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Interim Site Characterization Report and Ground-Water Monitoring Program for the Hanford Site Solid Waste Landfill

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Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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INTERIM SITE CHARACTERIZATION REPORT AND GROUND-WATER MONITORING PROGRAM FOR THE HANFORD SITE SOLID WASTE LANDFILL

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Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

The procedures and preliminary interpretations in this document reflect conditions in 1988 and are thus subject to change as a result of ongoing technical audits and reviews.

Concentrations of ground-water constituents are compared to federal drinking water standards throughout this document for reference purposes. All drinking water supplied from the sampled aquifer meets regulatory standards for drinking water quality.

ABSTRACT

Federal and state regulations governing the operation of landfills require utilization of ground-water monitoring systems to determine whether or not landfill operations impact ground water at the point of compliance (ground water beneath the perimeter of the facility). A detection-level ground-water monitoring system was designed, installed, and initiated at the Hanford Site Solid Waste Landfill (SWL). Chlorinated hydrocarbons were detected at the beginning of the ground-water monitoring program and continue to be detected more than 1 year later. The most probable source of the chlorinated hydrocarbons is washwater discharged to the SWL between 1985 and 1987. This is an interim report and includes data from the characterization work that was performed during well installation in 1987, such as field observations, sediment studies, and geophysical logging results, and data from analyses of ground-water samples collected in 1987 and 1988, such as field parameter measurements and chemical analyses.

EXECUTIVE SUMMARY

The Hanford Site Solid Waste Landfill (SWL) is owned by the U.S. Department of Energy (DOE) and is presently operated by Westinghouse Hanford Company. In 1986, Rockwell Hanford Operations was the SWL operator and requested the services of the Pacific Northwest Laboratory (PNL) to design, install, and maintain an independent ground-water monitoring system at the SWL.

Federal and state environmental regulations require that landfill operators monitor ground water at their facilities to detect possible contamination resulting from landfill operations. To comply with State of Washington Administrative Code (WAC) 173-304, governing solid waste landfills, six ground-water monitoring wells were installed and hydrogeologic characterization was begun in 1987 at the SWL. These six wells were completed in April 1987. Seven existing ground-water monitoring wells, designed to comply with WAC 173-303, governing hazardous waste landfills, had been completed in 1986 at the adjacent Nonradioactive Dangerous Waste Landfill (NRDW).

The ground-water monitoring system at the SWL was designed to be a detection-level system based on WAC 173-304. The purpose of all detection-level monitoring systems is to characterize the local hydrogeology and to evaluate water chemistry data to determine whether facility operations are affecting the ground water. Operations at either the SWL or the NRDW were found to be impacting the ground water. A group of chlorinated hydrocarbons were detected in the first ground-water samples collected at the SWL. Analyses for these constituents are not required by WAC 173-304. These constituents were included in the first round of SWL analyses because they recently had been detected in a Hanford Site well that was downgradient from the SWL.

Resampling was immediately initiated and the original findings were confirmed. Simultaneously, state and local officials were notified by the DOE. Drinking water standards were exceeded for coliform bacteria, primarily in NRDW wells, and for 1,1,2-trichloroethylene (TCE), primarily in SWL wells. Pacific Northwest Laboratory expanded the ground-water monitoring program at the SWL to include constituents covered by WAC 173-303 because the presence

of chlorinated hydrocarbons raised the possibility of other contaminants. Expansion of the ground-water monitoring program at the SWL was appropriate, in the opinion of PNL, because hazardous constituents had been detected in SWL wells, and because of the proximity of the NRDW and its ground-water monitoring program, which follows WAC 173-303.

Of the seven NRDW monitoring wells, three are upgradient and four are downgradient. Of the six SWL wells, one is upgradient and five are downgradient. Characterization work conducted during the construction of the six SWL wells included sediment, geologic, hydrologic, and geophysical field and laboratory studies. The subsequent ground-water monitoring effort included measurements of ground-water parameters and analysis of ground-water constituents. The results of seven rounds of sampling and analysis are included in this interim report.

In general, data from drilling and aquifer testing suggest that the stratigraphy and hydrogeology beneath the SWL is essentially the same as that beneath the NRDW. The water table is approximately 125 ft beneath the land surface, and the vadose zone comprises mostly unconsolidated sediments that can be divided into two units locally: an upper sandy unit and a lower gravelly unit. The direction of ground-water flow is generally west-northwest to east-southeast. Because of high transmissivities and an extremely flat hydraulic gradient (about 0.0001), data from nearby Hanford Site wells will be collected and evaluated to determine if the ground-water flow direction has been accurately calculated based on the SWL and NRDW well network data.

Results of the May 1987 chemical analyses indicated that four species of chlorinated hydrocarbons are present in the ground water at the SWL. Results from the next two samplings in June and July confirmed these findings. An additional species was detected (carbon tetrachloride). Thus far, the data are too limited for a trend analysis. One of the chlorinated hydrocarbons 1,1,2-trichloroethylene, was above the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 5 parts per billion (ppb); concentrations ranged from 4 to 10 ppb. The other chlorinated hydrocarbons detected were 1,1,1-trichloroethane (MCL is 200 ppb), perchloroethylene, and 1,1-dichloroethane. The extent of the contamination to the south and east of the SWL is unknown. Because of the NRDW ground-water monitoring well network, the extent of the chlorinated hydrocarbons to the north and northwest is known: chlorinated hydrocarbons occur only in the two NRDW downgradient wells closest to the SWL and only in concentrations below the MCLs.

Samples were analyzed for additional constituents listed in WAC 173-303 hazardous waste regulations in June 1987. No additional types of hazardous constituents were detected. However, the July sampling did detect small (just at or below the MCL of 5 ppb) concentrations of carbon tetrachloride, another volatile organic compound. The other three detected species have been consistently present in concentrations below MCL standards.

Possible sources for the contamination at the SWL were investigated. The NRDW was created in 1975 to dispose of nonradioactive but hazardous materials. The SWL received office trash, lunchroom garbage, sewage and construction debris (e.g., asphalt, barrels, and drums). In addition, solvent-containing washwater from the 1100 Area bus maintenance operations was discharged to the SWL from January 1985 to January 1987. It is this washwater that has been identified as the probable source of contamination, based on two lines of evidence: 1) analyses of washwater samples taken from the 1100 Area show the same chlorinated hydrocarbon species, and 2) the spatial distribution of the contaminants in the ground water at the SWL are all downgradient from the trenches where the washwater was discharged. The large volumes of washwater and sewage involved may have resulted in a rapid transit time to the water table.

Disposal of the washwater and sewage has been discontinued to comply with state and federal solid waste regulations. Results of the detection-level ground-water monitoring project required DOE to notify the Washington State Department of Ecology (hereafter called Ecology), the district EPA, and the local jurisdictional health department. Ecology and EPA representatives requested that they be sent a "plan of action" concerning the contamination at the SWL. One was prepared by PNL and presented to Westinghouse Hanford Company in July of 1987.

Assessment of the contamination at the SWL has included expanding the constituent list for SWL wells (based on WAC 173-303) and performing monthly water level measurements at SWL in conjunction with NRDW wells and nearby Hanford Site wells to more accurately determine the ground-water flow direction at the SWL.

Information that is needed to adequately assess the extent of contamination includes the following:

- source (quantities) of chlorinated hydrocarbons
- direction and velocity of ground-water flow at the SWL and NRDW, determined as accurately as possible
- quantity and distribution of residual chlorinated hydrocarbons in the soil column
- quantity and distribution of chlorinated hydrocarbons in the ground water to the east and south of the SWL and their vertical distribution in the aquifer
- expected future impacts to the ground water (based on residual quantities and determination and evaluation of transport mechanisms in the soil column and unconfined aquifer).

The purpose of the assessment-level program is to determine what further actions need to be taken.

ACKNOWLEDGMENTS

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INTRODUCTION

The Pacific Northwest Laboratory (PNL) is conducting characterization work on the geology, hydrology, and geochemistry at the Solid Waste Landfill (SWL), a facility located on the Hanford Site in southeastern Washington State (Figure 1). The SWL has been operated in its present location since 1973, first by Atlantic-Richfield until mid-1977, then by Rockwell Hanford Operations (Rockwell) until June 1987, and presently is operated by Westinghouse Hanford Company (Westinghouse Hanford) for the U.S. Department of Energy (DOE). Historically it has been operated as a sanitary landfill; currently it receives only solid wastes.

In 1975, a separate area adjacent to the SWL was designated to receive nonradioactive, hazardous waste materials from Hanford operations. This area became the Nonradioactive Dangerous Waste Landfill (NRDW). Complete documentation of materials received at the NRDW and SWL is not available.

The characterization work described in this document represents recent efforts by PNL to bring the SWL into compliance with the appropriate federal and state regulations concerning the monitoring of ground water. These regulations include sections of the 1984 Resource Conservation and Recovery Act (RCRA), as described in 40 CFR 257, and Washington Administrative Code (WAC) 173-304, Section 490, which applies to solid waste landfills. Pacific Northwest Laboratory prepared a detection-level ground-water monitoring plan based on these regulations; in October 1986 the DOE transmitted this plan to federal and state regulators and the local jurisdictional health district.

Geologic and hydrologic data collected during monitoring well construction between January 9 and April 15, 1987; chemical analysis from seven rounds of ground-water sampling and a separate field study; and the data requirements to complete hydrogeologic characterization and assess contamination at the SWL are presented in this interim report. Additional information on the SWL is available in the Ground-Water Monitoring Compliance Plan for the Hanford Site Solid Waste Landfill (DOE 1986a) and in the Interim Hydrogeologic Characterization Report and Ground-Water Monitoring System for the Nonradioactive Dangerous Waste Landfill, Hanford Site, Washington (Weekes, Luttrell, and Fuchs 1987).

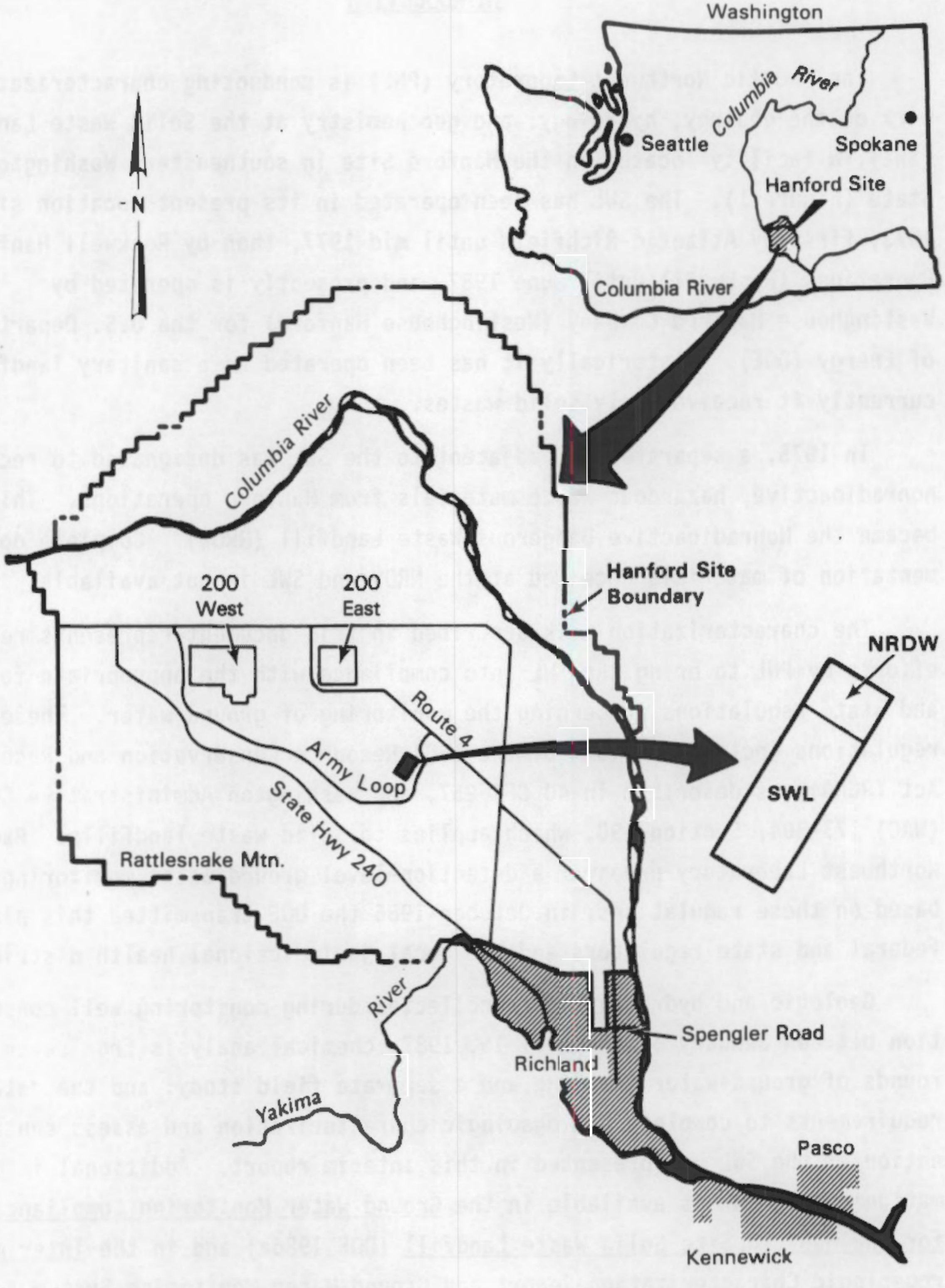

FIGURE 1. Location of the Solid Waste Landfill (SWL) and Nonradioactive Dangerous Waste Landfill (NRDW) on the Hanford Site, Washington. (The Hanford Site is 24 miles from east to west.)

DESCRIPTION OF THE HANFORD SITE AND SOLID WASTE LANDFILL

The DOE's Hanford Site is located in a semiarid region of southeastern Washington State (see Figure 1). The Site occupies an area of approximately 560 mi^2 and is about 30 mi long from north to south and about 24 mi wide from east to west. It provides limited access to land that encompasses facilities currently used for operations, waste storage, and waste disposal connected with plutonium production. Adjoining lands north, east, and west are used mainly for range and agricultural purposes. To the south are the towns of Richland, Kennewick, and Pasco (the Tri-Cities). The Tri-Cities are the nearest population center to the Hanford Site and collectively include about 130,000 people. Figure 2 delineates land uses.

The SWL and the NRDW occupy 76 acres of land; the SWL is approximately 65 acres of the total area. The NRDW is treated as a separate facility under federal regulation 40 CFR 265(f) and state regulation WAC 173-303. The landfills are located about 5 mi southeast of the 200 Areas. Physical facilities are limited to the perimeter fence and a mobile field office. Drinking water is brought to the sites in 5-gal containers. An aerial view of both the SWL and NRDW as well as the general topography and local vegetation is shown in Figure 3.

The SWL has primarily received paper wastes and construction debris, which were buried in shallow trenches, and sewage sludge, which was discharged to separate, shallow trenches along the inside east and west perimeters of the SWL. For a 2-year period, from January 1985 to January 1987, waste washwater from bus maintenance operations was discharged to shallow trenches along the western inside perimeter of the SWL. The same trenches were also used for sewage disposal. Sewage disposal at the SWL was discontinued by April 1987. The SWL disposal history and trench locations for trash and liquid disposal are shown in Figure 4.

Between the NRDW and the active sections of the SWL are 1220 ft of trenches called the Phase I Trash Trenches, which were closed in July 1982. The portion of the SWL called the Phase II trenches includes northern, middle, and southern trash trenches. The northern trenches began receiving

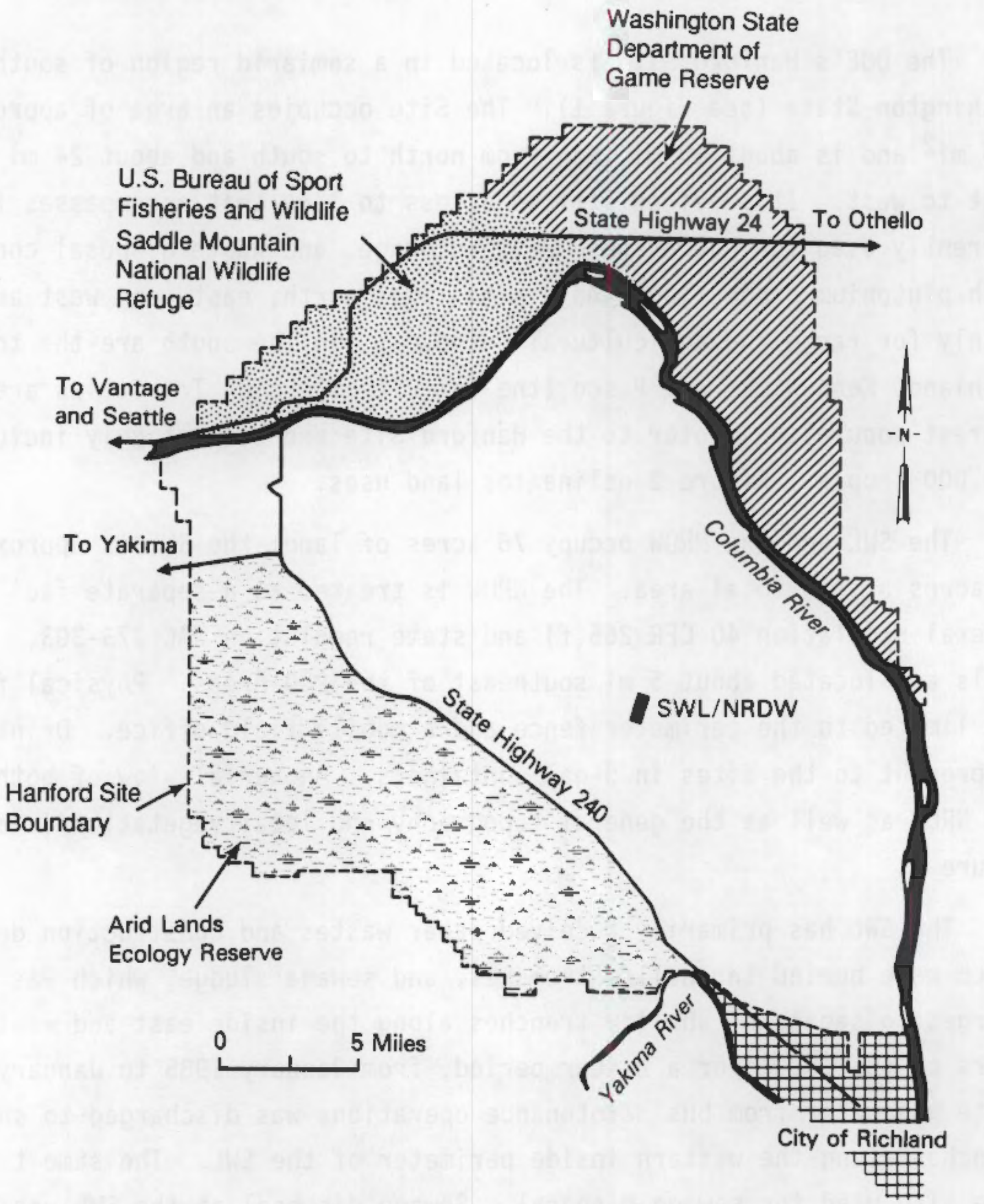

FIGURE 2. Land Use of the Hanford Site and Nearby Population Centers

trash after Phase I trenches were closed until the northern trenches were filled and closed in May 1987. Trenches in the middle are currently receiving waste. The southern trenches will be excavated and filled as needed.

FIGURE 3. Aerial View of Hanford's Solid Waste Landfill and Nonradioactive Dangerous Waste Landfill, Looking Northeast Across the Pasco Basin. The rectangular outline includes the Solid Waste Landfill (center and foreground); and the Nonradioactive Dangerous Waste Landfill, along the northern edge. Note the active trench in the Solid Waste Landfill in the center of the photograph. The section with the diagonal road across it is the closed Phase I section of the Solid Waste Landfill.

FIGURE 3. Aerial View of Hanford's Solid Waste Landfill and Nonradioactive Dangerous Waste Landfill, Looking Northeast Across the Pasco Basin. The rectangular outline includes the Solid Waste Landfill (center and foreground) and the Nonradioactive Dangerous Waste Landfill along the northernmost edge. Note the active trench in the Solid Waste Landfill in the center of the photograph. The section with the diagonal road across it is the closed (north) section of the Solid Waste Landfill.

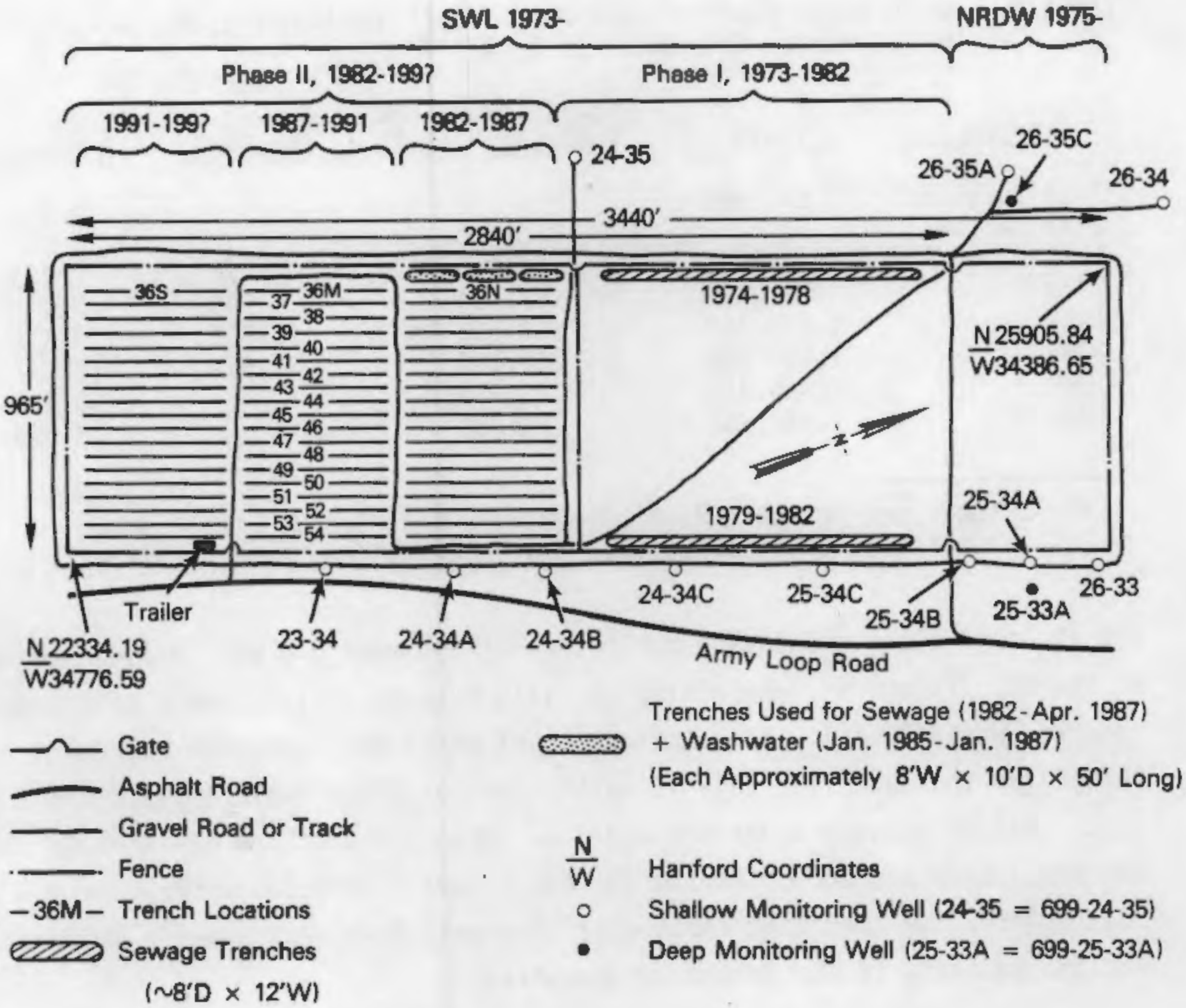

FIGURE 4. Plan of the Solid Waste Landfill and the Nonradioactive Dangerous Waste Landfill

As an example of annual waste received by the SWL, in FY 1984, 1,110,548 ft^3 of solid waste volume, based on trench volume estimates, was placed in the SWL. Categories of waste materials and estimates of their volumes, including sewage, are shown in Table 1. Washwater totaling about 100,000 gal from steam pad catch basins in the 1100 Area bus maintenance facility was also discharged to the SWL. Until April 1987, the SWL received sewage waste from chemical toilets and septic tanks at the Fast Flux Test Facility, the Washington Public Power Supply System construction site, and Hanford facilities. An estimated 1,000,000 to 1,500,000 gal of sewage was discharged to contiguous shallow trenches (8 ft deep and 15 ft wide by

TABLE 1. Solid Waste Landfill and Nonradioactive Dangerous Waste Landfill Waste Volumes Received, 1973-1987[a]

Dates	Trash	Liquid Sewage and Washwater (gal)	Chemicals	Asbestos
7-73 to 12-82	148,000			12,600
1975 to 1981		350,000		
1982	23,065	50,250	90	263
1983	37,629	187,350	195	400
1984	1,110,548	168,250	10,656	19,832
1985	1,154,582	220,750	3,592	19,840
1986	1,525,350	152,075		33,837
1987	1,567,962	98,050		23,523

(a) Volumes are in cubic feet unless otherwise noted. Solid waste volumes have been estimated based on calculated trench volumes.

100 ft long) along the inside perimeters of the east and west closed sections of the SWL (Figure 4). An estimated daily average of the amount of sewage received was 3000 gal. No detailed log of waste materials has been maintained for the landfill; this is partly because other Hanford contractors (e.g., Kaiser Engineers Hanford and J.A. Jones Construction Services Co. in the past) have had access to the SWL for disposal purposes without intercession from the operating contractor [Rockwell (now Westinghouse Hanford) for the majority of the length of operation].

Today the SWL receives wastes generated by DOE activities, including office waste materials, lunchroom-type garbage, construction waste materials, and some demolition and large-object wastes. All sewage sludge disposal was discontinued in April 1987 to bring the SWL into compliance with state regulations for solid waste landfill operation (neither sewage nor washwater liquids are being discharged to the SWL). Disposal trenches at the SWL are measured and flagged at intervals to ensure that trenches do not intersect. Spoil piles are created on both sides of the trench during excavation. The current trenches are constructed according to two basic designs: either 46 ft wide at the top, 14 ft wide at the base, and 15 ft deep; or 106 ft wide at the top, 65 ft wide at the base, and approximately 20 ft deep. Figure 5 is a photograph of one of the larger, newly excavated trenches. Before

FIGURE 5. Large Trench Excavation at the Solid Waste Landfill. Spoil piles form a row of "hills" around the trench. The trench is excavated to a depth of 18 to 20 ft. The trench walls display distinct horizontal layers.

disposal of waste into the trenches, "ballast gravel" is bulldozed across the top of the backfilled area to provide vehicle access to the dumping area and allow landfill equipment to compact the waste.

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GEOLOGY OF THE HANFORD SITE

The Hanford Site is situated in the Pasco Basin, one of five major basins in the Columbia Plateau, and is generally bounded by east-west trending anticlines to the southwest, west, and north; the Columbia River on the east and the city of Richland on the south. Most of the Hanford Site consists of an alluvial plain that ranges from 345 ft above mean sea level (MSL) in the southeast corner to 803 ft in the northwest. A plateau ranging from 623 to 804 ft in elevation occurs in the western central portion of the Hanford Site. Local outcrops of basalt (the anticlinal ridges) form hills and low mountains; the highest point is located on top of Rattlesnake Mountain (3585 ft) on the southwestern border of the Site.

STRUCTURAL GEOLOGY

The Pasco Basin is bounded on the north, west, and south by a series of anticlines formed by folding and faulting of basalt, intercalated sediments of the Ellensburg Formation and suprabasalt sediments. These large anticlinal ridges trend east and south and extend from the Cascade Mountains to the Pasco Basin. Of these ridges, the Hog Ranch-Naneum Ridge Anticline forms the western boundary of the Hanford Site. To the west and south of the Hanford Site are the Rattlesnake Hills and a series of doubly plunging anticlines that end in the Horse Heaven Hills. The Saddle Mountains border to the north, and the eastern boundary is a broad zone of increasing westward dip called the Jackass Mountain Monocline (Figure 6).

REGIONAL GEOLOGY

Two distinct types of geologic floods are recorded in the stratigraphy at the Hanford Site. Approximately 2 miles' thickness of basalt units underlies the area. These basalt units represent a portion of one of the world's largest flood basalt sequences (the Columbia River Basalt Group), which forms the Columbia Plateau geologic province. These basalts, and subsequent river and lake sediments, were covered by geologically recent catastrophic glacial

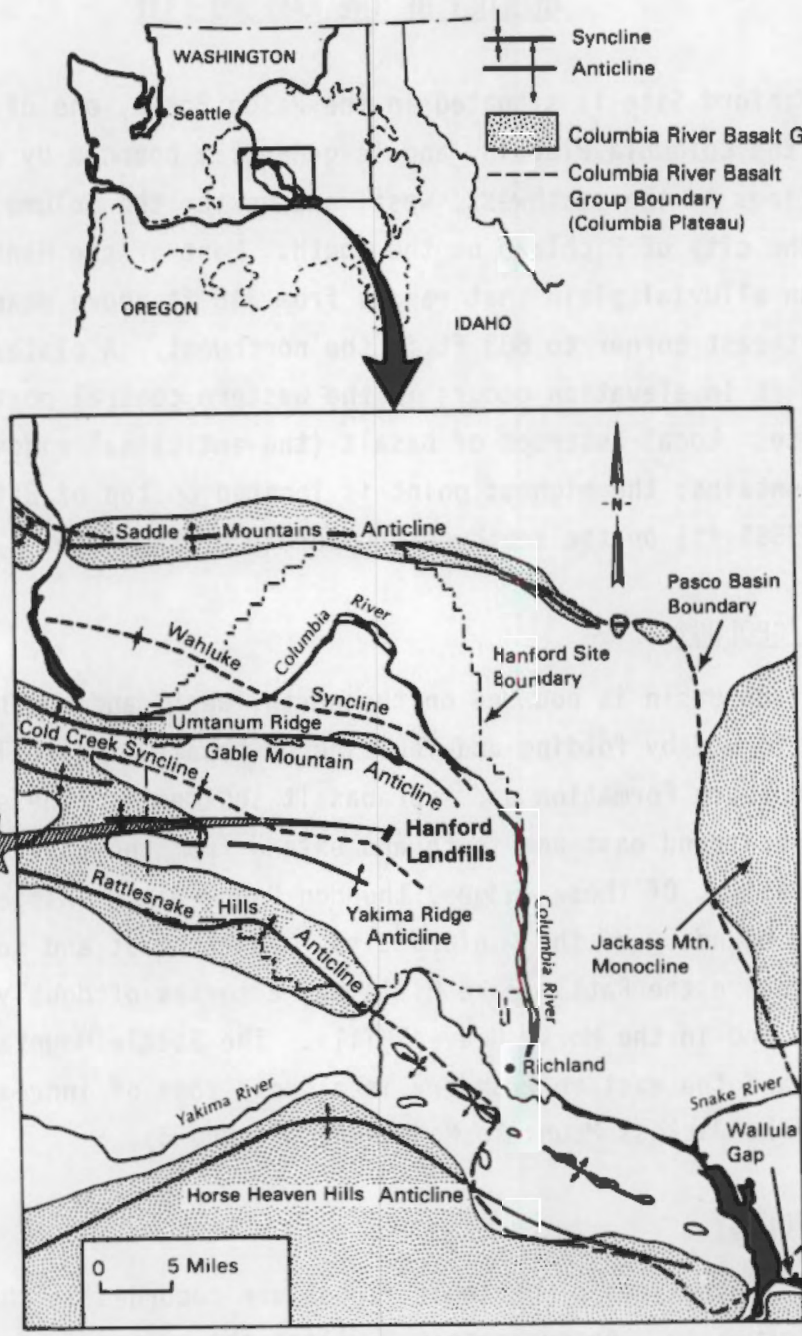


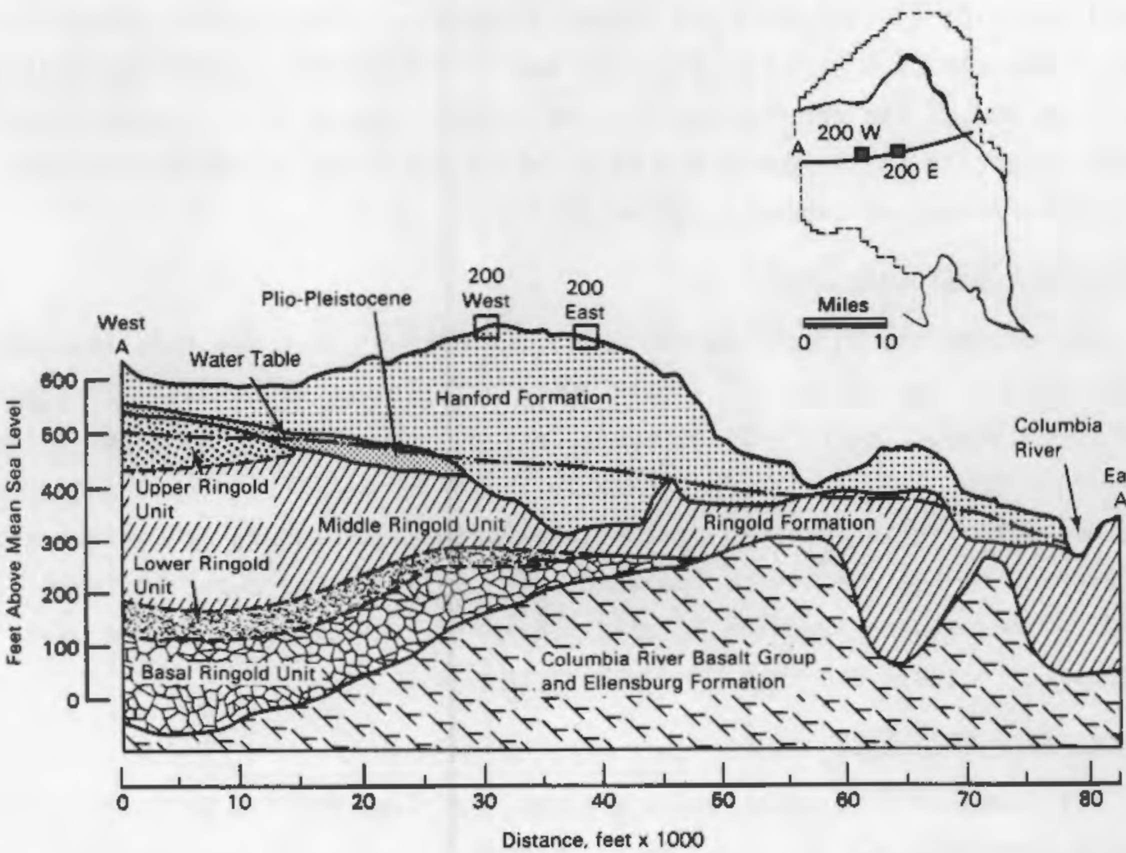
FIGURE 6. Structural Geology of the Hanford Site

flooding at the end of the last ice age. These glacial floods deposited hundreds of feet of silts, sand, and gravel sediments where the Hanford Site is today.

The major geologic units of the Hanford Site are, in ascending order, the Columbia River Basalt Group with intercalated sediments of the Ellensburg Formation, the Ringold Formation, the Plio-Pleistocene unit, and the Hanford formation (informal name). A generalized geologic cross section of the Hanford Site is presented in Figure 7.

<u>The Columbia River Basalt Group</u>

The Columbia Plateau is a major geologic province extending throughout sections of Washington, Idaho, and Oregon. According to Myers and Price et al. (1979), it is primarily composed of Miocene tholeiitic flood basalts covering about 78,000 mi^2. These basalts, named the Columbia River Basalt Group, formed between 6 and 17 million years before present (ybp) when large volumes of lava erupted from north-northwest trending linear vents in



<u>FIGURE 7</u>. A Generalized Geologic Cross Section of the Hanford Site (modified from Tallman et al. 1979)

southeastern Washington, northern Oregon and western Idaho. The basalts are interbedded with Miocene epiclastic and volcaniclastic sediments called the Ellensburg Formation (Myers/Price et al. 1979). The Elephant Mountain member of the Columbia River Basalt Group underlies the central portion of the Pasco Basin.

The Ringold Formation

Following the deposition of Columbia River basalts, fluvial and lacustrine sediments of the Ringold Formation accumulated in the Pasco Basin (DOE 1986). Fossil evidence and paleomagnetic data in the Pasco Basin show that this formation ranges from 8.5 million to 3.7 million ybp. Bjornstad (1985) described four units at a location 9 mi west of the SWL. These units include, from bottom to top: 1) quartzite conglomeritic sand overlain by a fine-grained fluvial facies capped by a paleosol, collectively called the basal Ringold; 2) laminated mud (lower Ringold); 3) quartzitic, braided stream gravels of the middle Ringold; and 4) alternately bedded and laminated sand and mud of the upper Ringold. These units appear to pinch out and/or grade laterally to the north and east, where the Ringold sediments consist of slackwater/overbank deposits (Brown 1959).

The Plio-Pleistocene Unit

Overlying the Ringold Formation is the Plio-Pleistocene Unit (Figure 7) consisting of two subunits: a fanglomerate facies which grades into a paleosol (DOE 1984). The Plio-Pleistocene Unit is unconformable with the Ringold Formation (DOE 1984). The fanglomerate facies is relatively thin and occurs predominantly in the western part of the Hanford Site where it was deposited by erosion of the basalts to the west. The paleosol was deposited when wind reworked and redeposited the Ringold sediments. Relatively high calcium carbonate contents are found in much of this unit.

The Hanford Formation

The Hanford formation, where present, overlies all the previously discussed formations in the Pasco Basin (Figure 7). The Hanford formation thins on the flanks of the Hanford Site and is not present on basalt ridges. This formation consists of two facies: a flood facies (Pasco Gravels) and a slackwater facies (Touchet Beds), both of which were deposited when ice dams in western Montana and northern Idaho were breached, resulting in catastrophic flooding through eastern Washington during Pleistocene time (Bretz 1969). Evidence exists for multiple flood events. Fecht et al. (1985) suggest that at least four major flood events occurred in the Pasco Basin during Pleistocene time. The last major flood sequence is dated at about 13,000 ybp, based on volcanic ash data (DOE 1984).

The Pasco Gravels are mostly composed of coarse sand and gravel. The facies represent a high-energy environment and are restricted mainly to the last Pleistocene flood bars. Webster and Crosby (1982) subdivide the Pasco Gravels into Pre-Missoula Flood Gravels and Missoula Flood Gravels, based on lithologic characteristics in the eastern part of the Pasco Basin. The Touchet Beds are rhythmically bedded, slackwater flood facies deposited away from flood bars and are generally coeval with the Pasco Gravels (DOE 1984). These beds consist of silt to fine sand with stringers of coarse sand and gravel (Myers/Price et al. 1979). The Touchet Beds were deposited when flood waters were imponded behind Wallula Gap (Myers/Price et al. 1979). The origin of the rhythmic layers is still controversial, but they may represent pulsations in the floodwater reaching the area (Baker 1973). Waitt (1980) proposed as many as 40 or more late Wisconsin floods, one flood for each observed rhythmite.

Surficial Deposits

Surficial deposits of alluvium, dune sand, loess, talus, colluvium, landslide debris, and ash deposits from historical volcanic eruptions occur in the Pasco Basin. Most of these deposits are Holocene, but some may be as old as Pleistocene (Myers and Price 1981).

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HYDROLOGY OF THE HANFORD SITE

The 560-mi^2 area of the Hanford Site is drained by the Columbia and the Yakima rivers. The free-flowing section of the Columbia River to the north and east of the Hanford Site is referred to as the Hanford Reach. River flow on the Hanford Reach is controlled by Priest Rapids Dam; the average annual flow is about 110,000 to 120,000 ft^3/sec [based on 65 years of record (DOE 1986b)]. Large floods have occurred in the past on the Hanford Reach (Skaggs and Walters 1981), but the likelihood of their recurrence has been reduced by the construction of several dams upstream. Normal Columbia River elevations within the Hanford Site range from 394 ft above MSL at the northwestern boundary to 341 ft at the southeastern boundary (near the 300 Area). The Yakima River forms a portion of the southern boundary of the Hanford Site (Figure 1). This section of the Yakima River follows a course that mimics the Hanford Reach (on a smaller scale) before entering the Columbia River south of Richland.

UNCONFINED AQUIFER

The unconfined aquifer is the uppermost aquifer and is contained within the glaciofluvial sands and gravels of the Ringold and Hanford formations. The bottom of the unconfined aquifer is a basalt surface or, in some areas, a clay zone belonging to the lower units of the Ringold Formation.

Sources of natural recharge to the unconfined aquifer are rainfall and runoff from the higher bordering elevations, water infiltrating from small ephemeral streams, and river water along influent reaches of the Yakima and Columbia rivers. Studies have been conducted to determine if the infiltration of onsite precipitation also contributes to natural recharge (e.g., Gee 1987). Conclusions vary depending on the location, vegetation, and annual precipitation. Little downward percolation of precipitation occurs on the 200 Area Plateau where soil texture is varied and layered with depth, and moisture penetrating the soil is removed by evaporation (e.g., Gee and Heller 1985). Tests conducted near the 300 Area showed downward water movement below the root zone where soils are coarse textured and precipitation was above normal (Gee 1987).

Ground water in the unconfined aquifer flows primarily from the recharge areas in the west to discharge areas in the east. This general west-to-east flow pattern is interrupted locally by the ground-water mounds beneath the 200 Areas (Graham et al. 1981). These mounds are caused by artificial recharge resulting from onsite disposal of cooling water (Figure 8); consequently, some ground water from the 200 Areas does flow to the north between Gable Butte and Gable Mountain (Graham et al. 1981). Figure 8 also shows that artificial discharge in the 200 Areas has an impact on the water table in the vicinity of the SWL. Ground-water flow directions are dynamic, and changes in the natural and artificial recharge will cause changes in the ground-water elevation and flow direction.

CONFINED AQUIFERS

The confined aquifers under the Hanford Site occur in sedimentary interbeds and/or interflow zones between dense basalt flows in the Columbia River Basalt Group. The main water-bearing portions of the interflow zones can be found within a network of interconnecting vesicles and fractures of the flow tops and bases. Locally, confined aquifers occur in the sediments of the basal Ringold Unit, which overlie the basalt sequence.

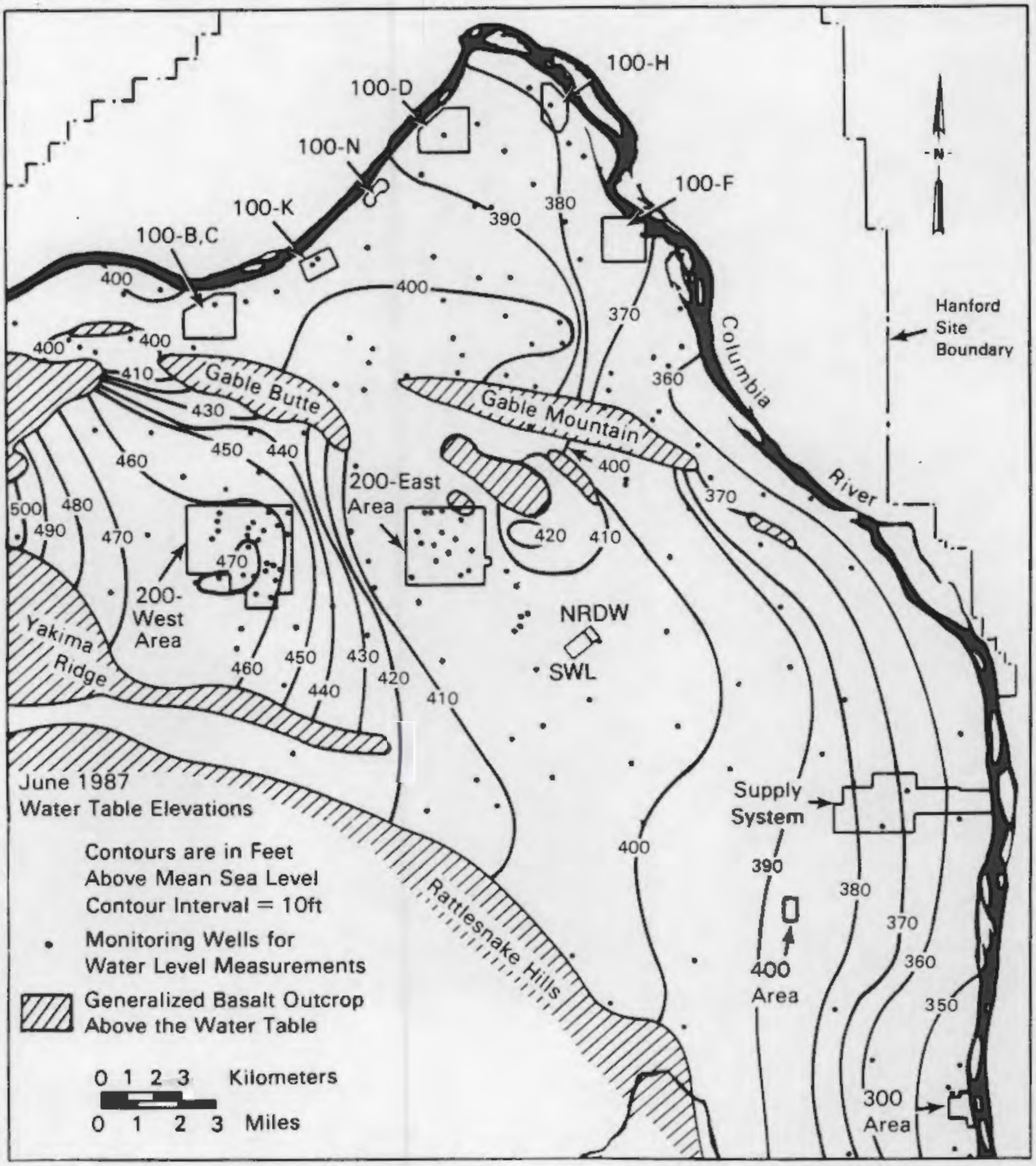

FIGURE 8. Hanford Site Water Table Map for 1987 (Schatz, Ammerman, and Serkowski 1987). Wells near the Solid Waste Landfill that contributed data used in compilation of this map are shown. The six Solid Waste Landfill wells had not been installed at this time.

WELL INSTALLATION AND CHARACTERIZATION EFFORTS

Plans for the ground-water monitoring well network at the SWL are described in Ground-Water Monitoring Compliance Plan for the Hanford Site Solid Waste Landfill (DOE 1986a). This compliance plan formed the basis for the characterization work, ground-water analyses, and monitoring network described in the remainder of this document.

DESIGN OF THE MONITORING PROJECTS

The two compliance ground-water monitoring projects were initiated to meet regulatory requirements for monitoring the ground water at the NRDW and the SWL. The NRDW compliance ground-water monitoring project was designed with three upgradient wells and four downgradient wells. One of the upgradient and one of the downgradient wells were drilled to the bottom of the unconfined aquifer to monitor for contamination at the base of the aquifer. The five shallow wells were first sampled in October 1986, and the remaining wells were sampled January 1987. The monitoring network was designed to meet the requirements of a RCRA interim-status detection-level monitoring system.

Five downgradient wells (699-23-34 through 699-25-34C, from south to north) along the eastern side of the SWL and one upgradient well (699-24-35) on the western side of the landfill were constructed (Figure 9). Each SWL well was completed in the top 10 to 15 ft of the unconfined aquifer. Drilling operations began in January 1987 and were completed in April of the same year. At the end of construction, submersible ground-water pumps were installed in each well to enable monitoring of the upper portion of the unconfined aquifer beneath the SWL. Submersible pumps were installed during the last week of April 1987. The Statement of Work documents the drilling and well installation specifications.[a]

(a) Pacific Northwest Laboratory. 1986. "Statement of Work, Well Drilling, 600 Area Solid Waste Landfill." PNL-SOW.600SW, Pacific Northwest Laboratory, Richland, Washington.

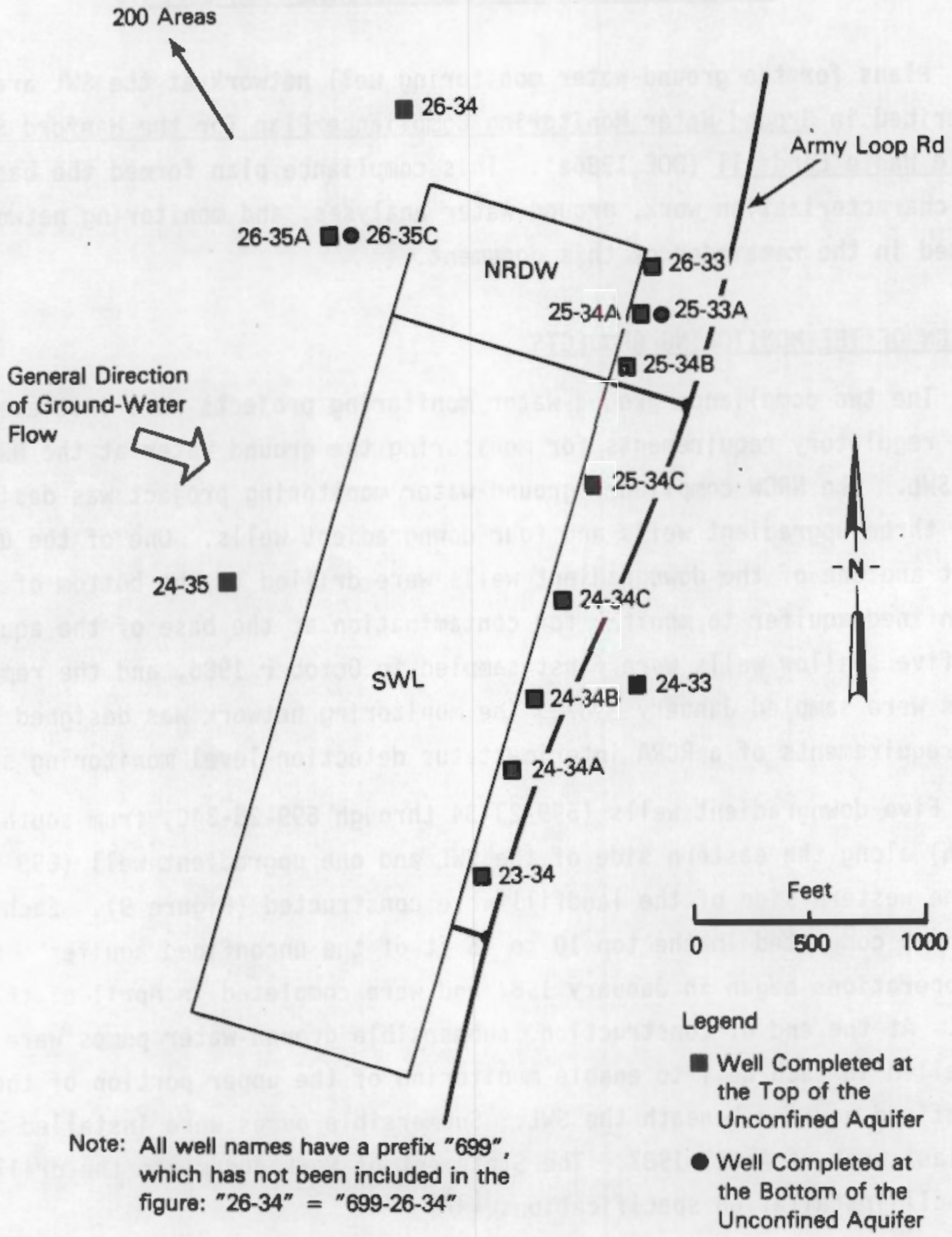

FIGURE 9. Ground-Water Monitoring Network at the Solid Waste Landfill, Nonradioactive Dangerous Waste Landfill, and Nearby Site Well, 699-24-33

The SWL compliance ground-water monitoring project was designed to provide detection-level monitoring. The wells were first sampled in May 1987. The constituent list for monitoring solid waste landfills is shorter than that for monitoring hazardous waste sites and originally did not include chlorinated hydrocarbons. However, during monitoring of hazardous materials for the entire Hanford Site, chlorinated hydrocarbons were detected in a nearby well downgradient from the SWL. This information was relayed to the SWL ground-water monitoring project manager and the SWL operation manager. Both managers agreed that adding chlorinated hydrocarbons to the SWL constituent list was necessary to determine if a possible source existed at the SWL.

The following section describes well installation and data collection techniques employed at the SWL.

WELL INSTALLATION

The six wells were assigned temporary numbers for use during drilling and installation. Permanent well numbers based on Hanford coordinates were assigned after the wells were completed and surveyed. Temporary well numbers used during construction are correlated below with permanently assigned well numbers.

Temporary Well Numbers	Permanent Well Numbers
SW-1	699-24-35
SW-2	699-23-34
SW-3	699-24-34A
SW-4	699-24-34B
SW-5	699-24-34C
SW-6	699-25-34C

WELL CONSTRUCTION

During the drilling operations, the objective was to drill 13 ft below the static water level and install 15 ft of 30-slot (0.03-in.) screen on top of a 3-ft-thick sand pack (10 ft of screen installed below static water and 5 ft above it). The purpose of the sand pack beneath and around the screened interval was to facilitate well development, which is necessary to provide a low sediment content in the water column. A water column of approximately 10 ft was considered adequate to accommodate the pump equipment and allow for changes in water table elevation. Because of the nearly flat topography of the SWL and the low water table gradient, all the wells were drilled to approximately the same depth (drilled depths ranged from 139 to 145.5 ft). An example of a typical SWL well is given in Figure 10. Appendix A contains well construction summaries for each of the six monitoring wells.

Aquifer tests were performed in two wells, 699-24-34A and 699-24-35, which required telescoping, 40-slot screen that fit just inside the 10-in.-dia casing. Otherwise, construction of these two wells was the same as that for the other four wells.

Some wells have a thicker sand fill below the screen than planned because the well was drilled past the target depth; this resulted when water level measurements were taken before the water reached its static level after drilling. Only 1 or 2 ft of additional sand fill was added to bring the bottom of the screen up to the proper level.

Drilling Methods

Monitoring wells installed at the SWL were drilled with Bucyrus Erie 22W™ cable-tool drilling rigs. Tools and machinery used in the construction of these wells were steam cleaned before arriving at the drill site and between boreholes. The tool lubricants used were Chevron Poly FM Grease™ (Food Grade) and mineral oil.

The drilling method used to initially advance the borehole involved drive (core) barreling. During the drilling from land surface to a depth of about 60 ft, unconsolidated sands were encountered, and the drilling rate was high. Beneath about 60 ft, gravel-rich layers were encountered, and the drilling rate slowed dramatically.

When drilling progress could no longer efficiently be made with the drive barrel, the wells were drilled by the "hard tool" method. The drive barrel method would not work because 1) the driller reached too great a depth to retain the sample in the drive barrel, 2) a lithologic change was

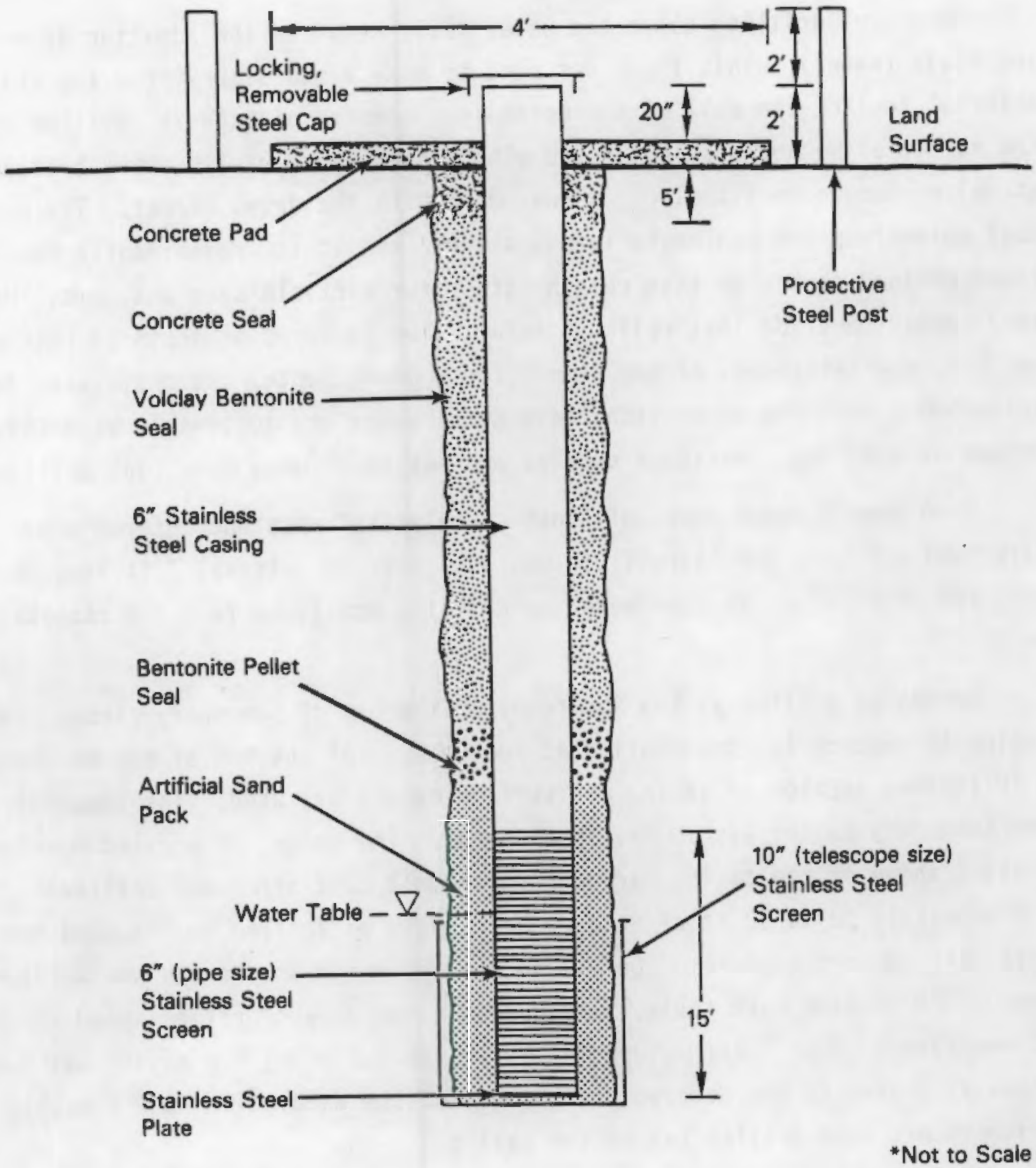

FIGURE 10. Example of a Solid Waste Landfill Shallow Monitoring Well

encountered that was too compact to penetrate or too coarse-grained to stay in the barrel, or 3) the sediments were too dry to stay in the drive barrel. The change to hard tools was made at depths between 75 to 110 ft for the six SWL wells, soon after intersecting a gravel subunit.

Hard-tool drilling above the water table required the addition of drilling fluid (water). This fluid was used to make a mud slurry from the drilled material to line the wall of the borehole. Samples of material drilled by the hard-tool method were collected with a dart valve bailer every 5 ft and at major changes in lithology, as was done with the drive barrel. The hard tool pulverizes the sediments into a slurry, and it is predominantly the finer-grained particles that remain intact for particle-size analysis. Hard-tool samples provide less reliable information in terms of depth of retrieval, representativeness of the sample for a given depth, and grain-size distribution. Only the major lithologic differences are noticeable with this method of drilling. Moisture samples are not taken when hard-tool drilling.

Even though large zones of "lost circulation" were encountered when hard-tool drilling (drilling fluid was lost over an interval 7 ft long in well 699-24-34A), at no time were any drilling additives (e.g., bentonite) used.

Boreholes drilled at the SWL required the use of temporary carbon steel casing to support the unconsolidated sediments. At the top of the borehole, a 10-ft-long section of 14-in.-dia surface casing was used. The remainder of the temporary casing was 10-in. in diameter. The amount of uncased borehole drilled ahead of the casing varied between well conditions and drillers. Approximately 30 to 50 ft of uncased hole could be drilled in the sand subunit with the drive barrel. Only 1 to 8 ft of uncased borehole was achieved when drilling with hard tools. The borehole was always drilled ahead of the casing except after intersecting the water table. Here, the casing was occasionally driven to the desired depth ahead of the excavation, and the plug of sediment was then drilled out of the casing.

The temporary casing was lengthened initially by adding 20-ft sections. As drilling rates slowed with depth, 10-ft-long sections were added. A drive shoe was milled on the outside of each casing to permit easier retrieval during well completion. Drive shoes were replaced only if cracked; three new shoes were required during construction of all wells.

DATA COLLECTION ASSOCIATED WITH WELL CONSTRUCTION

One of the major purposes of characterization work during installation of a ground-water monitoring well network is to collect data related to sediment interaction and transport capabilities that would be needed should contamination of the ground water be detected. Both saturated and unsaturated zones need to be characterized. At the SWL, samples were collected for geologic descriptions and laboratory determination of physical characteristics such as field moisture content, water retention characteristics, and grain-size distributions. Geophysical logging was performed on each borehole after completion as another source of data pertaining to the characteristics of the saturated and unsaturated zones. In addition, aquifer tests were performed at two wells after each was completed to obtain data related to aquifer characteristics. All field data and test results are reported in the appendices of this report.

Sampling Techniques During Drilling

All sediment samples were collected using either the drive barrel itself or a dart bailer, when using hard tools. Samples obtained using the drive barrel were more representative of the in situ sediments because they were kept relatively intact. Because the hard-tool method required the addition of drilling fluids and pounding of the material in the borehole, samples obtained during this phase of the drilling were much less representative of the in situ material. Because of the drilling methods and the unconsolidated nature of the sediments, structures and textures of the lithostratigraphic units (such as cross-bedding) could not be observed.

Samples were taken every 5 ft and at changes in lithology. The driller measured the depths of these samples by marking the cable as the drilling proceeded. Measurements to the nearest half-foot were recorded at sampling depths. During drilling, the driller would set aside sediment-filled buckets for the geologist to describe. The sediment classification terminology (after Folk 1968) (Figure 11) is consistent with the terms used at the NRDW. The SWL data are presented in a format similar to that used in the NRDW report by Weekes, Luttrell, and Fuchs (1987) to facilitate comparisons between data from the SWL and NRDW.

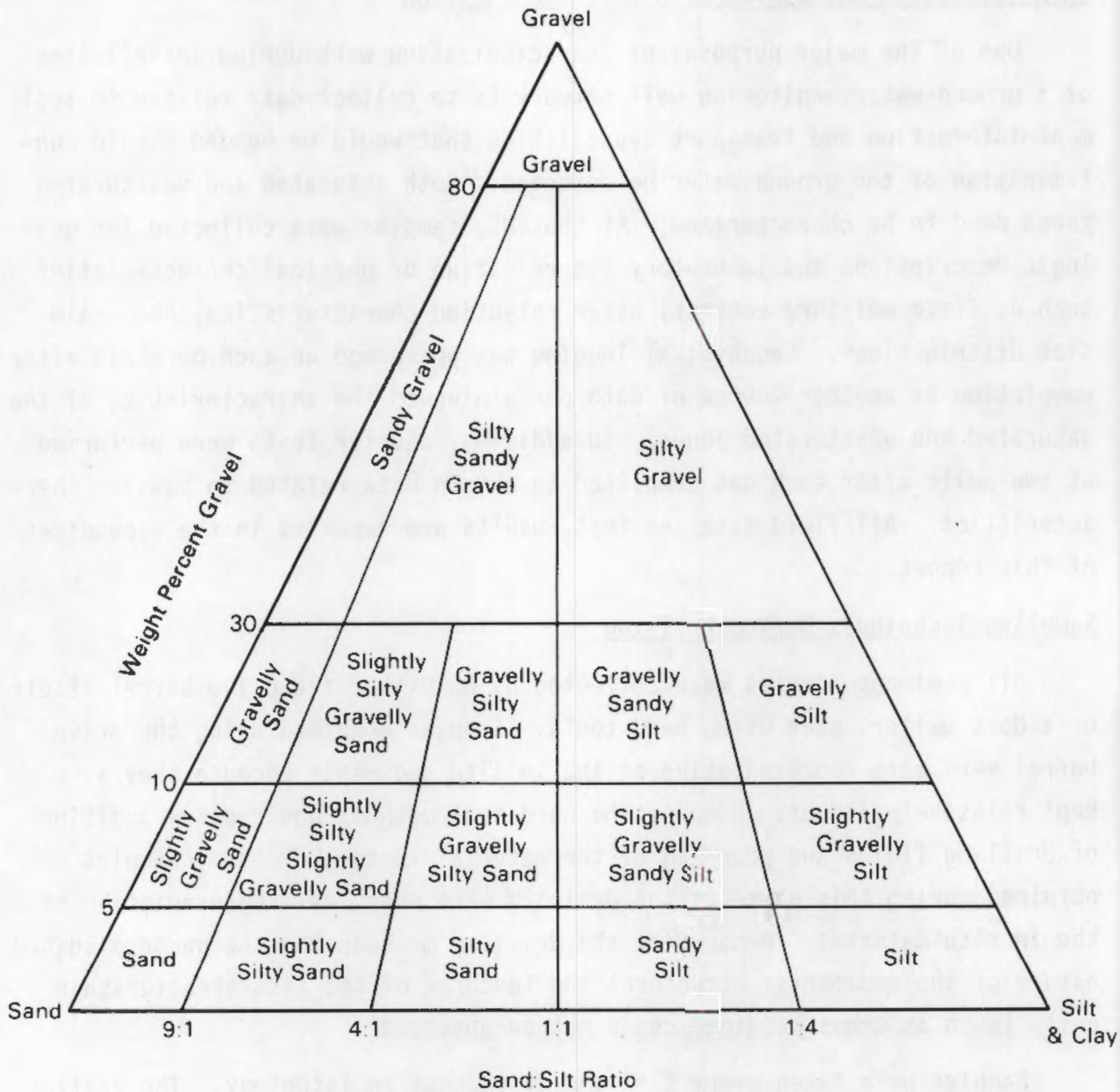

FIGURE 11. Sediment Classification Scheme (from Tallman et al. 1979)

Sample Types

One moisture and two sediment samples were removed from the bucket. The moisture sample was immediately taken from the bucket and sealed with tape in a prelabeled metal container, which was then wrapped in a plastic bag and also sealed with tape. These samples were delivered to PNL at the end of each day's shift and stored in a refrigerator until analyzed. Moisture samples were taken only when drilling with a drive barrel (because no fluids are added by this technique) and are important in determining the in situ water content at the sampled depth. Moisture samples could not be recovered when hard-tool drilling either because of the added water or because the samples were from below the water table. In addition to the moisture sample, two sediment samples were collected from each sampled interval. Sediment samples were placed into two labeled pint glass jars. One of the samples is archived in a drill cuttings warehouse (Hanford Geotechnical Sample Facility) on the Hanford Site. The second sediment sample was sent to PNL for further sediment and size analyses. The remainder of the sample in the bucket was used to describe the drilled interval.

Geophysical Data Collection Techniques

Geophysical logging was done and the natural gamma logs are included in Appendix B, along with the construction diagram and lithologic diagram for each SWL well and drill hole. The natural gamma probe contains only a detector and measures the natural radiation emitted by the sediments. The logs are uncalibrated, and therefore cannot be correlated between boreholes. At best they may provide information about each individual borehole. The natural gamma logs were not used for any interpretation, but are included for completeness.

Straightness Test

After the well was geophysically logged, a straightness test was performed. This test was accomplished by passing a section of clean pipe 20 ft long with a diameter of 8 in. through the entire length of the temporary casing in the drill hole. The depth reached by the straightness test pipe was determined by measuring the length of the wetted exterior on the pipe after it was retrieved (i.e., 13 ft or more of water needed to be present on the pipe if it touched bottom). All the wells passed this test successfully. Deviation of the borehole from vertical was avoided as much as possible by periodically using the hard tool as a plumb bob during drilling.

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GEOLOGY OF THE SOLID WASTE LANDFILL

This section describes the surface morphology, local structural geologic setting, and subsurface stratigraphy encountered in the vicinity of the SWL.

LOCAL GEOMORPHOLOGY

The area surrounding the SWL and NRDW is relatively flat with small ridges of stabilized dune sand that trend generally east-west. The relief on these ridges is approximately 5 to 25 ft. Inspection of aerial photography indicates that this dune sand belongs to the sparse east-west trending dune field found in the center of the Hanford Site. The dune sand is currently stabilized by vegetation typical to the Hanford Site, which includes deep-rooted perennial vegetation and shallow-rooted annuals. Active sand dunes exist within a mile both east and west of the landfill. The interaction between climate, rangefires, and human activity (such as removal of natural vegetation for operation of the SWL) all affect the biological system, which effects the ecology of the area in turn. Thus, stabilized dune sand may lose its vegetation and become active sand dunes, and vice versa.

Wind directions from the southwest prevail in this area, although strong winds came from many different directions (predominantly northeast and northwest) during the drilling of wells at the SWL (winter and early spring). Although previous observations and studies about the site were available before drilling, more site-specific information was gained during drilling of the SWL wells. Data from the available sources are presented below.

LOCAL STRUCTURAL GEOLOGY

The SWL and NRDW lie northeast of the axis of the Cold Creek syncline on the southwest flank of the Wye Barricade Depression (Figure 12). The Cold Creek syncline (Figure 6) is a major northwest-southeast trending structure. The top of the basalt dips approximately 90 ft/mi to the southwest beneath the SWL. The estimate of dip is taken from a structural contour map based on drilling done in 1980 and 1981 for Puget Sound Power and Light (PSPL) east of the landfill (PSPL 1982). Depth to the top of the basalt is estimated to be

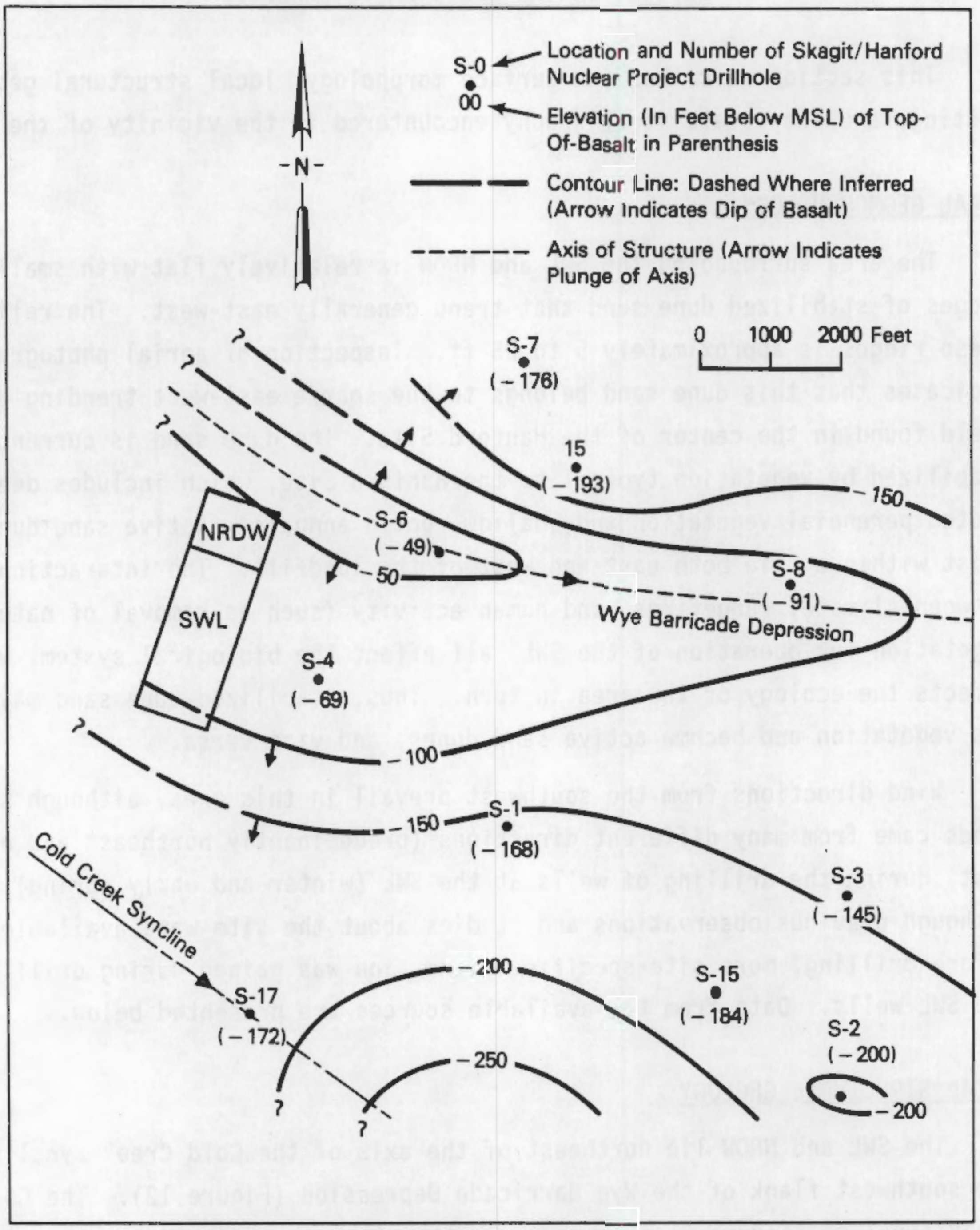


FIGURE 12. Topography of the Top of Basalt Underlying the General Area of the Solid Waste Landfill (modified after PSPL 1981)

between 578 and 586 ft below the ground surface. The basalt marks the top of confined aquifers on the Hanford Site and marks the base of the regional unconfined aquifer.

LOCAL STRATIGRAPHY

Holocene sediments overlying the Hanford formation near the SWL consist of both active sand dunes and stabilized dune sand. Other than surface eolian deposits, the sediments encountered during well construction at the SWL belong to the Pasco Gravels unit of the Hanford formation. Figure 13 summarizes the geologic column of the Pasco Basin. Generalized geologic

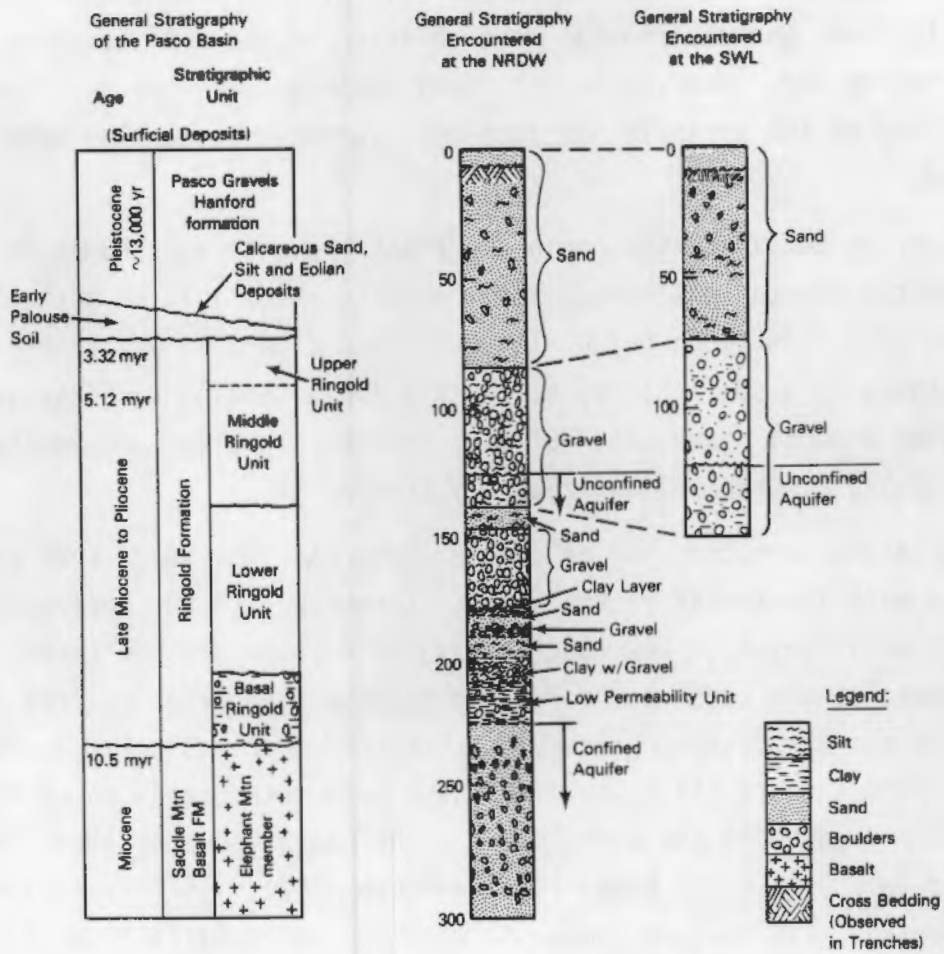


FIGURE 13. General Stratigraphy of the Pasco Basin Compared with the Stratigraphy at the Nonradioactive Dangerous Waste Landfill and the Solid Waste Landfill (from DOE 1986)

columns for the SWL and NRDW are also compared in this figure. Vertical changes in lithologies (on the scale of a few feet) were observed during drilling at the SWL. Most of these small-scale changes are probably localized and may not extend horizontally very far from the individual drill sites. The catastrophic glacial flood processes that deposited these sands and gravels are responsible for the large amount of variability in sediment distribution near the SWL and across the entire Hanford Site.

Stratigraphy Observed in Solid Waste Landfill Trenches

Trench excavations during landfill operations expose sections of the soil column that extend 15 to 20 ft beneath the land surface (Figure 5). Several of these trench sections, which displayed in situ bedding and sedimentary textures and structures, were observed in Phase II sections (Figure 14) before they received trash. Such features were not described during the drilling of the boreholes because undisturbed core samples were not collected.

The cross sections exposed in the trash trenches were composed primarily of horizontal strata that ranged from "massive" beds 1 ft or more thick to sequences of narrow (inch-thick) layers. Graded bedding was observed in a few locations on a small (inch) scale, and cross-bedding was observed at the top of some layered sequences. Glacial pebbles, cobbles, and boulders were also typically distributed horizontally (Figure 14).

The strata were composed of coarser grey basaltic sands that appeared to alternate with finer-grained tan silts. Exceptions to the horizontal bedding included small lenses (a few feet across) of coarser-grained sands, pebbles, and cobbles; random large boulders; and dikes of tan, fine-grained silts, containing coarser basaltic sands, that occurred perpendicular to the horizontal strata (Figure 15). The dikes have been interpreted to be routes by which water escaped to the surface after the water-laden sediments had been deposited (e.g., Last and Fecht 1986; Newcomb 1962). In this scenario, the upward-moving water dragged sediments with it, which solidified into clastic dikes. Black (1979) among others, proposes the opposite origin: water and sediment entered from above during and after the glacial flooding.

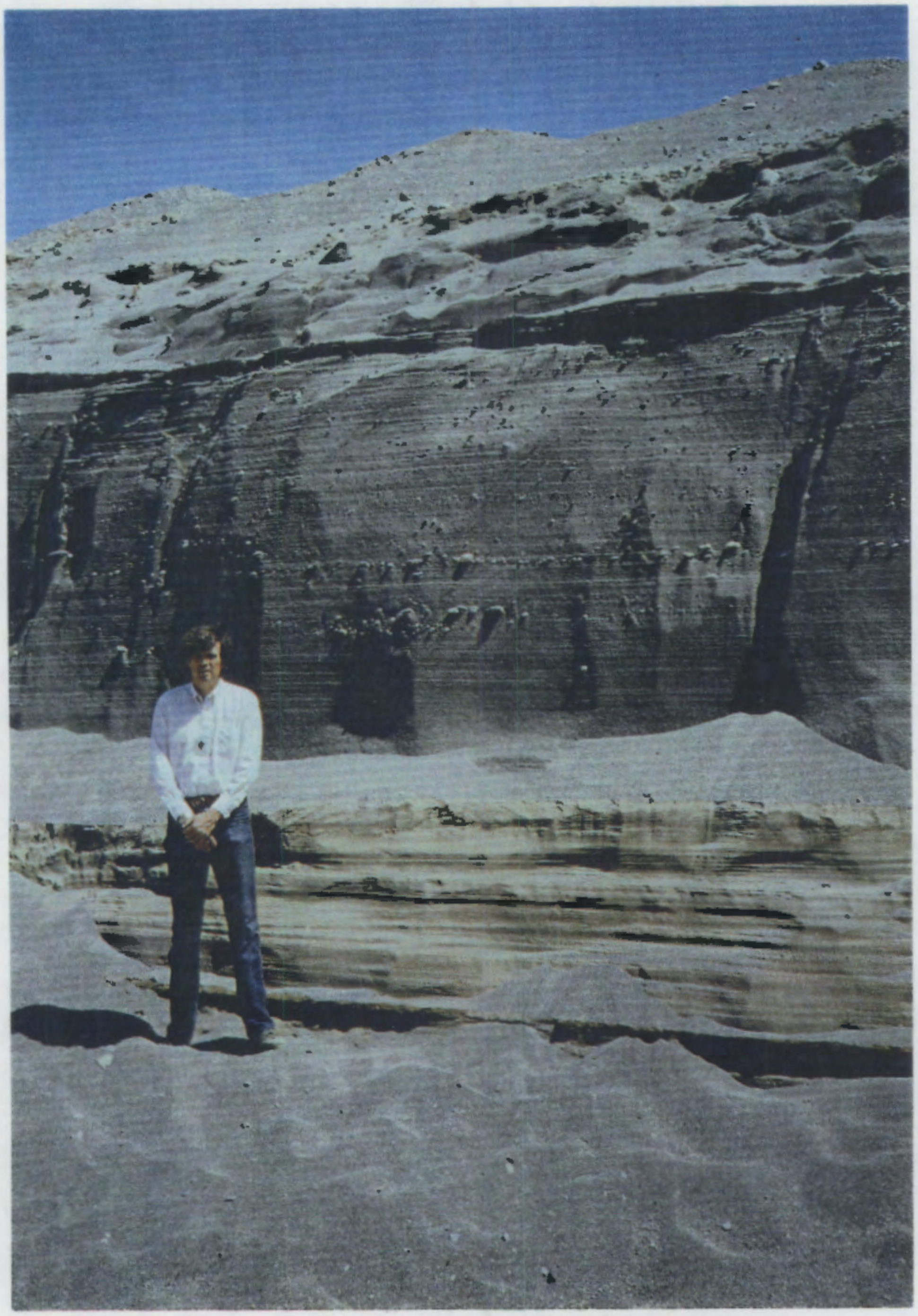


FIGURE 14. Exposed Layers in Excavated Trench. The bottom of the trench where the man (6 ft tall) is standing is about 18 to 20 ft beneath the land surface. Wind erosion subsequent to trench excavation has high-lighted the layering by causing the most resistant materials to stand out.

FIGURE [illegible]. Exposed layers in excavated trench. The bottom of the trench where the man (6 ft tall) is standing, is about 18 to 20 feet below the land surface. Wind erosion subsequent to trench excavation has highlighted the layering by causing the most resistant materials to stand out.

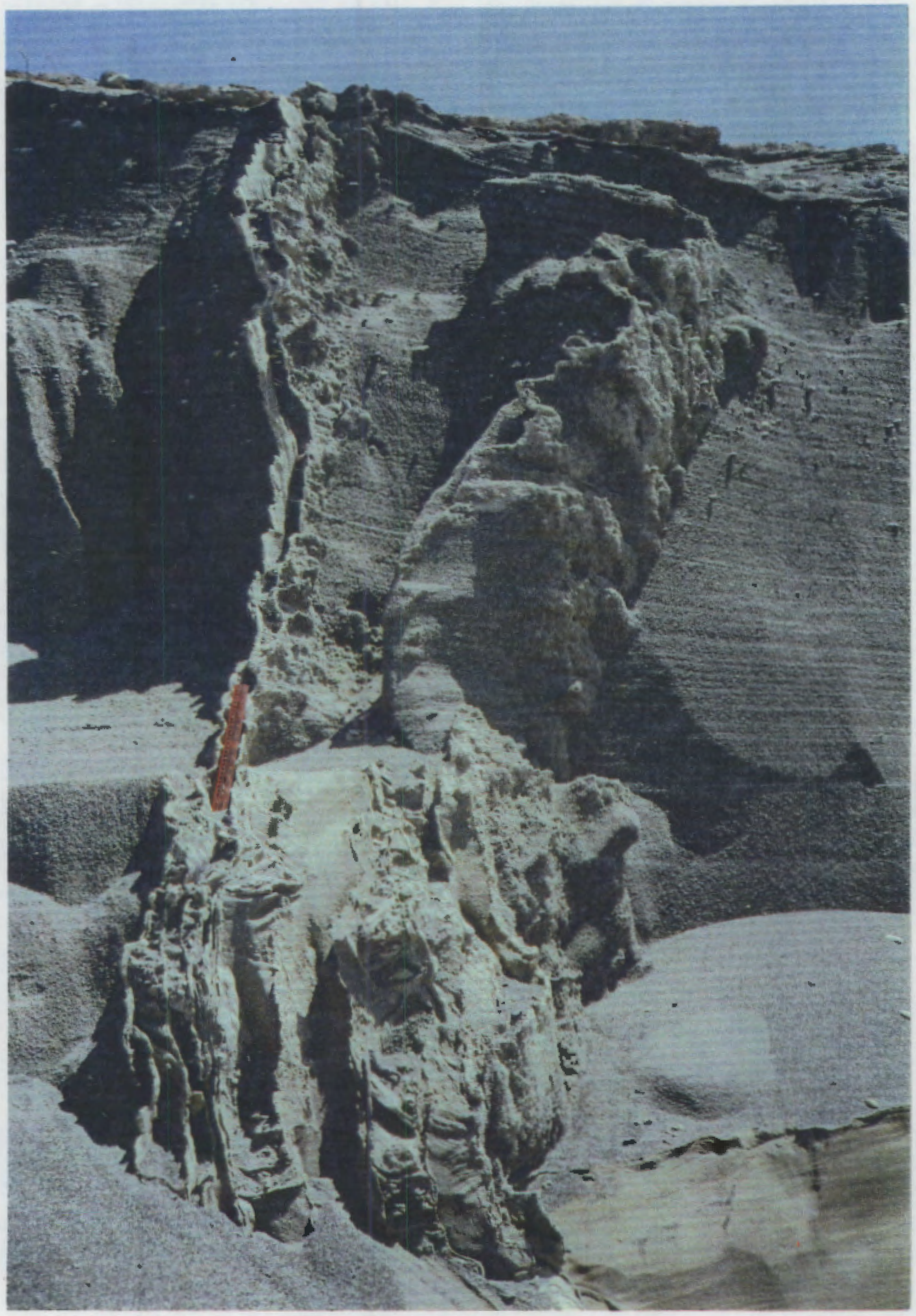


FIGURE 15. Clastic Dike of Silt Cutting Through Horizontal Layering

In the top 15 to 20 ft of the Phase II trenches studied, the following sequence was observed, beginning at the surface: 1) approximately 2 to 3 ft of recent dune sand material; 2) a tan silt containing moisture, 2 to 6 in. thick; 3) approximately 5 to 6 ft of basaltic sand and rounded gravels;

Figure 16. Clastic dike [illegible] cutting horizontal [illegible]

In the top 15 to 20 ft of the Phase II trenches studied, the following sequence was observed, beginning at the surface: 1) approximately 2 to 3 ft of [illegible] sand material; 2) [illegible] silt containing moisture 2 to 6 in. thick; 3) approximately 5 to 6 ft of [illegible] sand and rounded gravel; [illegible]

4) about 1 to 2 ft of tan silt containing moisture; 5) about 1 to 2 ft of basaltic sand; 6) gravel lenses; and 7) another tan, silty layer.

Personnel familiar with the SWL provided the following observations. A near-surface silt layer may extend across the entire area of the SWL along with an underlying basaltic sandy layer. Another lower silty layer may also be continuous across the entire landfill. The third silt layer described in the preceding paragraph has only been encountered in the Phase II area of the landfill, and no continuous gravel layers have been encountered in the top 20 ft of landfill excavations.

Stratigraphy Observed During Drilling

The water table occurs at about 404 ft above MSL (about 126 ft beneath the surface) at the SWL, and this marks the top of the unconfined aquifer. All of the SWL wells and five of the NRDW wells were completed in the top 15 ft of this aquifer. The average borehole depth at the SWL is 142 ft beneath the land surface (390 ft above MSL). Five deeper boreholes were drilled at the NRDW, which included two deep ground-water monitoring wells: an upgradient well drilled to 211 ft below land surface (319 ft above MSL) and a downgradient well drilled to a depth of 255 ft (271 ft above MSL). In addition, three boreholes for observation during aquifer testing were drilled at the NRDW and ranged in depth from 230 to 240 ft beneath the land surface (290 to 300 ft above MSL).

Two major sediment types were encountered during drilling at the SWL: a sand and an underlying gravel, both of which were interpreted to be subunits of the Hanford formation. The sand subunit contact with the underlying gravel subunit was gradational and ranged from 68 to 105 ft beneath the land surface (462 to 431 ft above MSL). The gravel subunit extended beyond the drilled depths at all of the SWL wells. Drilling at the NRDW penetrated much deeper and encountered gravels of the Hanford formation to a depth of about 193 ft below land surface (343 ft above MSL) (Weekes, Luttrell, and Fuchs 1987). Below that level at the NRDW, the Hanford formation is immediately underlain by the upper Ringold Formation of late Miocene to early Pliocene age (Weekes, Luttrell, and Fuchs 1987). Figure 9 shows the well locations, relative depths, and cross section locations for the SWL and NRDW.

Sediment classification terminology used in this report is after Folk (1968) and is defined in Figure 11. The terminology is the same used for geologic sample description in the NRDW report (Weekes, Luttrell, and Fuchs 1987), and its use at the SWL will facilitate comparisons of results reported for both the SWL and NRDW. Stratigraphic columns with sediment descriptions for each borehole are correlated in Appendix B with sediment analyses data from selected intervals. Appendix C presents the sediment analyses data that include, for selected samples, grain-size distributions, field moisture content, water retention studies, and hydraulic conductivities.

A detailed description of the stratigraphic units follows. Please note that the sand and gravel subunits, and the lithologies described within the sand and gravel subunits, are all informal divisions.

Holocene Dune Sand

Both active sand dunes and stabilized dune sand overlie the sands and gravels of the Hanford formation in the vicinity of the SWL. Observations of aerial photography suggest that these dunes belong to the dune field found in the center of the Hanford Site. Prevailing wind directions are from the southwest in this area. Some dunes are active and in the process of migrating from west to east across the landfill, but most have become stabilized by vegetation. The sand dunes range from 0 to 12 ft in height and consist of very fine to medium-sized sands. Dune sand is composed of 80% quartz. The quartz sand grains are frosted and pale olive to olive in color. Places where dune sand was not intersected during drilling may indicate that it was either not present or was removed during drill pad construction. Contact between the eolian sands and the Hanford formation sand subunit was narrow and sharp both in open SWL trash trenches and in several core barrel samples.

Hanford Formation

At the SWL, the Hanford formation is represented by an upper sand subunit and a lower gravel subunit of the Pasco Gravels facies. The "upper sand" and "lower gravel" subunits are names used for this report and do not represent formal geologic nomenclature at the Hanford Site.

Sand Subunit. The sand subunit is bounded by the overlying Holocene dune sands and by the first appearance of the underlying gravels. The sand subunit consists of sand, slightly gravelly sand, gravelly sand, slightly silty sand, silty sand, and gravelly silty sand. Generally, the percentage of gravel clasts increases downward in the sand subunit. However, this increase is erratic and may be reversed with depth locally. The distribution of gravel clasts within the sand subunit indicates discontinuous layers and lenses throughout all of the boreholes. The thickness of the sand subunit ranges from 65 to 97 ft, with an average thickness of 77 ft for the six wells drilled. Sand interlayered with gravels in well 699-25-34C is considered to belong to the gravel subunit; hence, it is not included in the sand subunit thickness.

Individual sand layers within the sand subunit cannot be correlated between boreholes (see Appendices A and B). Large variability in silt and gravel content is evidenced throughout the subunit; silt and gravel layers pinch out completely between wells (Figures 16 and 17). Although silt-bearing layers are common throughout the SWL, these silt layers were only found within the sand subunit. Their lateral extent is discontinuous and they can rarely be correlated between boreholes. This is in contrast with observations of the trash trenches.

The sands of this subunit are composed of basalt and quartz sands with varying proportions of basalt fragments, rock fragments (excluding quartz and basalt, predominantly quartzite), and quartz grains. Sample descriptions show that the sand subunit can be compositionally divided into basaltic sands (≥60 vol% basalt, <30 vol% quartz and rock fragments), quartzose sands (<30 vol% basalt and rock fragments, ≥60 vol% quartz), and mixed sands (40-50 vol% each of basalt and quartz). Rock fragments, not quartz or basalt, typically constituted between 10 to 20 vol% of the sample described. Because these percentages were determined qualitatively in the field, there may be appreciable error. Therefore, this is only a first approximation of sand compositions. Sands with 60 to 90% basalt were dark gray to black to olive-brown in color; sands with 10 to 40% basalt were olive-yellow to light yellow-brown to dark gray-brown; and the mixed sands were light brownish-gray to dark yellow-brown to very dark grayish-brown.

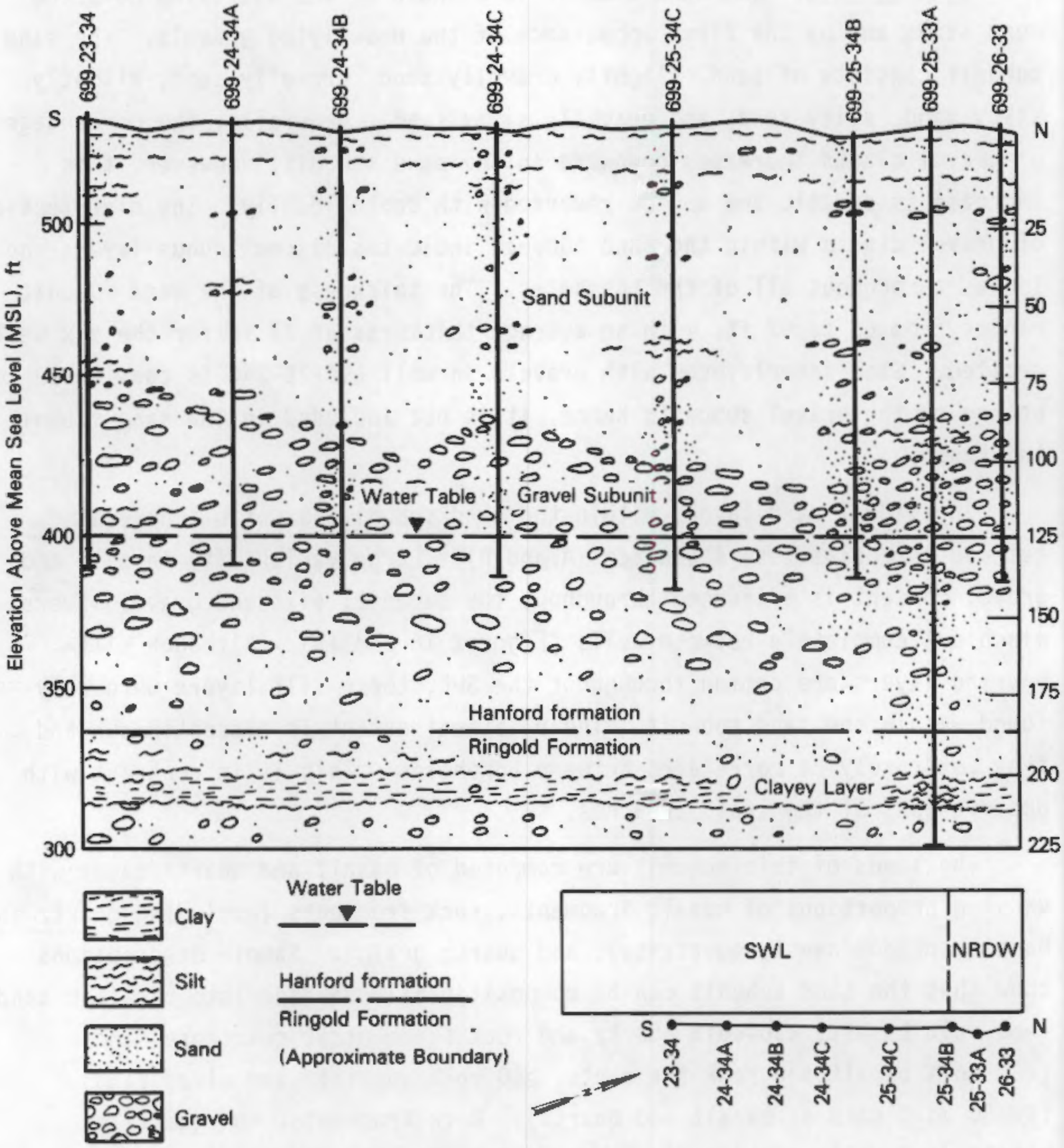


FIGURE 16. Cross Section Based on Wells Along the East Side of the Solid Waste and Nonradioactive Dangerous Waste Landfills, North-South Line (Total length of the SWL and NRDW is 3440 ft. Vertical exaggeration is approximately 2x.)

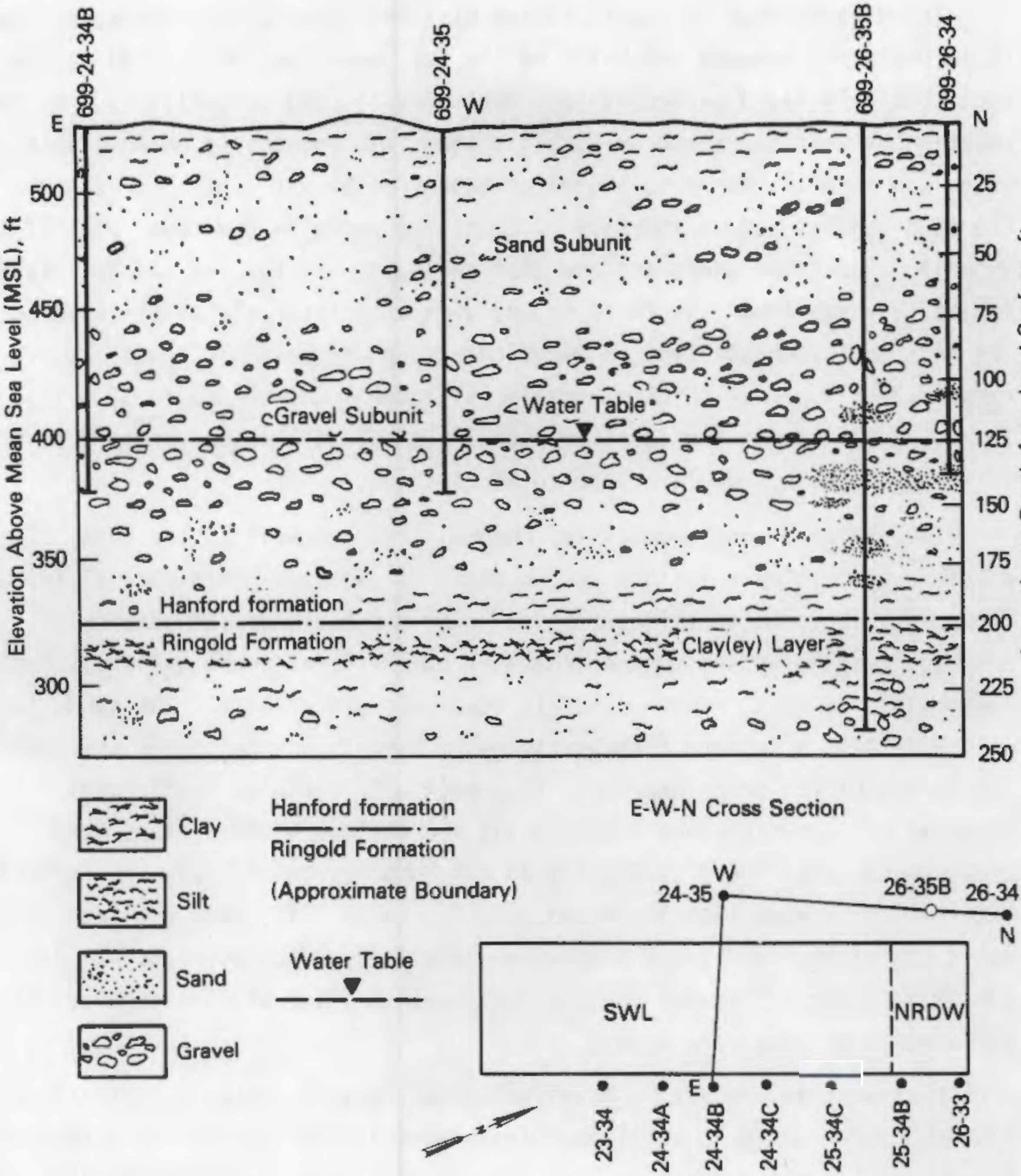


FIGURE 17. Cross Section Based on Wells in an East-West Line (Well 26-35B is not part of the monitoring network. Width across the landfill is 965 ft. Vertical exaggeration is approximately 2x.)

The distribution of quartzose and basaltic sands within the sand subunit is inconsistent between boreholes in the SWL, which may be related to the fact that only field determinations were made of sand compositions. No correlation between quartzose or basaltic sands was recognized between each well. In general, there is a greater amount of basalt sands near the top of the sand subunit and an increase in quartzose sands in the lower part of the subunit. Quartzose sands are the most abundant sand type at the SWL; layers typically range from 2 to 25 ft thick, with some intervals as thick as 50 ft. The next most abundant type is mixed quartzose and basaltic sands; layers range from 5 to 20 ft thick typically, although some were up to 52.5 ft thick. Basalt sands are least abundant; typical thicknesses range from 2 to 15 ft thick, with some layers up to 30 ft thick.

The dominant sand composition changes from one well to the next. It is possible to make correlations on the basis of sediment grain-size distributions, but it is more difficult to do so on the basis of composition. Although quartzose sands may dominate in one well, adjacent wells may contain more basalt or mixed sands or nearly equal amounts of both. The sands in well 699-24-35 alternate from quartzose to basaltic compositions throughout the length of the sand interval. This well also contains the largest interval of basaltic sands found in all the wells; no mixed sands were encountered. Wells 699-23-34, 699-24-34A, and 699-24-34B have the largest intervals of compositionally mixed sand (up to 52.5 ft), and the former two wells contain a significant proportion of mixed sands. Wells 699-24-34B, 699-24-34C, and 699-25-34C contain the greatest intervals (up to 50 ft thick) and amounts of quartzose sands.

Most sand layers are unconsolidated and react slightly or not at all to hydrogen chloride (HCl) solution. Those sand layers that are more consolidated have a greater reaction to a 10% solution of HCl, indicating they are cemented by calcium carbonate. Thin, weakly consolidated layers, which reacted to HCl, occurred within unconsolidated sand layers. There were no correlatable calcium carbonate layers between boreholes. Strong reactions were observed on all partly consolidated silt-bearing sand layers.

The distribution of calcium carbonate cement in the unconsolidated sand layers is highly variable. Many of the samples from the sand subunit contain small (≤1-in.) clumps of calcium carbonate-cemented sands that react moderately strongly to HCl. Some of these clumps of moderately cemented sands occur around roots of plants. These generally occur in the upper 20 ft of the sand subunit.

The irregularity in calcium carbonate distribution at the NRDW has been attributed to calcitic clastic dikes observed in trenches (Weekes, Luttrell, and Fuchs 1987). Clastic dikes were also observed in excavated trenches at the SWL. Similar features may be responsible for some of the calcitic cementation in the drill samples. Caliche coatings on gravel clasts in the sand subunit are most abundant within 5 to 20 ft of the surface. These coatings are thin and are found on one side of the gravel clasts.

Overall in the sand subunit, gravel content ranges from 0 to 25% of sample volume. [Appendix C presents grain-size data based on the Phi grain-size scale described in Folk (1968) for selected intervals and correlates it with stratigraphic units.] However, the two most abundant sand types encountered within the sand subunit are sand containing 0 to 5 vol% gravel and gravelly sands containing 10 to 25 vol% gravel. The gravel clasts are composed of a wide variety of lithologies. The most abundant compositions are basaltic, granitic, gneissic, quartzitic, and other assorted metavolcanic and metamorphic clasts. Clasts of basaltic compositions are by far the most abundant. Clasts range from rounded to subangular but most are rounded to subrounded on unbroken surfaces.

In contrast with the abrupt dune sand/Hanford formation contact, there is a gradational contact between the sand and gravel subunits within the Pasco Gravels facies. The sand subunit coarsens to gravelly sand at depths ranging from 40 to 87 ft beneath the land surface (492 to 444 ft above MSL). The gravelly sand ranges in thickness from 3 to 30 ft and forms the gradational layer between the two subunits. The appearance of coarse gravel clasts in the gravelly sand usually occurred where the driller changed from drive-barrel to the hard-tool drilling technique, and together often established the lower boundary of the sand subunit. The boundary between the sand and gravel subunits ranged from 68 to 105 ft beneath the land surface (462 to 431 ft above MSL).

Gravel Subunit. The gravel subunit of the Pasco Gravels is conformable with the overlying sand subunit. On the east side of the SWL, the top of the gravel subunit ranges from approximately 70 ft below the land surface (462 ft above MSL) near the southeast end (well 699-23-34) to approximately 90 ft below the surface (441 ft above MSL) at the northeast end (well 699-25-34C). The contact is somewhat lower on the west side of the SWL (well 699-24-35), being 105 ft beneath the land surface (431 ft above MSL). The lower boundary of the gravel subunit was not intersected by drilling at the SWL, but drilling at the NRDW indicates that the gravel subunit extends downward to the contact between the Hanford formation and the upper Ringold Formation at approximately 340 ft above MSL (Weekes, Luttrell, and Fuchs 1987).

Only two wells, 699-23-34 and 699-24-34A, penetrated the gravel subunit using the drive-barrel drilling method. Drilling at the other wells changed over to hard tools at or above the sand-gravel contact. Drilling rates decreased sharply across the sand-gravel contact, whether drilling with drive barrel or hard tools. Typical drill rates ranged from 10 to 60 ft/h in the sand subunit and from 1 to 3 ft/h in the gravel subunit. Consolidated gravel was rarely encountered at the SWL, but where it was found, the drive barrel was used. The material associated with cementation was calcium carbonate. None of the gravel clasts were cemented enough to survive disaggregation during hard-tool drilling.

Gravel clasts observed in the gravel subunit are similar to those sampled in the sand subunit. However, the gravel in the sand subunit contains a slightly greater percentage of basalt clasts and perhaps a greater percentage of cobbles. Basaltic clasts are the most abundant variety, with quartzite and granitic clasts the next most abundant. Seldom is there more than a 10% variance between the percentage of basalt clasts over a 5-ft interval. Although there is a decrease in the percentage of basalt gravel clasts near the bottom of most boreholes at the SWL, data from NRDW boreholes show that this decrease does not appear to indicate that the upper Ringold Formation was intersected (Weekes, Luttrell, and Fuchs 1987). The gravel content in the gravel subunit ranges from 30 to 80% of sample volume. The percentage of gravel clasts is fairly constant in the gravel subunit, with variances of 10 to 30% gravel observed between 5-ft sample intervals. Gravel clasts range from very fine pebbles to small cobbles; most clasts are medium to very coarse pebbles, but drilling with hard tools makes particle-size analyses of coarser materials somewhat unreliable. Gravel clasts are typically rounded to subrounded, but occasionally a subangular clast was observed. The appearance of worn surfaces was the only indicator of original clast size.

Layers of gravel (i.e., ≥80 vol% gravel) appear to be discontinuously distributed under the SWL. Figure 16 shows several gravel lenses within predominantly sandy gravel, the largest of which extends across wells 699-24-34A, 699-24-34B, and 699-24-34C.

Narrow zones of highly permeable material (relatively unconsolidated sands and gravels) were encountered in the gravel subunit. These zones provided an avenue of "escape" for the drilling fluids (water) away from the well bore. These zones also prevented the production of viscous drilling mud, thereby decreasing the drilling rate. Unrepresentative samples were obtained from these zones that contained a predominantly sand-sized fraction. The coarser materials were not sampled because they could not be entrained in the drilling mud. One 7-ft-long interval was not sampled in well 699-24-34A because drilling mud could not be generated.

COMPARISON OF SOLID WASTE LANDFILL AND NONRADIOACTIVE DANGEROUS WASTE LANDFILL STRATIGRAPHY

Based on characterization work performed during drilling at the SWL, the two major lithostratigraphic units of the Hanford formation, the sand subunit and the underlying gravel subunit, can be correlated across the SWL and NRDW (Figure 13). However, the division of the Hanford formation into two subunits at the SWL differs from that at the NRDW (Weekes, Luttrell, and Fuchs 1987) where the Hanford formation is divided into four subunits: upper sand, upper gravel, lower sand, and lower gravel.

On the eastern side of the SWL, the northernmost SWL well (699-25-34C) nearest to the NRDW does intersect two gravelly sand layers within the gravel subunit. From 95 to 105 ft beneath the land surface (438 to 428 ft above MSL), the sand is a mixture of basalt and quartz in the upper 5 ft, and basaltic sand in the lower 5 ft; quartzose sand occurs from 115 to 130 ft beneath the land surface (418 to 403 ft above MSL). These sand layers within the SWL's lower gravel subunit appear to pinch out to the southwest; they are not observed at other SWL well locations.

At the NRDW, the upper sand unit is approximately 63 ft thick, basaltic in composition, with thin, discontinuous silt layers, variable calcium carbonate contents, thin gravelly zones, and an increase in gravel content toward the bottom of this subunit (Weekes, Luttrell, and Fuchs 1987). The upper sand subunit at the NRDW appears to correlate with the upper sand subunit at the SWL. The upper gravel subunit at the NRDW was typically encountered at about the 80-to-90-ft depth (450 to 440 ft above MSL) and was observed to contain highly variable gravel contents of predominantly basaltic composition, followed by quartzite and granitic compositions. This "upper gravel" subunit described by Weekes, Luttrell, and Fuchs (1987) correlates with the gravel subunit observed at SWL well locations.

At all of the NRDW well locations, a lower sand subunit 3.5 to 16 ft thick was encountered at about 400 ft above MSL, ranging from 405 ft above MSL on the west side of the NRDW to 387 ft above MSL on the east side of the NRDW (Weekes, Luttrell, and Fuchs 1987). It is distinguishable from the gravel subunits above and below it by a finer grain-size distribution and a basaltic composition (Weekes, Luttrell, and Fuchs 1987). This fine-grained basaltic sand subunit may correlate with the basaltic sand layer found at only one well location (699-25-34C) at the SWL, located closest to the NRDW on the east side.

The lower gravel subunit encountered beneath the lower sand subunit at the NRDW is similar to the upper gravel subunit; there are no significant differences between the upper and lower gravels (Weekes, Luttrell, and Fuchs 1987). The thickness of the lower gravel subunit observed at the NRDW ranged from 30 to 47 ft. Based on NRDW characterization work, the lower gravel subunit of the Hanford formation ends at about 340 ft above MSL, where it is underlain by two units of the Ringold Formation to a depth of 271 ft above MSL (255 ft beneath land surface), deeper than the deepest borehole drilled at either the NRDW or SWL.

The two units of the Ringold Formation described in Weekes, Luttrell, and Fuchs (1987) include the upper Ringold, a fine-grained unit that was informally divided into three subunits; and the middle Ringold, a coarse gravelly unit, encountered at about 310 ft above MSL on the west side of the landfill and 307 ft above MSL on the east side of the landfill. The upper Ringold unit at the NRDW was found to contain a hard clayey silt layer 2 to 12 ft thick, which was a low-permeability unit, hydrologically, and defined the lower boundary of the unconfined aquifer at the NRDW (Weekes, Luttrell, and Fuchs 1987) at approximately 325 ft above MSL. Detailed stratigraphic data on units beneath those encountered at the SWL can be found in Weekes, Luttrell, and Fuchs (1987).

In general, the two major units at the SWL appear to correlate with units described at the NRDW: the upper SWL sand subunit with the upper NRDW sand subunit, and the SWL gravel subunit with the upper NRDW gravel subunit. In addition, within the SWL gravel subunit, the basaltic sand layer described in SWL well 699-25-34C may correlate with the lower basaltic sand subunit described in all NRDW wells. Based on trench observations, two silt layers in the upper sand subunit apparently correlate across both the SWL and NRDW. The narrow thickness of these silt layers, generally on the order of inches, accounts for their oversight during drilling operations because samples were only collected at 5-ft intervals.

Weekes et al. (1987) present a much more complete picture of the stratigraphy in the vicinity of the SWL and NRDW because, in addition to five shallow-depth wells (only slightly below the water table), there were five deeper wells drilled over 200 ft beneath land surface at the NRDW. The reader is referred to that report for a more complete description of the local stratigraphy.

HYDROLOGY OF THE SOLID WASTE LANDFILL

Hydrologic studies at the SWL and vicinity (e.g., Heller, Gee, and Myers 1984; Weekes, Luttrell, and Fuchs 1987) provide local information on the unconfined aquifer. Weekes, Luttrell, and Fuchs (1987) reported the depth to ground water at the NRDW to be about 125 ft. The water table in the vicinity of the SWL has risen approximately 10 ft over the last two decades because of Hanford operations in the 200 Areas. Figure 18 shows the changes in water level elevation through time for well 699-24-33, which is approximately 500 ft east of the SWL.

PREVIOUS STUDIES

Weekes, Luttrell, and Fuchs (1987) used several different techniques to determine the flow direction beneath the NRDW, but the magnitude of the hydraulic gradient was found to be on the order of 0.1 ft per 1300 ft or 0.0001, too low to define the flow direction any more specifically than generally west to east.

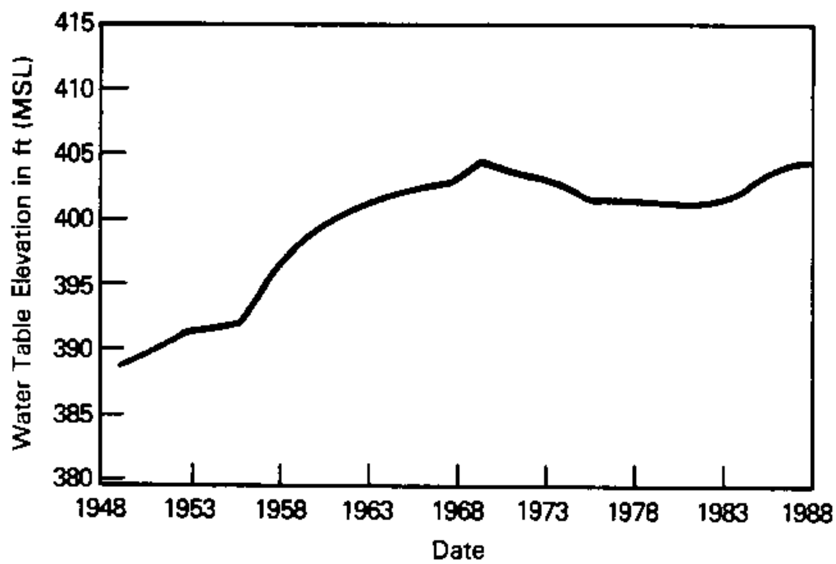


FIGURE 18. Water Level Measurements for Well 699-24-33 Through Time

Beneath the SWL and NRDW approximately the lower 50 to 70 ft of the Hanford formation is saturated, and the entire thickness of the Ringold is saturated (Weekes, Luttrell, and Fuchs 1987). Typically, on the Hanford Site the base of the unconfined aquifer is bedrock, which is the top of the Saddle Mountain Basalt (Weekes, Luttrell, and Fuchs 1987).

Representative hydraulic properties of the unconfined aquifer in the Pasco Basin, taken from Gephart et al. (1979), are given in Table 2. Work at the NRDW by Weekes, Luttrell, and Fuchs (1987) indicated that transmissivity values range from 100,000 to 300,000 ft^2/d, and hydraulic conductivity values range from 1700 to 5000 ft/d, based on a saturated thickness of 60 ft for the Hanford formation. This saturated thickness is an average based on borehole samples collected during NRDW drilling. Beneath the 50 to 70 ft of saturated Hanford formation, the sediments are finer-grained with more silt and clay, which are interpreted as the Ringold Formation (Weekes, Luttrell, and Fuchs 1987). These values are in good agreement with previous studies of nearby well 699-24-33 by Bierschenk (1959), who reported an aquifer transmissivity of 390,000 ft^2/d. Based on their studies, Weekes, Luttrell, and Fuchs (1987) calculated a ground-water velocity of 2 to 5 ft/d.

RECENT HYDROLOGIC STUDIES AT THE SOLID WASTE LANDFILL

The primary purpose of the hydrologic characterization at the SWL was to determine the direction and rate of ground-water movement beneath the site. These aquifer characteristics would be needed to determine the extent of

TABLE 2. Representative Hydraulic Properties of the Unconfined Aquifer in the Pasco Basin (from Gephart et al. 1979)

Stratigraphic Interval	Hydraulic conductivity (m/d)	(ft/d)
Hanford	150 to 6,100	500 to 20,300
Undifferentiated		
Hanford and Middle Ringold	30 to 2,100	100 to 7,000
Middle Ringold	6 to 180	20 to 600
Lower Ringold	03 to 3.0	0.1 to 10.0

possible contamination and its rate of movement at the SWL. Hydrologic studies at the SWL have included water level measurements and testing of the aquifer at two SWL wells, 699-24-34A and 699-24-35.

Water level measurements taken at the six SWL ground-water monitoring wells indicate a hydraulic gradient on the order of 0.0001. This is in good agreement with NRDW water level data (Weekes, Luttrell, and Fuchs 1987), but illustrates the very real problem associated with efforts to determine ground-water flow direction more precisely than "generally west to east." Table 3 presents two sets of water level measurements. All the water level measurements within each set were collected on the same day. The two sets of data were collected about 10 months apart. These data show a low hydraulic gradient from west to east under the SWL, as well as a negligible gradient in the north-south direction at the SWL. Water levels are shown on a map of the landfills in Figure 19. Appendix E presents water level measurements for the period April 1988 through September 1988. Water level data are still being collected and analyzed. More definitive interpretations of ground-water flow and velocity are not available at this time.

Two of the principal hydrologic properties of the unconfined aquifer are the hydraulic conductivity (K) L/t and transmissivity (T) L^2/t. Both hydraulic conductivity and transmissivity express the capacity of a porous medium

TABLE 3. Water Table Elevations [ft above mean sea level (MSL)] at the Solid Waste Landfill

Well Number	Elevation/5-87	Elevation/4-88
Upgradient:		
6-24-35	404.35	404.66
Downgradient:		
6-23-34	404.27	404.60
6-24-34A	404.27	404.60
6-24-34B	404.28	404.62
6-24-34C	404.27	404.60
6-25-34C	404.62	404.62
Downgradient Hanford Site Well:		
6-24-33	(no measurement)	404.51

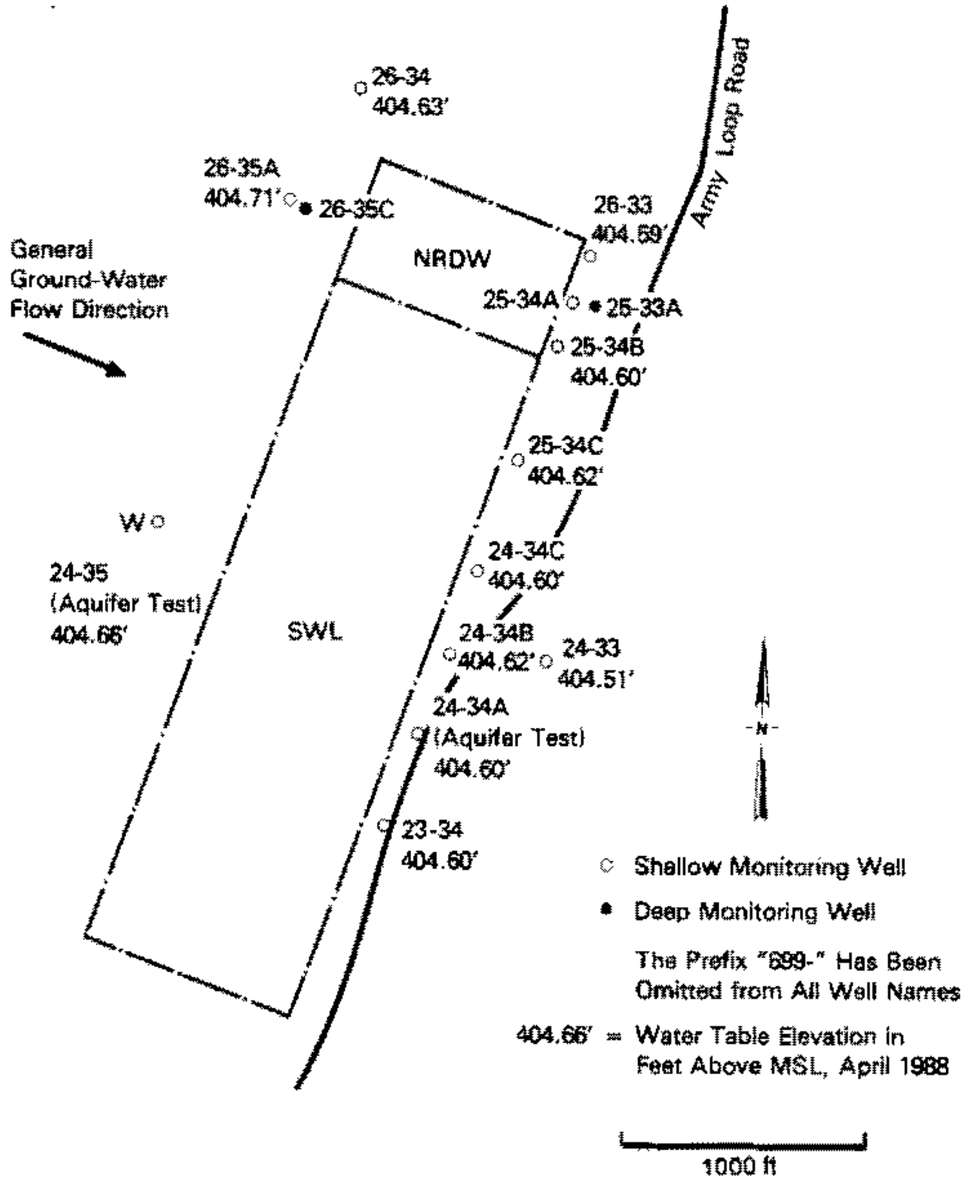


FIGURE 19. Aquifer Tests and Water Levels at Wells Near the Solid Waste and Nonradioactive Hazardous Waste Landfills

to transmit water. Hydraulic conductivity is defined as the volume of water (at 1 centipoise viscosity) that will move in a unit time under a unit hydraulic gradient through a unit area of a porous medium. Transmissivity is defined as the rate at which water moves through the vertical section of an aquifer 1 ft wide over the full saturated thickness of the aquifer under a unit hydraulic gradient (Freeze and Cherry 1979).

Only aquifer parameters for the uppermost hydrostratigraphic unit were measured at the SWL because all the SWL wells were completed in the top of the unconfined aquifer. One upgradient well (699-24-35) and one downgradient well (699-24-34A) at the SWL were tested by the constant-discharge method, designed to pump the well at a constant-discharge rate for a period of 8 h. The maximum pumping rate was intended to stress the aquifer system to the greatest extent possible to produce a measurable drawdown within the test wells and nearest observation wells. The nearest monitoring wells were used as observation wells. The aquifer test at well 699-24-35 used well 699-24-34A, which was more than 1000 ft away, as the observation well (Figure 19). The aquifer test at well 699-24-34A used well 699-23-34, which was about 400 ft away, as the observation well (Figure 19). Appendix E contains a description of each test and discussion of the test results.

Neither test at the SWL was conducted for the full 8-h period because of mechanical pump problems (Appendix E). Consequences of the shorter test durations are fewer data points and less reliable data. However, drawdown equilibrium was obtained relatively early in the test. Transmissivities could thus be estimated, but boundary effects were not observed, if present.

An aquifer thickness of 60 ft was used for calculations, based on studies done at the NRDW (Weekes, Luttrell, and Fuchs 1987). The most probable values for transmissivities ranged from 125,000 to 250,000 ft^2/d for well 699-24-34A and 250,000 ft^2/d for well 699-24-35. Calculated hydraulic conductivities ranged from 2100 to 4200 ft/d for well 699-24-34A and 4200 ft/d for well 699-24-35. These results may be less reliable, but they are similar to those reported by Weekes, Luttrell, and Fuchs (1987).

Recharge at the Solid Waste Landfill

At the time the ground-water monitoring well network was designed for the SWL, rainfall of about 6.2 in./yr was assumed to be the major source of recharge. Gee (1987) summarizes a variety of field programs carried out at the Hanford Site since 1970 to evaluate recharge and other water balance components (e.g., precipitation, infiltration, evaporation, and water storage changes). Vadose zone studies had been performed on borehole samples collected about 4 mi southeast of the SWL (Heller, Gee, and Myers 1984), where the distance from surface to ground water was about 130 ft. These studies estimated the time necessary for water to move from the soil surface to the ground water as ranging from less than 100 years to more than 600 years for annual water influx rates ranging from 2.0 to 0.02 in./yr.

Artificial Recharge

Estimates of sewage discharged to the SWL is on the order of 100,000 gal/yr (Table 1) and at least a million gal over a 10-year period. In addition, between January 1985 and January 1987, about 100,000 gal of washwater was discharged to the SWL in the same trenches being used at the time for sewage disposal. Although this liquid discharge does not appear to have affected the elevation of the water table beneath the SWL (Figure 18), evidence suggests that it has affected ground-water chemistry.

GROUND-WATER CHEMISTRY

The SWL wells were first sampled in May 1987. Because chlorinated hydrocarbons had been previously detected in a downgradient well about 500 ft to the east, a suite of volatile organics was included for analysis, in addition to the basic constituent list outlined in the compliance plan for the SWL (DOE 1986a). The constituent list was expanded in June 1987 after detection of four chlorinated hydrocarbons, and that expanded list was used again in the July 1987 sampling and analysis. The results of the first seven sampling rounds are presented in this section and in Appendix F. In addition, because of the proximity of the SWL and the NRDW, and because some constituents detected at the SWL were also detected at the NRDW, results of analyses from the compliance ground-water monitoring project at the NRDW are also included.

HANFORD SITE GROUND-WATER CHEMISTRY

The chemistry of ground water is influenced by the proximity of the ground water to recharge areas, rate of ground-water movement, and the chemical and physical nature of the sediments through which the ground water flows. The U.S. Geological Survey has measured the water chemistry for the unconfined aquifer outside the Hanford Site, and PNL has determined it within the Hanford Site. These analytical results are reported in annual documents by PNL (e.g., Environmental Monitoring at Hanford for 1987, PNL 1988). More recently, PNL determined average background values for a large number of trace constituents across the Site (Evans, Mitchell, and Dennison 1987). The waters are primarily of a calcium-bicarbonate type with a wide range of compositions attributed to natural variability of the water within the aquifer. The Basal Ringold water is sodium-bicarbonate in nature, whereas the glaciofluvial water of the Hanford formation is primarily a calcium-bicarbonate type (Graham et al. 1981). Table 4 compares averages for a number of measurements made in the Pasco Basin unconfined aquifer off and on the Hanford Site (from Graham et al. 1981).

Some of the variation is attributable to liquid waste disposal at Hanford. Thermal pollution from irradiated fuel processing and past

TABLE 4. Water Quality of the Unconfined Aquifer for the Pasco Basin and the Hanford Site (from Graham 1981)

Constituent (unit)	Location	n[a]	$\bar{x}$[b]	s[c]	Range
Temperature	Pasco Basin	193	13.5	2.6	3.1-21.2
(°C)	Hanford	89	19.2	3.2	14.5-39.1
Spec. Cond.	Pasco Basin	184	323	162	125-1,250
(µmhos/cm)	Hanford	99	409	117	194-927
pH	Pasco Basin	3	7.6	0.5	7.2-8.1
(pH Units)	Hanford	104	7.9	0.3	7.0-9.4
Ca^{++}	Pasco Basin	15	31.5	9.2	20.0-54.0
(mg/L)	Hanford	101	41.4	12.5	12.0-92.0
Mg^{++}	Pasco Basin	15	11.6	4.0	6.9-23.0
(mg/L)	Hanford	101	11.1	3.7	3.1-29.0
Na^{+}	Pasco Basin	17	15.8	9.6	5.9-43.0
(mg/L)	Hanford	101	22.6	10.4	2.9-64.0
K^{+}	Pasco Basin	16	3.1	1.0	1.4-4.9
(mg/L)	Hanford	101	6.2	1.9	1.9-13.0
HCO_3^{-}	Pasco Basin	16	166	44	82-244
(mg/L)	Hanford	101	146	38	53-314
Cl^{-}	Pasco Basin	16	4.7	4.1	2.6-19.0
(mg/L)	Hanford	101	11.1	6.6	2.5-32.0
$SO_4^{=}$	Pasco Basin	16	10.9	9.2	5.1-43.0
(mg/L)	Hanford	100	47.2	33.5	2.7-190.0
NO_3 as NO_3	Pasco Basin	(not available)			
(mg/L)	Hanford	101	26.0	39.0	0.05-270.0

(a) n = number of samples
(b) $\bar{x}$ = mean
(c) s = standard deviation

operation of production reactors is evidenced by the significantly higher mean temperature of the Hanford aquifer water compared to the mean temperature of the Pasco Basin aquifer water (Eddy 1979). High nitrate concentrations are related to waste disposal at Hanford, particularly to the large-volume process condensates. The nitrate plume is extensive and covers much of the Site. The most recent documentation of the nitrate plume can be found in the annual environmental monitoring report (PNL 1988). Agricultural practices also may add to the ambient nitrate concentrations in the Pasco Basin ground water.

SOURCES OF GROUND-WATER CHEMISTRY DATA

The ground-water chemistry data compiled here came from the following four sources:

1. NRDW - data from the RCRA Interim-Status Detection-Level Program initiated October 1986
2. SWL - data from the WAC 173-304 Detection-Level Program initiated May 1987
3. Hanford Well 699-24-33 - data from PNL's Hanford Site-wide Hazardous Materials Monitoring Project initiated for this well January 1986
4. Hanford Well 699-24-33 - radiological and hydrological data from continuous well samples since the early 1950s.

The types of data collected for hazardous waste constituents under the first three projects are summarized in Table 5. The data are not consistent because the three projects were designed for different purposes. Few data are available for some constituents.

A summary of the results and the raw data for those constituents that had at least one value reported as above the contractually required detection level are contained in Appendix F. This summary includes data from seven rounds of sampling collected in 1987 and 1988 at the SWL and NRDW wells.

STATISTICAL ANALYSIS OF GROUND-WATER CHEMISTRY DATA

The data from both SWL and NRDW programs are analyzed to provide assistance with overall site characterization.

TABLE 5. Samples Taken at the Solid Waste Landfill Through August 1988[a]

	-- 699-24-33 --			SWL							NRDW				
	Jan 86	Mar May 87	Jul Oct Jan Apr Jul 87/8	May 87	Jun 87	Jul 87	Nov[c] 87	Jan 88	Apr 88	Jul 88	Oct[b] Jan 86/7	May Jul 87	Nov 87	Jan 88	Apr Jul 88
pH, field	X[d]	X	X	X	X	X	X	X	4[e]	4	U[f]	U	U	4	4
pH, lab		X	X		X		X	X	4	4			X	4	4
Specific conductance, field	X	X	X	X	X	X	X	X	4	4	U	U	U	4	4
Specific conductance, lab							X	X	4	4			X	4	4
Total organic carbon	X	X	X	X	X	X	X	X	4	4	U	U	U	4	4
Total organic halogens	X										U	U			
Total organic halogens, Low DL		X	X		X		X	X	4	4			U	4	4
Coliforms	X			X	X	X	X	X	X	X	X	X	X	X	X
Gross alpha	X	X	X		X		X	X	X	X	X	X	X	X	X
Gross beta	X	X	X		X		X	X	X	X	X	X	X	X	X
Radium	X	X							X	X	X	X			
ICP Metals, unfiltered	E[g]			X	E	X	E	E	E	E	X	X	E	E	E
ICP Metals, filtered		E	E	X	E	X	E	E	E	E		X	E	E	E
Other metals, unfiltered	X				X		E	X	X	E	X	X	E	X	X
Other metals, filtered		X	X		X		E	X	X	E		X	E	X	X
Anions	X	X	X	X	X	X	X	E	E	E	X	X	X	X	E
Volatile organics	X	X	E	E	E	E	E	E	E	E		E	E	E	E
Fluoride, low DL			X				X	X	X	X			X	X	X
Phenol, low DL							X	X	X		X	X	X	X	X
Ammonium	X	X	X	X	X	X			X	X					
Alkalinity		X	X		X		X	X	X	X			X	X	X
Total carbon			X				X	X	X	X	X	X	X	X	X
Total dissolved solids							X	X	X	X			X	X	X
Semi-volatile organics		X	X		E	X				E		X			
Citrus red										X					
Cyanide		X	X		X					X					
Dioxin										X					
Direct Aqueous Injection		X								X					
Ethylene Glycol										X					
Herbicides	X				E				X	E	X	X			
PCB's	X				X					X					
Pesticides	X				E				X	E	X	X			
Phosphorous pesticides					X					X					
Thiourea, enhanced										X					

(a) This table describes the majority of the different samples taken, but does not account for every sample

(b) Two deep wells not sampled at NRDW in October 1986

(c) Well 6-25-34C not sampled at SWL in November 1987

(d) X - indicates constituent or group of constituents was sampled

(e) 4 - indicates quadruplicate samples taken in all wells

(f) U - indicates quadruplicate samples taken in up-gradient wells

(g) E - indicates enhanced group of constituents was sampled

Any of the constituents that had at least one value above the contractually required detection limit are candidates for statistical analysis. However, several constituents were not statistically analyzed because the number of data was small and/or most constituents were reported as below detection; these constituents or measurements include coliform bacteria, radium, laboratory pH, many of the filtered and unfiltered metals (e.g, strontium, cadmium, chromium, nickel, copper, aluminum, manganese, arsenic, lead, and iron), and some organic compounds (carbon tetrachloride and methylene chloride). The general approach used to analyze the remaining data was based on the RCRA Technical Enforcement Guidance Document (EPA 1986) in the areas where guidance was provided. This approach is as follows:

- any replicates were averaged before statistical analysis
- for data reported below detection limit, the detection limit was used as the data value
- the sampling month was used as a blocking factor to account for temporal variability that would make the statistical test more sensitive to differences
- the data were analyzed using an analysis of the variance procedure to test each downgradient well against the variability exhibited by the three upgradient wells.

Summaries of results of the statistical analyses are given in Table 6. The average value for each constituent analyzed in the upgradient wells is given in the first column. Each subsequent column gives the average for the constituent at the identified well.

Also included are results of the statistical tests of wells that are different from the upgradient wells at the probability (p) = < 0.01 significance level. These differing wells are marked with two asterisks (**); wells at the p = < 0.05 significance level are marked with one asterisk (*).

Results of these analyses compared with the upgradient wells show that the four southernmost downgradient wells from the SWL and well 699-24-33 exhibit differences for several major constituents, pH and conductivity, several trace elements, and volatile organics. Because volatile organic

TABLE 6. Solid Waste Landfill Ground-Water Monitoring Project Statistical Analyses for Data Through August 1988

Constituent Name	Upgradient Average	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33
Contamination Indicators[a]										
CONDFLD	355	489**	501**	504**	490**	520**	357	393**	368	351
CONDLAB	396	604**	524**	543**	.	515**	430	418	395	364
PH-LAB	7.78	7.09**	7.11**	7.19**	7.40**	7.45**	7.67	7.86	7.88	8.00
PHFIELD	7.08	6.07*	6.14*	6.08*	7.06	6.70	7.13	7.21	7.47	7.57
TOC	397	364	372	347	331	417	492	374	1110**	653**
TOXBOTH[b]	6.9	55.4**	47.7**	130.0**	25.0**	32.5**	12.5	57.2**	8.5	18.4**
Volatile[c] Organics										
1,1,1-T	2.5	47.0**	38.4**	48.2**	20.9**	26.6**	4.1**	2.5	2.7	ND
1,1-DIC	ND	4.6**	3.8**	3.7**	ND	2.2**	ND	ND	ND	ND
PERCENE	ND	7.6**	5.5**	7.0**	2.9**	3.8**	ND	ND	ND	ND
TRICENE	ND	7.7**	6.6**	7.5**	3.0**	3.8**	ND	ND	ND	ND
Metals										
BARIUM	34.6	75.3**	62.3**	65.4**	47.3	49.7**	38.7	34.3	35.3	33.0
FBARIUM	36.7	76.1**	61.0**	65.8**	58.7**	48.7**	36.8	33.3	36.2	33.0
CALCIUM	37,800	70,700**	67,400**	68,700**	.	62,600**	42,000	38,700	37,500	35,200
FCALCIU	37,400	69,200**	63,900**	67,500**	61,800**	61,900**	40,600	37,000	37,700	33,700
IRON	327	239	280	362	50	211	227	45	96	45
FIRON	38.5	51.7**	58.4**	72.1**	40.0	44.0*	44.7	36.7	37.8	36.7
MAGNES	10,800	16,000**	15,300**	15,800**	.	15,200**	11,800**	11,000	10,700	10,200*
FMAGNES	10,800	15,900**	15,100**	15,800**	15,500**	15,200**	11,600	10,800	11,100	10,100
POTASUM	6,270	7,510**	7,290**	7,270**	6,770	7,040**	6,420	6,070	6,000	5,830*
FPOTASS	6,360	7,400**	7,230**	7,290**	7,410**	7,060*	6,240	5,950	6,340	5,930
SODIUM	22,800	22,200	22,500	22,500	23,500	22,500	23,100	22,700	22,400	22,600
FSODIUM	22,400	22,000	22,900	22,200	23,500*	21,800	22,000	22,000	22,900	22,100

TABLE 6. (contd)

Constituent Name	Upgradient Average	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33
STRONUM	180	288**	267**	276**	.	275**	203	183	176	165
FSTRONT	182	289**	265**	279**	279**	272**	195	177	187	168
VANADUM	22.1	13.3**	14.9**	13.7**	10.7	14.4**	23.0	23.6	23.9	24.6
FVANADI	23.2	14.4**	16.1**	15.0**	16.8**	13.4**	21.3	22.8	23.8	24.2
ZINC	10.6	31.6**	48.4**	26.1**	.	57.4**	31.3**	6.1	11.5	5.6
FZINC	9.8	22.6**	26.7**	16.9	5.7	50.6**	24.7**	5.3	12.5	5.3
Anions										
CHLORID	7,670	8,400*	8,280	8,470*	8,510	8,360	7,750	7,510	7,420	7,110
FLUORID	647	629	639	656	615	629	632	695	676	707
LFLUORD	525	402**	440*	433*	458*	455*	502	554	541	558
NITRATE	26,500	20,900*	23,800	25,700	25,300	26,600	28,200	29,200	28,600	29,200
SULFATE	43,000	47,900	48,500	44,700	46,800	44,200	41,600	40,500	40,900	39,200
Other Constituents										
ALKALIN	120,000	300,000**	200,000**	217,000**	193,000**	206,000**	134,000	122,000	121,000	111,000
ALPHA (pCi/L)	2.89	4.03	3.22	3.28	3.56	3.60	2.72	2.43	2.41	2.08
BETA (pCi/L)	27.9	23.1	25.5	23.9	24.9	25.0	26.4	27.0	28.0	27.4
RADIUM (pCi/L)	0.060	0.170	0.050	0.098	0.185	0.055	0.090	0.015	0.033	0.058
TC	28,100	61,900**	53,600**	59,300**	48,500**	51,600	31,800	28,500	28,200	26,400
TDS	266,000	434,000**	353,00**	366,000**	.	357,000**	246,000*	267,000	235,000**	252,000

* - statistically significant at $p < .05$
** - statistically significant at $p < .01$
(a) Measurements are in ppb unless otherwise noted.
(b) Combined TOX and TOXLDL data and did not use January, 1987 data used reported data even if below contractual detection limit of 100 ppb for TOX and 20 ppb for TOXLDL.
(c) For volatile organics, used reported data even if below contractual detection limits of 5 or 10 ppb. Value of 2 was used for non-detected organics in analysis of 1,1,1-T. Data for 1,1-DIC, PERCENE, and TRICENE were analyzed using Fisher's exact probability test.

compounds are not expected to naturally occur and are not present in significant amounts in the upgradient wells, it must be assumed that they are coming from the SWL and/or the NRDW. Local differences in sedimentary geochemistry could be the source of differences in trace-element concentrations in the aquifer; however, the association of high trace-element concentrations with chlorinated hydrocarbons suggests that these trace elements may represent either additional impacts from the SWL or, more probably, leached materials from the sediments caused by the liquid discharge. Thus, trace-element analyses combined with sediment chemistry and mineralogical analyses would help to characterize the sources of the contamination and the mechanisms of contaminant transport through the vadose zone.

COMPARISON OF SOLID WASTE LANDFILL AND SITE-WIDE GROUND-WATER CHEMISTRY

The ground-water chemistry at the SWL is discussed in the context of the SWL, NRDW, and Site-wide ground-water monitoring programs because constituents discharged to the SWL have been detected at SWL and NRDW wells, and at Hanford Site well 699-24-33. Consequently, the following discussions and graphs include data from all three ground-water monitoring programs.

Concentrations for selected constituents in the ground-water of upgradient and downgradient wells at the SWL compared with average Site-wide background concentrations are shown in Table 7. The averages for the Site are taken from the compilation of Evans, Mitchell, and Dennison (1987). Their data are based on averages of approximately 40 wells located in the 600 Area that are assumed to be unaffected by Hanford waste disposal practices, at least for the constituents under consideration. No attempt was made to calculate a background level for nitrate, because a large part of the 600 Area is affected by nitrate contamination. The area affected by nitrate includes the SWL, which has ground-water nitrate concentrations about 40 times higher than those of ground-water samples taken upgradient of the 200 Areas.

Table 7 does not contain data for chlorinated hydrocarbons. Chlorinated hydrocarbon contamination is low in the 300 Area and relatively high in the 200-West Area and environs. The principal chlorinated hydrocarbon contaminant found in the 200-West Area is carbon tetrachloride. The contaminant

TABLE 7. Estimated Background Concentration Levels for Selected Constituents in Hanford Ground Water Compared to Samples from Upgradient and Downgradient Wells at the Solid Waste Landfill and Nonradioactive Dangerous Waste Landfill

Constituent	600 Area[a] "Background"	SWL (WEST-side) upgradient (1 well)	SWL (EAST-side) downgradient (3 wells)
Ag (μg/L)[b]	< 10	< 10	< 10
Al (μg/L)	< 150	< 150	< 150
As (μg/L)	< 5	< 5	< 5
Ba (μg/L)	43 ± 21	45 ± 5	67 ± 8
Ca (mg/L)	43 ± 14	40 ± 5	64 ± 8
Cd (μg/L)	< 2	< 2	< 2
Cl (mg/L)	9.4 ± 5.5	8.1 ± 0.7	8.5 ± 0.3
CN (μg/L)	< 10	< 10	< 10
Cr (μg/L)	< 10	< 10	< 10
Cu (μg/L)	< 10	< 10	< 10
F (μg/L)	630 ± 240	616 ± 68	595 ± 67
Hg (μg/L)	< 0.1	< 0.1	< 0.1
K (mg/L)	5.8 ± 1.4	6.8 ± 0.4	7.3 ± 0.3
Mg (mg/L)	11.7 ± 2.8	11.1 ± 0.6	15.5 ± 0.6
Mn (μg/L)	16 ± 25	< 5	< 5
Na (mg/L)	20.5 ± 6.6	21.6 ± 0.7	22.8 ± 0.9
NH_4 (μg/L)	60 ± 47	61 ± 11	57 ± 9
Ni (μg/L)	< 10	< 10	< 10
Pb (μg/L)	< 5	< 5	< 5
PO_4 (μg/L)	< 1000	< 1000	< 1000
Se (μg/L)	< 5	< 5	< 5
SO_4 (mg/L)	40.1 ± 13.2	47.9 ± 2.1	46.4 ± 2.2
Sr (μg/L)	320 ± 86	< 300	< 300
V (μg/L)	17 ± 7	20 ± 1	16 ± 2
Zn (μg/L)	10 ± 11	22 ± 11	33 ± 10
Alkalinity (mg/L)	123 ± 21	132	213 ± 14
pH	7.64 ± 0.16	7.37	6.91 ± 0.03
TOC (μg/L)	586 ± 347	442 ± 239	395 ± 225
Conductivity (μmho/cm)	380 ± 82	358 ± 15	474 ± 27
Gross Alpha (pCi/L)	2.5 ± 1.4	4.1	2.9 ± 0.9
Gross Beta (pCi/L)	19 ± 1218	23 ± 1	
Radium (pCi/L)	< 0.2	< 0.2	< 0.2

(a) The 600 Area background levels are based on data from other Hanford Site wells.
(b) Concentrations are approximately equivalent to parts per billion (ppb).

plume is relatively localized, however, and no chlorinated hydrocarbon contamination has been identified to date in the 200-East Area or environs. None of the sampled wells located between the 200-East and 200-West Areas and the SWL have shown any evidence of chlorinated hydrocarbon contamination. This suggests that chlorinated hydrocarbon contamination detected in the vicinity of the SWL originates somewhere within the SWL.

Concentrations for SWL downgradient wells (shown in Table 7) are calculated for averages of the three wells showing the highest levels of chlorinated hydrocarbons (699-23-34, 699-24-34A, and 699-24-34B). This grouping is intended to test the premise that chlorinated hydrocarbons can be used as tracers for the local source of contamination. A single well, 699-24-35, was used to determine the upgradient ground-water concentrations. The average concentrations for the upgradient well match the Site-wide averages. The averages for the downgradient wells, by comparison, show some noteworthy features for the same species found to be anomalous in the statistical analysis. Species that are significantly higher in the downgradient wells than in either the upgradient wells or Site-wide averages include the alkali earths (barium, calcium, magnesium), alkalinity, and conductivity. Zinc may also be slightly elevated.

A standard indicator of potential ground-water contamination is pH. The pH is clearly lower in the downgradient wells at the SWL. These values were consistent in both the field and laboratory readings. The reason for the effect is probably related to the formation of organic and inorganic acids resulting from oxidation of organic material (sewage) discharged to the landfill. Oxidation of organic material to organic acids, buffered to a pH of 5, commonly occurs in municipal landfills (Drever 1982). It is for this reason that there is a step in both the Extracted Procedure Toxicity Test and the U.S. Environmental Protection Agency (EPA)-proposed toxicity characteristic Leaching Procedure for buffering leaching solutions to a pH of 5.

ANALYTICAL RESULTS AT THE SOLID WASTE LANDFILL

The following figures are graphical presentations of water-sample chemical data from both SWL and NRDW wells and Hanford Site well 699-24-33. Most of these illustrate significant differences between water samples from upgradient (west side) and downgradient (east side) wells, as well as significant trends in north-south spatial distribution. Graphs of some of the constituents do not show significant differences, but their inclusion provides a more complete characterization.

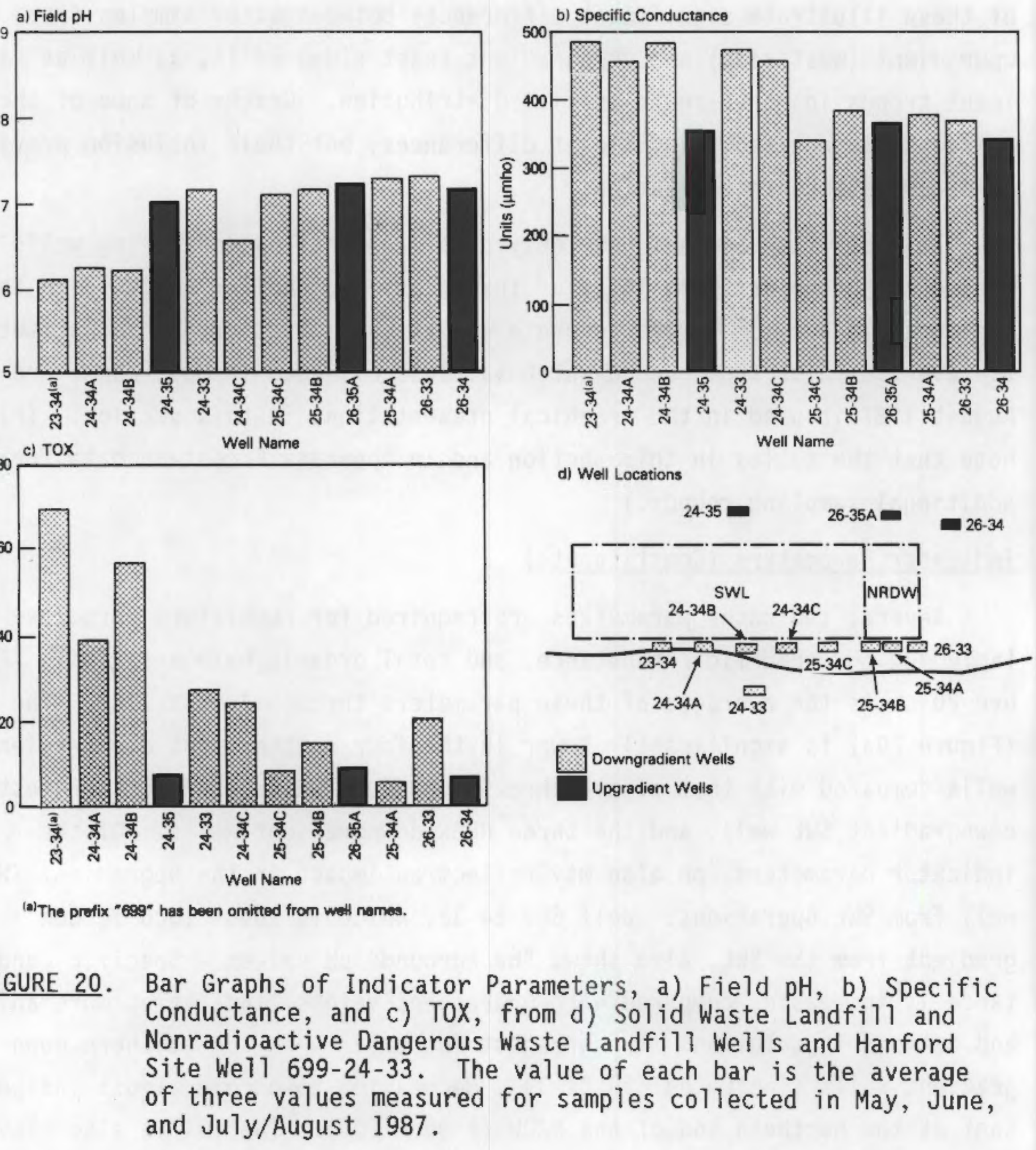
To facilitate comparisons, only data from shallow monitoring wells completed in the upper 10 to 15 ft of the unconfined aquifer are used in this section. To provide a more accurate analytical value for each constituent, the average value from ground-water samples collected in May, June, and July/August 1987 is used in the graphical presentations in this section. (Please note that the tables in this section and in Appendix F contain data for four additional sampling rounds.)

Indicator Parameters (Constituents)

Several indicator parameters are required for regulatory purposes, including pH, specific conductance, and total organic halogens (TOX). Figure 20 shows the averages of these parameters through August 1987. The pH (Figure 20a) is significantly lower in the four southernmost downgradient wells compared with that of all three upgradient wells, the northernmost downgradient SWL well, and the three NRDW downgradient wells. Of the indicator parameters, pH also may reflect an impact on the upgradient SWL well from SWL operations. Well 699-24-33, which is about 1000 ft downgradient from the SWL, also shows "background" pH values. Specific conductance is increased, compared with upgradient values, indicating more anions and cations in solution. The greatest increase is in the southern downgradient wells (including 699-24-33), decreasing to become almost insignificant at the northern end of the NRDW (Figure 20b). The TOX is also elevated in the southern downgradient wells, with decreasing levels to the north (Figure 20c).

Cations

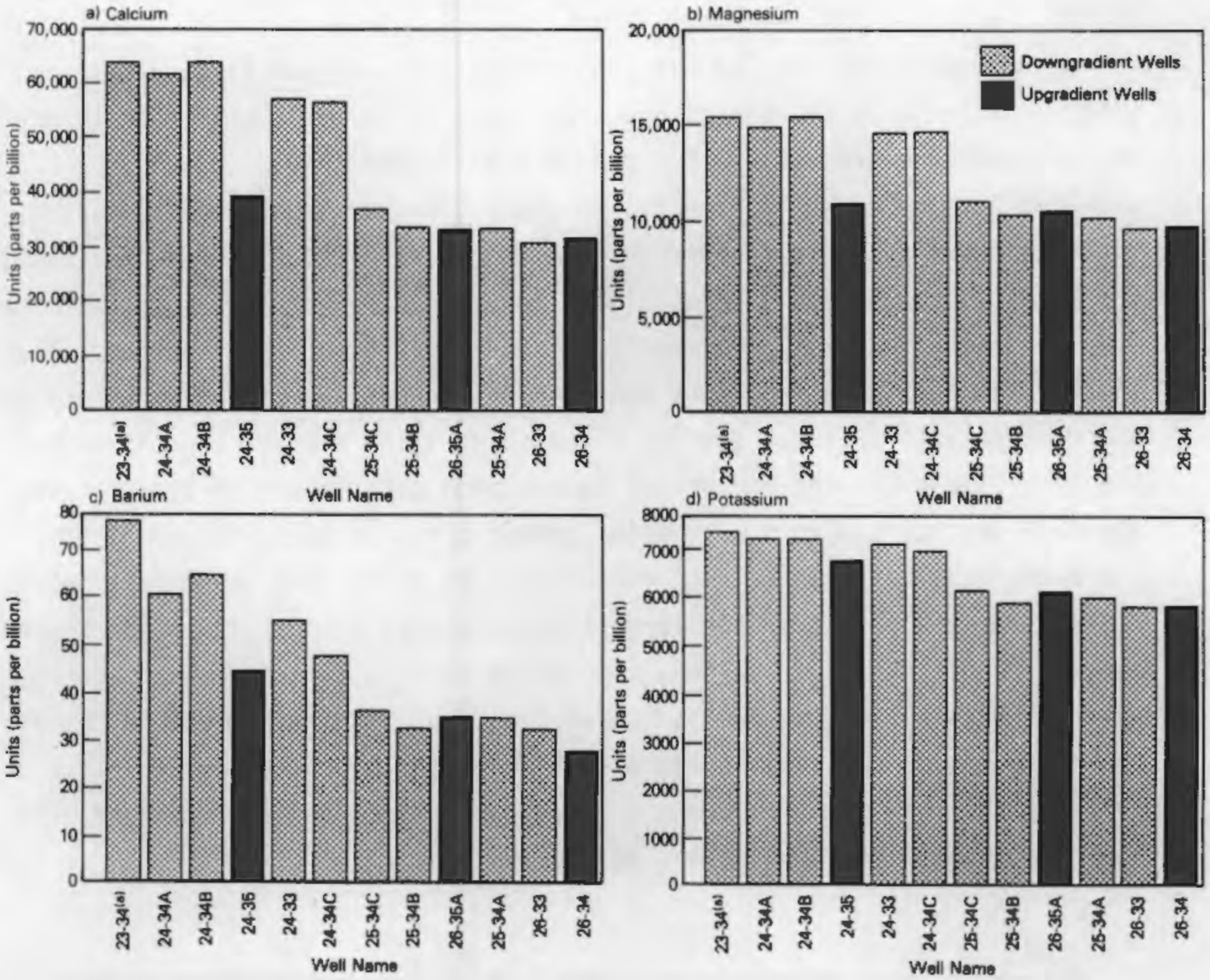
Figures 21a and b present filtered-water data for cations calcium and magnesium. Both cations display elevated levels in the southern downgradient wells, decreasing toward the northern end of the NRDW. Concentrations are also above background levels for downgradient well 699-24-33. The same



(a)The prefix "699" has been omitted from well names.

FIGURE 20. Bar Graphs of Indicator Parameters, a) Field pH, b) Specific Conductance, and c) TOX, from d) Solid Waste Landfill and Nonradioactive Dangerous Waste Landfill Wells and Hanford Site Well 699-24-33. The value of each bar is the average of three values measured for samples collected in May, June, and July/August 1987.

pattern is seen in the (filtered) barium and potassium distributions (Figures 21c and d). All four cations display a similar pattern in the upgradient wells; there appears to be a decrease in concentration levels from the southern to the more northern upgradient wells. This decrease suggests that upgradient wells, particularly the most southern one, may be impacted by SWL



(a)The prefix "699" has been omitted from well names.

FIGURE 21. Graph of Cation Concentrations Including a) Calcium, b) Magnesium, c) Barium, and d) Potassium

operations. The fact that all of these cations display a similar pattern suggests that the same process is occurring in each case.

Two different types of processes are possible: 1) addition of contamination or 2) a cation-exchange effect stemming from lower pH and higher fluid flux, which may have changed the cation-exchange capacity of the soil column through which the increased liquid volumes moved.

Metals

Zinc concentrations (Figure 22a) indicate a more complicated pattern. A general decrease in concentrations from south to north is observed in both up- and downgradient wells. Downgradient wells 699-24-33, 699-25-34B, 699-25-34A, and 699-26-33 display low (near limit of detection) concentrations, as does the most northern upgradient well, 699-26-34. However, well 699-24-34C shows a high concentration; this could either represent an impact from landfill operations or reflect a local difference in subsurface composition of the sediments. Because zinc concentrations are elevated in both up- and downgradient wells at the SWL compared with the average concentration on the Site (Table 7), and because it is a common constituent in sewage, zinc may represent contamination from the sewage disposal (e.g., Drever 1982). The occurrence of elevated zinc concentrations in the one upgradient SWL well is probably the result of the large liquid volumes discharged inside the west fence. The large liquid volumes combined with silt layers in the vadose zone may have spread zinc (as well as other constituents) laterally from the disposal trenches, including in the direction of the upgradient well. This suggests the upgradient well may not be the best source of background data for comparison with downgradient well data.

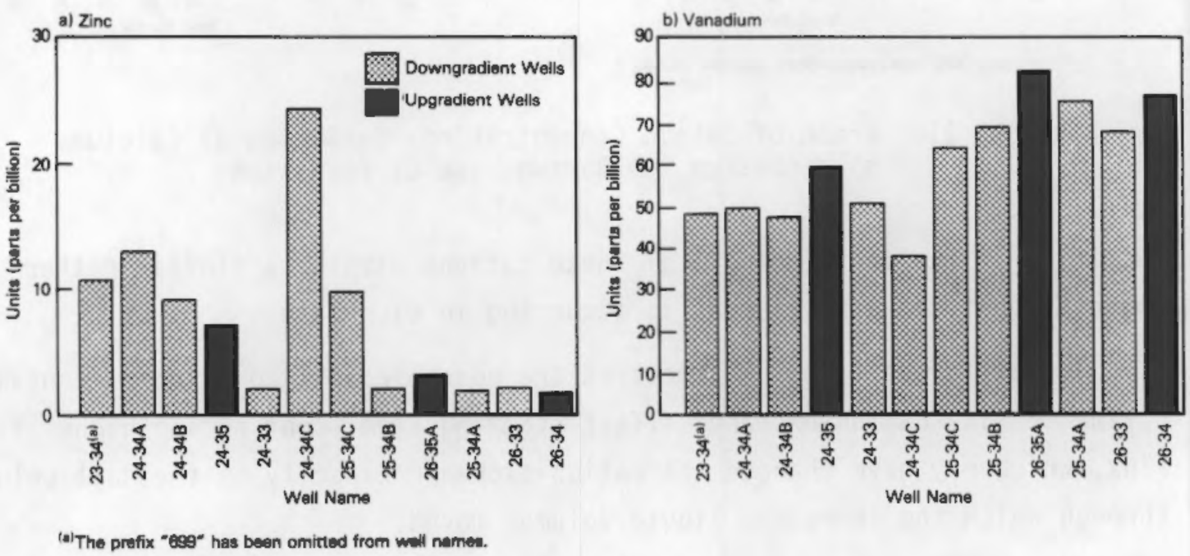
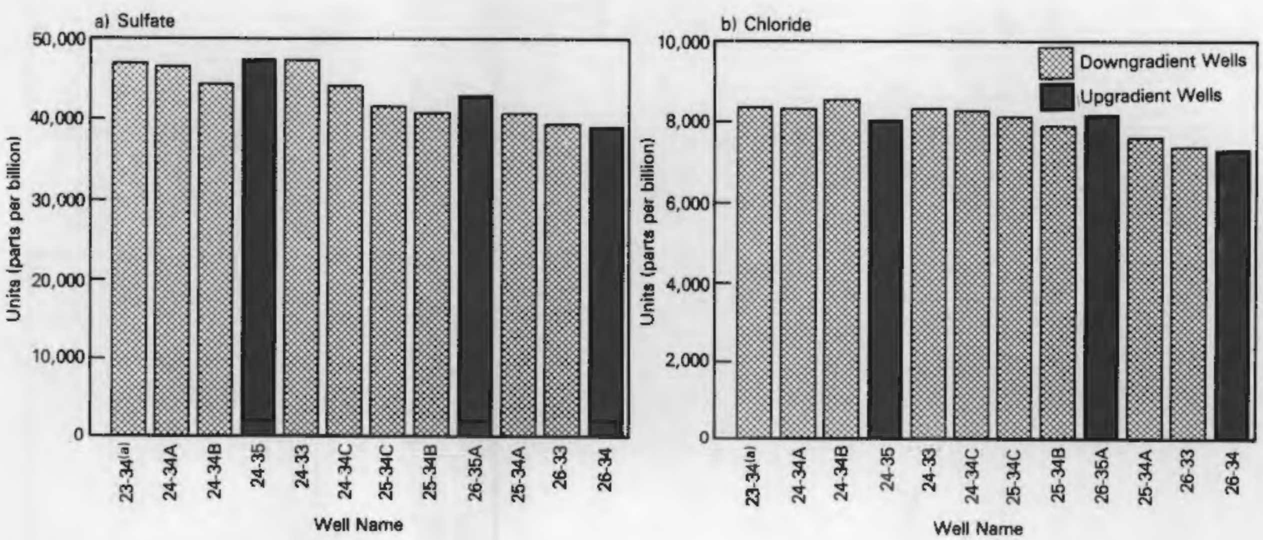


FIGURE 22. Graphs of a) Zinc Concentrations and b) Vanadium Concentrations

Vanadium concentrations (Figure 22b) appear to be anticorrelated with zinc, with a general increase toward the north in both up- and downgradient wells; well 699-24-34C, which shows elevated zinc levels (compared with all other wells), displays a lower vanadium level (compared with all other wells). However, this "relationship" between these two constituents may be fortuitous. The high zinc concentrations in well 699-24-34C may reflect a local source of zinc, and/or mobilization of zinc, and not be related to vanadium concentrations.

Anions

The anions, chloride and sulfate, display either a straightforward pattern or slightly decreasing concentration levels from south to north in both up- and downgradient wells (Figure 23a and b). Variations are assumed to result from natural chemical gradients or from other waste sources (e.g., 200-East Area).



[a]The prefix "699" has been omitted from well names.

FIGURE 23. Graphs of a) Sulfate Concentrations and b) Chloride Concentrations

Chlorinated Hydrocarbons

Concentrations for four of the volatile organics (chlorinated hydrocarbons) are shown in Figures 24 and 25. The three-dimensional presentation provides a clear picture of the pattern of contamination. Chlorinated hydrocarbons do not occur naturally in ground water; hence, their presence indicates contamination from SWL operations.

The chlorinated hydrocarbons detected are dense, non-aqueous phase liquids (DNAPLs). They are highly volatile in open systems, but are denser

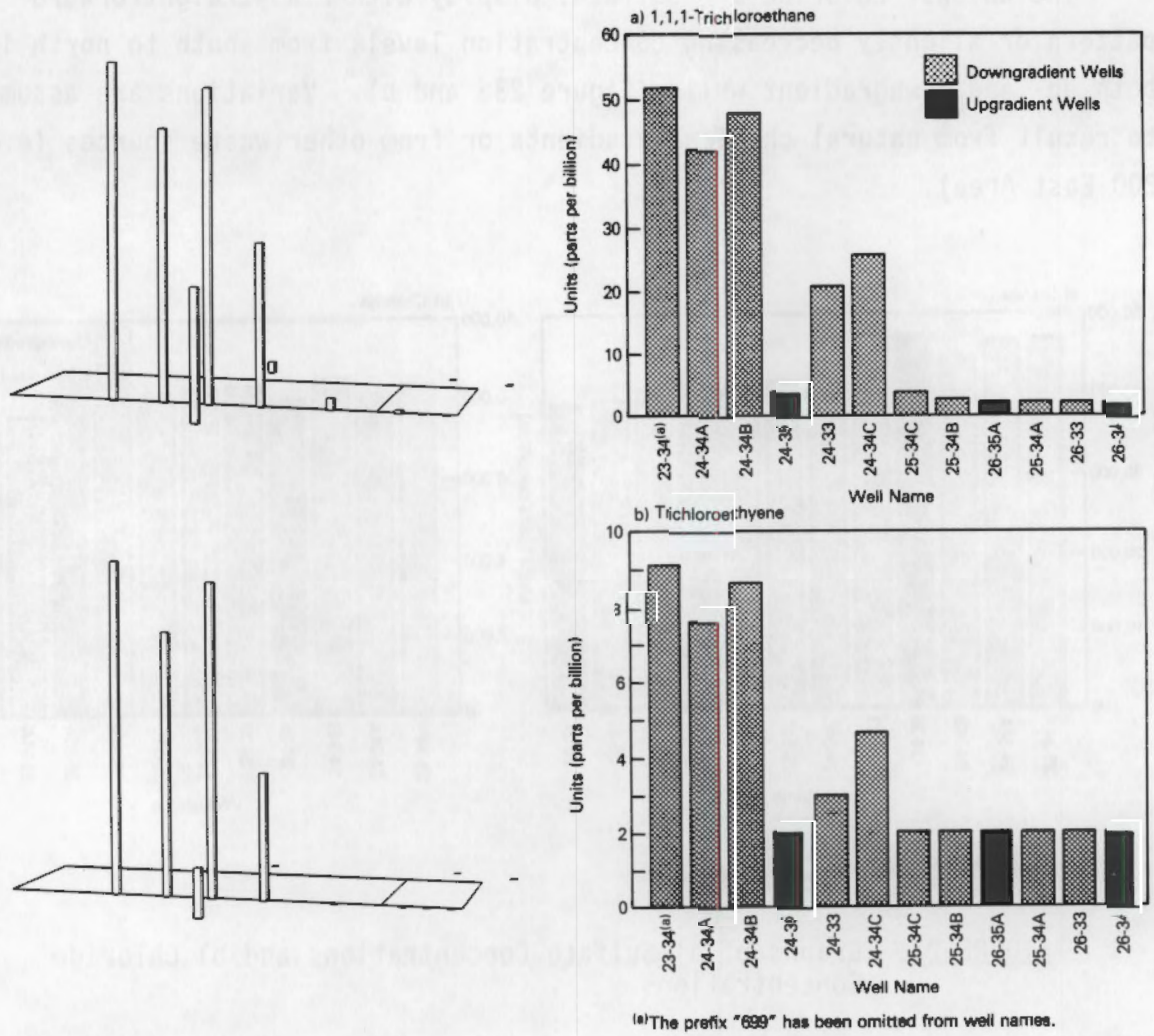
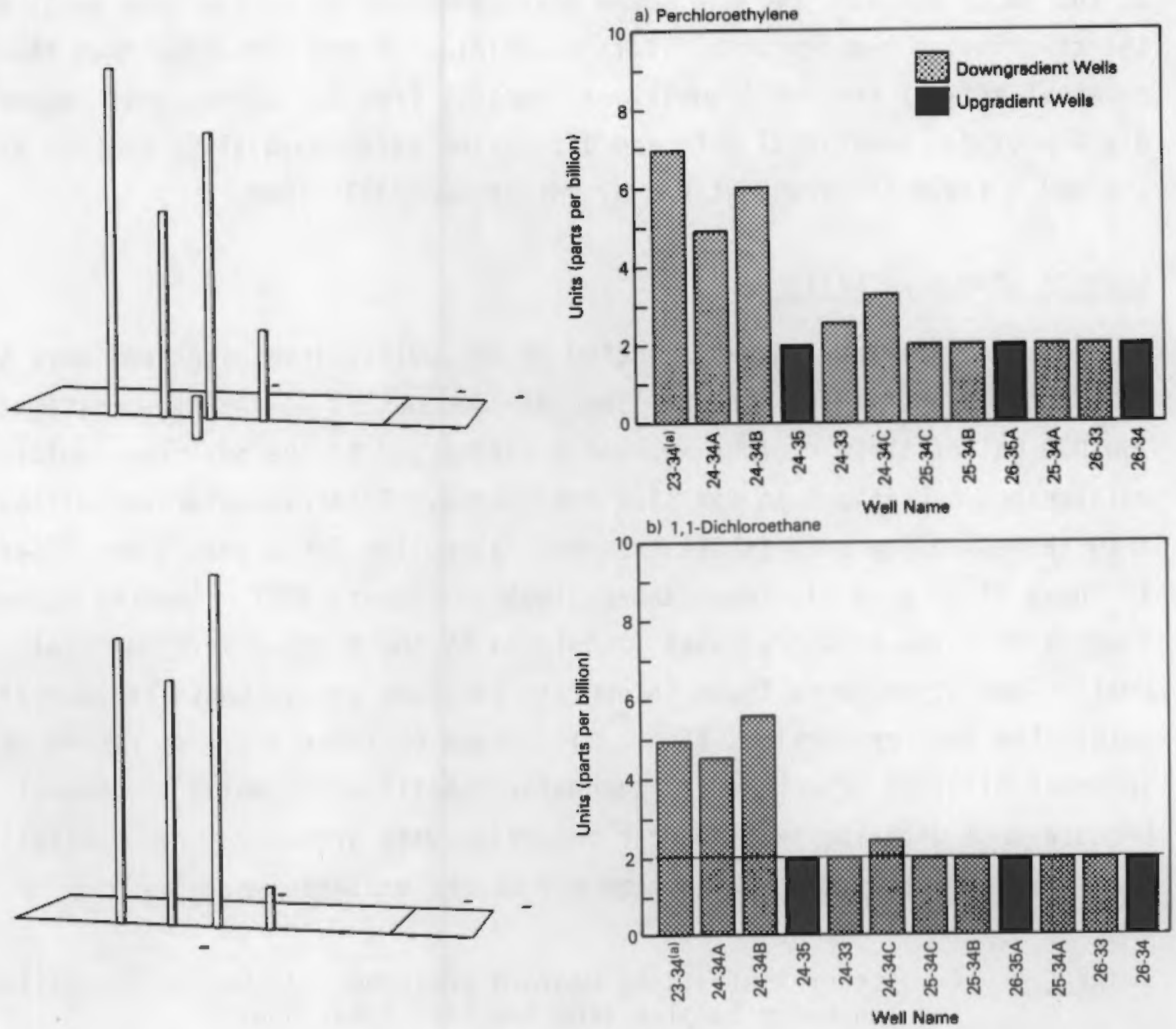


FIGURE 24. Bar and Three-Dimensional Graphs of a) 1,1-Trichloroethane and b) Trichloroethylene



(a)The prefix "699" has been omitted from well names.

FIGURE 25. Bar and Three-Dimensional Graphs of a) Perchloroethylene and b) 1,1-Dichloroethane

than water and only slightly soluble. In ground water, they would be expected to sink until they reached a confining layer. These DNAPLs would also be expected to continue downward migration in the soil column in their liquid phase but, being volatile, would also be expected to migrate as a vapor. The direction of the vadose zone vapor transport would be controlled by the local environment and specific processes.

Differences in trace elements, cations, and anions observed in downgradient wells could be explained by differences in underlying geochemistry at the SWL. However, because these differences occur in the same wells as the chlorinated hydrocarbons, it is plausible, if not probable, that the chemical effects represent additional impacts from SWL operations. Appendix G provides additional data and discussion based on quality control analysis and a field study undertaken by PNL in June/July 1988.

SOURCES OF CONTAMINATION

After contamination was detected in SWL wells, investigations were initiated to determine its source. The only documented source is an estimated 100,000 gal of steam cleaner washwater discharged to the SWL from Hanford bus maintenance operations in the 1100 Area shops. This washwater was discharged into three shallow pits (short trenches) along the SWL's west side of Section I, Phase II (Figure 3), from January 1985 to January 1987. Several washwater samples from the 1100 Area shops, analyzed by the Hanford Environmental Health Foundation, were found to contain the same constituents in approximately the same proportions (Table 8). Based on these analyses, there is no apparent dilution effect of the washwater constituents, which is unusual because some dilution should occur on mixing with ground water. Variability in washwater compositions with time may be the explanation.

TABLE 8. Results of Analysis by Hanford Environmental Health Foundation for Two Water Samples from the 1100 Area Shops

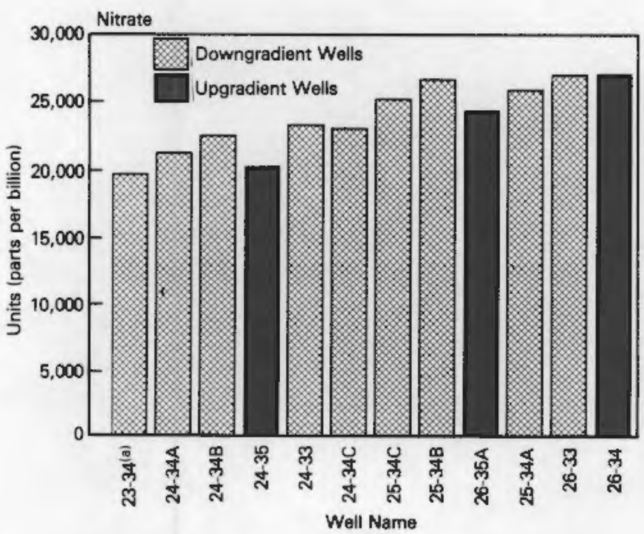
Parameter	Results ($\mu g/L$) Heavy Equipment	Bus Shop
Carbon Tetrachloride	5.5	31
1,1,1-Trichloroethane	208	87
Carbon Tetrachloride	18	< 60[a]
Trichloroethylene (1,1,2-Trichloroethene)	< 10	< 40[a]
Perchloroethylene	26	< 60[a]
1,2-Dichloroethane	not detected	not detected

(a) Instrument problems would not allow lower detection limits for this sample.

Organic degradation of the sewage sludge may be the source of the coliform bacteria detected. Coliform was found in several upgradient wells, both deeper monitoring wells, and several downgradient wells at the northern end of the NRDW. Coliform has not been detected in most of the SWL wells, probably because the chlorinated hydrocarbons kill the coliform bacteria. The coliform appears to increase and decrease in several of the same wells; this may correlate with a closer coupling of discharge and sampling operations or with coliform bacterial life cycles. The coliform data do not show any discernible or explainable trends.

Nitrate Plume

A new nitrate plume from the Plutonium Uranium Extraction Plant's (PUREX) B Pond operations may be affecting the ground water at the NRDW. A nitrate graph similar to those presented for other chemical constituents is shown in Figure 26. The spatial trend of the plume is the reverse direction displayed by those of most constituents. For example, the nitrate increases from south to north in both up- and downgradient wells. Nitrate and tritium plots through time for well 699-24-33 indicate that this trend is probably



(a)The prefix "699" has been omitted from well names.

FIGURE 26. Bar Graph of Nitrate Concentrations

not a result of SWL operations. Figure 27 presents 1970 to mid-1987 nitrate and tritium data. Both plots indicate a recent increase, which is probably related to the restart of PUREX in 1983.

A plot through time of the water levels in well 699-24-33, shown in Figure 18, indicates that artificial discharge to B Pond has dramatically affected the water levels in the area of the SWL. The most recent increase in water level appears to correlate with the most recent increase in nitrate and tritium concentrations. Effects from the 200 Areas on wells need to be understood and separated from operational impacts when considering groundwater monitoring projects.

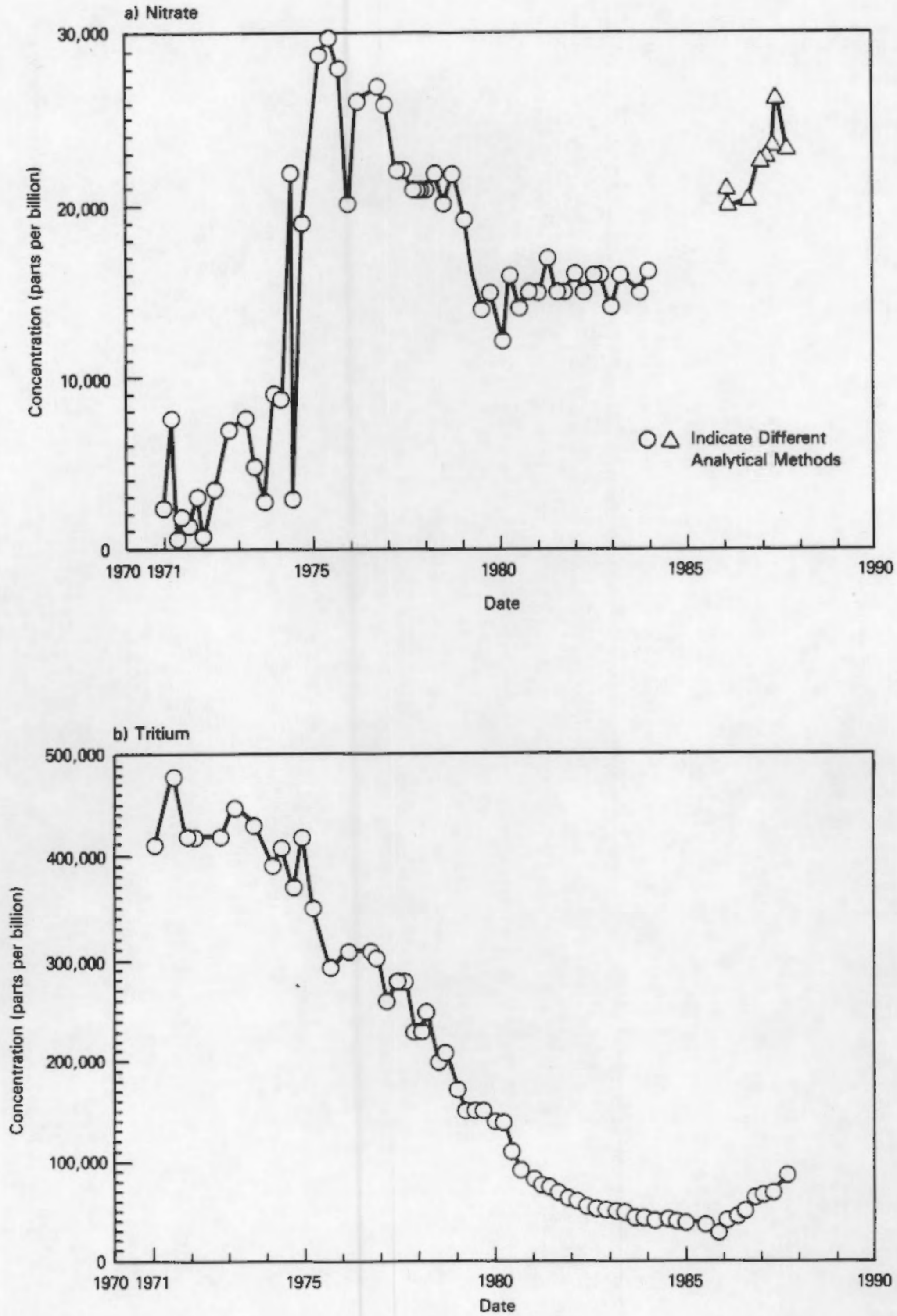


FIGURE 27. Plot of Tritium and Nitrate Concentrations from 1971 Through 1987 for Well 699-24-33

FIGURE 27. Plot of Tritium and Nitrate Concentrations From 1971 Through 1987 for Well 60-29-11

SYNOPSIS AND CONCLUSIONS

A synopsis and conclusions based on the characterization work performed at both the SWL and NRDW during well installation, and the initial results of both the SWL and NRDW detection-level ground-water monitoring efforts are presented in this section. Information is still needed to provide adequate characterization of the hydrogeologic environment and assessment of the constituents detected at the SWL. PNL has based the assessment activities on EPA (1986) and the constituent list WAC 173-303, where the chlorinated hydrocarbons found in SWL wells are listed. Chlorinated hydrocarbons are not specifically covered in WAC 173-304, the state regulation concerning facilities such as the SWL.

GEOLOGY

The geology at the SWL is similar to that at the NRDW because of their proximity. In the vicinity of the SWL there are 500 to 600 ft of sediments (Hanford and Ringold formations) overlying approximately a mile-thick basalt sequence (Columbia River basalts). Structurally, the SWL and NRDW are on the north flank of the Cold Creek syncline.

Locally, the Hanford formation is about 180 ft thick, based on NRDW characterization work. Drilling extended to about 140 ft at the SWL; within this thickness the two major lithostratigraphic units, a sand subunit overlying a gravel subunit, correlate across the SWL and NRDW. Several near-surface, very narrow silt layers also appear to extend across the SWL and NRDW, based on trench observations.

Composition of the geologic units is based on field observations only; no petrographic or chemical analyses have been done to date.

HYDROLOGY

The top of the unconfined aquifer at the SWL occurs in a highly transmissive portion of the Hanford formation, about 125 ft below the land surface. Hanford Site water table elevation data indicate a general flow direction from west to east across the Site with localized exceptions caused by buried structures and artificial recharge from site operations. The hydraulic gradient in the vicinity of the SWL and NRDW is extremely low (on the order of 0.0001). Because of this, neither characterization work performed at the SWL nor at the NRDW was able to precisely determine the ground-water flow direction. Data collected during well installation at the SWL and NRDW indicate ground-water flow direction is generally west to east. Ground-water chemistry data from the SWL monitoring program indicate the flow direction may have a northwest to southeast vector. The low hydraulic gradient also suggests that the ground-water flow direction in the vicinity of the SWL may be very responsive to influences from Site operations and could vary considerably over space and time.

Transport through the vadose zone has been accelerated because of sewage and washwater discharges to the SWL. So far the data do not indicate whether or not these disposal practices have affected the hydraulic gradient in the vicinity of the SWL. All liquid disposal at the SWL was discontinued in April 1987; travel times should increase in the vadose zone, and the amount of chlorinated hydrocarbons introduced to the ground water should decrease.

GROUND-WATER CHEMISTRY

In 1985 at Hanford, a Site-wide ground-water monitoring program was initiated to monitor the unconfined aquifer for hazardous constituents, in addition to the ongoing radiological ground-water monitoring effort. Four species of chlorinated hydrocarbons were detected by this program in the January 1986 sampling of well 699-24-33, approximately 500 ft downgradient from the SWL. Transport of chlorinated hydrocarbons through the vadose zone (110 ft from the bottom of the trenches) and unconfined aquifer (about 1500 ft) to downgradient well 699-24-33 was accomplished in less than 1 year. This was the result of large volumes of washwater and sewage sludge being discharged to the same SWL pits during the same time period: sewage sludge from 1982 through April 1987; washwater from January 1985 through January 1987.

The same four species of chlorinated hydrocarbons were detected by the first (May 1987) analyses of the initial SWL ground-water monitoring effort.

An immediate resampling was initiated to confirm these findings. The presence of chlorinated hydrocarbons was confirmed by the June sampling. Carbon tetrachloride was also reported in three wells in the August sampling.

A number of constituents appear to have either lower or higher concentrations in the ground water at the SWL compared with background values for the Hanford Site. These values include pH and conductivity, some major ground-water constituents, several trace elements, several volatile organics, and coliform bacteria. Of these constituents, 1,1,2-trichloroethylene (TCE), carbon tetrachloride, and coliform bacteria have reported values that have exceeded regulatory limits. The EPA's maximum contaminant level for TCE is 5 ppb, compared with the 5- to 10-ppb range observed at the SWL.

SOURCES OF CONTAMINATION AND IMPACT TO THE GROUND WATER

The specific source of the volatile organic compounds at the SWL appears to be the steam cleaner washwater originating from the steam pad catch basins at the 1100 Area bus maintenance garage. Several hundred thousand gallons of this washwater were discharged from January 1985 to January 1987 to short trenches excavated on the west side of the north section of the SWL (Figure 3). Analysis of similar washwater (Table 8) shows that the same mix of chlorinated hydrocarbons including carbon tetrachloride, all common industrial solvents, are typically present. The concentrations of solvents in the washwater may vary with time because of the uncontrolled nature of the cleaning operations. Although the types of contaminants placed into the SWL are known, along with their disposal locations, their concentrations or quantities are not.

Tanks of sewage sludge were also discharged to the SWL from 1973 until April 1987. The sewage sludge was placed in shallow trenches along the east and west inside perimeter of the SWL (Figure 3). An estimated total of 1 to 1.5 million gal of sewage sludge was disposed of at the landfill. Approximately 3000 gal/d may have been discharged into trenches. Trucks brought septic tank waste from the Fast Flux Test Facility, the Washington Public Power Supply System construction sites, and other chemical toilets and septic tanks on the Hanford Site. This sewage is the most likely source of coliform bacteria detected in several of the NRDW wells.

Removal of surface vegetation, excavation, and especially discharge of large volumes of liquid associated with the sewage sludge (and washwater) accelerated the transport of contaminants through the vadose zone and into the ground water. Additional impacts from the sewage sludge probably include decreased pH values of the ground water and dissolution of soluble minerals in the soil column, and may have also supplied sodium ions that replaced adsorbed cations in the soil column. Organic degradation of the sewage sludge may have produced methane, organic acids (Drever 1982), or large amounts of carbon dioxide, which may be partly responsible for some of the changes in ground water from background composition. The lower pH and higher fluid flux may be responsible for the elevated calcium, magnesium, alkalinity, and barium observed in downgradient wells. The soil column may have acted like a cation-exchange complex, with a redistribution of cations occurring.

Organic degradation may be the source of the few positive coliform bacteria detected. These bacteria were found in several upgradient wells, both deeper monitoring wells, and several downgradient wells at the northern end of the NRDW. Coliform was not detected in most of the SWL wells, possibly because the chlorinated hydrocarbons kill the coliform bacteria. The coliform appears to increase and decrease in several of the wells; there are no apparent trends and no explanation at this time.

The large volumes of washwater, on contact with acids produced from organic degradation, would have a lower pH value than they did initially, and this would increase the potential to dissolve any carbonate-rich horizons. This would not increase sediment porosity perceptibly, because carbonate is not a major component of the soil.

ASSESSMENT ACTIVITIES

After chlorinated hydrocarbons were reported and confirmed at the SWL, the scope of the project was expanded to assess the persistence of the contamination and better define its extent. The following actions have been taken:

- The Washington State Department of Ecology (hereafter called Ecology), district EPA, and the city of Richland Health Department were informed of the detection of contamination at the SWL; Ecology and the district EPA requested copies of a plan of action in response to the detection of contamination.
- A plan of action was presented to Westinghouse Hanford in July 1987.
- The SWL's constituent list was expanded, based on WAC 173-303, to continue monitoring chlorinated hydrocarbons, and to determine if other impacts to the ground water were occurring.
- In FY88, the frequency of water-level measurements and the number of wells were increased to more accurately determine the ground-water flow direction.

At the SWL, the source of chlorinated hydrocarbons seems likely to be washwater from the 1100 Area, discharged to shallow trenches. These constituents have been distributed in the vadose zone to a totally unknown extent. Their extent in the ground water is known in part. The NRDW well network provides evidence that significant concentrations of chlorinated hydrocarbons in the ground water have not extended to the northern (either east or west) side of the NRDW. Hanford Site well 699-24-33, which is about 500 ft east (downgradient) of the SWL, provides evidence that concentrations of chlorinated hydrocarbons persist in this direction, but concentration levels decrease.

The SWL well network, although successful for detection-level monitoring, does not provide adequate assessment monitoring either laterally, along the southern and southeastern sides of the SWL, or vertically in the unconfined aquifer (all SWL monitoring wells are completed at the point of compliance, in the upper 13 ft of the aquifer). The chlorinated hydrocarbons in the ground water at the SWL are dense, non-aqueous phase liquids (DNAPLs), which can be expected to sink in the ground water until a confining layer is reached. There are no SWL wells that extend to the first confining zone in the unconfined aquifer. Efficient siting of additional ground-water monitoring wells at the SWL would benefit from understanding the following:

- source (quantities) of chlorinated hydrocarbons
- quantity and distribution of residual chlorinated hydrocarbons in the soil column
- quantity and distribution of chlorinated hydrocarbons in the ground water to the east and south of the SWL and their vertical distribution in the aquifer
- expected future impacts to the ground water (based on residual quantities and determination and evaluation of transport mechanisms in the soil column and unconfined aquifer).

Assessment would also benefit from including additional Hanford Site wells in the hydrology effort to determine the direction of ground-water flow and velocity (confirming that the local direction and velocity of ground-water flow determined at the SWL and NRDW are consistent with the regional hydrology).

Assessment of the contamination in the vadose zone would provide useful information concerning future impacts to the ground water. Expansion of the ground-water monitoring network at the SWL is needed to provide adequate assessment-level monitoring.

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GLOSSARY

GEOLOGIC/HYDROLOGIC TERMS

Alluvial Plain - A valley deposit resulting from the deposition of muds, sands, or gravels by flood waters or streams.

Anticline - A geologic structure referred to as a fold, in which the layers dip away from the center (axis) of the feature on both sides; the geologic units are convex upward.

Aquifer - A permeable geologic unit that can transmit significant quantities of water.

Basalt - In general, any fine-grained, dark-colored rock formed by the solidification of molten (igneous) material that has been extruded onto a planetary surface.

Confined Aquifer - An aquifer that is bounded above and below by less permeable layers. Ground water in a confined aquifer is under a pressure greater than atmospheric pressure.

Epiclastic - A textural term applied to mechanically deposited sediments of mud, sand, and gravel, consisting of weathered products of older rocks.

Fanglomerate - A sedimentary unit composed of heterogeneous materials that were originally deposited in an alluvial fan but that became cemented into solid rock after deposition.

Flood Basalt (plateau basalt) - A term applied to those basalts that occur in very thick sequences over a large regional area and appear to represent multiple fissure eruptions spanning a considerable length of geologic time.

Fluvial - Pertaining to, produced by, or formed in rivers.

Ground Water - This is broadly defined as subsurface water that is in the pore spaces of soil and geologic units; the term is usually reserved for the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.

Hydraulic Conductivity - This term is used to describe one of the principal hydrologic properties of soil and geologic units. It is one way of expressing the capacity of a porous medium to transmit water. Hydraulic conductivity is defined as the volume of water (at 1 centipoise viscosity) that will move in a unit time under a unit hydraulic gradient through a unit area of a porous medium.

Lacustrine - Pertaining to, produced by, or formed in lakes.

Paleosol - A buried soil.

Saturated Zone - A subsurface zone below which all soil or rock pore space is filled with water under pressure greater than that of the atmosphere.

Syncline - A geologic structure referred to as a fold, in which the layers dip inward toward the center (axis) from both sides of the feature; the geologic units are concave upward.

Transmissivity - This term is one way of expressing the capacity of a porous medium to transmit water. Transmissivity is defined as the rate at which water moves through the vertical section of an aquifer 1 ft wide over the full saturated thickness of the aquifer under a unit hydraulic gradient.

Unconfined Aquifer - An aquifer that is not confined above by relatively impermeable rocks. The pressure at the top of the unconfined aquifer is equal to that of the atmosphere.

Unsaturated Zone (same as "vadose zone") - A subsurface zone containing water under less than atmospheric pressure, and air or gases generally under atmospheric pressure. This zone is bounded above by the land surface and below by the surface of the zone of saturation, i.e., the water table.

Volcaniclastic - A textural term applied to mechanically deposited sediments of mud, sand, and gravel, consisting of the weathered products of older, volcanic rocks.

Water Table - A theoretical surface that is represented by the elevation of water surfaces in wells penetrating only a short distance into the unconfined aquifer.

ANALYTICAL TERMS

Blank - An artificial sample designed to monitor the introduction of artifacts into the process. For water samples, reagent water is used as a blank matrix sample. Blanks are subjected to the usual analytical or measurement process to establish a zero baseline or background value that is used to determine the existence and magnitude of contamination problems. Blank data values can be used to adjust or correct routine analytical results. Blanks used to evaluate sampling conditions can be divided into several types, each measuring the quality of a different phase of sampling:

- Method Blank (previously called reagent blank) - An aliquot of analyte-free water or solvent analyzed with each analytical batch, used as a baseline for the analytical portion of the method. It contains all reagents, internal standards, and surrogate standards, and is processed through an entire analytical method. It must be carried through the complete procedure as the sample. The method blank is used to define the level of laboratory background contamination.

- Field Blank - A blank that is prepared, handled, and analyzed in the same manner as normal carrying agents except that it is not exposed to the material to be selectively captured. Field blanks are used to evaluate ambient conditions. Equipment blanks and trip blanks are two specific types of field blanks.

- Equipment Blank - A blank that is used to measure the cleanliness of sampling equipment used for sampling at several locations. Equipment blanks are prepared in the field by simulating the collection of a sample through a decontaminated piece of equipment or by pouring the blank over/through the sample collection device, collecting the equipment blank in a sample container, and returning it to the laboratory for analysis.

- Trip Blank - A trip blank is prepared in the laboratory by filling a sample vial with organic-free reagent water and carefully capping to ensure integrity. These samples are transported from the laboratory to the field and are carried back to the laboratory along with all other samples collected. Trip blanks are used to determine whether any cross-contamination occurs during sample collection or between samples while in transport to the field or back to the laboratory.

Calibration - The establishment of a relationship between various calibration standards and the measurement(s) of those standards obtained by a measurement system, or a portion of a measurement system. The levels of the calibration standards should, at least, bracket the range of levels over which the actual measurement(s) are to be made.

Detection Limit - A detection limit in analytical chemistry represents the maximum practical sensitivity of the analytical method for a particular analyte in a given sample matrix. For a given analytical method and constituent, the actual detection limit (the concentration below which the constituent is not detected) will depend upon many factors, including objective criteria such as instrument calibration and more subjective factors such as analyst experience. A detection limit cannot be used to extrapolate precision at any detectable concentration, and it is never an indicator of accuracy. Just as there are different types of "blanks," "standards," and "spikes," there are a number of different types of "detection limits." Definitions for "detection limits" used in this report are given below:

- Contractually Required Detection Limit (CRDL) - The CRDL is the detection limit stated in an analytical laboratory's contract that will be achieved by the analytical laboratory with 99% confidence.

- Instrument Detection Limit (IDL) - The instrument detection limit is the actual detection limit (i.e., the minimum concentration of the constituent that can be observed by the instrument, distinguished from background or instrument noise, and measured) achieved by a specific instrument and analyst. This varies depending upon the given instrument and analyst, but it can be estimated by the analyst and supported by interlaboratory comparisons. Based on interlaboratory comparisons, for example, the UST GC/MS instrument detection limit for TCE (in water) is between 2 and 3 ppb.

Duplicate and Replicate Samples - Field duplicates and laboratory replicates are used to assess the reproducibility of sample collection techniques and method variability, respectively.

- Duplicates - Duplicates are two (or more) samples collected independently and placed in separate sample containers at a sampling location during a single act of sampling. Duplicates are used to measure sample variance related to field conditions are field sampling and to assess precision.

- Replicates - Replicates are single samples that are divided into two equal parts for the purpose of analysis. These samples are often referred to as "splits."

Internal Standard - A compound of known concentration that can be added to a blank, matrix spike, matrix spike duplicate, sample, sample extract, or another standard prior to analysis. Internal standards are used to quantify compounds of interest or to determine the accuracy and/or precision of an instrument. Internal standard has a specific meaning for GC/MS work: Internal standards are used to estimate concentrations of organic compounds not contained within the calibration standard by comparing mass spectral response of the compound with that of an internal standard. Several types of internal standards follow:

- Calibration Standard - A standard used to quantify the relationship between the output of a sensor and a property to be measured. Calibration standards should be traceable to Standard Reference Materials (SRM), Certified Reference Materials (CRM), or a primary standard.

- Check Standard (or check sample) - A blank that has been spiked with the analyte(s) from an independent source in order to monitor the execution of the analytical method. This is also called the calibration check. Check samples are prepared from stock solution different from that used to prepare standards. The known composition of this material is measured periodically. The results of these multiple measurements are frequently plotted on control charts to provide a visual trend of the calibration of the instrument.

- Control Standard - A material of known composition that is analyzed concurrently with test samples to evaluate the measurement process.

- Primary Standard - A material having a known property that is stable, that can be accurately measured or derived from established physical or chemical constants, and that is readily reproducible.

- Secondary Standard - A material having a property that is based upon comparison with some primary standard. Once its value has been established, a secondary standard can become a primary standard for some other user.

- Internal Standard (for volatile organic analysis-VOA-and semi-volatile analysis) - Compound added to every standard, blank, matrix spike, matrix spike duplicate, sample (for VOAs) and sample extract (for semivolatiles) at a known concentration, prior to analysis. Internal standards are used as the basis for quantitation of target compounds and are used to estimate concentrations of other compounds not contained within the calibration standard.

- Quality Control Reference Sample (or working standard) - A material used to assess the performance of a measurement or portions thereof. It is intended primarily for routine intra-laboratory use in maintaining control of accuracy and would be prepared from or traceable to a calibration standard.

- Surrogates (surrogate standard) - Organic compounds that are similar to analytes of interest in chemical composition, extraction, and chromatography, but that are not normally found in environmental samples. These compounds are spiked into all blanks, standards, samples, and spiked samples prior to analysis. For organic, GC/MS methods, surrogates are brominated, fluorinated, or isotopically labeled compounds not expected to be detected in environmental (natural) media.

- Analytical or Reagent Blank - A blank used as a baseline for the analytical portion of a method. For example, a blank consisting of a sample from a batch of absorbing solution used for normal samples but processed through the analytical system only, and used to adjust or correct routine analytical results.

- Blind Sample - A sample submitted for analysis for which the composition is known to the submitter but is unknown to the analyst. A blind sample is one way to test the proficiency of a measurement process.

- Blind Standard - A standard submitted for which the composition is known by the submitter but not by the analyst. A blind standard is one way to test the proficiency of a measurement process.

- Double Blind Standard - A standard submitted as a sample for which its identity as a check standard and its composition are known to the submitter but not to the analyst. This is currently not part of the UST program.

Matrix - The predominant material of which the sample to be analyzed is composed.

Matrix Spike - An aliquot of a matrix spiked with known quantities of specific compounds and subjected to the entire analytical procedure in order to indicate the appropriateness of the method for the matrix by measuring recovery.

Matrix Spike Duplicate - A second aliquot of the same matrix as the matrix spike that is spiked in order to determine the precision of the analytical method. The relative percent difference between the samples is calculated and used to assess analytical precision.

Method Quantification Limit (MQL) - The MQL is the limit of detection for an analytical method and is the minimum concentration of the constituent that can be observed by the (instrument) method, measured, and reported, based on comparisons of many laboratories' results.

Practical Quantification Limit (PQL) - The PQL is the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions (based on an individual laboratory's results).

Random Sample - A sample selected from a population, using a randomization process.

Reference Material (RM) - A material for which the properties are sufficiently well established to be used for the calibration of an apparatus, the assessment of a method, or the assignment of values to materials.

- Certified Reference Material (CRM) - A material for which the property values are certified by a technically valid procedure, accompanied by or traceable to a certificate or other documentation issued by a certifying body.

- Standard Reference Material (SRM) - A material produced in quantity, of which certain properties have been certified by the National Bureau of Standards (NBS) or other agencies to the extent possible to satisfy its intended use. The material should be in a matrix similar to actual samples to be measured by a measurement system or should be used directly in preparing such a matrix. Intended uses include 1) standardization of solutions, 2) calibration of equipment, and 3) auditing the accuracy and precision of measurement systems.

- Standard Reference Sample (SRS) - A carefully prepared material produced from or compared against an SRM (or other equally well characterized material) such that there is little loss of accuracy. The sample should have a matrix similar to actual samples used in the measurement system. These samples are intended for use primarily as reference standards 1) to determine the precision and accuracy of measurement systems, 2) to evaluate calibration standards, and 3) to evaluate quality control reference samples. They may be used "as is" or as a component of a calibration or quality control measurement system.

Spiked Field Sample - A normal field sample of material (gas, solid, or liquid) to which is added a known amount of some substance of interest. The extent of the spiking is unknown to those analyzing the sample. Spiked samples may be used to check on the performance of a routine analysis or the recovery efficiency of an analytical method (not part of the UST procedures).

Standardization - A physical or mathematical adjustment or correction of a measurement system to make the measurements conform to predetermined values. The adjustments or corrections are usually based on a single-point calibration level (as opposed to a multi-point "calibration").

System Performance Check Compounds (SPCC) - Target compounds designated to monitor chromatographic performance, sensitivity, and compound instability or degradation on active sites. Minimum response factor criteria for the SPCCs are defined in the analytical protocol.

ABBREVIATIONS AND ACRONYMNS

ASTM	-	American Society for Testing and Materials
BHC	-	benzene hexachloride
$CaCO_3$	-	calcium carbonate
Carbon Tet	-	carbon tetrachloride
CCl_4	-	carbon tetrachloride
CFR	-	Code of Federal Regulations
cm	-	centimeter
cm/sec	-	centimeter per second
CRDL	-	contractually required detection limit
CRM	-	Certified Reference Material
c/s	-	counts per second
D	-	depth
D_4	-	deuterated
d	-	day
DCA	-	1,1-dichloroethane (1,1-DIC)
DDD	-	dichlorodiphenyldichloroethane
DDE	-	dichlorodiphenyldichloroethylene
DDT	-	dichlorodiphenyltrichloroethane
dia.	-	diameter
DL	-	Detection Limit
DNAPLs	-	dense, non-aqueous-phase liquids
DNBP	-	2-sec-Butyl-4,6-dinitrophenol
DOE	-	U.S. Department of Energy
D/W	-	depth to water
DWS	-	drinking water standards
E	-	east
ECD	-	electron capture detector
Ecology	-	Washington State Department of Ecology
EMSL	-	Environmental Monitoring Support Laboratory
EPA	-	U.S. Environmental Protection Agency
EPAP	-	EPA proposed Maximum Contaminant Level Goals
EPAS	-	EPA Secondary Maximum Contaminant Levels

E-tape	-	electric sounding tape
FID	-	flame ionization detector
FR	-	Federal Register
ft	-	foot
ft^2	-	square foot
ft^3	-	cubic foot
ft/d	-	feet per day
ft^2/d	-	square feet per day
FY	-	fiscal year
g	-	gram
gal	-	gallon
GC/MS	-	Gas Chromatography/Mass Spectrometer
gpd	-	gallons per day
gpm	-	gallons per minute
h	-	hour
HCl	-	hydrogen chloride
H_2O	-	water
hp	-	horsepower
IC	-	ion chromatography
ICP	-	inductively coupled plasma atomic spectroscopy
IDL	-	instrument detection limit
in.	-	inch
Inc.	-	Incorporated
ISE	-	ion-specific electrode
K	-	conductivity
KW	-	kilowatt
L	-	liter
lb	-	pound
LDL	-	lower detection limit
Lpm	-	liters per minute
LSD	-	land surface datum
m	-	meter
max	-	maximum
MCL	-	maximum concentration limit

m/d	-	meters per day
m^2/d	-	square meters per day
MDL	-	method detection limit
mg/L	-	milligrams per liter
mi	-	mile
mi^2	-	square mile
min	-	minute
mL	-	milliliter
mm	-	millimeter
MP	-	measuring point
MPN	-	most probable number
MQL	-	method quantitation limit
MSL	-	Mean Sea Level
myr	-	million years
μg/L	-	micrograms per liter
μmho	-	micro-mhos
μmho/cm	-	micro-mhos per centimeter
N	-	north
NGS	-	National Geodetic Survey
NRDW	-	Nonradioactive Dangerous Waste Landfill
PCB	-	polychorinated biphenyl
PCE	-	perchloroethylene (PERCENE)
pCi/L	-	picocuries per liter
PE	-	Performance Evaluation
PNL	-	Pacific Northwest Laboratory
ppb	-	parts per billion
PQL	-	Practical Quantitation Limit
PSPL	-	Puget Sound Power and Light
PUREX	-	Plutonium Uranium Extraction Plant
QA/QC	-	Quality Assurance/Quality Control
RCRA	-	Resource Conservation and Recovery Act of 1976
RM	-	Reference Material
rpm	-	revolutions per minute
RPT	-	Radiation Protection Technologist

RSD	-	Relative Standard Deviation
s	-	second
s.d.	-	standard deviation
sec	-	second
SPCC	-	System Performance Check Compound
SRM	-	Standard Reference Material
SRS	-	Standard Reference Sample
s.s.	-	stainless steel
S-tape	-	steel tape
SWL	-	Solid Waste Landfill
T	-	transmissivity
t	-	time
T/C	-	top of casing
TCA	-	1,1,1-trichloroethane (1,1,1-T)
TCE	-	1,1,2-trichloroethene (trichloroethylene, TRICENE)
T.D.	-	total depth
TETRANE	-	carbon tetrachloride
TM	-	trademark
TOC	-	total organic carbon
TOX	-	total organic halogen
UST	-	United States Testing Company, Incorporated analytical laboratory
VOA	-	Volatile Organic Analysis
Vol.	-	volume
vol%	-	volume percent
W	-	width
WAC	-	Washington Administrative Code
WDOE	-	Washington State Department of Ecology
W.L.	-	water level
WP	-	Water Pollution
WS	-	Water Supply
wt	-	weight
wt%	-	weight percent
x	-	times

ybp	-	years before present
yr	-	year
±	-	plus or minus
′	-	foot
″	-	inch
~	-	approximately
°C	-	degrees Celsius
2,4-D	-	2,4-dichlorophenoxyacetic acid
2,4,5-T	-	2,4,5-trichlorophenoxyacetic acid
2,4,5-TP	-	2,4,5-trichlorophenoxypropionic acid

APPENDIX A

WELL CONSTRUCTION SUMMARIES AND FINISHED WELL SPECIFICATIONS

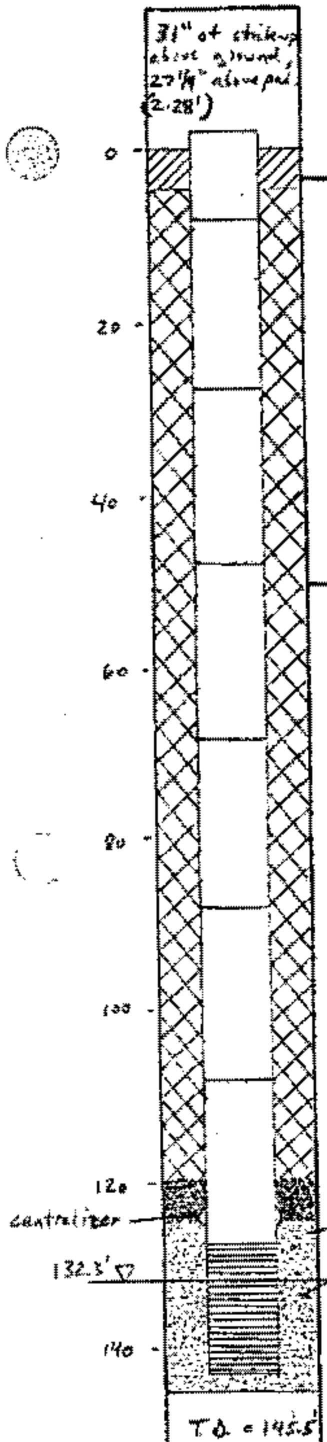
APPENDIX A

WELL CONSTRUCTION SUMMARIES AND FINISHED WELL SPECIFICATIONS

The first part of this appendix contains well construction summaries for wells 699-24-35 (SW-1), 699-23-34 (SW-2), 699-24-34A (SW-3), 699-24-34B (SW-4), 699-24-34C (SW-5), and 699-25-34C (SW-6) at the Solid Waste Landfill. The second part lists finished specifications for these wells.

WELL CONSTRUCTION SUMMARIES

Well construction summaries provide information about the drilling techniques, borehole, well design, and construction materials used. A separate summary is provided for each of the six SWL wells. Diagrams of each well and borehole are also included.



Well Construction Summary

Well SW-1
JAS-1911-ANO

Location: Central Landfill
Personnel: Wilbur/Hagen

Elevation: Ground Level (brass plate) 536.52' above
Top of Casing 538.81 ft above MSL

DRILLING SUMMARY:

Total Depth 145.5' (DLW=132.3')
Borehole Diameter 16"

Driller L. Rultena/D. Ludtke

Rig Cable Tool (Red 22W)
Bit(s) Drive barrel / hard tool

Drilling Fluid Water from well SW-2 (central landfill)
Surface Casing 14" diam x 19' long

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
Drive barrel (0-85')	2/3	0730	2/5	1500
Hard tool (85'-145')	2/6	0730	2/13	0915
Geophys. Logging:	2/12	1435	2/12	1530
Casing:				
14" diam.	2/3	0900	2/3	0905
10" diam.	2/3	1045		
6" diam.	2/24	0715	2/24	0805
Filter Placement:	2/13	1200	2/24	1050
Cementing:	2/27	1000	3/2/97	0915
Development:	2/17	0740	2/27	1310
Other:				
Volclay pellets	2/24	1055	2/24	1057
Volclay grout	2/25	0945	2/27	0925

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

0 - 19	C1	(removed)	
+3' - 146'	C2	(removed)	
+2' - 143'	C3		
128' - 143'	S1		
128' - 143'	S2		

Casing: C1 14" diam carbon steel
C2 10" diam carbon steel
C3 6" diam. stainless steel
C4

Screen: S1 10" diam, S.S. 40-slot (telescoping)
S2 6" diam. 30-slot S.S.
S3
S4

Centralizers 1 located at 123' (20' above bottom of screen)

Filter Material 8-12 mesh and 10-20 mesh silica sand

Cement

Other Volclay pellets and Volclay grout

used 8 sacks of concrete

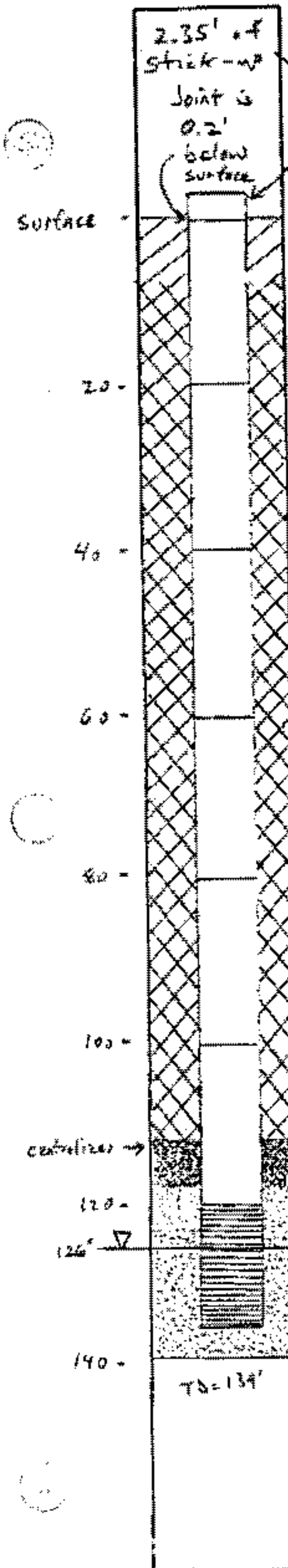
Comments:
Used 2 bags 10-20 mesh silica sand
used 8 bags 8-12 mesh silica sand
Used 4 buckets Volclay pellets
used 26 bags Volclay grout
Filter placed from 145.5' to ~124'
(used 8-12 mesh on bottom and 10-20 on top).
Pellets placed from ~124' to ~119'
Grout placed from ~119' to 5'
Concrete placed from 5' to surface

Key:

Bentonite
Cement/Grout
Sand Pack
Drill Cuttings
Gravel
Sand
Silt
Clay
Screen

Well Construction Summary

Well SW-2
JAJ-1911-Altho



Location: Central Landfill Elevation: Ground Level (brass plate) 530.50' above msl
Personnel: HAGEN / Last / Dudzick Top of Casing 532.86' above MSL

DRILLING SUMMARY:

Total Depth 139' (D/W = 126')
Borehole Diameter 18"

Driller Lenny Rultens
Oswego Drilling Co.
Rig Cable Tool (Rod 22w)
Bit(s) Core barrel hard tool

Drilling Fluid Water from Well SW-2 @ landfill
Surface Casing 14" carbon steel - later removed

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

0 - 10'	C1	(later removed)	
0 - 140'	C2	(later removed)	
+2.4' - 121	C3		
121' - 136'	S1		

Casing: C1 14" diam. carbon steel
C2 10" diam. carbon steel
C3 6" diam. stainless steel
C4

Screen: S1 30-slot, 6" diam. stain. steel
S2 15.3' long
S3
S4

Centralizers one located @ 113' below surface.

Filter Material 8-12 and 10-20 Colorado Silica sand

Cement from 7.5' to surface - used 19 bags for plug + sand (Portland Cement)

Other Volclay pellets from 118' - 112' 4 buckets used.
Volclay grout from 112' to ~5' - 24 bags used.

CONSTRUCTION TIME LOG:

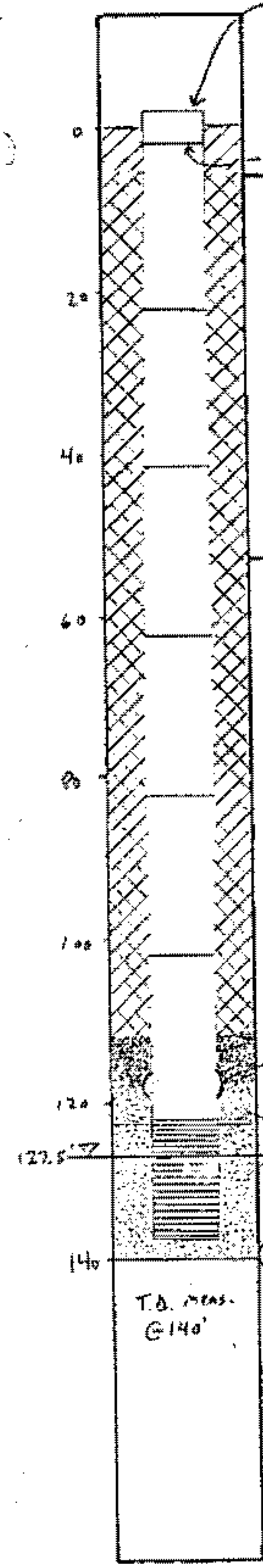
Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
Core barrel	1/9	0905	1/14	1500
hard tool	1/15	0845	1/21	1120
Geophys. Logging:	1/21	1223	1/21	1405
Casing:				
14" carbon steel	1/9	1210	1/9	1230
10" carbon steel	1/12	0845	1/20	1320
6" stainless steel	1/22	0856	1/22	1300
Filter Placement:	1/21	1445	1/23	0915
Cementing:	1/29	1000	1/29	1530
Development:	1/30	0845	1/30	1400
Other:				
Volclay pellets	1/23	1000	1/23	1130
Volclay grout	1/23	1402	1/28	1655
cement	1/29	1000	1/29	1530

Comments:
Core barrel drilling from 0-95'
hard tool drilling from 95-139'

Filter = 9 bags of 8-12 sand on bottom (from 139' to about 123') and 2½ bags of 10-20 sand on top (from about 123' to 118').

Key:
Bentonite
Cement/Grout
Sand Pack
Drill Cuttings
Gravel
Sand
Silt
Clay
Screen

Reviewed/approved JR Raymond 2/5/87



Well Construction Summary

Well SW-3
JAS-1911-RHO

Location: Central Landfill
Elevation: Ground Level (brass plate) 531.71' above msl
Personnel: HAGEN
Top of Casing: 533.89' above msl

DRILLING SUMMARY:

(s/w = 122.5')

Total Depth: 141.5' drilled, 140' meas.

Borehole Diameter: 10"

Driller: Darrel Ludtke, Ounsey Drilling Co

Rig: Cable Tool (Yellow Rig)

Bit(s): Core barrel, hard tool

Drilling Fluid: SM-2 well water (Central landfill)

Surface Casing: 14" diam x 10' long

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
Core barrel	1-19	0825	1-23	0925
Hard tool	1-23	1308	1/29	1200
Geophys. Logging:	1/29	1213	1/29	1320
Casing:				
14" carbon steel	1-19	0930	1-19	0930
10" carbon steel	1-19	1150	1-29	1015
6" stainless steel	2/2	1230	2/2	1230
Filter Placement:	1/29	1430	2/3	1015
Cementing:	2/6	1410	2/9	1330
Development:	2/9	0846	2/9	0900
Other:				
Volclay pellets	2-13	1340	2/13	1343
Volclay grout	2/14	0750	2/16	1352

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

From - To	String	
0 - 10'	C1	(removed)
0 - 143	C2	(removed)
+2.5 - 122.5	C3	
122.5 - 137.5	S1 S2	

Casing:
C1 14" carbon steel
C2 10" carbon steel
C3 6" stainless steel
~~C4~~

Screen:
S1 6" stainless steel (30-slot)
S2 10" stainless steel (40-slot)
~~S3~~ screen (telescoping) set
~~S4~~ from 122.5 - 132.5 for pump test.

Centralizers: 1 located @ 117.5' (20' above bottom of screen)

Filter Material: 8-12 silica sand
10-20 silica sand

Cement: Portland cement placed from 6' to surface

Other:

Comments:

Core barrel drilling from surface to 107'. Hard tool from 107' to 141.5'.
Filter placed from 140' to 118'
Volclay pellets placed from 118' to 112'
Volclay grout placed from 112' to 6'
Cement placed from 6' to 0'
4" concrete pad placed above cement plug

Key:

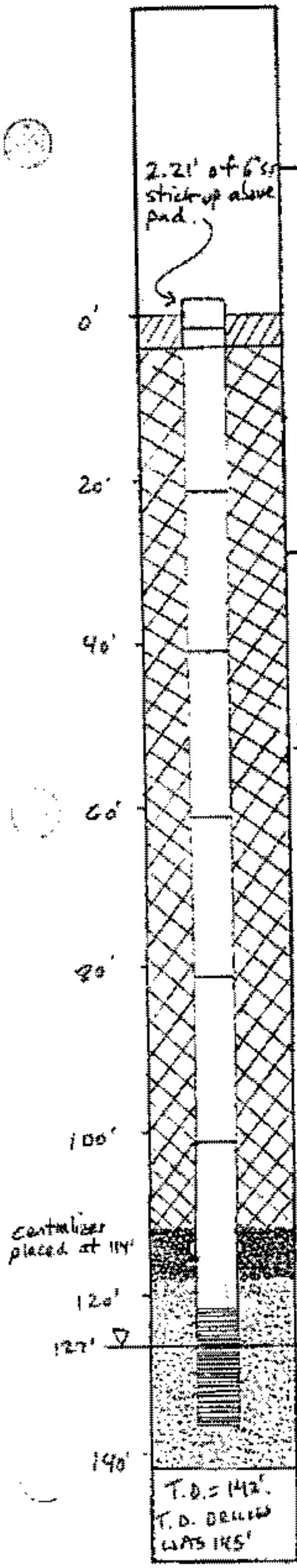
Bentonite, Sand, Cement/Grout, Silt, Sand Pack, Clay, Drill Cuttings, Screen, Gravel

Well Construction Summary

Well SW-4
JAJ-1911-RIfo

Location: Solid Waste Landfill
Personnel: HAGEN

Elevation: Ground Level (brass plate) 531.28' above M
Top of Casing 533.50' above MSL



DRILLING SUMMARY: (S/W = 127')

Total Depth DRILLED TO 145' meas. to 142'
Borehole Diameter 10"
Driller Ludtke / Doy
Rig Cable Tool (C55B)
Bit(s) Drive barrel, hard tool
Drilling Fluid water from well SM-2 solid waste landfill
Surface Casing 14" diam. X 10' long.

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
Drive barrel	2/11/87	1417	2/23/87	0920
Hard tool	2/23/87	1235	3/3/87	1502
Geophys. Logging:	3/3/87	1547	3/3/87	1645
Casing:				
14" surface c.s.	2/11/87	1438	2/11/87	1428
10" carbon steel	2/12/87	1257	3/3/87	1548
6" stainless steel	3/4/87	1314	3/4/87	1439
Filter Placement:	3/4/87	1135	3/5/87	0805
Cementing:	3/9/87	1233		
Development:	3/10/87	0745	3/11/87	1045
Other:				
Volclay pellets	3/5/87	0813	3/5/87	0910
Volclay grout	3/9/87	1114	3/9/87	1145

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

From	To	String	
0	10'	C1	(REMOVED)
+1	144 3/4"	C2	(REMOVED)
+2'	122'	C3	
122'	137'	S1	

Casing: C1 14" diam. carbon steel
C2 10" diam. carbon steel
C3 6" diam. stainless steel
C4

Screen: S1 6" diam 30-slot stainless steel
S2
S3
S4

Centralizers one at 114' (23' up from bottom of screen)

Filter Material 8-12 mesh silica sand
10-20 mesh silica sand
Cement Portland Cement
Other Sand placed from 142-118'
Volclay pellets placed from 118-112'
Volclay grout placed from 112'-4'
cement placed from 4' to surface.

Comments:
Drive barrel from surface to 90'.
Hard tool from 90' to 145'
Added 16 bags of 8-12 sand
Added 3 1/3 bags of 10-20 sand
Added 7 buckets of Volclay pellets.
Added 35 bags of Volclay grout
Added 19 bags of cement
TOTAL LENGTH OF CASING + SCREEN MEAS. FROM SURFACE IS 139' 4 1/2". BOTTOM OF SCREEN IS 136' 10" BELOW SURFACE, OR 137' 2" BELOW TOP OF PAD

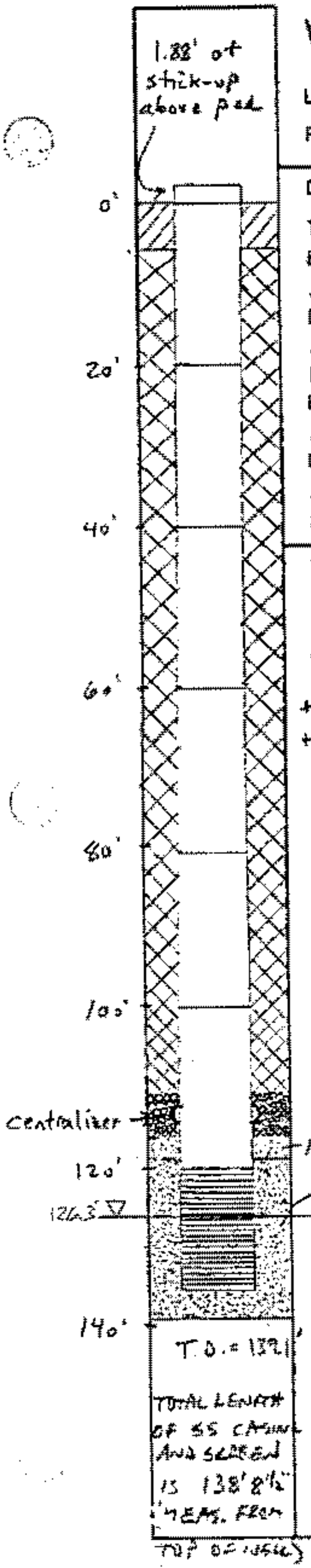
Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

Well Construction Summary

JAJ-1911-RHo   Well SW-5

Location: Solid Waste Landfill   Elevation: Ground Level (brass plate) 530.67' above MSL

Personnel: Hasen   Top of Casing 532.58' above MSL



DRILLING SUMMARY:

Total Depth: Drilled 140-141' measured 139.1' (H₂O = 126.3')

Borehole Diameter: 10"

Driller: D. Ludtke, K. Olsen

Rig: Cable Tool Red 22W

Bit(s): Drive barrel, hard tool

Drilling Fluid: Water

Surface Casing: 14" diam x 10' long

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

0 - 10'	C1	(removed)	
+1.7' - 132.5'	C2	(removed)	
+2' - 121'	C3		
121' - 136'	S1		

Casing: C1 14" diam. Carbon steel
C2 10" diam. Carbon steel
C3 6" diam. stainless steel
C4

Screen: S1 30-slot, 6" stainless steel
S2
S3
S4

Centralizers: 1 placed at 113' (23' above bottom of screen)

Filter Material: 8-12 and 10-20 mesh silica sand

Cement

Other: Volclay grout
Hydrophyllic tablets (bentonite pellets).

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
Drive barrel	3/2/87	1537	3/4	1100
hard tool	3/11	1158	3/13	1126
Geophys. Logging:	3/13	1221	3/13	1325
Casing:				
14" diam surface	3/2/87	1034	3/2/87	1324
10" diam	3/3/87	0946	3/4/87	1218
Filter Placement:	3/13/87	1429	3/17/87	0935
Cementing:	3/20/87	1251	4/6/87	1030
Development:	3/23/87	0735	3/23/87	1130
Other:				
Pellets	3/17/87	0943	3/17/87	0945
Volclay grout	3/17/87	1015	3/20/87	1105

Comments:
Sand (8-12, 10-20) placed from 139-116.5'
Pellets placed from 116.5'-111'
Volclay grout placed from 111-6.5'
Cement placed from 6.5'-0'
Used 13 bags of 8-12 Sand
Used 1 bag of 10-20 sand
Used 4 buckets of pellets
Used 31 bags of Volclay grout
Used ~10 bags of Portland cement.
Drive barrel used from 0-77'
Hard tool used from 77-141'

Key:
Bentonite; Sand; Cement/Grout; Silt; Sand Pack; Clay; Drill Cuttings; Screen; Gravel

Well Construction Summary

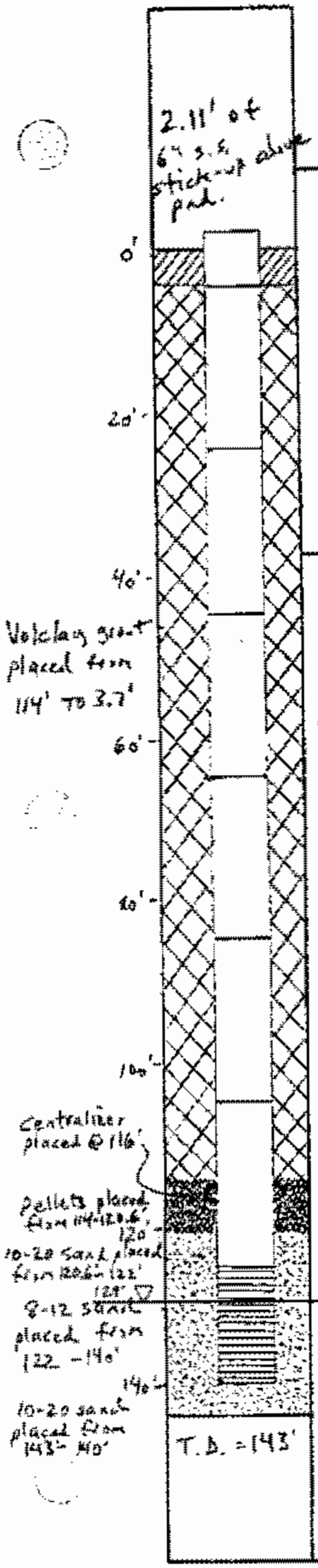
SW-6

Location: Solid Waste Landfill

Elevation: Ground Level (brass plate) 533.35' above MSL

Personnel: HAKEN JAJ-1911-RHO

Top of Casing 535.46' above MSL



DRILLING SUMMARY:

Total Depth 143' (Dtw = 129')

Borehole Diameter 10"

Driller H. Jay / D. Garcia

Rig Cable Tool, C556

Bit(s) Drive barrel, hard tool

Drilling Fluid water

Surface Casing 14" diam x 10' long

WELL DESIGN:

Basis:

Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

0 - 10' C1 (removed)

+1.78 - 141' C2 (removed)

+2.5 - 124.2 C3

123.2 - 138.5 S1

Casing: C1 14" diam. carbon steel

C2 10" diam. carbon steel

C3 6" diam. stainless steel

C4

Screen: S1 30-slot, 6" diam. stainless steel

S2

S3

S4

Centralizers One, placed 8' above top joint of screen (@ 115.5')

Filter Material 10-20 and 8-12 mesh silica sand (Colorado S.S.)

Cement Portland Cement, MORTAR-MIX CONCRETE (PRE-MIX) FOR PAD

Other Volclay grout (bentonite) Hydrophyllic tablets (pellets)

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
Drive barrel	3/16	0826	3/19	0755
hard tool	3/19	0904	3/27	0831
Geophys. Logging:	3/26	1421	3/26	1535
Casing:				
14" carbon steel	3/16	0913	3/16	0918
10" carbon steel	3/16	1240	3/26	1325
6" stainless steel	3/27	1205	3/27	1358
Filter Placement:	3/27	0930	3/30	1400
Cementing:	4/9	0800	4/15	
Development:	4/9	1042	4/9	1440
Other:				
Volclay pellets	3/30	1440	3/30	1445
Volclay grout	3/31	1242	4/8	1500

Comments:

Drive barrel from 0'-87'

hard tool from 87'-143'

Added 9 bags of 8-12 sand

Added 4 bags of 10-20 sand

Added 4 buckets of Hydrophyllic Tablets

Added 55 bags of Volclay grout

Added ? bags of Portland cement

Key:

- Bentonite
- Sand
- Cement/Grout
- Silt
- Sand Pack
- Clay
- Drill Cuttings
- Screen
- Gravel

FINISHED WELL SPECIFICATIONS

Finished well specifications include surveyed elevations (National Geodetic Survey-NGS) and horizontal coordinates (Lambert), drilling information, well completion data, well development and aquifer test descriptions, and remarks on well construction and pump installation.

Well 699-24-35

Well Location and Elevation

Temporary Well Number: SW-1
Permanent Well Number: 699-24-35
Lambert Coordinates: N 429,562.90, E 2,260,059.50
Well-Pad Elevation (brass plate): 536.52 ft
Stainless-Steel Casing Elevation: 538.81 ft
Depth Water First Encountered: 132.5 ft below surface (2/13/87)
Water Surface Depth Before Development: 132.3 ft below surface (2/17/87)

Drilling Information

Drilling Company: Onwego Drilling
Drilled Depth of Well: 14.5 ft
Measured Depth of Well: 146.0 ft
Drilled Diameter of Well: 10 in.
Drill Rig Type: Bucyrus Erie 22W Cable Tool
Depth Drilled by Drive Barrel: surface to 85 ft
Depth Drilled by Hard Tool: 85 to 145.5 ft
Lithologies Encountered in Drilling: sand, slightly silty sand, silty sand, slightly gravelly sand, gravelly sand, sandy gravel, gravel
Oate Began, Completed Drilling: 2/3/87, 2/13/87

Well Completion Information

Depth of Temporary Steel Casing: 146.6 ft
Permanent Casing Type, Length, and Diameter: 304 stainless steel; 129.86 ft; 6-in. dia
Screen Type, Slot-Size, and Length: 304 stainless steel, continuous slot with bottom plate; 10-in. dia 40-slot and 6-in. dia 30-slot; each 15.25 ft long
Screened Interval: 127.75 to 143 ft below surface
Total Length of Casing and 6-in.-dia Screen in Well: 145.16 ft
Filter Material: 8-12 and 10-20 mesh Colorado Silica Sand
Filter Placement: 8-12 sand from 146.0 to ~128 ft; 10-20 sand from ~128 ft to ~125 ft
Quantity of Filter Materials (dry wt): 800 lb of 8-12 sand; 200 lb of 10-20 sand
Annular Seal Materials: bentonite-based Volclay pellets and grout and Portland Cement

Annular Seal Placement: Volclay pellets from ~125 to 118.5 ft; Volclay grout from 118.5 to 5 ft; Portland Cement from 5 ft to the surface
Quantity of Annular Seal Materials (dry wt): 200 lb of Volclay pellets; 1352 lb of Volclay grout; 564 lb of Portland Cement
Type and Placement of Centralizer: stave - 123 ft below surface
Height of Casing Stick-Up Above Pad: 2.27 ft
Date Well Completed: 3/2/87

Well Development Information

Method of Well Development: Dart bailer - step drawdown (4 steps) and continuous discharge aquifer tests
Duration and Magnitude of Discharge: bailed for 5.5 h - 420 gpm for 50 min, 520 gpm for 15 min, 750 gpm for 50 min, 775 gpm for 20 min; 750 gpm for 2 h
Water Appearance After Development: clear, after pump tests

Aquifer Test Information

Type of Aquifer Test Performed: step drawdown and continuous discharge
Pumping Rates Achieved: 420, 520, 750, 775 gpm
Maximum Drawdown of Water Surface: 0.98 ft
Date(s) of Aquifer Test(s): 2/18/87 and 2/20/87

Remarks on Well Construction

On completion of the geophysical logging, a 10-in.-dia telescoping stainless-steel screen was set on a sand pack of 8-12 mesh silica sand. The screen settled to 143 ft after pulling the carbon steel casing back to expose the screen. The well was developed for 5.5 h using a dart bailer before a turbine pump was installed in the well. After the aquifer tests were performed and the turbine was removed, a 6-in.-dia stainless-steel screen and casing was set inside the 10-in.-dia screen.

A centralizer was affixed to the stainless-steel casing, 20 ft above the bottom of the screen. This screen was sealed in the Volclay pellet zone to minimize potential contamination arising from ground water coming into contact with welds on the centralizer. These welds were not performed in a helium atmosphere (as requested by the drilling company), but instead were welded using a flux. The flux is a potential aquifer contaminant when allowed to interact with vadose-zone water.

The annular space was filled with silica sand, Volclay pellets and grout, and Portland Cement. Each was added as the carbon-steel casing was withdrawn from the well following the specifications outlined in the statement of work.[a] Only the Volclay grout was added to the well via the tremie pipe method. After filling the annular space, the well was checked for development using a dart bailer for 30 min. The water was clear (from the aquifer tests) so the pad and posts were set to complete the well.

A Peabody Barnes 1/2-horse power electric submersible pump was installed approximately 2 ft above the bottom of the well (water intake located about 6 ft beneath the water surface). The pump is attached to 1.5-in.-dia ABS plastic pipe that extends to the surface.

Well 699-23-34

Well Location and Elevation

Temporary Well Number: SW-2
Permanent Well Number: 699-23-34
Lambert Coordinates: N 428,374.81, E 2,261,074.22
Well-Pad Elevation (brass plate): 530.50 ft
Stainless-Steel Casing Elevation: 532.86 ft
Depth Water First Encountered: 125.9 ft below surface (1/22/87)
Water Surface Depth Before Development: 125.9 ft below surface (1/30/87)

Drilling Information

Drilling Company: Onwego Drilling
Drilled Depth of Well: 139 ft
Measured Depth of Well: 139 ft
Drilled Diameter of Well: 10 in.
Drill Rig Type: Bucyrus Erie 22W Cable Tool
Depth Drilled by Drive Barrel: surface to 95 ft
Depth Drilled by Hard Tool: 95 to 139 ft
Lithologies Encountered in Drilling: sand, slightly silty sand, silty sand, slightly gravelly sand, gravelly sand, silty sandy gravel, sandy gravel
Date Began, Completed Drilling: 1/9/87, 1/21/87

Well Completion Information

Depth of Temporary Steel Casing: 139 ft
Permanent Casing Type, Length, and Diameter: 304 stainless steel; 123.42 ft; 6-in. dia
Screen Type, Slot-Size, and Length: 304 stainless steel, continuous slot with bottom plate; 30-slot; 15.25 ft.
Screened Interval: 120.95 to 136.2 ft below surface
Total Length of Casing and 6-in.-dia Screen in Well: 138.67 ft
Filter Material: 8-12 and 10-20 mesh Colorado Silica Sand

(a) Pacific Northwest Laboratory. 1986. "Statement of Work, Well Drilling, 600 Area Solid Waste Landfill." PNL-SOW.600SW, Pacific Northwest Laboratory, Richland, Washington.

Filter Placement: 8-12 mesh sand placed from 139 to ~122 ft; 10-20 sand placed from ~122 to 118 ft
Quantity of Filter Materials (dry wt): 900 lb of 8-12 mesh sand; 250 lb of 10-20 mesh sand
Annular Seal Materials: bentonite-based Volclay pellets and grout and Portland Cement
Annular Seal Placement: Volclay pellets from 118 to 112 ft; Volclay grout from 112 to 7 ft; Portland Cement from 7 ft to surface
Quantity of Annular Seal Materials (dry wt.): 200 lb of Volclay pellets; 1248 lb of Volclay grout; 1598 lb of Portland Cement
Type and Placement of Centralizer: stave - 113 ft below surface
Height of Casing Stick-Up Above Pad: 2.35 ft
Date Well Completed: 1/30/87

Well Development Information

Method of Well Development: dart bailer
Duration of Development: nearly 2 h
Water Appearance After Development: Water contains fine to very fine sand; color is light brown

Remarks on Well Construction

This well was constructed following the specifications outlined in the statement of work. The centralizer was placed 8 ft above the top of the screen within the Volclay pellet-grout zone to keep it away from the filter. Because the welds on the centralizer were made using a flux [(stick-welded), a potential contaminant source], the centralizer should not come into contact with ground water.

The drive shoe contained two cracks after it was removed from the well. None of the annular materials were added to the well via the tremie pipe method.

A small amount of Volclay bentonite grout was found on the steel tape used in measuring the depth of the well after the well was completed. This grout may have entered the well from a loose joint in the stainless-steel casing, because, when the last piece of stainless steel casing was attached after all the grout was added, the casing string turned more than necessary to screw on the last piece of casing. This grout was removed by bailing the well for about 2 h.

A Peabody Barnes 1/2-horse power electric submersible pump was installed approximately 2 ft off the bottom of the well (water intake located approximately 6 ft below the water surface). The pump is attached to 1.5-in.-dia ABS plastic pipe that extends to the surface.

Well 699-24-34A

Well Location and Elevation

Temporary Well Number: SW-3
Permanent Well Number: 699-24-34A
Lambert Coordinates: N 428,758.47, E 2,261,193.41
Well-Pad Elevation (brass plate): 531.71 ft
Stainless-Steel Casing Elevation: 533.89 ft
Depth Water First Encountered: 127.6 ft below surface (1/29/87)
Water Surface Depth Before Development: 127.1 ft below surface (1/30/87)

Drilling Information

Drilling Company: Onwego Drilling
Drilled Depth of Well: 141.5 ft
Measured Depth of Well: 140.0 ft
Drilled Diameter of Well: 10 in.
Drill Rig Type: Bucyrus Erie 22W Cable Tool
Depth Drilled by Drive Barrel: surface to 107 ft
Depth Drilled by Hard Tool: 107 to 141.5 ft
Lithologies Encountered in Drilling: sand, gravelly silty sand, gravelly sand, sandy gravel, gravel
Date Began, Completed Drilling: 1/19/87, 1/29/87

Well Completion Information

Depth of Temporary Steel Casing: 141.5 ft
Permanent Casing Type, Length, and Diameter: 304 stainless steel; 124.76 ft long; 6-in. dia
Screen Type, Slot-Size, and Length: 304 stainless steel, continuous slot with bottom plate; 10-in.-dia 40-slot, 6-in.-dia 30-Slot; each 15.25 ft long
Screened Interval: 122.3 to 137.5 ft below surface for the 6-in.-dia. screen; 122.75 to 138 ft for the 10-in.-dia telescoping screen
Total Length of Casing and 6-in.-dia Screen in Well: 140.01 ft
Filter Material: 8-12 and 10-20 mesh Colorado Silica Sand
Filter Placement: 8-12 mesh sand from 140 to ~138.5 ft; 10-20 sand from ~138.5 to 138 ft; 8-12 mesh sand from 138 to 122.8 ft; 10-20 mesh sand from 122.8 to 118 ft
Quantity of Filter Materials (dry wt): 600 lb of 8-12 mesh sand; 350 lb of 10-20 mesh sand
Annular Seal Materials: bentonite-based Volclay pellets and grout and Portland Cement
Annular Seal Placement: Volclay pellets from 118 to 113 ft; Volclay grout from 113 to 6 ft; Portland Cement from 6 ft to the surface
Quantity of Annular Seal Materials (dry wt): 200 lb of Volclay pellets; 1872 lb of Volclay grout; 658 lb of Portland Cement

Type and Placement of Centralizer: stave - 117.5 ft below surface
Height of Casing Stick-Up Above Pad: 2.17 ft
Date Well Completed: 2/9/87

Well Development Information

Method of Well Development: dart bailer; step-drawdown (3 steps) and continuous discharge aquifer tests
Duration and Magnitude of Discharge: bailed for 1 h; pumped for 1 h at 330 gpm, 1 h at 450 gpm, 1 h at 680 gpm; 45 min between 436 to 700 gpm
Water Appearance After Development: clear

Aquifer Test Information

Type of Aquifer Test Performed: step-drawdown and continuous discharge
Pumping Rates Achieved:s 330, 450, 680, and between 436 to 700 gpm
Maximum Drawdown of Water Surface: 0.6 ft
Date(s) of Aquifer Test(s): 1/31/87

Remarks on Well Construction

On completion of drilling and geophysical logging, 10-in.-dia telescoping stainless-steel screen (40-slot) was set on a sand pack of 8-12 and 10-20 mesh silica sand. When the carbon-steel casing was pulled back to 128.6 ft, the screen bottom settled to 138 ft. The well was then developed for 1 h using a dart bailer. A turbine pump was installed in the well and an aquifer test was performed. On completion of the aquifer test, the depth to bottom in the screen was 137.5 ft below the surface. A 6-in.-dia stainless-steel screen was then set in the well (the 10-in.-dia screen was not removed). The centralizer was placed 20 ft above the bottom of the screen in order to locate it in the Volclay pellet zone; this was done to minimize the amount of contamination that may occur when water contacts the welds on the centralizer. These welds were not made in a helium atmosphere but instead were performed using a flux. As a result, these welds are less stable in an oxidizing environment (i.e., within the vadose zone) and the flux may release contaminants to the aquifer unless kept from water.

The annular space was filled, according to the specifications given in the statement of work, with silica sand, Volclay tablets and grout, and Portland Cement as the temporary carbon-steel casing was withdrawn (see above information for filled annulus intervals). Only Volclay grout was added to the well using a tremie pipe. The well was checked for development using a dart bailer for 14 min. The water was clear, so the well needed no further development.

A Peabody Barnes 1/2-horse power electric submersible pump was installed about 2 ft off the bottom of the well (water intake located approximately 6 ft beneath the water surface). The pump is attached to 1.5-in.-dia ABS plastic pipe that extends to the surface.

Well 699-24-34B

Well Location and Elevation

Temporary Well Number: SW-4
Permanent Well Number: 699-24-34B
Lambert Coordinates: N 429,093.43, E 2,261,297.36
Well-Pad Elevation (brass plate): 531.28 ft
Stainless-Steel Casing Elevation: 533.50 ft
Depth Water First Encountered: 127.0 ft below surface (3/4/87)
Water Surface Depth Before Development: 127.0 ft below surface (3/9/87)

Drilling Information

Drilling Company: Onwego Drilling
Drilled Depth of Well: 145 ft (as measured by driller)
Measured Depth of Well: 142.3 ft (steel tape)
Drilled Diameter of Well: 10 in.
Drill Rig Type: Bucyrus Erie 22W Cable Tool
Depth Drilled by Drive Barrel: surface to 90 ft
Depth Drilled by Hard Tool: 90 ft to 145 ft
Lithologies Encountered in Drilling: sand, gravelly sand, sandy gravel, gravel
Date Began, Completed Drilling: 2/11/87, 3/3/87

Well Completion Information

Depth of Temporary Steel Casing: 144.0 ft
Permanent Casing Type, Length, and Diameter: 304 stainless steel; 124.03 ft long; 6-in. dia
Screen Type, Slot-Size, and Length: 304 stainless steel, continuous slot with bottom plate; 30-slot; 15.25 ft
Screened Interval: 121.6 to 136.8 ft below surface
Total Length of Casing and 6-in.-dia Screen in Well: 139.28 ft
Filter Material: 8-12 and 10-20 mesh Colorado Silica Sand
Filter Placement: 8-12 mesh sand placed from 142.3 to ~139 ft; 10-20 mesh sand placed from ~f139 to ~136 ft; 8-12 mesh sand from ~136 to ~128 ft; 10-20 mesh sand from ~128 to 125.5 ft; 8-12 mesh sand from 125.5 to ~121 ft; 10-20 mesh sand from ~121 to ~119 ft
Quantity of Filter Materials (dry wt): 1000 lb of 8-12 mesh sand; 370 lb of 10-20 mesh sand
Annular Seal Materials: bentonite-based Volclay pellets and grout and Portland Cement Annular Seal Placement:
Volclay pellets from ~119 to 112 ft;
Volclay grout from 112 to 4.3 ft; Portland Cement from 4.3 ft to surface
Quantity of Annular Seal Materials (dry wt): 350 lb of Volclay pellets; 1820 lb of Volclay grout; 1410 lb of Portland Cement
Type and Placement of Centralizer: stave - located at 114 ft below surface
Height of Casing Stick-Up Above Pad: 2.21 ft

Date Well Completed: 3/11/87

Well Development Information

Method of Well Development: dart bailer
Duration of Development: 3 h
Water Appearance After Development: water contained very fine sand and some coarse sand (from filter); water color was light brown

Remarks on Well Construction

This well was constructed following the specifications outlined in the statement of work. Because the centralizer was welded together using flux from stick-welding techniques rather than welding in a helium atmosphere, the centralizer was placed 23 ft above the bottom of the screen so as to seal it in the Volclay pellet and grout. This was done to minimize the quantity of water coming into contact with potentially reactive flux on the welds of the centralizer and thus minimize potential contamination from corrosion of these welds.

This well needed three additional buckets of Volclay pellets because of an open zone at approximately 116 to 120 ft below the surface. Of all the annular materials placed in the well, only the Volclay grout was added using a tremie pipe.

The drive shoe at the end of the casing string had at least three long (2 to 4 in.) cracks at its lower-most end.

A Peabody Barnes 1/2-horse power electric submersible pump was installed approximately 2 ft off the bottom of the well (water intake located about 6 ft below the water surface). The pump is attached to 1.5-in.-dia ABS plastic pipe that extends to the surface.

Note: Chevron Poly FM Grease 2 (food grade) was used on stainless steel joints (threaded ends) during casing assembly.

Well 699-25-34C

Well Location and Elevation

Temporary Well Number: SW-5
Permanent Well Number: 699-25-34C
Lambert Coordinates: N 429,472.15, E 2,261,409.71
Well-Pad Elevation (brass plate): 530.67 ft
Stainless-Steel Casing Elevation: 532.58 ft
Depth Water First Encountered: 126.3 ft below surface (3/12/87)
Water Surface Depth Before Development: 126.0 ft below surface (3/20/87)

Drilling Information

Drilling Company: Onwego Drilling
Drilled Depth of Well: 140-141 ft
Measured Depth of Well: 139.1 ft
Drilled Diameter of Well: 10 in.
Drill Rig Type: Bucyrus Erie 22W Cable Tool
Depth Drilled by Drive Barrel: surface to 77 ft
Depth Drilled by Hard Tool: 77 to 141 ft
Lithologies Encountered in Drilling: sand, silty sand, slightly gravelly sand, gravelly sand, sandy gravel, gravel
Date Began, Completed Drilling: 3/2/87, 3/13/87

Well Completion Information

Depth of Temporary Steel Casing: 139.6 ft
Permanent Casing Type, Length, and Diameter: 304 stainless steel; 123.4-ft long; 6-in. dia
Screen Type, Slot-Size, and Length: 304 stainless steel, continuous slot with bottom plate; 30-slot; 15.33 ft
Screened Interval: 120.9 to 136.2 ft below surface
Total Length of Casing and 6-in.-dia Screen in Well: 138.72 ft
Filter Material: 8-12 and 10-20 mesh Colorado Silica Sand
Filter Placement: 8-12 mesh sand placed from 139.1 to ~119 ft; 10-20 mesh sand from ~119 to ~117 ft
Quantity of Filter Materials (dry wt): 1300 lb of 8-12 mesh sand; 100 lb of 10-20 mesh sand
Annular Seal Materials: bentonite-based Volclay pellets and grout and Portland Cement
Annular Seal Placement: Volclay pellets from ~117 to ~112 ft; Volclay grout from ~112 to 6.5 ft; Portland Cement from 6.5 ft to surface
Quantity of Annular Seal Materials (dry wt): 200 lb of Volclay pellets; 1612 lb of Volclay grout; 564 lb of Portland Cement
Type and Placement of Centralizer: stave - placed at 113 ft below surface
Height of Casing Stick-Up Above Pad: 1.88 ft
Date Well Completed: 4/6/87

Well Development Information

Method of Well Development: dart bailer
Duration of Development: 3.5 h
Water Appearance After Development: water contained fine sand and was light brown in color

Remarks on Well Construction

This well was constructed following the specifications given in the statement of work. Any deviations from this procedure are given below.

The centralizer was placed 23 ft above the bottom of the screen to locate it within the Volclay pellet and grout zone; this was necessary to minimize the potential contact between ground water and welds on the centralizer. These welds were not made in a helium atmosphere (heli-arc welding), but were instead "stick-welded" with a flux. This flux may be a contaminant if it comes into contact with the aquifer. None of the annular materials were added to the well using the tremie pipe method. See the above information for depth intervals of materials placed in the well annulus.

A Peabody Barnes 1/2-horse power electric submersible pump was installed approximately 2 ft above the bottom of the well (water intake located about 6 ft below the water surface). The pump is attached to 1.5-in.-dia ABS plastic pipe that extends to the surface.

Note: Chevron Poly FM Grease 2 (food grade) was used on stainless steel joints (threaded ends) during casing assembly.

Well 699-25-34C

Well Location and Elevation

Temporary Well Number: SW-6
Permanent Well Number: 699-25-34
Lambert Coordinates: N 429,967.73, E 2,261,561.70
Well-Pad Elevation (brass plate): 533.35 ft
Stainless-Steel Casing Elevation: 535.46 ft
Depth Water First Encountered: 129.6 ft below surface (3/27/87)
Water Surface Depth Before Development: 128.9 ft below surface (4/9/87)

Drilling Information

Drilling Company: Onwego Drilling
Drilled Depth of Well: 143 ft
Measured Depth of Well: 143.0 ft
Drilled Diameter of Well: 10 in.
Drill Rig Type: Bucyrus Erie 22W Cable Tool
Depth Drilled by Drive Barrel: surface to 87 ft
Depth Drilled by Hard Tool: 87 to 143 ft
Lithologies Encountered in Drilling: sand, silty sand, slightly gravelly sand, gravelly sand, sandy gravel
Date Began, Completed Drilling: 3/16/87, 3/27/87

Well Completion Information

Depth of Temporary Steel Casing: 141.0 ft
Permanent Casing Type, Length, and Diameter: 304 stainless steel; 125.54-ft long; 6 in. dia
Screen Type, Slot-Size, and Length: 304 stainless steel, continuous slot with bottom plate; 30-slot; 15.33 ft
Screened Interval: 123.2 to 138.5 ft below surface
Total Length of Casing and 6-in.-dia Screen in Well: 140.87 ft
Filter Material: 8-12 and 10-20 mesh Colorado Silica Sand
Filter Placement: 10-20 mesh sand from 143.0 to ~139 ft; 8-12 mesh sand from ~139 to 122 ft; 10-20 mesh sand from 122 to 120.6 ft
Quantity of Filter Materials (dry wt): 900 lb of 8-12 mesh sand; 400 lb of 10-20 mesh sand
Annular Seal Materials: bentonite-based Volclay, Hydrophyllic pellets, Volclay grout, and Portland Cement
Annular Seal Placement: Bentonite pellets from 120.6 to ~114 ft; Volclay grout from ~114 to 3.5 ft; Portland Cement from 3.5 ft to surface
Quantity of Annular Seal Materials (dry wt): 200 lb of Volclay and Hydrophyllic pellets; 2860 lb of Volclay grout; 188 lb of Portland Cement
Type and Placement of Centralizer: stave - 115.5 ft below surface
Height of Casing Stick-Up Above Pad: 2.11 ft
Date Well Completed: 4/15/87

Well Development Information

Method of Well Development: dart bailer
Duration of Development: 3 h
Water Appearance After Development: water contained fine to very fine sand; color was light brown

Remarks on Well Construction

This well was constructed following the specifications given in statement of work. After the well was drilled, the stainless-steel screen and casing were set on 10-20 mesh silica sand (8-12 mesh sand was unavailable at that time). Sand (8-12 mesh) was placed around the entire length of the screen, and then 10-20 mesh sand was placed above the screen.

After the bentonite pellets were set, the site geologist added water before leaving for the day. This water caused the pellets to swell and bridge across the inside of the 10-in.-dia casing. When the 10-in. casing was pulled back, the stainless-steel casing was brought up also. A bumper bar was used to tap on the bottom of the screen to reset the stainless-steel screen and casing. The stainless-steel screen was reset to within 6 to 7 in. of the desired placement by this method. Volclay grout was added to the well before beginning this process to provide positive pressure on the bridge to help break it.

A zone of lost circulation was intersected when adding the Volclay grout. During 1 day's operations nearly one half of the total amount of Volclay grout used (1404 lb dry weight) was installed in the well; this raised the grout level in the borehole from 87 to 80 ft below the surface. A plug of grout 40-ft thick was left in the borehole the previous night. Another grout plug, which was 8-ft thick, was left in the borehole overnight after adding the large quantity of grout. The grout that moved into the formation and hardened, however, was probably responsible for sealing this open zone because much better progress was made when adding grout the next day. Volclay grout was the only annular material added to the well by the tremie pipe method.

A Peabody Barnes 1/2-horse power electric submersible pump was installed approximately 2 ft off the bottom of the well (water intake located about 6 ft below the water surface). The pump is attached to 1.5-in.-dia ABS plastic pipe that extends to the surface.

Note: Chevron Poly FM Grease 2 (food grade) was used on stainless steel joints (threaded ends) during casing assembly.

APPENDIX B

COMPLETION DIAGRAMS, LITHOLOGIC DIAGRAMS, AND GEOPHYSICAL LOGGING RESULTS

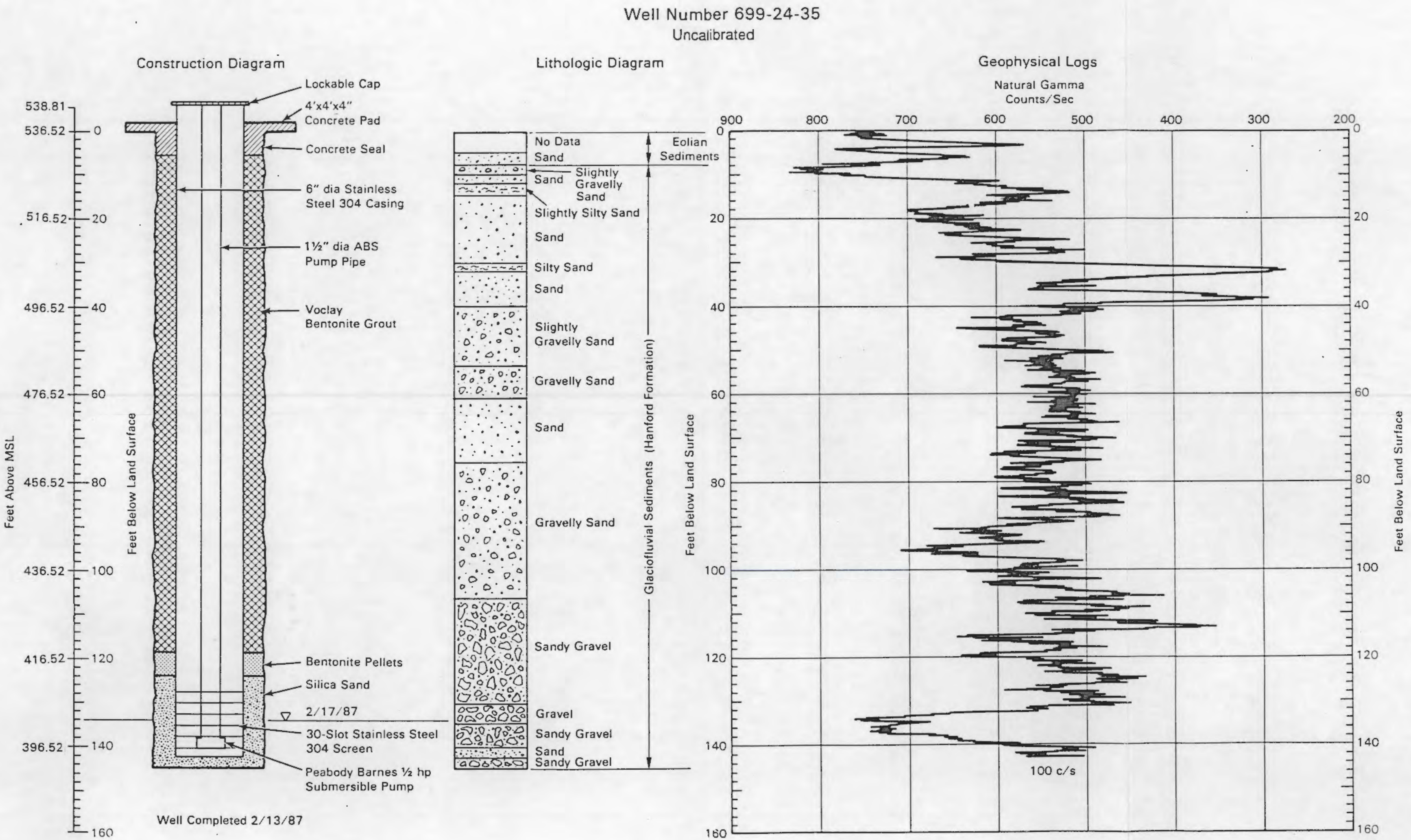
APPENDIX B

COMPLETION DIAGRAMS, LITHOLOGIC DIAGRAMS, AND GEOPHYSICAL LOGGING RESULTS

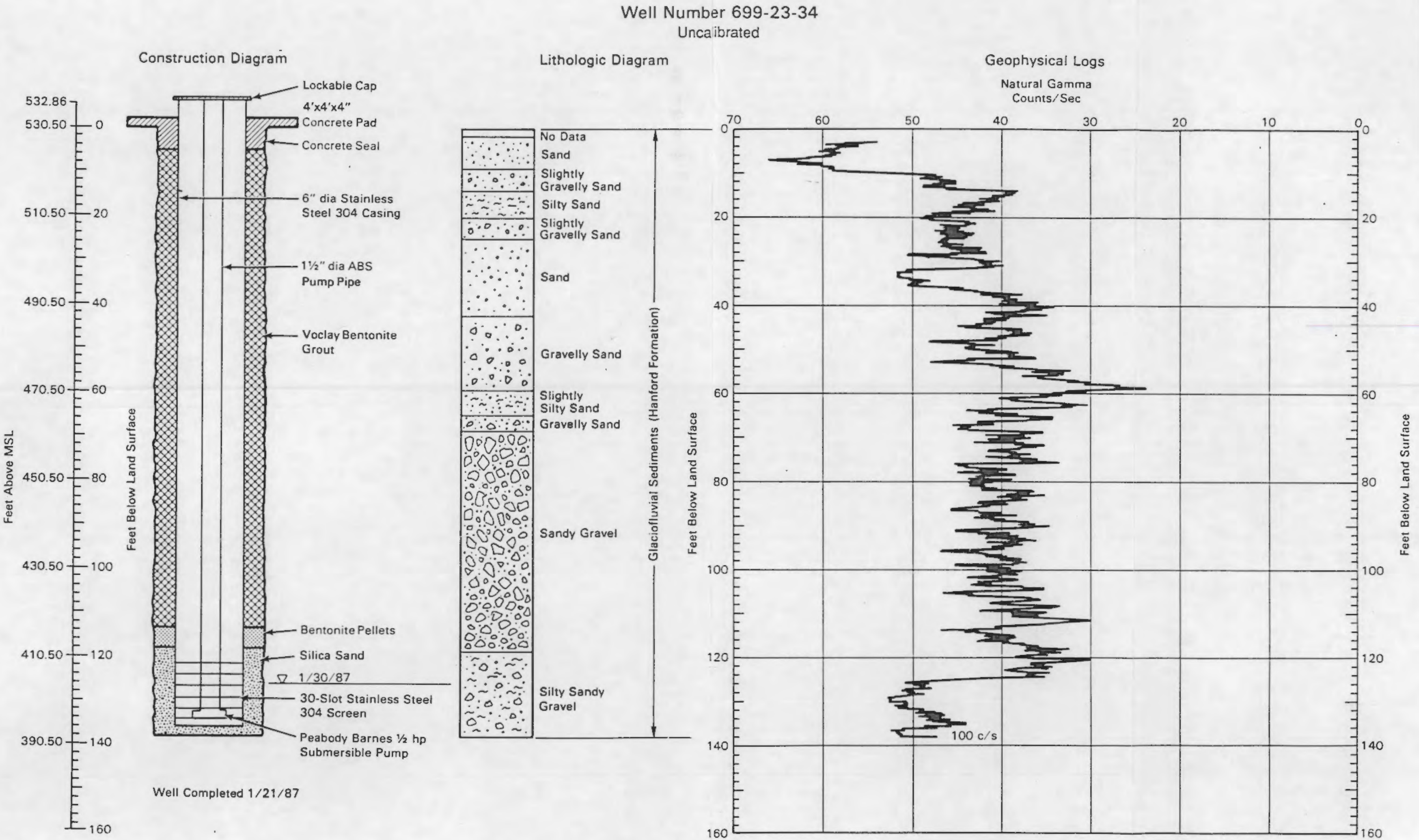
This appendix contains a completion diagram, lithologic diagram based on field observations, and the natural gamma geophysical log for each of the wells drilled near the Solid Waste Landfill. These wells are

- 699-24-35 (upgradient)
- 699-23-34 (downgradient)
- 699-24-34A (downgradient)
- 699-24-34B (downgradient)
- 699-24-34C (downgradient)
- 699-25-34C (downgradient).

Please note that the natural gamma geophysical logs are uncalibrated.

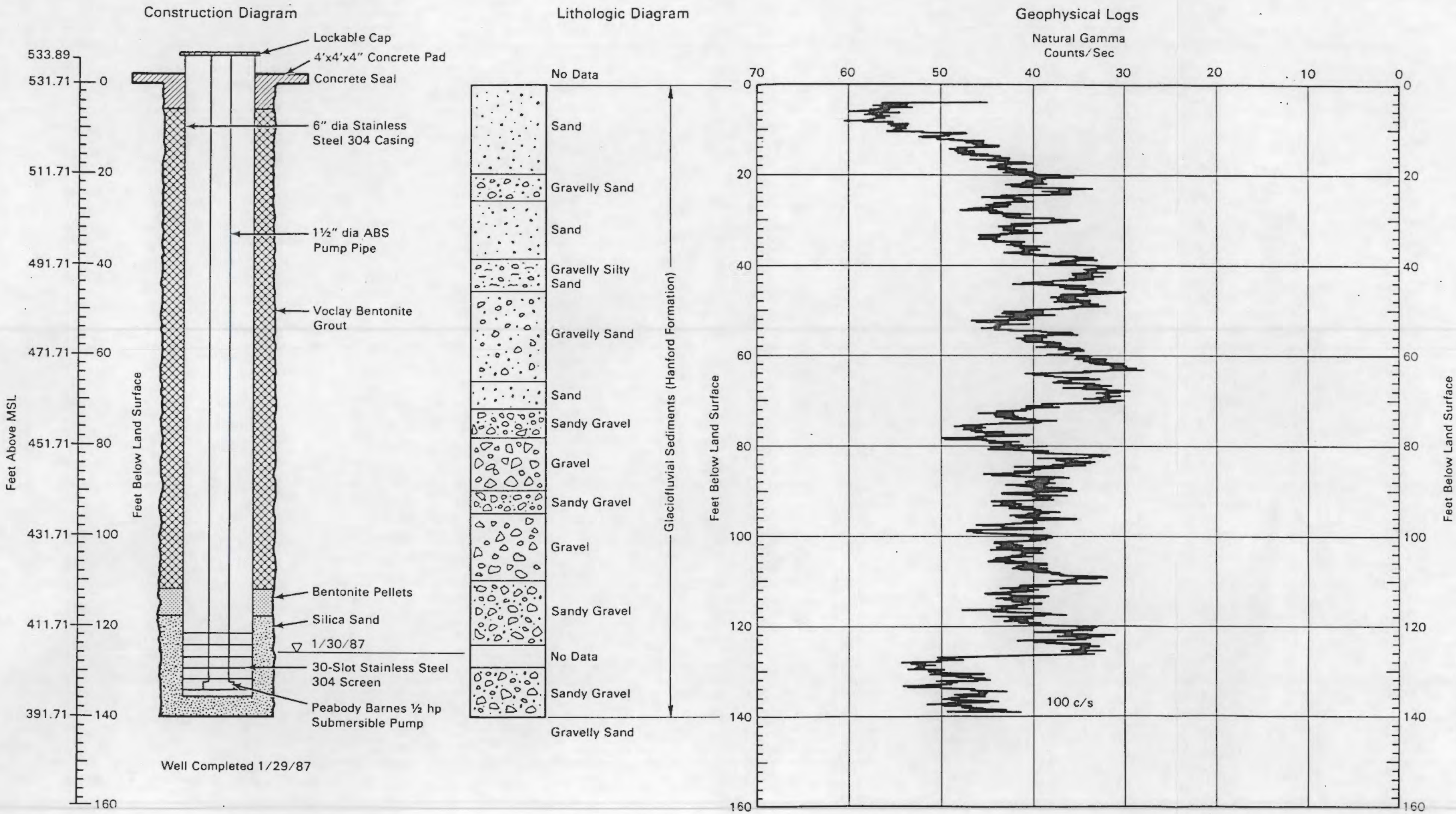


Well Number 699-24-35
Uncalibrated
Construction Diagram
Lithologic Diagram
Geophysical Logs
Lockable Cap
4'x4'x4" Concrete Pad
Concrete Seal
6" dia Stainless Steel 304 Casing
1½" dia ABS Pump Pipe
Voclay Bentonite Grout
Bentonite Pellets
Silica Sand
2/17/87
30-Slot Stainless Steel 304 Screen
Peabody Barnes ½ hp Submersible Pump
Well Completed 2/13/87
Feet Above MSL
Feet Below Land Surface
538.81
536.52
516.52
496.52
476.52
456.52
436.52
416.52
396.52
No Data
Sand
Sand
Slightly Gravelly Sand
Slightly Silty Sand
Sand
Silty Sand
Sand
Slightly Gravelly Sand
Gravelly Sand
Sand
Gravelly Sand
Sandy Gravel
Gravel
Sandy Gravel
Sand
Sandy Gravel
Eolian Sediments
Glaciofluvial Sediments (Hanford Formation)
Natural Gamma Counts/Sec
900
800
700
600
500
400
300
200
100 c/s

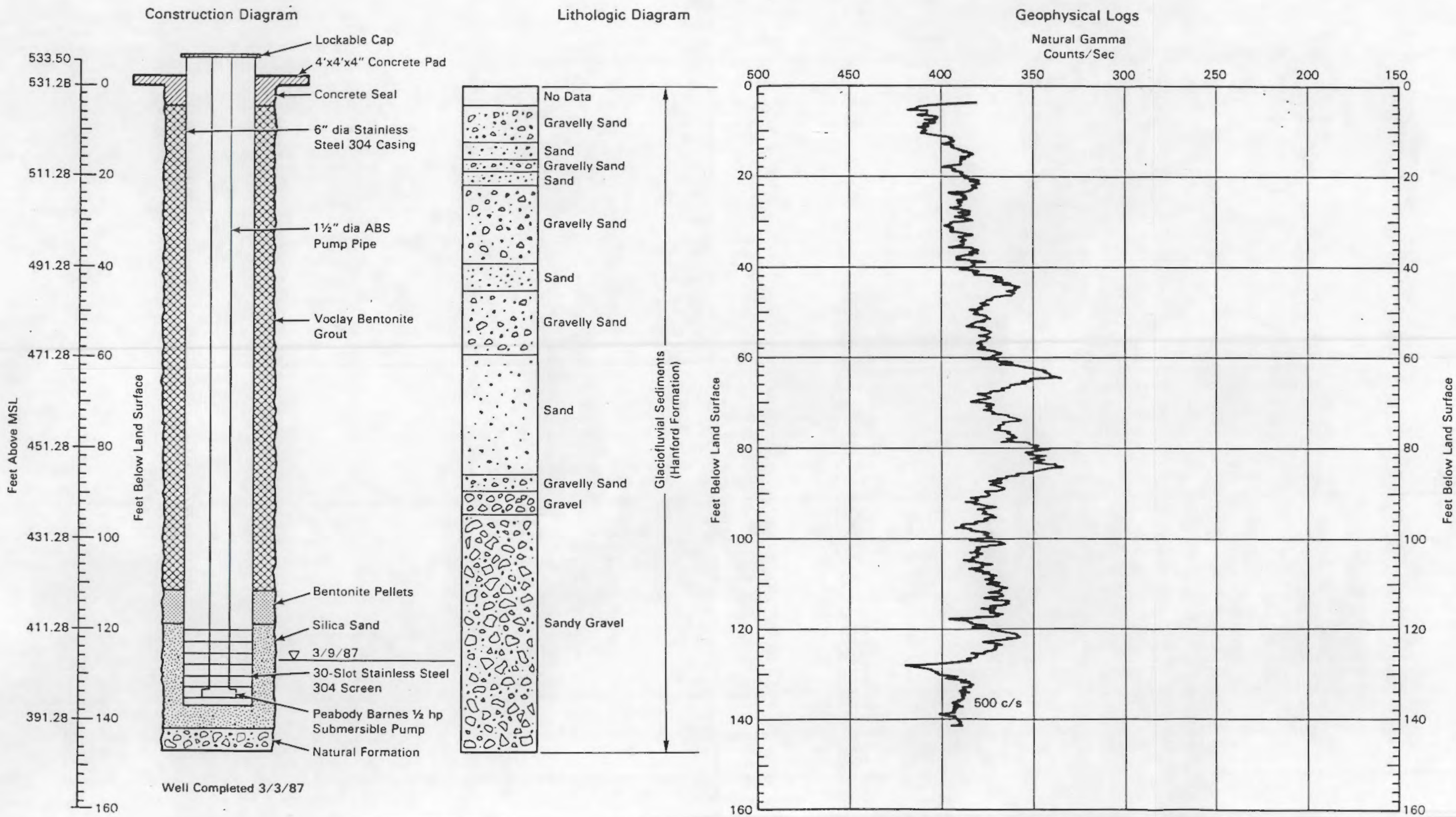


Well Number 699-23-34
Uncalibrated
Construction Diagram
Lithologic Diagram
Geophysical Logs
Natural Gamma
Counts/Sec
Lockable Cap
4'x4'x4"
Concrete Pad
Concrete Seal
6" dia Stainless Steel 304 Casing
1½" dia ABS Pump Pipe
Voclay Bentonite Grout
Bentonite Pellets
Silica Sand
1/30/87
30-Slot Stainless Steel 304 Screen
Peabody Barnes ½ hp Submersible Pump
Well Completed 1/21/87
Feet Above MSL
Feet Below Land Surface
532.86
530.50
510.50
490.50
470.50
450.50
430.50
410.50
390.50
No Data
Sand
Slightly Gravelly Sand
Silty Sand
Slightly Gravelly Sand
Sand
Gravelly Sand
Slightly Silty Sand
Gravelly Sand
Sandy Gravel
Silty Sandy Gravel
Glaciofluvial Sediments (Hanford Formation)
100 c/s
70
60
50
40
30
20
10
0
80
100
120
140
160

Well Number 699-24-34A
Uncalibrated

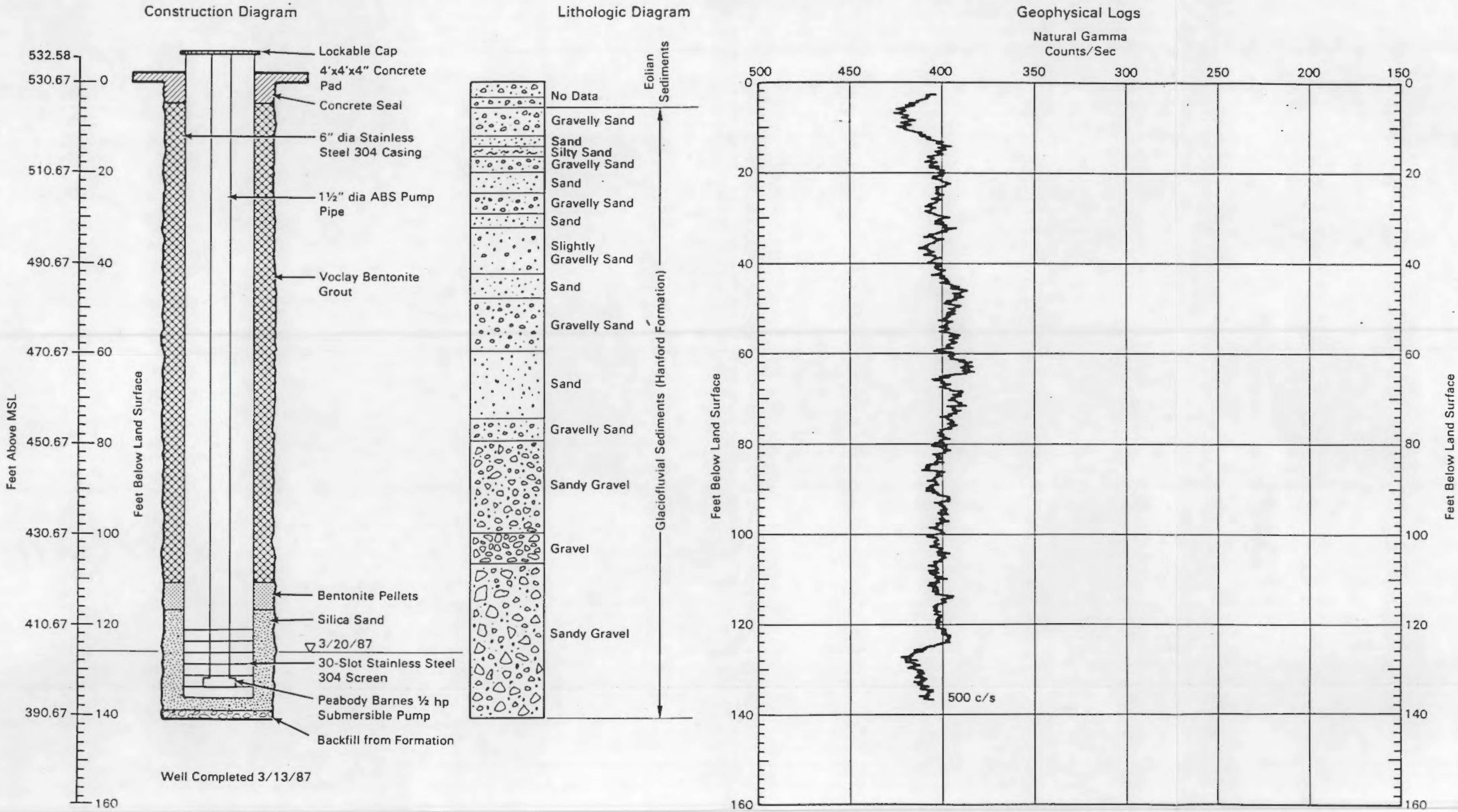


Well Number 699-24-34B
Uncalibrated

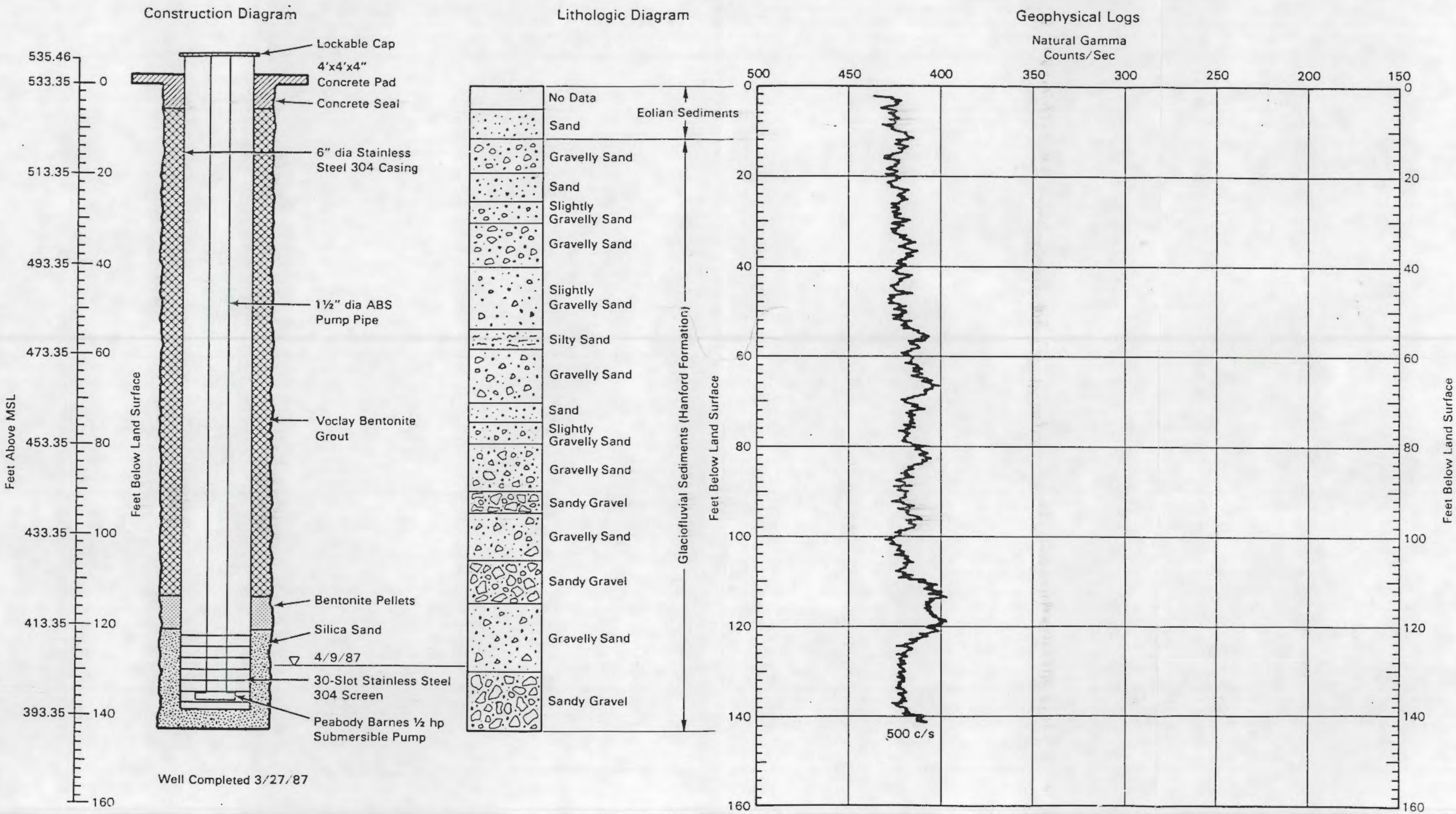


Well Number 699-24-34C

Uncalibrated



Well Number 699-25-34C
Uncalibrated



APPENDIX C

STRATIGRAPHIC COLUMNS WITH FIELD DESCRIPTIONS OF UNITS, FIELD MOISTURE DATA, AND SIZE DISTRIBUTION DATA

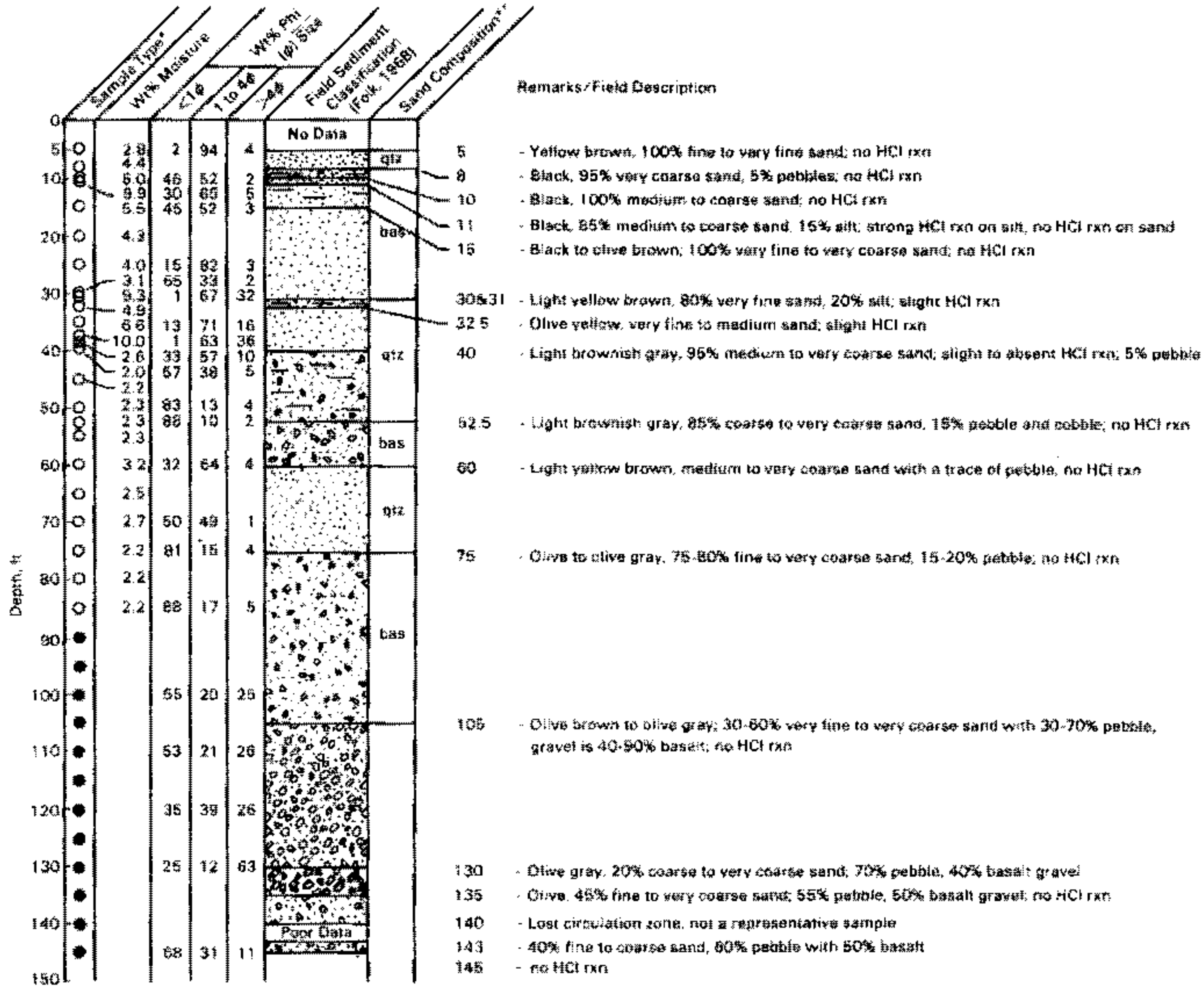
APPENDIX C

STRATIGRAPHIC COLUMNS WITH FIELD DESCRIPTIONS OF UNITS, FIELD MOISTURE DATA, AND SIZE DISTRIBUTION DATA

Stratigraphic columns are presented in this appendix, along with remarks and field descriptions of the units encountered during drilling. Samples were typically collected at 5-ft intervals, and in addition to field descriptions, laboratory analyses are provided for selected samples for moisture content and grain-size distribution. "Sample type" refers to the drilling technique employed at that interval.

Weight percent moisture content and the particle-size distribution using the Phi (ϕ) scale are taken from tables of raw data presented in Appendix D.

The "6" prefixing the well numbers in the following diagrams refers to the "699" prefix that identifies wells in the 600 Area of the Hanford Site.

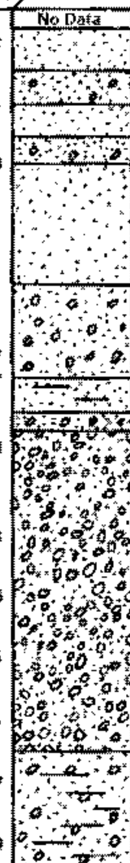


Lambert Coordinates: N429562.90
E2,260,069.50
Hanford Well No.: 6-24-35 (SW-1)
Date Drilling Completed: 2/13/87
Drilled Depth: 145.4 ft
Elevation: 636.52 (MSL)

*○ = Drive barrel sample
● = Hard tool sample
**Bas = Basaltic (≥60 vol % basalt)
Qtz Quartzose (≥60 vol % quartz)
Mix = Mixture (40-60 vol % each quartz and basalt)
rxn = Reaction

Depth, ft	Sample Type*	Wt% Moisture	Wt% Phi (φ) Size <1φ	1 to 4φ	>4φ
	O	2.7			
	O	3.1	80	18	2
10	O	4.2			
	O	20.4	5	81	14
20	O	6.2			
	O	5.3	47	50	3
30	O	5.5			
	O	5.4			
40	O	3.6	38	61	1
	O	3.1			
50	O	2.4			
	O	2.5	26	69	6
60	O	5.8	1	92	7
	O	2.1			
	O	2.0			
70	O	2.1	78	14	8
	O	2.0			
80	O	1.6			
	O	2.8	79	13	8
90	O	2.2			
	O	2.5	67	25	8
100	●				
	●		37	38	25
110	●				
	●		30	56	14
120	●				
	●		54	19	27
130	●				
	●		48	23	29
140	●				
150					

Field Sediment Classification (Folk, 1968)



Sand Composition**: bas (3–15.5 ft); mix

Remarks/Field Description

Depth	Remarks/Field Description
3	Gray to dark gray, >95% very fine to very coarse sand, <5% pebble. Caliche coats gravel; no HCl rxn on sand
10	Dark gray, <95% very fine to very coarse sand, >5% pebble; sand clumps react strongly with HCl
15.5	Dark gray brown, 80% fine to medium sand, 20% silt
20.5	Dark gray brown, 95% very fine to very coarse sand, 5% pebble
25	Dark gray brown to very dark gray brown, >95% fine to very coarse sand, <5% pebble; slight to absent HCl rxn
44.5	Gray brown, 75-90% very fine to very coarse sand, 10-20% pebble, 0-5% silt; slight to absent HCl rxn
59.5	Light olive brown, 90% very fine to medium sand, 10% silt, no HCl rxn
65	Gray brown, 75% very fine to very coarse sand, 20% pebble, 5% silt; slight HCl rxn
68	Gray brown to olive gray, 30-70% very fine to very coarse sand, 30-70% pebble and cobble with a trace of silt; slight HCl rxn. Gravel is 40-70% basalt
120	Olive gray, 30-65% very fine to very coarse sand, 35-70% pebble; gravel is 30-60% basalt
139	

Lambert Coordinates: N428374.81
E2,261,074.22
Hanford Well No.: 6-23-34 (SW-2)
Date Drilling Completed: 1/21/87
Drilled Depth: 139 ft
Elevation: 530.90 (MSL)

*O = Drive barrel sample
● = Hard tool sample
**Bas = Basaltic (≥60 vol % basalt)
Qtz = Quartzose (≥60 vol % quartz)
Mix = Mixture (40-60 vol % each quartz and basalt)
rxn = Reaction

Depth, ft	Sample Type*	Wt% Moisture	Wt% Phi (φ) Size <1φ	1 to 4φ	>4φ
5	○	3.1			
10	○	4.6	77	22	1
15	○	4.4			
20	○	4.5			
25	○	10.7	2	83	15
30	○	4.1			
35	○	3.4	26	72	2
40	○	5.8	52	45	3
45	○	3.1			
50	○	2.3	86	12	2
55	○	2.3			
60	○	2.3	88	11	1
65	○	2.2			
70	○	2.5	52	45	3
75	○	2.0			
80	○	1.9	85	9	6
85	○	1.9			
90	○	2.8	67	20	13
95	○	1.7			
100	○	1.7	75	16	9
105	○	3.6			
110	●				
115	●		67	18	15
120	●				
131	●		54	23	23
135	●				
140	●				

Field Sediment Classification (Folk 1968)

Sand Composition**: bas (5–20 ft); mix (20–40 ft); qtz (40–48 ft); mix (50–65 ft); qtz (65–72 ft)

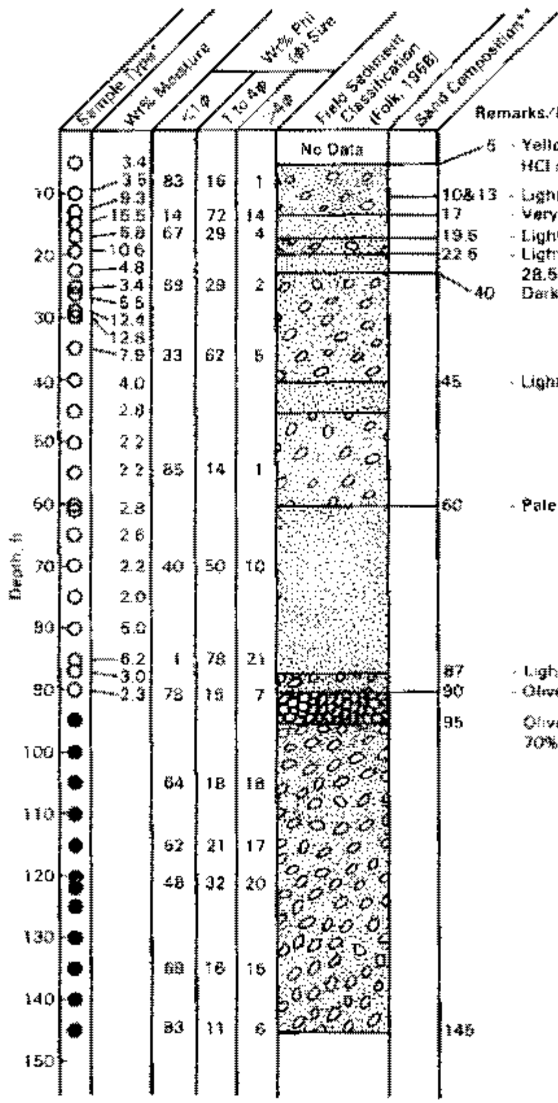
Remarks/Field Description

- 5 - Black to grayish brown, 90-99% very fine to very coarse sand, 1-10% pebble; moderate to absent HCl rxn, caliche coatings on some pebbles
- 20 - Dark grayish brown, 90% very fine to very coarse sand, 10% pebble; no HCl rxn
- 25 - Grayish brown, 100% very fine to medium sand with a trace of silt; no HCl rxn
- 40 - Grayish brown, 70% very fine to very coarse sand, 20% silt, 10% pebble, strong HCl rxn on silt, no rxn on sand
- 45&50 - Dark grayish brown to grayish brown, 80-90% very fine to very coarse sand, 10-20% pebble, no HCl rxn
- 65 - Dark grayish brown, >95% very fine to very coarse sand, <5% pebble; no HCl rxn; sand clumps cemented with caliche
- 72&75 - Grayish brown, 30% very fine to very coarse sand, 65% pebble and cobble, 5% silt
- 80 - Grayish brown, 20% very fine to very coarse sand, 80% pebble and cobble; slight to absent HCl rxn, caliche coating some gravel
- 90 - Grayish brown, 30% very fine to very coarse sand, 70% pebble and cobble; slight HCl rxn
- 95 - Same as 80 ft description, except grayish brown to olive gray color and slight HCl rxn
- 110 - Olive gray, 30-40% very fine to very coarse sand, 60-70% pebble
- 125
- 131.5 - Olive gray, 30-40% very fine to very coarse sand, 60-70% pebble
- 140 - Olive gray, 90% very fine to very coarse sand, 10% pebble

Lambert Coordinates: N428758.47
E2,261,193.41
Hanford Well No.: 6-24-34A (SW-3)
Date Drilling Completed: 1/29/87
Drilled Depth: 141.5 ft
Elevation: 531.71 (MSL)

*○ = Drive barrel sample
● = Hard tool sample
**Bas = Basaltic (≥60 vol % basalt)
Qtz = Quartzose (≥60 vol % quartz)
Mix = Mixture (40-50 vol % each quartz and basalt)
rxn = Reaction

C.5



Wt% Moisture	<1φ	1 to 4φ	>4φ
3.4			
3.5	83	16	1
8.3			
15.5	14	72	14
5.8	67	29	4
10.6			
4.8			
3.4	69	29	2
5.5			
12.4			
12.8			
7.9	33	62	5
4.0			
2.8			
2.2			
2.2	85	14	1
2.8			
2.6			
2.2	40	50	10
2.0			
5.0			
6.2	1	78	21
3.0			
2.3	78	15	7
	64	18	18
	62	21	17
	48	32	20
	68	16	15
	83	11	6

Remarks/Field Description

5 - Yellowish brown to very dark gray, 80-90% very fine to very coarse sand, 10-20% pebble and cobble, <5% silt, strong to moderate HCl rxn

10&13 - Light olive brown, >95% very fine to medium sand, <5% pebble, no HCl rxn

17 - Very dark gray, 80% very fine to very coarse sand, 20% pebble

19.5 - Light olive brown, >95% fine to coarse sand, <5% pebble

22.5 - Light olive brown to very dark grayish brown, 75-90% very fine to very coarse sand, 10-25% pebble. Partly consolidated from 28.5 to 30 feet with a strong rxn to HCl; moderate to absent HCl rxn elsewhere

40 - Dark gray, >95% very fine to very coarse sand, <5% pebbles; no HCl rxn

45 - Light olive gray to grayish brown, 85-90% very fine to very coarse sand, 10-15% pebble, trace of cobble; slight to absent HCl rxn

60 - Pale olive to light olive brown, 100% very fine to medium sand, trace of pebble; slight HCl rxn

87 - Light olive brown, 75% very fine to fine sand, 25% pebble and cobble; gravel is 90% basalt; slight HCl rxn

90 - Olive gray, 20% very fine to very coarse sand, 80% pebble and cobble; gravel is 50% basalt; moderate HCl rxn on sand

95 Olive gray to dark olive gray, 25-60% very fine to very coarse sand, 40-75% pebble with a trace of cobble. Gravel clasts are 40-70% basalt

145

Lambert Coordinates N429093.43
E2,261,297.38

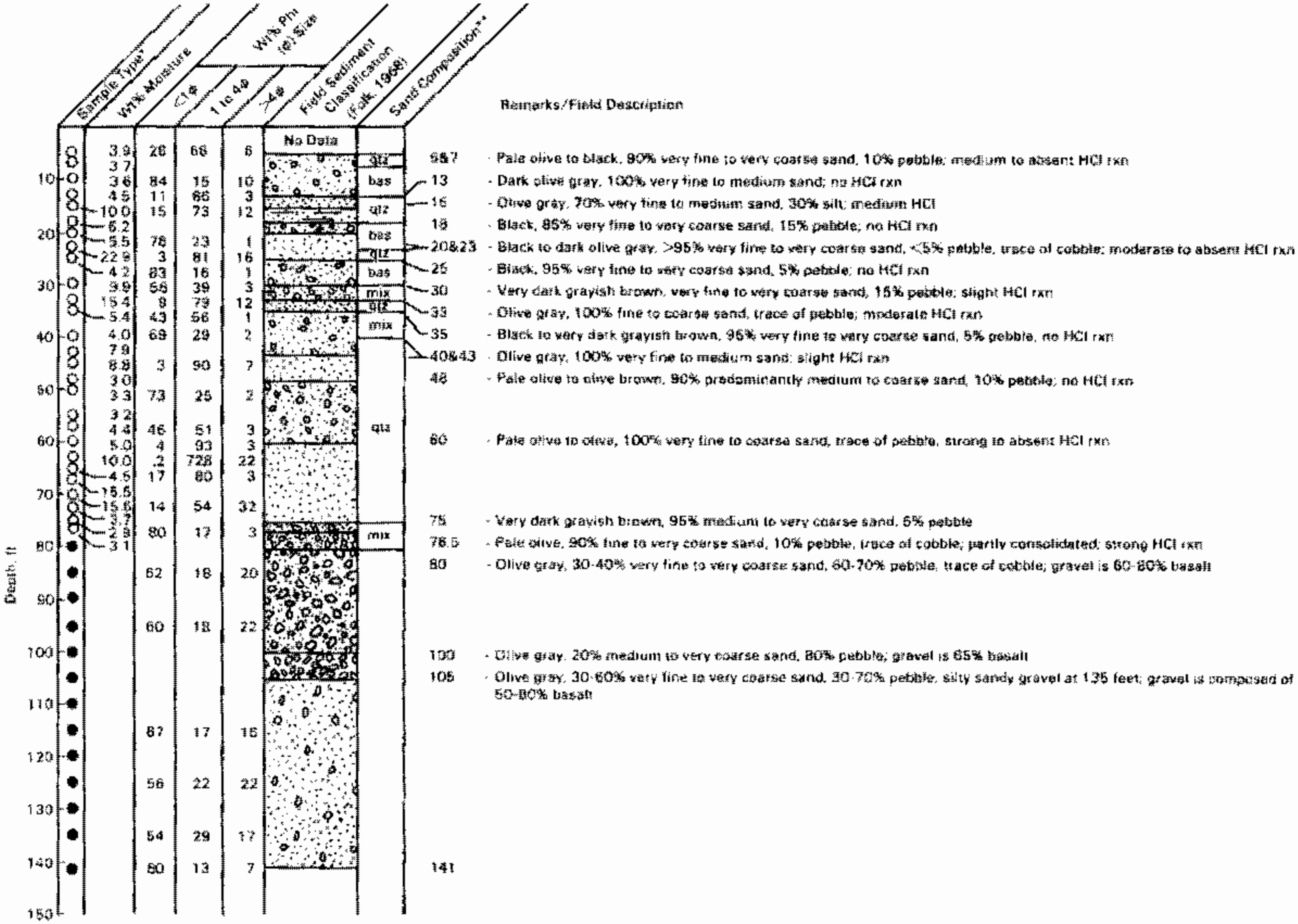
Hanford Well No.: 6-24-34B (SW-4)

Date Drilling Completed: 3/3/87

Drilled Depth: 145 ft

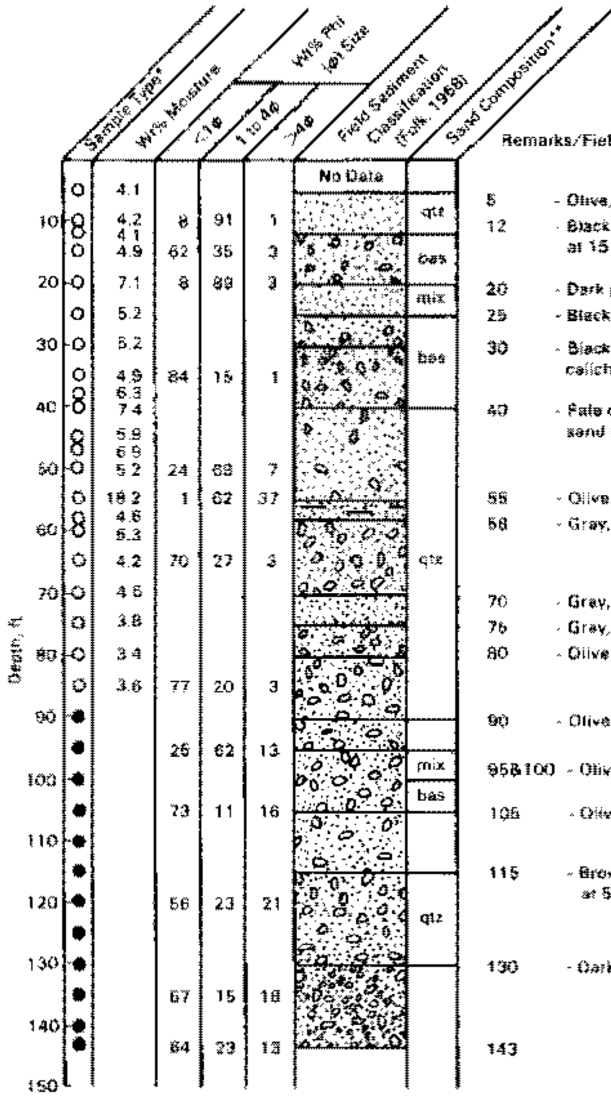
Elevation: 631.28 (MSL)

* ○ = Drive barrel sample
● = Hard tool sample
**Bas = Basaltic (≥60 vol % basalt)
Qtz = Quartzose (≥60 vol % quartz)
Mix = Mixture (40-60 vol % each quartz and basalt)
rxn = Reaction



Lambert Coordinates: N429472.15
E2,261,409.71
Hanford Well No.: 6-24-34C (SW-5)
Date Drilling Completed: 3/13/87
Drilled Depth: 141 ft
Elevation: 630.67 (MSL)

*○ = Drive barrel sample
● = Hard tool sample
**Bas = Basaltic (≥60 vol % basalt)
Qtz = Quartzose (>60 vol % quartz)
Mix = Mixture (40-60 vol % each quartz and basalt)
rxn = Reaction



Remarks/Field Description

5 - Olive, 100% fine to medium sand, trace of pebble and cobble; slight HCl rxn

12 - Black, 90% medium to very coarse sand, 10% pebble, slight to absent HCl rxn; partly consolidated at 15 feet, caliche coating some pebbles, caliche cementing sand clumps

20 - Dark gray, 100% very fine to medium sand; slight HCl rxn, sand clumps with caliche cement

25 - Black, 95% fine to very coarse sand, 5% pebbles, medium HCl rxn on sand clumps

30 - Black, 90% medium to very coarse sand, 10% pebble, slight to moderate HCl rxn; sand clumps with caliche cement

40 - Pale olive to dark olive gray, 95% very fine to very coarse sand, 5% pebble; slight to absent HCl rxn; sand clumps with caliche cement

55 - Olive, 80% very fine to medium sand, 20% silt; partly consolidated, slight to moderate HCl rxn

58 - Gray, 90% medium to very coarse sand, 10% pebble, sand clumps with caliche cement, slight HCl rxn

70 - Gray, >95% medium to very coarse sand, trace of pebble; sand clumps with caliche cement; slight HCl rxn

75 - Gray, 95% medium to very coarse sand, 5% pebble, slight HCl rxn

80 - Olive gray, 90% medium to very coarse sand, 10% pebble, sand clumps with caliche cement; slight HCl rxn

90 - Olive gray, 30% very fine to very coarse sand, 70% pebble; gravel composed of 80% basalt

95&100 - Olive gray, 80-90% very fine to very coarse sand, 10-20% pebble, gravel is 50-70% basalt

105 - Olive gray, 40% fine to very coarse sand, 60% pebble, gravel is 70% basalt

115 - Brownish olive gray, 75-90% medium to very coarse sand, 10-25% pebble, sand is similar to that at 58 to 85 feet

130 - Dark gray to olive gray, 30-60% fine to very coarse sand, 40-70% pebble, composed of 80% basalt

143

Lambert Coordinates: N429987.73 / E2,261,561.70
Hanford Well No. 6-25-34C (SW-6)
Date Drilling Completed: 3/27/87
Drilled Depth: 143 ft
Elevation: 533.35 (MSL)

* ○ = Drive barrel sample
● = Hard tool sample
**Bas = Basaltic (≥60 vol % basalt)
Qtz = Quartzose (≥60 vol % quartz)
Mix = Mixture (40-50 vol % each quartz and basalt)
rxn = Reaction

APPENDIX D

SEDIMENT ANALYSIS DATA FROM SELECTED BOREHOLE INTERVALS

APPENDIX D

SEDIMENT ANALYSIS DATA FROM SELECTED BOREHOLE INTERVALS

Sediment was analyzed from samples collected from selected borehole intervals of wells drilled at the Solid Waste Landfill. This appendix presents descriptions and results of these analyses.

Samples were taken from six different wells and submitted for study during April and May 1987. Table D.1 lists the well numbers and the various depths identified for analysis.

All samples submitted were sieved to determine size distribution; samples that were obtained with a hard tool were wet-sieved and oven-dried before rotapping. Moisture retention and saturated hydraulic conductivity were determined on a tool of 20 specified samples from wells 699-24-35 and 699-24-34C.

HYDRAULIC CONDUCTIVITY

Hydraulic conductivity was determined for each of the 20 predetermined samples using a constant-head method (Klute and Dirksen 1986). In this method, the sample is placed in a container (5.36 cm dia, 3 cm high) and enclosed with lids having an inflow valve at one end and an outflow valve at the other. The inflow valve is connected to a constant-head device; the outflow valve is connected to a collection vessel. The sample is saturated before any test are run. An initial time is recorded, and water is allowed to flow through the sample for a predesignated amount of time. The amount of discharge is recorded. The hydraulic conductivity is determined using the following equation:

$$K = (L/H)\ (Q/At) \qquad \text{(E.1)}$$

where L = length of the sample
H = hydraulic-head difference

Q = volume of water that passed through the sample in known time, t

A = cross-sectional area of the sample.

Table D.2 presents the results of the analyses.

TABLE D.1. Well Numbers and Sampled Intervals (Depth from Surface)

LOG NUMBER/ DEPTH (FT)	LOG NUMBER/ DEPTH (FT)	LOG NUMBER/ DEPTH (FT)	LOG NUMBER/ DEPTH (FT)
SW-1 5'	SW-1 50'	SW-2 5'	SW-2 85'
SW-1 10'	SW-1 52.5'	SW-2 15'	SW-2 95'
SW-1 11'	SW-1 60'	SW-2 24.5'	SW-2 105'W
SW-1 15'	SW-1 70'	SW-2 40'	SW-2 115'W
SW-1 25'	SW-1 75'	SW-2 55'	SW-2 125'W
SW-1 30'	SW-1 85'	SW-2 59'	SW-2 135'W
SW-1 31'	SW-1 100'W*	SW-2 70.5'	
SW-1 35'	SW-1 110'W		
SW-1 37.5'	SW-1 120'W		
SW-1 38.5'	SW-1 130'W		
SW-1 40'	SW-1 145'W		
SW-3 10.5'	SW-3 80'	SW-4 10'	SW-4 85'
SW-3 25'	SW-3 90'	SW-4 15'	SW-4 90'
SW-3 35'	SW-3 100'	SW-4 17'	SW-4 105'W
SW-3 40'	SW-3 115'W	SW-4 25'	SW-4 115'W
SW-3 50'	SW-3 131'W	SW-4 35'	SW-4 122'W
SW-3 60'	SW-3 140'W	SW-4 55'	SW-4 135'W
SW-3 70'		SW-4 70'	SW-4 145'W
SW-5 5'	SW-5 57'	SW-6 10'	SW-6 85'
SW-5 10'	SW-5 60'	SW-6 15'	SW-6 95'W
SW-5 13'	SW-5 63'	SW-6 20'	SW-6 105'W
SW-5 15'	SW-5 65'	SW-6 35'	SW-6 120'W
SW-5 20'	SW-5 70'	SW-6 50'	SW-6 135'W
SW-5 23'	SW-5 76'	SW-6 55'	SW-6 143'W
SW-5 25'	SW-5 85'W	SW-6 65'	
SW-5 30'	SW-5 95'W		
SW-5 33'	SW-5 115'W		
SW-5 35'	SW-5 125'W		
SW-5 40'	SW-5 135'W		
SW-5 45'	SW-5 141'W		
SW-5 50'			

* W denotes a hard tool sample that was wet-sieved prior to rotapping

TABLE D.2. Hydraulic Conductivity

SAMPLE	HYDRAULIC CONDUCTIVITY (cm/sec)	SAMPLE	HYDRAULIC CONDUCTIVITY (cm/sec)
SW-1 10'	2.00e-02	SW-5 10'	3.94e-02
SW-1 11'	4.04e-03	SW-5 15'	9.00e-04
SW-1 25'	2.13e-02	SW-5 23'	5.60e-04
SW-1 31'	7.80e-03	SW-5 25'	1.60e-03
SW-1 35'	7.00e-04	SW-5 33'	3.10e-03
SW-1 37.5'	4.60e-04	SW-5 45'	5.60e-03
SW-1 40'	1.06e-02	SW-5 57'	1.77e-02
SW-1 50'	1.04e-02	SW-5 70'	3.00e-04
SW-1 70'	1.03e-02	SW-5 63'	2.35e-02
SW-1 85'	3.99e-02	SW-5 75'	2.30e-02

WATER RETENTION

Water retention characteristics were measured at 0.1, 0.3, and 1.0 bars (Table D.3) applied pressure using a pressure plate extractor (Soilmoisture Equipment Corporation, Santa Barbara, California). Equilibrium water contents were obtained by packing samples in containing rings on a porous plate where they were saturated and pressure-drained in the extractor.

Both the samples and the porous plate were brought to saturation by allowing an excess of water to stand on the surface of the plate for 24 h. On complete saturation, the plate was placed in the extractor vessel and the internal air pressure raised to the desired test level. Equilibrium was reached when drainage ceased. At the end of each pressure run, each sample was carefully weighed and oven-dried to determine the moisture contents at that pressure level. This procedure was modified from that given by Klute (1986).

PARTICLE-SIZE ANALYSIS

Particle-size analysis was determined using both dry sieve and wet sieve analysis. Dry samples were weighed, total sample weight was recorded, and the sample was sieved through 8-in. sieves for a total of 20 min. The sieve sizes included 2.00 mm, 1.00 mm, 0.50 mm, 0.25 mm, 0.125 mm, and 0.63 mm (Table D.4). Samples obtained by hard tool were weighed, wet-sieved through 0.63-mm-sized sieves, and oven-dried for 24 h before dry-sieving; it was

TABLE D.3. Water Retention Characteristics

Sample	Water Retention (Water Content) 0.1 bar (g/g)	0.3 bar (g/g)	1.00 bar (g/g)
SW-1 10'	0.0536	0.04400	0.0427
SW-1 11'	0.0888	0.08050	0.0742
SW-1 25'	0.0501	0.04360	0.0371
SW-1 31'	0.1916	0.10140	0.0665
SW-1 35'	0.1048	0.06480	0.0448
SW-1 37.5'	0.2240	0.09470	0.0662
SW-1 40'	0.0459	0.02880	0.0181
SW-1 50'	0.0398	0.02890	0.0168
SW-1 70'	0.0237	0.02080	0.0165
SW-1 85'	0.0485	0.02970	0.0175
SW-5 10'	0.0345	0.03050	0.0200
SW-5 15'	0.0824	0.06490	0.0451
SW-5 23'	0.1052	0.07460	0.0432
SW-5 25'	0.0367	0.02340	0.0170
SW-5 33'	0.0796	0.06200	0.0408
SW-5 45'	0.0645	0.05610	0.0427
SW-5 57'	0.0309	0.01783	0.0120
SW-5 63'	0.0718	0.05630	0.0393
SW-5 70'	0.1651	0.09630	0.0649
SW-5 76'	0.0241	0.02490	0.0160

necessary to wet-sieve these samples to remove the fine grains from the larger ones for a more accurate particle analysis. The sieve analysis was done in accordance with ASTM procedure D 422 (ASTM 1986b) and Uebelacker (1985).

FIELD MOISTURE CONTENT

Field moisture content was determined on all samples taken above the water table. In the field, samples for field moisture content were placed in air tight containers, taped, and placed in plastic bags. In the lab, after the plastic bag and tape were removed, the entire container of soil was weighed and dried to determine the water content (Table D.5). This was done in accordance with ASTM procedure D 2216 (ASTM 1986a).

TABLE D.4. Particle-Size Distribution

Sample	PERCENT OF SAMPLE PASSING 2.00 mm	1.00 mm	0.50 mm	0.25 mm	0.125 mm	0.063 mm
SW-1 5'	100.00	99.960	98.38	70.84	18.84	4.20
SW-1 10'	99.96	98.050	54.19	9.23	4.94	2.41
SW-1 11'	99.86	95.080	70.82	52.93	23.58	5.27
SW-1 15'	99.82	95.570	55.44	16.05	8.43	3.33
SW-1 25'	100.00	99.560	85.47	15.42	5.77	3.13
SW-1 30'	98.80	83.480	35.33	9.77	4.28	1.78
SW-1 31'	99.88	99.760	99.51	98.84	85.67	32.41
SW-1 35'	99.78	97.450	88.86	62.72	33.33	16.04
SW-1 37.5'	99.95	99.900	99.56	98.49	87.99	36.74
SW-1 38.5'	96.21	91.660	66.65	33.76	20.71	9.56
SW-1 40'	95.47	82.690	43.28	16.95	9.19	5.16
SW-1 50'	84.89	50.520	16.76	8.87	6.48	3.58
SW-1 52.5'	72.22	40.890	11.84	5.12	3.46	1.62
SW-1 60'	99.38	95.190	67.94	17.42	6.48	3.68
SW-1 70'	95.08	84.050	50.19	10.69	3.91	1.42
SW-1 75'	77.46	38.310	18.64	10.10	6.21	4.19
SW-1 85'	68.24	38.970	21.94	12.36	7.80	5.46
SW-1 100'	71.09	56.970	44.84	35.74	34.83	24.80
SW-1 110'	71.72	57.930	46.80	38.07	36.12	26.06
SW-1 120'	96.76	92.580	64.77	36.03	32.95	26.36
SW-1 130'	91.34	82.050	74.71	68.78	67.39	62.70
SW-1 145'	81.27	52.280	32.38	20.44	18.87	11.44
SW-2 5'	98.93	79.790	20.61	6.68	4.25	2.27
SW2 15'	10.00	99.150	95.31	80.30	55.30	13.89
SW-2 24-25.5'	97.26	89.290	46.83	8.06	4.05	2.59
SW-2 40'	100.00	94.500	37.94	6.71	2.92	1.28
SW-2 55-56.5'	84.76	68.690	25.36	14.45	10.33	6.42
SW-2 59-60'	100.00	99.890	99.43	87.55	26.15	7.41
SW-2 70.5'	70.06	38.360	22.84	15.54	11.53	8.08
SW-2 85'	43.57	30.140	21.30	14.86	10.69	7.58
SW-2 96'	45.74	32.460	23.15	15.89	11.16	7.70
SW-2 105'	53.23	44.060	37.00	31.66	30.52	25.24
SW-2 115'	46.98	37.050	29.29	22.16	21.42	14.38
SW-2 125'	68.08	55.820	46.40	38.56	36.84	27.01
SW-2 135'	75.72	62.680	52.03	42.83	39.99	29.20
SW-3 10.5'	99.63	89.790	22.77	4.72	2.97	1.38
SW-3 25'	100.00	99.870	98.44	78.51	32.35	15.16
SW-3 35'	98.55	94.170	74.20	16.78	4.49	2.01
SW-3 40'	98.45	88.100	48.50	14.58	5.74	3.28
SW-3 50'	82.86	49.940	13.80	5.89	3.96	2.22
SW-3 60'	90.71	56.440	12.19	3.33	2.13	1.05
SW-3 70'	98.93	89.850	48.56	14.09	5.47	2.70
SW-3 80'	27.26	19.540	14.83	10.88	8.17	6.17
SW-3 90'	55.30	43.640	33.36	24.31	18.09	12.95
SW-3 100'	43.78	32.840	24.52	17.96	13.41	9.31
SW-3 115'	48.79	40.570	33.12	25.21	23.45	15.40
SW-3 131'	70.35	57.130	45.95	36.30	29.81	23.36
SW-3 140'	94.87	84.550	63.50	33.63	21.97	8.44

TABLE D.4. (contd)

Sample	2.00 mm	1.00 mm	0.50 mm	0.25 mm	0.125 mm	0.063 mm
	PERCENT OF SAMPLE PASSING					
SW-4 10'	92.10	70.350	17.42	3.66	2.46	0.89
SW-4 15'	99.10	96.840	85.78	65.69	43.80	14.36
SW-4 17'	67.17	61.190	33.22	19.02	11.30	4.46
SW-4 25'	99.10	88.610	31.12	8.58	4.93	1.74
SW-4 35'	96.38	87.260	67.42	30.71	12.20	5.03
SW-4 55'	84.14	49.290	15.06	4.40	2.20	1.30
SW-4 70'	99.26	92.740	60.28	27.03	16.73	9.67
SW-4 85'	99.94	99.940	99.70	97.02	57.29	21.28
SW-4 90'	32.99	27.050	22.09	16.53	12.23	7.37
SW-4 105'	59.79	47.623	36.54	27.15	26.00	17.97
SW-4 115'	59.73	50.870	38.13	28.18	25.32	17.07
SW-4 122'	75.63	66.870	51.98	34.68	31.51	19.98
SW-4 135'	46.87	38.840	31.15	24.31	23.21	15.46
SW-4 145'	81.86	37.710	17.04	10.67	10.23	6.13
SW-5 5'	89.56	86.900	74.08	41.49	18.85	5.93
SW-5 10'	97.52	75.390	16.33	3.61	2.60	0.94
SW-5 13'	100.00	99.710	89.16	29.09	6.06	2.92
SW-5 15'	100.00	98.950	86.33	68.83	49.44	11.86
SW-5 20'	99.70	83.670	23.99	5.06	2.13	0.90
SW-5 23'	100.00	99.530	98.68	82.13	54.34	15.63
SW-5 25'	95.82	74.920	17.11	3.20	1.85	0.82
SW-5 30'	92.73	82.080	42.38	10.21	6.14	2.77
SW-5 33'	99.44	97.240	90.84	79.77	67.45	11.91
SW-5 35'	99.58	95.500	57.23	6.14	3.33	1.22
SW-5 40'	98.95	87.120	31.10	6.24	4.03	1.59
SW-5 45'	99.99	99.750	97.23	62.14	21.20	6.55
SW-5 50'	97.68	78.810	27.10	7.83	5.29	1.92
SW-5 57'	99.83	93.290	53.82	14.45	7.13	2.78
SW-5 60'	100.00	99.980	96.11	28.32	6.89	2.68
SW-5 63'	100.00	100.000	99.98	97.91	57.47	21.71
SW-5 65'	98.44	96.060	83.05	26.19	7.83	3.20
SW-5 70'	99.68	95.290	86.81	79.10	64.32	31.87
SW-5 78'	88.30	56.220	19.46	8.81	4.44	2.75
SW-5 85'	65.35	47.930	37.70	30.02	28.85	20.38
SW-5 95'	66.14	49.910	39.40	31.60	30.12	21.87
SW-5 115'	48.88	40.630	33.46	25.12	23.50	16.73
SW-5 125'	68.40	56.750	43.77	33.25	30.01	21.66
SW-5 135'	84.53	72.210	46.12	29.74	26.40	16.97
SW-5 141'	53.31	33.030	19.49	11.53	11.20	6.78
SW-6 10'	99.08	98.530	92.41	46.79	13.04	1.22
SW-6 15'	97.37	87.960	38.30	10.26	6.39	3.02
SW-6 20'	100.00	99.770	92.20	51.14	19.84	3.49
SW-6 35'	96.20	89.040	16.01	4.73	3.65	1.16
SW-6 50'	99.60	95.840	76.27	37.22	17.86	6.90
SW-6 55'	99.96	99.940	99.36	90.27	68.65	37.49
SW-6 65'	95.84	77.090	29.66	10.36	8.42	3.34
SW-6 85'	85.45	65.540	22.66	7.68	6.17	2.63
SW-6 95'	93.26	86.790	74.51	48.67	29.16	12.62
SW-6 105'	39.76	31.980	26.80	22.11	21.59	15.68
SW-6 120'	71.34	58.820	43.71	35.06	34.25	20.88
SW-6 135'	55.00	42.170	32.85	25.86	22.39	17.67
SW-6 143'	75.30	51.860	35.59	24.04	22.07	12.89

TABLE D.5. Field Moisture Contents

SAMPLE	FIELD H20 CDNTENT (wt%)	SAMPLE	FIELD H20 CONTENT (wt%)	SAMPLE	FIELD H20 CONTENT (wt%)
SW-1 5'	2.77	SW-3 60'	2.30	SW-5 65'	4.55
SW-1 8'	4.36	SW-3 65'	2.19	SW-5 67'	15.47
SW-1 10'	5.04	SW-3 70'	2.49	SW-5 70'	15.57
SW-1 11'	9.86	SW-3 75'	2.03	SW-5 72.5'	3.72
SW-1 15'	5.47	SW-3 80'	1.92	SW-5 75'	2.86
SW-1 20'	4.33	SW-3 85'	1.92	SW-5 76'	3.13
SW-1 25'	4.02	SW-3 90	2.78	SW-6 5'	4.08
SW-1 30'	3.09	SW-3 95'	1.76	SW-6 10'	4.20
SW-1 31'	9.32	SW-3 100'	1.75	SW-6 12'	4.05
SW-1 32.5'	4.87	SW-3 105'	3.65	SW-6 15'	4.87
SW-1 35'	6.63	SW-4 5'	3.36	SW-6 20'	7.05
SW-1 37.5'	9.99	SW-4 10'	3.52	SW-6 25'	5.17
SW-1 38.5'	2.55	SW-4 13'	9.28	SW-6 30'	5.22
SW-1 40'	2.04	SW-4 15'	15.52	SW-6 35'	4.89
SW-1 45'	2.18	SW-4 17'	6.85	SW-6 38'	6.31
SW-1 50'	2.27	SW-4 20'	10.62	SW-6 40'	7.36
SW-1 52.5	2.31	SW-4 21-22'	4.84	SW-6 45'	5.93
SW-1 55'	2.26	SW-4 25'	3.36	SW-6 47'	6.92
SW-1 60'	3.18	SW-4 26-27'	5.44	SW-6 50'	5.15
SW-1 65'	2.47	SW-4 28-29'	12.44	SW-6 55'	18.24
SW-1 70'	2.73	SW-4 30'	12.81	SW-6 58'	4.55
SW-1 75'	2.21	SW-4 35'	7.88	SW-6 60'	5.29
SW-1 80'	2.22	SW-4 40'	3.96	SW-6 65'	4.20
SW-1 85'	2.16	SW-4 45'	2.81	SW-6 70'	4.65
SW-2 2-4'	2.72	SW-4 50'	2.24	SW-6 75'	3.78
SW-2 5'	3.09	SW-4 55'	2.24	SW-6 80'	3.42
SW-2 10'	4.23	SW-4 60'-A	2.95	SW-6 85'	3.61
SW-2 15-16'	20.39	SW-4 60'-B	2.75		
SW-2 20-21'	6.22	SW-4 65'	2.64		
SW-2 24-25.5'	5.29	SW-4 70'	2.18		
SW-2 29-30'	5.45	SW-4 75'	2.06		
SW-2 34.5-35.5'	5.37	SW-4 80'	5.00		
SW-2 40'	3.47	SW-4 85'	6.25		
SW-2 44-45'	3.08	SW-4 87'	3.01		
SW-2 50'	2.44	SW-4 90'	2.26		
SW-2 55-55.5'	2.46	SW-5 5'	3.87		
SW-2 59-60'	5.79	SW-5 7'	3.66		
SW-2 65'	2.06	SW-5 10'	3.61		
SW-2 68'	2.02	SW-5 13'	4.51		
SW-2 70.5'	2.07	SW-5 15'	10.06		
SW-2 75'	1.94	SW-5 18'	6.18		
SW-2 80'	1.81	SW-5 20'	5.45		
SW-2 85'	2.81	SW-5 23	22.87		
SW-2 90'	2.24	SW-5 25'	4.17		
SW-2 95'	2.54	SW-5 30'	9.87		
SW-3 5'	3.07	SW-5 33'	15.39		
SW-3 10.5'	4.56	SW-5 35'	5.39		
SW-3 15'	4.40	SW-5 40'	4.01		
SW-3 20'	4.47	SW-5 43'	7.87		
SW-3 25'	10.68	SW-5 45'	8.78		
SW-3 30'	4.05	SW-5 48'	3.03		
SW-3 35'	3.37	SW-5 50'	3.30		
SW-3 40'	5.82	SW-5 55'	3.23		
SW-3 45'	3.06	SW-5 57'	4.36		
SW-3 50'	2.32	SW-5 60'	4.94		
SW-3 55'	2.32	SW-5 63'	9.95		

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APPENDIX E

AQUIFER TESTING, WELL CONSTRUCTION SUMMARY, AND WATER LEVEL DATA

APPENDIX E

AQUIFER TESTING, WELL CONSTRUCTION SUMMARY, AND WATER LEVEL DATA

During 1987, two aquifer tests were performed at the Solid Waste Landfill (SWL) during installation of the ground-water monitoring network. These were single well tests in that nearby observation wells were not drilled specifically for aquifer test purposes. Instead, previously drilled monitoring wells were used for observation during the aquifer tests. The first aquifer test was conducted at well 699-24-34A with well 699-23-34 as the observation well; the second aquifer test was at well 699-24-35 with well 699-24-34A as the observation well.

This appendix includes a discussion, summary, and the field data sheets for each aquifer test; water level measurements taken from April to September for each SWL well are also provided.

E.1 AQUIFER TEST DESIGN

The aquifer tests were designed to stress the aquifer as much as possible by pumping at a maximum discharge rate and measuring changes in water levels in the pumped well and the nearest monitoring well, which was used as an observation well. These were single well tests in that nearby observation wells were not drilled specifically for aquifer test purposes. The constant-discharge tests were conducted by first placing a turbine pump in a well drilled to depth. A temporary 10-in. dia. casing and a permanent No. 40 slot, 10 in. dia. continuous-wound stainless-steel telescoping screen were installed approximately 5 ft above the water table and about 10 ft into the aquifer. The screen was exposed to the formation by backpulling the drive casing.

The wells were planned to be pumped at a constant-discharge rate for up to 8 h. Water levels were monitored during the drawdown period of pumping and, subsequently, during the recovery of the water levels after pumping was terminated.

The aquifer tests were preceded first by bailing and then by a pumping period to develop the well and determine the optimal discharge rate and anticipated drawdown. The wells were developed for up to 2 h by pumping at variable discharge rates beginning with a low rate and increasing the rate in an incremental step-like manner. All data pertaining to the development of the well were recorded on the field data sheets along with the actual aquifer test data.

Water samples were not collected before, during, or after aquifer testing for chemistry analyses. The SWL wells were installed before the 200 Area wells, which encountered carbon tetrachloride contamination during the drilling phase. The information provided by the operations contractor concerning landfill operations did not indicate any hazardous materials had been discharged to the SWL, and no water analyses were planned before initiation of the ground-water monitoring phase.

E.1.1 Data Collection Methods and Equipment

Data collected during the aquifer tests conducted on the wells at the SLW may be considered in two categories: discharge-rate measurements and water-level measurements.

E.1.1.1 Discharge-Rate Measurements

Discharge was measured with an in-line Precision® flowmeter No. 8337808 and corroborated with either a 4- or 5-in. orifice mounted on an 8-in. discharge pipe. The meter reading was recorded at the start of pumping and again after the pump had been stopped. An attempt was made to maintain discharge at a constant rate with variations of no more than + or - 10%. Water was discharged at a distance sufficient to prevent possible recharge to the aquifer during the period of the aquifer test, normally at least 1000 ft from the pumping and observation well(s). The total quantity of water discharged is recorded on the aquifer-test data sheets in this appendix.

E.1.1.2 Water-Level Measurements

Water levels were measured manually with an electric sounding tape (E-tape) and a steel tape, incremented in 1/100 of ft. The steel tape was used primarily to obtain absolute measurements at the beginning and end of each test.

E.2 AQUIFER TEST FOR WELL 699-24-34A

Well 699-24-34A, with a total depth of 141.5 ft, was installed within the top 13 ft of the uppermost hydrostratigraphic unit, approximately 50 to 70 ft thick at this location (Weeks, Luttrell, and Fuchs 1987). For aquifer testing, a temporary 10-in. dia. casing and a permanent telescoping screen was set from 137.5 to 122.5 ft. Well 699-23-34, located 402 ft distant from the pumped well, was measured during the testing of well 699-24-34A. Well 699-23-34 was completed with 15 ft of screen set from 136 to 121 ft. Appendix B summarizes the stratigraphy and well construction for each well.

On January 31, 1987, well 699-24-34A was developed by step-pumping for 2.75 h. The pump intake was set at approximately 137 ft below the land surface during the step-drawdown and constant-discharge tests. Water-level measurements were made from the top of the casing when the stilling hose suspended in the well was pinched off against the side of the casing by the turbine pump. The static water level in well 699-24-34A was 127.06 ft below land surface [404.15 ft above mean sea level (msl)] at the time of the constant-discharge test, on the same day. Before the constant-discharge test, the static water level was 126.30 ft (404.20 ft above msl) below the land surface in the observation well (699-23-34).

E.2.1 Description of the Aquifer Test

The constant-discharge pumping test was conducted January 31, 1987. The water level was measured manually with E-tapes dedicated to both the pumped well and the observation well. Flow rates during the test were measured with the Precision^R flow meter and a 4-in. orifice at the end of an 8-in. discharge pipe. Flow measurements were recorded primarily using the flow meter, and the measurements were corroborated by the height water rose in a piezometer tube set back from the orifice opening.

The flow-meter measurements are considered to be more accurate in this particular instance because of the water loss between the pump and the orifice at the end of the discharge line. The total discharge volume during the test was approximately 30,000 gal; when divided by 43 min of pumping, this gives a value of 700 gpm. The discharge rate was monitored throughout the pumping phase of the aquifer test. The pumping rate apparently did not vary more than 20 gpm during the test, a variation of less than 3%. The discharge data are documented on the field data collection sheets presented in the back of this section. The water from the test was discharged about 1000 ft downgradient from the pumped well.

The pumping was terminated after 43 min because water levels had apparently equilibrated in the pumping well and the generator driving the turbine pump was overheating. The maximum drawdown was 0.56 ft at the time pumping stopped. The specific capacity of well 699-24-34A was approximately 1250 gpm/ft. Well 699-23-34 did not provide data useful for calculating aquifer characteristics.

Water levels were observed in the pumping and observation wells immediately following termination of pumping. The observation well did not show any change in water level following cessation of pumping. The water level in the pumped well recovered above the static level by 0.04 ft within 30 s of pump shutoff and 0.09 ft within 1 min of pump shutoff. The water level fluctuated from 0.01 to 0.14 ft above static for the 60 min during which recovery was measured. Because of the fluctuations and sudden recovery in the pumped well and the lack of visible effects of pumping on the observation well, recovery measurements could not be used to determine aquifer coefficients.

E.2.2 Transmissivity Calculations for the Drawdown Test

Although the drawdown in well 699-24-34A was only 0.56 ft, corrections are probably required for collected data because the well penetrated 15 ft of the aquifer's total saturated thickness of approximately 60 ft; these corrections would only be necessary if the unconfined aquifer ranged from the static water table to the top of the Ringold Formation and the layer depth was correlated from nearby wells. However, after briefly examining the data and applying Jacob's equation (Jacob 1963), the maximum drawdown of 0.56 ft would be corrected to 0.5574 ft, suggesting little difference between corrected and uncorrected water levels. Therefore, the data were not corrected for partial penetration.

The data considered most representative of the aquifer are taken during the latter portion of the test, unless some hydraulic boundary is encountered. For this test, an attempt was made to analyze data for the period from 1.5 to 43 min. Plotted water-level data earlier than 1.5 min into the test indicate pumping rate adjustments or borehole storage effects. The plotted data from the drawdown-versus-time curve fall on the flattened portion of the Theis-type curve (Theis 1963), which makes it difficult to interpret. However, a least-squares analysis was done on the drawdown data and a regression line drawn and matched to the Theis-type curve. Transmissivity is approximately 360,000 ft^2/d. Test results are shown in Figure E.1.

Because water levels in the observation well did not respond to the pumping of well 699-24-34A, storativity values could not be calculated. A

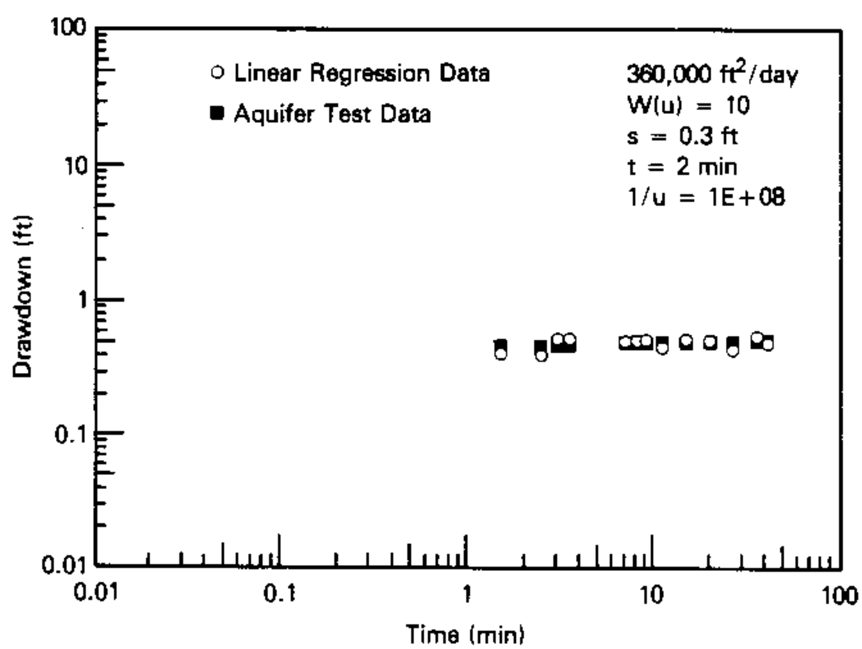

FIGURE E.1. Aquifer Test Results for Well 699-24-34A Based on the Theis-Type Curve line could be fitted to the data using the Cooper-Jacob (Cooper and Jacob 1946) method only by fitting a trend line determined by a least-squares fit (as is evident from the semilogarithmic plot of the drawdown data presented in Figure E.1). A line drawn to match the least-squares trend indicates a transmissivity of about 350,000 ft^2/d (Figure E.2).

A specific capacity approximation was also used to estimate the transmissivity from data collected during this aquifer test. The specific capacity approximation of transmissivity is given by the formula from Theis (1963):

$$T' = \text{estimated transmissivity of the well (gpd/ft)}$$
$$T' = Q/s\ (K - 264 \log_{10} 5S + \log_{10} t)$$

where T′ is the estimated transmissivity of the well (gpd/ft)
Q is the discharge rate, in gpm
s is the drawdown, in ft
K is a constant to obtain transmissivity from specific capacity
S is the storativity of the aquifer, dimensionless
t is the duration of the pumping period, in days.

If the storativity is estimated at 0.1, t is 43 min or 0.03 d, and the well screen is 10 in. in diameter; then the following formula may be written:

$$T' = 700\ \text{gpm}/0.56\ \text{ft}\ [1{,}575 - 264 \log (5 \times 0.1) + 264 \log 0.03]$$
$$T' = 1{,}250\ \text{gpm/ft}\ (1{,}575 + 79 - 402)$$
$$T' = 1{,}250\ (1{,}575 - 323)\ \text{gpd/ft}$$
$$T' = 1{,}250 \times 1{,}252\ \text{gpd/ft} = 1.565 \times 10^6\ \text{gpd/ft}$$
$$T' = 210{,}000\ \text{ft}^2/\text{day}$$

The estimated transmissivity using the Jacob modification of the Theis nonequilibrium formula (Jacob 1963a,b) would result in a value of 250,000 ft^2/d if the same parameters are used as for the above estimate.

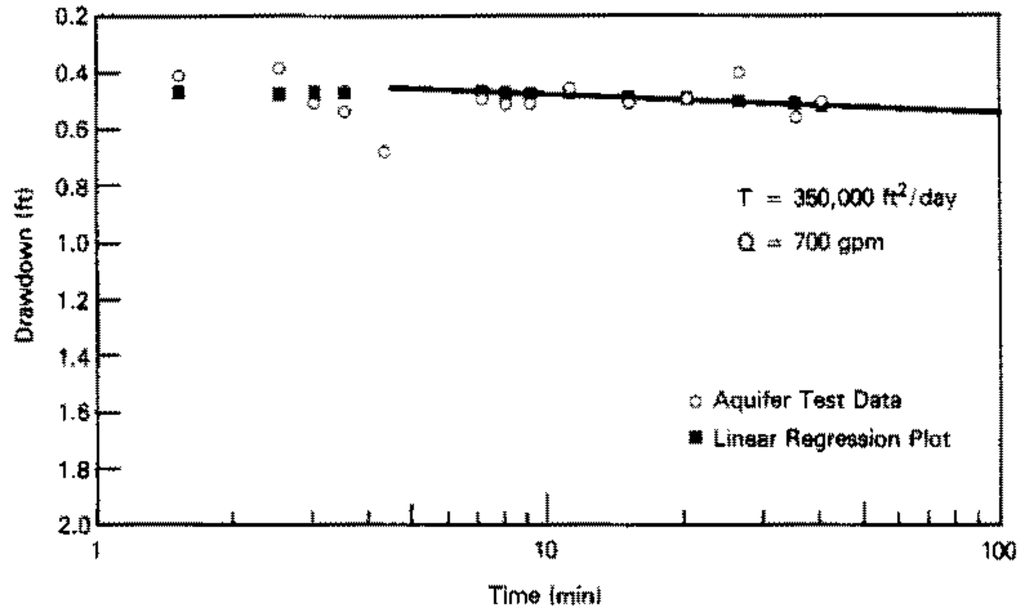

FIGURE E.2. Aquifer Test Data for Well 699-24-34A Based on the Cooper-Jacob (modified Theis) Method of Analysis

No data for the aquifer test could be plotted because of the quick response and fluctuations in the pumped well and the lack of response in the observation well. The water level in the pumped well recovered within 30 sec of the time the pump was shut off.

An average transmissivity of 300,000 ft^2/d was calculated from the drawdown data by using curve-matching and straight-line analytical methods and a specific capacity estimation. The recovery data could not be analyzed because the water level recovered too quickly. The curve-matching and straight-line methods gave transmissivities of 360,000 and 350,000 ft^2/d, respectively. The estimated transmissivity calculated from the specific capacity is 210,000 to 290,000 ft^2/d. The hydraulic conductivity for the unconfined aquifer at well 699-24-34A is approximately 3500 to 6000 ft/d, and averages 5,000 ft/d, if the aquifer thickness is about 60 ft at this location. The aquifer testing data and the construction data for well 699-24-34A are summarized in the next section. The field data are presented after that.

E.2.3 Aquifer Testing and Well Construction Summary

WELL: 699-24-34A (SW-3) DATE OF TEST: 1/31/87

LAND SURFACE DATUM (LSD) ELEVATION (ft above MSL): 531.71
(brass cap)

TOP OF CASING (ft above MSL): 533.89

STATIC WATER LEVEL (date of test): 127.06 ft below LSD

ELEVATION: 404.15 ft above MSL

MAXIMUM PUMPING WATER LEVEL: 127.62 ft below LSD

ELEVATION: 403.59 ft above MSL

MAXIMUM DRAWDOWN: 0.56 ft

PUMPING RATE: 700 gpm

PUMPING TIME: 43 min TOTAL DISCHARGE: >30,000 gal

ESTIMATED DEPTH TO:

TOP OF CLAY: 210 ft below LSD 321.71 ft above MSL
(Weeks, Luttrell, and Fuchs 1987)

ESTIMATED THICKNESS OF AQUIFER: 60 ft (18.3 m)
(Weeks, Luttrell, and Fuchs 1987)

TOP OF SCREEN: 122.5 ft below LSD ELEVATION: 409.21 ft above MSL

BOTTOM OF SCREEN: 137.5 ft below LSD ELEVATION: 394.21 ft above MSL

OBSERVATION WELLS:
#1 Well 699-23-34 (SW-2) TOP OF SCREEN: 121 ft
BOTTOM OF SCREEN: 136 ft
DISTANCE FROM PUMPED WELL: 402 ft

Aquifer Test Data Summary

PARAMETER	PUMPED WELL
DRAWDOWN	
TRANSMISSIVITY; ft^2/d (m^2/d)	
Specific Capacity Estimation (Theis) ft (m)	250,000 (23,225)
RECOVERY	
TRANSMISSIVITY: ft^2/d (m^2/d)	__________
PROBABLE VALUE ft^2/d (m^2/d)	250,000 (23,225)
STORATIVITY:	__________
CONDUCTIVITY: ft/d (m/d)	4200 (1281)

Aquifer Test Data

6-24-34A

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Data for Well SW-3
Pumping Well SW-3
Observation Wells SW-2 (6-23-34)

Location CENTRAL LANDFILL SITE
Type of Aquifer Test
How Q Measured FLOW METER/ORIFICE PLATE
How W.L.'s Measured E-TAPE / STEEL TAPE Depth of Pump/Airpipe 137'
Rad./Dist. of/From Pumping Well Pump On: date 1/31/87 time
Meas. Point for W.L.'s T/PVC HOSE Pump Off: date 1/31/87 time
Elevation of Meas. Point Duration of Aquifer Test
129.97 129.03 T/C

1.945
.210
2.155

128.99
1.91
127.08

Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'	129.04 START	Discharge Reading	Q	Recorded By	Comments
		Time t = ___ at t' = 0			Water Level Data Steel Static Water Level 128.79 tape								
1/31	0859	0					129.03			[illegible]	0	CSC	MEASURED T/C
	0900	0					129.04						Measuring tube
		:30					129						pinched off
		1											FLOW MEASURED
		1:30											by PRECISION
		2											METER # 8333000
		2:30											STARTED PUMP
		3											SAND COMING OUT
		3:30											
		4											
		4:30											PUMPING AT
		5											RATE TO PULL
		6											SAND OUT
		7											
		8											4" ORIFICE
		9					129.10						13.75" = 229 gpm
		10					128.9						losing H₂O around pipe
		12					129.10						~ 300 gpm
		14											
		16											
		18					129.12						
		20								[illegible]			
		25								[illegible]	330		330 gpm
		30					129.14						
		40					129.17						
		45								[illegible]	338		
		50					129.12						
	1000	60					129.14						
		:30					129.22						STEP UP
		1					129.23						
		1:30					129.23						
		2					129.22						
		3											
		4					129.22			~450			
		5											
	10	6											
	12	7					129.26						
	14	8											
	16	9					129.22						

Aquifer Test Data

Data for Well SW 3
Pumping Well SW 3
Observation Wells SW 3

Location CENTRAL LANDFILL
Type of Aquifer Test STEP DRAWDOWN
How Q Measured FLOW METER/ORIFICE
How W.L.'s Measured E-TAPE/STEEL TAPE
Rad./Dist. of/From Pumping Well —
Meas. Point for W.L.'s T/C
Elevation of Meas. Point

Depth of Pump/Airline 137
Pump On: date 1/21/87 time 0900
Pump Off: date time
Duration of Aquifer Test

Time: t = ___ at t' = D					Water Level Data: Static Water Level ___					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
	1020	20					129.25'						2nd step
		25					129.22				450		
		30					129.23						
		40					129.22				440		
		50					129.22						
		60					129.23						
		1:30					129.35'						—— STEP #3
		1											E TAPE STUCK in
		1:30											hole
		2											New set-up with
													E-TAPE NEW MEAS. PT
		22					129.32				600		WILL GET OTHER
		30					129.30				600		E-TAPE WHEN PULL
		45					129.40						PUMP
	1100	60					129.57			——	——		PIEZO. 46"
		1:30					129.57						4" ORIFICE
		1											396 gpm losing
		1:30											much H_2O along
		2					129.60						discharge pipe
		3					129.45						
		4					129.60						FLOW METER IS
		5					129.59						JAMMED WITH
		6											COARSE SAND/GRAVE
		7											
		8											
		9											
		10					129.61						57" PIEZO
		15					129.60						4" ORIFICE
													441 gpm - losing H_2O
		22					129.69						along discharge pipe
		30					129.66						over heating —
	1145	45											PUMP SHUT OFF
RECOVERY													Water on wires ?
		35					128.9						MEASURING
		45					128.9						RECOVERY

Aquifer Test Data

page 3 of 4

Data for Well SW 3
Pumping Well SW 3
Observation Wells SW 2

Location CENTRAL LANDFILL
Type of Aquifer Test CONSTANT - DISCHARGE
How Q Measured FLOW METER / ORIFICE
How W.L.'s Measured E-TAPE STEEL TAPE
Rad./Dist. of/From Pumping Well ———
Meas. Point for W.L.'s T/hole in casing 1.80' LSD
Elevation of Meas. Point
Depth of Pump/~~Airpipe~~ 137'
Pump On: date 1/31/87 time 1345 hr
Pump Off: date ______ time ______
Duration of Aquifer Test ______

Time: t = ___ at t' = 0					Water Level Data (Note) Static Water Level 128.94 TC					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
1/31													
	1345	0					128.94	0					
		:30					128.84						
		1											
		1:30					129.35	.41					
		2											
		2:30					129.32	.38					
		3					129.95	.51					
		3:30					129.47	.53					
		4:30											
		5											
		6									680		680 GPM METER
		7					129.43	.49					
		8					129.45	.51					
		9					129.45	.51					56" PIEZO
		10											4" ORIFICE
		11					129.40	.46					437 gpm losing H_2O
		12											along discharge pipe
		13											
		14											
		15					129.45	.51					
		20					129.44	.50					
		26					129.35	.41			700		55 3/4" PIEZO
		30											4" ORIFICE
		35					129.50	.56					436 gpm losing H_2O
		40					129.45	.51					along discharge pipe
		43											Shut off @43 min
		—	RECOVERY										
		0:30	.5				128.90	-.04					Problems with
		1	1				128.85	-.09					measuring E-TAPE
		1.5	1.5				128.93	-.01					tries to hang up on
		2	2				128.93	-.01					joints or loose in
		E											hole
			3.5				128.80	-.14					
			4				128.95	-.01					
			5				128.93	-.01					
			6										

7 128.84 -.07
8 128.??

Aquifer Test Data

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Data for Well SW3
Pumping Well SW3
Observation Wells SW2

Location Central Landfill
Type of Aquifer Test CONSTANT-DISCHARGE
How Q Measured FLOW METER/ORIFICE 4"
How W.L.'s Measured E-TAPE /STEEL TAPE Depth of Pump/~~Airpipe~~ 137'
Rad./Dist. of/From Pumping Well ——— Pump On: date 1/13/87 time 1345
Meas. Point for W.L.'s T/Rock casing 1.88' LSD Pump Off: date 1/21/87 time
Elevation of Meas. Point Duration of Aquifer Test

Time: t = ___ at t' = 0					Water Level Data: Static Water Level ___					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
		12											
		14											
		17					128.91						
		21					128.93						
		27:30					128.92						
		35					128.80						
		40					128.93						
		45					128.82						
		50					128.80						
		60					128.92						

Aquifer Test Data

page 1 of 4
Data for Well SW-2
Pumping Well SW-3
Observation Wells SW-2

Location CENTRAL LANDFILL SITE
Type of Aquifer Test STEP DRAWDOWN
How Q Measured FLOW METER / ORIFICE
How W.L.'s Measured E-TAPE / STEEL TAPE   Depth of Pump/Airpipe 137'
Rad./Dist. of/From Pumping Well 402' [illegible]   Pump On: date 1/31/87 time 0900
Meas. Point for W.L.'s T/C 2.35' [illegible]   Pump Off: date 1/31/87 time
Elevation of Meas. Point   Duration of Aquifer Test
W.L. 128.65' − 2.35

Time t = ___ at t' = 0					Water Level Data Static Water Level 126.30' [illegible]					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
1/31	0840	0					128.53						
	0858	0					128.54						
		:30					128.54						
		1					128.54						
		1:30					128.53						
		2:00					128.53						
		2:30					128.53						
		3					128.53						
	0907	3:30					128.53						
	0908	4					128.53						
	0909	[illegible]					128.55						
	0910	5					128.55						
	0911	[illegible]					128.52						
	0912	[illegible]					128.52						
	0913	[illegible]					128.57						
	0914	[illegible]					128.56						
	0916	[illegible]					128.57						
	0918	[illegible]					128.56						
	0920	[illegible]					128.57						
	0922	[illegible]					128.57						
	0927	[illegible]					128.56						
	0932	[illegible]					128.56						
	0937	[illegible]					128.55						
	0942	[illegible]					128.56						
	0947	[illegible]					128.57						
	0952	[illegible]					128.54						
	0957	[illegible]					128.55						
		[illegible]					—						
	0958	[illegible]					128.52						
		:30					128.50						
		1					128.56						
		1:30					128.54						
		2					128.57						
		2:30					128.57						
		3					128.54						
		3:30					128.56						
		4					128.55						
		4:30					128.57						
		5					128.55						

Aquifer Test Data

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Data for Well SW-2
Pumping Well SW-3
Observation Wells SW-2

Location Central Landfill
Type of Aquifer Test STEPD RAWDOWN
How Q Measured FLOW METER/ORIFICE
How W.L.'s Measured E-TAPE - STEEL TAPE
Rad./Dist. of/From Pumping Well 402 '
Meas. Point for W.L.'s T/C 2.55' ABV LSD
Elevation of Meas. Point

Depth of Pump/~~Airpipe~~ 137'
Pump On: date 1/31/87 time 0900
Pump Off: date ______ time ______
Duration of Aquifer Test ______

Time t = ____ at t' = 0					Water Level Data Static Water Level ____					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
		6					128.54						
		7					128.56						
		8					128.56						
		9					128.56						
		10					128.58						
		12					128.58						
		14					128.56						
		16					128.56						
		18					128.57						
		20					128.57						
		25					128.55						
		30					128.56						
		35					128.53						
		40					128.55						
		45					128.53						
		50					128.55						
		60					128.54						
		:30					128.54						
		1					128.56						
		1.30					128.55						
		2					128.53						
		2:30					128.54						
		3					128.55						
		3:30					128.57						
		4					128.55						
		4:30					—						
		5					128.56						
		6					128.53						
		7					128.57						
		8					128.55						
		9					128.56						
		10					128.56						
		15					128.57						
		20					128.58						
		25					128.55						
		30					128.58						
		40					128.55						
		50					128.55						
		60											

Aquifer Test Data

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Data for Well SW-2
Pumping Well SW-3
Observation Wells SW-2

Location Central Landfill
Type of Aquifer Test STEP DRAWDOWN
How Q Measured FLOW METER / 4" ORIFICE 8" PIPE
How W.L.'s Measured E-TAPE / STEEL TAPE
Depth of Pump/Airline (Bowls Intake) 137'
Rad./Dist. of/From Pumping Well 402'
Pump On: date 1/31/87 time 0700
Meas. Point for W.L.'s T/C 2.35' above [illegible]
Pump Off: date ____ time ____
Elevation of Meas. Point ____
Duration of Aquifer Test ____

Time: Day	Clock Time	t	t'	t/t'	Water Level Data (Static Water Level ____): Reading	Conversions or Corrections	Water Level	s or s'		Discharge: Reading	Q	Recorded By	Comments
		60					128.55						
		:30					128.57						
		1:00					128.55						
		1:30					128.55						
		2					128.54						
		2:30					128.58						
		3					128.56						
		3:30					128.57						
		4					128.54						
		4:30					128.54						
		5					128.54						
		6					128.55						
		7					128.58						
		8					128.56						
		9					128.55						
		10					128.56						
		15					128.56						
		20					128.57						
		25					128.52						S-TAPE = 128.66'
		30					128.57						
		40					128.57						
		45					128.56						Shut off @ 4 1/30"
		50					128.56						last reading

2700 gpm

Aquifer Test Data

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Data for Well SW-2
Pumping Well SW-3
Observation Wells SW-2

Sustained pump test

Location Central Landfill
Type of Aquifer Test CONSTANT-DISCHARGE
How Q Measured FLOW METER / ORIFICE 4"
How W.L.'s Measured E-TAPE / STEEL TAPE
Depth of Pump/~~Airpipe~~ 137'
Rad./Dist. of/From Pumping Well 402'
Pump On: date 1/31/87 time 1345
Meas. Point for W.L.'s T/C 2.35' ABV LSD
Pump Off: date 1/31/87 time 1425
Elevation of Meas. Point
Duration of Aquifer Test

Time: t = ___ at t' = 0					Water Level Data: Static Water Level ___					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
	1345	0					128.57						STAPE = 128.64 ST.
		:30					128.56						
		1					128.57						
		1:30					128.55						
		2					128.55						
		2:30					128.56						
		3					128.55						
		3:30					128.54						
		4					128.55						
		4:30					128.54						
		5					128.56						
		6					128.58						
		7					128.58						
		8					128.53						
		9					128.55						
		10					128.55						
		15					128.53						
		20					128.57						
		25					128.57						
		30											
		40											
		Recovery											
		63					128.57						

E.3 AQUIFER TEST FOR WELL 699-24-35

Well 699-24-35 was tested at an average pumping rate of 760 gpm for 120 min. Appendix B illustrates the site stratigraphy and well construction at well 699-24-35. The screen was set from 128 to 143 ft. Well 699-24-34A, approximately 1000 ft distant from well 699-24-35, was used as an observation well while pumping well 699-24-35. Well 699-24-34A was completed with 15 ft of screen set from 122.5 to 137.5 ft, as documented in Appendix B.

On February 18, 1987, the well was developed by step-pumping for approximately 60 min until the radiator on the generator overheated. Development was continued for another 70 min on February 20, 1987. The pump intake was set at approximately 141.5 ft below the land surface during the step-drawdown and constant-discharge tests. Discharge was measured with a Precision^{R} flow meter No. 8337808 and corroborated with a 5-in. orifice and an 8-in. discharge pipe. The water from the test was discharged nearly 1000 ft downgradient from the pumped well.

Water levels were measured by an E-tape and recorded manually. Measurements were taken from the top of a stilling hose suspended in the well. The static water level in well 699-24-35 was 132.45 ft below the land surface (404.07 ft above msl) measured at the time of the constant-discharge test. Before the constant-discharge test, static water level in well 699-24-34A was 127.53 ft (404.18 ft above msl) below the land surface.

The constant-discharge pumping test was conducted on February 20, 1987. Water levels were measured manually using E-tapes dedicated to the pumped well and the observation well. The pumping was terminated after 120 min because water levels had apparently equilibrated in the pumped well. The maximum drawdown was 1.19 ft at the time pumping stopped. The specific capacity of well 699-24-35 was approximately 640 gpm/ft. Observation well 699-24-34A did not provide data useful for calculating aquifer coefficients.

Flow rates during the test were measured with a 5-in. orifice at the end of an 8-in. discharge pipe and the Precision^{R} flow meter. Flow measurements were recorded primarily using the flow meter, and measurements were corroborated by the height water rose in a piezometer tube set back from the orifice opening. The flow meter measurements are considered to be more accurate, in this particular instance, because of the loss of water between the pump and the orifice at the end of the discharge line. The total discharge in the test was approximately 91,000 gal, which, when divided by the 120 min of pumping, gives a figure of 760 gpm. The discharge rate was monitored throughout the pumping phase of the aquifer test. The pumping rate apparently did not vary more than 40 gpm during the test, a variation of less than 6%. The discharge data are documented on field data collection sheets at the end of this section.

Water levels were observed in the pumping well and the observation well immediately following termination of pumping. The observation well did not show any change in water level following cessation of pumping. The water level in the pumped well recovered and equilibrated at a static water level 0.04 ft below the original static level within 2 min of the start of recovery measurements. After the initial 30 s of recovery, water levels fluctuated only 0.02 ft below the original static level for the entire 30 min recovery was measured. Because of the sudden recovery to a static water level in the pumped well and the lack of visible effects of pumping on the observation well, recovery measurements could not be used to determine aquifer coefficients.

E.3.1 Transmissivity Calculations for the Drawdown Test

The maximum drawdown in well 699-24-35 was 1.19 ft, and corrections to the collected data were necessary because the well only partially penetrated the aquifer's total saturated thickness of approximately 60 ft. However, after briefly examining the data and applying Jacob's equation (Jacob 1963a,b) and Hantush's (1964) correction, the maximum drawdown of 1.19 ft would be corrected to 1.18 ft, suggesting very little difference between corrected and uncorrected water levels. Therefore, corrections were not applied to the data collected from this well.

The Theis (1935) and Cooper-Jacob (modified Theis) (Cooper 1963) methods are used to analyze portions of the drawdown data. The Theis plot of the drawdown data is presented in Figure E.3. The assumptions are the same as

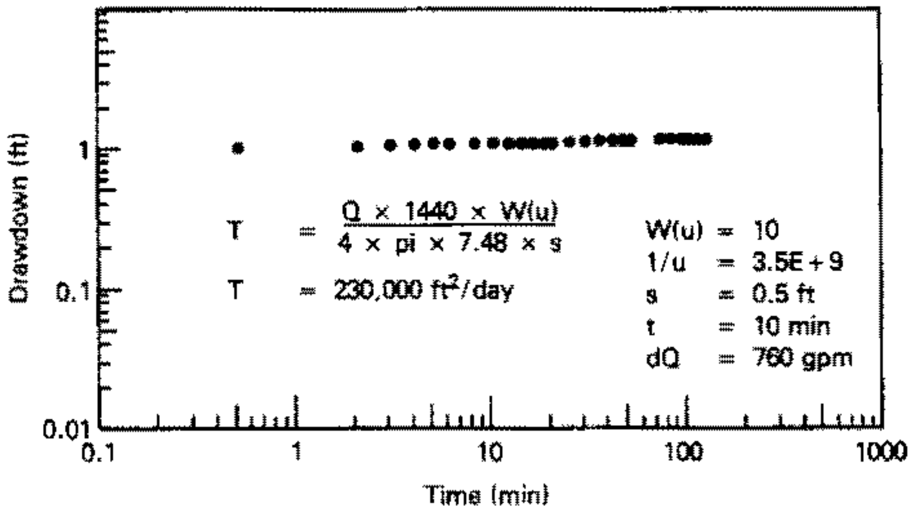

FIGURE E.3. Aquifer Test Results for Well 699-24-35 Based on the Theis-Type Curve

those mentioned for the previous test. For this test, data are analyzed for the period from 10 to 100 min. Plotted water-level data earlier than 10 min into the test indicate pumping rate adjustments or borehole storage effects. The plotted data from the drawdown-versus-time curve fall on the flattened portion of the Theis type curve, which makes it difficult to interpret. However, a transmissivity was determined by this method of analysis. The transmissivity calculated using the Theis curve matching method is 230,000 ft^2/d. The transmissivity calculated using the Cooper-Jacob method is 270,000 ft^2/d. The Cooper-Jacob semilogarithmic plot of the drawdown data is presented in Figure E.4.

Recovery data were not plotted because of the quick response and equilibration in the pumped well and the lack of response in the observation well. The water level in the pumped well recovered to its approximate initial static level within 30 s of the time the pump was shut off.

The aquifer testing data and the construction data for well 699-24-35 are summarized in the next section. The transmissivity ranges from 230,000 to 270,000 ft^2/d. The average transmissivity is approximately

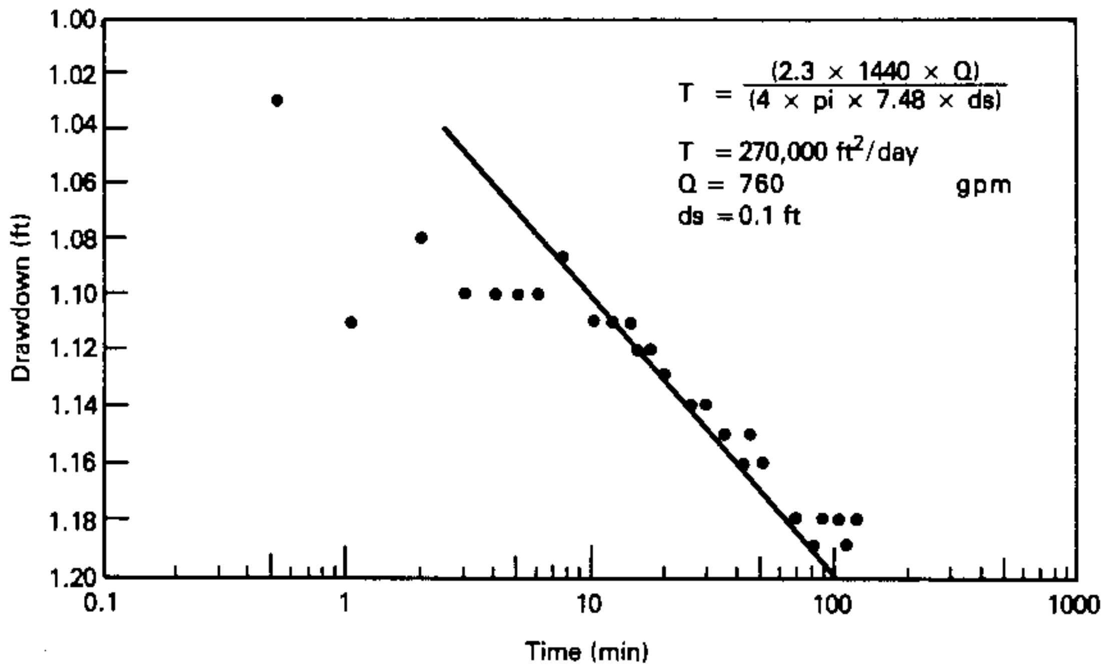

FIGURE E.4. Aquifer Test Data for Well 699-24-35 Based on the Cooper-Jacob (Modified Theis) Method of Analysis

250,000 ft^2/day. If the highly transmissive Hanford formation is considered to have an aquifer thickness of 60 ft, the average hydraulic conductivity is 4200 ft/d, similar to that reported by Weeks, Luttrell and Fuchs (1987). Field data are presented at the end of this appendix.

E.3.2 Aquifer Testing and Well Construction Summary

WELL: 699-24-35 (SW-1) DATE OF TEST: 2/20/87

LAND SURFACE DATUM (lsd) ELEVATION (ft above MSL): 536.52
(brass cap)

TOP OF CASING (ft above MSL): 538.81

STATIC WATER LEVEL (date of test): 132.45 ft below LSD

ELEVATION: 404.07 ft above MSL

MAXIMUM PUMPING WATER LEVEL: 133.64 ft below LSD

ELEVATION: 402.88 ft above MSL

MAXIMUM DRAWDOWN: 1.19 ft

PUMPING RATE: 760 gpm

PUMPING TIME: 120 min TOTAL DISCHARGE: 91,000 gal

ESTIMATED DEPTH TO:

TOP OF CLAY: 210 ft below LSD 326.52 ft above MSL

TOP OF BASALT: 142 ft below LSD 243.62 ft above MSL

ESTIMATED THICKNESS OF AQUIFER: 60 ft (18.3 m)

TOP OF SCREEN: 128 ft below LSD ELEVATION: 408.52 ft above MSL

BOTTOM OF SCREEN: 143 ft below LSD ELEVATION: 393.52 ft above MSL

OBSERVATION WELLS:

#1 Well 699-24-34A (SW-3) TOP OF SCREEN: 122.5 ft
BOTTOM OF SCREEN: 137.5 ft
DISTANCE FROM PUMPED WELL: 402 ft

Aquifer Test Data Summary

PARAMETER	PUMPED WELL
DRAWDOWN	
TRANSMISSIVITY; ft^2/d (m^2/d)	
Curve Match (Theis)	230,000 (21,367)
W(u) = 10	
1/u = 3.5E+9	
s (ft) = 0.5	
t (min) = 10	
Q (gpm) = 760	
Straight-Line Semilog Plot (Cooper-Jacob) ft (m)	270,000 (25,083)
RECOVERY	
TRANSMISSIVITY: ft^2/d (m^2/d)	____________
PROBABLE VALUE ft^2/d (m^2/d)	250,000 (23,225)
STORATIVITY:	____________
CONDUCTIVITY: ft/d (m/d)	4200 (1281)

Aquifer Test Data

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Data for Well SW-1/6-24-35
Pumping Well SW-1/6-24-35
Observation Wells

Location CENTRAL LANDFILL
Type of Aquifer Test STEP TEST DD - DEVELOPMENT
How Q Measured ORIFICE (5"/8" DISCH. PIPE) / FLOW METER
How W.L.'s Measured E-TAPE / STEEL TAPE
Rad./Dist. of/From Pumping Well
Meas. Point for W.L.'s HOSE 1.45' ABV LSD
Elevation of Meas. Point

Depth of Pump/Airpipe 141.5' LSD
Pump On: date 2/18/97 time
Pump Off: date time
Duration of Aquifer Test

Time: t = ___ at t' = 0					Water Level Data MP — Static Water Level 133.9' E-Tape					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		#542 —
2/18		0					133.9	0		Strainer		CSC	FLOW METER
		:30											450 gpm
		1											
		2					134.3	.40				CSC	
		3											
		4					134.36	.46				CSC	
		5											
		6					134.40	.50				CSC	
		7											
		8					134.43	.53				CSC	
		9											
		10					134.45	.55				CSC	
		12					134.46	.56				CSC	FLOW METER ~ 475
		14											
		16					134.49	.59			420	CSC	According to
		18											Orifice/Piezo.
		20					134.52	.62				CSC	
		25					134.56	.66				CSC	
		30					134.57	.67				CSC	
		35					134.59	.69				CSC	
		40					134.60	.70				CSC	
		45					134.60	.70				CSC	
		50					134.61	.70				CSC	
→		:30					134.96	1.06				CSC	1500 RPM
		1					134.98	1.08				CSC	
		2					135.0	1.10				CSC	
		4					135.0	1.10				CSC	
		6					135.0	1.10			520	CSC	
		8					135.0	1.10				CSC	
		10					135.0	1.10				CSC	
		15					135.0	1.11				CSC	OVERHEATED ON
													RADIATOR
2/20	1345		MP		STEEL TAPE		134.14			578000		CSC	NEW TEST
			HOSE					2	no weight				measured through
	1345	0			E-TAPE		133.92	0				CSC	hose
		:30					134.6	.68				CSC	
		1											1500 RPM
		2					135.0	1.08				CSC	
		3					135.02	1.10				CSC	FLOW METER SAYS
		4					135.04	1.12				CSC	600 gpm

Aquifer Test Data

Data for Well SW-1
Pumping Well SW-1
Observation Wells SW 2

Location LANDFILL RCRA
Type of Aquifer Test STEP DD
How Q Measured ORIFICE / FLOWMETER
How W.L.'s Measured E TAPE
Rad./Dist. of/From Pumping Well
Meas. Point for W.L.'s TOP OF HOSE 1.45' ABV LSD
Elevation of Meas. Point

Depth of Pump/Airline 191.5 LSD
Pump On: date 8/20/82 time 1345
Pump Off: date time
Duration of Aquifer Test

Time: t = ___ at t' = 0					Water Level Data: Static Water Level 134.14					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
8/20		6					135.06	1.14				csc	31" 5' / ORIFICE
		7					135.07	1.15				csc	8" PIPE
		8					135.07	1.15			544	csc	
		9					135.08	1.16			680	csc	
	1355	10					135.08	1.16				csc	FLOWMETER = 750
		12					135.08	1.16				csc	
		14					135.08	1.16				csc	
		16					135.09	1.17				csc	
		18					135.10	1.18				csc	
	1405	20					135.10	1.18				csc	
		25					135.12	1.20				csc	730 gpm flowmeter
	1415	30					135.09	1.17			552	csc	
		35					135.08	1.16			497	csc	32" ORIFICE
	1425	40					135.09	1.17				csc	
		45					135.09	1.17				csc	
	1435	50					135.07	1.15				csc	
STEP →		1:30					135.09	1.17				csc	1625 RPM MAX
		1					135.10	1.18				csc	
		2					135.10	1.18				csc	
		3											
		4					135.09	1.13				csc	775 gpm flowmeter
		5											
		6					135.09	1.17				csc	
		8					135.10	1.18				csc	
	1445	10					135.10	1.18			560	csc	
		12					135.10	1.18			705	csc	orifice
		14											
		16					135.12	1.20				csc	
		18					135.12	1.20				csc	
	1455	20					135.10	1.09				csc	
		1:30					133.97					csc	Recovery
		2					133.98					csc	
		3					133.98					csc	
		4					133.98					csc	
		5					133.98					csc	
		7					133.97					csc	
	1505	10					133.94					csc	
		12					133.98					csc	
		14					133.96					csc	

Aquifer Test Data

Data for Well SW-1
Pumping Well SW-1
Observation Wells SW-3

Location CENTRAL LANDFILL
Type of Aquifer Test CONSTANT - DISCHARGE
How Q Measured FLOWMETER / ORIFICE
How W.L.'s Measured E-TAPE
Rad./Dist. of/From Pumping Well 402'
Meas. Point for W.L.'s Top Hose 1.45' abv LSD
Elevation of Meas. Point

Depth of Pump/~~Airpipe~~ 141.5 LSD
Pump On: date 2/20/87 time ~~1345~~ 1530
Pump Off: date 2/20/87 time 1730
Duration of Aquifer Test 2 hrs

Time t = ___ at t' = 0					Water Level Data Static Water Level ___					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
		16					133.96					CSC	
		18					133.97					CSC	
	1515	20					133.95					CSC	
		25					133.95					CSC	
	1525	30					133.95					CSC	
	1530	35					133.96					CSC	
	1530	0					133.96	0					
		:30					134.99	~~1.08~~ 1.03				CSC	CONSTANT-DISCHARGE
		1					135.07	1.11				CSC	TEST
		2					135.04	1.08				CSC	
		3					135.06	1.10				CSC	
		4					135.06	1.10				CSC	725 gpm FLOWMETER
	1535	5					135.06	1.10				CSC	5?
		6					135.06	1.10				CSC	
		8					135.05	1.09				CSC	
	1540	10					135.07	1.11				CSC	
		12					135.07	1.11				CSC	
		14					135.07	1.11				CSC	
		16					135.08	1.12				CSC	
		18					135.08	1.12				CSC	
	1550	20					135.09	1.13				CSC	
		25					135.10	1.14				CSC	
	1600	30					135.10	1.14				CSC	
		35					135.11	1.15				CSC	
	1610	40					135.12	1.16			552	CSC	552 gpm orifice
		45					135.11	1.15				CSC	750 gpm flowmeter
	1620	50					135.12	1.16				CSC	losing a lot of
	1630	60											H_2O between flowmeter
		70					135.14	1.18				CSC	+ orifice
		80					135.15	1.19				CSC	
	1700	90					135.14	1.18				CSC	
		100					135.14	1.18				CSC	~ 800 gpm
		110					135.15	1.19				CSC	
	1730	120	0				135.14	1.18				CSC	RECOVERY
		:30	.5				133.98					CSC	
		121.5	1.5				133.99					CSC	
		122	2				133.98					CSC	
		123	3				134.00					CSC	
		124	4				133.98					CSC	

Aquifer Test Data

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Data for Well SW-1
Pumping Well SW-1
Observation Wells SW-3

Location LANDFILL RCRA
Type of Aquifer Test CONSTANT-DISCHARGE
How Q Measured FLOW METER / ORIFICE
How W.L.'s Measured E-TAPE
Rad./Dist. of/From Pumping Well —
Meas. Point for W.L.'s TOP OF WELL 1.45' ABV LSD
Elevation of Meas. Point

Depth of Pump/~~Airpipe~~ 141.5 LSD
Pump On: date 2/20/87 time 1530
Pump Off: date 2/20/87 time 1730
Duration of Aquifer Test 2 hr

Time t = ___ at t' = 0					Water Level Data Static Water Level ___					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
		5					133.99					CSC	
		6					134.00					CSC	
		7					134.00					CSC	
		8					134.00					CSC	
		9					133.99					CSC	
		10					134.00					CSC	
		15					133.99					CSC	
		20					134.00					CSC	
		25					134.00					CSC	
		30					134.00					CSC	END OF RECOVERY
										[illegible]		RH	

Aquifer Test Data

page 1 of 1

Data for Well SW-3
Pumping Well SW-1
Observation Wells SW-3

Location SW-3 (Central land fill) observation well
Type of Aquifer Test
How Q Measured
How W.L.'s Measured from top of casing S-TAPE
Rad./Dist. of/From Pumping Well
Meas. Point for W.L.'s T/C 533.89' elev msl
Elevation of Meas. Point 533.89' elev msl

Depth of Pump/Airpipe 144 sc
Pump On: date 2/20/87 time
Pump Off: date 2/20/87 time
Duration of Aquifer Test 120 min

Time: t = ___ at t' = 0					Water Level Data 129.71 msl; Static Water Level 127.53 LSD					Discharge		Recorded By	Comments
Day	Clock Time	t	t'	t/t'	Reading	Conversions or Corrections	Water Level	s or s'		Reading	Q		
2/20	13:42						129.71						S-TAPE
2/20	13:47						129.67						E-TAPE
2/20	13:54						129.67						E-TAPE
2/20	13:59						129.67						E-TAPE
	14:10						129.72						E-TAPE
	14:28						129.69						E-TAPE
	14:30						129.69						E-TAPE
	14:38						129.71						E-TAPE
	14:43						129.72						E-TAPE
	14:53						129.71						E-TAPE
	15:03						129.71						E-TAPE
	15:13						129.69						E-TAPE
	15:20						129.69						E-TAPE
	15:25						129.67						E-TAPE
	15:30						129.67						E-TAPE
	15:35						129.72						E-TAPE
	15:40						129.72						E-TAPE
	15:45						129.72						E-TAPE
	15:50						129.72						E-TAPE
	16:00						129.72						E-TAPE
	16:10						129.71						E-TAPE
	16:40						129.72						E-TAPE
	16:50						129.71						E-TAPE
	17:10						129.71						E-TAPE
	17:20						129.72						E-TAPE
													E-TAPE

E.4 WATER LEVEL DATA

Table E.1 lists water level data collected April through September 1988 for SWL wells. The 6 under the well name stands for 699.

TABLE E.1. Water Level Measurements at the Solid Waste Landfill

Well Name	Casing Elevation (ft above MSL)	Collection Date	Depth to Water (ft)	Water Table (ft above MSL)
6-20-20	505.58	01APR88	103.17	402.41
		09MAY88	103.14	402.44
		02JUN88	103.17	402.41
		07JUL88	103.17	402.41
		29JUL88	103.14	402.44
		02SEP88	103.05	402.53
6-20-39	539.98	01APR88	135.13	404.85
		09MAY88	135.43	404.55
		02JUN88	135.39	404.59
		07JUL88	135.34	404.64
		29JUL88	135.26	404.72
		02SEP88	135.25	404.73
6-23-34	532.86	01APR88	128.26	404.60
		09MAY88	128.44	404.42
		02JUN88	128.52	404.34
		07JUL88	128.33	404.53
		29JUL88	128.28	404.58
		02SEP88	128.18	404.68
6-24-33	524.21	01APR88	119.70	404.51
		09MAY88	119.89	404.32
		02JUN88	119.96	404.25
		07JUL88	119.78	404.43
		29JUL88	119.73	404.48
		02SEP88	119.63	404.58
6-24-34A	533.89	01APR88	129.29	404.60
		09MAY88	129.46	404.43
		02JUN88	129.55	404.34
		07JUL88	129.35	404.54
		29JUL88	129.30	404.59
		02SEP88	129.20	404.69
6-24-34B	533.50	01APR88	128.88	404.62
		09MAY88	129.06	404.44
		02JUN88	129.15	404.35
		07JUL88	128.94	404.56

TABLE E.1. (contd)

Well Name	Casing Elevation (ft above MSL)	Collection Date	Depth to Water (ft)	Water Table (ft above MSL)
		29JUL88	128.90	404.60
		02SEP88	128.79	404.71
6-24-34C	532.58	01APR88	127.98	404.60
		09MAY88	128.15	404.43
		02JUN88	128.24	404.34
		07JUL88	128.04	404.54
		29JUL88	128.00	404.58
		02SEP88	127.89	404.69
6-24-35	538.81	01APR88	134.15	404.66
		09MAY88	134.34	404.47
		02JUN88	134.42	404.39
		07JUL88	134.21	404.60
		29JUL88	134.17	404.64
		02SEP88	134.06	404.75
6-25-34B	529.13	01APR88	124.53	404.60
		09MAY88	124.70	404.43
		02JUN88	124.79	404.34
		07JUL88	124.58	404.55
		29JUL88	124.54	404.59
		02SEP88	124.44	404.69
6-25-34C	535.46	01APR88	130.84	404.62
		09MAY88	131.02	404.44
		02JUN88	131.10	404.36
		07JUL88	130.91	404.55
		29JUL88	130.86	404.60
		02SEP88	130.76	404.70
6-26-33	535.49	01APR88	130.90	404.59
		09MAY88	131.06	404.43
		02JUN88	131.15	404.34
		07JUL88	130.94	404.55
		29JUL88	130.90	404.59
		02SEP88	130.79	404.70
6-26-34	528.09	01APR88	123.46	404.63
		09MAY88	123.62	404.47
		02JUN88	123.72	404.37
		07JUL88	123.49	404.60
		29JUL88	123.46	404.63
		02SEP88	123.33	404.76

TABLE E.1. (contd)

Well Name	Casing Elevation (ft above MSL)	Collection Date	Depth to Water (ft)	Water Table (ft above MSL)
6-26-35A	532.37	01APR88	127.66	404.71
		09MAY88	127.87	404.50
		02JUN88	127.95	404.42
		07JUL88	127.73	404.64
		29JUL88	127.69	404.68
		02SEP88	127.58	404.79
6-28-40	559.44	01APR88	154.23	405.21
		09MAY88	154.58	404.86
		02JUN88	154.59	404.85
		07JUL88	154.33	405.11
		29JUL88	154.32	405.12
		02SEP88	154.19	405.25
6-31-31	529.32	01APR88	124.74	404.58
		09MAY88	124.93	404.39
		02JUN88	125.01	404.31
		07JUL88	124.80	404.52
		29JUL88	124.76	404.56
		02SEP88	124.65	404.67
6-34-39A	537.07	01APR88	131.70	405.37
		09MAY88	132.04	405.03
		02JUN88	132.09	404.98
		07JUL88	131.70	405.37
		29JUL88	131.78	405.29
		02SEP88	131.53	405.54

E.5 REFERENCES

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APPENDIX F

RAW ANALYTICAL DATA FOR GROUND-WATER SAMPLES COLLECTED FROM WELLS AT THE SOLID WASTE LANDFILL

APPENDIX F

RAW ANALYTICAL DATA FOR GROUND-WATER SAMPLES COLLECTED FROM WELLS AT THE SOLID WASTE LANDFILL

F.1 SUMMARY OF ANALYTICAL RESULTS

A simple summary of the results is presented in Table F.1 with the following information:

- Database Constituent Code
- Database Abbreviated Constituent Name
- Analysis units: MPN = most probable number
  pCi/L = picoCuries per liter
  μmho = micro-mhos
  ppb = parts per billion
- Number of samples analyzed to date
- Number of samples below Detection Limit (see Section F.2)
- Indication (***) that ALL samples were below Detection Limits. Note that no further data summaries will be given for these.
- Regulatory Limits (. indicates no limit at present)
- Regulating Agency for Limit
- Indication (xxx) that one or more results have exceeded a regulatory limit
- Full Name for Constituent.

The main uses for Table F.1 are to

- summarize the scope of the sampling efforts near the Solid Waste Landfill (SWL) and Nonradioactive Dangerous Waste Landfill (NRDW)
- give a full description of the computerized information for each constituent

TABLE F.1. SWL and NRDW Ground-water Monitoring Compliance Projects
Sample Summary for Data Collected Through August 1988

---------- GROUP=Individual Analyses ----------

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
088	CONDLAB	umho	150	0		700	WDOE		Specific conductance, laboratory
109	COLIFRM	MPN	94	81		1	EPA	xxx	Coliform bacteria
111	BETA	pCi/L	93	0		50	EPA		Gross beta
181	RADIUM	pCi/L	41	0		5	EPA		Total radium
191	CONDFLD	umho	244	0		700	WDOE	xxx	Specific conductance, field
199	PHFIELD		244	0		8.5	EPAS		pH, field
207	PH-LAB		162	0		8.5	EPAS		pH, laboratory
212	ALPHA	pCi/L	93	0		15	EPA		Gross alpha
C68	TOX	ppb	56	36		.			Total organic halogen
C69	TOC	ppb	238	0		.			Total organic carbon
C70	CYANIDE	ppb	18	18	***	.			Cyanide
C80	AMMONIU	ppb	42	27		.			Ammonium ion
C81	ETHYGLY	ppb	6	6	***	.			Ethylene glycol
C86	DIOXIN	ppb	6	6	***	.			Dioxin
C87	CITRUSR	ppb	6	6	***	.			Citrus red
H16	TC	ppb	81	0		.			Total carbon
H17	TDS	ppb	51	0		500000	EPAS	xxx	Total dissolved solids
H42	TOXLDL	ppb	140	8		.			Total organic halogens, low DL
H57	LPHENOL	ppb	71	62		.			Phenol, low DL
H58	ALKALIN	ppb	63	0		.			Total alkalinity, as CaCO3
H62	LHYDRAZ	ppb	1	1	***	.			Hydrazine, low DL
H63	LFLUORD	ppb	57	0		4000	EPA		Fluoride, low DL
H64	BISMUTH	ppb	1	1	***	.			Bismuth
J73	MIBK	ppb	1	0		.			4-Methyl-2-pentanone

---------- GROUP=Direct Aqueous Injection ----------

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A97	1,1-DIM	ppb	2	2	***	.			1,1-Dimethylhydrazine
A98	1,2-DIM	ppb	2	2	***	.			1,2-Dimethylhydrazine
C53	HYDRAZI	ppb	8	8	***	.			Hydrazine
C88	CYANBRO	ppb	2	2	***	.			Cyanogen bromide
C89	CYANCHL	ppb	2	2	***	.			Cyanogen chloride
C90	PARALDE	ppb	8	8	***	.			Paraldehyde
C94	ACRYIDE	ppb	8	8	***	0	EPAP		Acrylamide
C95	ALLYLAL	ppb	8	8	***	.			Allyl alcohol
C96	CHLORAL	ppb	2	2	***	.			Chloral
C97	CHLACET	ppb	8	8	***	.			Chloroacetaldehyde
C98	CHLPROP	ppb	8	8	***	.			3-Chloropropionitrile
C99	CYANOGN	ppb	2	2	***	.			Cyanogen
H01	DICPROP	ppb	2	2	***	.			Dichloropropanol
H03	ETHCARB	ppb	8	8	***	.			Ethyl carbamate
H04	ETHCYAN	ppb	8	8	***	.			Ethyl cyanide
H07	FLUOROA	ppb	2	2	***	.			Fluoroacetic acid
H08	GLYCIDY	ppb	2	2	***	.			Glycidylaldehyde
H09	ISOBUTY	ppb	8	8	***	.			Isobutyl alcohol
H10	METZINE	ppb	2	2	***				Methyl hydrazine

TABLE F.1. (continued)

GROUP=Herbicides

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
H11	PROPYLA	ppb	10000	8	8 ***	.			n-Propylamine
H12	PROPYNO	ppb	8000	8	8 ***	.			2-Propyn-1-ol
H13	2,4-D	ppb	2	47	47 ***	100	EPA		2,4-D [2,4-Dichlorophenoxyacetic acid]
H14	2,4,5TP	ppb	2	47	47 ***	10	EPA		2,4,5-TP silvex

GROUP=Herbicides, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
H15	2,4,5-T	ppb	12	12	***	.			2,4,5-T

GROUP=ICP Metals, filtered

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
H18	FZINC	ppb	91	40		5000	EPAS		Zinc, filtered
H19	FCALCIU	ppb	91	0		.			Calcium, filtered
H20	FBARIUM	ppb	91	0		1000	EPA		Barium, filtered
H21	FCADMIU	ppb	91	86		10	EPA		Cadmium, filtered
H22	FCHROMI	ppb	91	89		50	EPA		Chromium, filtered
H23	FSILVER	ppb	91	91	***	50	EPA		Silver, filtered
H24	FSODIUM	ppb	91	0		.			Sodium, filtered
H25	FNICKEL	ppb	91	91	***	.			Nickel, filtered
H26	FCOPPER	ppb	91	90		1300	EPAP		Copper, filtered
H27	FVANADI	ppb	91	0		.			Vanadium, filtered
H28	FALUMIN	ppb	91	91	***	.			Aluminum, filtered
H29	FMANGAN	ppb	91	73		50	EPAS	xxx	Manganese, filtered
H30	FPOTASS	ppb	91	0		.			Potassium, filtered
H31	FIRON	ppb	91	63		300	EPAS	xxx	Iron, filtered
H32	FMAGNES	ppb	91	0		.			Magnesium, filtered

GROUP=ICP Metals, filtered, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
H33	FBERYLL	ppb	65	65	***	.			Beryllium, filtered
H34	FOSMIUM	ppb	9	9	***	.			Osmium, filtered
H35	FSTRONT	ppb	65	9		.			Strontium, filtered
H36	FANTIMO	ppb	65	65	***	.			Antimony, filtered

TABLE F.1. (continued)

GROUP=ICP Metals, unfiltered

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A04	ZINC	ppb	95	38		5000	EPAS		Zinc
A05	CALCIUM	ppb	95	0		.			Calcium
A06	BARIUM	ppb	98	0		1000	EPA		Barium
A07	CADMIUM	ppb	98	91		10	EPA		Cadmium
A08	CHROMUM	ppb	98	91		50	EPA		Chromium
A10	SILVER	ppb	98	98	***	50	EPA		Silver
A11	SODIUM	ppb	98	0		.			Sodium
A12	NICKEL	ppb	98	95		.			Nickel
A13	COPPER	ppb	98	92		1300	EPAP		Copper
A14	VANADUM	ppb	98	1		.			Vanadium
A16	ALUMNUM	ppb	98	97		.			Aluminum
A17	MANGESE	ppb	98	76		50	EPAS	xxx	Manganese
A18	POTASUM	ppb	98	0		.			Potassium
A19	IRON	ppb	98	31		300	EPAS	xxx	Iron
A50	MAGNES	ppb	95	0		.			Magnesium

GROUP=ICP Metals, unfiltered, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A01	BERYLUM	ppb	57	57	***	.			Beryllium
A02	OSMIUM	ppb	6	6	***	.			Osmium
A03	STRONUM	ppb	57	5		.			Strontium
A15	ANTIONY	ppb	60	60	***	.			Antimony

GROUP=Ion Chromatography

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
C72	NITRATE	ppb	107	0		45000	EPA		Nitrate
C73	SULFATE	ppb	107	0		250000	EPAS		Sulfate
C74	FLUORID	ppb	107	33		4000	EPA		Fluoride
C75	CHLORID	ppb	107	0		250000	EPAS		Chloride
C76	PHOSPHA	ppb	107	107	***	.			Phosphate

GROUP=Ion Chromatography, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
H66	BROMIDE	ppb	34	33		.			Bromide
H67	NITRITE	ppb	34	32		.			Nitrite

TABLE F.1. (continued)

GROUP=Other metals

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
A20	ARSENIC	ppb	86	76		50	EPA		Arsenic
A21	MERCURY	ppb	86	86	***	2	EPA		Mercury
A22	SELENUM	ppb	86	84		10	EPA		Selenium
A51	LEADGF	ppb	86	81		50	EPA		Lead (graphite furnace)

GROUP=Other metals, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
A23	THALIUM	ppb	18	18	***	.			Thallium

GROUP=Other metals, filtered

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
H37	FARSENI	ppb	72	61		50	EPA		Arsenic, filtered
H38	FMERCUR	ppb	77	77	***	2	EPA		Mercury, filtered
H39	FSELENI	ppb	72	72	***	10	EPA		Selenium, filtered
H41	FLEAD	ppb	73	72		50	EPA		Lead, filtered

GROUP=Other metals, filtered, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
H40	FTHALLI	ppb	19	19	***	.			Thallium, filtered

GROUP=Pesticides

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
A33	ENDRIN	ppb	47	47	***	0.2	EPA		Endrin
A34	METHLOR	ppb	47	47	***	100	EPA		Methoxychlor
A35	TOXAENE	ppb	47	47	***	5	EPA		Toxaphene
A36	a-BHC	ppb	47	47	***	4	EPA		Alpha-BHC
A37	b-BHC	ppb	47	47	***	4	EPA		Beta-BHC
A38	g-BHC	ppb	47	47	***	4	EPA		Gamma-BHC
A39	d-BHC	ppb	47	47	***	4	EPA		Delta-BHC

TABLE F.1. (continued)

GROUP=Pesticides, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A40	DDD	ppb	12	12	***	.			DDD
A41	DDE	ppb	12	12	***	.			DDE
A42	DDT	ppb	12	12	***	.			DDT
A43	HEPTLOR	ppb	12	12	***	0	EPAP		Heptachlor
A44	HEPTIDE	ppb	12	12	***	0	EPAP		Heptachlor epoxide
A46	DIELRIN	ppb	12	12	***	.			Dieldrin
A47	ALDRIN	ppb	12	12	***	.			Aldrin
A48	CHLDANE	ppb	12	12	***	0	EPAP		Chlordane
A49	ENDO1	ppb	12	12	***	.			Endosulfan I (alpha)
A52	ENDO2	ppb	12	12	***	.			Endosulfan II (beta)
C62	CHLLATE	ppb	12	12	***	.			Chlorobenzilate

GROUP=Phosphorus pesticides

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
C61	TETEPYR	ppb	12	12	***	.			Tetraethylpyrophosphate
C63	CARBPHT	ppb	12	12	***	.			Carbophenothion
C64	DISULFO	ppb	12	12	***	.			Disulfoton
C65	DIMETHO	ppb	12	12	***	.			Dimethoate
C66	METHPAR	ppb	12	12	***	.			Methyl parathion
C67	PARATHI	ppb	12	12	***	.			Parathion

GROUP=Polychlorinated biphenyls

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A54	AR1016	ppb	15	15	***	0	EPAP		Arochlor 1016
A55	AR1221	ppb	15	15	***	0	EPAP		Arochlor 1221
A56	AR1232	ppb	15	15	***	0	EPAP		Arochlor 1232
A57	AR1242	ppb	15	15	***	0	EPAP		Arochlor 1242
A58	AR1248	ppb	15	15	***	0	EPAP		Arochlor 1248
A59	AR1254	ppb	15	15	***	0	EPAP		Arochlor 1254
A60	AR1260	ppb	15	15	***	0	EPAP		Arochlor 1260

GROUP=Semivolatile Organics

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
B61	12-dben	ppb	38	38	***	.			1,2-Dichlorobenzene
B62	13-dben	ppb	38	38	***	.			1,3-Dichlorobenzene
B63	14-dben	ppb	38	38	***	.			1,4-Dichlorobenzene
B89	HEXCBEN	ppb	38	38	***	.			Hexachlorobenzene

<u>TABLE F.1</u>. (continued)

GROUP=Semivolatile Organics

Code	Constituent Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
C26	PENTCHB	ppb	38	38	***	.			Pentachlorobenzene
C37	TETRCHB	ppb	38	38	***	.			1,2,4,5-Tetrachlorobenzene
C43	TRICHLB	ppb	38	38	***	.			1,2,4-Trichlorobenzene
C54	HEXACHL	ppb	38	38	***	.			Hexachlorophene
C55	NAPHTHA	ppb	38	38	***	.			Naphthalene
C56	123TRI	ppb	38	38	***	.			1,2,3-Trichlorobenzene
C57	PHENOL	ppb	38	38	***	.			Phenol
C58	135TRI	ppb	38	38	***	.			1,3,5-Trichlorobenzene
C59	1234TE	ppb	38	38	***	.			1,2,3,4-Tetrachlorobenzene
C60	1235TE	ppb	38	38	***	.			1,2,3,5-Tetrachlorobenzene
C79	KEROSEN	ppb	38	38	***	.			Kerosene
I21	TRIBUPH	ppb	9	9	***	.			Tributylphosphoric acid

GROUP=Semivolatile Organics, enhanced list

Code	Constituent Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
B20	ACETOPH	ppb	12	12	***	.			Acetophenone
B21	WARFRIN	ppb	12	12	***	.			Warfarin
B22	ACEFENE	ppb	12	12	***	.			2-Acetylaminofluorene
B23	AMINOYL	ppb	12	12	***	.			4-Aminobiphenyl
B24	AMIISOX	ppb	12	12	***	.			5-(Aminomethyl)-3-isoxazolol
B25	AMITROL	ppb	12	12	***	.			Amitrole
B26	ANILINE	ppb	12	12	***	.			Aniline
B27	ARAMITE	ppb	12	12	***	.			Aramite
B28	AURAMIN	ppb	12	12	***	.			Auramine
B29	BENZCAC	ppb	12	12	***	.			Benz[c]acridine
B30	BENZAAN	ppb	12	12	***	.			Benz[a]anthracene
B31	BENDICM	ppb	12	12	***	.			Benzene, dichloromethyl
B32	BENTHOL	ppb	12	12	***	.			Benzenethiol
B33	BENDINE	ppb	12	12	***	.			Benzidine
B34	BENZBFL	ppb	12	12	***	.			Benzo[b]fluoranthene
B35	BENZJFL	ppb	12	12	***	.			Benzo[j]fluoranthene
B36	PBENZOU	ppb	12	12	***	.			p-Benzoquinone
B37	BENZCHL	ppb	12	12	***	.			Benzyl chloride
B38	BIS2CHM	ppb	12	12	***	.			Bis(2-chloroethoxy) methane
B39	BIS2CHE	ppb	12	12	***	.			Bis(2-chloroethyl) ether
B40	BIS2EPH	ppb	12	12	***	.			Bis(2-ethylhexyl) phthalate
B41	BROPHEN	ppb	12	12	***	.			4-Bromophenyl phenyl ether
B42	BUTBENP	ppb	12	12	***	.			Butyl benzyl phthalate
B43	BUTDINP	ppb	12	12	***	.			2-sec-Butyl-4,6-dinitrophenol (DNBP)
B44	CHALETH	ppb	12	12	***	.			Chloroalkyl ethers
B45	CHLANIL	ppb	12	12	***	.			p-Chloroaniline
B46	CHLCRES	ppb	12	12	***	.			p-Chloro-m-cresol
B47	CHLEPOX	ppb	12	12	***	0	EPAP		1-Chloro-2,3-epoxypropane
B48	CHLNAPH	ppb	12	12	***	.			2-Chloronaphthalene
B49	CHLPHEN	ppb	12	12	***	.			2-Chlorophenol

<u>TABLE F.1</u>. (continued)

-- GROUP=Semivolatile Organics, enhanced list --

Code	Constituent Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
B50	CHRYSEN	ppb	12	12	***	.			Chrysene
B51	CRESOLS	ppb	12	12	***	.			Cresols
B52	CYCHDIN	ppb	12	12	***	.			2-Cyclohexyl-4,6-dinitrophenol
B53	DIBAHAC	ppb	12	12	***	.			Dibenz[a,h]acridine
B54	DIBAJAC	ppb	12	12	***	.			Dibenz[a,j]acridine
B55	DIBAHAN	ppb	12	12	***	.			Dibenz[a,h]anthracene
B56	DIBCGCA	ppb	12	12	***	.			7H-Dibenzo[c,g]carbazole
B57	DIBAEPY	ppb	12	12	***	.			Dibenzo[a,e]pyrene
B58	DIBAHPY	ppb	12	12	***	.			Dibenzo[a,h]pyrene
B59	DIBAIPY	ppb	12	12	***	.			Dibenzo[a,i]pyrene
B60	DIBPHTH	ppb	12	12	***	.			Di-n-butyl phthalate
B64	DICHBEN	ppb	12	12	***	.			3,3'-Dichlorobenzidine
B65	24-dchp	ppb	12	12	***	.			2,4-Dichlorophenol
B66	26-dchp	ppb	12	12	***	.			2,6-Dichlorophenol
B67	DIEPHTH	ppb	12	12	***	.			Diethyl phthalate
B68	DIHYSAF	ppb	12	12	***	.			Dihydrosafrole
B69	DIMETHB	ppb	12	12	***	.			3,3'-Dimethoxybenzidine
B70	DIMEAMB	ppb	12	12	***	.			p-Dimethylaminoazobenzene
B71	DIMBENZ	ppb	12	12	***	.			7,12-Dimethylbenz[a]anthracene
B72	DIMEYLB	ppb	12	12	***	.			3,3'-Dimethylbenzidine
B73	THIONOX	ppb	12	12	***	.			Thiofanox
B74	DIMPHAM	ppb	12	12	***	.			alpha,alpha-Dimethylphenethylamine
B75	DIMPHEN	ppb	12	12	***	.			2,4-Dimethylphenol
B76	DIMPHTH	ppb	12	12	***	.			Dimethyl phthalate
B77	DINBENZ	ppb	12	12	***	.			Dinitrobenzene
B78	DINCRES	ppb	12	12	***	.			4,6-Dinitro-o-cresol and salts
B79	DINPHEN	ppb	12	12	***	.			2,4-Dinitrophenol
B80	24-dint	ppb	12	12	***	.			2,4-Dinitrotoluene
B81	26-dint	ppb	12	12	***	.			2,6-Dinitrotoluene
B82	DIOPHTH	ppb	12	12	***	.			Di-n-octyl phthalate
B83	DIPHAMI	ppb	12	12	***	.			Diphenylamine
B84	DIPHHYD	ppb	12	12	***	.			1,2-Diphenylhydrazine
B85	DIPRNIT	ppb	12	12	***	.			Di-n-propylnitrosamine
B86	ETHMINE	ppb	12	12	***	.			Ethyleneimine
B87	ETHMETS	ppb	12	12	***	.			Ethyl methanesulfonate
B88	FLUORAN	ppb	12	12	***	.			Fluoranthene
B90	HEXCBUT	ppb	12	12	***	.			Hexachlorobutadiene
B91	HEXCCYC	ppb	12	12	***	.			Hexachlorocyclopentadiene
B92	HEXCETH	ppb	12	12	***	.			Hexachloroethane
B93	INDENOP	ppb	12	12	***	.			Indeno(1,2,3-cd)pyrene
B94	ISOSOLE	ppb	12	12	***	.			Isosafrole
B95	MALOILE	ppb	12	12	***	.			Malononitrile
B96	MELPHAL	ppb	12	12	***	.			Melphalan
B97	METHAPY	ppb	12	12	***	.			Methapyrilene
B98	METHNYL	ppb	12	12	***	.			Metholonyl
B99	METAZIR	ppb	12	12	***	.			2-Methylaziridine
C01	METCHAN	ppb	12	12	***	.			3-Methylcholanthrene
C02	METBISC	ppb	12	12	***	.			4,4'-Methylenebis(2-chloroaniline)
C03	METACTO	ppb	12	12	***	.			2-Methyllactonitrile

TABLE F.1. (continued)

GROUP=Semivolatile Organics, enhanced list

Code	Constituent Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
C05	METHSUL	ppb	12	12	***	.			Methyl methanesulfonate
C06	METPROP	ppb	12	12	***	.			2-Methyl-2-(methylthio) propionaldehyde-
C07	METHIOU	ppb	12	12	***	.			Methylthiouracil
C08	NAPHQUI	ppb	12	12	***	.			1,4-Naphthoquinone
C09	1-napha	ppb	12	12	***	.			1-Naphthylamine
C10	2-napha	ppb	12	12	***	.			2-Naphthylamine
C11	NITRANI	ppb	12	12	***	.			p-Nitroaniline
C12	NITBENZ	ppb	12	12	***	.			Nitrobenzene
C13	NITPHEN	ppb	12	12	***	.			4-Nitrophenol
C14	NNIBUTY	ppb	12	12	***	.			N-nitrosodi-n-butylamine
C15	NNIDIEA	ppb	12	12	***	.			N-nitrosodiethanolamine
C16	NNIDIEY	ppb	12	12	***	.			N-nitrosodiethylamine
C17	NNIDIME	ppb	12	12	***	.			N-nitrosodimethylamine
C18	NNIMETH	ppb	12	12	***	.			N-nitrosomethylethylamine
C19	NNIUREI	ppb	12	12	***	.			N-nitroso-n-methylurethane
C20	NNIVINY	ppb	12	12	***	.			N-nitrosomethylvinylamine
C21	NNIMORP	ppb	12	12	***	.			N-nitrosomorpholine
C22	NNINICO	ppb	12	12	***	.			N-nitrosonornicotine
C23	NNIPIPE	ppb	12	12	***	.			N-nitrosopiperidine
C24	NITRPYR	ppb	12	12	***	.			Nitrosopyrrolidine
C25	NITRTOL	ppb	12	12	***	.			5-Nitro-o-toluidine
C27	PENTCHN	ppb	12	12	***	.			Pentachloronitrobenzene
C28	PENTCHP	ppb	12	12	***	220	EPAP		Pentachlorophenol
C29	PHENTIN	ppb	12	12	***	.			Phenacetin
C30	PHENIAE	ppb	12	12	***	.			Phenylenediamine
C31	PHTHEST	ppb	12	12	***	.			Phthalic acid esters
C32	PICOLIN	ppb	12	12	***	.			2-Picoline
C33	PRONIDE	ppb	12	12	***	.			Pronamide
C34	RESERPI	ppb	12	12	***	.			Reserpine
C35	RESORCI	ppb	12	12	***	.			Resorcinol
C36	SAFROL	ppb	12	12	***	.			Safrol
C39	TETRCHP	ppb	12	12	***	.			2,3,4,6-Tetrachlorophenol
C40	THIURAM	ppb	12	12	***	.			Thiuram
C41	TOLUDIA	ppb	12	12	***	.			Toluenediamine
C42	OTOLHYD	ppb	12	12	***	.			o-Toluidine hydrochloride
C44	245-trp	ppb	12	12	***	.			2,4,5-Trichlorophenol
C45	246-trp	ppb	12	12	***	.			2,4,6-Trichlorophenol
C46	TRIPHOS	ppb	12	12	***	.			O,o,o-triethyl phosphorothioate
C47	SYMTRIN	ppb	12	12	***	.			Sym-trinitrobenzene
C48	TRISPHO	ppb	12	12	***	.			Tris(2,3-dibromopropyl) phosphate
C49	BENZOPY	ppb	12	12	***	.			Benzo[a]pyrene
C50	CHLNAPZ	ppb	12	12	***	.			Chlornaphazine
C51	BISZETH	ppb	12	12	***	.			Bis(2-chloroisopropyl) ether
C52	HEXAENE	ppb	12	12	***	.			Hexachloropropene
C91	STRYCHN	ppb	12	12	***	.			Strychnine
C92	MALHYDR	ppb	12	12	***	.			Maleic hydrazide
C93	NICOTIN	ppb	12	12	***	.			Nicotinic acid

TABLE F.1. (continued)

GROUP=Thiourea, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A24	THIOURA	ppb	6	6	***	.			Thiourea
A25	ACETREA	ppb	6	6	***	.			1-Acetyl-2-thiourea
A26	CHLOREA	ppb	6	6	***	.			1-(o-Chlorophenyl) thiourea
A27	DIETROL	ppb	6	6	***	.			Diethylstilbesterol
A28	ETHYREA	ppb	6	6	***	.			Ethylenethiourea

GROUP=Volatile Organics

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A29	NAPHREA	ppb	6	6	***	.			1-Naphthyl-2-thiourea
A32	PHENREA	ppb	6	6	***	.			N-phenylthiourea
A61	TETRANE	ppb	98	90		5	EPA	xxx	Tetrachloromethane [Carbon Tetrachloride
A64	METHONE	ppb	98	98	***	.			Methyl ethyl ketone
A67	1,1,1-T	ppb	98	41		200	EPA		1,1,1-Trichloroethane
A68	1,1,2-T	ppb	98	98	***	.			1,1,2-Trichloroethane
A69	TRICENE	ppb	98	67		5	EPA	xxx	Trichloroethylene [1,1,2-Trichloroethene
A70	PERCENE	ppb	98	68		.			Perchloroethylene
A71	OPXYLE	ppb	98	98	***	440	EPAP		Xylene-o,p
A80	CHLFORM	ppb	95	93		100	EPA		Chloroform [Trichloromethane]
A93	METHYCH	ppb	95	84		.			Methylene chloride
B14	M-XYLE	ppb	98	98	***	440	EPAP		Xylene-m
H68	HEXONE	ppb	60	60	***	.			Hexone

GROUP=Volatile Organics, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards Standard	Agency	Exceeded	Full name
A62	BENZENE	ppb	96	96	***	5	EPA		Benzene
A63	DIOXANE	ppb	96	96	***	.			Dioxane
A65	PYRIDIN	ppb	96	96	***	.			Pyridine
A66	TOLUENE	ppb	96	96	***	2000	EPAP		Toluene
A72	ACROLIN	ppb	93	93	***	.			Acrolein
A73	ACRYILE	ppb	93	93	***	.			Acrylonitrile
A74	BISTHER	ppb	93	93	***	.			Bis(chloromethyl) ether
A75	BROMONE	ppb	93	93	***	.			Bromoacetone
A76	METHBRO	ppb	93	93	***	.			Methyl bromide
A77	CARBIDE	ppb	93	93	***	.			Carbon disulfide
A78	CHLBENZ	ppb	93	93	***	60	EPAP		Chlorobenzene
A79	CHLTHER	ppb	93	93	***	.			2-Chloroethyl vinyl ether
A81	METHCHL	ppb	93	93	***	.			Methyl chloride [Chloromethane]
A82	CHMTHER	ppb	93	93	***	.			Chloromethyl methyl ether
A83	CROTONA	ppb	93	93	***	.			Crotonaldehyde
A84	DIBRCHL	ppb	93	93	***	0	EPAP		1,2-Dibromo-3-chloropropane

TABLE F.1. (continued)

GROUP=Volatile Organics, enhanced list

Constituent Code	Name	Units	Samples	Below Detection		Drinking Water Standards: Standard	Agency	Exceeded	Full name
A85	DIBRETH	ppb	93	93	***	.			1,2-Dibromoethane
A86	DIBRMET	ppb	93	93	***	.			Dibromomethane
A87	DIBUTEN	ppb	93	93	***	.			1,4-Dichloro-2-butene
A88	DICDIFM	ppb	93	93	***	.			Dichlorodifluoromethane
A89	1,1-DIC	ppb	93	72		.			1,1-Dichloroethane
A90	1,2-DIC	ppb	93	93	***	5	EPA		1,2-Dichloroethane
A91	TRANDCE	ppb	93	92		70	EPAP		trans-1,2-Dichloroethene
A92	DICETHY	ppb	93	92		7	EPA		1,1-Dichloroethylene
A94	DICPANE	ppb	93	93	***	6	EPAP		1,2-Dichloropropane
A95	DICPENE	ppb	93	93	***	.			1,3-Dichloropropene
A96	NNDIEHY	ppb	93	93	***	.			N,N-diethylhydrazine
A99	HYDRSUL	ppb	93	93	***	.			Hydrogen sulfide
B01	IODOMET	ppb	93	93	***	.			Iodomethane
B02	METHACR	ppb	93	93	***	.			Methacrylonitrile
B03	METHTHI	ppb	93	93	***	.			Methanethiol
B04	PENTACH	ppb	93	93	***	.			Pentachloroethane
B05	1112-tc	ppb	93	93	***	.			1,1,1,2-Tetrachlorethane
B06	1122-tc	ppb	93	93	***	.			1,1,2,2-Tetrachlorethane
B08	BROMORM	ppb	93	93	***	100	EPA		Bromoform [Tribromomethane]
B09	TRCMEOL	ppb	93	93	***	.			Trichloromethanethiol
B10	TRCMFLM	ppb	93	88		.			Trichloromonofluoromethane
B11	TRCPANE	ppb	93	93	***	.			Trichloropropane
B12	123-trp	ppb	93	93	***	.			1,2,3-Trichloropropane
B13	VINYIDE	ppb	93	93	***	2	EPA		Vinyl chloride
B15	DIETHY	ppb	93	93	***	.			Diethylarsine
B19	ACETILE	ppb	62	62	***	.			Acetonitrile
C04	METACRY	ppb	93	93	***	.			Methyl methacrylate
C71	FORMALN	ppb	96	96	***	.			Formalin
H05	ETHOXID	ppb	62	62	***	.			Ethylene oxide
H06	ETHMETH	ppb	93	93	***	.			Ethyl methacrylate

*** - Indicates all samples were below detection limits
xxx - Indicates that Drinking Water Standards were exceeded
EPA - based on Maximum Contaminant Levels given in 40 CFR Part 141 (July,1987) National Primary Drinking Water Regulations as amended by 52 FR 25690
EPAR - based on National Interim Primary Drinking Water Regulations, Appendix IV, EPA-570/9-76-003
EPAP - based on proposed Maximum Contaminant Level Goals in 50 FR 46936
EPAS - based on Secondary Maximum Contaminant Levels given in 40 CFR Part 143 National Secondary Drinking Water Regulations
WDOE - based on additional Secondary Maximum Contaminant Levels given in WAC 248-54, Public Water Supplies

- easily identify those constituents that were never detected
- easily identify those constituents that have exceeded regulatory limits.

Review of Table F.1 shows that the constituents detected near the SWL and NRDW include the Resource Conservation and Recovery Act indication parameters (conductivity, pH, total organic carbon, total organic halogens), major ground-water constituents, some minor ground-water constituents, anions, and organics. Additional constituents on the extended WAC 173-303-9905 list were not detected in the ground water. All raw data for those constituents that had at least one value reported as above detection are listed in Table F.2.

Table F.2 presents raw data for those constituents that were detected at least once in samples collected near the SWL and NRDW between January 1986 and July/August 1988.

The following codes have been used in marking the data:

* = radioactive data where the reported result was less than the 2-sigma counting error

m = data point is missing because scheduled sampling was not collected

• = data point is missing because it was not scheduled to be sampled.

F.2 ACCURACY AND PRECISION OF CHEMICAL ANALYSES

Accuracy and precision of chemical analysis data generated by the SWL monitoring project may be estimated using a variety of methods. These methods include matrix spike and surrogate recovery statistics from the analytical laboratory, U.S. Testing Company (UST); accuracy and precision regression formulas from Environmental Protection Agency (EPA) method studies; and EPA Performance Evaluation (PE) Studies. The applicability of these methods depends both on the analysis and on the relationship of the analysis value to the (instrument or method) detection limit.

TABLE F.2 Constituents Detected at Least Once at the Central Landfill January, 1986 to August, 1988

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
1,1,1-T	Jan86		.	.	.	.	.	.	.	30	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	22	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	27	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	21	.	.	.	.	.	.
	May87		5	<2	<2	<2	52	43	56	17	24	3	2	<2	<2	<2
	Jun87		3	.	.	.	49	41	40	.	25	4	.	.	.	.
	Jul/Aug87		3	<2	<2	<2	54	42	46	18	28	3	3	<2	<2	<2
	Oct/Nov87		3	<2	<2	<2	47	42	64	23	35	.	3	5	<2	<2
		1	.	.	.	.	.	.	61	.	.	.	.	.	.	.
	Jan/Feb88		4	<2	<2	<2	60	44	58	23	28	5	<2	<2	<2	<2
	Apr88		3	<2	<2	<2	37	32	41	19	24	4	<2	<2	<2	<2
		1	.	.	.	.	.	32	41	.	.	.	.	.	.	.
		2	.	.	.	.	.	29	.	.	.	.	.	.	.	.
	Jul/Aug88		3	<2	<2	<2	30	26	35	20	23	5	3	3	<2	<2
		1	.	.	.	.	.	.	34	.	.	.	.	.	.	.
PERCENE	Jan86		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	3	.	.	.	.	.	.
	May87		<2	<2	<2	<2	8	6	7	3	4	<2	<2	<2	<2	<2
	Jun87		<2	.	.	.	7	5	6	.	3	<2	.	.	.	.
	Jul/Aug87		<2	<2	<2	<2	6	4	5	3	3	<2	<2	<2	<2	<2
	Oct/Nov87		<2	<2	<2	<2	7	6	8	3	4	.	<2	<2	<2	<2
		1	.	.	.	.	.	.	8	.	.	.	.	.	.	.
	Jan/Feb88		<2	<2	<2	<2	10	7	8	3	4	<2	<2	<2	<2	<2
	Apr88		<2	<2	<2	<2	8	6	8	3	4	<2	<2	<2	<2	<2
		1	.	.	.	.	.	6	8	.	.	.	.	.	.	.
		2	.	.	.	.	.	6	.	.	.	.	.	.	.	.
	Jul/Aug88		<2	<2	<2	<2	7	5	7	4	5	<2	<2	<2	<2	<2
		1	.	.	.	.	.	.	7	.	.	.	.	.	.	

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
TRICENE	Jan86		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	4	.	.	.	.	.	.
	May87		<2	<2	<2	<2	10	8	10	3	5	<2	<2	<2	<2	<2
	Jun87		<2	.	.	.	9	8	8	.	4	<2	.	.	.	.
	Jul/Aug87		<2	<2	<2	<2	8	7	8	3	5	<2	<2	<2	<2	<2
	Oct/Nov87		<2	<2	<2	<2	7	6	8	3	4	.	<2	<2	<2	<2
		1	.	.	.	.	.	.	7	.	.	.	.	.	.	.
	Jan/Feb88		<2	<2	<2	<2	9	7	8	3	3	<2	<2	<2	<2	<2
	Apr88		<2	<2	<2	<2	6	5	6	3	3	<2	<2	<2	<2	<2
		1	.	.	.	.	.	5	6	.	.	.	.	.	.	.
		2	.	.	.	.	.	6	.	.	.	.	.	.	.	.
	Jul/Aug88		<2	<2	<2	<2	5	5	5	3	3	<2	<2	<2	<2	<2
		1	.	.	.	.	.	.	6	.	.	.	.	.	.	.
1,1-DIC	May87		<2	<2	<2	<2	5	5	6	.	3	<2	<2	<2	<2	<2
	Jun87		<2	.	.	.	5	4	6	.	2	<2	.	.	.	.
	Jul/Aug87		<2	<2	<2	<2	5	4	5	<2	2	<2	<2	<2	<2	<2
	Oct/Nov87		<2	<2	<2	<2	4	4	5	<2	<2	.	<2	<2	<2	<2
		1	.	.	.	.	.	.	5	.	.	.	.	.	.	.
	Jan/Feb88		<2	<2	<2	<2	6	5	5	<2	<2	<2	<2	<2	<2	<2
	Apr88		<2	<2	<2	<2	4	4	4	<2	<2	<2	<2	<2	<2	<2
		1	.	.	.	.	.	4	4	.	.	.	.	.	.	.
		2	.	.	.	.	.	4	.	.	.	.	.	.	.	.
	Jul/Aug88		<2	<2	<2	<2	3	3	4	<2	<2	<2	<2	<2	<2	<2
		1	.	.	.	.	.	.	4	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells			(Deep)	Downgradient Wells									(Deep)
			24-35	26-35A	26-34	26-35C	23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	25-33A
TRCMFLM	May87		<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5	<5	<5
	Jun87		<5	.	.	.	<5	<5	<5	.	<5	<5	.	.	.	.
	Jul/Aug87		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Oct/Nov87		<5	<5	<5	<5	<5	5	6	3	5	.	<5	<5	<5	<5
		1	.	.	.	.	.	.	6	.	.	.	.	.	.	.
	Jan/Feb88		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Apr88		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		1	.	.	.	.	.	<5	<5	.	.	.	.	.	.	.
		2	.	.	.	.	.	<5	.	.	.	.	.	.	.	.
	Jul/Aug88		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
CHLFORM	Mar87		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	May87		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Jun87		<5	.	.	.	<5	<5	<5	.	<5	<5	.	.	.	.
	Jul/Aug87		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Oct/Nov87		<5	<5	<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
	Jan/Feb88		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Apr88		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		1	.	.	.	.	.	<5	<5	.	.	.	.	.	.	.
		2	.	.	.	.	.	<5	.	.	.	.	.	.	.	.
	Jul/Aug88		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
METHYCH	Mar87		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	May87		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	220	<10	<10	<10
	Jun87		<10	.	.	.	<10	<10	<10	.	<10	<10	.	.	.	.
	Jul/Aug87		<10	<10	<10	360	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Oct/Nov87		<10	<10	<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.
	Jan/Feb88		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Apr88		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		1	.	.	.	.	.	<10	<10	.	.	.	.	.	.	.
		2	.	.	.	.	.	<10	.	.	.	.	.	.	.	.
	Jul/Aug88		510	<10	<10	<10	<10	1200	<10	<10	160	<10	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.
TETRANE	Jan86		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	<2	.	.	.	.	.	.
	May87		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Jun87		<2	.	.	.	<2	<2	<2	.	<2	<2	.	.	.	.
	Jul/Aug87		<2	<2	<2	<2	7	5	6	<2	<2	<2	<2	<2	<2	<2
	Oct/Nov87		<2	<2	<2	<2	<2	<2	<2	<2	<2	.	<2	<2	<2	<2
		1	.	.	.	.	.	.	<2	.	.	.	.	.	.	.
	Jan/Feb88		<2	<2	<2	<2	7	5	6	3	3	<2	<2	<2	<2	<2
	Apr88		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
		1	.	.	.	.	.	<2	<2	.	.	.	.	.	.	.
		2	.	.	.	.	.	<2	.	.	.	.	.	.	.	.
	Jul/Aug88		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
		1	.	.	.	.	.	.	<2	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
ALKALIN	Mar87		.	.	.	.	.	.	.	192000	.	.	.	.	.	.
	May87		.	.	.	.	.	.	.	189000	.	.	.	.	.	.
	Jun87		132000	.	.	.	227000	200000	211000	.	196000	130000	.	.	.	.
	Jul/Aug87		.	.	.	.	.	.	.	192000	.	.	.	.	.	.
	Oct/Nov87		132000	120000	111000	123000	222000	201000	218000	194000	208000	.	122000	134000	111000	124000
	Jan/Feb88		136000	117000	108000	122000	235000	203000	227000	196000	208000	138000	123000	119000	112000	129000
	Apr88		134000	117000	108000	116000	224000	201000	218000	195000	210000	134000	122000	115000	110000	132000
	Jul/Aug88		130000	115000	106000	122000	593000	195000	212000	.	209000	135000	119000	115000	111000	131000
ALPHA	Jan86		.	.	.	.	.	.	.	4.67	.	.	.	.	.	.
	Oct86		.	1.75	4.64	.	.	.	.	.	.	.	2.25	3.63	1.43	.
	Jan87		.	2.64	2.78	1.34	.	.	.	.	.	.	3.72	3.04	2.7	1.64
	Mar87		.	.	.	.	.	.	.	3.47	.	.	.	.	.	.
	May87		.	4.49	2.4	1.78	.	.	.	3.6	.	.	2.43	3.93	2.18	3.3
	Jun87		4.13	.	.	.	3.95	2.32	2.38	.	3.72	3.08	.	.	.	.
	Jul/Aug87		.	2.91	2.75	1.21	.	.	.	2.96	.	.	1.94	2.06	2.85	2.64
	Oct/Nov87		4.1	2.92	3.4	2.54	4.04	2.76	3.29	3.88	2.15	.	2.09	1.31	1.13	3.44
		1	.	.	.	.	.	.	2.95	.	.	.	.	.	.	.
	Jan/Feb88		3.12	3.49	2.07	*0.832	4.28	3.54	4.57	3.78	5.07	2.58	3.79	*0.572	2.45	2.35
	Apr88		1.74	1.83	2.15	*0.917	3.14	4.35	1.74	2.54	4.78	1.81	1.49	2.42	2.56	2.5
		1	.	.	.	.	.	.	4.24	.	.	.	.	.	.	.
	Jul/Aug88		3.73	1.6	2.15	1.61	4.76	3.14	5.61	.	2.28	3.41	1.76	2.3	1.35	1.83
		1	.	.	.	.	.	.	*1.1	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
ALUMNUM	Jan86		.	.	.	.	.	.	.	<150	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<150	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<150	.	.	.	.	.	.
	Oct86		.	<150	<150	.	.	.	.	.	.	.	<150	<150	<150	.
	Jan87		.	<150	<150	<150	.	.	.	.	.	.	<150	<150	<150	<150
	May87		<150	522	<150	<150	<150	<150	<150	.	<150	<150	<150	<150	<150	<150
	Jun87		<150	.	.	.	<150	<150	<150	.	<150	<150	.	.	.	.
	Jul/Aug87		<150	<150	<150	<150	<150	<150	<150	.	<150	<150	<150	<150	<150	<150
	Oct/Nov87		<150	<150	<150	<150	<150	<150	<150	.	<150	.	<150	<150	<150	<150
	Jan/Feb88		<150	<150	<150	<150	<150	<150	<150	.	<150	<150	<150	<150	<150	<150
	Apr88		<150	<150	<150	<150	<150	<150	<150	.	<150	<150	<150	<150	<150	<150
	Jul/Aug88		<150	<150	<150	<150	<150	<150	<150	.	<150	<150	<150	<150	<150	<150
AMMONIU	Jan86		.	.	.	.	.	.	.	195	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	130	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	145	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	<50	.	.	.	.	.	.
	May87		72	.	.	.	62	51	70	<50	60	52	.	.	.	.
	Jun87		56	.	.	.	72	54	55	.	86	98	.	.	.	.
	Jul/Aug87		<50	.	.	.	<50	<50	<50	<50	<50	<50	.	.	.	.
	Oct/Nov87		.	.	.	.	.	.	.	<50	.	.	.	.	.	.
		1	.	.	.	.	.	.	<50	.	.	.	.	.	.	.
	Jan/Feb88		.	.	.	.	.	.	.	<50	.	.	.	.	.	.
	Apr88		<50	.	.	.	<50	<50	<50	<50	<50	<50	.	.	.	.
		1	.	.	.	.	.	.	<50	.	.	.	.	.	.	.
	Jul/Aug88		<50	.	.	.	<50	<50	<50	.	<50	<50	.	.	.	.
		1	.	.	.	.	.	.	<50	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	26-35C (Deep)	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	25-33A (Deep)
ARSENIC	Jan86		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	Oct86		.	<5	<5	.	.	.	.	.	.	.	<5	<5	<5	.
	Jan87		.	<5	<5	<5	.	.	.	.	.	.	<5	<5	<5	<5
	May87		.	5	<5	<5	.	.	.	.	.	.	<5	5	<5	6
	Jun87		<5	.	.	.	<5	<5	<5	.	<5	<5	.	.	.	.
	Jul/Aug87		.	<5	<5	<5	.	.	.	.	.	.	<5	5	<5	<5
	Oct/Nov87		<5	<5	<5	<5	<5	<5	<5	.	<5	.	<5	<5	<5	<5
	Jan/Feb88		<5	<5	7	<5	<5	<5	<5	.	<5	<5	<5	<5	<5	<5
	Apr88		<5	<5	5	<5	<5	<5	<5	.	<5	<5	<5	5	5	<5
	Jul/Aug88		<5	<5	<5	<5	<5	<5	6	.	<5	<5	<5	5	<5	<5
ARSENIF	Mar87		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	May87		.	<5	<5	<5	.	.	.	<5	.	.	<5	<5	<5	5
	Jun87		<5	.	.	.	<5	<5	<5	.	<5	<5	.	.	.	.
	Jul/Aug87		.	<5	<5	<5	.	.	.	5	.	.	<5	<5	<5	<5
	Oct/Nov87		<5	<5	<5	M	<5	<5	<5	<5	<5	.	5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
	Jan/Feb88		5	.	.	.	<5	<5	<5	<5	<5	<5	.	.	.	.
	Apr88		<5	5	5	<5	<5	<5	<5	<5	<5	<5	<5	6	5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
	Jul/Aug88		<5	<5	<5	<5	<5	<5	<5	.	<5	6	8	<5	5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
BARIUM	Jan86		.	.	.	.	.	.	.	46	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	48	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	48	.	.	.	.	.	.
	Oct86		.	30	27	.	.	.	.	.	.	.	33	33	33	.
	Jan87		.	31	28	53	.	.	.	.	.	.	31	33	31	25
	May87		42	44	29	55	74	61	63	.	46	34	32	34	33	15
	Jun87		48	.	.	.	77	61	66	.	55	42	.	.	.	.
	Jul/Aug87		43	34	30	55	79	64	68	.	51	35	34	36	35	23
	Oct/Nov87		43	31	27	51	73	58	65	.	48	.	35	37	31	24
	Jan/Feb88		44	30	27	50	75	65	66	.	46	41	38	38	37	30
	Apr88		45	35	28	45	73	62	64	.	50	40	33	36	34	23
	Jul/Aug88		42	31	26	49	76	65	66	.	52	40	38	35	30	20
BARIUMF	Mar87		.	.	.	.	.	.	.	53	.	.	.	.	.	.
	May87		41	37	27	56	71	58	62	56	46	34	31	32	30	14
	Jun87		51	.	.	.	78	63	67	.	47	40	.	.	.	.
	Jul/Aug87		43	33	28	54	80	62	66	57	51	35	34	37	34	28
	Oct/Nov87		48	35	32	M	83	60	62	61	49	.	34	40	33	30
		1	.	.	.	.	.	.	68	.	.	.	.	.	.	.
	Jan/Feb88		43	31	32	52	77	63	70	65	48	38	33	34	33	26
	Apr88		44	34	29	47	76	60	67	60	52	38	35	36	36	26
		1	.	.	.	.	.	.	67	.	.	.	.	.	.	.
	Jul/Aug88		43	36	30	47	68	61	67	.	48	36	33	38	32	26
		1	.	.	.	.	.	.	60	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
BETA	Jan86		.	.	.	.	.	.	.	28.5	.	.	.	.	.	.
	Oct86		.	18.2	36.1	.	.	.	.	.	.	.	19.4	22.9	13.5	.
	Jan87		.	31	38	29.5	.	.	.	.	.	.	32.3	32.5	33.9	6.8
	Mar87		.	.	.	.	.	.	.	27.8	.	.	.	.	.	.
	May87		.	35.7	36.1	32.5	.	.	.	23	.	.	34.3	28.7	32.6	10.9
	Jun87		17.8	.	.	.	23.8	21.9	22.3	.	27.9	16.7	.	.	.	.
	Jul/Aug87		.	25.7	21.3	15.5	.	.	.	14.8	.	.	25.2	21.6	23.5	9.74
	Oct/Nov87		16.2	24.2	31.3	23.1	19.1	24.2	24.3	24.9	18.9	.	22.2	22.9	22.9	8.38
		1	.	.	.	.	.	.	27.9	.	.	.	.	.	.	.
	Jan/Feb88		17.2	27.7	27.6	26	21.8	23.8	21.7	25.7	26.1	28.4	31	33.6	28.7	5.94
	Apr88		21.9	30.6	34.4	19.4	22.2	29.1	24.6	29.8	25.2	34	24.4	30.7	31.3	7.23
		1	.	.	.	.	.	.	26.9	.	.	.	.	.	.	.
	Jul/Aug88		27.4	30.3	36.3	22.5	28.6	28.5	24.1	.	27	26.3	27.5	31.2	32.4	8.88
		1	.	.	.	.	.	.	23.6	.	.	.	.	.	.	.
BROMIDE	Jan/Feb88		<1000	.	.	.	<1000	<1000	<1000	.	764	<1000	.	.	.	.
	Apr88		<1000	<1000	<1000	<1000	<1000	<1000	<1000	.	<1000	<1000	<1000	<1000	<1000	<1000
		1	.	.	.	.	.	.	<1000	.	.	.	.	.	.	.
	Jul/Aug88		<1000	<1000	<1000	<1000	<1000	<1000	<1000	.	<1000	<1000	<1000	<1000	<1000	<1000
		1	.	.	.	.	.	.	<1000	.	.	.	.	.	.	.
CADMIUM	Mar87		.	.	.	.	.	.	.	<2	.	.	.	.	.	.
	May87		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Jun87		<2	.	.	.	<2	<2	<2	.	<2	<2	.	.	.	.
	Jul/Aug87		2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Oct/Nov87		<2	<2	2	M	<2	3	<2	<2	<2	.	<2	<2	<2	<2
		1	.	.	.	.	.	.	<2	.	.	.	.	.	.	.
	Jan/Feb88		<2	<2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2
	Apr88		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
		1	.	.	.	.	.	.	<2	.	.	.	.	.	.	.
	Jul/Aug88		<2	<2	<2	<2	<2	<2	<2	.	<2	<2	<2	<2	<2	<2
		1	.	.	.	.	.	.	<2	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
CADMIUM	Jan86		.	.	.	.	.	.	.	<2	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<2	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<2	.	.	.	.	.	.
	Oct86		.	<2	<2	.	.	.	.	.	.	.	<2	<2	<2	.
	Jan87		.	<2	<2	<2	.	.	.	.	.	.	<2	<2	<2	<2
	May87		<2	<2	<2	<2	<2	<2	2	.	2	<2	<2	<2	<2	<2
	Jun87		2	.	.	.	<2	<2	<2	.	<2	<2	.	.	.	.
	Jul/Aug87		3	<2	<2	<2	<2	2	<2	.	<2	<2	<2	<2	<2	<2
	Oct/Nov87		2	<2	<2	<2	2	<2	<2	.	<2	.	<2	<2	<2	<2
	Jan/Feb88		<2	<2	<2	<2	<2	<2	<2	.	<2	<2	<2	<2	<2	<2
	Apr88		<2	<2	<2	<2	<2	<2	<2	.	<2	<2	<2	<2	<2	<2
	Jul/Aug88		<2	<2	<2	<2	<2	<2	<2	.	<2	<2	<2	<2	<2	<2
CALCIUF	Mar87		.	.	.	.	.	.	.	59800	.	.	.	.	.	.
	May87		43100	36500	37100	48500	70600	69400	69500	63700	63600	41300	37700	36900	35200	27200
	Jun87		42800	.	.	.	69300	66700	68500	.	56200	39800	.	.	.	.
	Jul/Aug87		34100	30900	26600	37800	53900	50800	55700	49300	51200	31200	30400	30600	26900	28200
	Oct/Nov87		42300	31700	29800	M	70400	51000	54900	59700	54100	.	35100	42400	32400	28500
		1	.	.	.	.	.	.	58400	.	.	.	.	.	.	.
	Jan/Feb88		46500	39800	36000	46000	79800	73500	82700	69200	73100	46000	41400	39600	37700	35500
	Apr88		42800	38500	35400	43900	73600	67800	70600	69100	68200	41900	39600	35700	35800	31100
		1	.	.	.	.	.	.	70900	.	.	.	.	.	.	.
	Jul/Aug88		42400	40700	33700	44100	67000	68300	73700	.	66700	43300	37900	41200	34400	34600
		1	.	.	.	.	.	.	63900	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells			(Deep)	Downgradient Wells									(Deep)
			24-35	26-35A	26-34	26-35C	23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	25-33A
CALCIUM	Oct86		.	38400	36900	.	.	.	.	.	.	.	40100	37900	36900	.
	Jan87		.	38300	35100	45100	.	.	.	.	.	.	36700	37800	35700	33300
	May87		46200	44500	36700	49700	76600	66400	71500	.	58400	44800	38700	38900	37300	26700
	Jun87		41100	.	.	.	68100	67100	65600	.	58000	40000	.	.	.	.
	Jul/Aug87		40100	31000	28500	38500	63900	70500	65500	.	59900	35900	34200	35300	33600	30800
	Oct/Nov87		37800	32700	29300	39000	64400	52000	58200	.	55400	.	36400	37900	29600	29600
	Jan/Feb88		42700	38300	35800	44700	76600	76500	73700	.	59800	44300	42200	38700	37300	34900
	Apr88		45200	39700	33700	44700	74700	70700	74000	.	74000	45100	40900	38200	36100	34500
	Jul/Aug88		42700	39400	36000	44800	70800	68400	72500	.	73000	42000	40000	35100	34900	31000
CHLORID	Jan86		.	.	.	.	.	.	.	8740	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	8560	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	8370	.	.	.	.	.	.
	Oct86		.	8480	8260	.	.	.	.	.	.	.	8420	8330	8500	.
	Jan87		.	8440	6890	9970	.	.	.	.	.	.	7790	6950	6980	6300
	Mar87		.	.	.	.	.	.	.	9040	.	.	.	.	.	.
	May87		7260	7870	7160	9040	8110	8100	8590	7730	7700	7540	8010	7550	6960	6990
	Jun87		8610	.	.	.	8830	8580	8760	.	8480	9120	.	.	.	.
	Jul/Aug87		8480	8010	6850	9490	8480	8550	8580	8280	8820	7860	7510	7630	7010	6550
	Oct/Nov87		8660	8620	7050	9920	8950	8600	8860	8790	9200	.	7850	8310	7580	6850
		1	.	.	.	.	.	.	8690	.	.	.	.	.	.	.
	Jan/Feb88		7710	7680	7700	8750	7880	8260	8300	8610	7880	7500	7060	7080	6720	7010
	Apr88		8080	7600	6640	9780	8820	8360	9020	8590	8990	7530	6750	6900	6750	6750
		1	.	.	.	.	.	.	7910	.	.	.	.	.	.	.
	Jul/Aug88		7740	6500	6130	8420	7750	7500	7710	.	7430	6950	6710	6640	6380	6470
		1	.	.	.	.	.	.	7870	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
CHROMIF	Mar87		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	May87		<10	13	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Jun87		<10	.	.	.	<10	<10	<10	.	<10	<10	.	.	.	.
	Jul/Aug87		<10	<10	<10	<10	11	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Oct/Nov87		<10	<10	<10	M	<10	<10	<10	<10	<10	.	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.
	Jan/Feb88		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Apr88		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.
	Jul/Aug88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.
CHROMUM	Jan86		.	.	.	.	.	.	.	10	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	11	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	10	.	.	.	.	.	.
	Oct86		.	<10	<10	.	.	.	.	.	.	.	<10	<10	<10	.
	Jan87		.	<10	<10	<10	.	.	.	.	.	.	<10	<10	<10	<10
	May87		<10	<10	<10	10	<10	<10	<10	.	<10	<10	<10	<10	<10	16
	Jun87		<10	.	.	.	<10	<10	<10	.	<10	<10	.	.	.	.
	Jul/Aug87		<10	<10	<10	10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
	Oct/Nov87		<10	<10	<10	<10	<10	<10	<10	.	<10	.	<10	<10	<10	<10
	Jan/Feb88		<10	<10	<10	10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
	Apr88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
	Jul/Aug88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
CONDFLD	Jan86	F	.	.	.	.	.	.	.	517	.	.	.	.	.	.
	Oct86		.	411	397	.	.	.	.	.	.	.	406	394	397	.
		1	.	411	397	.	.	.	.	.	.	.	.	.	.	.
		2	.	410	396	.	.	.	.	.	.	.	.	.	.	.
		3	.	410	397	.	.	.	.	.	.	.	.	.	.	.
	Jan87		.	355	344	339	.	.	.	.	.	.	380	380	380	328
		1	.	361	354	340	.	.	.	.	.	.	.	.	.	.
		2	.	362	365	369	.	.	.	.	.	.	.	.	.	.
		3	.	365	367	388	.	.	.	.	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	465	.	.	.	.	.	.
	May87		362	371	352	370	524	471	508	442	505	378	381	387	369	316
		1	.	363	352	370	.	.	.	.	.	.	.	.	.	.
		2	.	358	367	370	.	.	.	.	.	.	.	.	.	.
		3	.	356	358	378	.	.	.	.	.	.	.	.	.	.
	Jun87		370	.	.	.	452	456	485	.	448	335	.	.	.	.
	Jul/Aug87		341	342	288	359	476	439	459	.	427	312	357	347	330	371
		1	.	341	279	357	.	.	.	.	.	.	.	.	.	.
		2	.	340	279	356	.	.	.	.	.	.	.	.	.	.
		3	.	340	280	357	.	.	.	.	.	.	.	.	.	.
	Oct/Nov87		416	372	361	424	587	554	593	494	566	.	437	471	379	413
		1	.	371	359	424	.	.	.	.	.	.	.	.	.	.
		2	.	370	358	424	.	.	.	.	.	.	.	.	.	.
		3	.	369	358	423	.	.	.	.	.	.	.	.	.	.
	Jan/Feb88		358	394	341	362	506	557	566	420	464	287	406	270	255	273
		1	.	394	340	362	.	.	.	.	.	.	406	269	254	272
		2	.	394	341	362	.	.	.	.	.	.	406	269	254	272
		3	.	394	341	361	.	.	.	.	.	.	406	269	254	271
	Apr88		485	382	413	441	612	563	631	561	714	484	521	390	419	469
		1	485	384	413	442	612	563	630	.	723	483	522	391	418	469
		2	483	385	413	443	613	566	629	.	725	484	520	393	418	471
		3	484	385	414	443	613	584	630	.	726	484	520	393	419	470
	Jun88		.	.	.	.	.	.	.	.	.	.	337	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
CONDFLD	Jul/Aug88		281	207	214	222	267	458	285	529	508	346	309	307	279	270
		1	280	207	214	221	265	460	286	.	509	346	308	306	279	271
		2	280	207	214	222	265	460	286	.	508	346	308	307	280	269
		3	280	207	214	222	265	460	286	.	508	345	309	307	280	270
CONDLAB	Oct/Nov87		417	333	333	375	563	453	474	.	458	.	495	417	370	365
	Jan/Feb88		434	396	396	459	604	573	584	.	563	448	396	406	401	406
		1	.	396	396	459	.	.	.	.	.	.	396	302	281	292
		2	.	396	396	459	.	.	.	.	.	.	406	302	292	292
		3	.	406	396	459	.	.	.	.	.	.	406	297	292	297
	Apr88		417	386	375	406	563	552	458	.	417	344	323	375	375	313
		1	417	386	375	406	563	521	417	.	417	344	313	375	375	297
		2	417	386	375	406	563	521	417	.	417	344	313	375	375	297
		3	417	386	375	406	552	521	417	.	417	344	313	375	365	313
	Jul/Aug88		468	409	385	427	697	542	657	.	624	494	463	459	399	400
		1	464	412	387	426	688	543	697	.	616	505	462	461	399	399
		2	467	415	388	422	685	542	697	.	622	487	463	461	399	399
		3	467	410	387	422	688	541	694	.	619	509	461	459	398	399
COLIFRM	Jan86		.	.	.	.	.	.	.	<3	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<3	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<3	.	.	.	.	.	.
	Oct86		.	>16	<2.2	.	.	.	.	.	.	.	2.2	<2.2	<2.2	.
	Jan87		.	<2.2	<2.2	2.2	.	.	.	.	.	.	<2.2	<2.2	<2.2	<2.2
	May87		<2.2	>16	>16	>16	<2.2	<2.2	<2.2	.	<2.2	5.1	<2.2	<2.2	<2.2	>16
	Jun87		<2.2	.	.	.	<2.2	<2.2	<2.2	.	<2.2	2.2	.	.	.	.
	Jul/Aug87		2.2	<2.2	<2.2	>16	<2.2	<2.2	<2.2	.	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2
	Oct/Nov87		<2.2	<2.2	<2.2	>16	<2.2	<2.2	<2.2	.	<2.2	.	<2.2	<2.2	<2.2	<2.2
	Jan/Feb88		<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	.	<2.2	M	<2.2	M	M	M
	Apr88		<2.2	<2.2	2.2	<2.2	<2.2	<2.2	<2.2	.	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2
	Jul/Aug88		<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	.	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
COPPER	Jan86		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	Oct86		.	<10	<10	.	.	.	.	.	.	.	<10	<10	<10	.
	Jan87		.	<10	<10	<10	.	.	.	.	.	.	<10	<10	<10	17
	May87		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	28
	Jun87		<10	.	.	.	<10	<10	<10	.	<10	<10	.	.	.	.
	Jul/Aug87		51	<10	<10	<10	<10	21	<10	.	<10	<10	<10	<10	<10	<10
	Oct/Nov87		<10	<10	<10	<10	<10	<10	10	.	<10	.	<10	<10	<10	<10
	Jan/Feb88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	30
	Apr88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
	Jul/Aug88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
COPPERF	Mar87		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	May87		<10	14	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Jun87		<10	.	.	.	<10	<10	<10	.	<10	<10	.	.	.	.
	Jul/Aug87		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Oct/Nov87		<10	<10	<10	M	<10	<10	<10	<10	<10	.	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.
	Jan/Feb88		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	Apr88		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.
	Jul/Aug88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
		1	.	.	.	.	.	.	<10	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells			(Deep)	Downgradient Wells									(Deep)
			24-35	26-35A	26-34	26-35C	23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	25-33A
FLUORID	Jan86		.	.	.	.	.	.	.	687	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	696	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	718	.	.	.	.	.	.
	Oct86		.	<500	<500	.	.	.	.	.	.	.	<500	<500	<500	.
	Jan87		.	<500	<500	<500	.	.	.	.	.	.	<500	<500	<500	<500
	Mar87		.	.	.	.	.	.	.	<500	.	.	.	.	.	.
	May87		619	581	701	<500	601	611	629	<500	634	636	732	677	685	602
	Jun87		547	.	.	.	<500	503	532	.	568	550	.	.	.	.
	Jul/Aug87		683	674	704	555	650	648	679	<500	635	682	685	673	693	638
	Oct/Nov87		754	646	594	<500	737	700	676	676	643	.	758	760	801	565
		1	.	.	.	.	.	.	684	.	.	.	.	.	.	.
	Jan/Feb88		676	673	730	532	739	698	750	760	700	684	684	705	712	672
	Apr88		644	538	580	<500	545	671	668	641	594	609	617	565	643	<500
		1	.	.	.	.	.	.	663	.	.	.	.	.	.	.
	Jul/Aug88		<500	<500	515	<500	<500	<500	<500	.	<500	<500	<500	<500	<500	<500
		1	.	.	.	.	.	.	<500	.	.	.	.	.	.	.
IRON	Jan86		.	.	.	.	.	.	.	<50	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<50	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<50	.	.	.	.	.	.
	Oct86		.	227	59	.	.	.	.	.	.	.	<50	263	<50	.
	Jan87		.	<50	<50	51	.	.	.	.	.	.	<50	<50	<50	129
	May87		<50	4610	294	70	102	60	54	.	66	96	<50	<50	<50	238
	Jun87		90	.	.	.	120	225	325	.	92	98	.	.	.	.
	Jul/Aug87		142	245	<50	<50	481	355	132	.	61	86	<50	<50	<50	66
	Oct/Nov87		100	496	126	34	488	447	702	.	128	.	46	267	<30	89
	Jan/Feb88		77	<30	<30	66	112	145	82	.	388	402	<30	<30	<30	132
	Apr88		88	263	<30	164	281	584	1170	.	602	557	53	<30	71	94
	Jul/Aug88		<30	360	<30	140	86	144	68	.	137	125	<30	<30	31	96

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
IRONF	Mar87		.	.	.	.	.	.	.	<50	.	.	.	.	.	.
	May87		<50	66	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	69
	Jun87		<50	.	.	.	<50	54	62	.	<50	<50	.	.	.	.
	Jul/Aug87		50	<50	<50	<50	<50	<50	57	<50	69	<50	<50	<50	<50	<50
	Oct/Nov87		36	<30	<30	M	49	54	56	<30	38	.	<30	37	<30	37
		1	.	.	.	.	.	.	59	.	.	.	.	.	.	.
	Jan/Feb88		<30	<30	<30	<30	34	42	34	<30	41	39	<30	<30	<30	30
	Apr88		<30	<30	<30	<30	41	68	39	<30	<30	49	<30	<30	<30	<30
		1	.	.	.	.	.	.	390	.	.	.	.	.	.	.
	Jul/Aug88		<30	<30	<30	<30	88	91	<30	.	<30	<30	<30	<30	<30	<30
		1	.	.	.	.	.	.	<30	.	.	.	.	.	.	.
LEADF	Mar87		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	May87		.	<5	<5	<5	.	.	.	<5	.	.	<5	<5	<5	<5
	Jun87		<5	.	.	.	<5	<5	<5	.	<5	5	.	.	.	.
	Jul/Aug87		.	<5	<5	<5	.	.	.	<5	.	.	<5	<5	<5	<5
	Oct/Nov87		<5	<5	<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
	Jan/Feb88		<5	.	.	.	<5	<5	<5	<5	<5	<5	.	.	.	.
	Apr88		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
	Jul/Aug88		<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
LEADGF	Jan86		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	Oct86		.	<5	<5	.	.	.	.	.	.	.	<5	<5	<5	.
	Jan87		.	<5	<5	<5	.	.	.	.	.	.	<5	5.1	<5	5.2
	May87		.	<5	8	<5	.	.	.	.	.	.	5	<5	<5	<5
	Jun87		<5	.	.	.	<5	<5	<5	.	<5	<5	.	.	.	.
	Jul/Aug87		.	<5	<5	<5	.	.	.	.	.	.	<5	<5	<5	<5
	Oct/Nov87		<5	<5	<5	<5	<5	<5	<5	.	<5	.	<5	<5	<5	<5
	Jan/Feb88		<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5	<5	5
	Apr88		<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5	<5	<5
	Jul/Aug88		<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5	<5	<5
LFLUORD	Jul/Aug87		.	.	.	.	.	.	.	490	.	.	.	.	.	.
	Oct/Nov87		525	590	620	420	440	470	480	490	510	.	580	560	690	490
	Jan/Feb88		513	560	632	435	450	485	470	428	483	560	620	588	614	496
	Apr88		432	457	498	341	360	372	381	425	393	450	482	476	476	395
		1	.	.	.	.	.	.	379	.	.	.	.	.	.	.
	Jul/Aug88		437	498	540	367	358	432	396	.	433	496	533	538	451	384
		1	.	.	.	.	.	.	404	.	.	.	.	.	.	.
LPHENOL	Oct86		.	4.1	4.4	.	.	.	.	.	.	.	2	3.2	2.9	.
	Jan87		.	<1	3.8	<1	.	.	.	.	.	.	7.21	2.23	3.38	<1
	May87		.	<1	<1	<1	.	.	.	.	.	.	<1	<1	<1	<1
	Jul/Aug87		.	<1	<1	<1	.	.	.	.	.	.	<1	<1	<1	<1
	Oct/Nov87		<1	<1	<1	<1	<1	<1	<1	.	<1	.	<1	<1	<1	<1
	Jan/Feb88		<1	<1	<1	<1	<1	<1	<1	.	<1	<1	<1	<1	<1	<1
	Apr88		<1	<1	<1	<1	<1	<1	<1	.	<1	<1	<1	<1	<1	<1
	Jul/Aug88		.	<1	<1	<1	.	.	.	.	.	.	<1	<1	<1	<1

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
MAGNES	Oct86		.	11200	10900	.	.	.	.	.	.	.	11400	10900	10600	.
	Jan87		.	10800	10100	11600	.	.	.	.	.	.	10300	10700	10100	7500
	May87		11100	11000	10200	12900	16200	15400	15600	.	14300	11400	10800	10600	10400	7260
	Jun87		11000	.	.	.	16500	14600	15300	.	15300	11700	.	.	.	.
	Jul/Aug87		10600	10500	9890	12000	16200	15400	16000	.	14800	10700	10400	10400	10000	8450
	Oct/Nov87		10900	10900	9980	12300	15200	14700	16000	.	15500	.	11300	11600	9690	9410
	Jan/Feb88		11300	11100	10400	11900	16800	16400	16100	.	14600	12100	11200	10900	10200	9420
	Apr88		11400	11200	9960	11600	15800	15600	15800	.	15900	12200	11300	10700	10200	9350
	Jul/Aug88		11200	11600	10700	12300	15500	14900	15800	.	16200	12600	11300	10100	10200	8860
MAGNESF	Mar87		.	.	.	.	.	.	.	14900	.	.	.	.	.	.
	May87		10900	10700	10200	12800	15600	14900	15200	15000	14900	11200	10600	10100	9960	7510
	Jun87		11800	.	.	.	16300	16000	16300	.	14700	11700	.	.	.	.
	Jul/Aug87		10700	10600	9370	11900	15100	14400	15400	14400	14800	10600	10300	10400	9380	8810
	Oct/Nov87		12000	10900	10300	M	17400	14600	15100	16200	15400	.	11100	12700	10300	9350
		1	.	.	.	.	.	.	15900	.	.	.	.	.	.	.
	Jan/Feb88		11400	11100	10400	12100	16600	15900	17400	16300	16000	12500	11100	11100	10500	9380
	Apr88		10800	11300	10500	11700	15700	14700	15400	16000	15600	11600	10800	10600	10500	8990
		1	.	.	.	.	.	.	15900	.	.	.	.	.	.	.
	Jul/Aug88		10900	11700	9910	11400	14300	15500	16100	.	15000	11800	10800	11700	9830	9550
		1	.	.	.	.	.	.	14200	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
MANGANF	Mar87		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	May87		<5	11	<5	110	<5	<5	6	<5	35	5	<5	<5	<5	8
	Jun87		<5	.	.	.	<5	<5	5	.	8	<5	.	.	.	.
	Jul/Aug87		<5	<5	<5	100	6	<5	<5	<5	<5	<5	<5	<5	<5	6
	Oct/Nov87		<5	<5	<5	M	<5	<5	<5	<5	<5	.	<5	<5	<5	5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
	Jan/Feb88		<5	<5	<5	91	<5	<5	<5	<5	<5	<5	<5	<5	<5	7
	Apr88		<5	<5	<5	66	<5	<5	<5	<5	<5	<5	<5	<5	<5	6
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
	Jul/Aug88		<5	<5	<5	45	<5	<5	<5	.	<5	<5	<5	<5	<5	7
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.
MANGESE	Jan86		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	Oct86		.	<5	<5	.	.	.	.	.	.	.	<5	<5	<5	.
	Jan87		.	<5	<5	152	.	.	.	.	.	.	<5	<5	<5	11
	May87		<5	44	<5	120	<5	<5	7	.	37	<5	<5	<5	<5	9
	Jun87		<5	.	.	.	<5	8	6	.	8	<5	.	.	.	.
	Jul/Aug87		<5	<5	<5	103	<5	<5	<5	.	5	<5	<5	<5	<5	6
	Oct/Nov87		<5	5	<5	104	<5	<5	<5	.	<5	.	<5	<5	<5	6
	Jan/Feb88		<5	<5	<5	90	<5	<5	<5	.	<5	<5	<5	<5	<5	5
	Apr88		<5	7	<5	62	<5	<5	<5	.	<5	<5	<5	<5	<5	6
	Jul/Aug88		<5	<5	<5	55	<5	<5	<5	.	<5	<5	<5	<5	<5	<5

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
NICKEL	Jan86		.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<10	.	.	.	.	.	.
	Oct86		.	<10	<10	.	.	.	.	.	.	.	<10	<10	<10	.
	Jan87		.	<10	<10	<10	.	.	.	.	.	.	<10	<10	<10	<10
	May87		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	12
	Jun87		10	.	.	.	<10	<10	<10	.	<10	<10	.	.	.	.
	Jul/Aug87		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	10
	Oct/Nov87		<10	<10	<10	<10	<10	<10	<10	.	<10	.	<10	<10	<10	<10
	Jan/Feb88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
	Apr88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
	Jul/Aug88		<10	<10	<10	<10	<10	<10	<10	.	<10	<10	<10	<10	<10	<10
NITRATE	Jan86		.	.	.	.	.	.	.	20900	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	20100	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	19900	.	.	.	.	.	.
	Oct86		.	25400	29300	.	.	.	.	.	.	.	28100	25500	28500	.
	Jan87		.	24700	27200	23200	.	.	.	.	.	.	27300	27600	27900	4040
	Mar87		.	.	.	.	.	.	.	23600	.	.	.	.	.	.
	May87		21600	24900	27500	20500	21100	22400	23600	26400	24000	25800	27700	26700	27900	4180
	Jun87		20700	.	.	.	20100	22100	23400	.	23500	25500	.	.	.	.
	Jul/Aug87		18700	22800	24600	19400	18200	19400	20700	23200	21700	24600	23900	24100	24000	5750
	Oct/Nov87		21800	28500	30600	21800	22100	24400	27700	26300	28000	.	28900	27300	29100	6540
		1	.	.	.	.	.	.	27200	.	.	.	.	.	.	.
	Jan/Feb88		19100	30000	31000	20800	19500	23600	26300	28200	27300	29200	30700	30900	29100	5830
	Apr88		22300	31900	35200	18500	21200	25400	28200	29200	29500	31900	32700	32900	33100	5580
		1	.	.	.	.	.	.	28200	.	.	.	.	.	.	.
	Jul/Aug88		22900	33800	35400	22100	24100	29200	30400	.	31900	32100	34000	34100	34200	5090
		1	.	.	.	.	.	.	30300	.	.	.	.	.	.	.
NITRITE	Jan/Feb88		<1000	.	.	.	<1000	<1000	<1000	.	1130	<1000	.	.	.	.
	Apr88	1	<1000	<1000	<1000	1400	<1000	<1000	<1000	.	<1000	<1000	<1000	<1000	<1000	<1000
	Jul/Aug88		<1000	<1000	<1000	<1000	<1000	<1000	<1000	.	<1000	<1000	<1000	<1000	<1000	<1000
		1	.	.	.	.	.	.	<1000	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
PH-LAB	Mar87		.	.	.	.	.	.	.	7.13	.	.	.	.	.	.
	May87		.	.	.	.	.	.	.	7.26	.	.	.	.	.	.
	Jun87		7.37	.	.	.	6.92	6.93	6.87	.	7.12	7.46	.	.	.	.
	Jul/Aug87		.	.	.	.	.	.	.	7.46	.	.	.	.	.	.
	Oct/Nov87		7.75	7.97	8.04	8.06	7.19	7.23	7.12	7.42	7.88	.	7.82	7.72	7.96	8.26
	Jan/Feb88		7.47	7.83	7.7	7.77	6.8	6.99	7.19	7.52	7.22	7.53	7.63	7.78	7.92	7.99
		1	.	7.83	7.72	7.79	.	.	.	.	.	.	7.66	7.92	7.98	8.06
		2	.	7.84	7.7	7.86	.	.	.	.	.	.	7.7	7.9	7.95	8.04
		3	.	7.85	7.73	7.86	.	.	.	.	.	.	7.72	7.83	7.93	8.02
	Apr88		7.7	8	8	8.1	7.3	7.3	7.5	7.6	7.8	7.9	8	8	8.1	8.2
		1	7.8	8	8	8.1	7.3	7.3	7.4	.	7.7	7.9	8.1	8	8.1	8.2
		2	7.8	8	8	8.1	7.3	7.2	7.5	.	7.8	8	8	8	8.1	8.2
		3	7.7	8	8	8.1	7.2	7.2	7.3	.	7.6	7.9	8	8	8.1	8.2
	Jul/Aug88		7.8	7.7	7.9	7.8	7.11	7.1	7.2	.	7.3	7.7	7.9	8	8	8.1
		1	7.7	7.7	7.8	7.8	7.41	7.2	7.3	.	7.3	7.7	7.9	7.9	8	8
		2	7.7	7.7	7.8	7.8	7.3	7.1	7.3	.	7.3	7.8	7.9	7.9	8	8.1
		3	7.7	7.7	7.8	7.8	7.2	7.2	7.5	.	7.3	7.8	7.9	7.9	8	8

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
PHFIELD	Jan86	F	.	.	.	.	.	.	.	7.5	.	.	.	.	.	.
	Oct86		.	7	7	.	.	.	.	.	.	.	6.8	7.1	7	.
		1	.	7	7.1	.	.	.	.	.	.	.	.	.	.	.
		2	.	7	7.2	.	.	.	.	.	.	.	.	.	.	.
		3	.	7.1	7.2	.	.	.	.	.	.	.	.	.	.	.
	Jan87		.	6.9	6.8	7.6	.	.	.	.	.	.	7	7.1	7.1	7.4
		1	.	6.9	7	7.6	.	.	.	.	.	.	.	.	.	.
		2	.	6.9	7	7.3	.	.	.	.	.	.	.	.	.	.
		3	.	6.9	7.1	7.2	.	.	.	.	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	7.1	.	.	.	.	.	.
	May87		7	7.5	7.5	7.6	6.5	6.7	6.5	6.9	6.9	7.3	7.4	7.5	7.6	8.3
		1	.	7.5	7.5	7.5	.	.	.	.	.	.	.	.	.	.
		2	.	7.5	7.6	7.6	.	.	.	.	.	.	.	.	.	.
		3	.	7.5	7.6	7.6	.	.	.	.	.	.	.	.	.	.
	Jun87		6.9	.	.	.	5.8	5.9	5.9	.	6.3	6.6	.	.	.	.
	Jul/Aug87		7.2	7.4	6.9	7	6.1	6.2	6.3	.	6.5	7.4	7.4	7.4	7.5	7.8
		1	.	7.5	7	7	.	.	.	.	.	.	.	.	.	.
		2	.	7.5	7	7.1	.	.	.	.	.	.	.	.	.	.
		3	.	7.5	7	7.1	.	.	.	.	.	.	.	.	.	.
	Oct/Nov87		5.5	6.9	6.7	4.8	5.1	6.9	6.8	7.1	6.9	.	8.1	6.8	7.1	6
		1	.	6.8	6.7	4.6	.	.	.	.	.	.	.	.	.	.
		2	.	6.8	6.6	4.5	.	.	.	.	.	.	.	.	.	.
		3	.	6.8	6.5	4.4	.	.	.	.	.	.	.	.	.	.
	Jan/Feb88		7.1	5.4	7.8	7.6	6.3	3.9	3.5	6.9	6.5	6.8	5.8	7.9	8.1	8.2
		1	.	5.4	7.8	7.6	.	.	.	.	.	.	5.8	7.9	8.1	8.2
		2	.	5.4	7.8	7.6	.	.	.	.	.	.	5.8	8	8.1	8.2
		3	.	5.4	7.8	7.6	.	.	.	.	.	.	5.9	8	8.1	8.2
	Apr88		6	8.2	8.5	8.2	6.4	6.7	7.1	6.8	6.9	7.8	7.5	8.4	8.2	7.8
		1	6.1	8.3	8.3	8.2	6.4	6.7	7.1	.	7.1	7.8	7.5	8.3	8.3	7.9
		2	6.1	8.3	8.5	8.2	6.4	6.8	7.1	.	7	7.8	7.6	8.4	8.5	7.9
		3	6.1	8.3	8.4	8.2	6.5	6.8	7.1	.	7	7.8	7.5	8.4	8.3	8
	Jun88		.	.	.	.	.	.	.	.	.	.	7.8	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
PHFIELD	Jul/Aug88		7.3	7.2	7.6	7.4	6.3	6.6	6.4	7.1	6.8	6.8	7	7.5	7.8	7.9
		1	7.2	7.3	7.6	7.4	6.2	6.6	6.4	.	6.9	6.9	7.1	7.5	7.8	7.9
		2	7.3	7.3	7.6	7.4	6.2	6.6	6.5	.	6.8	6.9	7.1	7.5	7.8	7.9
		3	7.3	7.3	7.6	7.4	6.3	6.6	6.5	.	6.8	6.9	7.1	7.5	7.8	7.9
POTASSF	Mar87		.	.	.	.	.	.	.	7240	.	.	.	.	.	.
	May87		6430	6280	6050	6360	7270	7070	6910	7330	6840	6030	6070	6050	6070	5640
	Jun87		7210	.	.	.	7660	7750	7660	.	7130	6350	.	.	.	.
	Jul/Aug87		6790	5980	5590	5940	7310	6980	7170	6850	7000	6120	5750	5910	5540	5780
	Oct/Nov87		7910	6450	6270	M	8900	7700	7380	8330	7580	.	6860	7380	6500	6080
		1	.	.	.	.	.	.	7690	.	.	.	.	.	.	.
	Jan/Feb88		6310	5780	5980	5930	6970	7050	7550	7330	6800	6430	5720	6010	5780	5360
	Apr88		5940	6450	6240	5930	6870	6590	7270	7400	7160	6240	5210	6100	6100	5320
		1	.	.	.	.	.	.	7440	.	.	.	.	.	.	.
	Jul/Aug88		6580	6700	5970	5680	6850	7480	7330	.	6910	6270	6090	6590	5560	5340
		1	.	.	.	.	.	.	6410	.	.	.	.	.	.	.
POTASUM	Jan86		.	.	.	.	.	.	.	6710	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	6640	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	6960	.	.	.	.	.	.
	Oct86		.	6130	6110	.	.	.	.	.	.	.	5980	5540	5670	.
	Jan87		.	6300	5870	6050	.	.	.	.	.	.	5960	6240	5850	5520
	May87		6600	6400	6070	6290	7510	7570	7200	.	6790	6110	6260	6200	6180	5460
	Jun87		6850	.	.	.	7850	7020	7030	.	7220	6300	.	.	.	.
	Jul/Aug87		6500	5940	5740	5810	7860	7650	7750	.	6960	6230	6350	6180	6020	5770
	Oct/Nov87		6560	6100	5930	6250	6860	7450	7490	.	7330	.	6140	6090	5760	5790
	Jan/Feb88		7090	6350	6110	5960	7820	7020	7500	.	6990	6380	5560	5930	5390	5430
	Apr88		6600	6440	5880	5940	7090	7120	7010	.	6900	6680	6100	6090	5900	5180
	Jul/Aug88		6500	6180	5990	5740	7560	7190	6930	.	7100	6840	6220	5740	5860	4940

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
RADIUM	Jan86		.	.	.	.	.	.	.	0.3	.	.	.	.	.	.
	Oct86		.	*0.108	*0.055	.	.	.	.	.	.	.	*-0.026	*0.102	*0.075	.
	Jan87		.	*0.079	*0.087	*0.02	.	.	.	.	.	.	*0.042	*0.058	*0.07	*0.043
	Mar87		.	.	.	.	.	.	.	0.264	.	.	.	.	.	.
	May87		.	*0.058	*-0.018	*-0.079	.	.	.	*-0.009	.	.	*0.056	*-0.046	*0.029	0.206
	Jul/Aug87		.	*0.054	*0.012	*0.034	.	.	.	.	.	.	*-0.013	*0.016	*0.059	*0.037
	Apr88		*0.104	.	.	.	0.168	*0.085	0.261	.	*0.128	*0.141	.	.	.	.
	Jul/Aug88		*0.057	.	.	.	*0.171	*0.014	*-0.065	.	*-0.018	*0.038	.	.	.	.
SELENUM	Jan86		.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	<5	.	.	.	.	.	.
	Oct86		.	<5	<5	.	.	.	.	.	.	.	<5	<5	<5	.
	Jan87		.	<5	<5	<5	.	.	.	.	.	.	<5	<5	<5	<5
	May87		.	<5	<5	<5	.	.	.	.	.	.	<5	<5	<5	<5
	Jun87		<5	.	.	.	<5	<5	<5	.	<5	<5	.	.	.	.
	Jul/Aug87		.	<5	<5	<5	.	.	.	.	.	.	<5	<5	<5	<5
	Oct/Nov87		<5	<5	<5	<5	<5	<5	<5	.	<5	.	<5	<5	<5	<5
	Jan/Feb88		<5	<5	<5	<5	<5	<5	<5	.	<5	<5	<5	<5	<5	<5
	Apr88		<5	<5	<5	<5	6	<5	<5	.	<5	<5	<5	<5	<5	<5
	Jul/Aug88		<5	<5	<5	<5	<5	5	<5	.	<5	<5	<5	<5	<5	<5

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
SODIUM	Jan86		.	.	.	.	.	.	.	22500	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	23000	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	25100	.	.	.	.	.	.
	Oct86		.	22500	23500	.	.	.	.	.	.	.	22600	21100	22000	.
	Jan87		.	22900	22800	19300	.	.	.	.	.	.	22300	23300	22400	24200
	May87		21200	23100	23200	20600	21800	23700	22400	.	21900	21600	23200	23200	23700	42600
	Jun87		22400	.	.	.	23700	21500	21900	.	23700	23100	.	.	.	.
	Jul/Aug87		21300	22100	22500	19700	23200	23500	23800	.	21800	23000	23600	23500	23200	38600
	Oct/Nov87		21400	22300	22500	21200	20400	23000	23300	.	23300	.	23100	21600	22300	38300
	Jan/Feb88		23200	23100	24200	20700	22800	21100	22800	.	22400	22300	20300	22000	20300	31800
	Apr88		21800	23300	22900	19900	21300	22300	21900	.	21900	23400	22800	22700	22500	29700
	Jul/Aug88		22100	24100	24900	20500	22500	22400	21600	.	22500	25100	23300	22000	24300	28300
SODIUMF	Mar87		.	.	.	.	.	.	.	23700	.	.	.	.	.	.
	May87		21300	23600	22700	21000	21900	21600	21700	24000	22100	22200	22900	22000	22700	43200
	Jun87		24100	.	.	.	22800	24100	23900	.	22700	22800	.	.	.	.
	Jul/Aug87		22300	22000	21800	19900	22000	21800	22600	21100	22200	22700	21700	22700	21700	37300
	Oct/Nov87		24400	23100	23700	M	25000	23200	22400	24800	23300	.	23800	24300	23700	38100
		1	.	.	.	.	.	.	23500	.	.	.	.	.	.	.
	Jan/Feb88		20400	21200	23400	20600	20400	21800	23200	23400	21400	23000	21000	22800	22200	30200
	Apr88		20000	20900	21200	17700	21200	21200	19700	23700	19600	19500	20200	20300	20700	26300
		1	.	.	.	.	.	.	20000	.	.	.	.	.	.	.
	Jul/Aug88		21600	24800	23500	19200	20400	26900	22700	.	21500	21800	22600	25300	21700	29100
		1	.	.	.	.	.	.	20100	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
STRONTF	Mar87		.	.	.	.	.	.	.	<300	.	.	.	.	.	.
	May87		.	.	.	.	.	.	.	<300	.	.	.	.	.	.
	Jun87		<300	.	.	.	<300	<300	<300	.	<300	<300	.	.	.	.
	Jul/Aug87		.	.	.	.	.	.	.	<300	.	.	.	.	.	.
	Oct/Nov87		216	179	166	M	317	265	276	286	279	.	181	210	170	231
		1	.	.	.	.	.	.	290	.	.	.	.	.	.	.
	Jan/Feb88		201	178	162	229	301	277	301	278	279	205	180	178	170	207
	Apr88		189	179	161	221	280	252	267	274	267	188	173	171	170	197
		1	.	.	.	.	.	.	271	.	.	.	.	.	.	.
	Jul/Aug88		193	193	161	224	257	264	280	.	264	191	174	190	161	208
		1	.	.	.	.	.	.	248	.	.	.	.	.	.	.
STRONUM	Jun87		<300	.	.	.	302	<300	<300	.	<300	<300	.	.	.	.
	Oct/Nov87		196	175	156	235	281	256	276	.	274	.	189	193	160	225
	Jan/Feb88		203	179	164	232	304	286	284	.	263	202	184	177	169	212
	Apr88		199	175	155	218	285	267	271	.	279	197	180	172	163	203
	Jul/Aug88		199	192	169	246	282	257	272	.	284	211	180	161	167	193

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
SULFATE	Jan86		.	.	.	.	.	.	.	56400	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	55400	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	55100	.	.	.	.	.	.
	Oct86		.	41100	38800	.	.	.	.	.	.	.	40600	39400	39400	.
	Jan87		.	46700	41100	55900	.	.	.	.	.	.	42800	42100	41300	25700
	Mar87		.	.	.	.	.	.	.	48700	.	.	.	.	.	.
	May87		46000	43100	39100	70500	45900	46000	43200	41800	42900	41500	41400	42100	39100	56000
	Jun87		50100	.	.	.	49700	49200	47700	.	46700	45400	.	.	.	.
	Jul/Aug87		47600	42100	37600	74400	46900	45700	43700	45100	43900	38900	39800	40100	38500	63700
	Oct/Nov87		51500	43900	38500	69600	51200	47500	45500	46500	44600	.	42700	45500	41000	67300
		1	.	.	.	.	.	.	44800	.	.	.	.	.	.	.
	Jan/Feb88		46500	41400	40000	60600	45900	46000	43600	48300	42000	40500	38700	38900	37100	48600
	Apr88		48400	41400	36500	55700	48300	57700	45100	41900	44700	42100	38900	42200	40600	48800
		1	.	.	.	.	.	.	44600	.	.	.	.	.	.	.
	Jul/Aug88		48300	43000	35700	54500	47600	47300	44800	.	44500	41400	38800	36500	36300	43800
		1	.	.	.	.	.	.	44700	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
TC	Oct86		.	28400	26900	.	.	.	.	.	.	.	29300	28000	27400	.
	Jan87		.	29300	27800	29800	.	.	.	.	.	.	30000	29300	28500	32500
	May87		.	29600	26200	28200	.	.	.	.	.	.	27900	27500	26800	26600
	Jul/Aug87		.	27900	26100	28500	.	.	.	46100	.	.	28300	27600	26500	29300
	Oct/Nov87		30700	26500	25400	27400	59500	52400	57700	47700	51200	.	28100	31700	25200	28200
	Jan/Feb88		34100	27700	27200	29800	69400	57500	65400	49800	53900	32400	29300	27800	25900	30200
	Apr88		31900	27200	25500	27100	60600	52900	57600	50300	52300	31600	27800	27100	25800	29800
	Jul/Aug88		30600	27400	25100	28400	58000	51500	56300	.	48900	31400	27200	26400	24900	30000
TDS	Oct/Nov8		263000	255000	244000	273000	344000	337000	358000	.	342000	.	255000	257000	236000	264000
	Jan/Feb88		276000	267000	262000	281000	373000	356000	383000	.	359000	173000	272000	146000	245000	247000
	Apr88		290000	269000	260000	255000	349000	367000	360000	.	365000	276000	278000	284000	268000	259000
	Jul/Aug88		287000	263000	256000	270000	668000	350000	362000	.	363000	290000	264000	252000	257000	235000

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
TOC	Jan86		.	.	.	.	.	.	.	383	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	402	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	431	.	.	.	.	.	.
	Oct86		.	32	117	.	.	.	.	.	.	.	202	140	563	.
	Jan87		.	368	397	225	.	.	.	.	.	.	433	483	284	218
		1	.	293	326	234	.	.	.	.	.	.	.	.	.	.
		2	.	278	343	214	.	.	.	.	.	.	.	.	.	.
		3	.	345	279	239	.	.	.	.	.	.	.	.	.	.
	Mar87		.	.	.	.	.	.	.	296	.	.	.	.	.	.
	May87		166	531	302	292	140	336	201	562	260	316	331	285	1470	409
		1	.	328	452	315	.	.	.	.	.	.	.	.	.	.
		2	.	515	369	297	.	.	.	.	.	.	.	.	.	.
		3	.	598	379	412	.	.	.	.	.	.	.	.	.	.
	Jun87		569	.	.	.	272	319	282	.	389	459	.	.	.	.
	Jul/Aug87		590	495	441	344	786	514	708	288	596	817	335	354	375	378
		1	.	395	396	377	.	.	.	.	.	.	.	.	.	.
		2	.	378	440	510	.	.	.	.	.	.	.	.	.	.
		3	.	352	500	296	.	.	.	.	.	.	.	.	.	.
	Oct/Nov87		256	464	362	.	264	438	300	166	425	.	589	643	1290	1320
		1	.	3730	706	407	.	.	.	.	.	.	.	.	.	.
		2	.	544	426	191	.	.	.	.	.	.	.	.	.	.
		3	.	320	346	293	.	.	.	.	.	.	.	.	.	.
	Jan/Feb88		221	295	318	181	315	268	274	346	294	421	377	394	294	261
		1	.	279	333	222	.	.	.	.	.	.	370	307	312	250
		2	.	416	456	212	.	.	.	.	.	.	365	340	355	212
		3	.	347	310	314	.	.	.	.	.	.	323	442	331	233
	Apr88		222	373	362	240	186	304	314	251	519	474	378	402	330	225
		1	279	346	380	388	188	532	314	.	372	450	318	564	429	248
		2	163	344	422	295	176	230	291	.	597	509	288	521	455	202
		3	204	324	477	235	224	297	326	.	383	362	308	367	303	226

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
TOC	Jul/Aug88		408	362	504	387	470	352	358	.	338	417	430	22900	625	343
		1	419	377	446	295	404	455	318	.	415	382	403	507	653	512
		2	308	416	1000	272	1080	353	310	.	585	673	413	473	380	229
		3	354	588	503	296	346	380	416	.	613	479	424	667	506	216
TOX	Jan86		.	.	.	.	.	.	.	45.4	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	55.6	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	22.4	.	.	.	.	.	.
	Oct86		.	13.7	7	.	.	.	.	.	.	.	18.4	11.4	6.5	.
	Jan87		.	<100	<100	<100	.	.	.	.	.	.	<100	<100	<100	<100
		1	.	<100	<100	<100	.	.	.	.	.	.	.	.	.	.
		2	.	<100	<100	<100	.	.	.	.	.	.	.	.	.	.
		3	.	<100	<100	<100	.	.	.	.	.	.	.	.	.	.
	May87		.	12.3	9.6	3.4	.	.	.	.	.	.	270	<100	<100	<100
		1	.	4.1	3.1	nd	.	.	.	.	.	.	.	.	.	.
		2	.	6	25.3	nd	.	.	.	.	.	.	.	.	.	.
		3	.	14.2	2.4	nd	.	.	.	.	.	.	.	.	.	.
	Jul/Aug87		.	6.5	3.9	203	.	.	.	.	.	.	11.7	5.6	31.1	5.1
		1	.	6.2	7.8	230	.	.	.	.	.	.	.	.	.	.
		2	.	1.3	3.4	230	.	.	.	.	.	.	.	.	.	.
		3	.	2.8	7.4	229	.	.	.	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
TOXLOL	Jan87		.	<20	<20	<20	.	.	.	.	.	.	<20	<20	<20	<20
	Mar87		.	.	.	.	.	.	.	28.8	.	.	.	.	.	.
	May87		.	.	.	.	.	.	.	23.8	.	.	.	.	.	.
	Jun87		7.7	.	.	.	68.8	39.2	56.8	.	24.4	8.2	.	.	.	.
	Jul/Aug87		.	.	.	.	.	.	.	17.4	.	.	.	.	.	.
	Oct/Nov87		3.4	4.8	12.3	5.4	49.5	46.8	63.3	17.8	35.6	.	2.6	14.7	19	10.2
		1	.	4.2	4.4	4.1	.	.	.	.	.	.	.	.	.	.
		2	.	8.4	4.3	4.3	.	.	.	.	.	.	.	.	.	.
		3	.	6.6	11.6	6.7	.	.	.	.	.	.	.	.	.	.
	Jan/Feb88		13.6	6.4	1.1	9.5	56.6	79.2	57.2	25	25	13.8	28.3	14.9	25.2	10.8
		1	.	5.4	2.5	4.3	.	.	.	.	.	.	2.2	5.2	19.4	12.6
		2	.	3.8	20	3	.	.	.	.	.	.	5.7	9.7	14.1	48
		3	.	9.8	1.2	2.4	.	.	.	.	.	.	6.2	9.5	26.8	9.8
	Apr88		1	4	3	2	56	31	356	21	28	9	15	12	5	6
		1	3	5	4.5	2	49	21	373	.	29	9	14	12	12	18
		2	5	4	1	5	44	27	288	.	56	7	232	13	7	4
		3	6	3	2	4	38	23	356	.	28	21	228	2	7	13
	Jun88		.	.	.	.	.	.	.	.	.	.	23.5	.	.	.
		1	.	.	.	.	.	.	.	.	.	.	13	.	.	.
		2	.	.	.	.	.	.	.	.	.	.	4.2	.	.	.
		3	.	.	.	.	.	.	.	.	.	.	-0.5	.	.	.
	Jul/Aug88		830	.	.	.	49.6	798	43.8	.	82.4	16.3	6.8	5.4	.	.
		1	224	.	.	.	50.2	1080	52.9	.	58.2	16.8	9.7	4.4	.	.
		2	238	.	.	.	38.3	426	33.0	.	146	17.9	14.6	11.2	.	.
		3	246	.	.	.	46.3	1000	49.0	.	65.2	12.5	16.7	8.9	.	.
VANADIF	Mar87			.	.	.	.	.	.	18	.	.	.	.	.	.
	May87		21	32	26	9	14	15	15	16	14	22	23	27	22	13
	Jun87		20	.	.	.	18	20	19	.	10	19	.	.	.	.
	Jul/Aug87		19	23	25	7	17	15	14	17	14	23	23	23	23	11
	Oct/Nov87		21	27	30	M	15	19	18	18	18	.	20	18	24	10
		1	.	.	.	.	.	.	13	.	.	.	.	.	.	.

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
VANADIF (contd)	Jan/Feb88		18	24	21	8	13	15	16	17	14	20	24	25	26	10
	Apr88		18	26	26	12	11	13	13	15	9	23	24	25	26	8
		1	.	.	.	.	.	.	10	.	.	.	.	.	.	.
	Jul/Aug88		16	24	23	11	13	16	14	.	15	21	23	25	24	7
		1	.	.	.	.	.	.	14	.	.	.	.	.	.	.
VANADUM	Jan86		.	.	.	.	.	.	.	11	.	.	.	.	.	.
		1	.	.	.	.	.	.	.	10	.	.	.	.	.	.
		2	.	.	.	.	.	.	.	11	.	.	.	.	.	.
	Oct86		.	19	22	.	.	.	.	.	.	.	26	25	25	.
	Jan87		.	23	24	11	.	.	.	.	.	.	22	23	23	11
	May87		18	26	26	13	12	16	15	.	15	23	24	25	25	17
	Jun87		21	.	.	.	17	17	16	.	15	26	.	.	.	.
	Jul/Aug87		22	23	24	9	17	18	15	.	16	27	22	30	30	11
	Oct/Nov87		19	26	26	8	16	16	17	.	15	.	26	18	21	8
	Jan/Feb88		20	18	24	11	6	12	8	.	13	22	23	24	27	10
	Apr88		20	23	25	9	14	12	11	.	13	24	23	25	23	7
	Jul/Aug88		17	21	21	11	11	13	14	.	14	16	23	21	23	<5
ZINC	Oct86		.	8	5	.	.	.	.	.	.	.	<5	<5	<5	.
	Jan87		.	<5	<5	<5	.	.	.	.	.	.	<5	<5	<5	6
	May87		18	17	6	7	30	36	24	.	79	37	5	7	6	10
	Jun87		30	.	.	.	42	95	47	.	130	57	.	.	.	.
	Jul/Aug87		43	6	<5	<5	58	61	31	.	37	8	9	7	9	9
	Oct/Nov87		11	12	28	26	64	92	62	.	71	.	10	53	<5	15
	Jan/Feb88		<5	<5	<5	<5	9	15	<5	.	37	38	<5	<5	<5	<5
	Apr88		<5	<5	<5	<5	13	30	9	.	35	33	<5	5	<5	<5
	Jul/Aug88		<5	<5	<5	<5	<5	10	<5	.	13	15	<5	<5	<5	<5

TABLE F.2 (continued)

Constituent Name	Sample Period	Rep Num	Upgradient Wells 24-35	26-35A	26-34	(Deep) 26-35C	Downgradient Wells 23-34	24-34A	24-34B	24-33	24-34C	25-34C	25-34B	25-34A	26-33	(Deep) 25-33A
ZINCF	Mar87		.	.	.	.	.	.	.	9	.	.	.	.	.	.
	May87		15	14	5	<5	25	37	20	<5	69	32	<5	6	<5	<5
	Jun87		34	.	.	.	36	51	40	.	115	49	.	.	.	.
	Jul/Aug87		16	<5	<5	<5	37	30	23	<5	36	7	7	5	7	5
	Oct/Nov87		27	<5	5	M	35	23	18	<5	46	.	<5	49	<5	<5
		1	.	.	.	.	.	.	14	.	.	.	.	.	.	.
	Jan/Feb88		8	<5	<5	<5	11	16	7	<5	46	25	<5	<5	<5	<5
	Apr88		13	<5	<5	<5	9	20	7	<5	29	26	<5	<5	<5	8
		1	.	.	.	.	.	.	8	.	.	.	.	.	.	.
	Jul/Aug88		<5	<5	<5	<5	<5	10	<5	.	13	9	<5	<5	<5	<5
		1	.	.	.	.	.	.	<5	.	.	.	.	.	.	.

This section includes several tables listing constituents that have been detected in the ground water at the SWL, arranged by analysis method. The first two numeric columns in these tables (see Table F.3) list the UST Contractually Required Detection Limits (CRDLs) for these constituents and typical values for each constituent from the SWL monitoring project. The third numeric column is the SWL value divided by the CRDL, which is labeled "N TIMES DL." This factor is important in determining appropriate error limits for certain of the analysis methods.

This summary of accuracy and precision is based on typical analysis values for the SWL. However, these methods may be applied to a range of analysis values, appropriate for other projects.

F.2.1 Definitions

Accuracy is defined in SW-846, Third Edition, as nearness to a result of the mean (X) of a set of results to the true value. Accuracy is assessed by means of reference samples and percent recoveries.

Precision means the measurement of agreement of a set of replicate results among themselves without the assumption of the true result. Precision is assessed by means of duplicate/replicate sample analysis.

F.2.2 Volatile Organics by Gas Chromatography-Mass Spectrometry

Typical values for several volatile constituents found at the SWL are at levels approximately equal to the UST CRDL. The constituent causing the most controversy, trichloroethylene (TCE), has been detected at levels from 5 to 10 ppb in well 699-24-34B. The UST CRDL for TCE is 5 ppb, which is the lowest concentration at which a calibration is run. However, the peak for TCE is visible when the concentration is below this concentration.

Table F.3 gives estimates for the concentration of trichloroethylene and its precision (±2 s.d.), assuming that the typical "true concentration" of TCE is 8 ppb. The column labeled "EPA METHOD DATA" gives an estimate based on the method accuracy and precision given in SW-846, Third Edition, method 8240. The regression formulas on which the calculations are based are from SW-846, Third Edition, Table 7, and are given in Table F.4. Applying

TABLE F.3. Estimation of Analytical Variance for Volatile Analysis by Gas Chromatography-Mass Spectrometry

Constituent	UST CRDL (ppb)	Typical SWL Analysis Values (ppb)	N Times DL	UST Matrix Spike[a] Data Recovery sd (%)		EPA Method Data Calculated ± 2s (ppb)		EPA Performance Data Calculated ± 2s (ppb)		UST Matrix Spike Data Calculated ± 2s (ppb)	UST Surrogate[b] Calculated ± 2s	
A67 1,1,1-TCA	5	50	10.0			53.7	20.2	50.8	13.7		47.1	6.3
A68 1,1,2-TCA	5	4	0.8			5.52	1.4				3.8	0.5
A69 Trichloroethylene	5	8	1.6	103	14.4	10.6	3.1	7.9	2.5	8.2 ± 2.3	7.5	1.0
A70 Perchlorothylene	5	8	1.6			9.1	1.7	7.9	2.3		7.5	1.0
A89 1,1-Dichloroethane	10	5	0.5			5.6	2.5				4.7	0.6
A93 Methylene Chloride	10	10	1.0			10.6	14.4	10.3	3.3		9.4	1.3

(a) Matrix spike level 50 ppb for TCE.
(b) For the surrogate 1-2 Dichloroethane - D_4 at a level of 50 ppb.

TABLE F.4. Method Accuracy and Precision as Functions of Concentration (SW-846, Method 8240, Table 7)

Constituent	Accuracy, X',[c] as Recovery	EPA Method Data[a]: Single Analyst Precision, s_r'[e]	EPA Method Data[a]: Overall Precision, S'[f]	EPA Performance Data[b]: Accuracy, $\bar{X}$ as Recovery	EPA Performance Data[b]: Precision S
A61 Carbon Tet	1.10C + 2.00	$0.12\bar{X} + 0.25$	$0.11\bar{X} + 0.37$	0.974C - 0.0077	0.165C + 0.104
A67 1,1,1,-TCA	1.06C + 0.73	$0.12\bar{X} - 0.15$	$0.21\bar{X} - 0.39$	1.016C + 0.0193	0.135C + 0.013
A68 1,1,2-TCA	0.95C + 1.71	$0.14\bar{X} + 0.02$	$0.18\bar{X} + 0.00$	*[g]	
A69 Trichloroethylene	1.04C + 2.27	$0.13\bar{X} + 0.36$	$0.12\bar{X} + 0.59$	0.973c + 0.0999	0.117C + 0.296
A70 Perchlorothylene	1.06C + 0.60	$0.13\bar{X} - 0.18$	$0.16\bar{X} - 0.45$	0.972C + 0.116	0.117C - 0.199
A89 1,1-Dichloroethane	1.05C + 0.36	$0.13\bar{X} - 0.05$	$0.16\bar{X} + 0.47$	*	
A93 Methylene Chloride	0.87C + 1.88	$0.15\bar{X} + 1.07$	$0.32\bar{X} + 4.00$	0.953C + 0.742	0.153C + 0.125

(a) Estimates based on the performance in a single laboratory.
(b) Estimates based on WS and WP data, compiled by Paul Britton 06/86.
(c) X' = Expected recovery for one or more measurements of a sample containing concentration C (µg/L), where C is the true value for the concentration. NOTE: Units of µg/L are equivalent to ppb.
(d) $\bar{X}$ = Average recovery found for measurements of samples containing a concentration of C (µg/L).
(e) s_r' = Expected single analyst standard deviation at an average concentration of X (µg/L).
(f) S' = Expected interlaboratory standard deviation of measurements at an average concentration found of X (µg/L).
(g) * = Constituent not included in performance evaluation.

this regression formula, the estimate of TCE concentration based on a "true concentration" of 8 ppb is 10.6 ± 3.1 ppb.

The column labeled "EPA PERFORMANCE DATA" gives the values, calculated from regressions based on statistics from EPA Water Pollution (WP) and Water Supply (WS) PEs, also given in Table F.4. The statistics from the WS and WP PEs are compiled by Paul Britton of Environmental Monitoring Support Laboratory (EMSL), Cincinnati. The regressions are based on the results from a large number of laboratories that participate in the evaluations. U.S. Testing has participated in these programs since 1986. The analytical methods used include methods in addition to those listed in SW-846. The WP statistics cited are based on results of six studies, each having samples at two concentration levels, and each with 33 to 44 laboratories participating, or a total of about 450 samples.

The regression formula given for carbon tetrachloride is based on WS data; a total of 75 samples. It is used in preference to the WP information because the concentrations covered (2.5 to 6.7 ppb) are much closer to the SWL values than the range of concentrations for the WP studies (10.5 to 52.9 ppb).

The estimate of accuracy and precision (± 2S) using the WP regression formulas for TCE is 7.9 ± 2.5 ppb.

The last two columns in Table F.3 and the last column in Tables F.7, F.9, F.10, and F.11 are based on the most recent matrix spike and surrogate recovery data from UST (covering April 1 through June 30, 1988). Trichloroethylene is the only one of the volatile compounds listed in Table F.3 for which a standard is run. The estimate based on matrix spike recovery is 8.2 ± 2.3 ppb. The recovery of surrogate deuterated 1,2-dichloroethane (1,2-dichloroethane-D_4) is used to estimate all the listed volatile compounds. The estimate based on surrogate recovery is 7.5 ± 1 ppb.

These four methods of estimating the accuracy and precision of the reported values for TCE show that for a true value of 8 ppb, the range of results expected is approximately 5 and 11 ppb.

There is no question that the constituent may be detected at concentrations less than the CRDL. The UST CRDL is generally numerically equivalent to the Practical Quantitation Limit (PQL) for the analysis, rather than at the method detection limit (MDL). The uncertainty in the quantitation is greater at values less than the CRDL. The UST CRDL could be brought down lower by UST (for a fee), by calibrating to a lower standard. The relationship between the UST CRDL, the PQL, and the MDL for the analytes of interest is given in Table F.5.

As an added assurance that TCE has been detected at the SWL, interlaboratory comparisons have been performed by the Pacific Northwest Laboratory (PNL), using the more sensitive gas chromatography/electron capture analysis. The quantitation of TCE by PNL has been very close to that by UST; differences are on the order of 1 ppb (see Appendix G).

F.2.3 Metals by Gas Furnace, Atomic Absorption

Arsenic, selenium, and lead are analyzed by atomic absorption, furnace technique. Detection limits, sensitivity, and optimum ranges of the metals vary with the matrices and models of atomic absorption spectrophotometers. Table F.6 compares UST CRDLs with the optimum concentration range and the

TABLE F.5. Detection Limits, Defined According to UST Contract and SW-846, Method 8240

Constituent		UST CRDL (ppb)	PQL[a] (ppb)	Method DL[b] (ppb)
A61	Carbon Tetrachloride	5	5	2.8
A67	1,1,1-Trichloroethane	5	5	3.8
A68	1,1,2-Trichloroethane	5	5	5.0
A69	Trichloroethylene	5	5	1.9
A70	Perchloroethylene	5	5	4.1
A80	Chloroform	5	5	1.6
A89	1,1-Dichloroethane	10	5	4.7
A93	Methylene Chloride	10	5	2.8

(a) SW-846, Third Edition, Method 8240, Table 2.
(b) SW-846, Second Edition, Method 8240, Table 1.

TABLE F.6. Detection Limits for Atomic Absorption, Furnace Technique from SW-846, Third Edition

Element	Method	UST CRDL (ppb)	Optimum Range (ppb)	IDL (ppb)
Arsenic	7060	5	5 - 100	1
Selenium	7740	5	5 - 100	2
Lead	7421	5	5 - 100	1

instrument detection limit (IDL). The IDL refers to ideal conditions. The UST CRDLs are in the practical range for the analyses.

At values close to the IDL, where most of the uncertainty is from instrument noise, the uncertainty is greater than that for the optimal range. At the IDL, the uncertainty is approximately ±IDL. At the UST CRDL, the (95% confidence limit) uncertainty is about 0.5 times the CRDL. At a level of about 3 to 5 times the CRDL, the calculated error limits should apply.

Table F.7 lists the constituents arsenic, selenium, and lead (both filtered and unfiltered), which have been detected occasionally at the SWL. Because these constituents appear at about the CRDL, error limits of ±0.5 CRDL, or 2.5 ppb, are presented in the table rather than values computed using the matrix spike information.

F.2.4 Metals by Inductively Coupled Plasma Atomic Emission Spectroscopy

Inductively coupled plasma atomic emission spectroscopy (ICP) is used to analyze a group of metals. Detection limits, sensitivity, and optimum ranges of the metals will vary with the matrices, the model of spectrometer, and wavelengths used. Approximate IDLs of selected metals are listed in Table F.8 and compared with the UST CRDLs. The UST CRDL for sodium is purposely elevated to reduce unnecessary reporting of minor incidental blank contamination.

According to SW-846, Third Edition, for wavelength dispersive instrumentation, multiple determinations of digestates with no detectable analyte may be used to establish noise level. The detection limit of the instrument is defined as three times the standard deviation of a series of 10 replicate

TABLE F.7. Metals Concentrations Analyzed by Gas Furnace, Atomic Absorption

Constituent		UST CRDL (ppb)	Typical SWL Analysis Values (ppb)	N Times DL	UST Matrix Spike Data Recovery	sd (%)	Matrix Spike Level[b] (ppb)	EPA Method Data Calculated ± 2s (ppb)	EPA Performance Data Calculated ± 2s (ppb)	UST Matrix Spike Data Calculated ± 2s (ppb)
A20	Arsenic	5	8	1.6	92.9	7.86	20	7.9 ± 3.2	7.9 ± 3.2	7.4 ± 2.5[a]
A22	Selenium	5	5	1.0	89	9.46	20	4.6 ± 2.0	4.6 ± 2.0	4.5 ± 2.5[a]
A51	Lead	5	5	1.0	107	9.88	20	5.3 ± 2.1	5.3 ± 2.8	5.4 ± 2.5[a]
H37	F Arsenic	5	8	1.6	97.5	8.77	20	7.9 ± 3.2	7.9 ± 3.2	7.8 ± 2.5[a]
H39	F Selenium	5	5	1.0	92.1	7.39	20	4.6 ± 2.0	4.6 ± 2.0	4.6 ± 2.5[a]
H41	F Lead	5	5	1.0	102	14	20	5.3 ± 2.1	5.3 ± 2.8	5.1 ± 2.5[a]

(a) Analysis value < 2DL. Used ± 0.5 DL instead of calculated 2 s value.
(b) Matrix spike level for the majority of the reporting period from April 1 through June 30, 1988, was 20 ppb. The matrix spike level was changed to 50 ppb in June 1988.

TABLE F.8. Detection Limits for Inductively Coupled Plasma Method

Constituent	UST CRDL (ppb)	IDL (ppb)
Barium	6	2
Chromium	10	7
Copper	10	6
Iron	30	7
Magnesium	50	30
Manganese	5	2
Nickel	10	15
Sodium	200	29
Vanadium	5	8
Zinc	5	2

measurements of reagent blank signal at the same wavelength. The method quantitation limit (MQL) is 5 times this level.

At values close to the IDL, the uncertainty of the analysis value is greater than that for the optimal range. The Relative Standard Deviation (RSD), a measure of the reproducibility of the analysis, is defined as the standard deviation from three consecutive runs times 100 divided by the average result.

At concentrations less than 100 times the IDL, the RSD is a linear decreasing value (Dalager, Davison, and Ajhar 1975). In this portion of the RSD versus concentration curve, most of the uncertainty in the measurement is attributed to error generated from the ICP source. As the concentration increases above a certain value, the error of the system is from the counting statistic of the detector system.

The RSD is about 50% at the IDL, corresponding to an uncertainty of ±DL at the 95% confidence level. At the UST CRDL, the error would be about equal to ±0.5 times the CRDL.

Table F.9 shows typical values for (filtered) metals found at the SWL. The naturally occurring minerals calcium, sodium, potassium, and magnesium

TABLE F.9. Filtered Metals by Inductively Coupled Plasma Atomic Emission Spectroscopy

Constituent	UST CRDL (ppb)	Typical SWL Analysis Values (ppb)	N Times DL	UST Matrix Spike Data Recovery	sd (%)	Matrix Spike level (ppb)	EPA Method Data Calculated ± 2s (ppb)	EPA Performance Data Calculated ± 2s (ppb)	UST Matrix Spike Data Calculated ± 2s (ppb)
H18 F Zinc	5	10	2.0	92.6	5.04	500	11.7 ± 14.6	10.3 ± 3.9	9.3 ± 2.5[a]
H19 F Calcium	50	50,000	1,000.0	109	17.2	10,000	50,960 ± 5,980	49,500 ± 4,740	54,500 ± 17,200
H20 F Barium	6	50	8.3	94.6	4.4	500	41.7 ± 31.1	61.5 ± 24.5	47.3 ± 4.4
H22 F Chromium	10	10	1.0	95.7	4.16	500	9.2 ± 6.6	10.0 ± 2.7	9.6 ± 5[a]
H24 F Sodium	200	25,000	125.0	95.3	12.8	8,000	25,300 ± 3,840	24,800 ± 2,440	23,800 ± 6,400
H25 F Nickel	10	10	1.0	92.7	4.52	500	12.2 ± 13.4	10.1 ± 3.6	9.3 ± 5[a]
H26 F Copper	10	10	1.0	92.1	3.67	500	8.2 ± 5.9	10.1 ± 2.3	9.2 ± 5[a]
H27 F Vanadium	5	20	4.0	94.4	3.88	500	19.6 ± 6.4	20.1 ± 12.9	18.9 ± 1.6
H29 F Manganese	5	40	8.0	92.4	6.01	500	38.4 ± 6.5	39.4 ± 6.2	37.0 ± 4.8
H30 F Potassium	100	7,500	75.0	91.6	7.7	2,000	6,860 ± 1,310	7,370 ± 1,060	6,870 ± 1,160
H31 F Iron	50	80	1.6	94.4	4.91	500	82.4 ± 43.4	81.1 ± 14.7	75.5 ± 7.9
H32 F Magnesium	50	15,000	300.0	98	11.3	2,000	15,200 ± 1,740	14,800 ± 1,760	14,700 ± 3,390
H35 F Strontium	20	200	10.0	94.4	4.45	500	206 ± 29.3	201 ± 28.3	189 ± 17.8

(a) For values near the DL, 0.5 DL is used instead of ± 2s.

show up at much greater than trace levels. Strontium shows up with regularity; trace amounts of zinc, chromium, nickel, and copper are detected occasionally. For constituents that appear at about the CRDL, error limits of ±0.5 CRDL are presented in the table rather than values computed using the matrix spike information. The concentrations of the metals listed are all below drinking water standards.

F.2.5 Anions by Ion Chromatography and Fluoride by Ion-Specific Electrode

Table F.10 shows uncertainty estimates for anions by ion chromatography (IC) and fluoride by ion-specific electrode (ISE). The variability based on matrix spike data is probably greater than the true variability of the analyses, because the statistics from UST do not eliminate results where the limits do not actually apply. Limits do not apply when the concentration of the sample is much greater than the spike level.

Performance Evaluation data are from an aggregation of methods used by laboratories on PE Studies, rather than strictly from the IC method. For low-level fluoride analysis, regression formulas based on WS (drinking water) rather than WP (waste water) PE Studies were used because they are applicable to a lower concentration range.

F.2.6 Total Organic Halogen and Total Organic Carbon

Screening analyses for total organic halogen (TOX) and total organic carbon (TOC) are performed by SW-846, Second Edition, methods 9020 and 9060, respectively. Table F.11 shows uncertainty estimates for these analyses.

Interferences can lead to inconsistent TOX results. Currently, interference in SWL samples is being investigated.

F.3 REFERENCE

Dalager, P. D., A. L. Davison, and R. M. Ajhar. 1975. "The Inductively Coupled Plasma - The Answer to Many Unsolved Spectrochemical Problems." Paper presented at the FACSS Symposium, October 5-10, Indianapolis, Indiana.

TABLE F.10. Anion by Ion Chromatography and Low-Level Fluoride by Ion-Specific Electrode

Constituent	UST CRDL (ppb)	Typical SWL Analysis Values (ppb)	N Times DL	UST Matrix Spike Data Recovery (ppb)	sd (%)	Matrix Spike Level (ppb)	EPA Method Data Calculated ± 2s (ppb)	EPA Performance Data Calculated ± 2s (ppb)	UST Matrix Spike Data Calculated ± 2s (ppb)
C72 Nitrate	500	30,000	60.0	94.3	11.8	4,000		29,900 ± 3,670	38,300 ± 7,080
C73 Sulfate	500	55,000	110.0	104	22.2	4,000		54,500 ± 6,260	57,200 ± 24,400
C74 Fluoride	500	500	1.0	92.3	17.3	1,000		497 ± 61	462 ± 173
C75 Chloride	500	8,000	16.0	112	20.1	1,000		8,065 ± 1,830	8,960 ± 3,220
H67 Nitrite	1,000	1,000	1.0	109	10.2	1,000			1,090 ± 204
H63 L Fluoride	20	400	20.0	89.1	15.4	500		408 ± 47.6	356 ± 123

TABLE F.11. Screening Analyses

Constituent	UST CRDL (ppb)	Typical SWL Analysis Values (ppb)	N Times DL	UST Matrix Spike Data Recovery	sd (%)	Matrix Spike Level (ppb)	EPA Method Data Calculated ± 2s (ppb)	EPA Performance Data Calculated ± 2s (ppb)	UST Matrix Spike Data Calculated ± 2s (ppb)
H42 TOX LDL	20	300	15.0	91.3	15.4	50	258 ± 143		274 ± 92
C69 TOC	1,000	1,000	1.0	98.3	4.6	5,000		1099 ± 613	983 ± 92

APPENDIX G

CHLORINATED HYDROCARBON MEASUREMENTS AT THE SOLID WASTE LANDFILL

APPENDIX G

CHLORINATED HYDROCARBON MEASUREMENTS AT THE SOLID WASTE LANDFILL

Well 699-24-33 is located approximately 500 ft from the east fenceline of the Solid Waste Landfill (SWL). That well was sampled for volatile organics in January of 1986 as part of the 90-well Hazardous Materials Monitoring Project. 1,1,1 trichloroethane (TCA) was found in all three triplicate samples analyzed (27, 22, and 30 µg/L, respectively). Funding limitations on the project at that time prevented further followup of that observation. In fiscal year 1987, the Hazardous Materials Monitoring Project was combined with the Site-Wide Ground-Water Monitoring Project and given a greatly expanded scope. Resampling of well 699-24-33 in March 1987 confirmed the presence of contamination in that area. The SWL and Nonradioactive Dangerous Waste Landfill (NRDW) were considered as the most likely sources. A request was made at that time to sample the NRDW and the newly completed SWL wells for chlorinated hydrocarbons. Those samples taken in May and June of 1987 clearly showed the presence of chlorinated hydrocarbons downgradient of a liquid waste disposal trench in the SWL. Species detected included TCA, 1,1,2 trichloroethylene (TCE), perchloroethylene (PCE), and 1,1-dichloroethane (DCA). Proportions of the individual species were similar to those found in the Site-Wide well (699-24-33). Continued monitoring of those wells on nine separate samplings has clearly confirmed those results. Seven routine sets of samples have been collected to date by the Radiation Protection Technology (RPT) group. Those samples were analyzed at U.S. Testing (UST) by the routine Gas Chromatography/Mass Spectrometer (GC/MS) method. Four of those sample sets included splits made at the well and sent to Pacific Northwest Laboratory (PNL) for Quality Assurance/Quality Control (QA/QC) purposes. The PNL method employs electron capture gas chromatography, which is at least 100 times more sensitive than the GC/MS method used by UST. In addition to the routine sampling, a special study was undertaken by PNL in June of 1988 to conclusively establish the existence of the contaminant plume and verify that the sampling methods used by the RPTs are representative. Details of that study are discussed below.

WELL 699-24-33

Well 699-24-33 has been sampled nine times since early 1986. A summary of the results is given in Table G.1. Only TCA was reported by UST in 1986 because it was not their policy at that time to report results below the contractual detection limit of 10 μg/L. Subsequent analyses are reported relative to the quantifiable detection limit for the instrument, which is estimated to be 2 μg/L for the GC/MS method. The contamination levels have been remarkably constant over a period of 2.5 years.

TABLE G.1. Chlorinated Hydrocarbon Contaminants in Well 699-24-33 (μg/L)

	1,1,1 TCA		PCE		TCE	
Date	GC/MS[a]	GC[b]	GC/MS	GC	GC/MS	GC
1/23/86	21	NA[c]	<10	NA	<10	NA
1/23/86	23	NA	<10	NA	<10	NA
1/23/86	30	NA	<10	NA	<10	NA
3/23/87	21	NA	3	NA	4	NA
5/14/87	17	NA	3	NA	3	NA
8/25/87	18	NA	3	NA	3	NA
11/10/87	23	NA	3	NA	3	NA
2/03/88	23	NA	3	NA	3	NA
4/28/88	19	NA	3	NA	3	NA
6/29/88	NA	26	NA	3.4	NA	4.0
6/29/88	NA	27	NA	3.8	NA	4.3
7/30/88	20	23	4	3.1	3	3.9

(a) GC/MS analysis conducted by UST. The lowest level at which consistent agreement between laboratories is observed is 2.3 μg/L for all three species.
(b) GC analysis conducted by PNL. Quantifiable detection limit estimated to be 0.02 μg/L for all three species.
(c) NA = nonapplicable.

The highest chlorinated hydrocarbon levels have been found in well 699-24-34B. A summary of the measurements conducted to date on that well are included in Table G.2. Only the three most abundant species, TCA, PCE, and TCE, are reported here. Chloroform, DCA, and carbon tetrachloride have also been detected in that well as well as several others. Only TCE is present at levels of potential regulatory concern. The drinking water standards (DWS) and Maximum Contaminant Level (MCL) for TCE is 5 μg/L. Three other wells at the SWL were also found to have levels of TCE slightly above the DWS and MCL. Well 699-24-34B has been included in the PNL QA/QC program this year.

TABLE G.2. Chlorinated Hydrocarbon Contaminants in Well 699-24-34B (μg/L)

	1,1,1 TCA		PCE		TCE	
Date	GC/MS[(a)]	GC[(b)]	GC/MS	GC	GC/MS	GC
5/20/87	56	NA[(c)]	7	NA	10	NA
6/18/87	40	NA	6	NA	8	NA
7/28/87	4	NA	5	NA	8	NA
11/15/87	64	60	8	NA	8	NA
11/15/87	61	NA	8	NA	8	NA
1/18/88	58	47	8	6.9	8	NA
4/22/88	41	55	8	8.5	6	NA
4/22/88	41	50	8	9.0	6	NA
6/27/88	NA	51	NA	9.6	NA	8.7
6/27/88	NA	50	NA	9.5	NA	8.6
7/07/88	NA	51	NA	9.6	NA	8.7
7/07/88	NA	50	NA	9.5	NA	8.6
7/27/88	34	36	7	7.6	6	5.7
7/27/88	35	NA	7	NA	5	NA

(a) GC/MS analysis conducted by UST. The lowest level at which consistent agreement between laboratories is observed is 2.3 μg/L for all three species.
(b) GC analysis conducted by PNL. Quantifiable detection limit estimated to be 0.02 μg/L for all three species.
(c) NA = nonapplicable.

Several split measurements by both GC/MS (UST) and GC (PNL) are reported in the table. Agreement is excellent in all cases, although the PNL measurements in general have better precision because of the much greater sensitivity of the GC method. UST measurements below 10 $\mu g/L$ are only reported to one significant figure because of proximity to the detection limit.

PNL SPECIAL SAMPLING STUDY AT THE SOLID WASTE LANDFILL

Pacific Northwest Laboratory personnel conducted a series of sampling and analysis tests at the SWL from June 27 to July 11, 1988. The purpose of the study was to: 1) intercompare sampling methods employing centrifugal pumps, bladder pumps, and Teflon bailers; 2) obtain a full set of carefully prepared samples for high-sensitivity GC analysis; 3) perform careful pH measurements on all SWL wells with a flow-through pH cell; and 4) test soil-gas analysis techniques and equipment. All objectives were satisfactorily met. The pH and soil results will be discussed in detail elsewhere. Bladder pumps were added to two of the wells (699-24-34B and 699-24-35); however, the pump in well 699-24-35 did not perform satisfactorily and was not used. To facilitate rapid measurement of samples, the PNL mobile GC laboratory was moved to the SWL site. The laboratory was mounted inside a 30-ft motor home. A portable 15-KW generator was also set up at the site to provide power.

Volatile organic analysis (VOA) samples were collected in standard 40-mL VOA bottles, transferred to the motor home, and analyzed immediately. The wells were purged for time periods ranging from 20 to 40 min before sample collection. A teeing system containing two throttling valves and a critical orifice was used to provide a low flow path for VOA samples. VOA samples from the centrifugal pumps were collected through a 1/4-in. Teflon tube at a flow rate of approximately 1 Lpm. Bailer samples were taken with 1-L Teflon bailers lowered into the wells with a balloon winch and nylon fishing line. New dedicated bailers were used in the study. Approximately 20 ft of fishing line was discarded after each use to avoid cross contamination.

Samples were analyzed with a Hewlett-Packard Model 5880A gas chromatograph. The GC was equipped with two identical J&W DB-624 30 m X 0.53 mm fused silica capillary columns. The DB-624 columns were coated with a cross-linked and bonded stationary phase composed of cyanopropyl, phenyl, and dimethylsiloxane. The two columns were teed together at the inlet and were routed to separate electron capture (ECD) and flame ionization (FID) detectors. Sample introduction was via a Tekmar Model LSC-3 purge and trap unit. The LSC-3 contained a Tenax sorption trap. Samples were thermally desorbed from the Tenax trap and transferred to the columns through a heated transfer line. The LSC-3 was modified by addition of a pneumatic valve actuator to permit full automation of the purge and trap cycle by the GC run table. The HP 5880A was equipped with two separate integrators to simultaneously integrate data from both detectors. Analytical measurements were performed in accordance with the guidelines set forth in EPA SW-846, Method's 8010 (Halogenated Volatile Organics) and 8015 (Nonhalogenated Organics).

Analytical results for five species of interest in nine wells are presented in Tables G.3 through G.7. Table G.4 is of particular interest because it provides rather conclusive evidence for the presence of TCE at levels somewhat above the regulatory limit. TCE levels greater than the 5-μg/L limit were seen 25 times in four different wells in this study. It should be noted that the regulatory limit is about 300 times the measured system blank.

In addition to the measurements reported above, a time-dependent sampling study was performed at upgradient well 699-24-35. The purpose of that test was to determine if purging volume has any effect on the accuracy of the results. The well was first sampled with a bailer without purge (although it had been purged 4 days earlier). The well was then sequentially purged with the centrifugal pump at a flow rate of 5 gpm for 10-min intervals. VOA samples were taken at the end of each 10-min interval, the pump turned off, and bailer samples taken; the pump was then restarted immediately. Times were in all cases measured from the appearance of water at the pump discharge line. The sampling was continued for 1 hour. Each 10-min interval corresponded to about 3.5 bore volumes. The analytical results for four species are shown in Table G.8.

TABLE G.3. 1,1,1 Trichloroethane Results (μg/L)

Well Number	Date Collected	Centrifugal Pump	Bladder Pump	Bailer
699-25-34C	6/29/88	5.9	NA[a]	6.1
699-25-34C	6/29/88	5.9	NA	6.1
699-24-34C	6/27/88	33	NA	35
699-24-34C	6/27/88	33	NA	34
699-24-34B	6/27/88	51	48	NA
699-24-34B	6/27/88	50	47	56
699-24-34B	7/07/88	52	49	52
699-24-34B	7/07/88	53	53	50
699-24-34B	7/07/88	52[b]	50[b]	48[b]
699-24-34A	6/27/88	40	NA	43
699-24-34A	6/27/88	NA	NA	44
699-23-34	6/29/88	49	NA	46
699-23-34	6/29/88	50	NA	49
699-24-33	6/29/88	26	NA	24
699-24-33	6/29/88	27	NA	26
699-24-35	7/11/88	4.1	NA	4.3
699-24-35	7/11/88	4.1	NA	4.1
699-25-34B	7/11/88	3.6	NA	NA
699-25-34B	7/11/88	3.5	NA	NA
699-26-33	7/11/88	0.85	NA	NA
699-26-33	7/11/88	0.85	NA	NA
System Blank		0.014		

(a) NA = nonapplicable.
(b) 5-mL glass sampling syringe filled at well.

TABLE G.4. 1,1,2 Trichloroethene Results (μg/L)

Well Number	Date Collected	Centrifugal Pump	Bladder Pump	Bailer
699-25-34C	6/29/88	1.05	NA[(a)]	1.04
699-25-34C	6/29/88	1.05	NA	1.07
699-24-34C	6/27/88	5.3	NA	5.7
699-24-34C	6/27/88	5.4	NA	5.6
699-24-34B	6/27/88	8.7	8.2	NA
699-24-34B	6/27/88	8.6	8.1	9.4
699-24-34B	7/07/88	8.1	8.8	8.1
699-24-34B	7/07/88	8.1	8.2	8.0
699-24-34B	7/07/88	8.2[(b)]	7.8[(b)]	7.6[(b)]
699-24-34A	6/27/88	7.9	NA	8.4
699-24-34A	6/27/88	NA	NA	8.6
699-23-34	6/29/88	8.8	NA	8.3
699-23-34	6/29/88	9.0	NA	9.0
699-24-33	6/29/88	4.0	NA	3.6
699-24-33	6/29/88	4.3	NA	4.0
699-24-35	7/11/88	0.54	NA	0.59
699-24-35	7/11/88	0.55	NA	0.57
699-25-34B	7/11/88	0.65	NA	NA
699-25-34B	7/11/88	0.63	NA	NA
699-26-33	7/11/88	0.21	NA	NA
699-26-33	7/11/88	0.21	NA	NA
System Blank		0.017		

(a) NA = nonapplicable.
(b) 5-mL glass sampling syringe filled at well.

TABLE G.5. 1,1,2,2 Tetrachloroethene Results (μg/L)

Well Number	Date Collected	Centrifugal Pump	Bladder Pump	Bailer
699-25-34C	6/29/88	0.70	NA[(a)]	0.70
699-25-34C	6/29/88	0.70	NA	0.75
699-24-34C	6/27/88	5.6	NA	6.2
699-24-34C	6/27/88	5.7	NA	5.9
699-24-34B	6/27/88	9.6	9.0	NA
699-24-34B	6/27/88	9.5	8.8	10.0
699-24-34B	7/07/88	8.6	8.0	8.6
699-24-34B	7/07/88	8.6[(b)]	8.6[(b)]	8.6[(b)]
699-24-34B	7/07/88	8.6[(b)]	8.0[(b)]	7.6[(b)]
699-24-34A	6/27/88	7.0	NA	7.2
699-24-34A	6/27/88	NA	NA	7.4
699-23-34	6/29/88	7.8	NA	7.4
699-23-34	6/29/88	8.2	NA	8.0
699-24-33	6/29/88	3.4	NA	3.3
699-24-33	6/29/88	3.8	NA	3.6
699-24-35	7/11/88	0.54	NA	0.58
699-24-35	7/11/88	0.55	NA	0.55
699-25-34B	7/11/88	0.55	NA	NA
699-25-34B	7/11/88	0.51	NA	NA
699-26-33	7/11/88	0.092	NA	NA
699-26-33	7/11/88	0.090	NA	NA
System Blank		0.003		

(a) NA = nonapplicable.
(b) 5-mL glass sampling syringe filled at well.

TABLE G.6. Chloroform Results (μg/L)

Well Number	Date Collected	Centrifugal Pump	Bladder Pump	Bailer
699-25-34C	6/29/88	0.33	NA[a]	0.34
699-25-34C	6/29/88	0.34	NA	0.35
699-24-34C	6/27/88	0.99	NA	1.00
699-24-34C	6/27/88	0.88	NA	0.98
699-24-34B	6/27/88	1.29	1.33	NA
699-24-34B	6/27/88	1.33	1.28	2.06
699-24-34B	7/07/88	1.59	1.40	1.44
699-24-34B	7/07/88	1.52	1.46	1.51
699-24-34B	7/07/88	1.46[b]	1.17[b]	1.47[a]
699-24-34A	6/27/88	1.12	NA	1.10
699-24-34A	6/27/88	1.02	NA	1.19
699-23-34	6/29/88	1.40	NA	1.48
699-23-34	6/29/88	1.35	NA	1.58
699-24-33	6/29/88	0.80	NA	0.60
699-24-33	6/29/88	0.82	NA	0.92
699-24-35	7/11/88	0.15	NA	0.15
699-24-35	6/11/88	0.15	NA	0.14
699-25-34B	7/11/88	0.34	NA	NA
699-25-34B	7/11/88	0.33	NA	NA
699-26-33	7/11/88	0.17	NA	NA
699-26-33	7/11/88	0.18	NA	NA
System Blank		0.040		

(a) NA = nonapplicable.
(b) 5-mL glass sampling syringe filled at well.

TABLE G.7. Carbon Tetrachloride Results (µg/L)

Well Number	Date Collected	Centrifugal Pump	Bladder Pump	Bailer
699-25-34C	6/29/88	0.72	NA[a]	0.66
699-25-34C	6/29/88	0.70	NA	0.66
699-24-34C	6/27/88	0.33	NA	0.27
699-24-34C	6/27/88	0.27	NA	0.30
699-24-34B	6/27/88	0.30	0.26	0.37
699-24-34B	6/27/88	0.26	0.23	0.29
699-24-34B	7/07/88	0.28	0.32	0.27
699-24-34B	7/07/88	0.28	0.29	0.27
699-24-34B	7/07/88	0.30[b]	0.29[b]	0.27[b]
699-24-34A	6/27/88	0.26	NA	0.25
699-24-34A	6/27/88	0.23	NA	0.26
699-23-34	6/29/88	0.28	NA	0.26
699-23-34	6/29/88	0.31	NA	0.30
699-24-33	6/29/88	0.41	NA	0.43
699-24-33	6/29/88	0.43	NA	0.40
699-24-35	7/11/88	0.30	NA	0.31
699-24-35	7/11/88	0.31	NA	0.31
699-25-34B	7/11/88	0.82	NA	NA
699-25-34B	7/11/88	0.80	NA	NA
699-26-33	7/11/88	0.43	NA	NA
699-26-33	7/11/88	0.43	NA	NA
System Blank		<0.003		

(a) NA = nonapplicable.
(b) 5-mL glass sampling syringe filled at well.

TABLE G.8. Chlorinated Hydrocarbons Collected by Sequential Purging of Well 699-24-35, All Results in µg/L

Purge	TCA		TCE		PCE		CCl_4	
Time (min)	Pump	Bailer	Pump	Bailer	Pump	Bailer	Pump	Bailer
0	NA[(a)]	3.51	NA	0.45	NA	0.42	NA	0.31
0	NA	3.50	NA	0.45	NA	0.42	NA	0.31
10	3.94	3.85	0.53	0.52	0.51	0.51	0.32	0.30
10	3.95	3.97	0.53	0.52	0.52	0.50	0.32	0.31
20	4.03	4.12	0.54	0.55	0.51	0.54	0.30	0.30
20	4.18	4.17	0.56	0.53	0.55	0.53	0.32	0.29
30	4.09	4.29	0.54	0.59	0.54	0.58	0.30	0.31
30	4.11	4.13	0.55	0.57	0.55	0.55	0.31	0.31
40	4.07	4.18	0.54	0.55	0.53	0.53	0.31	0.29
40	4.13	4.07	0.55	0.54	0.53	0.53	0.32	0.29
50	4.18	5.24	0.55	0.73	0.52	0.74	0.30	0.30
50	4.16	5.41	0.55	0.77	0.54	0.80	0.31	0.28
60	4.15	5.52	0.55	0.77	0.53	0.79	0.32	0.29
60	4.04	5.46	0.55	0.76	0.53	0.81	0.31	0.29

(a) NA = nonapplicable.

CONCLUSIONS

The sampling program over the past 2 years has generated a large number of chlorinated hydrocarbon data. While these data have not yet been subjected to a rigorous statistical review, a number of conclusions appear to be definitive.

1. Widespread, low-level chlorinated hydrocarbon contamination is detectable throughout the extended landfill area. The concentrations found in well 699-24-33 suggest that the contamination has been present at least since early 1986 and has undergone little change since then. The relative concentrations of contaminants in that well are similar to those in other wells closer to the landfill.

2. Contaminants detected include chloroform, 1,1,1 trichloroethane; 1,1,2 trichloroethene; perchloroethene; 1,1 dichloroethane; and carbon tetrachloride. Chloroform is commonly found in chlorine-treated water. It may also be a decomposition product of 1,1,1 trichloroethane. 1,1,1 trichloroethane is the most abundant species. It is commonly used as a degreaser solvent. The highest level found is only about 1/4 of the drinking water standard but could be higher closer to the source (i.e., inside the landfill). Trichloroethylene is present in four of the wells at levels slightly above the drinking water standard. The relative concentrations of TCA, TCE, PCE, and DCA are similar in all wells tested including the Site-Wide well and the upgradient well. In contrast, carbon tetrachloride is relatively constant in all wells tested although some increase was observed near the NRDW. The carbon tetrachloride data are difficult to understand without further study.

3. The three sampling methods tested (centrifugal pump, bladder pump, and bailer) produced identical results in all cases. The bladder pump was judged to be unsatisfactory for routine use because of the high instantaneous flows produced during each pulse; however, the results showed little sensitivity to such effects.

4. Purge volume had little effect on results for the centrifugal pump. The bailer samples did show a small increase after the first 40 min of purge. The reason for the difference is unclear. During routine sampling, the wells are purged for 20 min before sampling.

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