log TP-102



Sample	Water Content Percent	Lab Tests
S-1	26	
S-2		

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 775

(Very dense), moist, red to red brown, silty GRAVEL. (Extremely weathered, fractured SILTSTONE)

(Soft to moderately hard), moist, red brown, moderately to severely weathered, extremely fractured SILTSTONE.

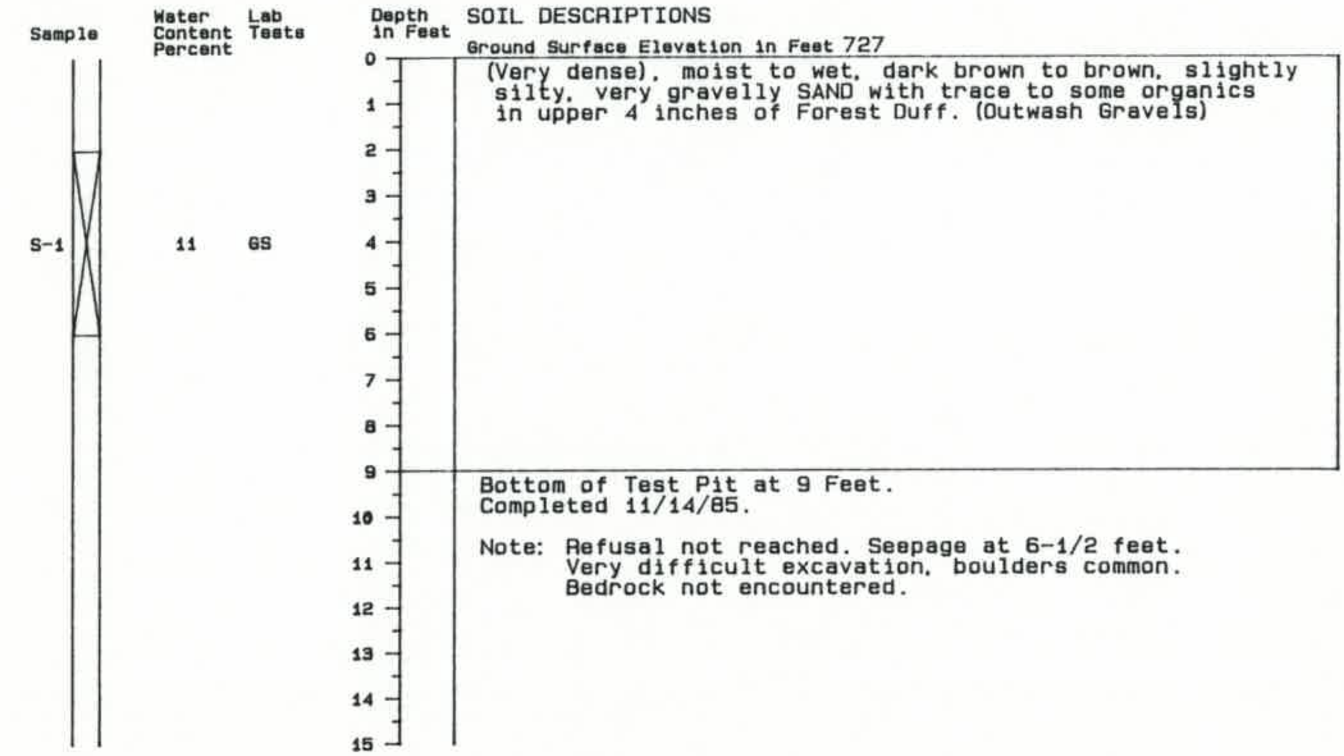
Bottom of Test Pit at 5 Feet.
Completed 11/14/85.

Note: Refusal at 5 feet.
Siltstone excavates into >4 inch fragments.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

J-1523-02 November 1985
HART-CROWSER & associates, inc.
Figure A-7

Test Pit Log TP-103



SOIL DESCRIPTIONS

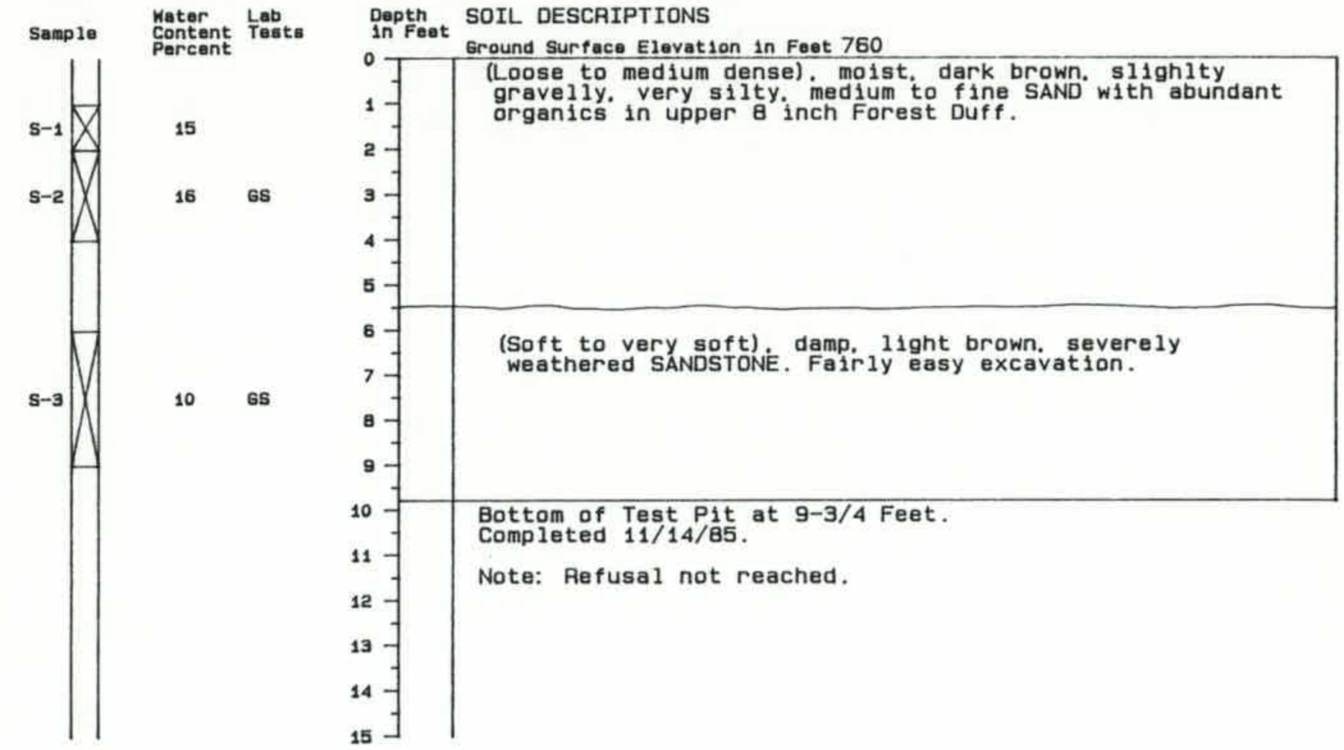
Ground Surface Elevation in Feet 727

(Very dense), moist to wet, dark brown to brown, slightly silty, very gravelly SAND with trace to some organics in upper 4 inches of Forest Duff. (Outwash Gravels)

Bottom of Test Pit at 9 Feet.
Completed 11/14/85.

Note: Refusal not reached. Seepage at 6-1/2 feet. Very difficult excavation, boulders common. Bedrock not encountered.

Test Pit Log TP-104



SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 760

(Loose to medium dense), moist, dark brown, slighlty gravelly, very silty, medium to fine SAND with abundant organics in upper 8 inch Forest Duff.

(Soft to very soft), damp, light brown, severely weathered SANDSTONE. Fairly easy excavation.

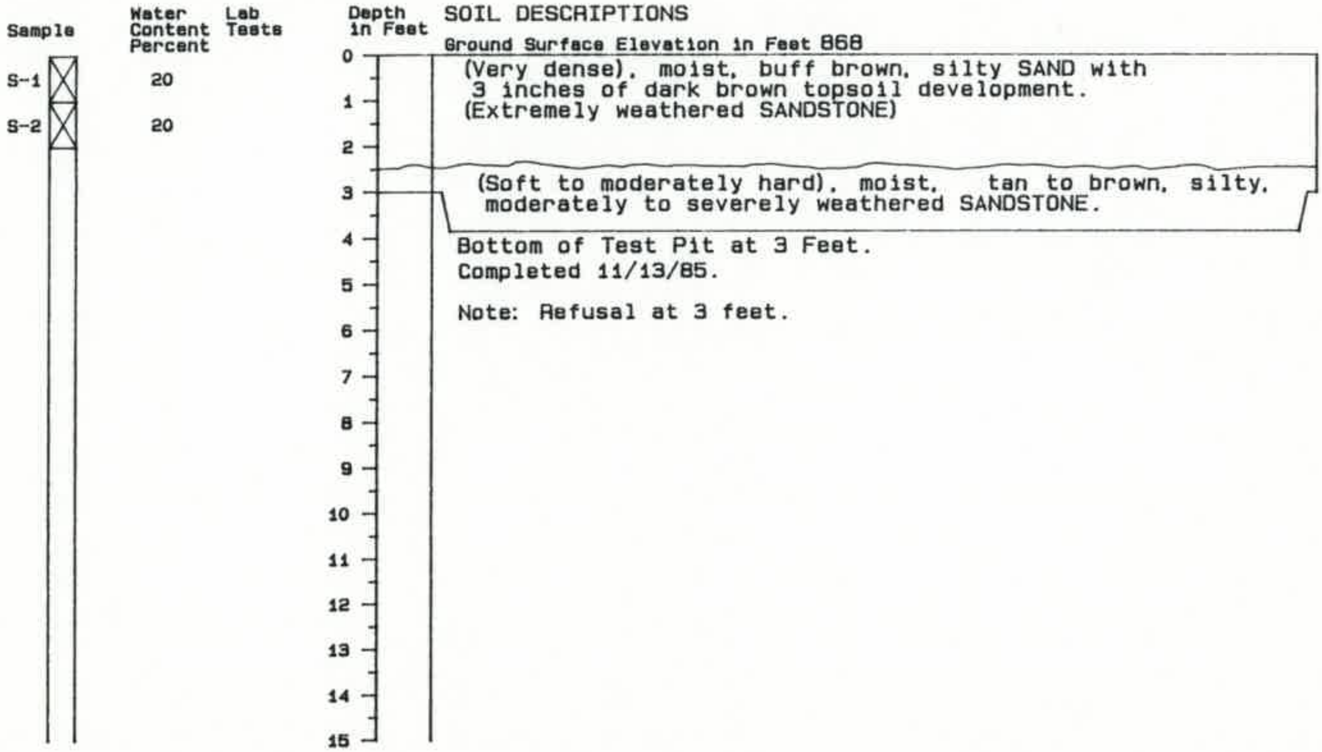
Bottom of Test Pit at 9-3/4 Feet.
Completed 11/14/85.

Note: Refusal not reached.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

J-1523-02 November 1985
HART-CROWSER & associates, inc.
Figure A-8

Test Pit Log TP-105



SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 868

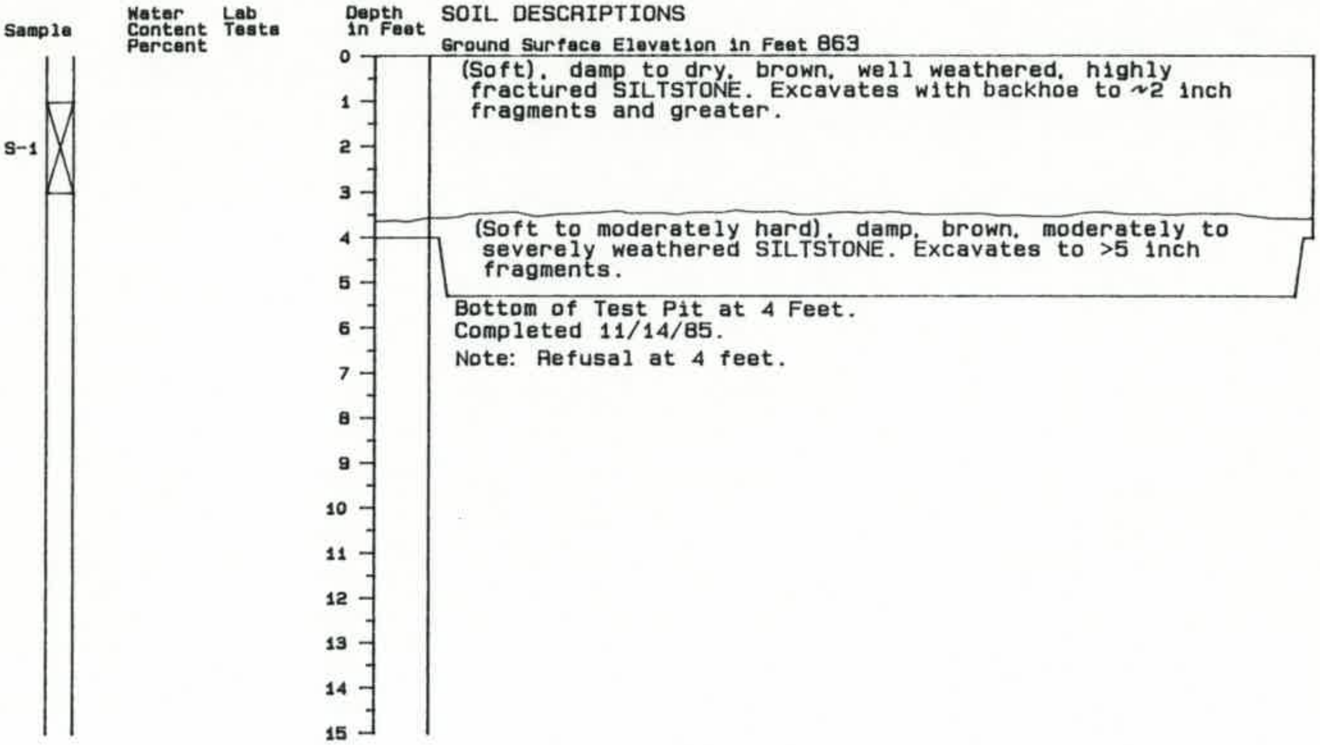
(Very dense), moist, buff brown, silty SAND with 3 inches of dark brown topsoil development. (Extremely weathered SANDSTONE)

(Soft to moderately hard), moist, tan to brown, silty, moderately to severely weathered SANDSTONE.

Bottom of Test Pit at 3 Feet.
Completed 11/13/85.

Note: Refusal at 3 feet.

Test Pit Log TP-106



SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 863

(Soft), damp to dry, brown, well weathered, highly fractured SILTSTONE. Excavates with backhoe to ~2 inch fragments and greater.

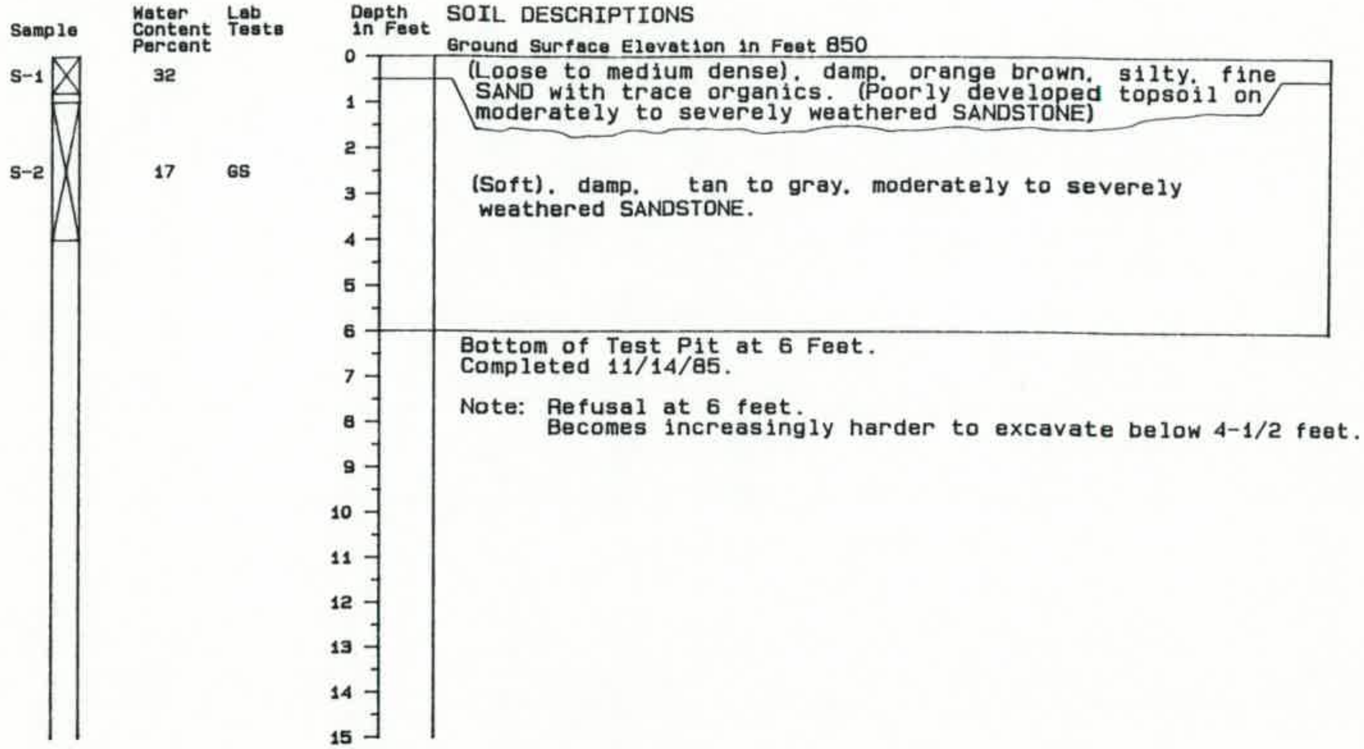
(Soft to moderately hard), damp, brown, moderately to severely weathered SILTSTONE. Excavates to >5 inch fragments.

Bottom of Test Pit at 4 Feet.
Completed 11/14/85.

Note: Refusal at 4 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

Test Pit Log TP-107



Sample	Water Content Percent	Lab Tests
S-1	32	
S-2	17	GS

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 850

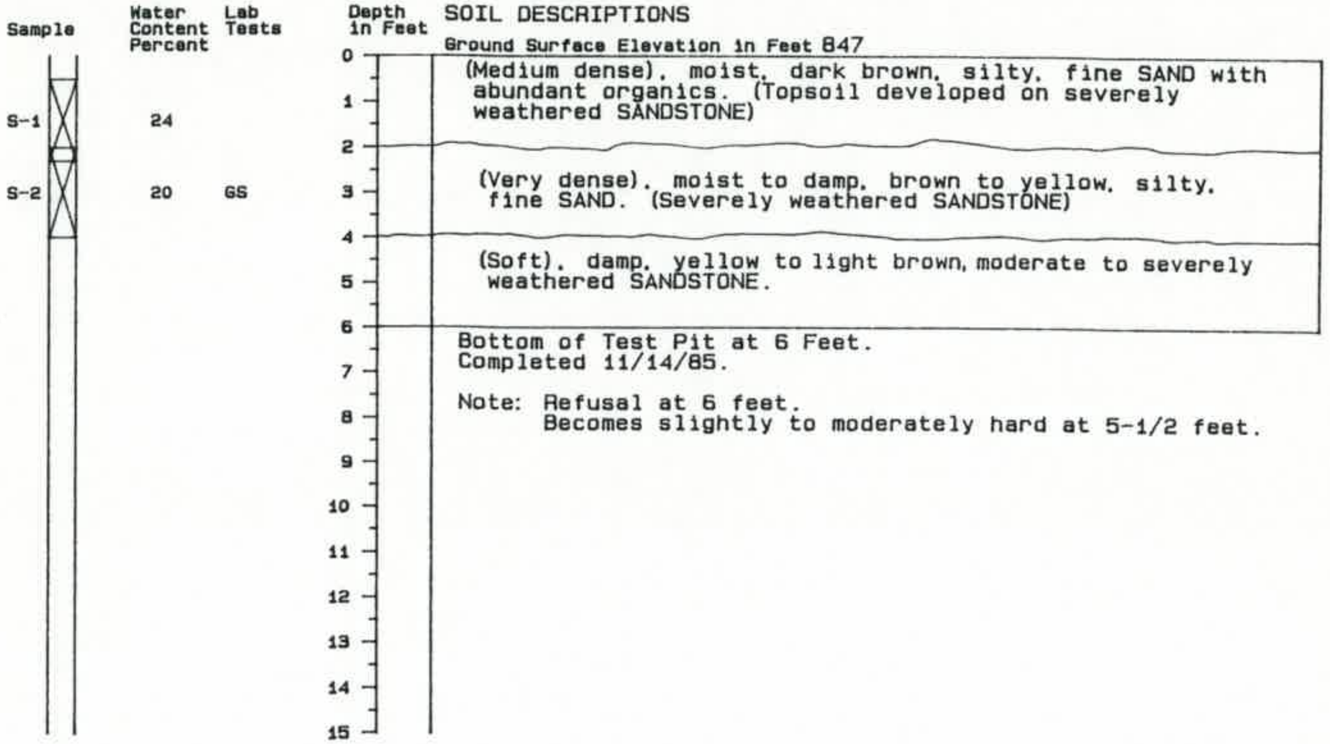
(Loose to medium dense), damp, orange brown, silty, fine SAND with trace organics. (Poorly developed topsoil on moderately to severely weathered SANDSTONE)

(Soft), damp, tan to gray, moderately to severely weathered SANDSTONE.

Bottom of Test Pit at 6 Feet.
Completed 11/14/85.

Note: Refusal at 6 feet.
Becomes increasingly harder to excavate below 4-1/2 feet.

Test Pit Log TP-108



Sample	Water Content Percent	Lab Tests
S-1	24	
S-2	20	GS

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 847

(Medium dense), moist, dark brown, silty, fine SAND with abundant organics. (Topsoil developed on severely weathered SANDSTONE)

(Very dense), moist to damp, brown to yellow, silty, fine SAND. (Severely weathered SANDSTONE)

(Soft), damp, yellow to light brown, moderate to severely weathered SANDSTONE.

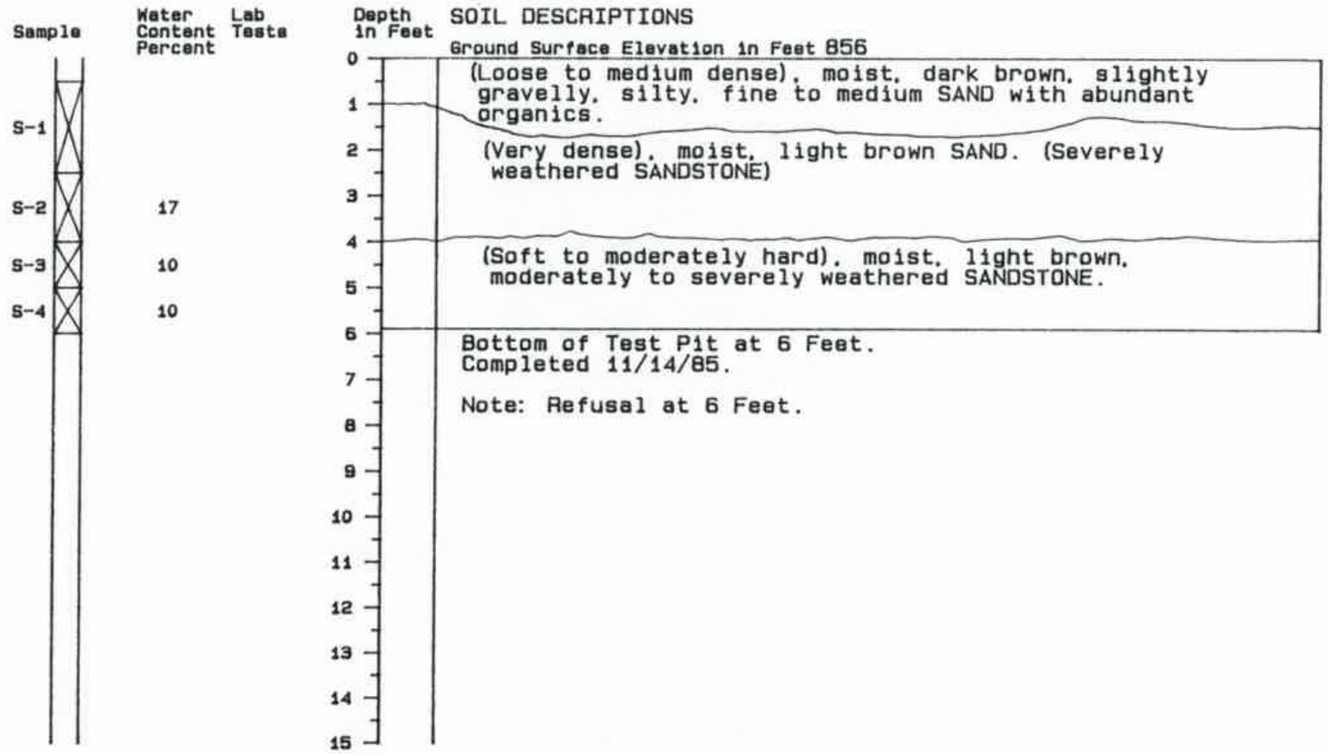
Bottom of Test Pit at 6 Feet.
Completed 11/14/85.

Note: Refusal at 6 feet.
Becomes slightly to moderately hard at 5-1/2 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

J-1523-02 November 1985
HART-CROWSER & associates, inc.
Figure A-10

Test Pit Log TP-109



Sample	Water Content Percent	Lab Tests
S-1		
S-2	17	
S-3	10	
S-4	10	

Ground Surface Elevation in Feet 856

(Loose to medium dense), moist, dark brown, slightly gravelly, silty, fine to medium SAND with abundant organics.

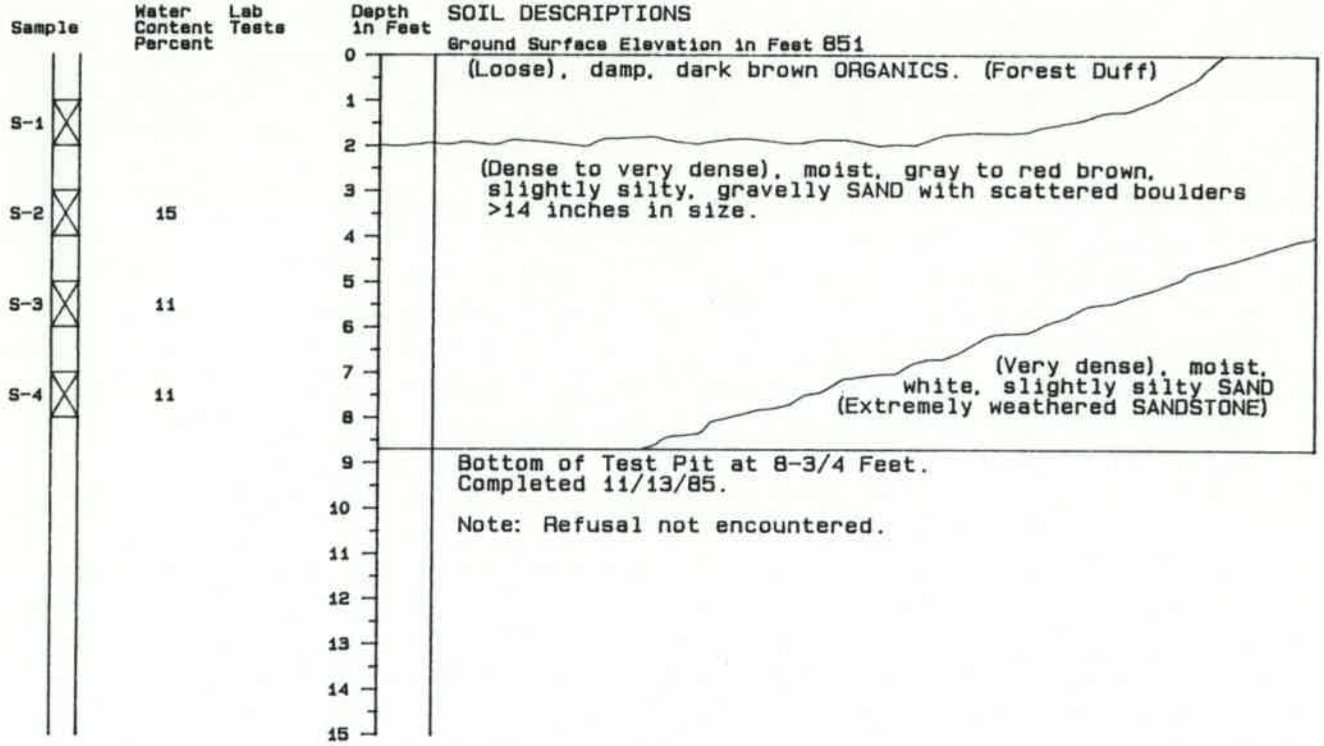
(Very dense), moist, light brown SAND. (Severely weathered SANDSTONE)

(Soft to moderately hard), moist, light brown, moderately to severely weathered SANDSTONE.

Bottom of Test Pit at 6 Feet.
Completed 11/14/85.

Note: Refusal at 6 Feet.

Test Pit Log TP-110



Sample	Water Content Percent	Lab Tests
S-1		
S-2	15	
S-3	11	
S-4	11	

Ground Surface Elevation in Feet 851

(Loose), damp, dark brown ORGANICS. (Forest Duff)

(Dense to very dense), moist, gray to red brown, slightly silty, gravelly SAND with scattered boulders >14 inches in size.

(Very dense), moist, white, slightly silty SAND (Extremely weathered SANDSTONE)

Bottom of Test Pit at 8-3/4 Feet.
Completed 11/13/85.

Note: Refusal not encountered.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

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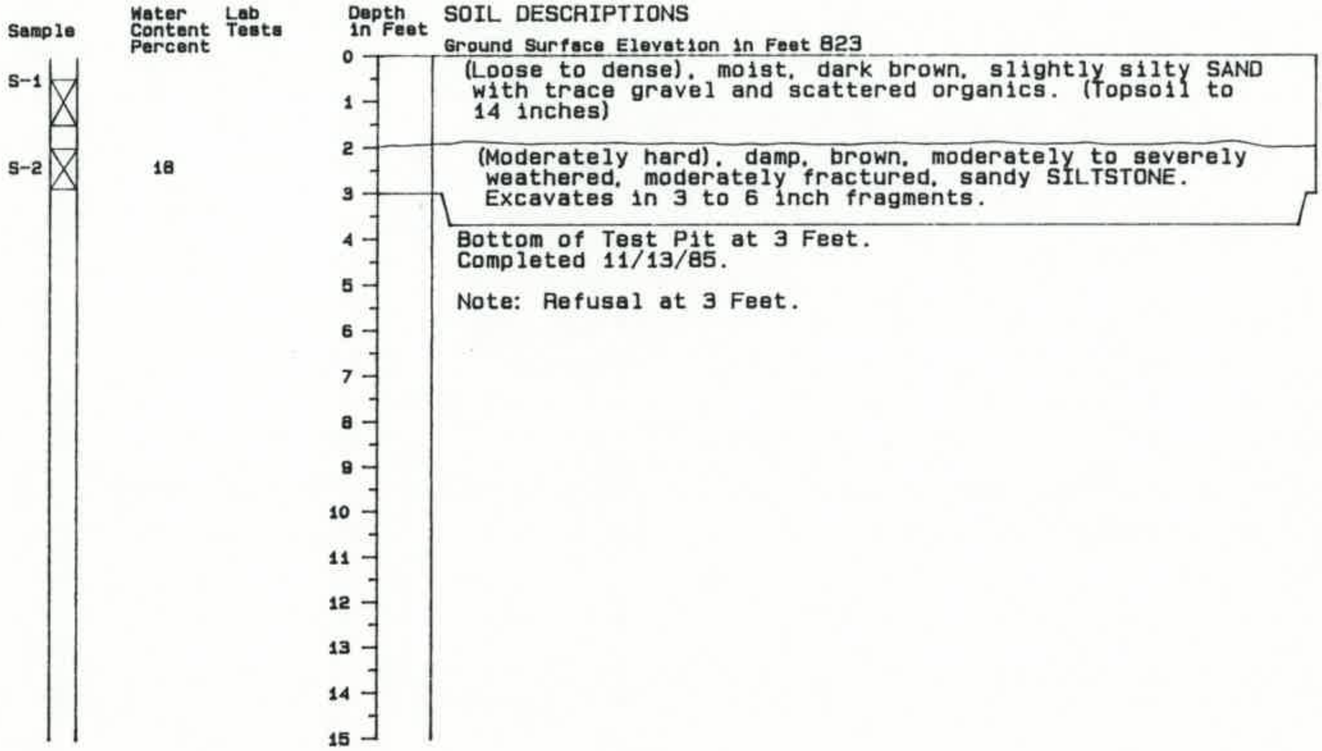
HART-CROWSER & associates, inc.
Figure A-11

Test Pit Log TP-111



SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 823

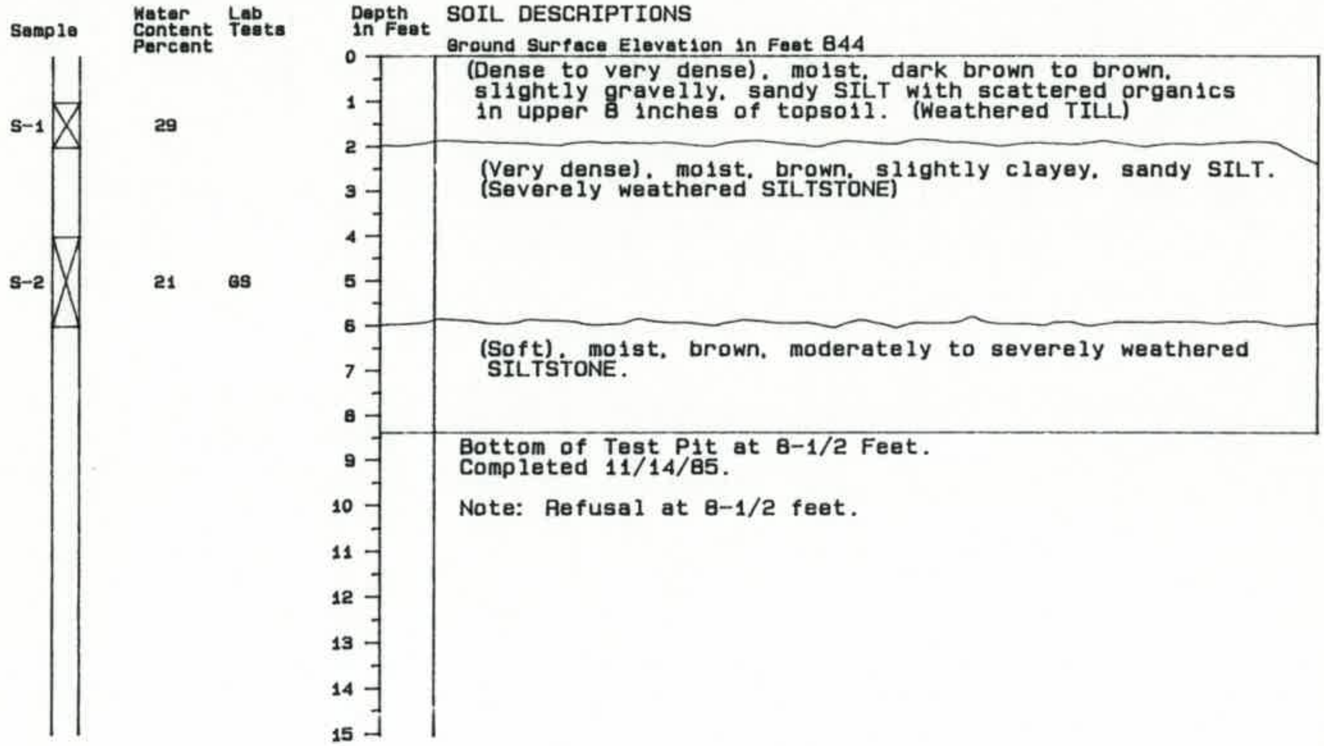
(Loose to dense), moist, dark brown, slightly silty SAND with trace gravel and scattered organics. (Topsoil to 14 inches)

(Moderately hard), damp, brown, moderately to severely weathered, moderately fractured, sandy SILTSTONE. Excavates in 3 to 6 inch fragments.

Bottom of Test Pit at 3 Feet.
Completed 11/13/85.

Note: Refusal at 3 Feet.

Test Pit Log TP-112



SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 844

(Dense to very dense), moist, dark brown to brown, slightly gravelly, sandy SILT with scattered organics in upper 8 inches of topsoil. (Weathered TILL)

(Very dense), moist, brown, slightly clayey, sandy SILT. (Severely weathered SILTSTONE)

(Soft), moist, brown, moderately to severely weathered SILTSTONE.

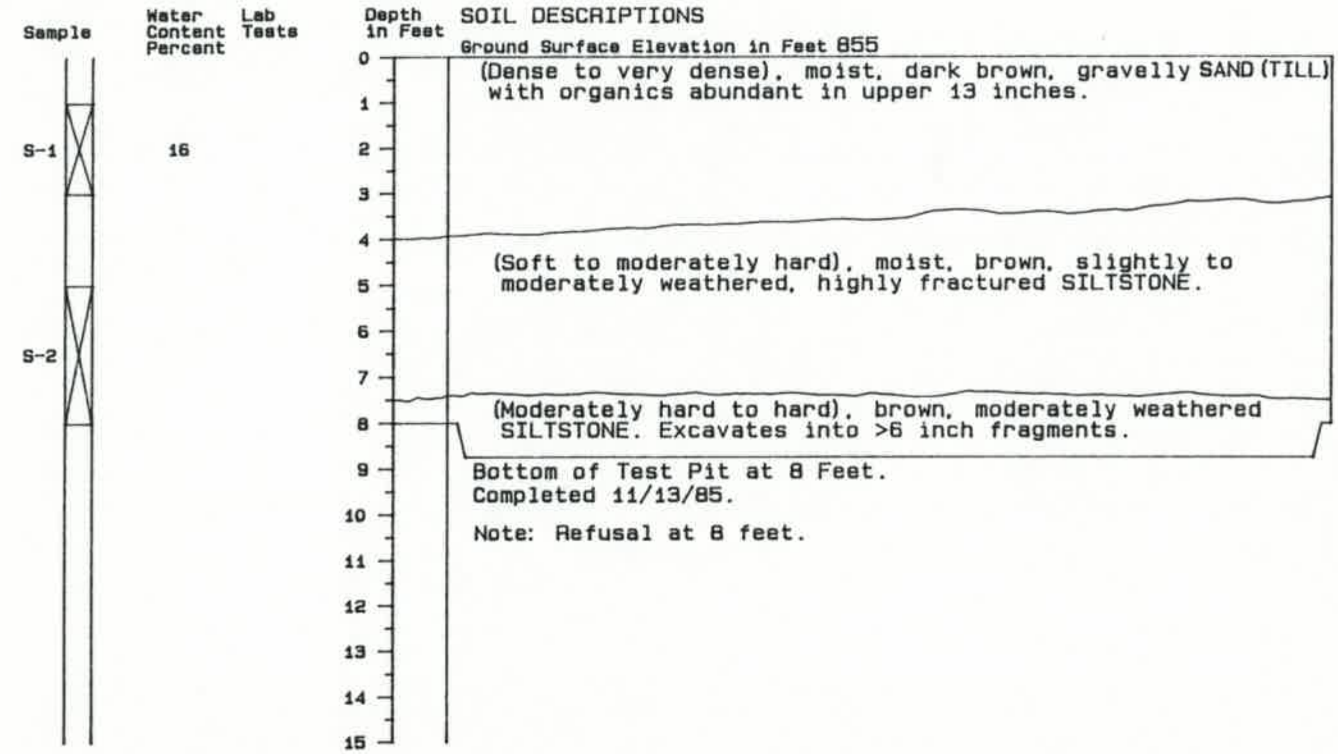
Bottom of Test Pit at 8-1/2 Feet.
Completed 11/14/85.

Note: Refusal at 8-1/2 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

J-1523-02 November 1985
HART-CROWSER & associates, inc.
Figure A-12

Test Pit Log TP-113



Sample	Water Content Percent	Lab Tests
S-1	16	
S-2		

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 855

(Dense to very dense), moist, dark brown, gravelly SAND (TILL) with organics abundant in upper 13 inches.

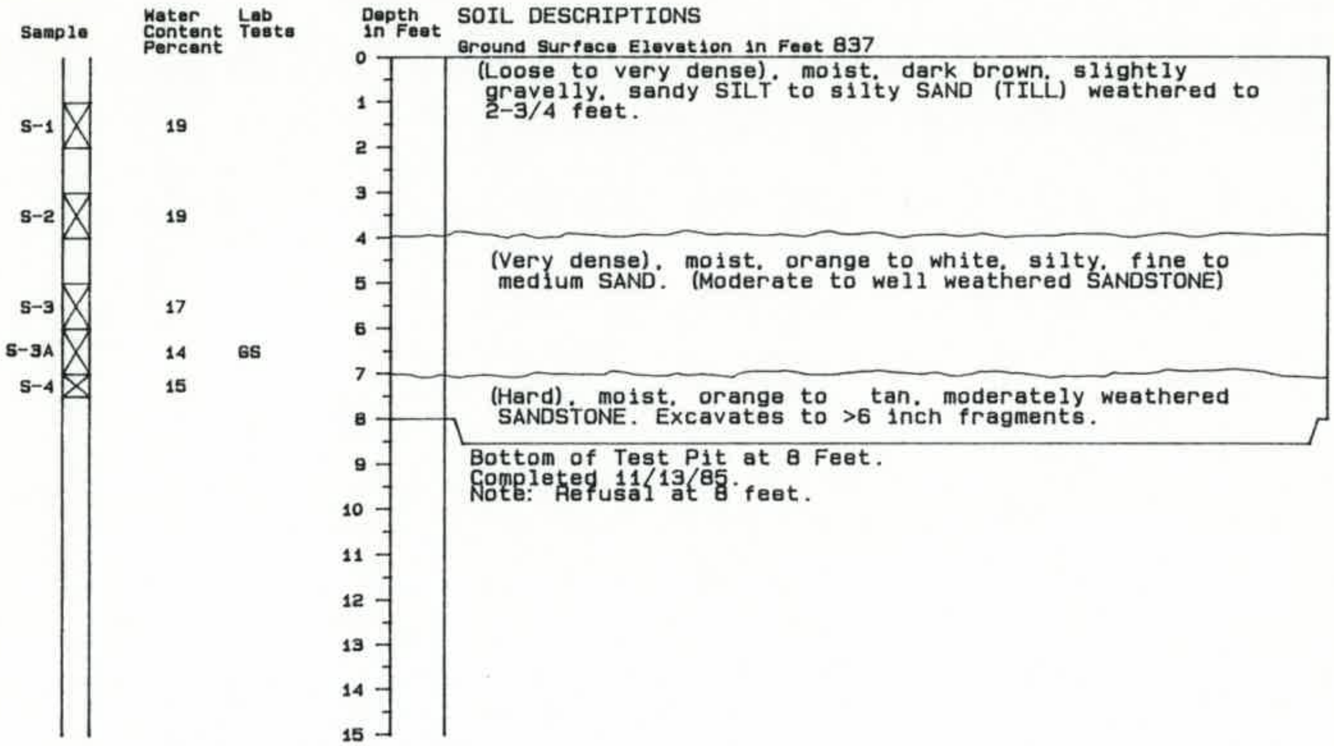
(Soft to moderately hard), moist, brown, slightly to moderately weathered, highly fractured SILTSTONE.

(Moderately hard to hard), brown, moderately weathered SILTSTONE. Excavates into >6 inch fragments.

Bottom of Test Pit at 8 Feet.
Completed 11/13/85.

Note: Refusal at 8 feet.

Test Pit Log TP-114



Sample	Water Content Percent	Lab Tests
S-1	19	
S-2	19	
S-3	17	
S-3A	14	GS
S-4	15	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 837

(Loose to very dense), moist, dark brown, slightly gravelly, sandy SILT to silty SAND (TILL) weathered to 2-3/4 feet.

(Very dense), moist, orange to white, silty, fine to medium SAND. (Moderate to well weathered SANDSTONE)

(Hard), moist, orange to tan, moderately weathered SANDSTONE. Excavates to >6 inch fragments.

Bottom of Test Pit at 8 Feet.
Completed 11/13/85.
Note: Refusal at 8 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

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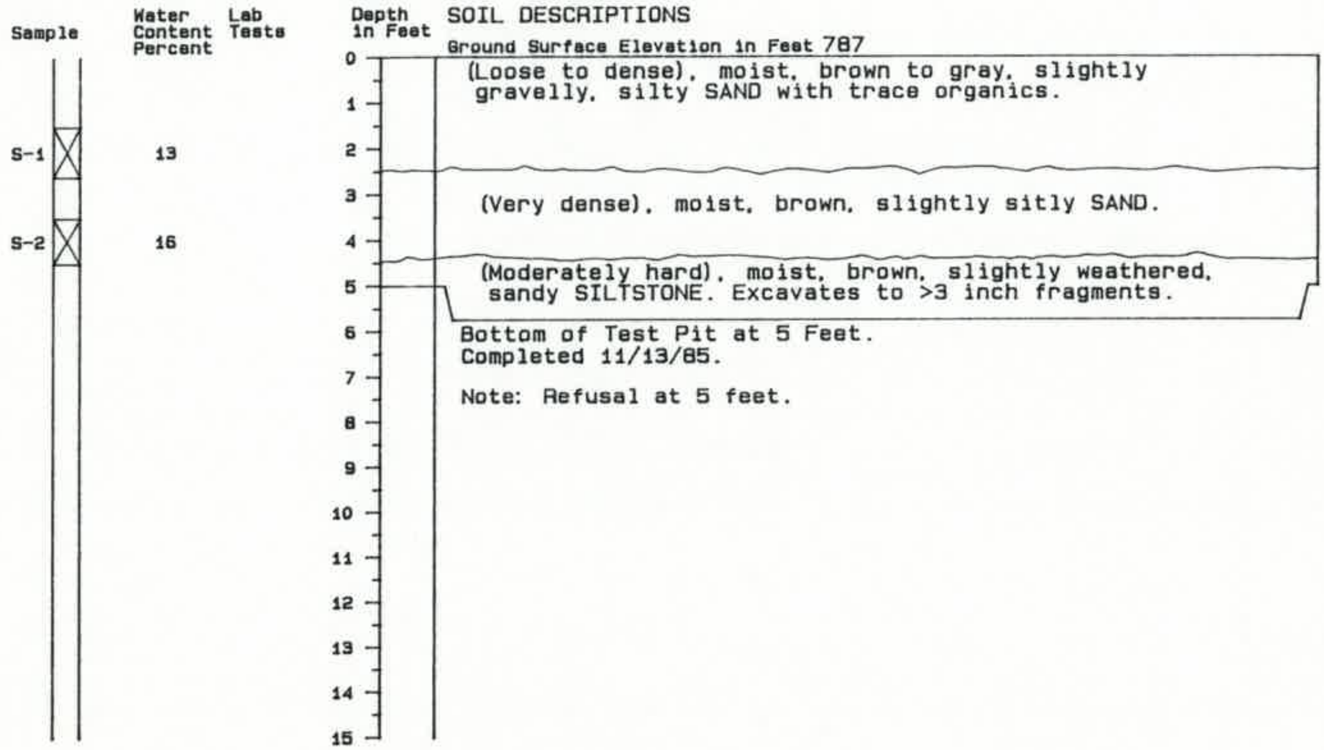
HART-CROWSER & associates, inc.
Figure A-13

Test Pit Log TP-115



Sample	Water Content Percent	Lab Tests
S-1	13	
S-2	16	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 787

(Loose to dense), moist, brown to gray, slightly gravelly, silty SAND with trace organics.

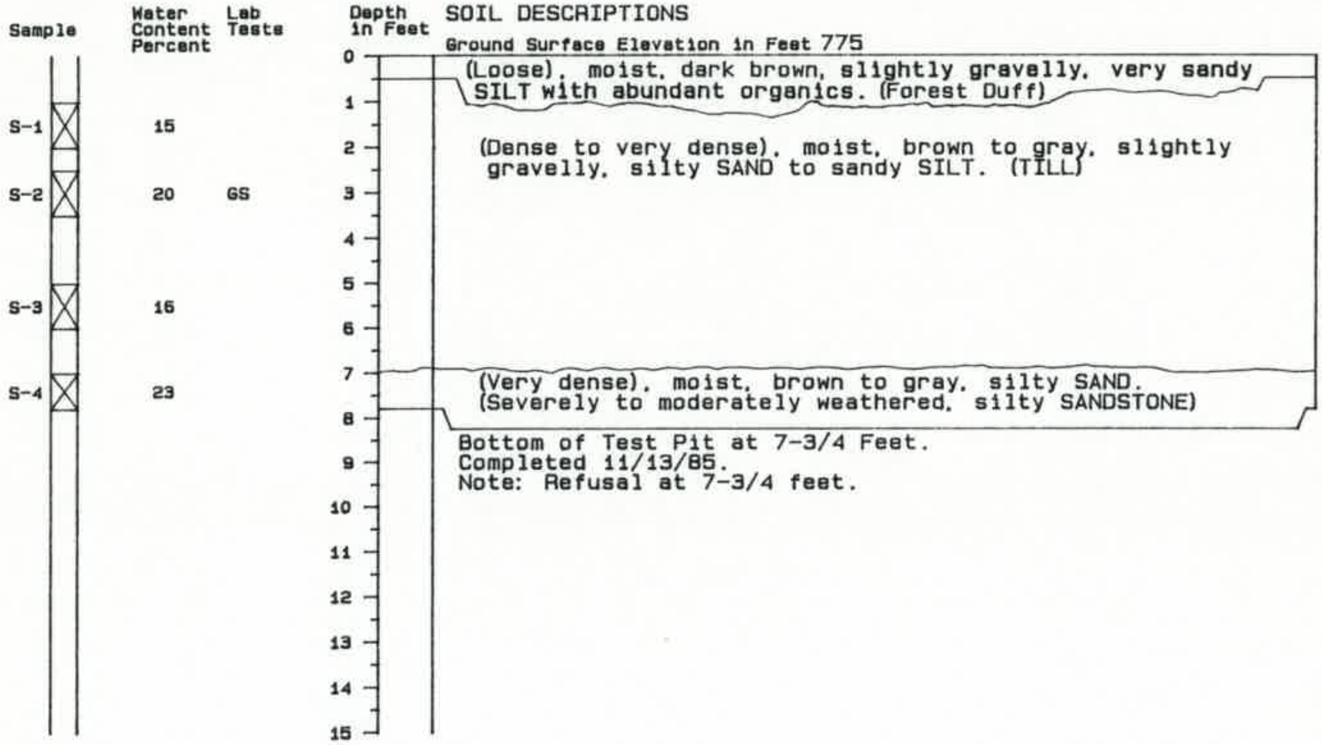
(Very dense), moist, brown, slightly sitly SAND.

(Moderately hard), moist, brown, slightly weathered, sandy SILTSTONE. Excavates to >3 inch fragments.

Bottom of Test Pit at 5 Feet.
Completed 11/13/85.

Note: Refusal at 5 feet.

Test Pit Log TP-116



Sample	Water Content Percent	Lab Tests
S-1	15	
S-2	20	GS
S-3	16	
S-4	23	

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet 775

(Loose), moist, dark brown, slightly gravelly, very sandy SILT with abundant organics. (Forest Duff)

(Dense to very dense), moist, brown to gray, slightly gravelly, silty SAND to sandy SILT. (TILL)

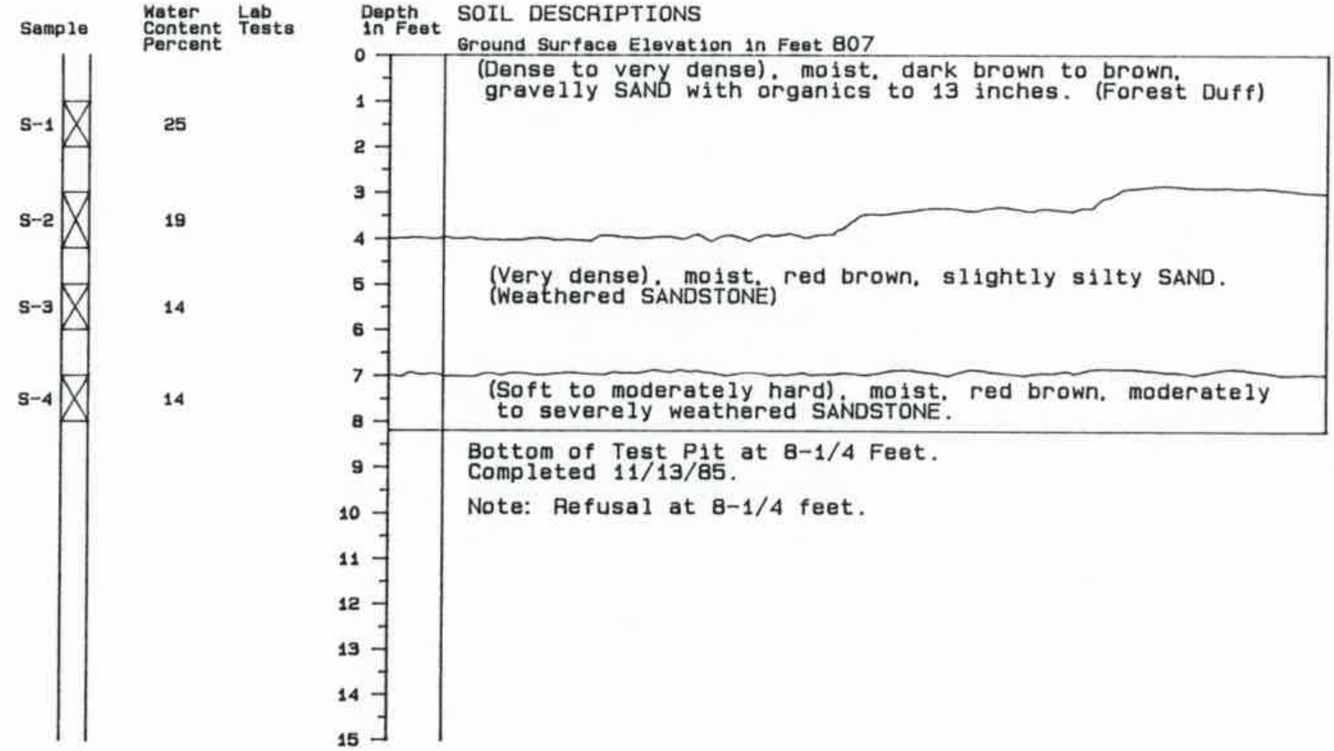
(Very dense), moist, brown to gray, silty SAND. (Severely to moderately weathered, silty SANDSTONE)

Bottom of Test Pit at 7-3/4 Feet.
Completed 11/13/85.
Note: Refusal at 7-3/4 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

J-1523-02 November 1985
HART-CROWSER & associates, inc.
Figure A-14

Test Pit Log TP-117



(Dense to very dense), moist, dark brown to brown, gravelly SAND with organics to 13 inches. (Forest Duff)

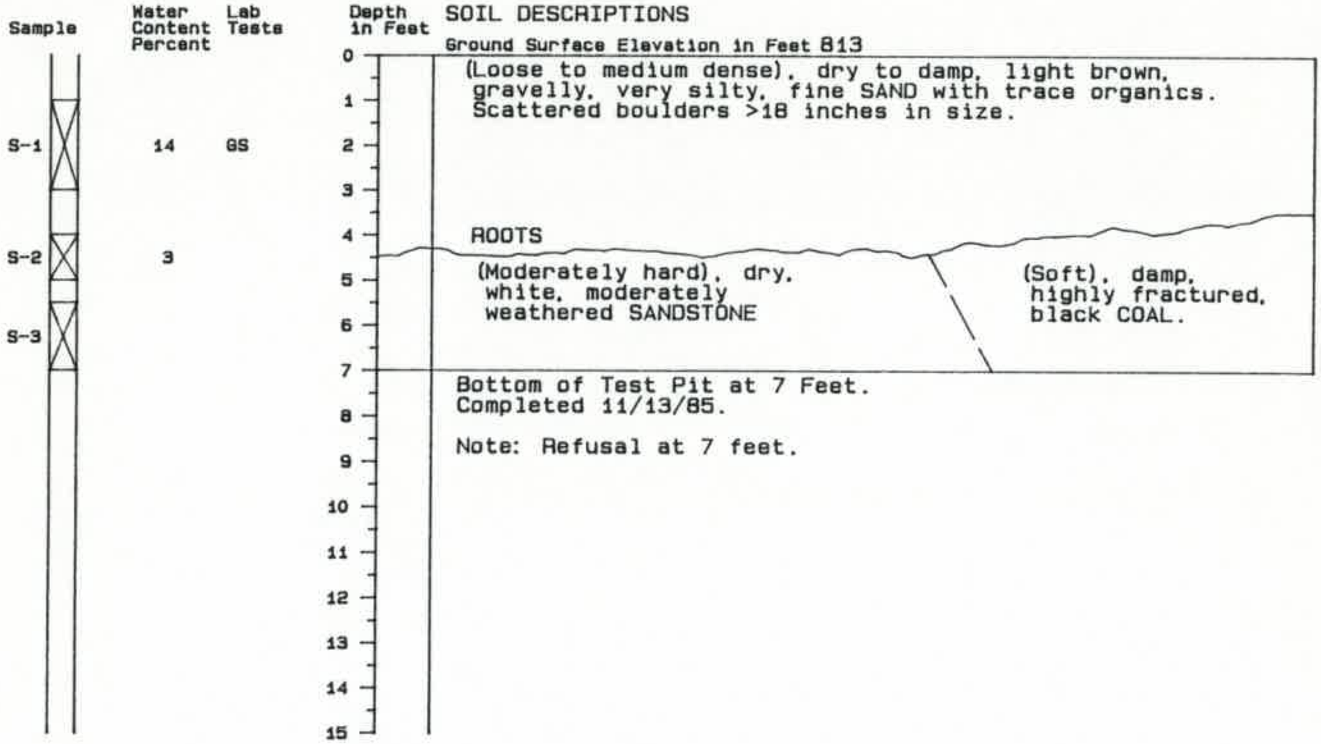
(Very dense), moist, red brown, slightly silty SAND. (Weathered SANDSTONE)

(Soft to moderately hard), moist, red brown, moderately to severely weathered SANDSTONE.

Bottom of Test Pit at 8-1/4 Feet.
Completed 11/13/85.

Note: Refusal at 8-1/4 feet.

Test Pit Log TP-118



(Loose to medium dense), dry to damp, light brown, gravelly, very silty, fine SAND with trace organics. Scattered boulders >18 inches in size.

(Moderately hard), dry, white, moderately weathered SANDSTONE

(Soft), damp, highly fractured, black COAL.

Bottom of Test Pit at 7 Feet.
Completed 11/13/85.

Note: Refusal at 7 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water conditions, if indicated, are at time of excavation. Conditions may vary with time.

APPENDIX B
LABORATORY TESTING PROGRAM

A laboratory testing program was performed for this study to evaluate the basic index and geotechnical engineering properties of the site soils. Laboratory tests were performed on both disturbed and relatively undisturbed samples. The laboratory tests performed and the procedures followed are outlined below.

Soil Classification

Soil samples recovered in the explorations were visually classified in the field and then taken to our laboratory where the classifications were verified in a relatively controlled environment. Visual field and laboratory observations include density/consistency, moisture condition, grain size and plasticity estimates.

The classifications of selected samples were checked by performing laboratory tests such as grain size analyses. Classifications were made in general accordance with the Unified Soil Classification (USC) System, ASTM D 2487, as presented on Figure B-1.

Water Content Determinations

Water contents were determined for most samples recovered in the explorations in general accordance with ASTM D 2216 as soon as possible following their arrival in our laboratory. Water contents were not determined for very small samples nor samples where large gravel contents would result in values considered unrepresentative. The results of these tests are plotted at the respective sample depth on the exploration logs. In addition, the water contents of samples subjected to other testing have been determined and are presented on the exploration logs as well as with the various test results which follow in this appendix.

Grain Size Analysis (GS)

Grain size analyses were performed on representative samples in general accordance with ASTM D 422. The wet sieve analysis method was used for most samples and determines the size distribution greater than the U.S. No. 200 mesh sieve. The size distribution for particles smaller than the No. 200 mesh sieve was determined by the hydrometer method for a selected number of samples. The results of the tests are presented as curves on Figures B-2 through B-5 plotting percent finer by weight versus grain size.

Pocket Penetrometer (PP) and Torvane (TV)

The pocket penetrometer and torvane procedures provide quick approximate tests of the consistency (undrained shear strength) of a cohesive soil sample. The pocket penetrometer device consists of a calibrated spring mechanism which measures penetration resistance of a 1/4-inch diameter steel tip over a given distance. The penetration resistance is correlated to the unconfined compressive strength of the soil, which is typically twice the undrained shear strength of a saturated, cohesive soil.

The torvane device consists of a 1-inch diameter plate with eight equally spaced and radially arranged 1/4-inch vanes. The vanes are pressed into the soil and the device is rotated. The vanes force a shear failure to take place over the area of the face of the plate, and the resistance at failure as measured by a calibrated spring is correlative to the undrained shear strength of the sample tested.

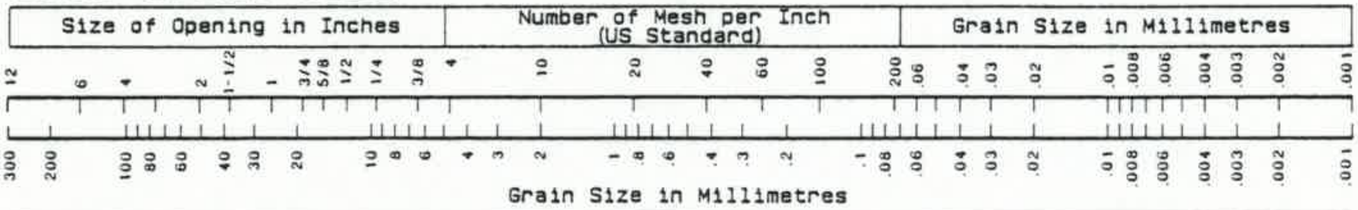
Hydraulic Conductivity Tests

Three vertical hydraulic conductivity tests were performed on soil samples of glacial till and residual soil using the constant head permeability method. The soil samples were obtained from the test pits and were recompacted in the laboratory using the Standard Proctor method. The samples were placed by hand in 4-inch molds and compacted to densities similar to those which may be attained in the field. The compaction density and moisture content, and determined hydraulic conductivity values are presented below.

Sample No.	Compaction in Percent of Maximum Dry Dry Density	Compaction Water Content in Percent	Hydraulic Conductivity in cm/sec
TP-7, BS-1	95	18	$1.6x10^{-7}$
TP-8, BS-1	90	23	$2.3x10^{-5}$
TP-2, BS-1	88	21	$1.7x10^{-6}$

Unified Soil Classification (USC) System

Soil Grain Size



COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines		* GRAVEL with >12% fines		Clean SAND <5% fines		* SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right)$ >4 for G W, >6 for S W & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A Line with PI <4

G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases requiring use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particle diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						

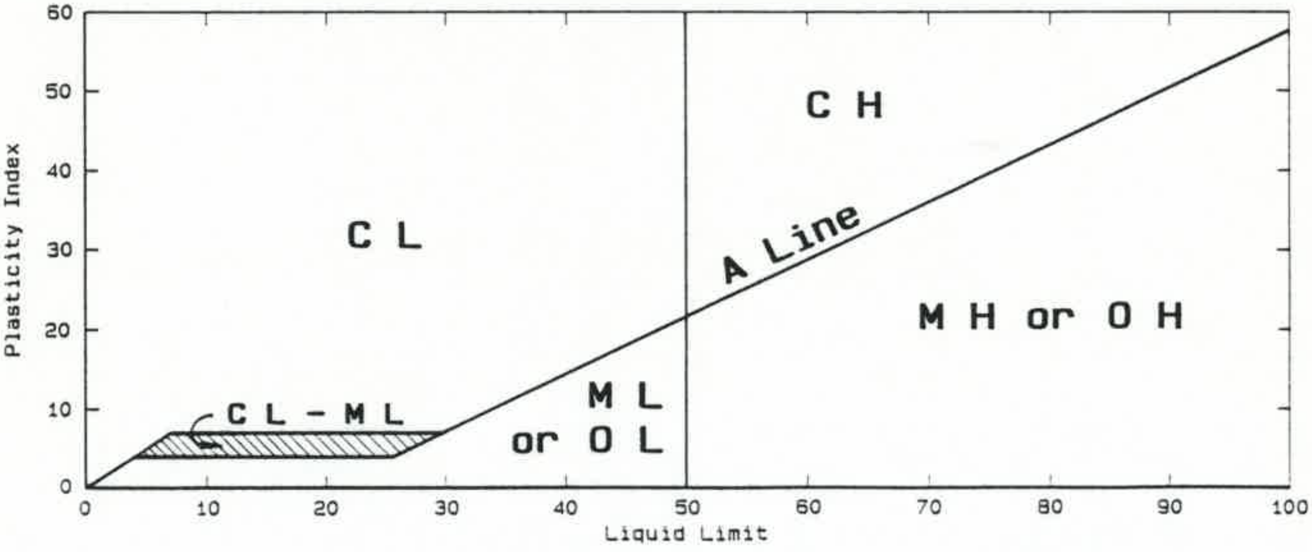


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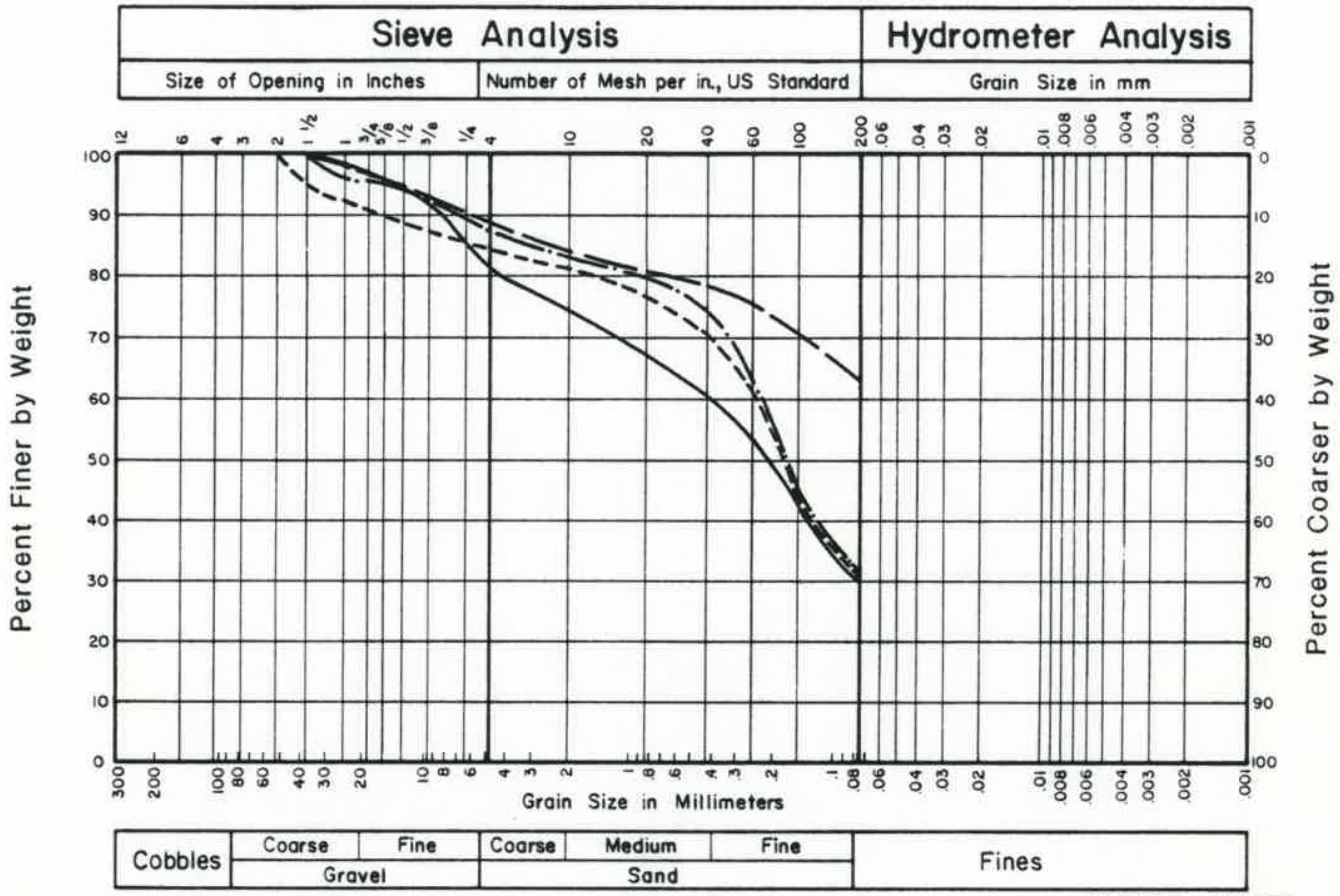
Figure B-1

Grain Size Classification



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	TP-2	BS-1	1.0- 3.0	Gravelly, silty SAND	SM	20
— —	TP-3	BS-1	2.0- 4.0	Slightly gravelly sandy SILT	ML	29
-----	TP-4	BS-1	2.0- 3.5	Gravelly, very silty, medium to fine SAND	SM	16
—·—	TP-5	BS-1	3.0- 4.5	Gravelly, very silty, medium to fine SAND	SM	16

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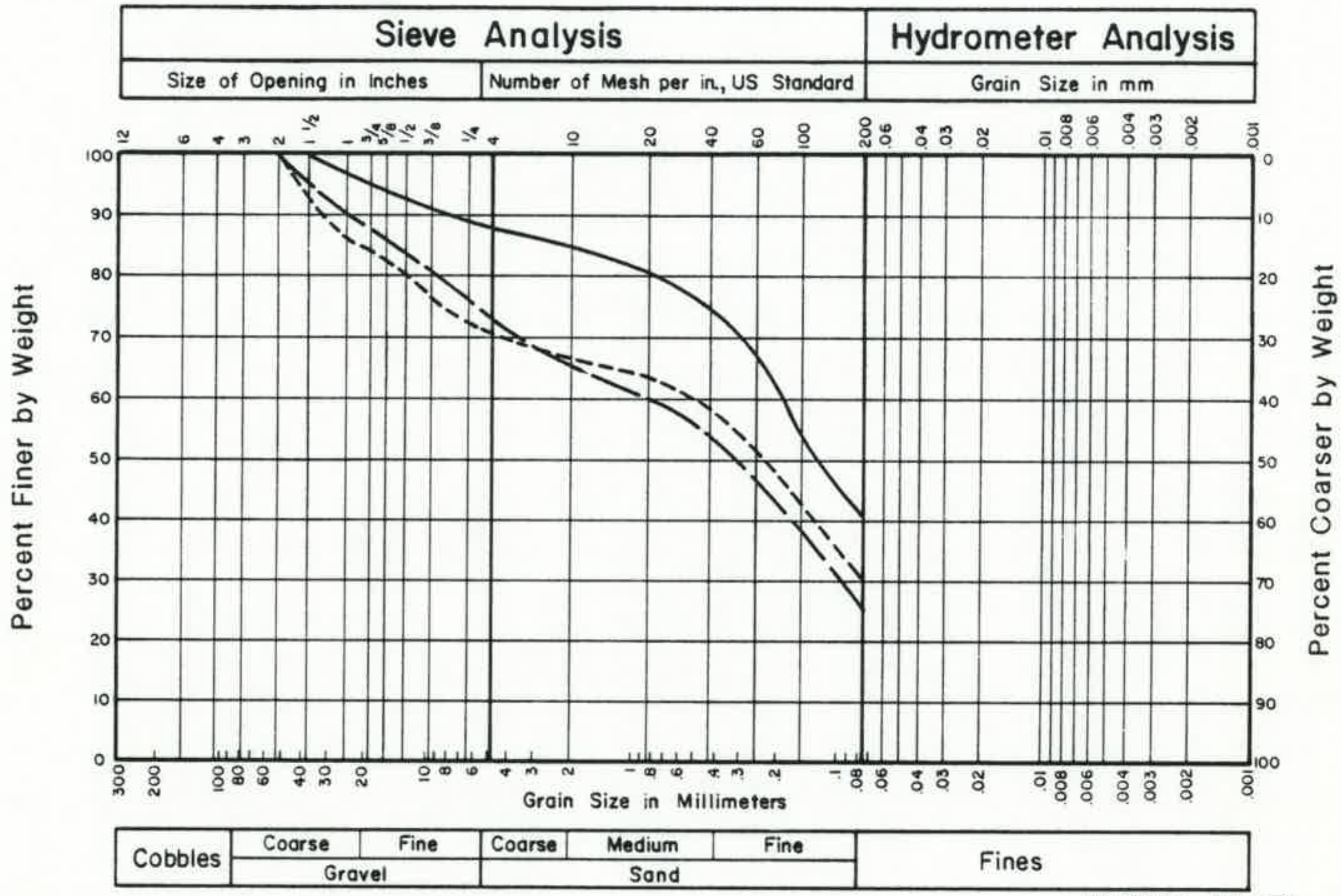
Figure B-2

Grain Size Classification



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	TP-7	BS-1	3.5- 5.0	Slightly gravelly, very silty, medium to fine SAND	SM	22
— —	TP-8	BS-1	1.0- 2.5	Silty, gravelly SAND	SM	17
------	TP-9	BS-1	8.0- 10.0	Silty, gravelly, medium to fine SAND	SM	13

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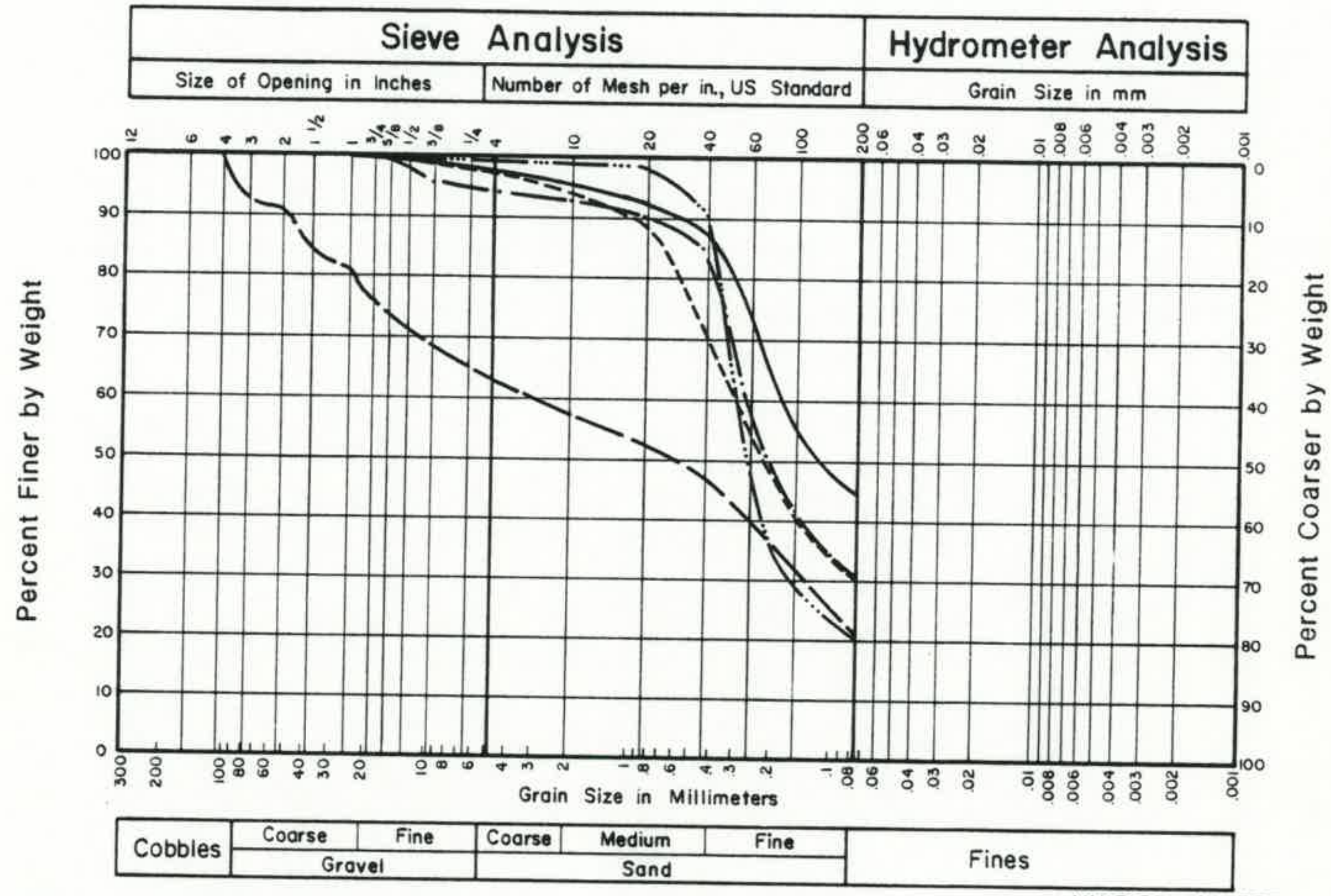
Figure B-3

Grain Size Classification



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	TP-101	S-2	3.0- 5.0	Very silty, medium to fine SAND	SM	20
— —	TP-103	S-1	2.0- 6.0	Silty, very gravelly SAND	SM	11
-----	TP-104	S-2	2.0- 4.0	Very silty, medium to fine SAND	SM	16
—·—	TP-104	S-3	6.0- 9.0	Slightly gravelly, very silty, medium to fine SAND	SM	10
—···—	TP-107	S-2	1.0- 4.0	Silty, fine SAND	SM	17

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Figure B-4

55-1625-01

Letter of Transmittal

HART CROWSER & associates inc.

Job No.: J-1523-02

Date: April 11, 1986

To: Parametrix
13020 Northrup Way, Suite 8
Bellevue, WA 98005

Attention: Clyde Moore

Regarding: Hydrogeologic and Geotechnical Assessment

We are sending the following items:

Date	Copies	Description
4-11-86	3	Hydrogeologic and Geotechnical Assessment. Newcastle
		Landfill. King County, Washington.

These are transmitted:

☐ For review and comment ☐ For your use

☐ For your information ☐ For action specified below ☐ As requested

Remarks:

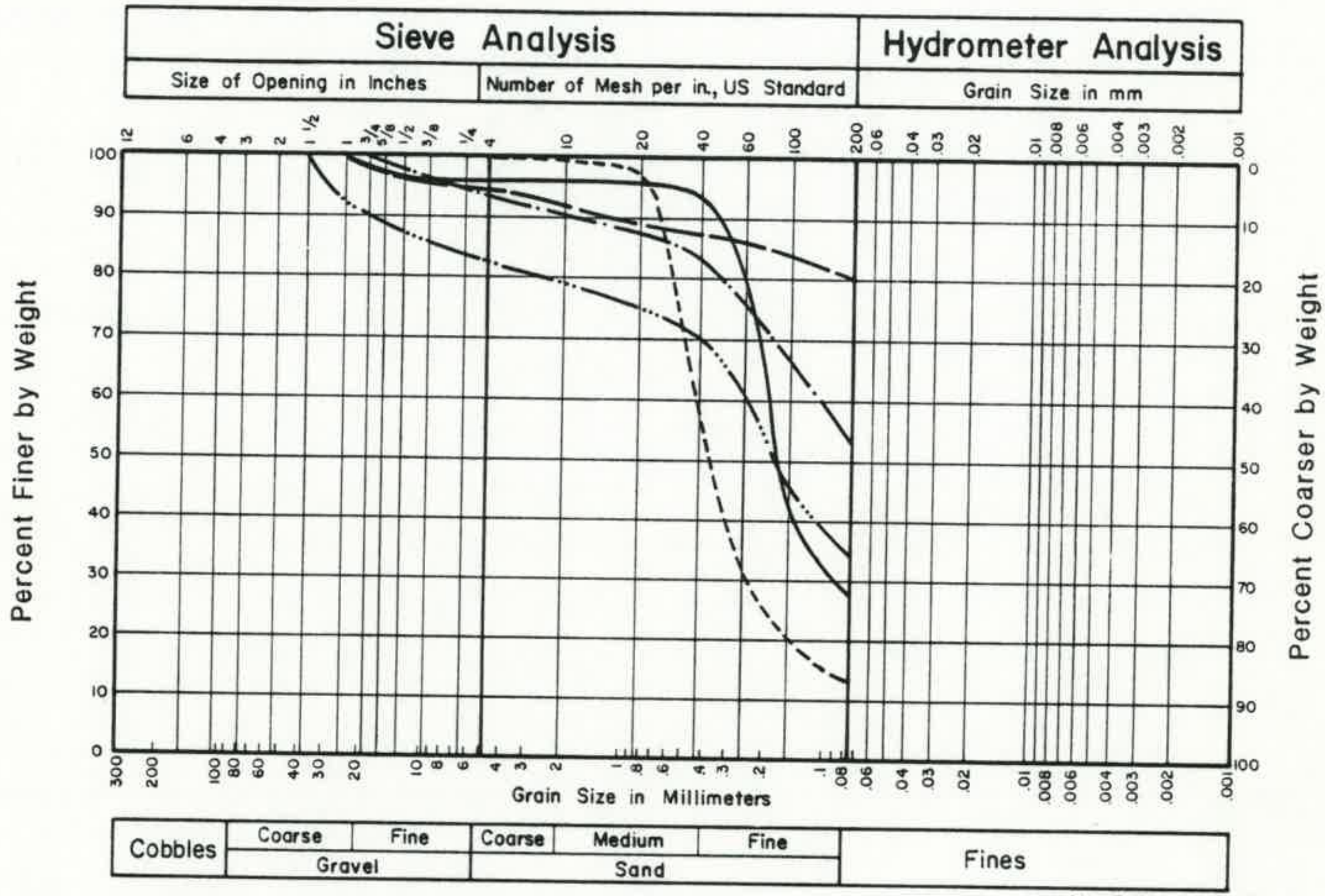
We have enjoyed working with you on this project. Please call if we can answer any questions or be of additional assistance.

Copies to:

Michael Bailey

By: MICHAEL J. BAILEY, P.E.
Title: Senior Project Engineer

Grain Size Classification



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
——	TP-108	S-2	2.0- 4.0	Silty, fine SAND	SM	20
— —	TP-112	S-2	4.0- 6.0	Slightly gravelly, sandy SILT	ML	21
-----	TP-114	S-3A	6.0- 7.0	Silty, medium to fine SAND	SM	14
—·—	TP-116	S-2	2.5- 3.5	Slightly gravelly, very sandy SILT	ML	20
—···—	TP-118	S-1	1.0- 3.0	Gravelly, very silty, medium to fine SAND	SM	14

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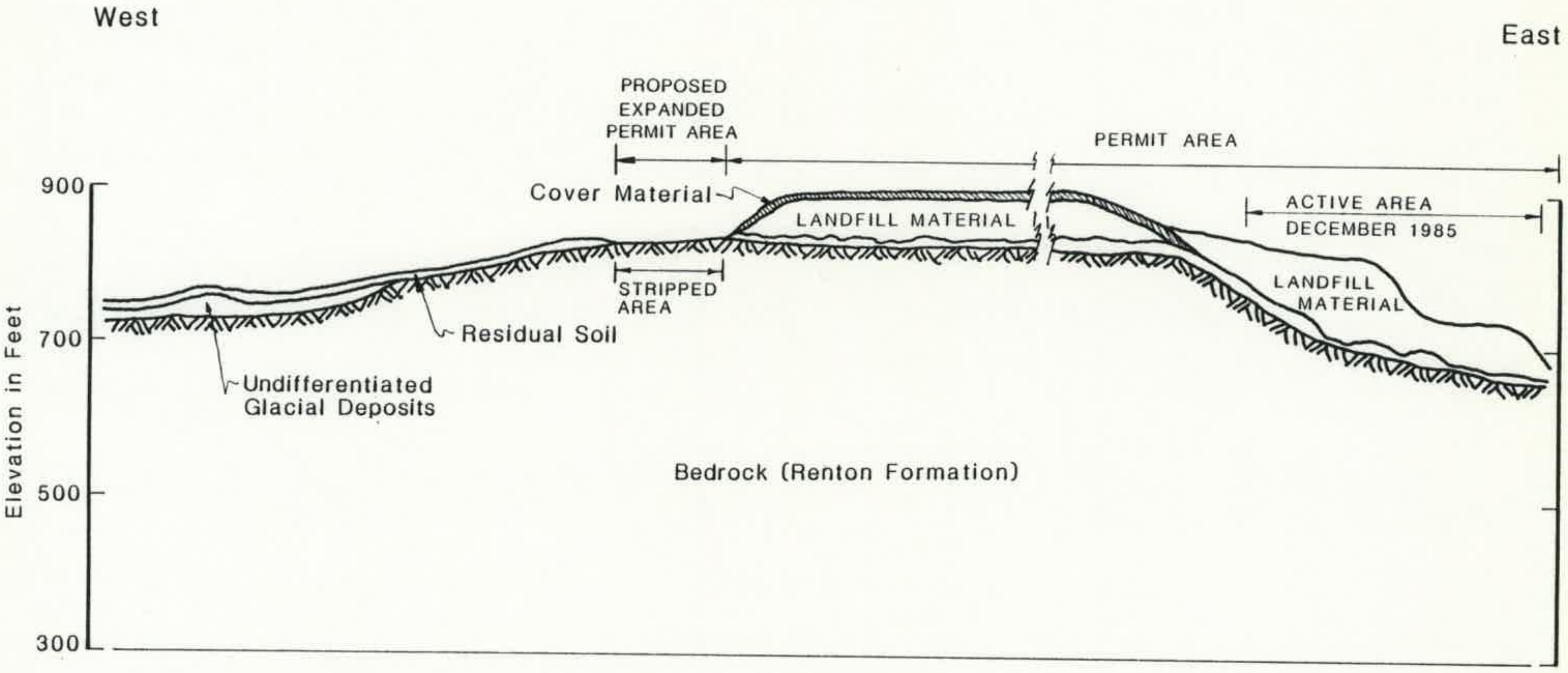
Figure B-5

Schematic Profile across Newcastle Landfill Area



Note: For position of mined zones see Figure 5.
Limits of permit area and proposed expanded permit area are approximate.

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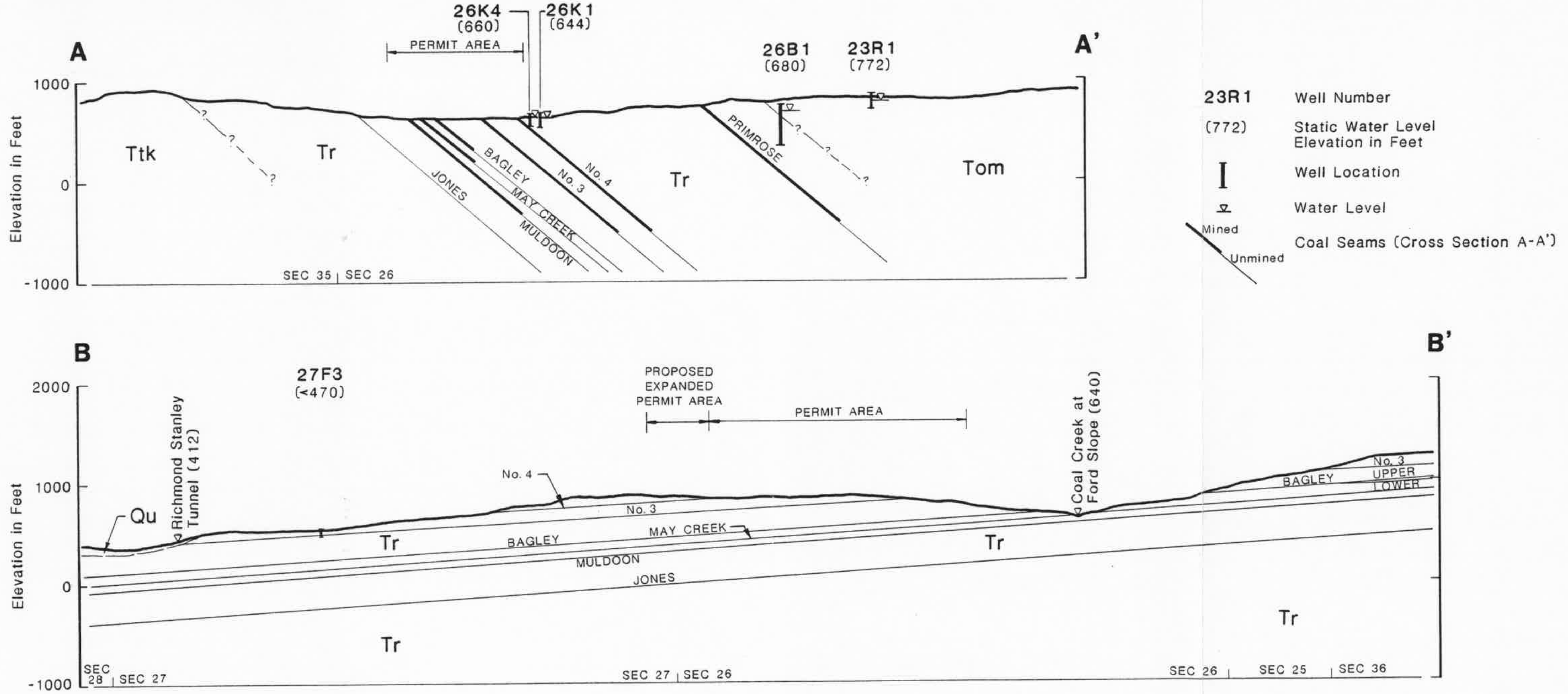
Figure 3

Generalized Subsurface Cross Sections A-A' and B-B'



Qu	Quaternary Undifferentiated
Tom	Oligocene-Miocene Marine Rocks
Tr	Tertiary Renton Formation
Ttk	Tertiary Tukwila Formation

Notes:

1. See Figure 4 for location of cross sections.
2. Subsurface stratigraphy compiled from various sources. Extent of mine workings in A-A' projected from east of landfill (Source: Cross Section C-C', Map of Newcastle Mine Composite, Pacific Coast Coal Co., Posted to 1928). Actual extent of workings varies locally in this vicinity.
3. Source: Vine (1969), Hart-Crowser (1981), Skelley and Loy (1985), and Hart-Crowser Field Investigations, Current Study.
4. Limits of permit area and proposed expanded permit area are approximate.

0 1000 2000
Scale in Feet

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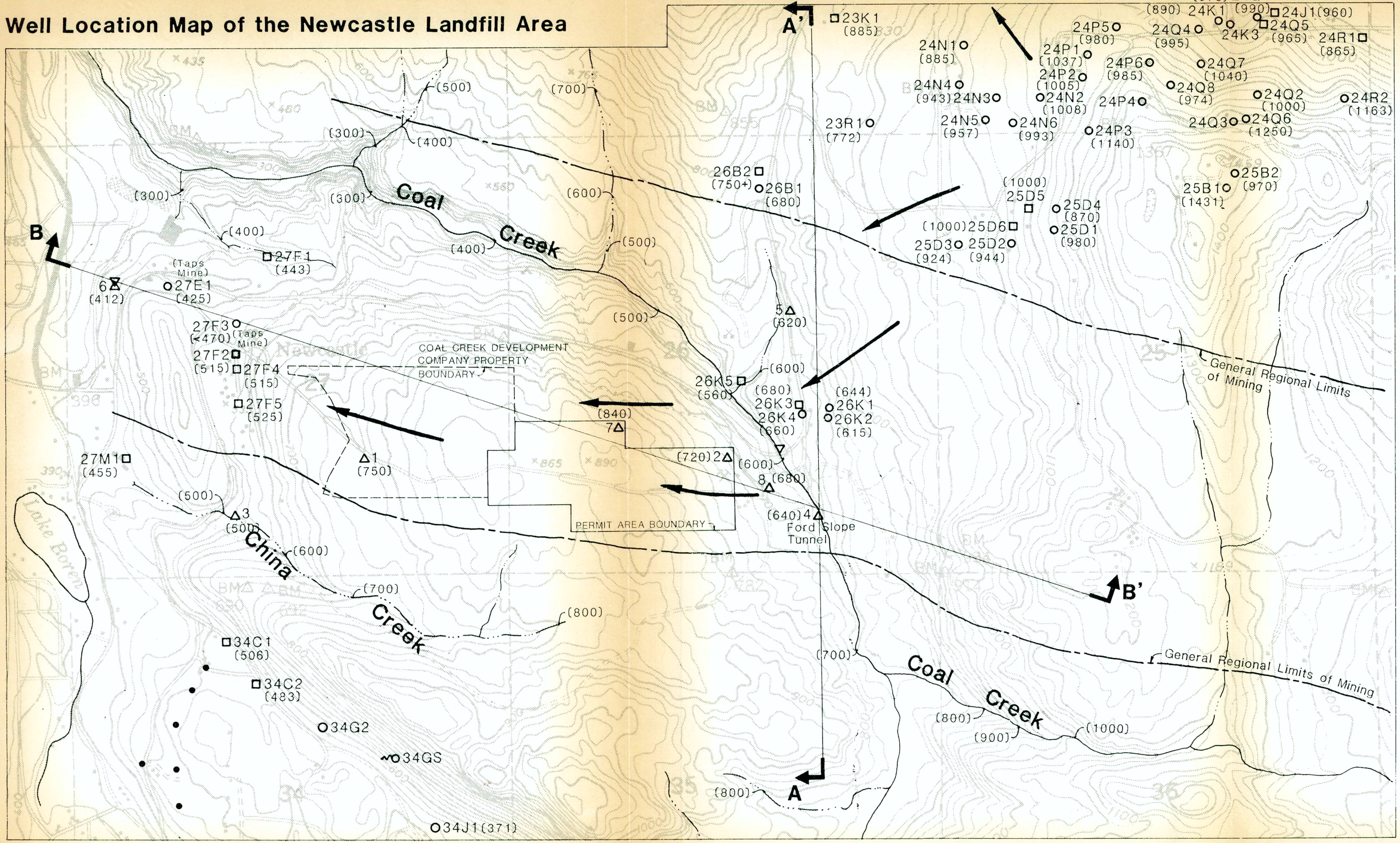
Figure 6

Well Location Map of the Newcastle Landfill Area



Domestic Well Location and Number

26B1 ○	Completed in Bedrock
27F5 □	Completed in Surficial Deposits
●	Possible Well, House Not Visited
~○	Spring
(970)	Water Level Elevation in Feet
←	Groundwater Flow Direction
▽	Surface Water Sampling Location Data by Others
5△	Surface Water Field Test Location and Number, Hart-Crowser, Current Study
A A'	Cross Section Location and Designation

Notes: 1. Well and surface water data presented in Table 1.

2. Base map compiled from U.S.G.S. 7.5-minute Quadrangles of Mercer Island and Issaquah, Washington.

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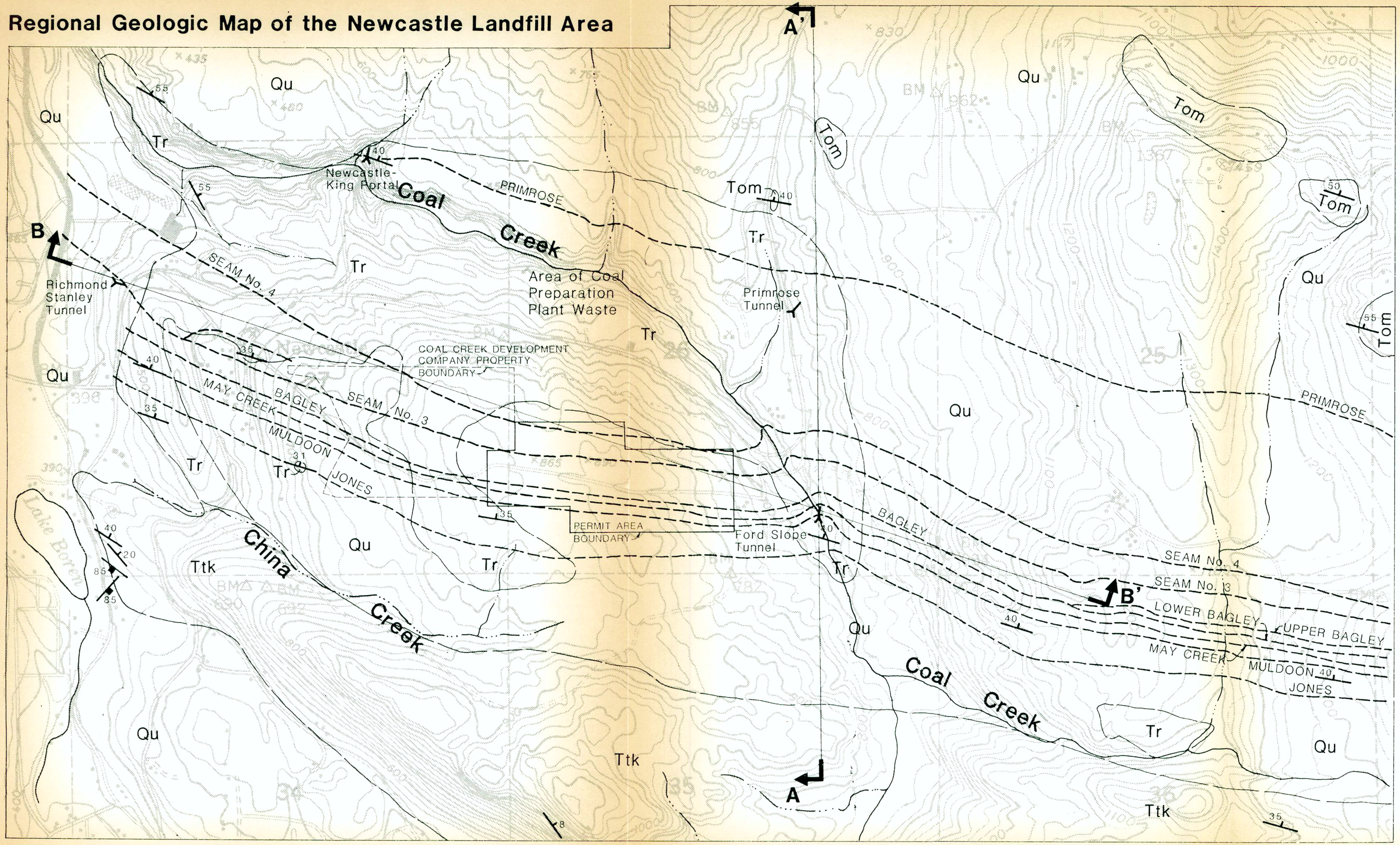
Figure 4

Regional Geologic Map of the Newcastle Landfill Area



Qu	Quaternary Undifferentiated
Tom	Oligocene-Miocene Marine Rocks
Tr	Tertiary Renton Formation
Ttk	Tertiary Tukwila Formation
35	Strike and Dip of Bedding
85	Strike and Dip of Fracture/Joint
	Mine Slope, Drift or Shaft
	Geologic Contact
	Known, Inferred or Assumed Surface Outcrop of Mined or Unmined Coal Seam
A A'	Cross Section Location and Designation

Notes: 1. Source: Compiled from works by Pacific Coast Coal Company (1928), Weaver (1937), Beikman, et al (1961), Liesch, et al (1963), Vine (1969), Luzier (1969), Hart-Crowser (1981), Skelley and Loy (1985) and Hart-Crowser Field Investigation, Current Study.

2. Base map compiled from U.S.G.S. 7.5-minute Quadrangles of Mercer Island and Issaquah, Washington.

N

0 1000 2000

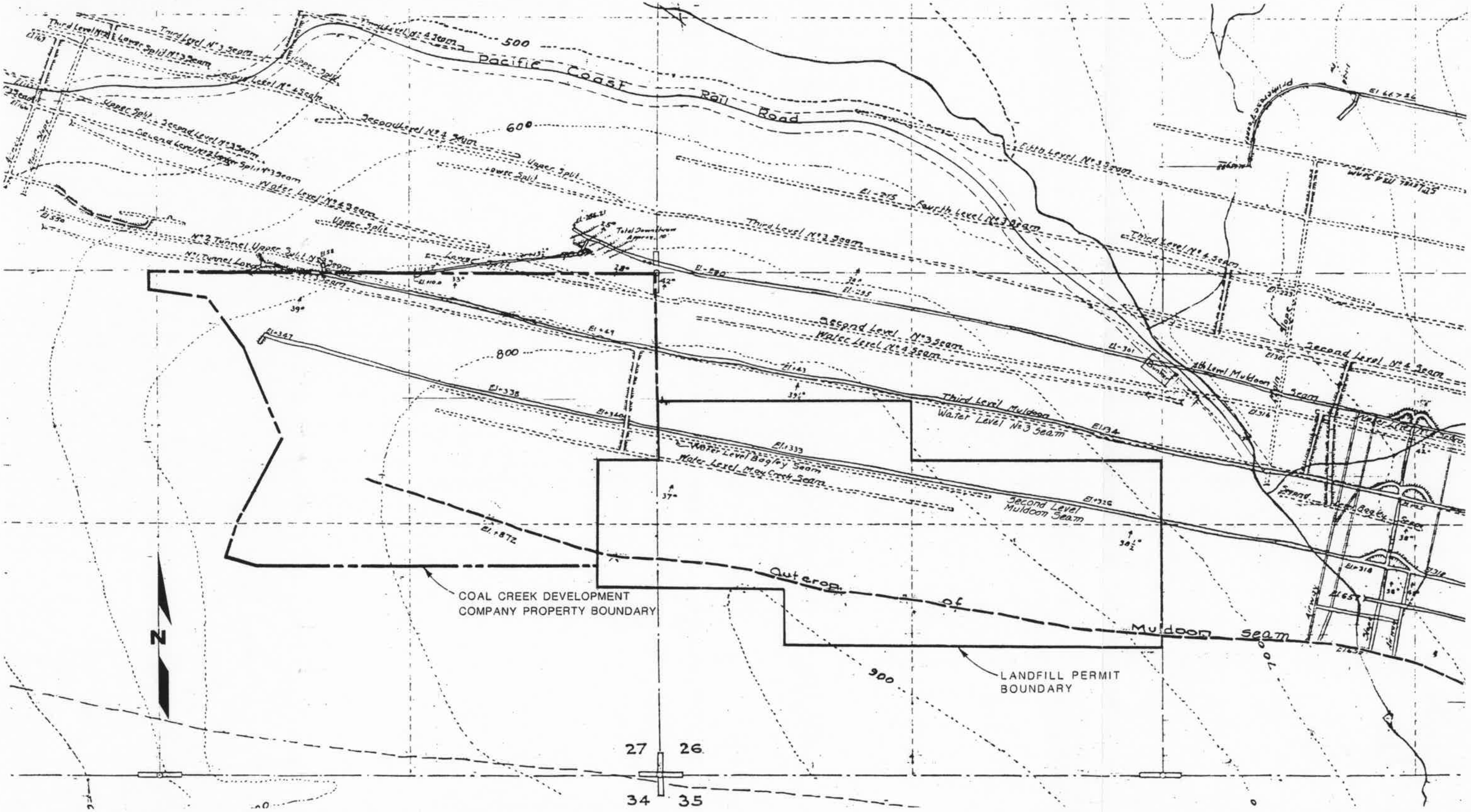
Scale in Feet

J-1523-02 December 1985

HART-CROWSER & associates, inc.

Figure 5

Map of Major Mine Tunnels (Referred to as "Gangways" or "Levels") in the Landfill Vicinity. Mine Workings Extended to the South of Each "Level".



Source: Base map prepared from what is believed to be "Composite Map of Newcastle-Issaquah Mines" by Pacific Coast Coal Company (1928), inventoried by DNR as K7-E.

J-1523-02 December 1985
HART-CROWSER & associates inc.
Figure 7