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Hydrological Conditions at the 800 Area at Argonne National Laboratory

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Pearl is currently employed by Eder Associates, Madison, Wisconsin, and Tsai by International Technology Corporation, Irvine, California.

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HYDROLOGICAL CONDITIONS AT THE 800 AREA AT ARGONNE NATIONAL LABORATORY

by

T.L. Patton, R.H. Pearl, and S.Y. Tsai

SUMMARY

This study examined the hydrological conditions of the glacial till underlying the 800 Area sanitary landfill at Argonne National Laboratory (ANL) near Lemont, Illinois. The study's purpose was to review and summarize hydrological data collected by ANL's Environment, Safety, and Health Department and to characterize, on the basis of these data, the groundwater movement and migration of potential contaminants in the area. Recommendations for further study have been made based on the findings of this review.

The 800 Area landfill is located on the western edge of ANL, just south of Westgate Road. It has been in operation since 1966 and has been used for the disposal of sanitary, general refuse. From 1969 through 1978, however, substantial quantities of liquid organic and inorganic wastes were disposed of in a "French drain" at the northeast corner of the landfill.

The 800 Area landfill is underlain by a silty clay glacial till. Dolomite bedrock underlies the till at an average depth of about 45.6 m (149.5 ft). Trace levels of organic contaminants and radionuclides have been detected in groundwater samples from wells completed in the till. Fractures in the clay as well as sand and gravel lenses present in the till could permit these contaminants to migrate downward to the dolomite aquifer. When this report was prepared, no chemical quality analyses have been made on groundwater samples from the dolomite.

Water levels measured in monitoring wells completed in the till indicate that the predominant direction of groundwater flow is to the southeast. The horizontal groundwater velocity was estimated to range from 1.4 to 6.0 cm/yr. Water levels in the dolomite wells were not available when this report was prepared.

The study found that existing information about subsurface characteristics at the site is inadequate to identify potential pathways for contaminant migration. Recommended actions include installation of five new well clusters and one background well, thorough record-keeping, sample collection and analysis during borehole drilling, slug testing to measure hydraulic conductivity, topographic mapping, continued monitoring of groundwater levels and quality, and monitoring of the unsaturated zone.

1 INTRODUCTION

This report presents the results of a study of the hydrology of the glacial till underlying the 800 Area sanitary landfill at Argonne National Laboratory (ANL) near Lemont, Illinois. The study was conducted by the Environmental Assessment and Information Systems Division at the request of the Environment, Safety, and Health Department (ESH) of ANL's Support Services Division. The study's objective is to characterize the movement of groundwater and potential contaminants based on a review of data collected by ESH. This report presents a summary of the groundwater monitoring program through the second quarter of 1989. Recommendations for further study have been made on the basis of this review.

This section briefly describes the history and physical setting of the 800 Area landfill, Sec. 2 describes the area's geology and hydrology, Sec. 3 reviews previous groundwater monitoring activities at the site, and Sec. 4 recommends actions to acquire additional data. Supplemental information is provided in the appendixes: App. A provides records of well installation and logging, App. B contains water levels measured in the wells since 1980, App. C contains well hydrographs, App. D contains analytic results for groundwater samples, App. E summarizes draft groundwater monitoring guidance from the Illinois Environmental Protection Agency (Illinois EPA), and App. F summarizes the monitoring well design and construction practices recommended by the U.S. Environmental Protection Agency (U.S. EPA).

1.1 SITE HISTORY

Figure 1 shows the location of ANL, which is in T37N, R11E, Sections 3, 4, 8, 9, 10, 15, 16, and 17, DuPage County, Illinois. The 8.8-ha (21.78-acre) landfill (in Section 8) is located just south of Westgate Road on the western edge of ANL (Fig. 2). The landfill has received waste continuously since July 1966 and operates under Illinois EPA Permit No. 1981-29-OP, issued September 17, 1981. It has been used for the disposal of sanitary general refuse, demolition debris, boiler-house ash, and other nonradioactive waste. From 1969 through 1978, substantial quantities of liquid organic and inorganic wastes, some of which would be classified as hazardous under current U.S. EPA regulations, were disposed of in a "French drain" at the northeast corner of the landfill (Golchert and Duffy 1988). The presence of low levels of tritium in some of the monitoring wells indicates that radioactive waste may have been disposed of in the landfill.

Since 1979, ESH, Plant Facilities and Services (PFS), and the U.S. Department of Energy (DOE) Environmental Survey Team have drilled 16 monitoring wells along the perimeter of the landfill to determine the local groundwater elevations and to monitor possible organic, inorganic, and radioactive contaminants in the groundwater beneath the landfill.

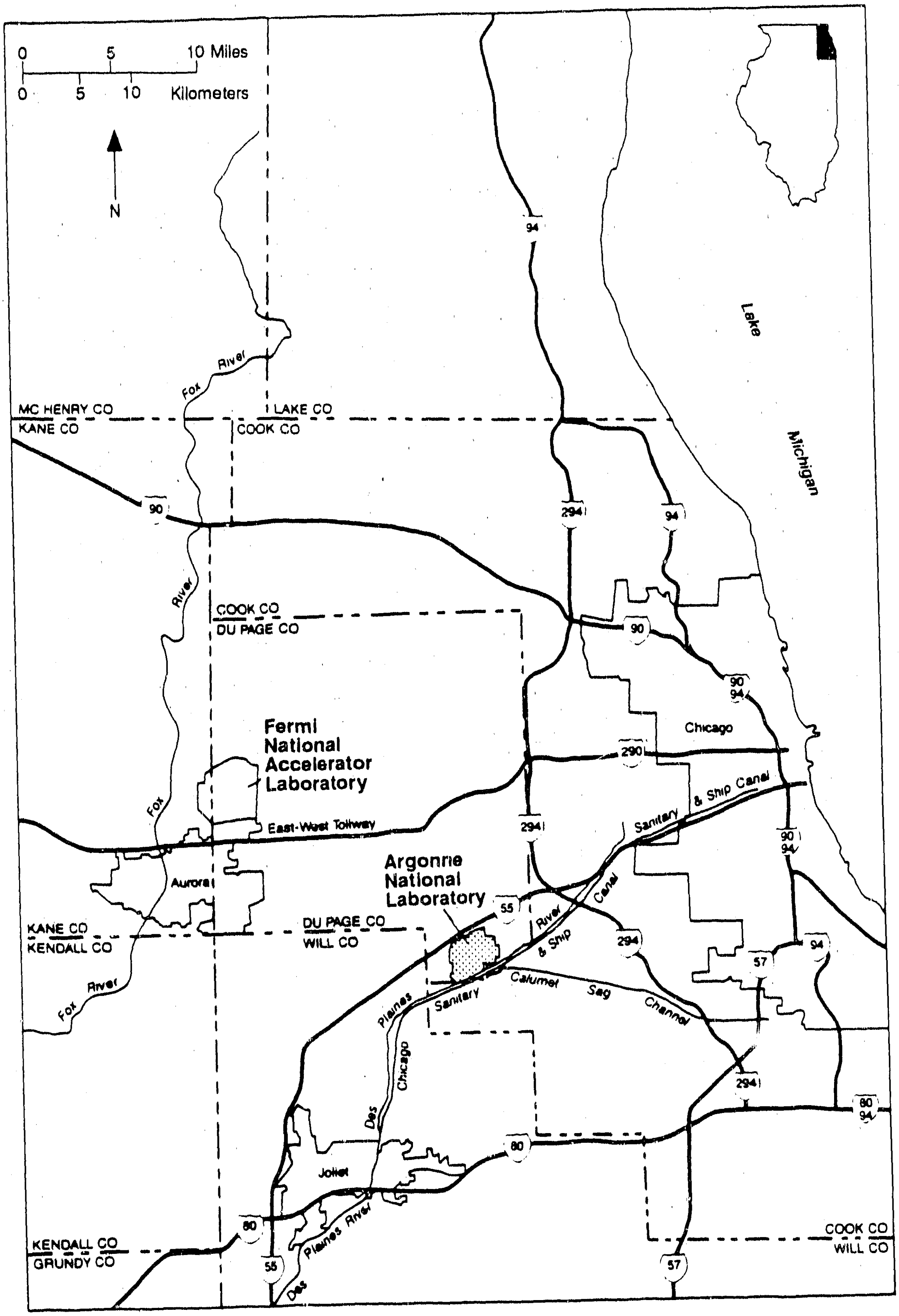


FIGURE 1 Location of Argonne National Laboratory, DuPage County, Illinois (Source: Modified from Killey and Trask 1989)

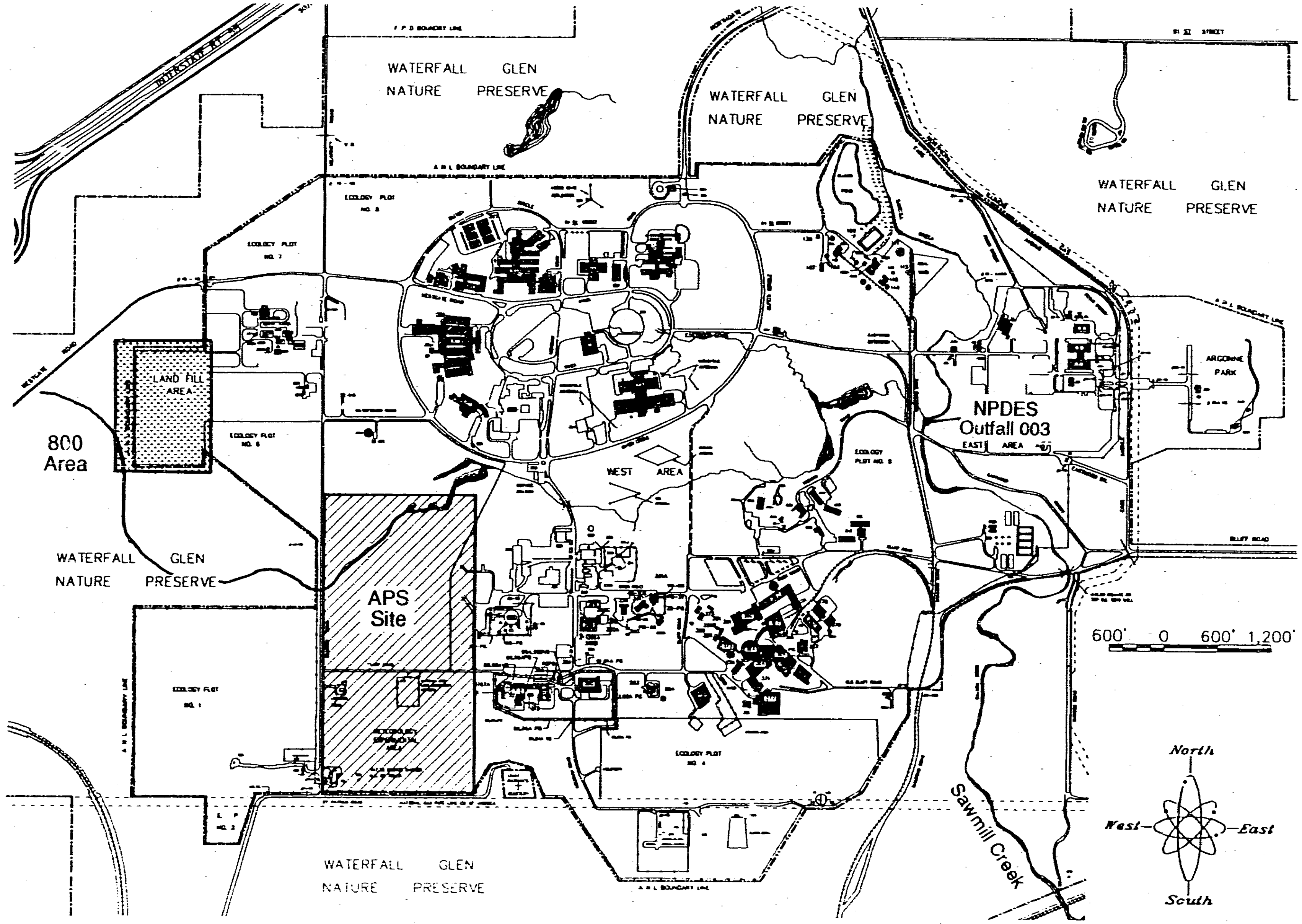


FIGURE 2 Map of Argonne National Laboratory Showing the Location of the 800 Area Landfill

1.2 TOPOGRAPHY

The surface of the land surrounding the 800 Area has been dissected into gently rolling hills by streams and creeks flowing to the Des Plaines River to the south. The major topographic feature of the region is the deeply incised Des Plaines River valley at an elevation of 183 m (600 ft) above mean sea level (MSL), about 49 m (160 ft) below that at the landfill (Fig. 3).

The land surface at the 800 Area landfill generally slopes to the south from an elevation of about 232 m (760 ft) above MSL at the north end to about 229 m (751 ft) above MSL at the south end (Soil Testing Services, Inc. 1980b).

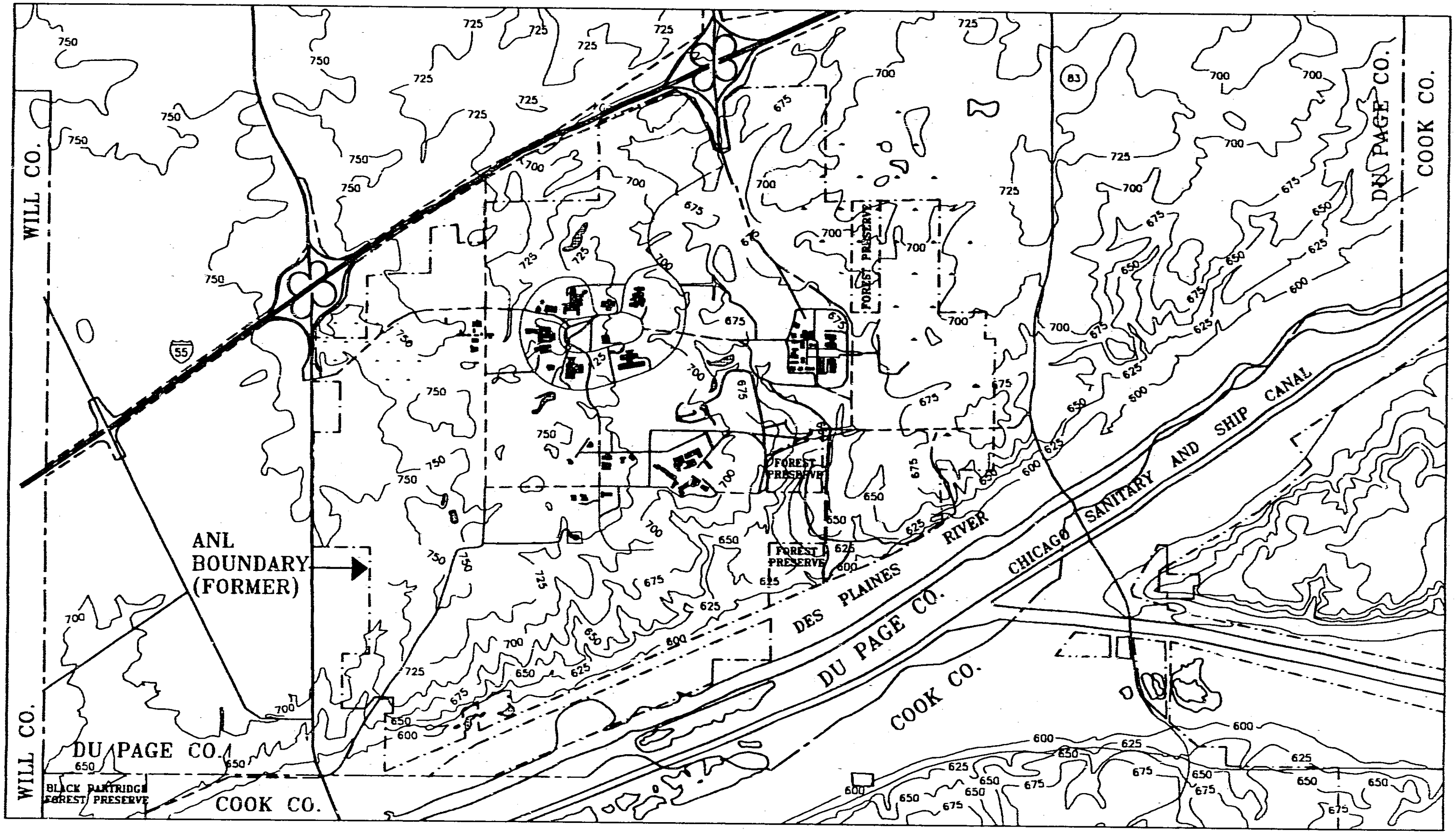


FIGURE 3 Topography of the Area near ANL (the map shows the ANL boundary before ANL property was transferred to the forest preserve) (Sources: Modified from USGS 1978, 1983)

2 GEOLOGY

ANL is located on a glacial till plateau that forms a complex arrangement of hills and depressions forming the Valparaiso Morraine, which has a northwest-southeast trend. The glacial till covering the area consists of a heterogeneous mixture of silt, clay, and sand. Deposits of sand and gravel occur as discontinuous lenses throughout the till. Silurian-age dolomite forms the bedrock surface beneath the glacial till and crops out along the bluffs adjacent to the Des Plaines River valley and Sawmill Creek.

2.1 STRATIGRAPHY

The stratigraphic column in Fig. 4 shows the sequence of lithologic units in DuPage County.

2.1.1 Bedrock Geology

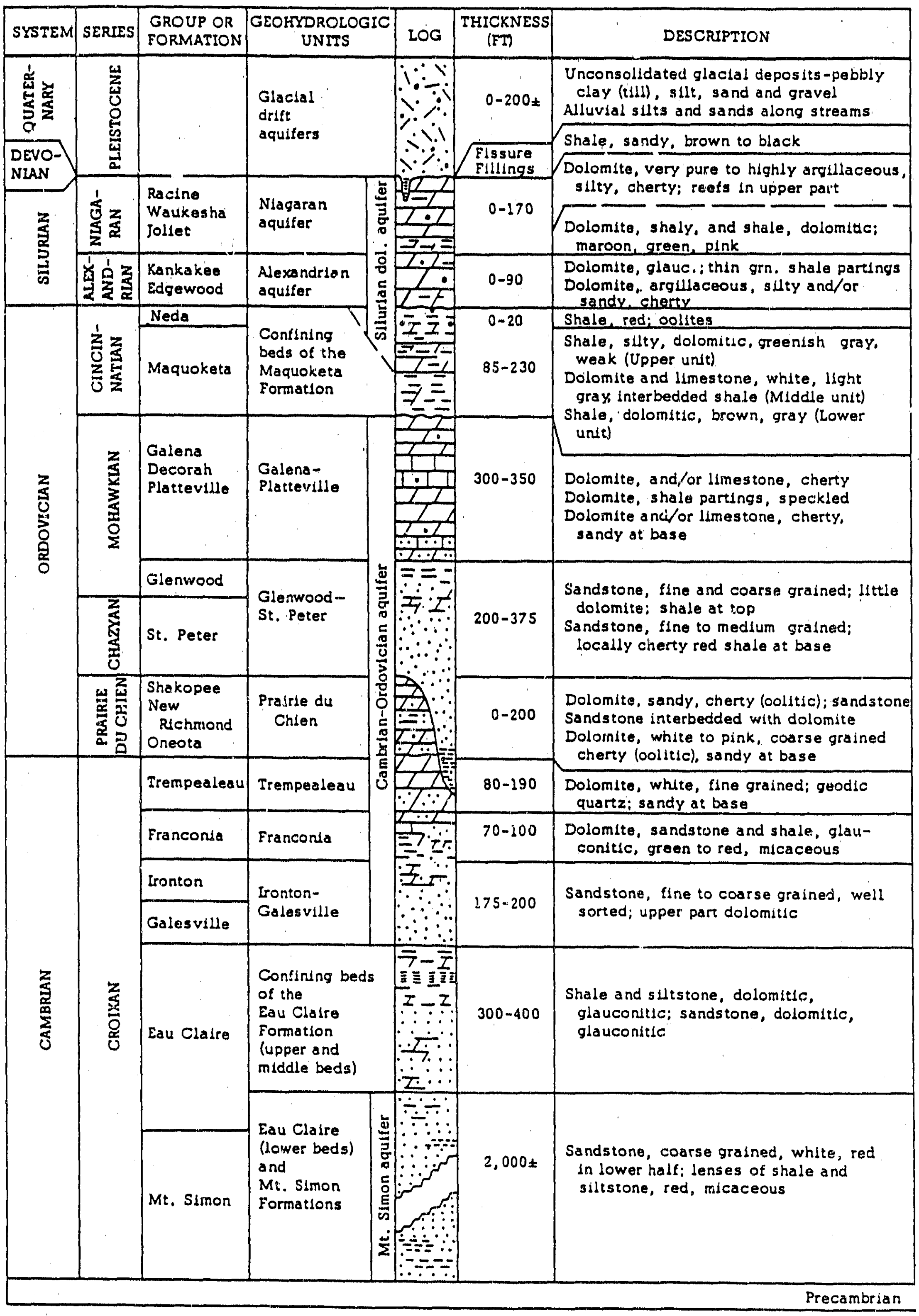
Silurian-age dolomite bedrock beneath the 800 Area landfill occurs at an average depth of 43.5 m (143 ft) below the land surface (Will County Well & Pump Co. 1988). The dolomite is underlain by the Ordovician-age Maquoketa shale group and the Galena-Platteville cherty dolomite. The Maquoketa shale group functions as a confining stratum that separates the Niagaran and Alexandrian aquifers of the Silurian dolomite and the underlying Ordovician-age Galena-Platteville dolomite, Glenwood-St. Peter sandstone, and Prairie du Chien dolomite.

2.1.2 Unconsolidated Deposits

The glacial drift underlying the 800 Area landfill consists of two units: the Lemont drift (till) and the overlying silty clay. The Lemont drift consists of a silty clay loam to silt loam and has an average fine-grained matrix (less than 2 mm) of 16% sand, 64% silt, and 20% clay; the drift was identified by the Illinois State Geological Survey (ISGS) in a study conducted at the Advanced Photon Source (APS) site, located about 1.1 km (3,600 ft) southeast of the landfill (Fig. 2) (Killey and Trask 1989). The base of the Lemont drift consists of dolomite boulders, gravel, and rock fragments (shale and dolomite) that overly the dolomite bedrock.

The overlying glacial till unit consists of a silty clay matrix intermixed with sand, gravel, pebbles, and rock fragments (shale and dolomite). At the APS site, the average till thickness is about 43.5 m (143 ft). Analyses performed by ISGS show that the average fine-grained matrix (less than 2 mm) consists of 16% sand, 45% silt, and 39% clay (Killey and Trask 1989). Pebble content (greater than 2 mm) was estimated to be 1-7%. The till contains lenses consisting of sand, sand and gravel, and silt that range in thickness from less than 0.3 m (1 ft) to about 1.2 m (4 ft).

In the drillers' logs for the 800 Area landfill, no distinction was made between the Lemont drift and the clay till. Since the two tills are mainly distinguished by the



SYSTEM	SERIES	GROUP OR FORMATION	GEOHYDROLOGIC UNITS	LOG	THICKNESS (FT)	DESCRIPTION
QUATERNARY	PLEISTOCENE		Glacial drift aquifers		0-200±	Unconsolidated glacial deposits-pebbly clay (till), silt, sand and gravel Alluvial silts and sands along streams
DEVONIAN					Fissure Fillings	Shale, sandy, brown to black
SILURIAN	NIAGARAN	Racine Waukesha Joliet	Niagaran aquifer Silurian dol. aquifer		0-170	Dolomite, very pure to highly argillaceous, silty, cherty; reefs in upper part Dolomite, shaly, and shale, dolomitic; maroon, green, pink
	ALEXANDRIAN	Kankakee Edgewood	Alexandrian aquifer		0-90	Dolomite, glauc.; thin grn. shale partings Dolomite, argillaceous, silty and/or sandy, cherty
ORDOVICIAN	CINCINNATIAN	Neda	Confining beds of the Maquoketa Formation		0-20	Shale, red; oolites
		Maquoketa			85-230	Shale, silty, dolomitic, greenish gray, weak (Upper unit) Dolomite and limestone, white, light gray, interbedded shale (Middle unit) Shale, dolomitic, brown, gray (Lower unit)
	MOHAWKIAN	Galena Decorah Platteville	Galena-Platteville Cambrian-Ordovician aquifer		300-350	Dolomite, and/or limestone, cherty Dolomite, shale partings, speckled Dolomite and/or limestone, cherty, sandy at base
		Glenwood	Glenwood-St. Peter		200-375	Sandstone, fine and coarse grained; little dolomite; shale at top Sandstone, fine to medium grained; locally cherty red shale at base
	CHAZYAN	St. Peter				
	PRAIRIE DU CHIEN	Shakopee New Richmond Oneota	Prairie du Chien		0-200	Dolomite, sandy, cherty (oolitic); sandstone Sandstone interbedded with dolomite Dolomite, white to pink, coarse grained cherty (oolitic), sandy at base
CAMBRIAN	CROIXAN	Trempealeau	Trempealeau		80-190	Dolomite, white, fine grained; geodic quartz; sandy at base
		Franconia	Franconia		70-100	Dolomite, sandstone and shale, glauconitic, green to red, micaceous
		Ironton	Ironton-Galesville		175-200	Sandstone, fine to coarse grained, well sorted; upper part dolomitic
		Galesville				
		Eau Claire	Confining beds of the Eau Claire Formation (upper and middle beds)		300-400	Shale and siltstone, dolomitic, glauconitic; sandstone, dolomitic, glauconitic
		Mt. Simon	Eau Claire (lower beds) and Mt. Simon Formations Mt. Simon aquifer		2,000±	Sandstone, coarse grained, white, red in lower half; lenses of shale and siltstone, red, micaceous
						Precambrian

FIGURE 4 Stratigraphy and Geohydrology of DuPage County (Source: Zeizel et al. 1962)

relative amount of silt and clay, they cannot be differentiated without the aid of laboratory analysis. Thus, no attempt is made here to differentiate them at the 800 Area landfill.

2.1.3 Site Stratigraphy

Drillers' or geologists' logs describing the geologic materials encountered during drilling are available for 13 of the 16 monitoring wells installed around the landfill (see Fig. 5 and App. A). The logs, which record textural and color criteria, allow the sedimentary units to be correlated from well to well. Cross sections based on the drillers logs are shown in Figs. 6-8 (see Fig. 5 for cross section locations). Logs for wells 11 and 13 did not contain enough detail to be useful in this endeavor. No boring data were recorded for wells 8, 9, and 12.

The cross sections show that the 800 Area is characterized by a silty clay till that is brown near the surface and grades with depth to a gray silty clay with intermixed coarse sand and fine gravel. Two sand lenses are present at depths of about 9.4 m (31 ft) and 12.2 m (40 ft) at wells 6 and 7b. These sand lenses do not appear to have wide lateral extent because they do not extend much farther north than well 6, and they do not extend to western well 3 or eastern well 5. Their southern extent beyond well 7b has not been determined.

Two wells (DH-1 and DH-2 -- see Fig. 5) have been drilled into the Silurian dolomite bedrock. Depths to bedrock at wells DH-1 and DH-2 were 45 m (148 ft) and 42 m (138 ft), respectively (Will County Well & Pump Co. 1988). At well DH-1, the drillers' log records three gravel beds at depths of 3.0-6.1 m (10-20 ft), 18.3-24.4 m (60-80 ft), and 31.1-44.5 m (102-146 ft). At DH-2, two sand and gravel beds were encountered at 30.5-33.5 m (100-110 ft) and 38.1-42.1 m (125-138 ft).

2.2 HYDROLOGY

2.2.1 Surface Water

Directly west of the 800 Area landfill is an off-site wetland, through which a small north-south flowing stream runs. Storm-water runoff from the 800 Area landfill is collected in a shallow ditch that empties into a marshy area in the southwest corner of the landfill site. From there it flows under the perimeter road and then off site into the small creek that drains the wetland area. This creek eventually enters ANL property from the west, where it flows through a large wetland and then into the Freund pond system (Fig. 2). Storm-water runoff from the rest of the ANL site flows primarily through the Freund ponds, which discharge through National Pollutant Discharge Elimination System (NPDES) Outfall 003 and then into Sawmill Creek. Sawmill Creek empties into the Des Plaines River located about 2.9 km (1.8 mi) to the south.

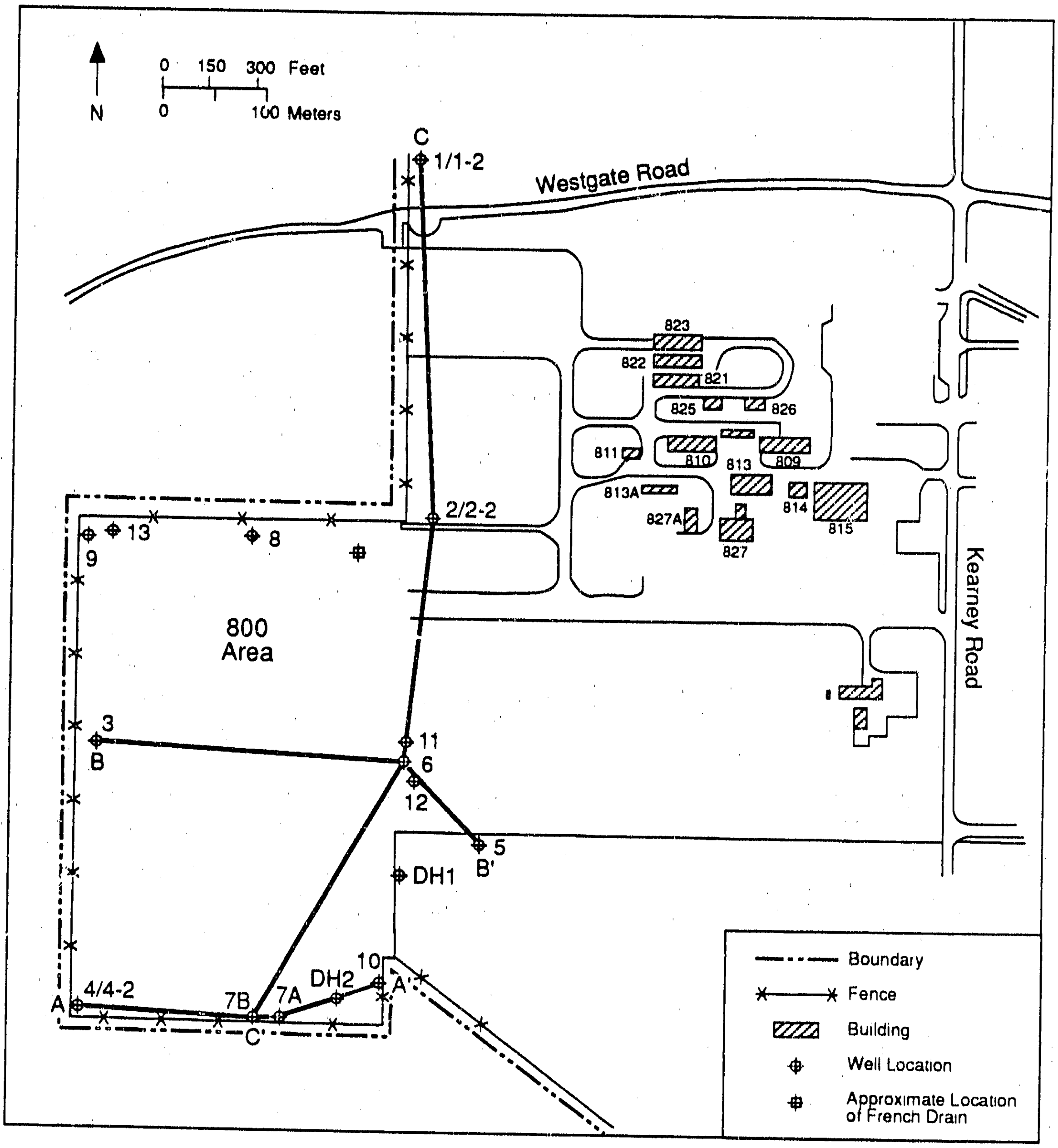


FIGURE 5 Locations of Monitoring Wells and Subsurface Cross Sections in the 800 Area Landfill

2.2.2 Groundwater

Groundwater under ANL and the 800 Area landfill is found in the Silurian dolomite bedrock and in the overlying glacial till. The Silurian dolomite consists of two aquifers: the Niagaran Series and the underlying Alexandrian Series (Fig. 4). The Niagaran dolomite occurs at depths of greater than 30 m (100 ft) in the 800 Area. Figure 9 shows the topographic features of the Niagaran dolomite surface under ANL. The unit may be greater than 61 m (200 ft) in thickness. The Niagaran Series dolomite is a zone of relatively high permeability and is the most productive of the Silurian dolomite

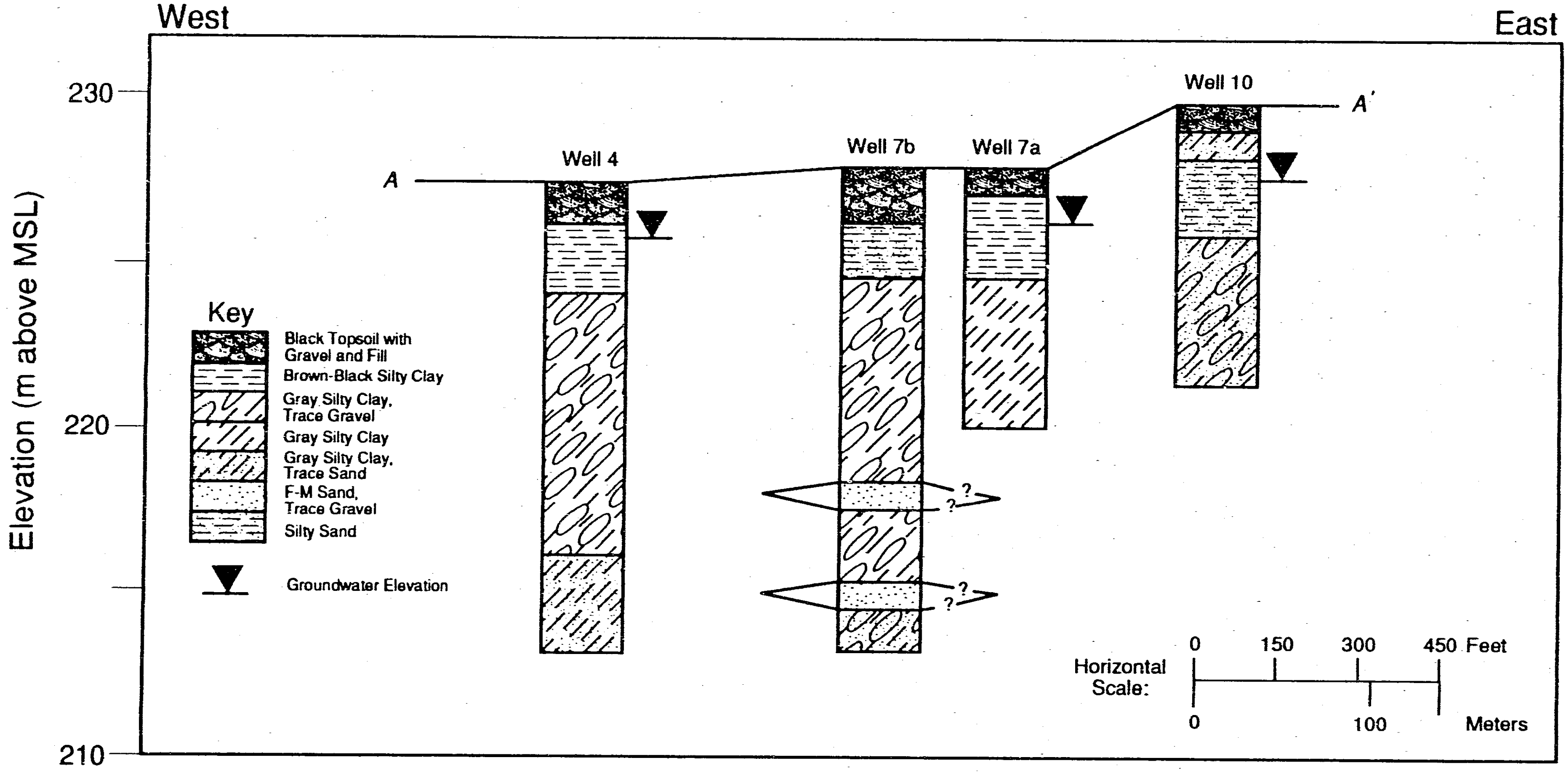


FIGURE 6 Geologic Cross Section A-A'

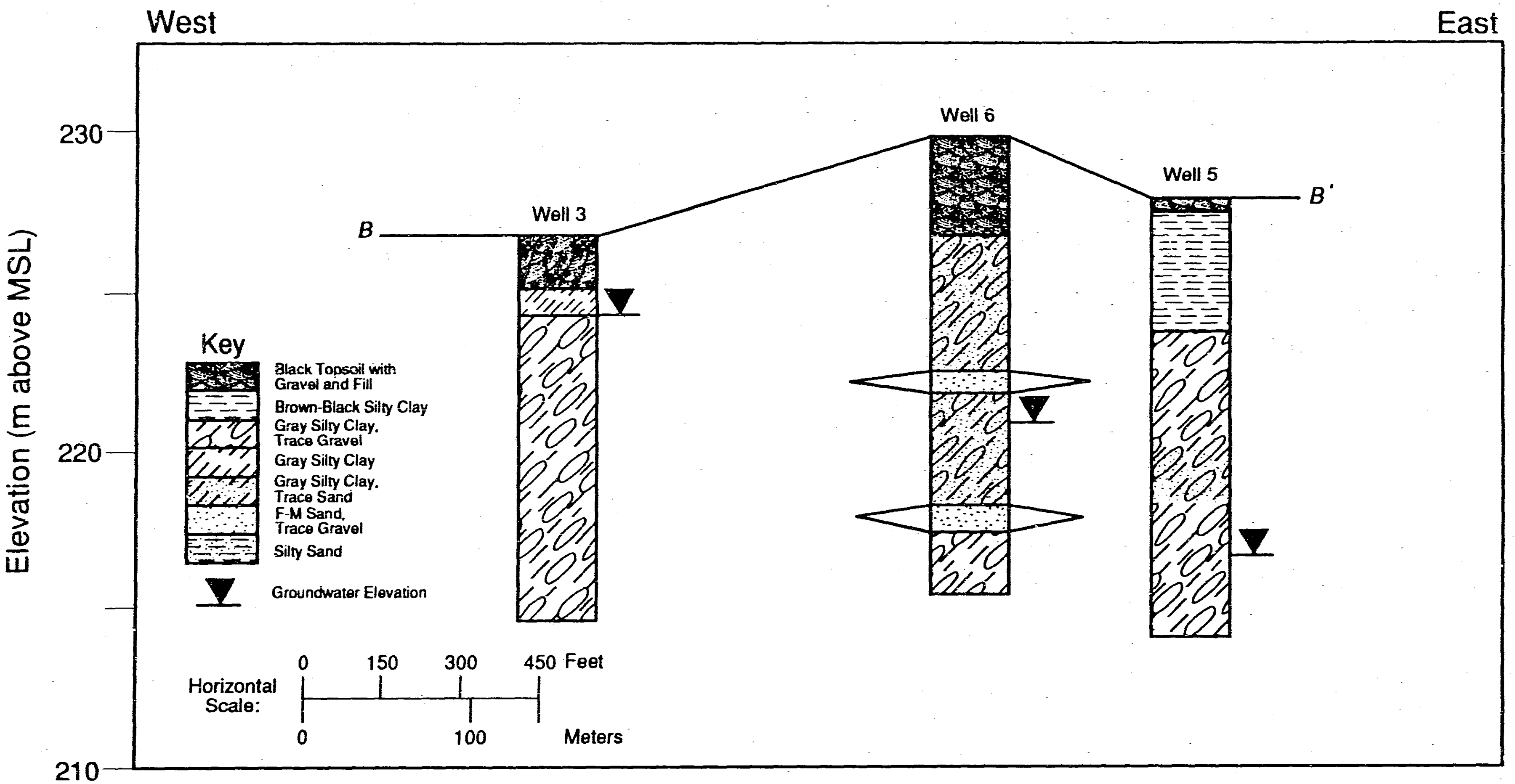


FIGURE 7 Geologic Cross Section B-B'

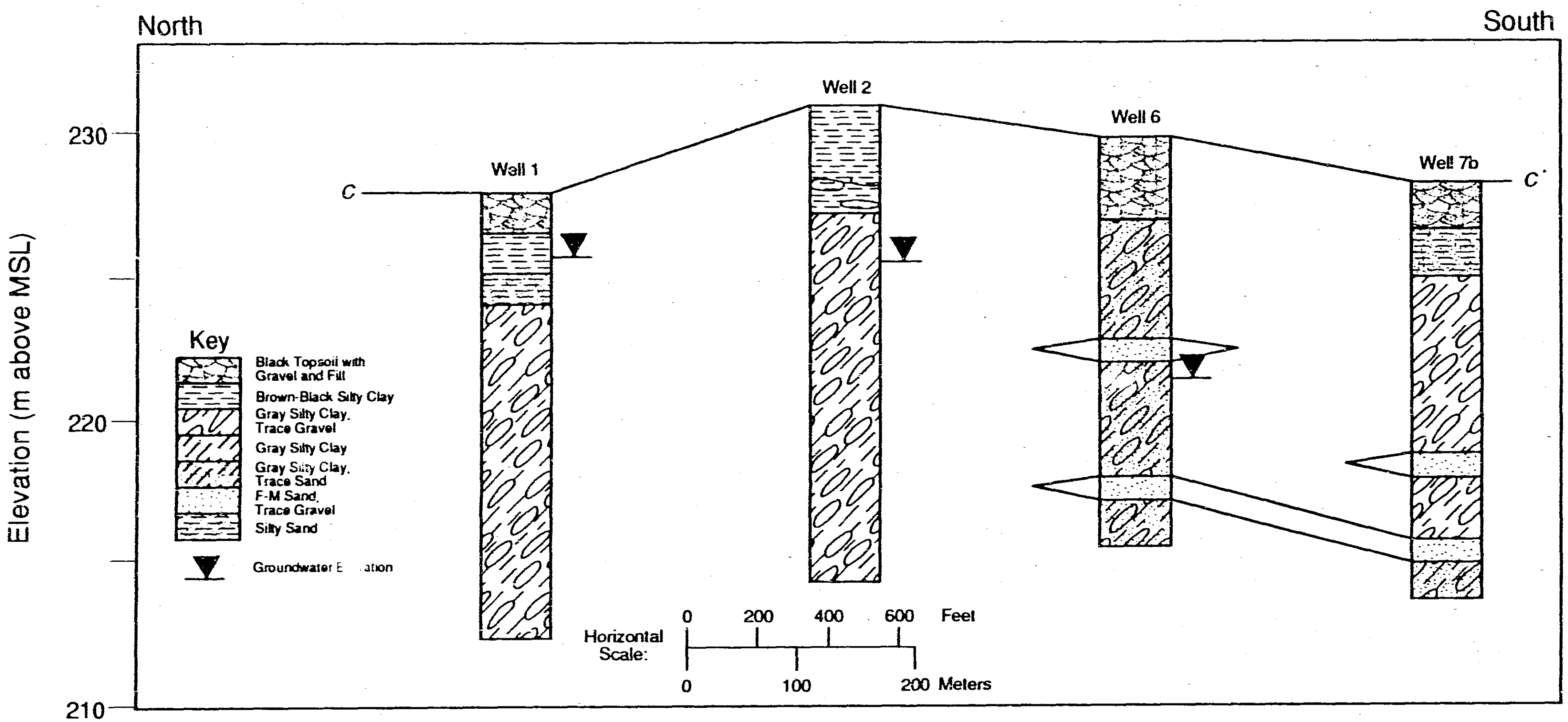


FIGURE 8 Geologic Cross Section C-C'

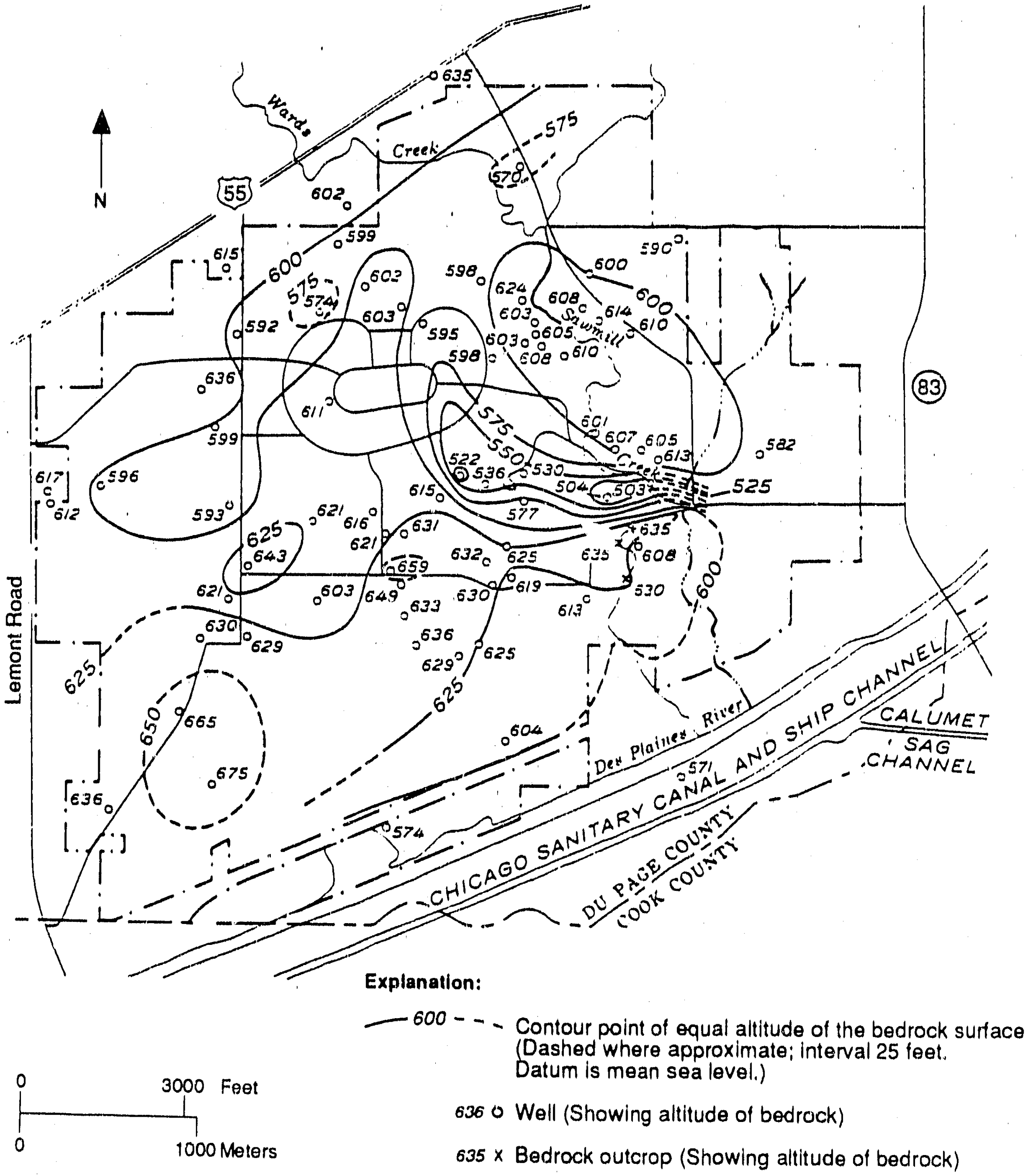


FIGURE 9 Approximate Elevation of the Niagaran Dolomite Bedrock Surface at ANL (Source: Modified from Knowles et al. 1963)

aquifers (Zeizel et al. 1962). Groundwater occurs in openings in the dolomite and moves through a complex network of interconnected joints, fractures, and solution cavities (Zeizel et al. 1962). Recharge is from vertical leakage through the glacial till.

Groundwater occurs in the till at shallow depths where recharge (precipitation) is able to migrate through small fractures in the weathered portions of the clay and in the small sand and gravel lenses distributed throughout the till.

2.2.3 Contaminant Migration Potential

Potential contaminants from the 800 Area landfill migrating downward in groundwater may be greatly retarded by the slow rate of percolation through the nearly impermeable clay of the glacial till; however, contaminants could migrate via fractures and the sand and gravel lenses in the clay till and reach the dolomite. This is of concern since the dolomite aquifer provides much of the groundwater used in southern DuPage County and at ANL. The groundwater in the dolomite aquifer flows southeast, discharging into the Des Plaines River about 2.9 km (1.8 mi) south of the landfill. Since no drinking water supplies are located between the 800 Area and the river (the area is the ANL site and a forest preserve); the potential for human consumption is considered to be low. Figure 10 shows a 1960 illustration of the piezometric surface of groundwater in the Silurian (Niagaran) dolomite at ANL.

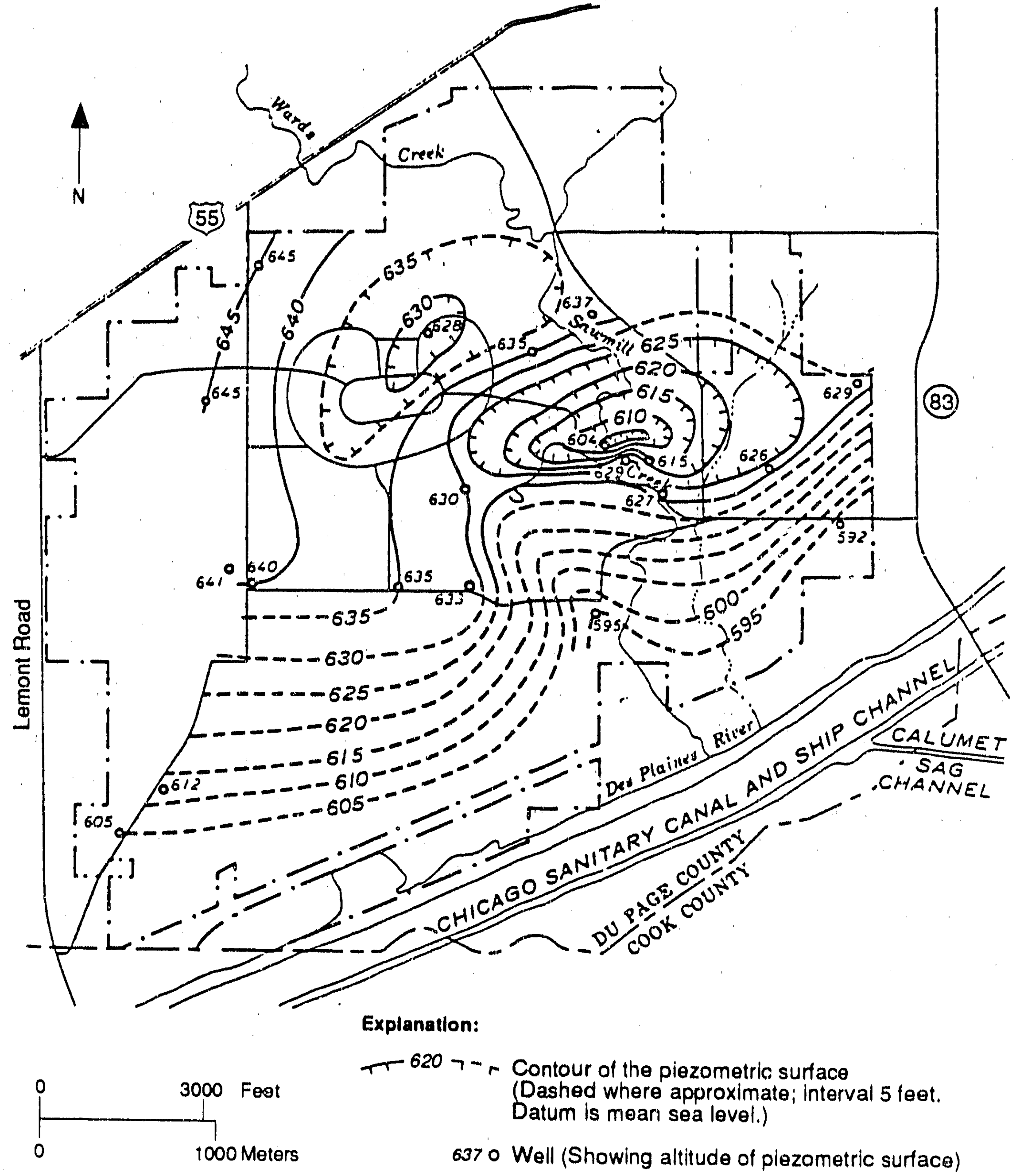


FIGURE 10 Piezometric Surface of Groundwater in the Niagaran Dolomite at ANL, June 1960 (Source: Modified from Knowles et al. 1963)

3 GROUNDWATER CONDITIONS AT THE 800 AREA

3.1 EXISTING WELL NETWORK

As part of the environmental monitoring program at ANL, ESH and PFS have installed 13 groundwater wells around the landfill since 1979. Three wells were installed by the DOE Environmental Survey Team. See Fig. 5 for their locations and App. A for all available construction diagrams and drillers' and geologists' logs.

Wells 1 through 5 were installed in October 1979. Because the general groundwater flow was assumed to be to the south, wells 1 and 2 were placed upgradient to serve as background wells. Wells 3, 4, and 5 were located downgradient to intercept groundwater leaving the site. Depths of these wells range from 12.2-15.2 m (40-50 ft) (Walter H. Flood & Co. 1979).

In April 1980, three additional wells were installed along the perimeter of the landfill. Well 6 was drilled to a depth of 13.4 m (44 ft) in the east section to sample groundwater flowing in a southeasterly direction; nested wells 7a and 7b were placed along the south side of the landfill. Wells 7a and 7b were installed to measure vertical water movement and to provide monitoring data for water at two depths: 7.6 and 13.7 m (25 and 45 ft), respectively; well 7b, however, has been dry since its emplacement (Soil Testing Services 1980a; Golchert and Duffy 1988).

Six additional wells were installed in September 1986. Wells 8, 9, and 10 were added to improve peripheral monitoring and were drilled to depths ranging from 6.1 to 9.1 m (20 to 30 ft). Original wells 1, 2, and 4 were suspected of being poorly sealed and were abandoned by pulling the casing and filling the holes with grout (App. A). Replacement wells were located within 1.5 m (5 ft) of the original wells and were designated 1-2, 2-2, and 4-2, respectively. The new wells were drilled to depths of 7.6 m (25 ft, wells 1-2 and 2-2) and 16.8 m (55 ft, well 4-2).

Wells 11, 12, and 13 were installed by the DOE Environmental Survey Team. Well 12 was installed in November 1987 at a depth of 10.1 m (33 ft). Wells 11 and 13 were installed in December 1987 at a depth of 23.8 m (78 ft). These wells were installed close to existing wells to gain information about vertical movement of groundwater in the till.

In September 1988, wells DH-1 and DH-2 were drilled into the dolomite at total depths of 46.0 m (151 ft) and 45.1 m (148 ft), respectively, in the southeast corner of the landfill (Will County Well & Pump Co. 1988).

The total depths of the monitoring wells drilled into the glacial till range from 6.1-23.8 m (20-78 ft). Polyvinyl chloride (PVC) casing and screens were used in all of the glacial till monitoring wells except for wells 11, 12, and 13, which were cased and screened with stainless steel. The wells were screened at the bottom with 1.5-m (5-ft) screens and packed with pea-sized gravel over intervals ranging from 1.5-10.7 m (5-35 ft). Only wells 6, 7a, and 7b have short gravel-packed intervals (1.5 m). Table 1 provides a summary of the design and construction of monitoring wells at the 800 Area

TABLE 1 Summary of the Design and Construction of Monitoring Wells at the 800 Area Landfill

Well	Elevation (m above MSL) Ground Surface	Well Point	Bottom of Seal	Monitoring Zone (m)	May 1989 Depth to Ground-water (m)	Casing Diameter/ Material[a]	Packing Material
1-2	227.69	220.00	224.33	4.33	2.05	2 in./PVC	Pea gravel
2-2	230.83	215.01	223.82	8.81	5.40	2 in./PVC	Pea gravel
3	226.77	218.11	224.33	6.22	2.50	2 in./PVC	Pea gravel
4-2	227.23	220.10	223.57	3.47	1.40	2 in./PVC	Pea gravel
5	227.53	215.40	224.48	9.08	9.48	2 in./PVC	Pea gravel
6	229.91	215.07	218.02	2.95	10.51	2 in./PVC	Pea gravel
7a	227.81	220.22	221.71	1.49	1.34	2 in./PVC	Pea gravel
7b	227.81	214.09	215.62	1.53	dry	2 in./PVC	Pea gravel
8	231.53	222.84	226.26	3.42	3.30	2 in./PVC	Pea gravel
9	230.00	224.09	227.26	3.17	2.56	2 in./PVC	Pea gravel
10	229.15	222.60	225.80	3.20	1.01	2 in./PVC	Pea gravel
11	229.91[b]	205.49	212.69	7.20	c	4 in./SS	#4 Silica sand
12	229.91[b]	219.17	223.36	4.19	8.35	4 in./SS	Pea gravel
13	230.00[b]	205.80	212.63	6.83	12.56	4 in./SS	#4 Silica sand
DH-1	227.53[d]	182.42	185.47	3.05[e]	c	6 in./CS	e
DH-2	229.15[d]	183.13	184.65	1.52[e]	c	6 in./CS	e

[a] CS = carbon steel, PVC = polyvinyl chloride, and SS = stainless steel.

[b] Wells 11 and 12 are estimated to have the same ground surface elevation as well 6; well 13 is estimated to have the same ground surface elevation as well 9.

[c] Not measured.

[d] Well DH-1 is estimated to have the same ground surface elevation as well 5; well DH-2 is estimated to have the same ground surface elevation as well 10.

[e] Dolomite wells DH-1 and DH-2 are open rock wells and have no screen. The casing was placed 1 ft into the dolomite. The monitoring zone length is assumed to be the same as the length of exposed dolomite.

landfill. Figure 11 is a schematic diagram comparing the monitoring intervals of all wells completed in the till.

3.2 DIRECTION OF GROUNDWATER FLOW

Groundwater in the glacial till is unconfined and generally occurs at shallow depths. Static water levels in the monitoring wells have been measured quarterly by ESH since 1980 and are summarized in Tables B.1-B.9 in App. B. Sampling and water-level measurement of the two dolomite wells was begun in late 1989; however, these data were not available when this report was prepared.

Table 2 gives water table elevations for four recent quarters (5/89, 3/89, 11/88, and 9/88), and Fig. 12 shows the elevation contours, based on May 1989 data, for all wells completed in the till. The direction of groundwater movement is at right angles to the contours. The figure indicates that the predominant direction of groundwater flow is south-southeast, with a hydraulic gradient that ranges from 0.007 to 0.023. The high water levels measured along the west boundary (wells 8 and 9) are most likely due to recharge from the adjacent wetlands.

3.3 RATE OF GROUNDWATER FLOW

3.3.1 Horizontal Flow

If it is assumed that groundwater flow is predominantly horizontal, the rate of horizontal groundwater flow in an aquifer is determined by its hydraulic gradient, hydraulic conductivity, and porosity. The velocity magnitude may be calculated using the following equation:

$$v = -(K/n) \times (dh/dl)$$

where:

v = average linear velocity,

K = hydraulic conductivity,

n = volumetric porosity, and

dh/dl = hydraulic gradient (Freeze and Cherry 1979).

The negative sign indicates that the flow is in the direction of decreasing hydraulic head.

Hydraulic conductivity values have been determined by the ISGS for the till underlying the APS site, about 1.1 km (3,600 ft) southeast of the landfill (Killey and Trask 1989). The values, which were derived by slug testing, range from 3.2×10^{-7} cm/s (2.8×10^{-4} m/d) to 4.2×10^{-6} cm/s (3.6×10^{-3} m/d). These values are greater than the range of 10^{-9} to 10^{-7} cm/s reported by Berg et al. (1984) for Illinois till containing greater than 25% clay.

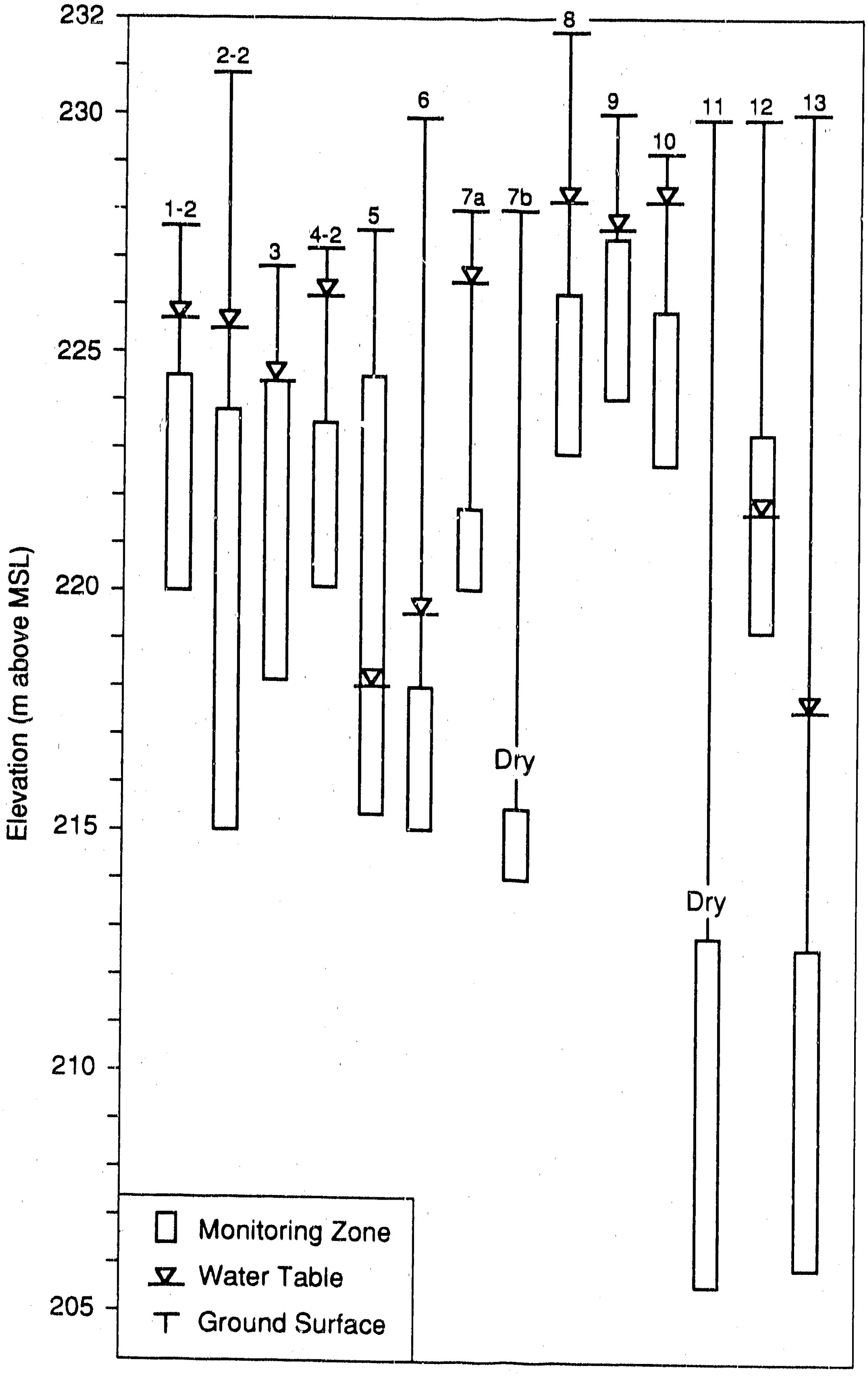


FIGURE 11 **Schematic Diagram of Well Point Elevations and Monitoring Intervals for All Monitoring Wells Completed in the Till at the 800 Area Landfill**

TABLE 2 Well Point and Water Elevations of Monitoring Wells Completed in the Till at the 800 Area Landfill, 1988-1989 (m above MSL)

Well	Ground Surface Elevation	Depth	Well Point Elevation	Quarterly Groundwater Elevations[a]			
				9/88	11/88	3/89	5/89
1-2	227.69	7.62	220.00	221.53	221.44	222.26	225.64
2-2	230.83	16.46	215.01	224.12	224.36	225.37	225.43
3	226.77	8.23	218.11	222.81	223.02	224.00	224.27
4-2	227.23	7.01	220.10	222.56	223.66	225.67	225.83
5	227.53	13.56	215.40	dry	dry	221.07	218.05
6	229.91	15.15	215.07	217.81	218.51	219.46	219.40
7a	227.81	7.62	220.22	223.75	224.88	227.05	226.47
7b	227.81	13.72	214.09	dry	dry	dry	dry
8	231.53	8.53	222.84	226.01	225.86	227.99	228.23
9	230.00	5.79	224.09	224.82	226.34	227.78	227.44
10	229.15	6.04	222.60	226.44	226.31	228.84	228.14
11	229.91[b]	24.42	205.49	c	c	c	c
12	229.91[b]	10.74	219.17	c	c	c	221.56
13	230.00[b]	24.20	205.80	c	c	c	217.44

[a] Water-equivalent precipitation for the 30-day periods prior to the measurements was 96.3 mL for 9/88, 110.2 mm for 11/85, 30.2 mm for 3/89, and 47.0 mm for 5/89. The 1988 values are from the meteorological station at O'Hare International Airport; the 1989 values are from the station at ANL.

[b] Wells 11 and 12 are estimated to have the same ground surface elevation as well 6; well 13 is estimated to have the same ground surface elevation as well 9.

[c] Not measured.

By using the APS site values for hydraulic conductivity, the horizontal groundwater velocity at the 800 Area landfill was estimated to range from 1.4×10^{-3} to 6.0×10^{-2} m/yr (1.4 to 6.0 cm/yr). For the calculation, the hydraulic gradient was assumed to range from 0.007 to 0.023 and the volumetric porosity (for clay) was assumed to be 50% (U.S. EPA 1989).

3.3.2 Vertical Flow

Although it is not possible to calculate the vertical gradient based on the available information, a plot of water levels against well depth indicates that there may be a significant component of downward groundwater flow. Nested wells are needed to quantify this downward component.

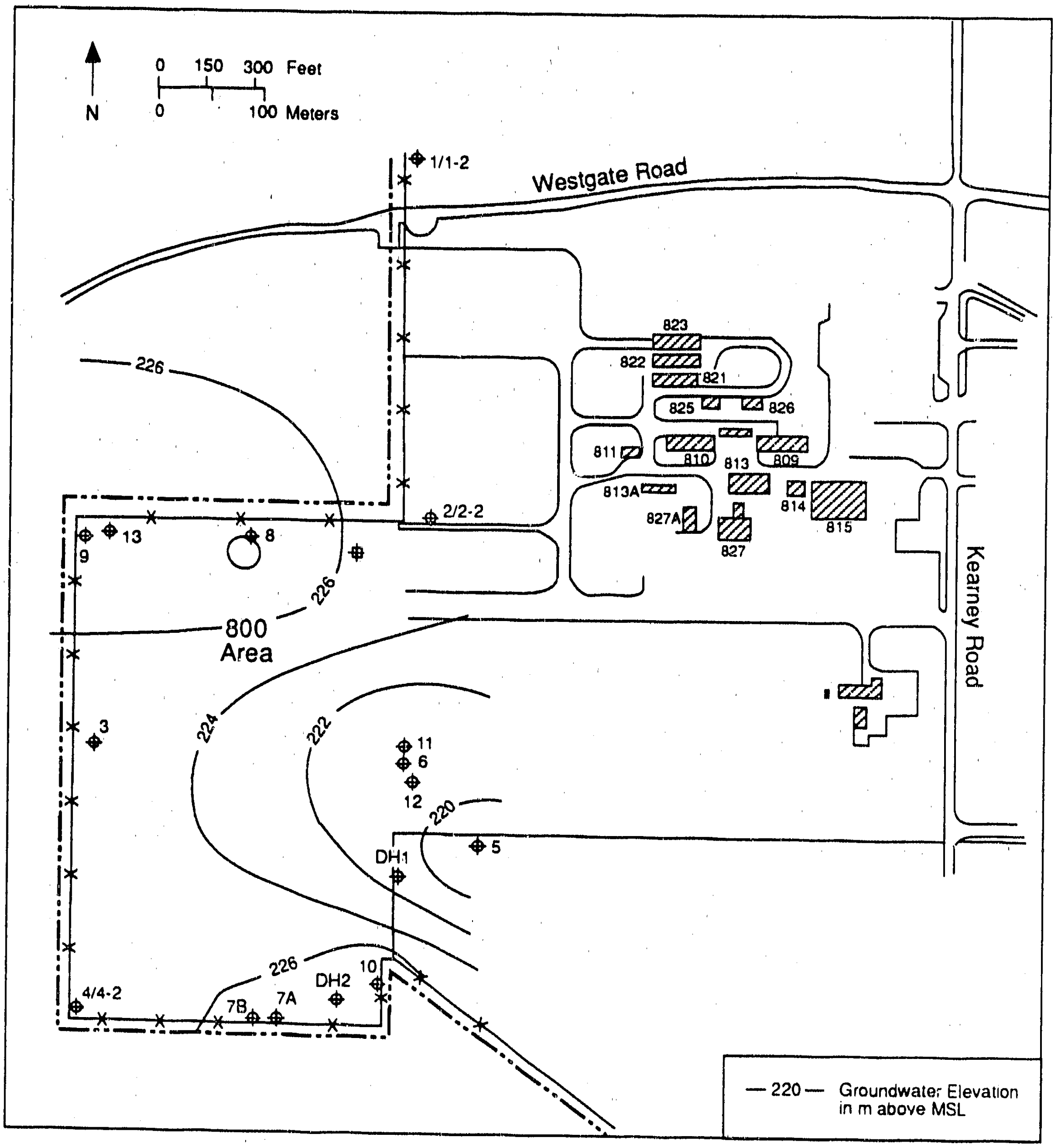


FIGURE 12 Groundwater Elevations at the 800 Area Landfill, May 1989

3.4 GROUNDWATER LEVEL FLUCTUATIONS

Hydrographs showing water level variations for all monitoring wells since 1980 are given in App. C. These figures indicate that the water levels in wells 1 through 4 have remained fairly stable over time. Replacement well 1-2 showed a decrease in water levels of about 3 m (10 ft) relative to well 1, which was suspected of being poorly sealed. Wells 5, 6, and 7a exhibited significant fluctuations that do not appear to be attributable simply to seasonal variation. The hydrographs indicate that the water levels for wells 8, 9, and 10, which were installed in 1984, are also fairly stable. The lowest water levels generally occurred in the third quarter of each year as a result of seasonal changes in precipitation (and evapotranspiration). Water levels did not decline significantly in response to the 1988 summer drought (relative to other summers).

3.5 GROUNDWATER QUALITY

ESH has conducted a groundwater monitoring program in the glacial till at the 800 Area since 1979 and has compiled the data in Annual Site Environmental Reports for ANL (e.g., Golchert and Duffy 1989). A summary of groundwater analyses for each monitoring well is given in App. D. When this report was prepared, no chemical data were available for the dolomite wells.

3.5.1 Inorganic Constituents

Levels of iron, manganese, and sulfates vary significantly with depth. Table 3 lists average chemical concentrations for wells classified by well point elevation into groups I, II, and III. (See Fig. 11 for well point elevations.)

Group I Wells

Group I includes wells 8, 9, and 10, with respective well point elevations of 222.84, 224.09, and 222.60 m. The variation of chemical levels with depth (in this case, a difference in depth of 1.5 m) is readily apparent when results for these three wells are compared. Wells 8 and 10, drilled to the same depths, have comparable concentrations of iron, manganese, sulfate, and barium (Table 3). Well 9, 125 m (410 ft) west of well 8, has average iron and manganese concentrations, which are much higher than concentrations in wells 8 and 10. Sulfate concentrations in wells 8 and 10 are 10 times those found in well 9.

Chloride concentrations are higher in wells 8 (79 mg/L) and 9 (108 mg/L) than in well 10 (5 mg/L) located near the southern boundary of the landfill. This is most likely because wells 8 and 9 are much closer to Westgate Road, which is salted in the winter.

Group II Wells

Group II consists of wells 1-2, 4-2, and 7a, with respective well point elevations of 220.00, 220.10, and 220.22 m. Average iron concentrations range from 1.47 mg/L (well 7a) to 7.20 mg/L (well 1-2). Manganese concentrations range from 0.084 mg/L (well 4) to 0.536 mg/L (well 1-2); sulfate ranges from 34 mg/L (well 4) to 178 mg/L (well 7a).

Significant variations in chloride concentrations have been detected: well 1-2, used as a control well, has chloride concentrations on the order of 20 times greater than most other wells. This is most likely due to its proximity to Westgate Road, which is salted in the winter. Thus, groundwater samples obtained from control well 1-2 are not truly representative of background conditions.

TABLE 3 Average Concentrations of Inorganic Analytes in Samples from Well Groups I, II, and III (mg/L)[a]

Group[b]	Well[a]	Iron	Manganese	Barium	Sulfate	Chloride
I	8	0.575	0.168	0.058	189	79
	9	52.8	2.76	0.367	11	108
	10	2.82	0.196	0.096	195	5
II	1-2	7.20	0.536	0.221	136	768
	4-2	2.50	0.084	0.449	34	2
	7a	1.47	0.297	0.091	178	29
III	2-2	1.18	0.459	1.23	81	16
	5	3.51	0.553	-	38	6
	6	16.0	1.77	0.123	65	234

[a] Results are averages of 1985-1988 sampling.

[b] Classification of Groups I, II, and III is based on the well point elevation for each monitoring well.

Group III Wells

Wells 2-2, 5, and 6 make up Group III, with respective well point elevations of 215.01, 215.40, and 215.07 m. Although these wells are drilled to similar depths, their chemistry is significantly different: average concentrations of iron, manganese, and chloride are much higher in well 6 than in wells 2-2 and 5. These differences may be attributed to a dilution effect; wells 2-2 and 5 monitor a zone about 9 m (30 ft) in length, while well 6 only monitors 3 m (10 ft) (see Fig. 11). Sulfate concentrations, however, do not appear to be diluted and range from 38 mg/L (well 5) to 81 mg/L (well 2-2).

3.5.2 Detected Contaminants

Groundwater samples collected from the till wells in 1988 were analyzed for metals and organic compounds on the U.S. EPA Target Compound List. Arsenic concentrations ranged from <5 μg/L in most wells to 86 μg/L in well 9. Lead levels varied between 6 μg/L (well 2-2) and 145 μg/L (well 9). Most organics were not detected. However, in 1988 well 6 contained trace levels of acetone and tetrahydrofuran* slightly above the detection limit of 30 μg/L. Trace levels of acetone were also

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*Tetrahydrofuran is a constituent of adhesives for PVC, which is used in well construction.

found in well 10 (Golchert and Duffy 1989). In 1987, samples were analyzed for volatile organics and polychlorinated biphenyls; none were detected (Golchert and Duffy 1988).

Tritium concentrations have been measured since October 1986. The highest levels were detected in well 9, which had a concentration of 1,048 pCi/L in January 1988, and in well 7a, which had a concentration of 1,070 pCi/L in November 1988. A summary of these analyses can be found in Golchert and Duffy (1989). Appendix D presents concentration ranges for chemical species detected in wells from 1985 to 1988.

3.5.3 Rate of Solute Transport

To estimate the transport rate for specific contaminants in groundwater, soil information such as bulk density, particle density, total organic content, and porosity must be known. Currently, this information is not available.

4 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

4.1 CONCLUSIONS

To date, the groundwater monitoring program conducted by ESH has yielded useful information on the direction of groundwater flow and contaminants in the groundwater. The next phase in assessing the hydrological conditions at the 800 Area landfill should answer questions regarding the physical characteristics (bulk density, particle density, organic content, porosity, and hydraulic conductivity) of the glacial till and dolomite bedrock. This information is needed to make reliable geologic cross sections across all portions of the site, to identify potential pathways for contaminant migration, and to estimate rates of groundwater movement (vertical and horizontal flow directions) and contaminant migration.

The review of the monitoring program reveals that there is little or no information on the groundwater levels or chemical quality of the dolomite aquifer beneath the site. It is very important to characterize the dolomite aquifer since it is a major drinking water source in DuPage County.

Wells installed before 1982 (1 through 5 [1979]; 6, 7a, and 7b [1980]) may not be reliable wells since they were constructed prior to the implementation of EPA well design and construction standards. The questionable quality of at least some of these wells is demonstrated by the detection in well 6 of tetrahydrofuran, a constituent of adhesive once used in PVC-cased wells. Well 7b has been dry since its emplacement. These wells should be decommissioned and sealed.

A study of the spatial variation of groundwater chemistry may be useful in identifying sources of organic contamination. Presently, the source of tritium is unknown.

Finally, a provision should be added to the current standard operating procedures manual to ensure that field personnel document all field activities and that thorough records are kept during the drilling of well bores and installation of wells (see Table 4).

4.2 RECOMMENDATIONS

4.2.1 Definition of Subsurface Geology

In order to identify potential pathways of contamination, it is necessary to more completely understand the subsurface geology beneath the landfill. Additional data needs are discussed in the following sections.

4.2.1.1 Soil Borings

Soil borings should be drilled at discrete locations near the French drain (Fig. 13). These will provide information about subsurface characteristics as well as data on the vertical extent of contamination near the drain.

TABLE 4 Information That Should Be Logged in the Field during the Drilling of Well Bores

---

General

Project name
Hole name/number
Date started/finished
Geologist's name
Driller's name
Sheet number (e.g., "2 of 3")
Hole location (map)
Ground surface elevation at hole
Rig type, bit/auger size
Petrologic/lithologic classification system used (e.g., Wentworth or unified soil)
Weather

Information Columns

Depth
Sample location/number
Blow counts and advance rate
Percentage of sample recovered
Narrative description
Depth to saturation

Narrative Description

Geologic observations

- Soil/rock type
- Color and staining
- Gross petrology
- Friability
- Moisture content
- Degree of weathering
- Presence of carbonate
- Fractures
- Solution cavities
- Bedding
- Discontinuities (foliation)
- Water-bearing zones
- Formational strike and dip
- Depositional structures
- Organic content
- Odor
- Suspected contaminant(s)
- Fossils

Drilling observations

- Loss of circulation
- Advance rates
- Rig chatter
- Water levels
- Air volume/pressure
- Drilling difficulties at different depths
- Changes in drilling methods or equipment
- Readings from detection equipment, if any
- Amount of water yield/ loss during drilling
- Amounts and types of any liquids used
- Running sands
- Caving/hole stability

Source: National Well Water Association 1986.

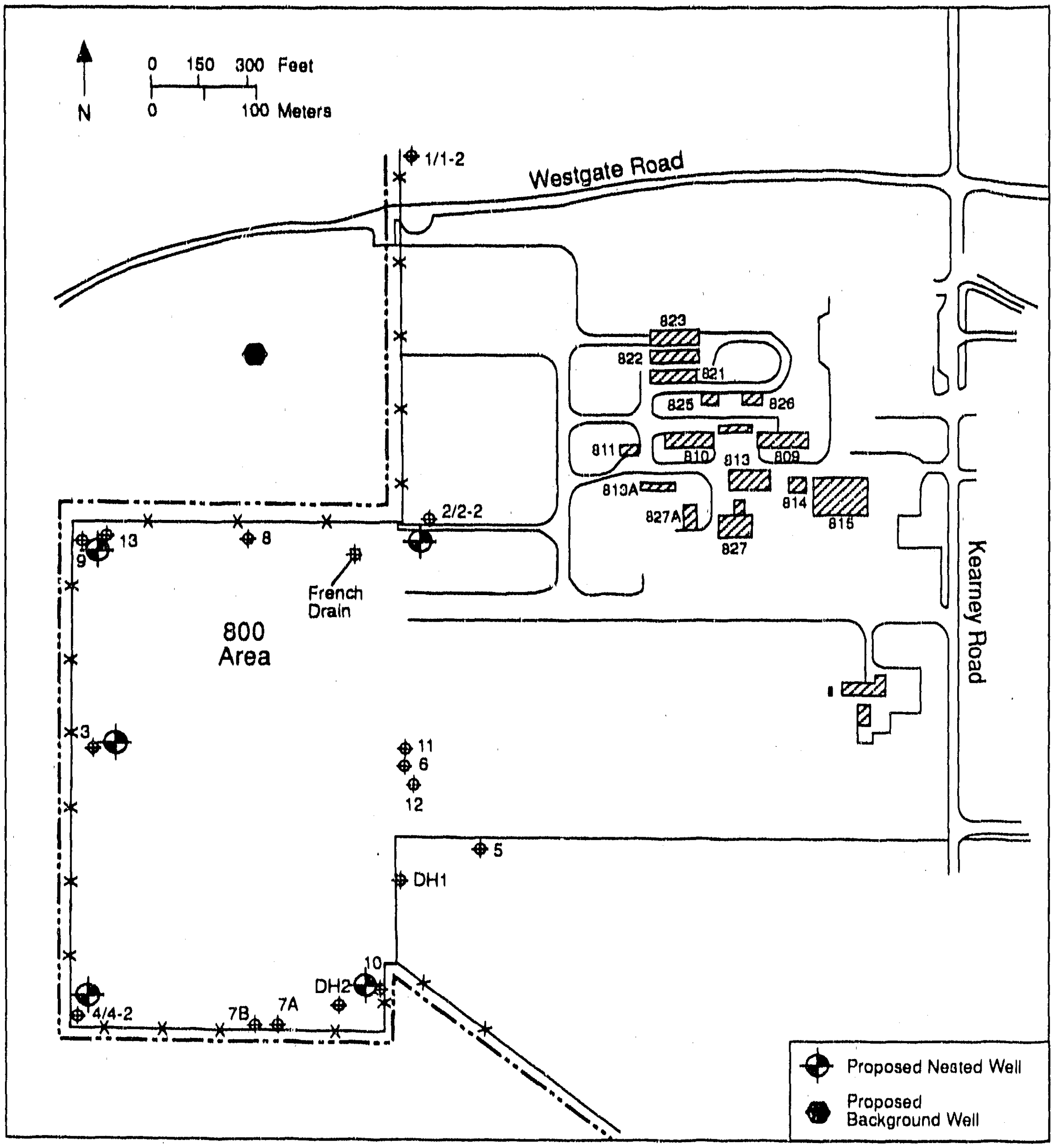

FIGURE 13 Locations of Proposed Monitoring Wells at the 800 Area Landfill

To define the lithologic conditions and all water-bearing zones, one or more borings should be drilled to the dolomite bedrock using a hollow-stem auger or an air rotary drill rig. To prevent cross contamination, continuous casing should be used during all drilling. Split-spoon samples should be taken during drilling and analyzed for all chemical parameters of interest (including soil characteristics and suspected contaminants) to develop a profile of chemical variation with depth.

For many of the existing wells, the boring logs lack the information needed to adequately depict significant subsurface characteristics, such as the precise depth of small- and large-scale permeable layers (sand and gravel lenses) and the depth at which water is first encountered. During the drilling of new wells in the 800 Area, continuous core samples should always be collected with a split-spoon sampler and recorded by a geologist in the field. Table 4 lists information that should be obtained during the drilling of well borings.

To reduce the number of potential contaminant pathways, the boreholes in which permanent wells are not constructed should be sealed with material at least 10 times less permeable than the surrounding media, in accordance with U.S. EPA and Illinois EPA guidelines.

4.2.1.2 Physical Laboratory Analyses

Laboratory analyses should be performed on soil samples to provide information on petrologic variation (i.e., grain size distribution, sorting, and cementation), moisture content, and hydraulic conductivity for the till. These data will provide a basis for correlating the stratigraphy of individual borings, identifying zones of potentially high hydraulic conductivity, and determining the continuity of petrologic characteristics. Soil characteristics -- bulk density, particle density, total organic content, and porosity -- should be measured to determine the potential for contaminant migration in the glacial till groundwater. Bulk density and porosity may be measured in situ using well logging techniques. Cementation, moisture content, and hydraulic conductivity values should be determined for the dolomite.

4.2.1.3 Field Measurements

A total of five monitoring well clusters should be installed on the perimeter of the 800 Area to more accurately define the vertical hydraulic gradient in each of the areas and to obtain discrete water samples from at least two depths in each location. Because little is known about the dolomite aquifer in this area, wells should also be drilled in the dolomite bedrock at these locations to monitor water levels and potential contaminants. At each location, wells should be placed in closely spaced but separate boreholes. Wells should not be located within the landfill, but rather on its perimeter.

Figure 13 shows the proposed locations of the nested wells. New wells may be coupled with existing wells 9, 4-2, and 10 to form well nests. However, new wells packed with gravel over shorter intervals may be preferable. Wells 6 and 12 may be considered nested wells. Once the depth and thickness of the permeable zone has been defined, other wells may be needed to complete the characterization. Since well 7b has been consistently dry, it should be decommissioned and sealed.

Hydraulic conductivity should be measured in the field by slug testing. This involves measuring water level changes after a solid teflon "slug" has been dropped into or removed from a well. A pressure transducer is placed into the well to sense changes in water level. Slug tests could be conducted in existing monitoring wells.

4.2.1.4 Topographic Mapping

The topography of the 800 Area landfill should be surveyed by a licensed surveyor. This survey should provide a map that shows elevation contours with 2-ft contour intervals, man-made features, well and boring locations, and any nearby water bodies. During this survey, the casing height of each monitoring well should be measured to an accuracy of 0.01 ft.

4.2.2 Monitoring Program

4.2.2.1 Groundwater Monitoring

To accurately define the shallow water table, new wells should be constructed in the first permeable water-bearing zone encountered during drilling. The bottom of the well should extend no more than 1.5 m (5 ft) below the water-bearing zone. To obtain useful, correlative data, it is important that water levels be measured for all wells within a 24-hour period (National Well Water Association 1986). For the monitoring of chemical species in the groundwater, it is desirable to sample discrete portions of a water-bearing formation. This can be accomplished by screening the well with screens 0.3-1.5 m (1-5 ft) long and extending the gravel pack no more than 0.3-0.6 m (1-2 ft) above the screen.

Because of the low hydraulic conductivity of the till in the 800 Area, the zone of contamination, if present, is likely to be shallow and no greater than a few feet thick. The U.S. EPA recommends limiting the screen length to 0.3-0.6 m (1-2 ft) in areas with low conductivity to minimize siltation problems as well as to eliminate possible dilution effects from water contributed by uncontaminated zones. The gravel pack should extend no more than a few feet above the screen. A quick sieve analysis in the field can be used to determine the correct screen and gravel-pack sizes to minimize siltation. Bentonite clay can then be extended from the gravel pack to within 0.6 m (2 ft) of the ground surface and a shrink-resistant, cement-grout seal extended to the ground surface. Appendixes E and F provide guidance on well design and construction.

Split-spoon samples should always be collected and logged by a geologist when a new well is drilled. Selected samples should be collected at specific intervals (depending on the well depth) and analyzed for suspected contaminants.

Most of the existing monitoring wells in the 800 Area are cased with PVC. The Illinois EPA (1987) recommends that stainless steel or teflon be used for the casing of wells used to monitor organic compounds (see App. E). Additionally, Illinois EPA (1987) regulations must be complied with to ensure that data collected from monitoring wells will be considered valid. Wells that do not conform to the state and federal protocols outlined in Apps. E and F, respectively, may be used during exploratory programs but not monitoring programs.

4.2.2.2 Background Monitoring

Figure 13 also shows the location of a proposed new control well north of the 800 Area landfill. Since the groundwater flow is predominantly to the south-southeast, this well should yield data representative of upgradient (background) conditions. Since this area is located off site, it will be necessary to obtain permission to drill this well. Under U.S. EPA regulations [40 CFR 265.92(a)(1)], upgradient wells must be located and constructed in the same portion of the aquifer that is being monitored by downgradient wells. Therefore, background wells should be completed in both the glacial till and dolomite bedrock. Since the direction of groundwater flow in the dolomite has not yet been established, it is recommended that the dolomite background well be installed after the monitoring wells are installed in the dolomite and water levels have been measured. Water levels from all wells should be monitored after new wells are installed prior to installing the background well to confirm that the proposed location is truly upgradient. It is recommended that use of well 1-2 as a control well be discontinued because it receives contamination from activities (salting and oiling) associated with Westgate Road.

4.2.2.3 Vadose Zone Monitoring

To characterize the areal extent of VOC contamination in the vadose (unsaturated) zone at the 800 Area, discrete soil and soil-gas samples should be taken at 5-ft intervals radiating away from the French drain (Fig. 13). Soil can be sampled directly using the core sampling method described in Dunlap et al. (1977). A soil gas survey can be conducted using gas probes that pump soil gas through an activated charcoal trap; gas is later desorbed from the trap for analysis by gas chromatography. Gas monitoring wells completed in the vadose zone can detect VOC vapors migrating from the landfill. These wells should be placed along the perimeter of the landfill, not within its boundaries.

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APPENDIX A:

AVAILABLE WELL INSTALLATION DIAGRAMS, DRILLERS' LOGS, AND GEOLOGISTS' LOGS FOR BORINGS IN THE 800 AREA

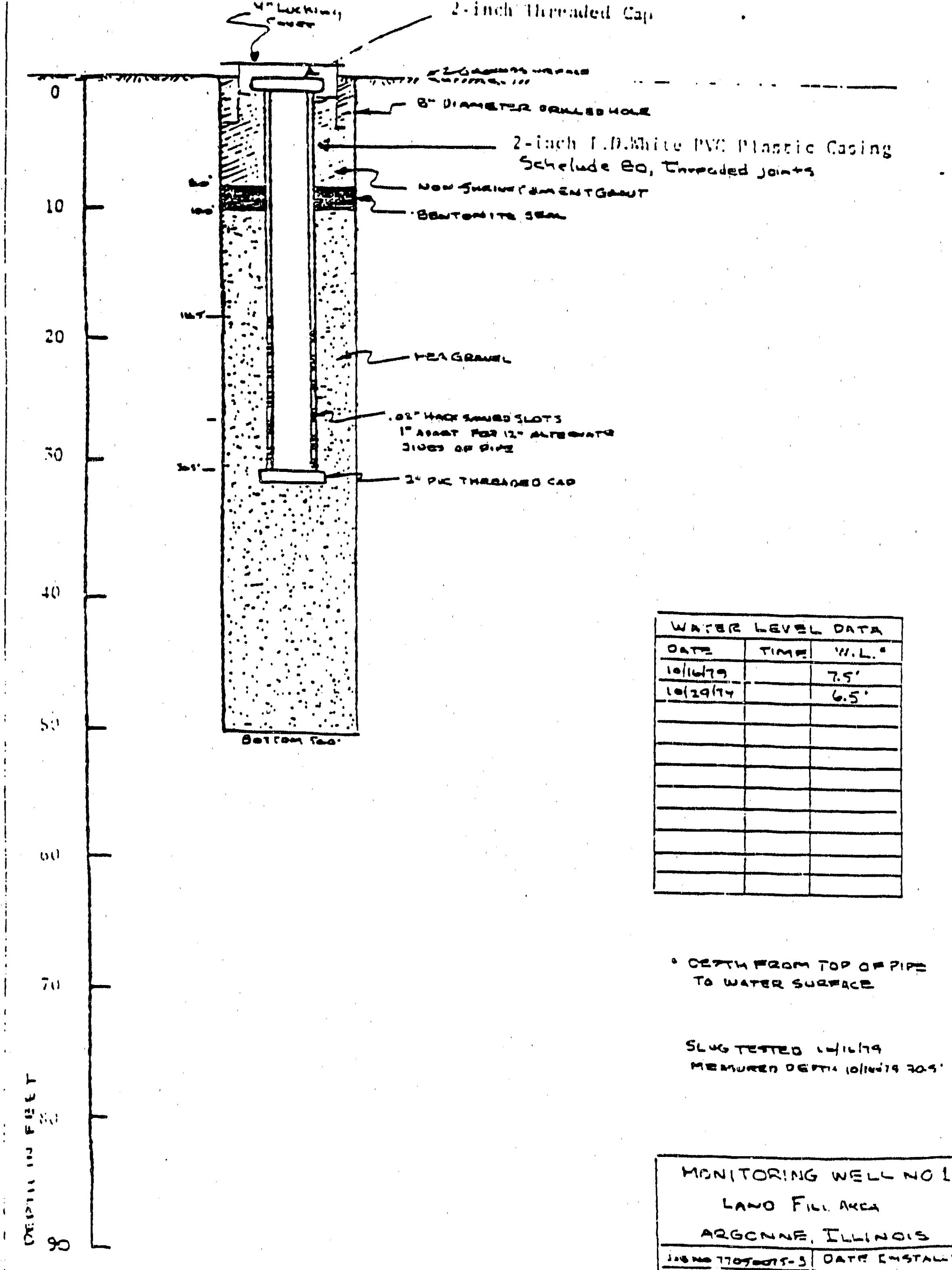
This appendix presents all available records for monitoring wells and boreholes drilled in the 800 Area. These records provided the basis for the analysis of the subsurface geology at the area. Table A.1 lists the contents of this appendix. All well and borehole records were provided by ESH.

TABLE A.1 Boring Diagrams and Logs Presented in Appendix A

Well	Geologist[a]	Item	Page
1	Unknown	Installation diagram	37
		Boring log	38
2	Unknown	Installation diagram	39
		Boring log	40
3	Unknown	Installation diagram	41
		Boring log	42
4	Unknown	Installation diagram	43
		Boring log	44
1-2[b]	R. Pearl, ANL	Installation diagram	45
		Completion record	48
2-2[b]	R. Pearl, ANL	Installation diagram	46
		Completion record	48
4-2[b]	R. Pearl, ANL	Installation diagram	47
		Completion record	48
5	Unknown	Installation diagram	49
		Boring log	50
6	Unknown	Installation diagram	51
		Core log	52
7a	Unknown	Installation diagram	53
		Core log	54
7b	Unknown	Installation diagram	53
		Core log	55
8	R. Pearl, ANL	Installation diagram	56
		Completion record	58
9	R. Pearl, ANL	Installation diagram	57
		Completion record	58
10	R. Pearl, ANL	Installation diagram	59
		Core log	60
11	M. Hampton, DOE	Installation diagram	61
		Subsurface exploration record	62-63
12	M. Hampton, DOE	Installation diagram	64
13	M. Hampton, DOE	Installation diagram	65
		Subsurface exploration record	66-67
DH-1	unknown	Completion record and core log	68
DH-2	unknown	Completion record and core log	68

[a] M. Hampton is affiliated with the U.S. Department of Energy, Environmental Survey Team, and R. Pearl, currently affiliated with Eder and Associates, was affiliated with ANL's Environmental Assessment and Information Sciences Division.

[b] Replacement wells.



WATER LEVEL DATA

DATE	TIME	W.L.*
10/16/79		7.5'
10/29/79		6.5'

* DEPTH FROM TOP OF PIPE
TO WATER SURFACE

SLUG TESTED 10/16/79
MEASURED DEPTH 10/16/79 30.5'

MONITORING WELL NO 1
LAND FILL AREA
ARGONNE, ILLINOIS

JOB NO 77050075-3	DATE INSTALLED
CK. BY RJF	10/16/79

Walter H. Flood & Co., Inc.
ENGINEERS
4421 HARRISON STREET
HILLSIDE, ILLINOIS 60162
7509 S. WESTNEDGE AVENUE
PORTAGE, MICHIGAN 49081

SOIL BORING LOG NO. 1

FOR: Argonne National Laboratory

PROJECT: Land Fill Monitoring Well

LOCATION: Argonne, Illinois

METHOD OF BORING HS	WATER LEVEL READINGS	DRILLING DATA	BACKFILLING DATA
S.S. O.D. 2" 140# HAMMER 30" DROP	4.5', 24.5' W.D.	DATE 10/19/79	DATE
SHELBY TUBE SIZE	11.0' B.C.R.	FOREMAN CE	BY
CASING SIZE 50'-3 3/4" IDHS	9.0' A.C.R.	CREW NO. 3	METHOD
CORE SIZE	7.5' @ 2.5 HRS. A.D.	JOB NO. 79050173-3	GROUT
	HRS. A.D.	VERT. SCALE 1"=10'	QUANTITY

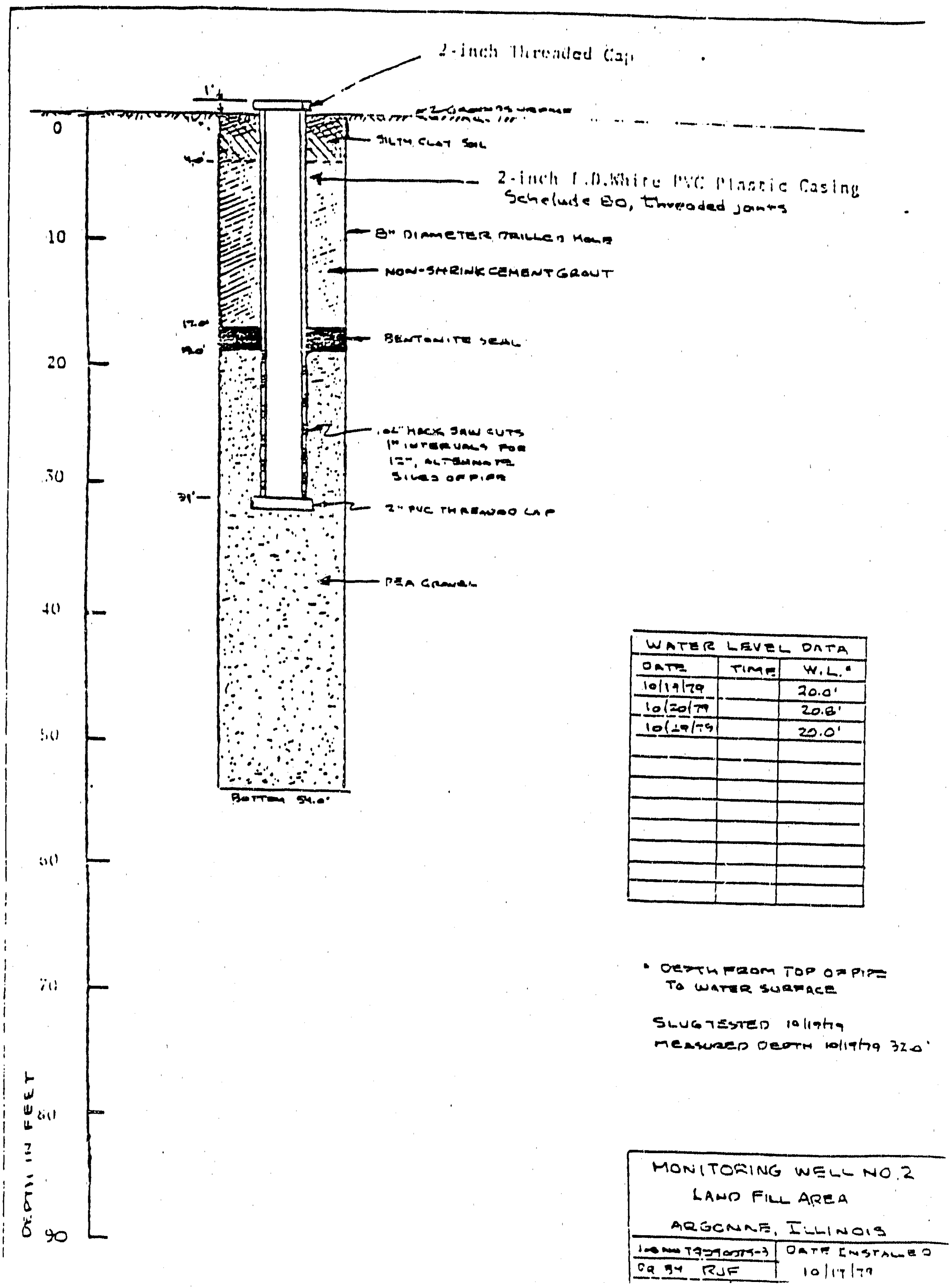
DEPTH	S	T	N	L R	DD	DESCRIPTION
0.0						Ground Surface (grass)
	1	SS	10			Black Silty clay
4.5	2	SS	24			
						Brown and black clayey silt, trace of small to medium gravel, very tough
9.5	3	SS	24			Brown sand and clay
12.5						Gray silty clay, trace of small gravel, occasional boulder, very tough to hard
	4	SS	38			
	5	SS	36			
	6	SS	[illegible]			
	7	SS	31			
	8	SS	25			
	9	SS	30			
	10	SS	39			
50.0	11	SS	44			End of Boring

Note: 2" PVC monitoring well installed this bore hole. See Well Installation Data

QU ● LABORATORY X 1000 PSF 2 4 6 8 10 O PENETROMETER

10 20 30 40 50 WC ▲ NATURAL %

LEGEND:
A—AUGER
ACR—AFTER CASING REMOVAL
AD—AFTER DRILLING
BCR—BEFORE CASING REMOVAL
C—CORE
DCI—DRY CAVE IN
DD—DRY DENSITY, LB. PER CU. FT
DEPTH—FEET BELOW GROUND SURFACE
FT—FISHTAIL
HA—HAND AUGER
HS—HOLLOW STEM AUGER
L—SAMPLE LENGTH
N—PENETRATION, BLOWS PER FT.
QU—UNCON. COMP. STRENGTH LBS. PER SQ. FT.
R—LENGTH OF SAMP. RECOVERED
S—SAMPLE NUMBER
SS—SPLIT SPOON
ST—SHELBY TUBE
T—TYPE OF SAMPLE
WC—WATER CONTENT %
WCI—WET CAVE IN
WD—WHILE DRILLING
WO—WASHOUT



WATER LEVEL DATA

DATE	TIME	W.L.*
10/19/79		20.0'
10/20/79		20.8'
10/29/79		20.0'

* DEPTH FROM TOP OF PIPE TO WATER SURFACE

SLUG TESTED 10/19/79
MEASURED DEPTH 10/19/79 32.0'

MONITORING WELL NO. 2
LAND FILL AREA
ARGONNE, ILLINOIS

[illegible] T979037-3	DATE INSTALLED
DR BY RJF	10/17/79

Walter H. Flood & Co., Inc.
ENGINEERS
4421 HARRISON STREET
HILLSIDE, ILLINOIS 60162
7509 S. WESTNEDGE AVENUE
PORTAGE, MICHIGAN 49081

SOIL BORING LOG NO. 2

FOR: Argonne National Laboratory

PROJECT: Land Fill Monitoring Wells

LOCATION: Argonne, Illinois

METHOD OF BORING HS
S.S. O.D. 2" 140# HAMMER 30" DROP
SHELBY TUBE SIZE
CASING SIZE 55'-3 3/4" IDHS
CORE SIZE

WATER LEVEL READINGS
30.5 W.D.
51' B.C.R.
51' A.C.R.
48.0' @1.5 HRS. A.D.
HRS. A.D.

DRILLING DATA
DATE 10/17/79
FOREMAN CE
CREW NO. 3
JOB NO. 79050173-3
VERT. SCALE 1"=10'

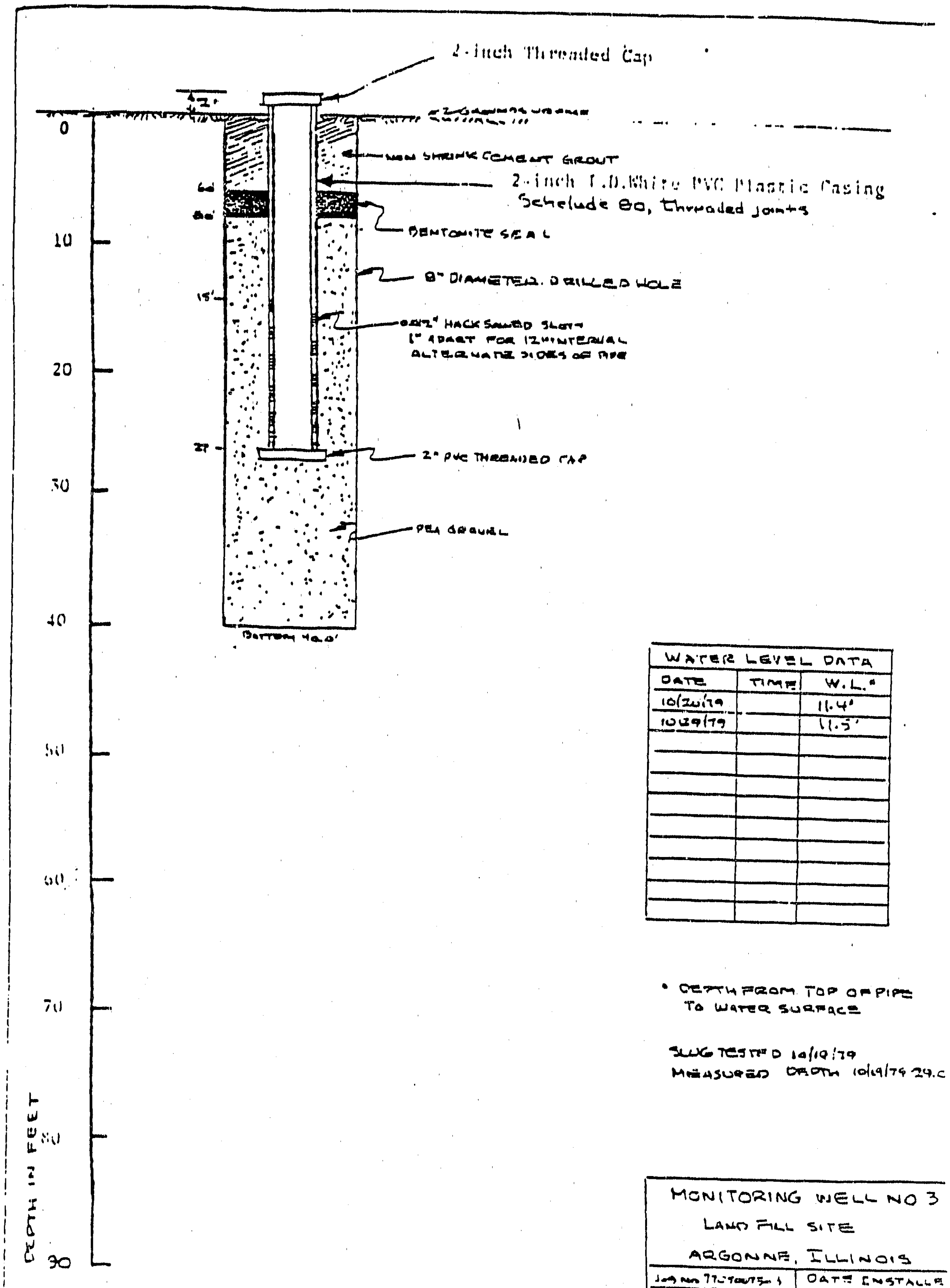
BACKFILLING DATA
DATE
BY
METHOD
GROUT
QUANTITY

QU ● LABORATORY X 1000 PSF 2 4 6 8 10 O PENETROMETER

DEPTH	S	T	N	L R	DD	DESCRIPTION
0.0						Ground Surface (grass)
	1	SS	22			Black and brown silty clay
4.0	2	SS	27			
						Brown and gray silty clay, very tough
10.0	3	SS	36			
						Black silt loam, trace of small gravel
12.0						Gray silty clay, trace of small to medium gravel, very tough to hard
	4	SS	26			
	5	SS	33			
	6	SS	39			
	7	SS	41			
	8	SS	59			
	9	SS	84			
	10	SS	49			
	11	SS	[illegible]			
	12	SS	79			
54.0						End of Boring Note: 2" PVC Monitorinc Well installed this bore hole, see Well Installation Data
DEPTH	S	T	N	L R	DD	DESCRIPTION

10 20 30 40 50
WC ▲ NATURAL %

LEGEND:
A—AUGER
ACR—AFTER CASING REMOVAL
AD—AFTER DRILLING
BCR—BEFORE CASING REMOVAL
C—CORE
DCI—DRY CAVE IN
DD—DRY DENSITY, LB. PER CU. FT.
DEPTH—FEET BELOW GROUND SURFACE
FT—FISHTAIL
HA—HAND AUGER
HS—HOLLOW STEM AUGER
L—SAMPLE LENGTH
N—PENETRATION, BLOWS PER FT.
QU—UNCON. COMP. STRENGTH LBS. PER SQ. FT.
R—LENGTH OF SAMP. RECOVERED
S—SAMPLE NUMBER
SS—SPLIT SPOON
ST—SHELBY TUBE
T—TYPE OF SAMPLE
WC—WATER CONTENT %
WCI—WET CAVE IN
WD—WHILE DRILLING



WATER LEVEL DATA		
DATE	TIME	W.L.*
10/26/79		11.4'
10/29/79		11.5'

* DEPTH FROM TOP OF PIPE TO WATER SURFACE

SLUG TESTED 10/19/79
MEASURED DEPTH 10/19/79 29.c

MONITORING WELL NO 3
LAND FILL SITE
ARGONNE, ILLINOIS

JOB NO 77-[illegible]	DATE INSTALLE
[illegible]	[illegible]

Walter H. Flood & Co., Inc.
ENGINEERS
4421 HARRISON STREET
HILLSIDE, ILLINOIS 60162
7509 S. WESTNEDGE AVENUE
PORTAGE, MICHIGAN 49081

SOIL BORING LOG NO. 3

FOR: Argonne National Laboratory

PROJECT: Land Fill Monitoring Well

LOCATION: Argonne, Illinois

METHOD OF BORING HS
S.S. O.D. 2" 140# HAMMER 30" DROP
SHELBY TUBE SIZE
CASING SIZE 40'-3 3/4" IDHS
CORE SIZE

WATER LEVEL READINGS	
14.5',23.0'	W.D.
38.0'	B.C.R.
15.0'	A.C.R.
15.0'@24	HRS. A.D.
	HRS. A.D.

DRILLING DATA
DATE 10/18/79
FOREMAN CE
CREW NO. 3
JOB NO. 79050173-3
VERT. SCALE 1"=10'

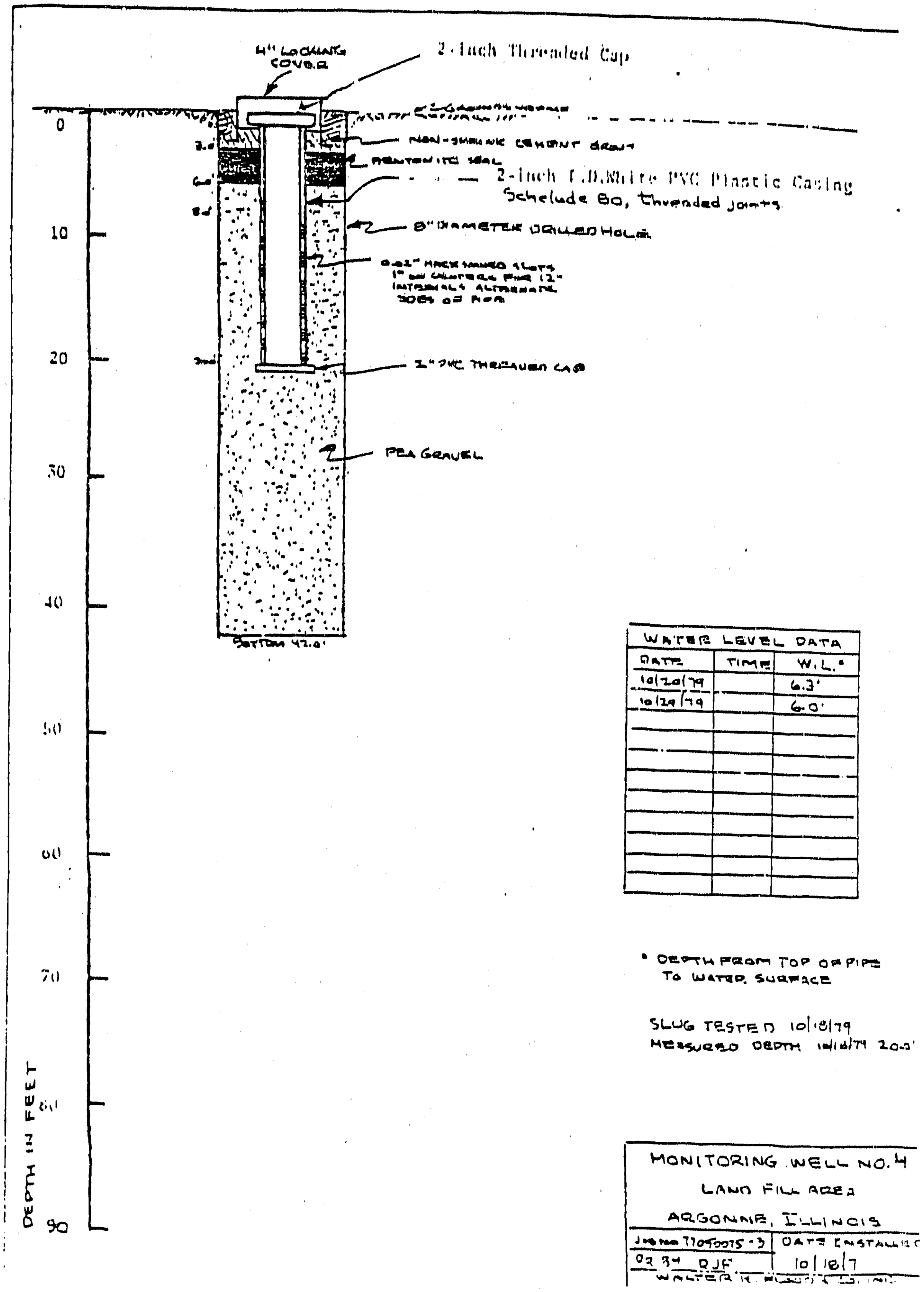
BACKFILLING DATA
DATE
BY
METHOD
GROUT
QUANTITY

DEPTH	S	T	N	LR	DO	DESCRIPTION
0.0						Ground Surface
	1	SS	26			Black silty clay
4.5	2	SS	11			
						Brown to gray silty clay, tough
3.0						
	3	SS	16			Gray silty clay, trace of small to medium gravel, very tough to hard
	4	SS	33			
	5	SS	45			
	6	SS	17			
	7	SS	24			
	8	SS	22			
	9	SS	20			
40.0	10	SS	32			
						End of Boring
						Note: 2" PVC Monitoring Well installed this bore hole, see Well Installation Data

QU ⊗ LABORATORY X 1000 PSF O PENETROMETER
2 4 6 8 10

10 20 30 40 50
WC ▲ NATURAL %

LEGEND:
A—AUGER
ACR—AFTER CASING REMOVAL
AD—AFTER DRILLING
BCR—BEFORE CASING REMOVAL
C—CORE
DCI—DRY CAVE IN
DD—DRY DENSITY, LB. PER CU. FT
DEPTH—FEET BELOW GROUND SURFACE
FT—FISHTAIL
HA—HAND AUGER
HS—HOLLOW STEM AUGER
L—SAMPLE LENGTH
N—PENETRATION, BLOWS PER FT.
QU—UNCON. COMP. STRENGTH LBS. PER SQ. FT.
R—LENGTH OF SAMP. RECOVERED
S—SAMPLE NUMBER
SS—SPLIT SPOON
ST—SHELBY TUBE
T—TYPE OF SAMPLE
WC—WATER CONTENT %
WCI—WET CAVE IN
WD—WHILE DRILLING
WO—WASHOUT



WATER LEVEL DATA		
DATE	TIME	W.L.*
10/20/79		6.3'
10/29/79		6.0'

* DEPTH FROM TOP OF PIPE TO WATER SURFACE

SLUG TESTED 10/18/79
MEASURED DEPTH 10/18/79 20.0'

MONITORING WELL NO. 4
LAND FILL AREA
ARGONNE, ILLINOIS

JOB NO. 7105015-3	DATE INSTALLE
02 34 RJF	10/18/7

WALTER H. FLOOD & CO. INC.

Walter H. Flood & Co., Inc.
ENGINEERS
4421 HARRISON STREET
HILLSIDE, ILLINOIS 60162
7509 S. WESTNEDGE AVENUE
PORTAGE, MICHIGAN 49081

SOIL BORING LOG NO. 4

FOR: Argonne National Laboratory

PROJECT: Land Fill Monitoring Well

LOCATION: Argonne, Illinois

METHOD OF BORING HS
S.S. O.D. 2" 140# HAMMER 30" DROP
SHELBY TUBE SIZE
CASING SIZE 45' - 3 3/4" IDHS
CORE SIZE

WATER LEVEL READINGS
9.5 ' W.D.
34 ' B.C.R.
36 ' A.C.R.
11:30 11 ' HRS. A.D.
11.0'@ 21 HRS. A.D.

DRILLING DATA
DATE 10/18/79
FOREMAN CE
CREW NO. 3
JOB NO. 79050173-3
VERT. SCALE 1"=10'

BACKFILLING DATA
DATE
BY
METHOD
GROUT
QUANTITY

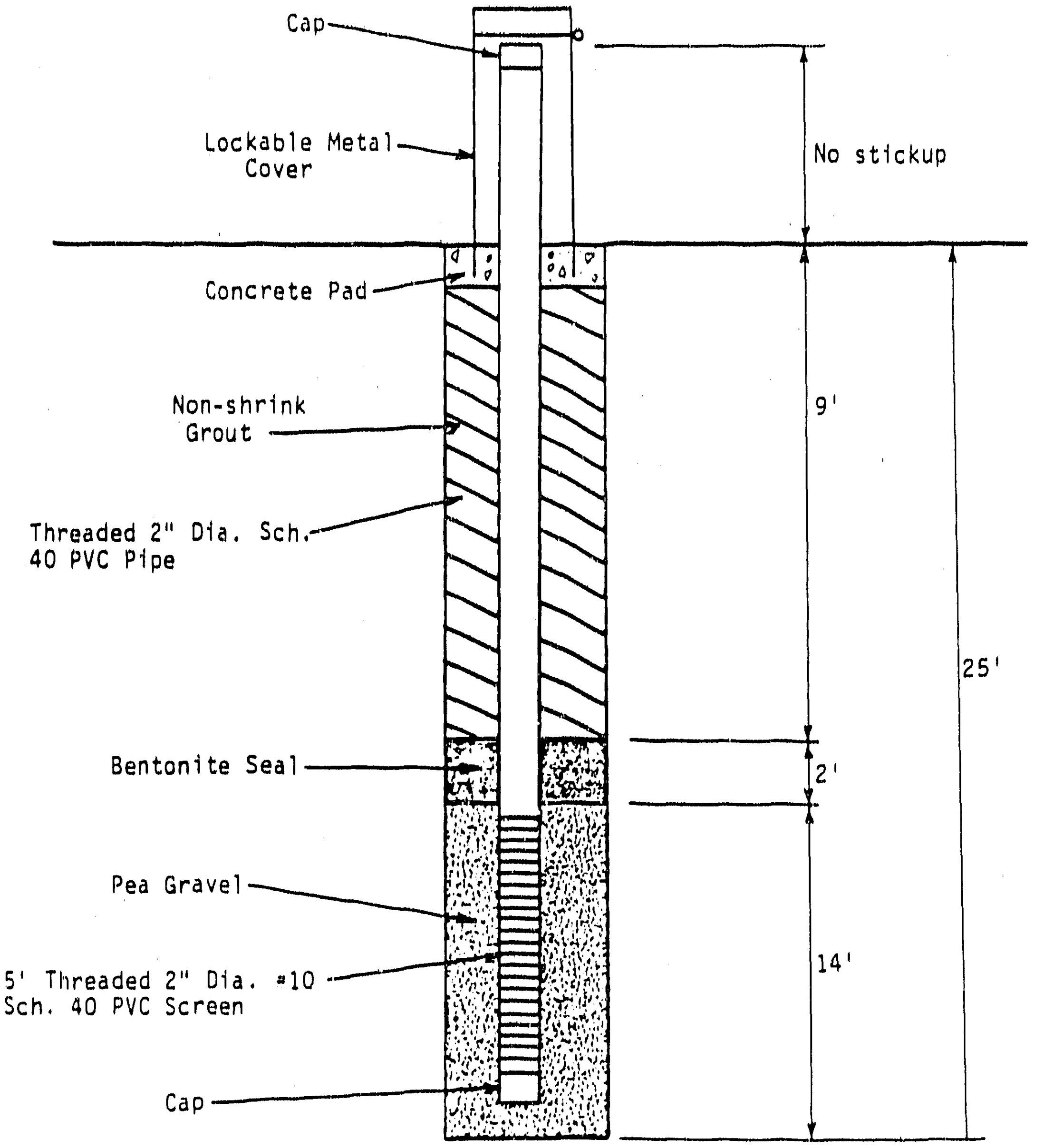
DEPTH	S	T	N	L R	DD	DESCRIPTION
						Ground surface (grass)
0.0	1	SS	9			Black Clay loam
3.5	2	SS	10			Brown to black silty clay, tough
9.5	3	SS	16			Gray silty clay, trace of small gravel, very tough
	4	SS	11			
	5	SS	21			
	6	SS	23			
	7	SS	27			
33.5	8	SS	31			Gray silty clay, trace of pink fine sand, very tough
42.0	9	SS	22			End of Boring
						Note: 2" PVC Monitoring Well installed this bore hole, see Well Installation Data
DEPTH	S	T	N	L R	DD	DESCRIPTION

QU ● LABORATORY X 1000 PSF 2 4 6 8 10 ○ PENETROMETER

10 20 30 40 50
WC ▲ NATURAL %

LEGEND:
A—AUGER
ACR—AFTER CASING REMOVAL
AD—AFTER DRILLING
BCR—BEFORE CASING REMOVAL
C—CORE
DCI—DRY CAVE IN
DD—DRY DENSITY, LB. PER CU. FT.
DEPTH—FEET BELOW GROUND SURFACE
FT—FISHTAIL
HA—HAND AUGER
HS—HOLLOW STEM AUGER
L—SAMPLE LENGTH
N—PENETRATION, BLOWS PER FT.
QU—UNCON. COMP. STRENGTH LBS. PER SQ. FT.
R—LENGTH OF SAMP. RECOVERED
S—SAMPLE NUMBER
SS—SPLIT SPOON
ST—SHELBY TUBE
T—TYPE OF SAMPLE
WC—WATER CONTENT %
WCI—WET CAVE IN
WD—WHILE DRILLING

Professional Service Industries



PROJECT NAME

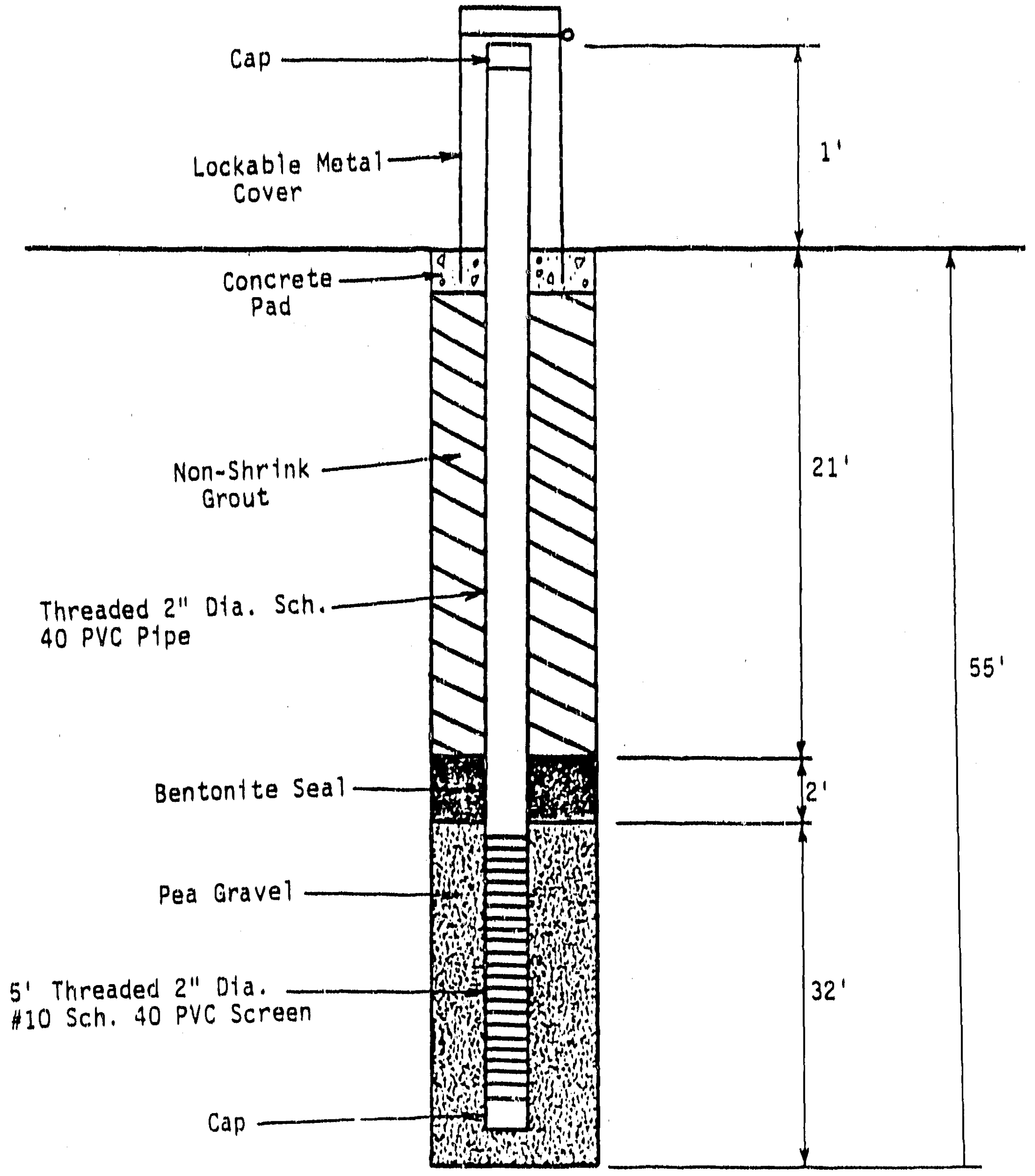
Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

REPLACEMENT WELL #1 DETAIL

PROJECT NO
152-65138

DATE
September 10, 1986

Professional Service Industries



PROJECT NAME

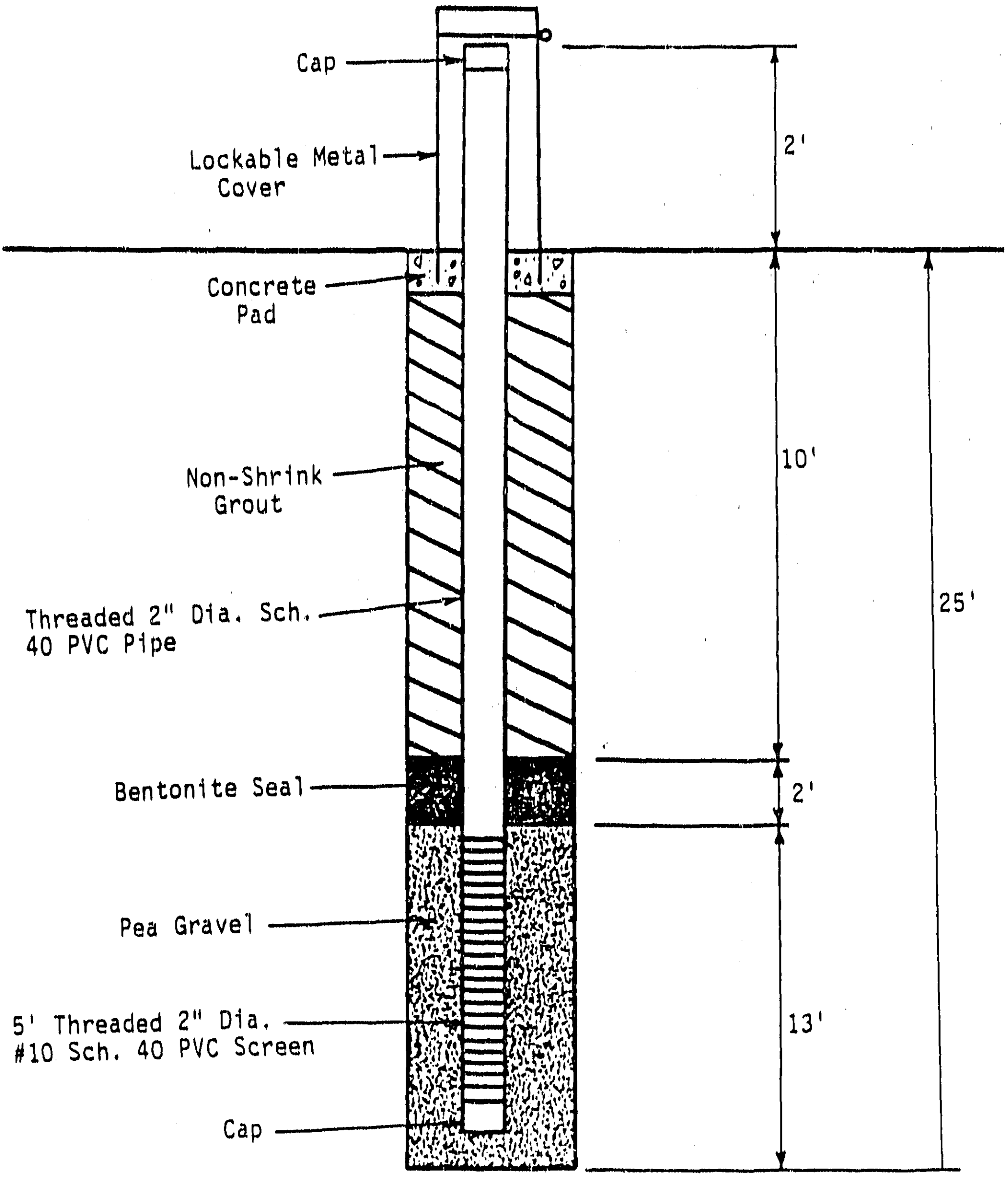
Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

REPLACEMENT WELL #2 DETAIL

PROJECT NO
152-65138

DATE
September 12, 1986

Professional Service Industries



PROJECT NAME

Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

REPLACEMENT WELL #4 DETAIL

PROJECT NO
152-65138

DATE
September 18, 1986

REPLACEMENT WELL NO. 1 (WEST GATE)

Location: By west gate, approx. 5 ft. north of original well No. 1
Date Drilled: Sept. 10, 1986
Total Depth: 25 ft.
Water level while drilling: 13 ft.
10/8/86: 20.64 ft. below land surface
Completion: Schedule 40 PVC blank casing and screen

0 - 20 ft. blank casing	0 - 11 ft. grout
20 - 25 ft screen	11 - 13 ft. bentonite
	13 - 25 ft. pea gravel

Geologist: R. H. Pearl, ANL

REPLACEMENT WELL NO. 2 (800 Area)

Location: Approx. 4 ft. north of original well no. 2 at east gate to sanitary landfill, 800 area
Date Drilled: Sept. 12, 1986
Total Depth: 55 ft.
Water level while drilling: 28.5 ft. approx.
10/8/86: 16.51 ft. below land surface
Completion: Schedule 40 PVC blank casing and screen

0 - 50 ft. blank casing	0 - 24 ft. grout
50 - 55 ft screen	24 - 26 ft. bentonite
	26 - 55 ft. pea gravel

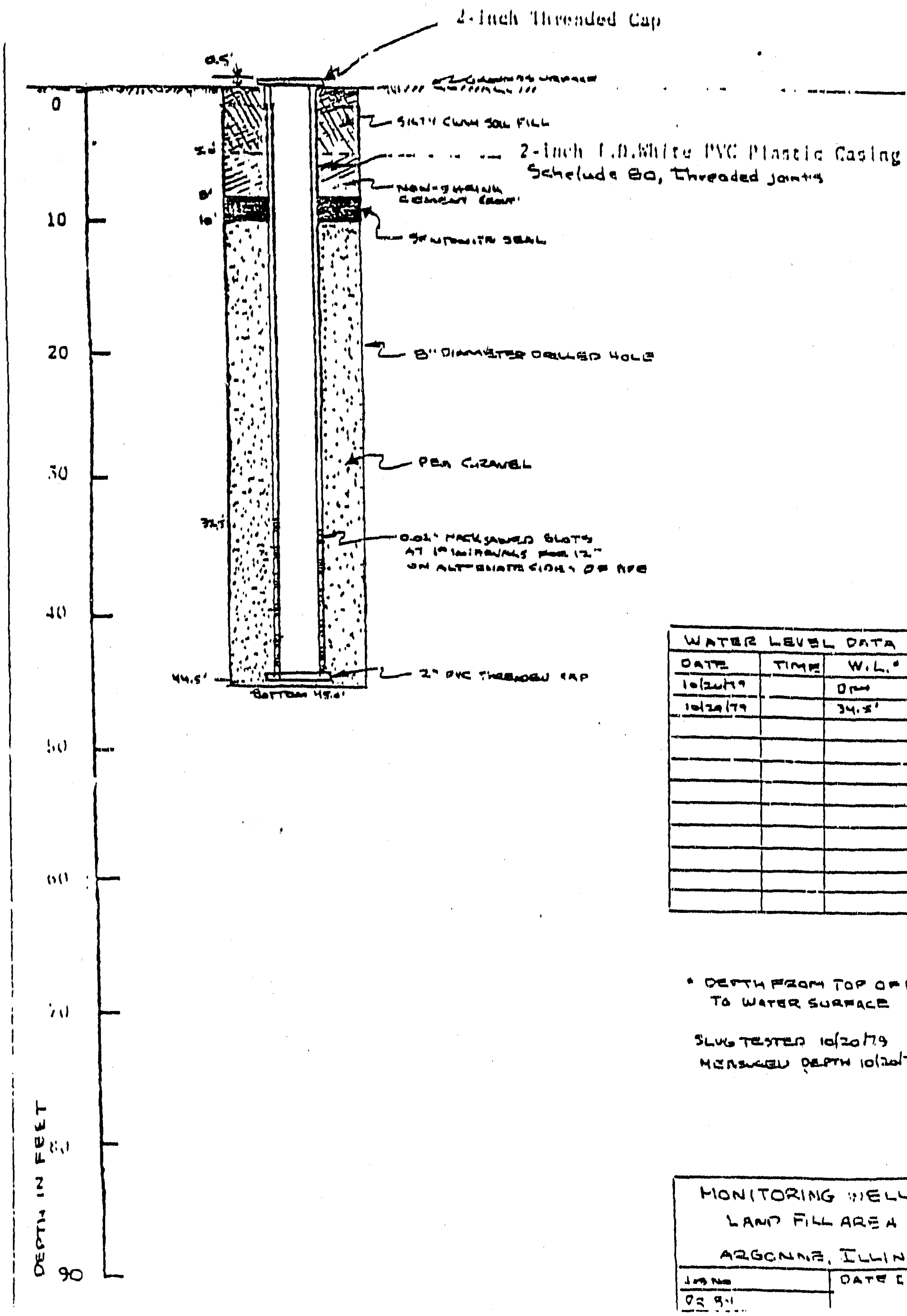
Old casing: Attempted to pull, broke at first joint. Rest of hole filled in with grout.
Remarks: There was some question whether or not ground water was encountered at 28 ft. The auger cuttings never became real wet. Reason for great depth.
Geologist: R. H. Pearl, ANL

REPLACEMENT WELL NO. 4 (800 Area)

Location: Approx. 3 ft north, northwest of original well no. 4, southwest corner of sanitary landfill, 800 area.
Date Drilled: Sept. 18, 1986
Total Depth: 25 ft.
Water level while drilling: 9 ft.? Never any real water like other holes.
10/8/86: 17.79 ft. below land surface
Completion: Schedule 40 PVC blank casing and screen

0 - 20 ft blank casing	0 - 7 ft. grout
20 - 25 ft screen	7 - 9 ft bentonite
	9 - 25 ft. pea gravel

Old casing: Pulled and hole filled with grout.
Geologist: R. H. Pearl, ANL



WATER LEVEL DATA

DATE	TIME	W.L.*
10/20/79		Dry
10/29/79		34.5'

* DEPTH FROM TOP OF PIPE TO WATER SURFACE

SLUG TESTED 10/20/79
MEASURED DEPTH 10/20/79 45.0'

MONITORING WELL NO. 5
LAND FILL AREA

ARGONNE, ILLINOIS

JOB No.	DATE INSTALLED
03 94	

Walter H. Flood & Co., Inc.
ENGINEERS
4421 HARRISON STREET
HILLSIDE, ILLINOIS 60162
7509 S. WESTNEDGE AVENUE
PORTAGE, MICHIGAN 49081

SOIL BORING LOG NO. 5

FOR: Argonne National Laboratory

PROJECT: Land Fill Monitoring Well

LOCATION: Argonne, Illinois

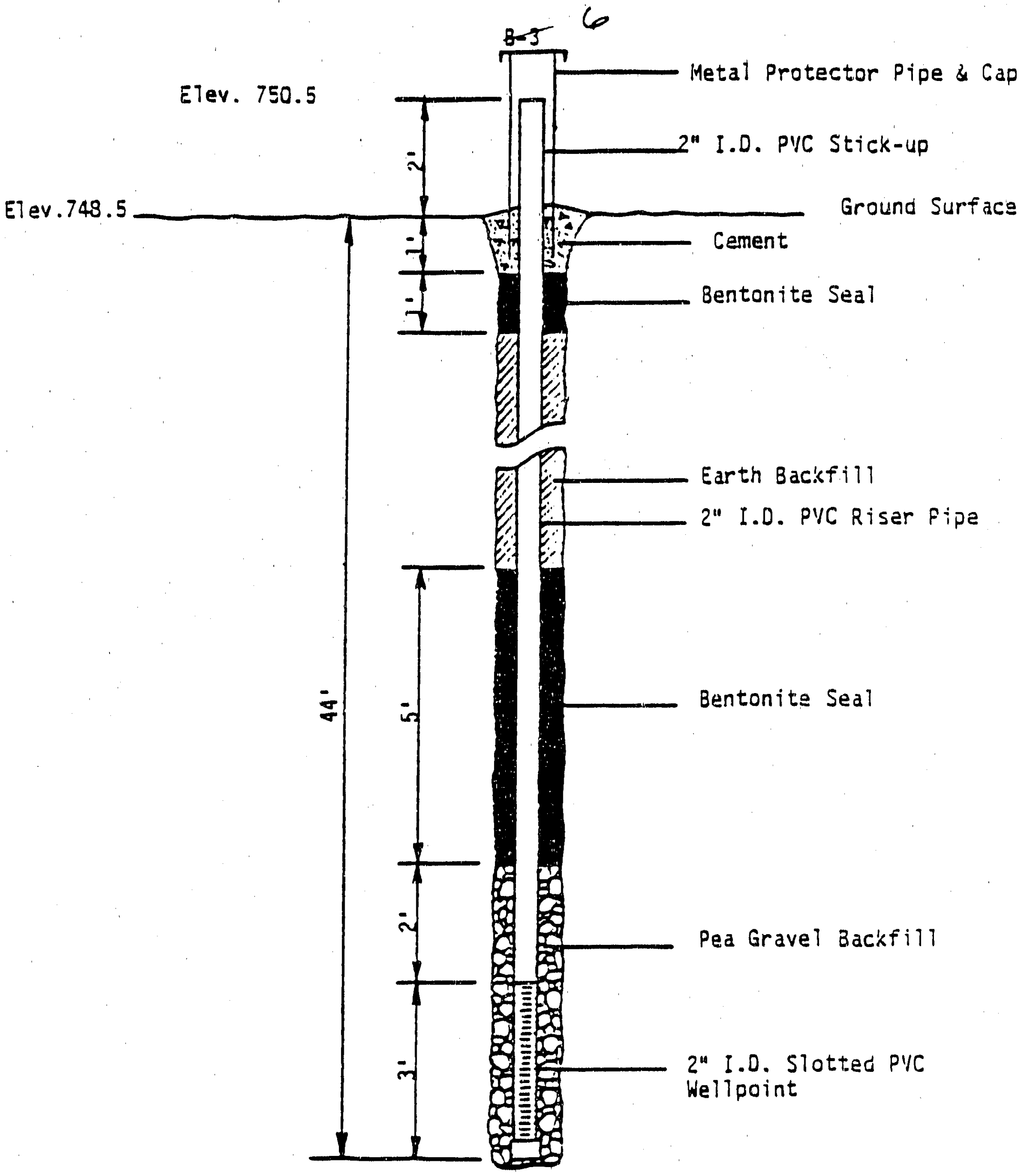
METHOD OF BORING HS	WATER LEVEL READINGS	DRILLING DATA	BACKFILLING DATA
S.S. O.D. 2" 140# HAMMER 30" DROP	Dry W.D.	DATE 10/19/79	DATE
SHELBY TUBE SIZE	Dry B.C.R.	FOREMAN C.	BY
CASING SIZE 45'-3 3/4" IDHS	Dry A.C.R.	CREW NO. 3	METHOD
CORE SIZE	HRS. A.D.	JOB NO. 79050173-3	GROUT
	HRS. A.D.	VERT. SCALE 1"=10'	QUANTITY

QU ● LABORATORY X 1000 PSF — 2, 4, 6, 8, 10 — O PENETROMETER

DEPTH	S	T	N	LR	DD	DESCRIPTION
0.0						Ground surface (grass)
1.5	1	SS	9			Black Silty loam till
						Brown and gray silty clay
	2	SS	20			
	3	SS	[illegible]			
12.0						Gray silty clay
	4	SS	33			
20.0	5	SS	19			Gray silty clay, trace of pink fine sand, small gravel
25.0	6	SS	22			Gray silty clay, trace of small to medium gravel
	7	SS	33			
	8	SS	42			
	9	SS	41			
43.0						End of Boring
						Note : 2" PVC Monitoring Well installed this bore hole, see Well Installation Data

10, 20, 30, 40, 50 — WC ▲ NATURAL %

LEGEND:
A—AUGER
ACR—AFTER CASING REMOVAL
AD—AFTER DRILLING
BCR—BEFORE CASING REMOVAL
C—CORE
DCI—DRY CAVE IN
DD—DRY DENSITY, LB. PER CU. FT.
DEPTH—FEET BELOW GROUND SURFACE
FT—FISHTAIL
HA—HAND AUGER
HS—HOLLOW STEM AUGER
L—SAMPLE LENGTH
N—PENETRATION, BLOWS PER FT.
QU—UNCON. COMP. STRENGTH LBS. PER SQ. FT.
R—LENGTH OF SAMP. RECOVERED
S—SAMPLE NUMBER
SS—SPLIT SPOON
ST—SHELBY TUBE
T—TYPE OF SAMPLE
WC—WATER CONTENT %
WCI—WET CAVE IN
WD—WHILE DRILLING
WO—WASHOUT



Well Installation Diagram
ANL Landfill
Argonne, Illinois
Boring B-3

SOIL TESTING SERVICES, INC.
111 PFINGSTEN ROAD
NORTHBROOK ILLINOIS 60062

SDM	5/2	No Scale	14236-P

FORM LB: D

OWNER Argonne National Laboratory

LOG OF BORING NUMBER B-3 (6) ANL Well No

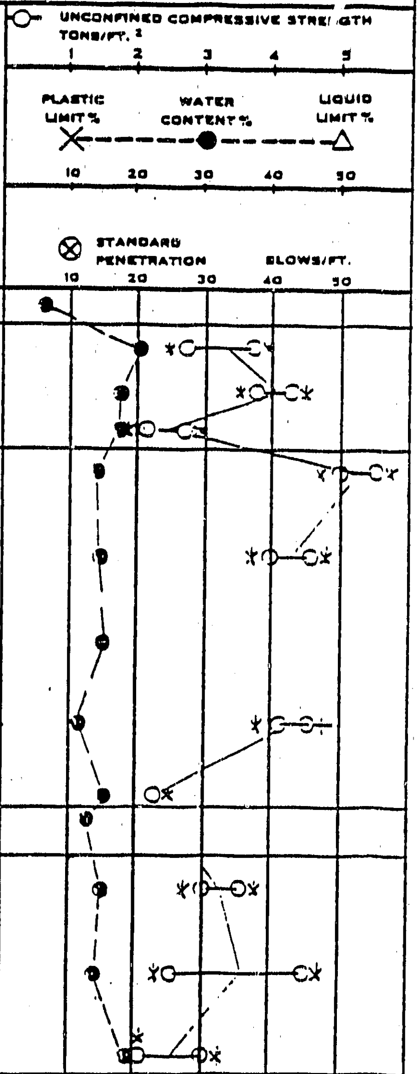
PROJECT NAME ANL Sanitary Landfill

ARCHITECT-ENGINEER

SITE LOCATION Argonne, Illinois

SURFACE ELEVATION 748.5

ELEVATION / DEPTH	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
	1	ST			6" crushed limestone gravel & sand, underlain by 6" silty clay fill and 1' black topsoil & cinder fill -lt. gray to dk. gray- moist (Fill)	105
	2	ST				119
	3	ST				
10.0	4	ST			"A"	
	5	ST				124
		FT			Silty clay, trace gravel, sand and shale -gray- very stiff to hard (CL) Sample 8: horizontal sand seams Sample 9: disturbed side	
	6	ST				124
20.0		FT				
	7	ST				
		FT				
	8	ST				123
30.0		FT				
	9 9A	ST			Silt, little clay & sand, trace gravel -gray- moist (ML) Large limestone gravel	
		FT				
	10	ST			Silty clay, trace gravel, sand and shale -gray- very stiff to hard (CL) Sample 10: diagonal silt seams Sample 11: hori. silt & sand seams, thin layers of reddish brown clay Sample 12: disturbed tip, top of sample gravelly clay	
40.0		FT				
	11	ST				
		FT				
47.0	12	ST				



END OF BORING

*CALIBRATED PENETROMETER

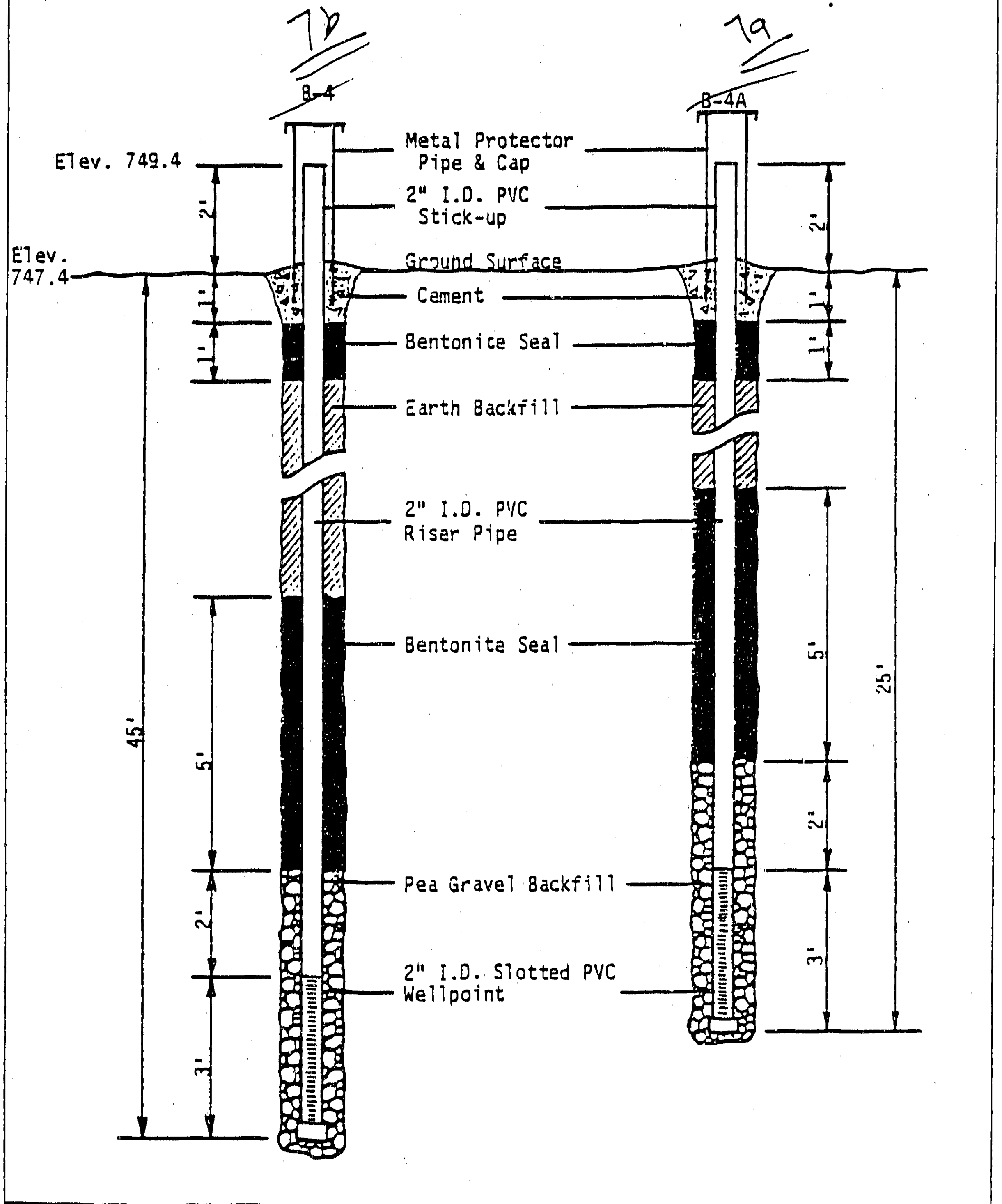
"A" - Silty clay, trace sand -brown & gray- very stiff to hard (CL)
Sample 2: trace gravel & roots
Sample 4: trace gravel, partly disturbed
Sample 3: horizontal seams of fine sand

Casing used: 10' of 4"

Well point installed, tip of wellscreen at 44'

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

WL 7'	WS ~~XXXX~~	BORING STARTED 4/22/80	SOIL TESTING SERVICES, INC. 111 PFINGSTEN ROAD NORTHBROOK ILLINOIS 60062	
WL BCR	ACR	BORING COMPLETED 4/23/80		
WL		RIG Rotary FOREMAN Lehtinen	APP'D BY SDM	STS JOB NO. 14236-P



Well Installation Diagram
ANL Landfill
Argonne, Illinois
Borings B-4 and B-4A

SOIL TESTING SERVICES, INC.
111 PFINGSTEN ROAD
NORTHBROOK ILLINOIS 60062

SDM	5/2	No Scale	14236-P

FORM LD: 5

OWNER
Argonne National Laboratory

LOG OF BORING NUMBER
B-4A

7a ANL well No

PROJECT NAME
ANL Sanitary Landfill

ARCHITECT-ENGINEER

SITE LOCATION
Argonne, Illinois

○ UNCONFINED COMPRESSIVE STRENGTH TONS/FT.² 1 2 3 4 5

PLASTIC LIMIT % ✕ — WATER CONTENT % ● — LIQUID LIMIT % △ 10 20 30 40 50

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50

SURFACE ELEVATION 747.4

ELEVATION / DEPTH	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
		FT			Black clayey topsoil - driller's observation	
10.0		FT			Light brown silty clay - driller's observation	
20.0 25.0		FT			Gray silty clay - driller's observation	

END OF BORING

NOTE: Drilled without sampling

Well point installed, tip of wellscreen at 25 ft

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

WL At surface WS ~~or WD~~ XXXXXX

WL BCR ACR

WL At surface AB

BORING STARTED 4/24/80

BORING COMPLETED 4/24/80

RIG Rotary FOREMAN Lehtiner

SOIL TESTING SERVICES, INC.
111 PFINGSTEN ROAD
NORTHBROOK ILLINOIS 60062

APP'D BY SDM

STS JOB NO. 14236-D

OWNER Argonne National Laboratory

LOG OF BORING NUMBER B-4 7b ANL well No 7b

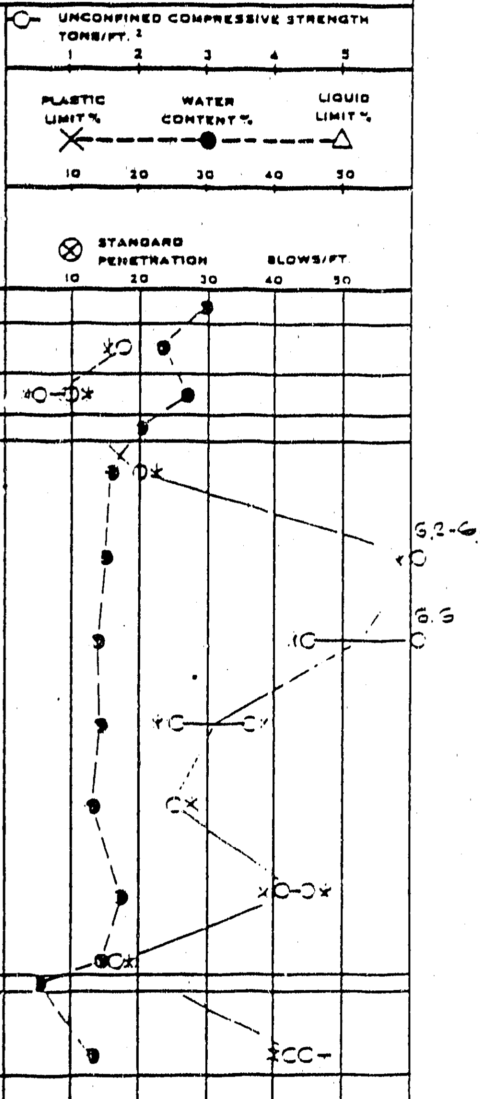
PROJECT NAME ANL Sanitary Landfill

ARCHITECT-ENGINEER

SITE LOCATION Argonne, Illinois

SURFACE ELEVATION 747.4

ELEVATION / DEPTH	SAMPLE NO.	SAMPLE TYPE	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
	1	ST	"A"	
			"B"	
	2	ST	Sandy clay, little silt, trace gravel -lt. brown & sl. gray- medium to soft (CL) Hori. sand seams	
	3	ST		
	4	ST	Silty fine to med. sand, little clay, trace gravel -lt. brown- saturated (SM-SC)	
10.0				
	5	ST		
		FT	Silty clay, trace gravel, sand and shale -gray- stiff to hard (CL)	
	6	ST	Sample 5: hori. silt seams	126
20.0		FT	Sample 7: disturbed tip	
	7	ST	Sample 8: hori. silt seams	127
			Sample 9: large sand pocket, silt seams	
		FT		
	8	ST	Sample 10: diagonal silt seams	
30.0		FT	Boulders from 23 to 23.5 ft	
	9	ST	(Driller's observation)	
		FT		
	10	ST		
40.0		FT	Fine to medium sand, little silt, trace gravel, coarse sand & clay lumps -gray- moist (SP-SM)	
	11 11A	ST		
		FT	Silty clay, little gravel, trace sand -gray- hard (CL) Disturbed tip	
47.0	12	ST	- large limestone gravel	133



END OF BORING

*CALIBRATED PENETROMETER

"A" - Clayey topsoil, little silt, trace sand & roots -black- moist (OH)

"B" - Silty clay, trace gravel, sand and shale -brown & gray- stiff to very stiff (CL-CH) Top 2" topsoil and clay

Casing used: 25' of 4"

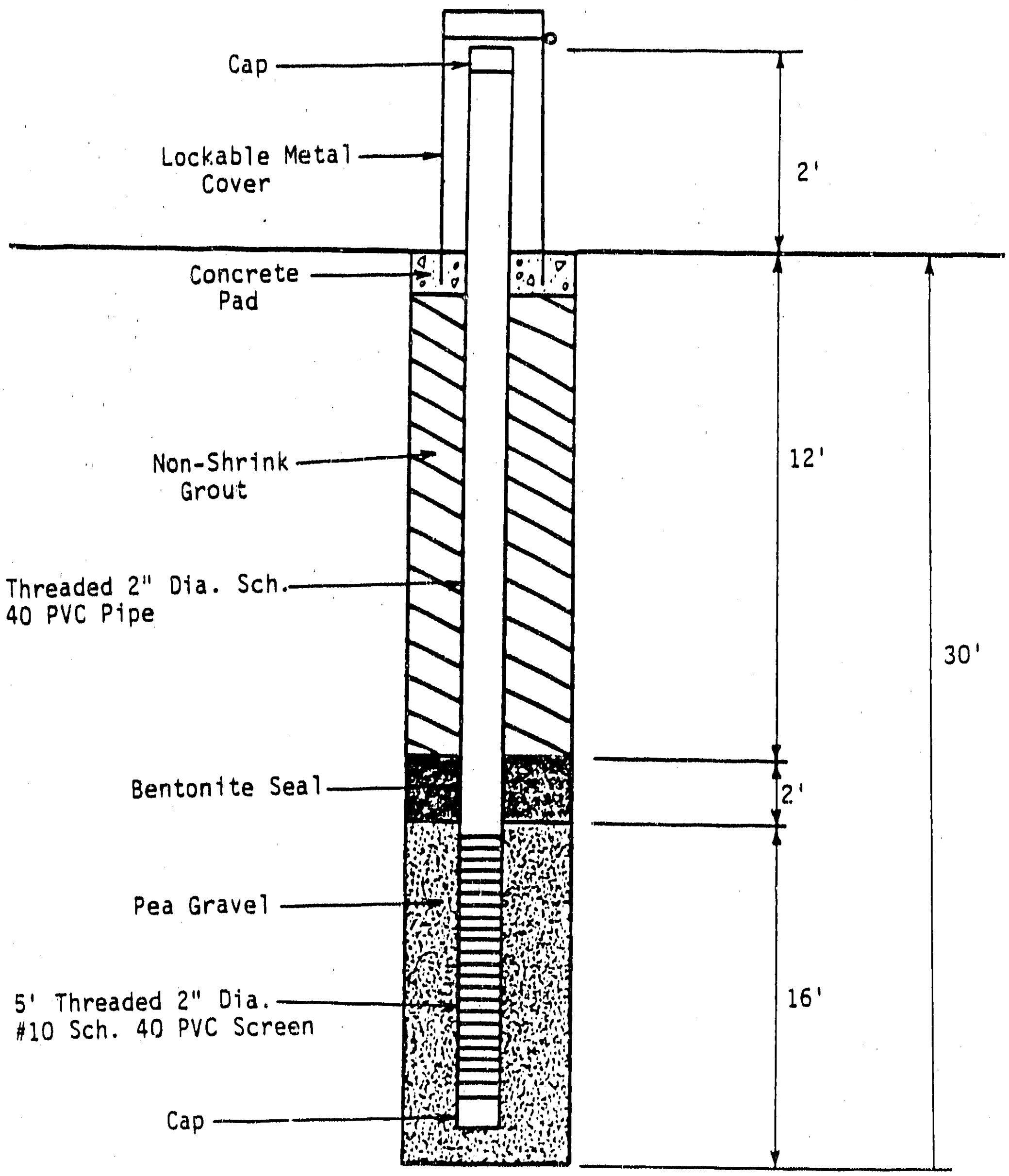
Well point installed, tip of wellscreen at 45 ft

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES: IN-SITU THE TRANSITION MAY BE GRADUAL

WL 5.5'	WS WD	BORING STARTED 4/23/80	SOIL TESTING SERVICES, INC. 111 PFINGSTEN ROAD NORTHBROOK ILLINOIS 60062
WL BCR	ACR	BORING COMPLETED 4/23/80	
WL		RIG Rotary FOREMAN Lehtinen	APP'D BY SDM / STS JOB NO. 14236-P

BL:I

Professional Service Industries



PROJECT NAME

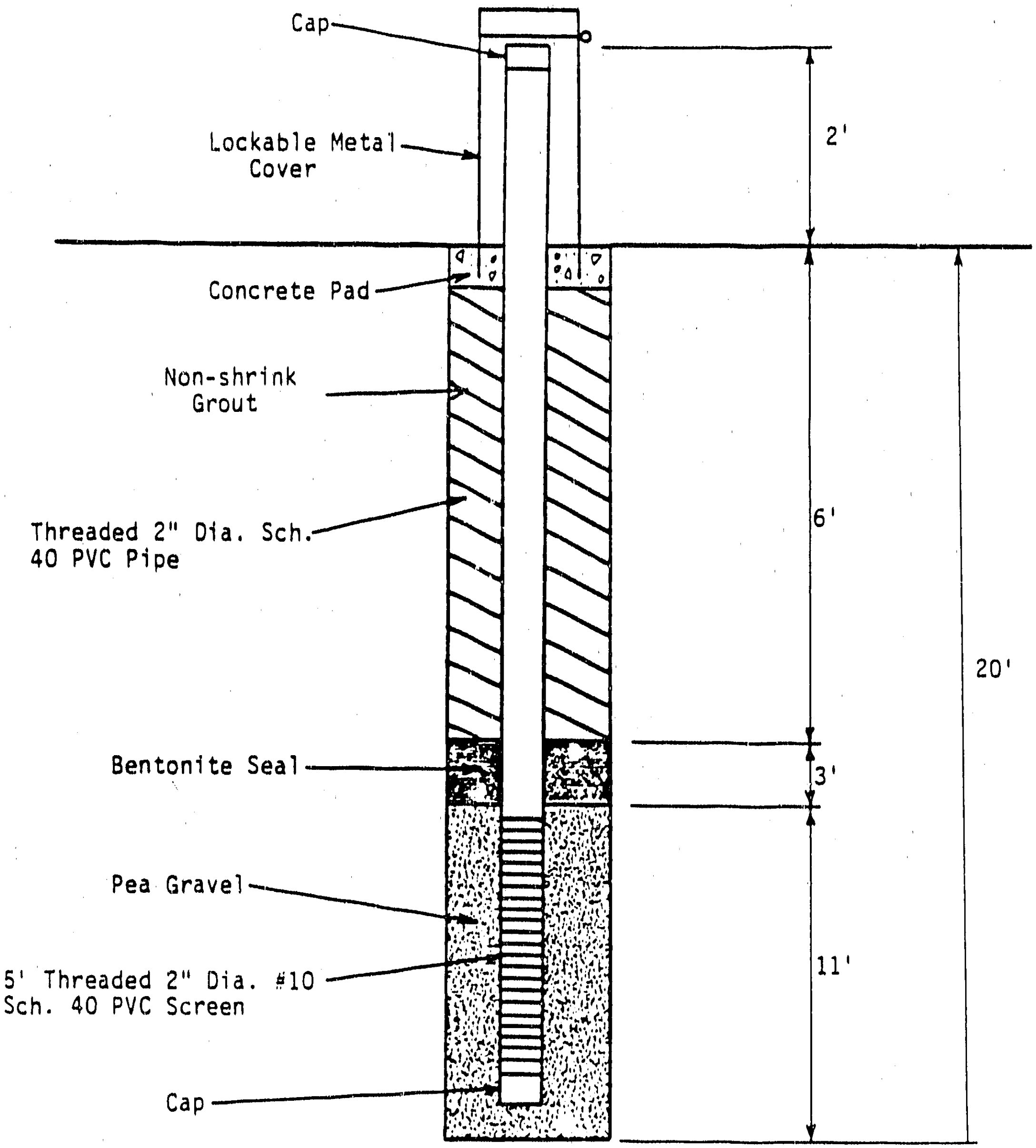
Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

MW-8 DETAIL

PROJECT NO
152-65138

DATE
September 28, 1986

Professional Service Industries



PROJECT NAME

Monitorwell stallation
Argonne National Laboratory
Argonne, Illinois

MW-9 DETAIL

PROJECT NO
162-65138

DATE
September 25, 1986

NEW WELL NO. 8 (800 Area)

Location: 407 ft. west of east gate to the 800 area land fill. Approximately in the middle of the north boundary.
Date Drilled: Sept. 18, 1986
Total Depth: 30 ft
Water level while drilling: ? at 8 ft cutting were damp, at 18 ft they became very wet
10/8/86: 18.64 ft. below land surface.
Completion: Schedule 40 PVC blank casing and screen

0 - 25 ft. blank casing	0 - 10 ft. grout
25 - 30 ft screen	10 - 12 ft. bentonite
	12 - 30 ft. pea gravel

Geologist: R. H. Pearl, ANL

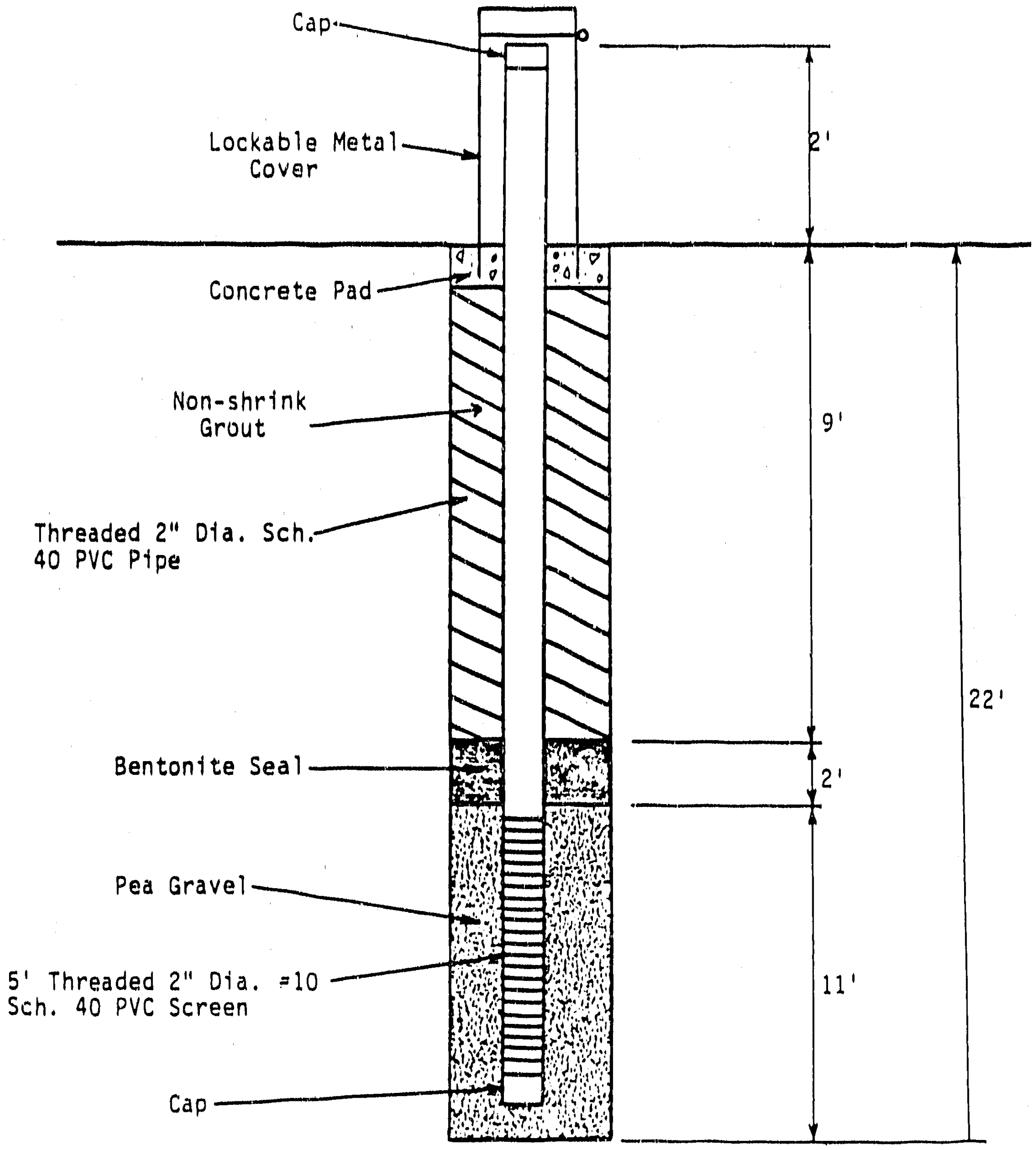
NEW WELL NO. 9 (800 Area)

Location: Northwest corner of sanitary landfill 800 area
Date Drilled: Sept. 25, 1986
Total Depth: 20 ft
Water level while drilling: 10 ft
10/8/86: 9.93 ft below land surface
Completion: Schedule 40 PVC blank casing and screen

0 - 15 ft. blank casing	0 - 06 ft. grout
15 - 20 ft screen	6 - 9 ft. bentonite
	9 - 20 ft. pea gravel

Note: Cuttings were a very black color (appearance of high organic content) Driller said he noted gas odor.
Geologist: R. H. Pearl, ANL

Professional Service Industries



PROJECT NAME

Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

MW-10 DETAIL

PROJECT NO
152-65138

DATE
September 29, 1986

NEW WELL NO. 10 (800 Area)
SPLIT SPOON CORE LOG

Location: 77 ft. north and 10 ft west of southeast corner of sanitary landfill, 800 area.
Date Drilled: Sept. 29, 1986
Total Depth: 22 ft.
Water level while drilling: 10? approx.
10/8/86: 4.32 ft. below land surface.
Completion: Schedule 40 PVC blank casing and screen

0 - 17 ft. blank casing	0 - 5 ft. grout
17 - 22 ft screen	5 - 7 ft. bentonite
	7 - 22 ft. pea gravel

Geologist: R. H. Pearl, ANL

Depth (ft)	Description
0 - 2	Soil, clay, roots, with some fine gravel
2 - 3	Clay, gray,
3 - 4	As above with very coarse sand and fine gravel.
4 - 6	Clay, brown, with very coarse sand and fine gravel.
6 - 8	As above, very poor return (3") Drilled hard.
8 - 10	Clay, black, plastic, with some sand and fine gravel. Was wet at one time.
10 - 12	Hit a rock, poor return (2")
12 - 14	Clay, gray, very sandy and fine gravel. WATER
14 - 16	Clay, gray, plastic, with silt-fine gravel. Bottom part dry. Wet zone was only about 1 ft thick.
16 - 18	As above
18 - 20	As above, very dry.
20 - 22	As above. Total Depth.

DOE ENVIRONMENTAL SURVEY **WELL COMPLETION RECORD**

DOE SITE NAME: Argonne

WELL ID NUMBER: ~~12~~ ANL NO 11

WELL COORDINATES or WELL LOCATION:
11' N 7 E of Tile Well # 6

DRILLING COMPANY: Patterson (Cannon Mclain)
TYPE OF RIG: Cable Tool

DATE INSTALLATION COMPLETED (dd/mmm/yy):
04/DEC/82

TOTAL DEPTH: 78 ft.

DEVELOPMENT See New Well Report #2

METHOD:

START DATE: __ __/__ __ __/__ __
TIME: __ __:__ __

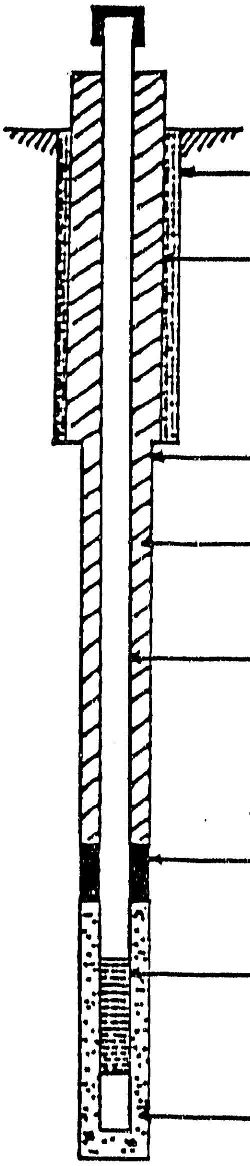
END DATE: __ __/__ __ __/__ __
TIME: __ __:__ __

TOTAL WATER REMOVED DURING DEVELOPMENT: ________ gal.

DESCRIPTION OF TURBIDITY AT END OF DEVELOPMENT:
[ ] Clear [ ] Slightly cloudy
[ ] Mod. turbid [ ] Very cloudy

ADDITIONAL COMMENTS: TAP Approximately To Bentonite Pellets to Insure Seal -No water in Borehole

WELL CONSTRUCTION SUMMARY



WELL CAP ELEVATION: ______ ft.

GROUND SURFACE ELEVATION: ______ ft.

CONDUCTOR HOLE DIA.: N/A in.
______ to ______ ft.

SURFACE CONDUCTOR
TYPE: N/A
ID: ____ in. OD: ____ in.
______ to ______ ft.

BOREHOLE DIA.: 7 in.
78 to 0 ft.

FILLER
TYPE: Washings
50 to 0 ft.

CASING (with screen)
TYPE: 316 SS
ID: 4.1 in. OD: 4.5 in.
1.0 to 0 ft.

SEAL
TYPE: Bentonite Pellets
56.5 to 50 ft.

SCREEN
TYPE: 316 SS 20 slot
ID: 4.1 in. OD: 4.5 in.
78 to 68 ft.

PACK
TYPE: #4 Silica Sand
78 to 56.5 ft.

RECORDED BY: ______ (Signature) CHECKED BY: ______ (Signature)
04-Dec.84

DOE ENVIRONMENTAL SURVEY **RECORD OF SUBSURFACE EXPLORATION**

DOE SITE NAME: Arrowood

PAGE 1 of 2

DATE (dd/mmm/yy): 0 3 / [illegible]

WELL ID NUMBER: ~~1~~ 11

WELL COORDINATES or DRILLING LOCATION: 10' North of Existing Well 6

GROUND WATER FIRST ENCOUNTERED AT — ft.

DEPTH (ft)	SAMPLE NUMBER	SAMPLE INTERVAL AND TYPE	SAMPLE ADVANCED/ RECOVERY (in)	BLOWS (per 6 in)	DESCRIPTION OF MATERIALS (indicate zones of lost circulation and water bearing zones)
5					
0	1	10-12	20"		Grey to Brown Clayey Silt, Large Coal Fragments noted
5					
10	2	20-22	24		Grey Clay w/ Iron Staining, pebbles & Rock Fragments noted, Trace Silt
15					
20	3	30-32	24		Grey Clay w/ Iron Staining - Sandy Clay Stringers About 1-2 inches thick starting at 31'. Pebbles & Rock Fragments Throughout
5					

RECORDED BY: Mark Hampton (Signature)
03-[illegible]-87

CHECKED BY: ______________ (Signatu

ENVIRONMENTAL SURVEY

RECORD OF SUBSURFACE EXPLORATION

SITE NAME: [illegible]

PAGE 2 of 2

DATE (dd/mmm/yy): 04/DEC/87

LL ID NUMBER: ~~12~~ 11

LL COORDINATES or DRILLING LOCATION: 10' North of Existing Well #6

UND WATER FIRST ENCOUNTERED AT — ft.

	SAMPLE				
DEPTH (ft)	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERY (in)	BLOWS (per 6 in)	DESCRIPTION OF MATERIALS (indicate zones of lost circulation and water bearing zones)
	30	43-45.	20		Grey Clay, Trace silT
	40	[illegible]	[illegible]		Trace Silt Grey Clay, Trace Silt, some Rock Fragments
	50	[illegible]	[illegible]		grading sand Clayey Silt grading into silty sand. Sand is 0.5 inches thick, followed by Silt - unsaturated
	60	[illegible]	[illegible]		Grey Clay with pebbles Trace silt Clay with pebbles Trace silt

OED BY: (Signature) CHECKED BY: __________ (Signature)

DOE ENVIRONMENTAL SURVEY **WELL COMPLETION RECORD**

DOE SITE NAME: Argonne #12

WELL ID NUMBER: ~~13~~ ANL

WELL COORDINATES or WELL LOCATION:
16' South of well #[illegible] -30 [illegible]

DRILLING COMPANY: Bowser Morner
TYPE OF RIG: ATV

DATE INSTALLATION COMPLETED (dd/mmm/yy):
28/NOV/87

TOTAL DEPTH: 33 ft.

DEVELOPMENT See New Well Logbook #2

METHOD: ________

START DATE: __/___/__
TIME: __:__

END DATE: __/___/__
TIME: __:__

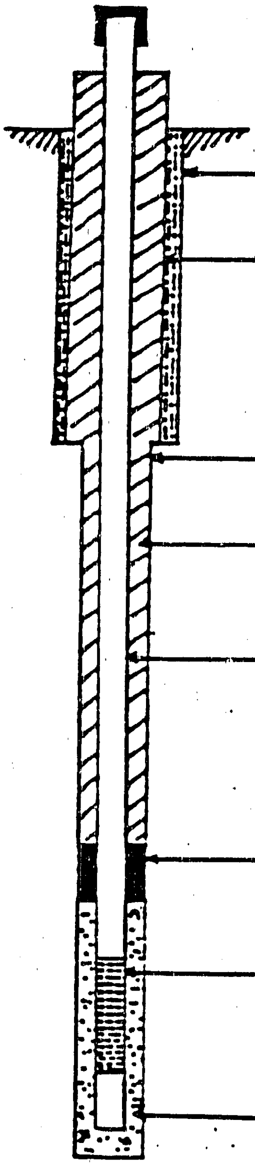
TOTAL WATER REMOVED DURING DEVELOPMENT: ______ gal.

DESCRIPTION OF TURBIDITY AT END OF DEVELOPMENT:
[ ] Clear [ ] Slightly cloudy
[ ] Med. turbid [ ] Very cloudy

ADDITIONAL COMMENTS: Very little
[illegible]
water in well

RECORDED BY: ______ (Signature) CHECKED BY: ______ (Signature)

WELL CONSTRUCTION SUMMARY



WELL CAP ELEVATION: ____ ft.

GROUND SURFACE ELEVATION: ____ ft.

CONDUCTOR HOLE DIA.: ____ in. ____ to ____ ft. NA

SURFACE CONDUCTOR
TYPE: ____
ID: ____ in. OD: ____ in. NA
____ to ____ ft.

BOREHOLE DIA.: 11 in.
0 to 33 ft.

FILLER
TYPE: Volclay Grout
18.0 to 1 ft.

CASING (with screen)
TYPE: 316 SS
ID: 4.1 in. OD: 4.5 in.
27.5 to 0 ft.

SEAL
TYPE: Bentonite Pellet
21.5 to 18 ft.

SCREEN
TYPE: 316 SS
ID: 4.1 in. OD: 4.5 in.
32.5 to 27.5 ft.

PACK
TYPE: Pea Gravel
33 to 21.5 ft.

DOE ENVIRONMENTAL SURVEY **WELL COMPLETION RECORD**

DOE SITE NAME: [illegible]

WELL ID NUMBER: ~~#~~ ANL #13

WELL COORDINATES or WELL LOCATION:
[illegible] Near Existing well #9

DRILLING COMPANY: Patterson (Bowser Morner)
TYPE OF RIG: Cable Tool

DATE INSTALLATION COMPLETED (dd/mmm/yy):
02/DEC/82

TOTAL DEPTH: 78 ft.

DEVELOPMENT See New Well Log Book #2

METHOD: ______

START DATE: __ __/__ __ __/__ __
TIME: __ __:__ __

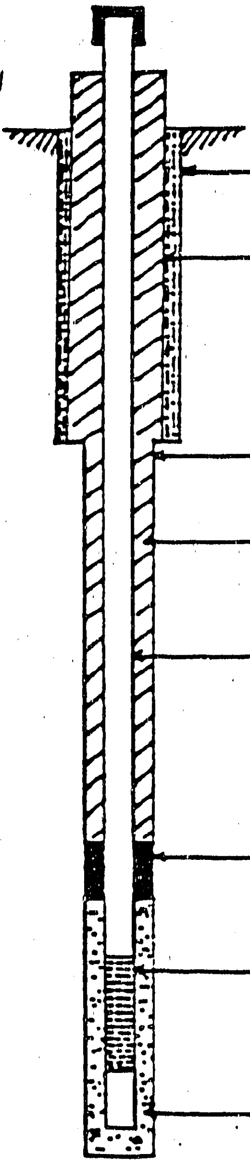
END DATE: __ __/__ __ __/__ __
TIME: __ __:__ __

TOTAL WATER REMOVED DURING DEVELOPMENT: ______ gal.

DESCRIPTION OF TURBIDITY AT END OF DEVELOPMENT:
☐ Clear ☐ Slightly cloudy
☐ Mod. turbid ☐ Very cloudy

ADDITIONAL COMMENTS: Added Tap water To Bentonite Pellets To Hydrate Seal - very little water in borehole

WELL CONSTRUCTION SUMMARY



WELL CAP ELEVATION: ______ ft.

GROUND SURFACE ELEVATION: ______ ft.

CONDUCTOR HOLE DIA.: ______ in.
______ to ______ ft.

SURFACE CONDUCTOR
TYPE: ______
ID: ______ in. OD: ______ in.
______ to ______ ft.

BOREHOLE DIA.: 7 in.
0 to 78 ft.

FILLER
TYPE: Volclay Grout
52 to 0 ft.

CASING (with screen)
TYPE: 316 SS
ID: 4.1 in. OD: 4.5 in.
68 to 0 ft.

SEAL
TYPE: Bentonite Pellets
57 to 52 ft.

SCREEN
TYPE: 316 SS 20 slot
ID: 4.1 in. OD: 4.5 in.
78 to 68 ft.

PACK
TYPE: #4 Silica Sand silica Sand
78 to 57 ft.

RECORDED BY: ______ (Signature)
02-Dec-87

CHECKED BY: ______ (Signature)

DOE ENVIRONMENTAL SURVEY **RECORD OF SUBSURFACE EXPLORATION**

DOE SITE NAME: Acheuve

PAGE 1 of 2

DATE (dd/mmm/yy): 01/DEC/87

WELL ID NUMBER: # 13

WELL COORDINATES or DRILLING LOCATION: NW Landfill near Existing Well #9

GROUND WATER FIRST ENCOUNTERED AT 60 ft.

DEPTH (ft)	SAMPLE			BLOWS (per 6 in)	DESCRIPTION OF MATERIALS (indicate zones of lost circulation and water bearing zones)
	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERY (in)		
5					
0	1	9-11'	0		No Recovery
	2	11-13	6		~~No Recovery~~ Dk. Grey To Black Clay, Heavy Organic Material Some pebbles
5					
10	3	20-22	3"		No Recovery - Waste in form
	4	22-24	6"		Heavy Clay Grey To Black Heavy Rock Fragments
15					
20	5	30-32	10"		Dk. Grey To Black Clay, Rock Fragments Abundant
5					

RECORDED BY: Mike Hampton (Signature)
01-Dec-87

CHECKED BY: ______________ (Signatu

E ENVIRONMENTAL SURVEY

RECORD OF SUBSURFACE EXPLORATION

E SITE NAME: Aeroport

PAGE 1 of 2

DATE (dd/mmm/yy): 02/DEC/8

LL ID NUMBER: #13

LL COORDINATES or DRILLING LOCATION: NW Landfill Near Existing Well #9

UND WATER FIRST ENCOUNTERED AT 60 ft.

	SAMPLE				
	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERY (in)	BLOWS (per 6 in)	DESCRIPTION OF MATERIALS (indicate zones of lost circulation and water bearing zones)
40	6	40-42	24"		Dk. Grey Clay w/ Traces of Sand, Silt. Rock Fragments Abundant, some >5cm in diameter
50	7	50-52	20"		Dk Grey Clay, Trace Sand, Trace Silt. Rock Fragments Abundant, many large (>5cm in dia)
					- - - - - - - - - -
60	8	60-62	20"		Grey Sand and Gravel, Saturated, ~~Few~~ w/ clay stringers Grading into Dk grey clay.
60	9	70-72	20"		Grey Clay w/ minor amounts of pebbles Trace Sand

GED BY: (Signature)
02 dec 87

CHECKED BY: ______________ (Signature)

Will County Well & Pump Co., Inc.
PUMP SALES & SERVICE
1200 SOUTH CEDAR ROAD
NEW LENOX, ILLINOIS 60451
(815) 485-2413 (815) 727-2322

September 30, 1988

Job #1 (South of dump) 800 Area Sanitary Landfill
Total Depth of Well - 148'
Cased to - 139' with one foot of casing above ground.
Water Level - 146' Producing 5 G.P.M.
Formations:

0' to 100' Clay
100' to 110' Sand & Gravel
110' to 125' Clay
125' to 138' Gravel
138' to 148' Limestone

Job #2 (S.E of Dump) 800 Area Sanitary Landfill
Total Depth of Well - 151'
Cased to - 147' with one foot of casing above ground.
Water Level - 148' Producing 20 G.P.M.
Formations:

0' to 10' Clay
10' to 20' Gravel
20' to 60' Clay
60' to 80' Gravel
80' to 120' Clay
102' to 146' Gravel
146' to 151' Limestone

APPENDIX B:

STATIC WATER LEVELS MEASURED IN MONITORING WELLS SINCE 1980

Tables B.1-B-9 present quarterly water level measurements for wells in the 800 Area. Table B.1 gives quarterly and annual average water levels for 1988, Table B.2 gives quarterly and annual average water levels for 1987, Table B.3 gives quarterly and annual average water levels for 1986, and so on. The tables are based on information provided by ESH.

TABLE B.1 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1988 (m above MSL)

			Quarterly Elevations[a]				
Well	Ground Surface Elevation	Well Point Elevation	1st	2nd	3rd	4th	1988 Avg.
1-2	227.69	220.00	222.83	222.47	221.53	221.44	222.07
2-2	230.83	215.01	226.07	225.28	224.12	224.36	224.96
3	226.77	218.11	224.88	224.27	222.81	223.02	223.75
4-2	227.23	220.10	225.74	225.55	222.56	223.66	224.38
5	227.53	215.40	b	220.86	dry	dry	220.86
6	229.91	215.07	219.64	219.52	217.81	218.51	218.87
7a	227.81	220.22	226.53	224.91	223.75	224.88	225.02
7b	227.81	214.09	dry	dry	dry	dry	-
8	231.53	222.84	229.45	227.66	226.01	225.86	227.25
9	230.00	224.09	227.90	226.83	224.82	226.34	226.47
10	229.15	222.60	228.75	227.84	226.44	226.31	227.34
11	229.91[c]	205.49	b	b	b	b	-
12	229.91[c]	219.17	b	b	b	b	-
13	230.00[c]	205.80	b	b	b	b	-

[a] Water-equivalent precipitation for the 30-day periods preceding the measurements was 43.4 mm for the 1st quarter, 24.6 mm for the 2nd, 96.3 mm for the 3rd, and 110.2 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

[c] Ground surface elevations for wells 11 and 12 are estimated to be the same as that for well 6. Well 13 is estimated to have the same ground surface elevation as well 9.

TABLE B.2 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1987 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[a]				1987 Avg.
			1st	2nd	3rd	4th	
1-2	227.69	220.00	222.47	b	b	b	222.47
2-2	230.83	215.01	226.80	b	b	b	226.80
3	226.77	218.11	224.24	b	224.09	b	224.16
4-2	227.23	220.10	224.64	b	b	b	224.64
5	227.53	215.40	222.29	b	b	b	222.29
6	229.91	215.07	225.10	b	219.46	b	222.28
7a	227.81	220.22	226.31	b	224.67	226.95	225.98
7b	227.81	214.09	dry	dry	dry	dry	-
8	231.53	222.84	228.91	b	226.86	229.09	228.29
9	230.00	224.09	227.56	b	226.68	227.96	227.40
10	229.15	222.60	229.03	b	227.87	b	228.45
11	229.91[c]	205.49	-	-	-	b	-
12	229.91[c]	219.17	-	-	-	b	-
13	230.00[c]	205.80	-	-	-	b	-

[a] Water-equivalent precipitation for the 30-day period preceding the measurements was 27.7 mm for the 1st quarter, 188.2 mm for the 3rd, and 50.8 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

[c] Ground surface elevations for wells 11 and 12 are estimated to be the same as that for well 6. Well 13 is estimated to have the same ground surface elevation as well 9.

TABLE B.3 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1986 (m above MSL)

Well[a]	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[b]				1986 Avg.
			1st	2nd	3rd	4th	
1-2	227.69	220.00	227.09	226.15	221.53	222.11	224.22
2-2	230.83	215.01	225.64	224.24	225.31	226.22	225.60
3	226.77	218.11	224.31	224.17	223.85	224.09	224.11
4-2	227.23	220.10	225.37	225.14	222.20	224.49	224.30
5	227.53	215.40	c	c	217.17	221.71	219.44
6	229.91	215.07	220.87	225.18	224.73	224.70	223.87
7a	227.81	220.22	226.51	223.96	225.61	226.28	225.59
7b	227.81	214.09	dry	dry	dry	dry	--
8	231.53	222.84	-	-	226.50	227.02	226.76
9	230.00	224.09	-	-	226.74	227.17	226.96
10	229.15	222.60	-	-	227.59	228.66	228.13

[a] Replacement wells 1-2, 2-2, and 4-2 and wells 8, 9, and 10 installed 9/86.

[b] Water-equivalent precipitation for the 30-day periods preceding the measurements was 37.9 mm for the 1st quarter, 83.6 mm for the 2nd, 173.5 mm for the 3rd, and 38.6 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[c] Not measured.

TABLE B.4 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1985 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[a]				1985 Avg.
			1st	2nd	3rd	4th	
1	227.53	218.23	227.17	226.07	225.03	226.86	226.28
2	230.58	220.83	226.04	225.31	224.39	225.61	225.34
3	226.77	218.08	224.67	224.27	223.33	224.24	224.13
4	227.23	221.13	225.37	225.19	224.42	225.31	225.07
5	227.53	215.34	b	b	dry	b	-
6	229.91	215.13	223.81	224.15	220.80	224.70	223.37
7a	227.81	220.19	226.28	225.77	222.78	226.50	225.33
7b	227.81	214.09	dry	dry	dry	dry	-

[a] Water-equivalent precipitation for the 30-day periods preceding the measurements was 127.8 mm for the 1st quarter, 63.5 mm for the 2nd, 46.2 mm for the 3rd, and 89.9 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

TABLE B.5 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1984 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[a]				1984 Avg.
			1st	2nd	3rd	4th	
1	227.53	218.23	227.38	226.28	225.28	226.47	226.35
2	230.58	220.83	226.16	225.70	224.70	225.22	225.44
3	226.77	218.08	224.82	224.67	223.54	224.03	224.27
4	227.23	221.13	225.43	225.09	222.63	225.43	224.64
5	227.53	215.34	b	221.86	216.71	b	219.28
6	229.91	215.13	223.69	224.18	222.96	b	223.61
7a	227.81	220.19	225.55	224.91	224.73	225.86	225.26
7b	227.81	214.09	dry	dry	dry	dry	-

[a] Water-equivalent precipitation for the 30-day periods preceding the measurements was 87.9 mm for the 1st quarter, 111.8 mm for the 2nd, 56.1 mm for the 3rd, and 96.0 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

TABLE B.6 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1983 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[a] 1st	2nd	3rd	4th	1983 Avg.
1	227.53	218.23	226.98	226.41	b	b	226.70
2	230.58	220.83	226.07	225.77	b	b	225.92
3	226.77	218.08	224.76	224.73	b	b	224.75
4	227.23	221.13	225.28	224.88	b	b	225.08
5	227.53	215.34	222.32	221.80	b	b	222.06
6	229.91	215.13	224.39	224.76	b	b	224.58
7a	227.81	220.19	222.60	223.72	b	b	223.16
7b	227.81	214.09	dry	dry	dry	dry	-

[a] Water-equivalent precipitation for the 30-day periods preceding the measurements was 17.0 mm for the 1st quarter and 36.3 mm for the 2nd. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

TABLE B.7 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1982 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[a] 1st	2nd	3rd	4th	1982 Avg.
1	227.53	218.23	227.35	226.41	226.50	225.73	226.50
2	230.58	220.83	226.28	b	b	b	226.28
3	226.77	218.08	224.61	224.55	224.49	223.85	224.38
4	227.23	221.13	225.52	225.28	225.25	224.79	225.21
5	227.53	215.34	b	b	b	b	-
6	229.91	215.13	220.86	220.64	222.69	221.80	221.50
7a	227.81	220.19	222.63	221.38	221.59	221.22	221.71
7b	227.81	214.09	dry	dry	dry	dry	-

[a] Water-equivalent precipitation for the 30-day periods preceding the measurements was 104.3 mm for the 1st quarter, 16.0 mm for the 2nd, 139.4 mm for the 3rd, and 41.9 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

TABLE B.8 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1981 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[a]				1981 Avg.
			1st	2nd	3rd	4th	
1	227.53	218.23	226.41	227.35	226.22	226.16	226.54
2	230.58	220.83	b	225.70	b	b	225.70
3	226.77	218.08	224.24	224.30	224.42	224.30	224.32
4	227.23	221.13	225.49	225.67	225.07	225.31	225.39
5	227.53	215.34	b	b	b	b	-
6	229.91[c]	215.13	215.89	216.07	215.52	218.66	216.54
7a	227.81	220.19	221.44	222.69	221.71	220.83	221.67
7b	227.81	214.09	dry	dry	dry	dry	-

[a] Water-equivalent precipitation for the 30-day periods preceding the measurements was 19.1 mm for the 1st quarter, 96.8 mm for the 2nd, 41.2 mm for the 3rd, and 14.7 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

[c] Ground surface rose 1.77 m after 3rd quarter measurement.

TABLE B.9 Well Point and Water Elevations of Monitoring Wells at the 800 Area Landfill, 1980 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations[a]				1980 Avg.
			1st	2nd	3rd	4th	
1	227.53	218.23	b	227.17	225.95	226.31	226.48
2	230.58	220.83	b	226.10	224.85	225.58	225.51
3	226.77	218.08	b	224.64	224.03	224.55	224.41
4	227.23	221.13	b	225.34	224.64	225.31	225.10
5	227.53	215.34	b	223.94	219.88	217.99	220.60
6	229.91	215.13	-	215.68[c]	b	b	215.68
7a	227.81	220.19	-	221.35[c]	b	b	221.35
7b	227.81	214.09	-	216.29[c]	b	b	216.29

[a] Water-equivalent precipitation for the 30-day periods preceding the measurements was 69.3 mm for the 2nd quarter, 91.2 mm for the 3rd, and 63.3 mm for the 4th. Precipitation was measured at O'Hare International Airport.

[b] Not measured.

[c] Water level measured about one week after drilling; value may not represent equilibrium conditions.

APPENDIX C:

MONITORING WELL HYDROGRAPHS

Figures C.1-C.10 are hydrographs for ten wells at the 800 Area (Nos. 1 and 1-2, 2 and 2-2, 3, 4 and 4-2, 5, 6, 7a, 8, 9, and 10). Each hydrograph shows the elevations of the ground surface, the well point, and available quarterly water levels. The absence of a point on the water-level curves indicates a quarter for which no measurements were made. The data used for the plots are given in App. B and were provided by ESH.

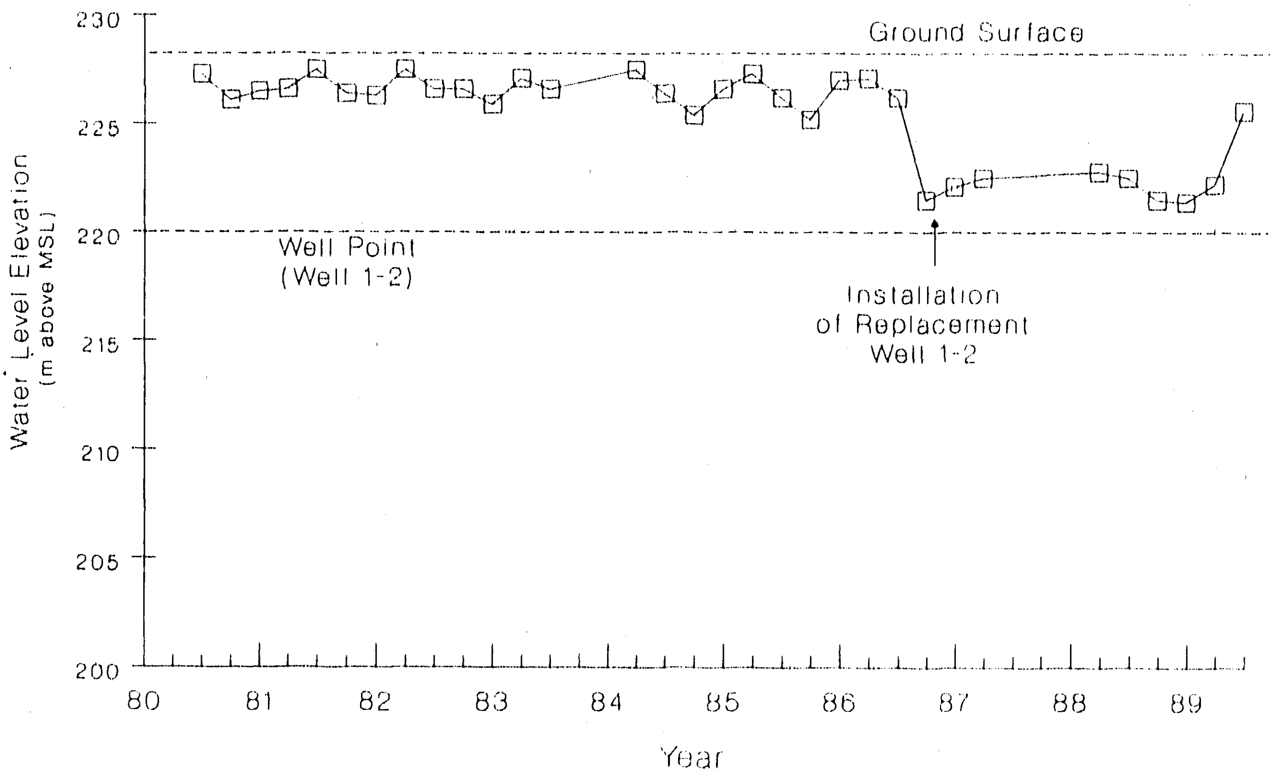


FIGURE C.1 Groundwater Elevations for Wells 1 and 1-2, 1980-1989

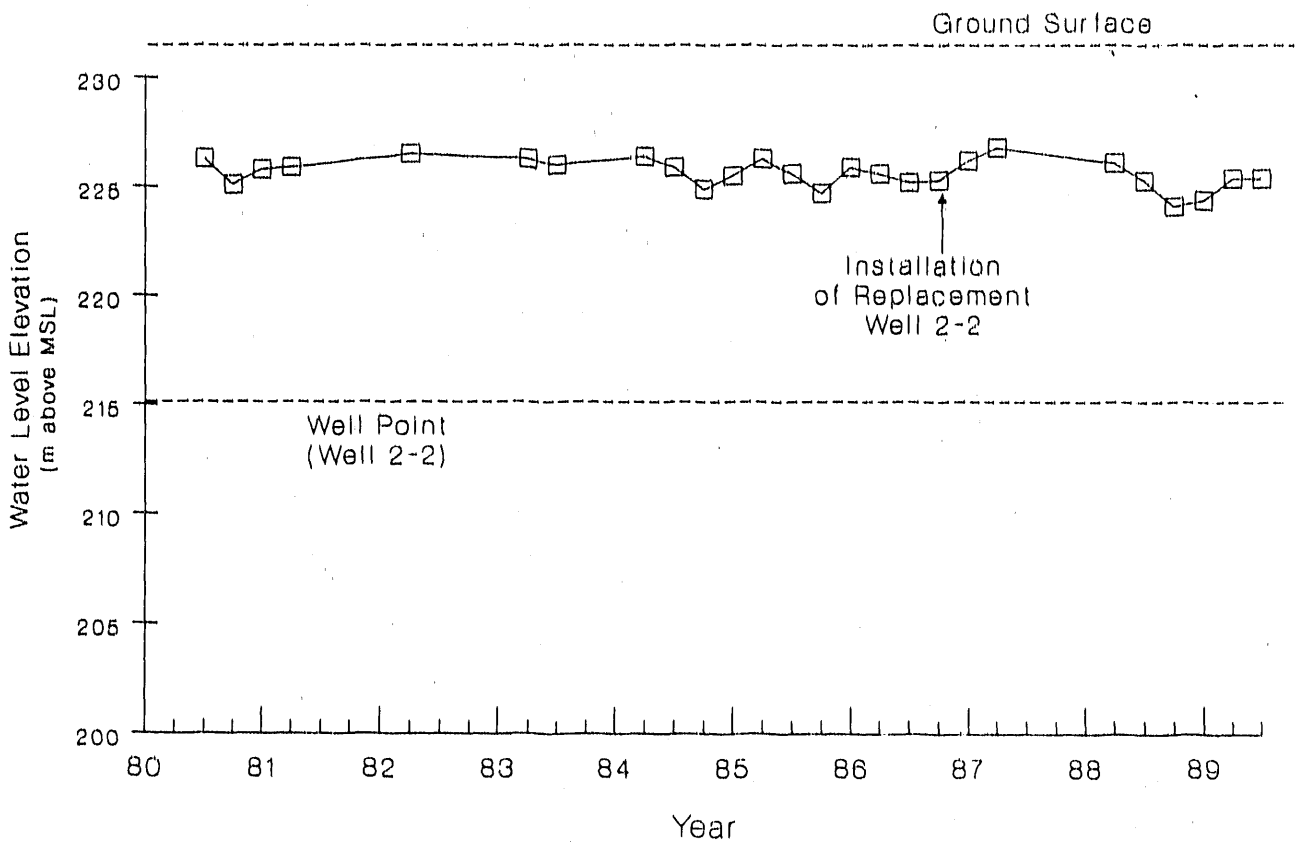


FIGURE C.2 Groundwater Elevations for Wells 2 and 2-2, 1980–1989

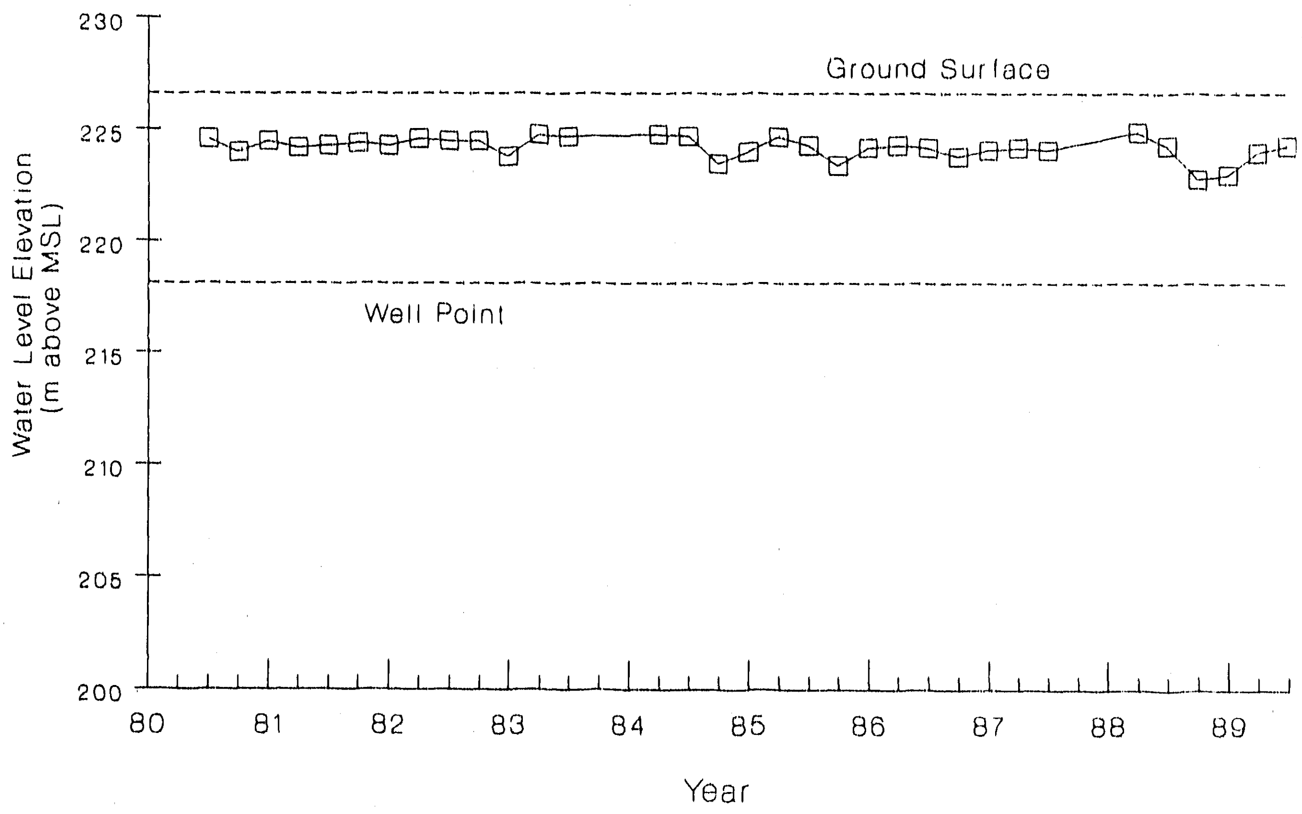


FIGURE C.3 Groundwater Elevations for Well 3, 1980–1989

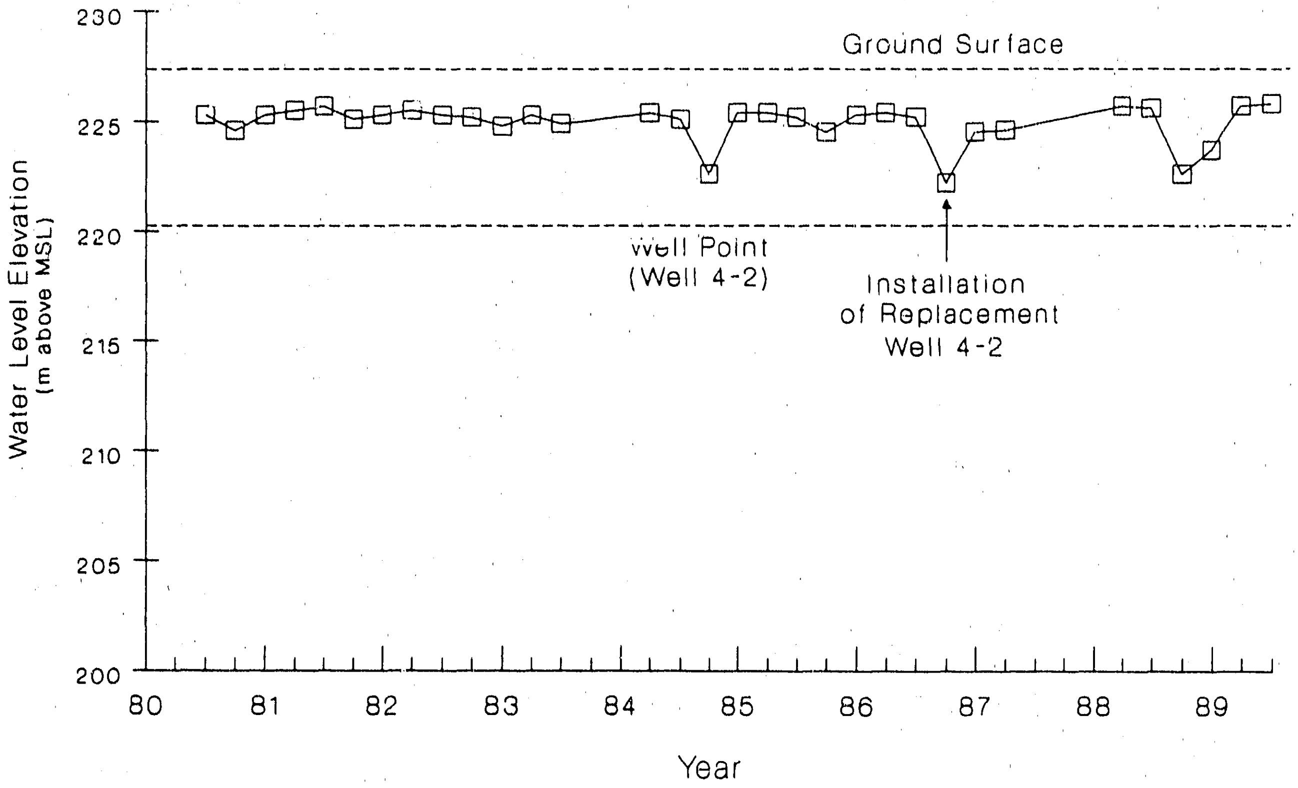


FIGURE C.4 Groundwater Elevations for Wells 4 and 4-2, 1980-1989

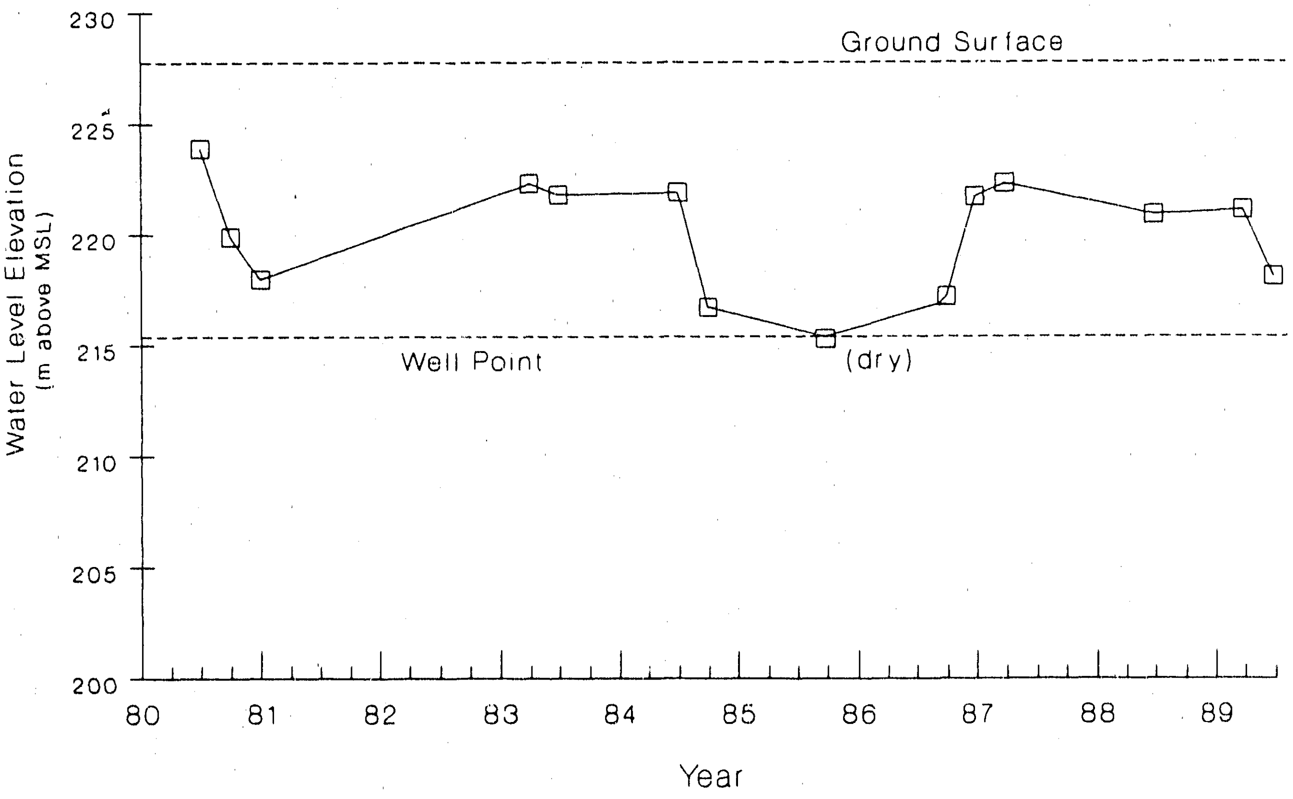


FIGURE C.5 Groundwater Elevations for Well 5, 1980-1989

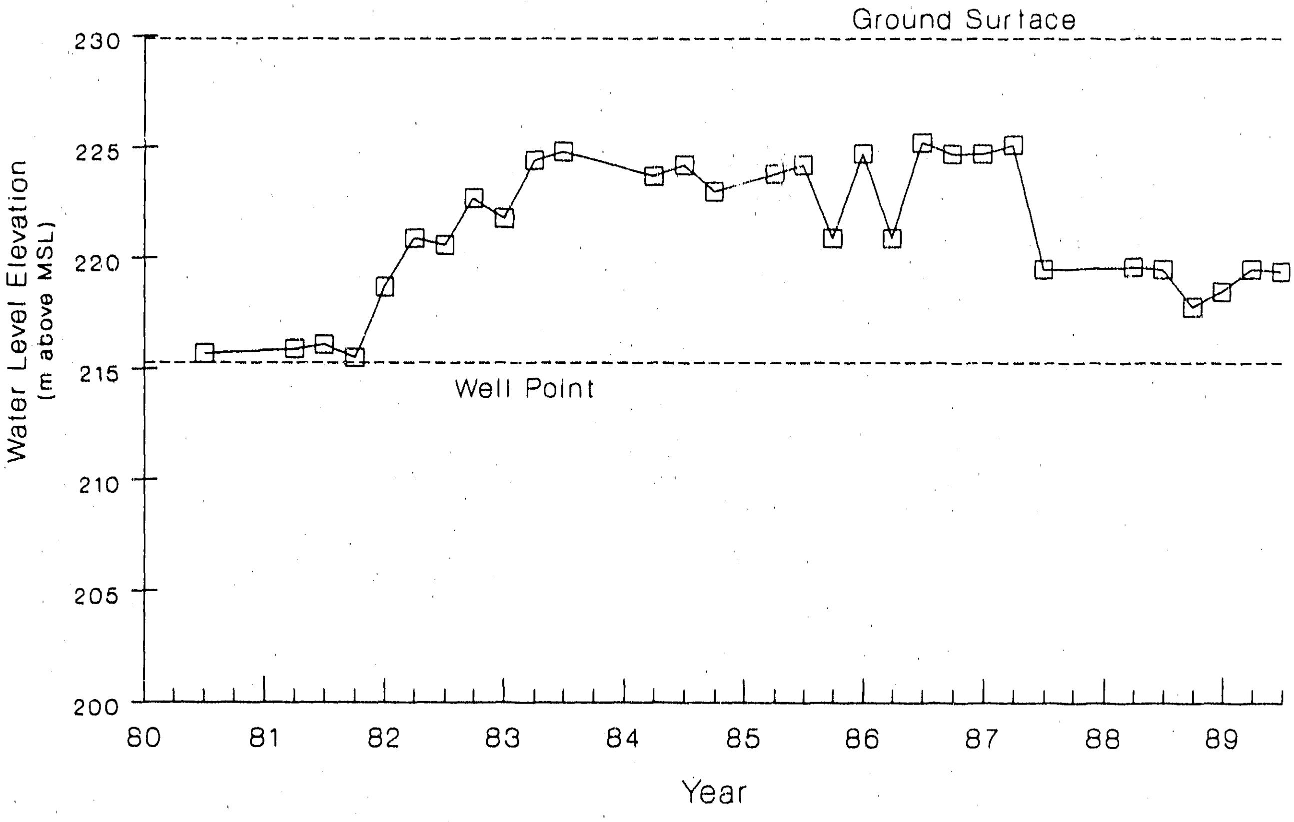


FIGURE C.6 Groundwater Elevations for Well 6, 1980-1989

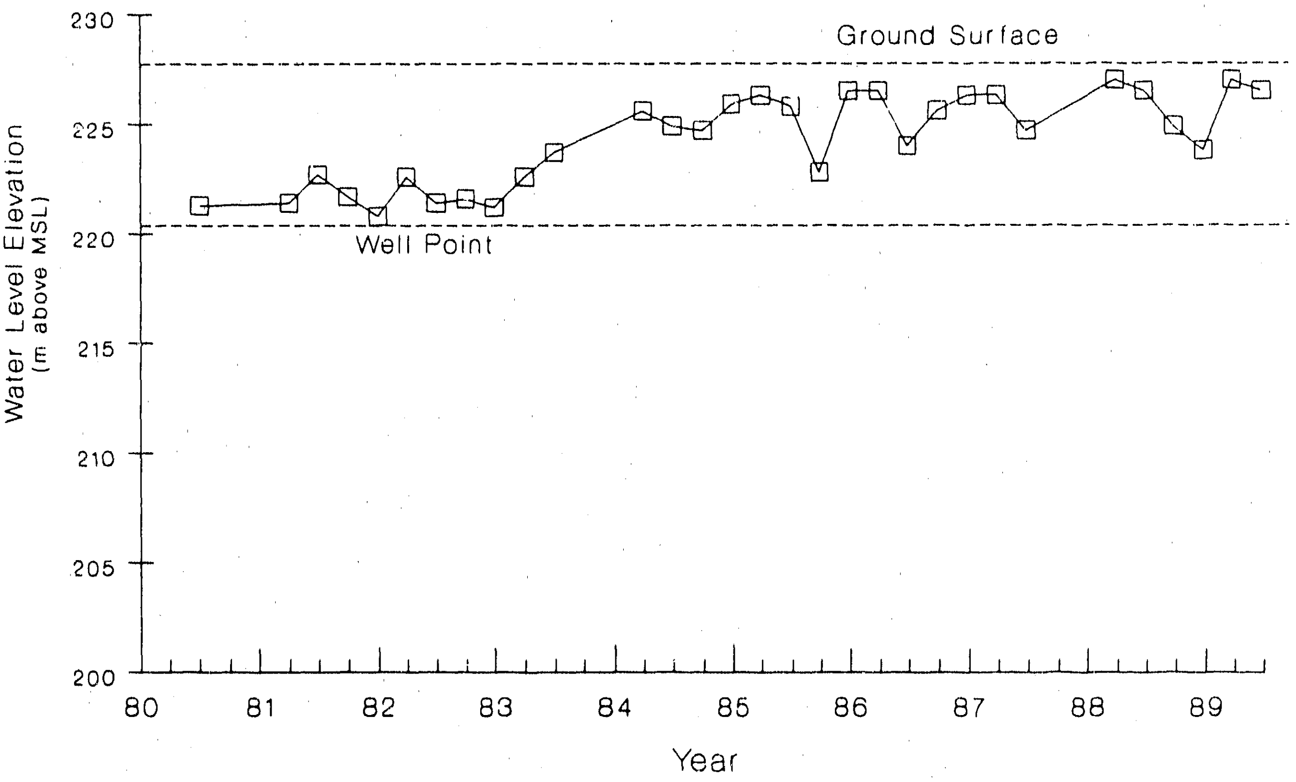


FIGURE C.7 Groundwater Elevations for Well 7a, 1980-1989

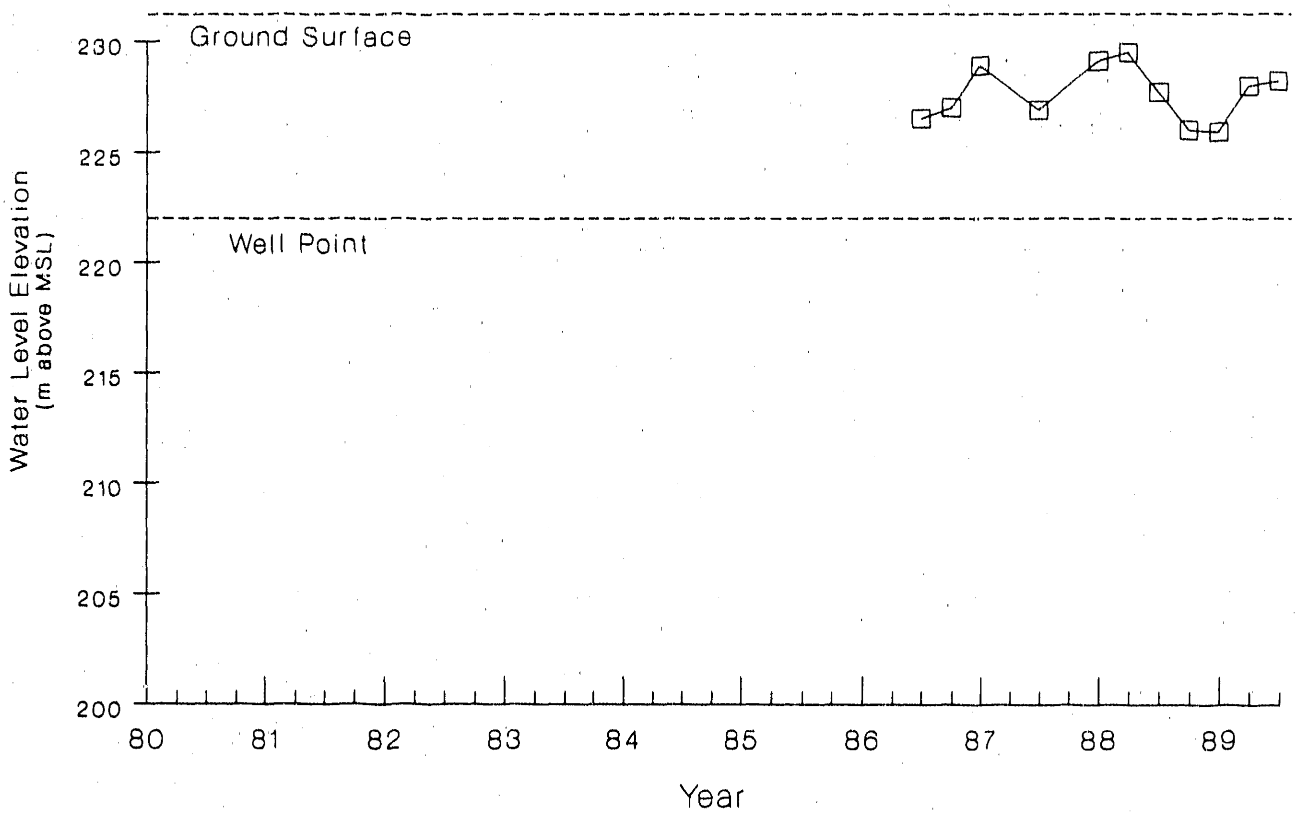


FIGURE C.8 Groundwater Elevations for Well 8, 1986-1989

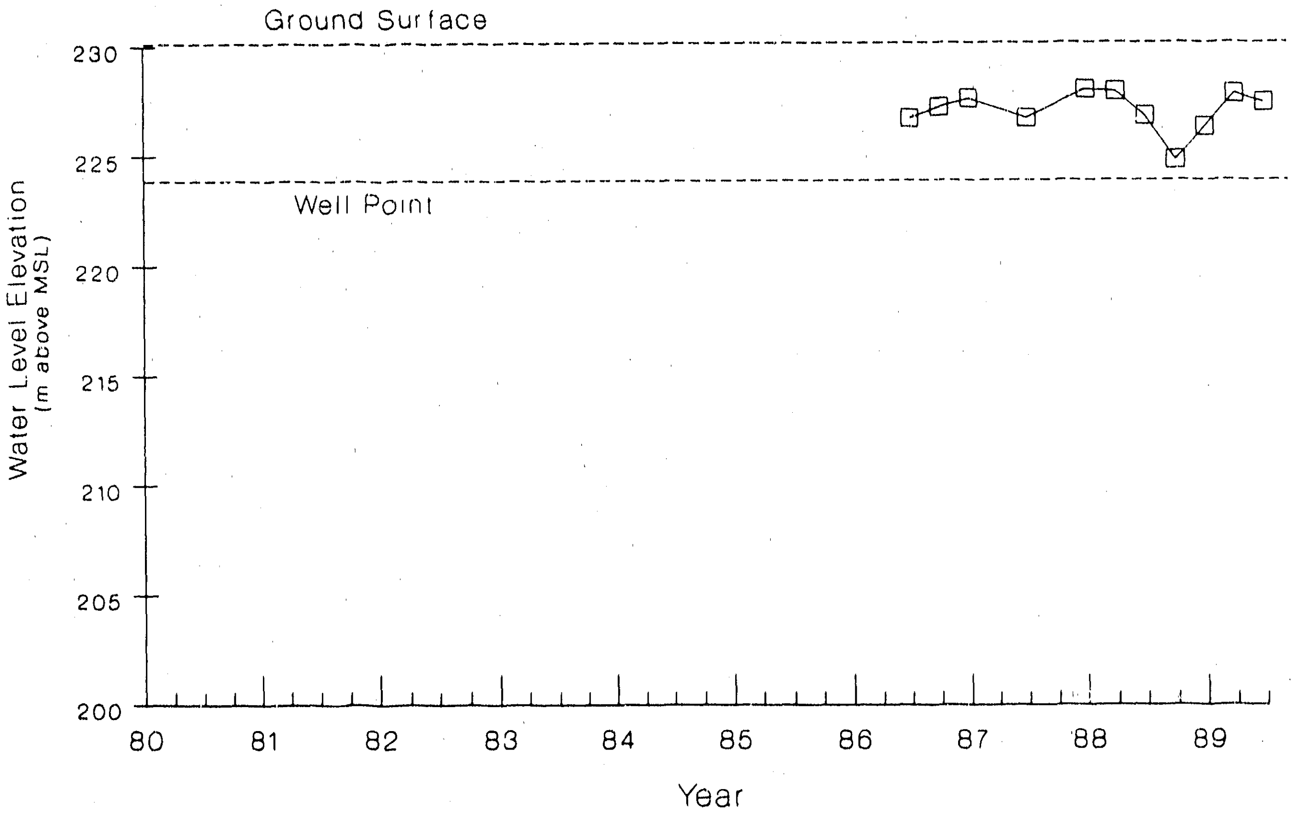


FIGURE C.9 Groundwater Elevations for Well 9, 1986-1989

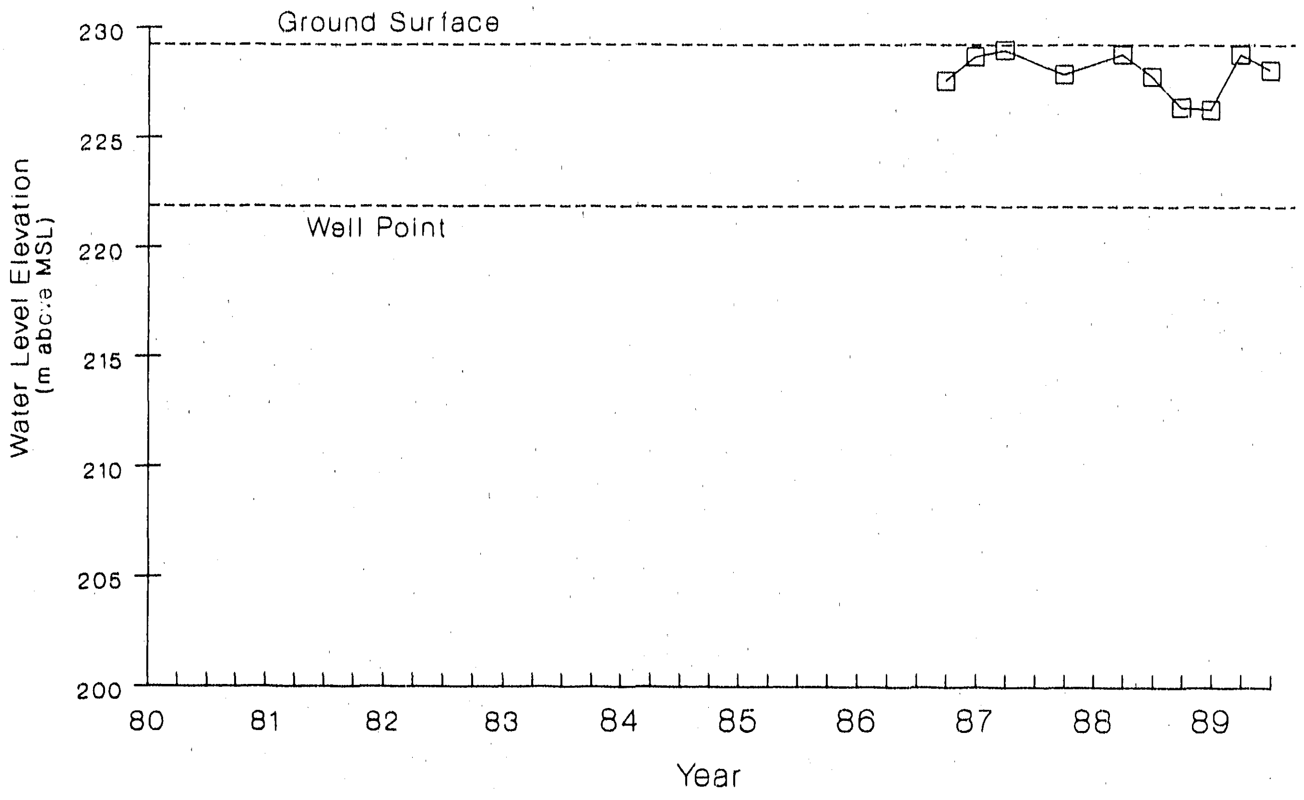


FIGURE C.10 Water Level Elevations for Well 10, 1986-1989

APPENDIX D:

ANALYTIC RESULTS FOR GROUNDWATER SAMPLES COLLECTED FROM 1985 TO 1988

Tables D.1-D.13 present analytic results of the monitoring of 10 wells in the 800 Area (no monitoring data are available for wells 7b, 11, 12, 13, DH-1, and DH-2). Two tables each are presented for wells 1, 2, and 4 to present results both before and after their replacement. The tables list annual concentration ranges for inorganic analytes, tritium, and organic analytes. Organic analytic data for 1987 and 1988 are not available; most analyses during this time did not detect organic contaminants (see Sec. 3.5). All data were provided by ESH.

TABLE D.1 Concentrations of Chemical Species in Samples from Well 1, 1985-1986

Analyte	Unit	1985	1986
Arsenic	µg/L	<5	<5
Barium	µg/L	134-375	49-277
Beryllium	µg/L	-	-
Cadmium	µg/L	-	-
Chloride	mg/L	848-1,210	1,020-1,110
Chromium	µg/L	-	-
Cobalt	µg/L	-	-
Copper	µg/L	-	-
Dissolved solids	mg/L	1,820-2,910	2,410-2,740
Fluoride	µg/L	138-160	148-162
Iron	µg/L	160-1,610	659-840
Lead	µg/L	-	-
Manganese	µg/L	177-266	157-184
Mercury	µg/L	<0.05	<0.05
pH	-	7.0-7.1	7.0-7.1
Selenium	µg/L	<5	<5
Sulfate	mg/L	105-191	121-168
Temperature	°C	10.0-14.7	9.8-12.7
Zinc	µg/L	-	-
Tritium	pCi/L	-	-
Benzene	µg/L	<10	<5
Toluene	µg/L	<10	<5
Ethylbenzene	µg/L	<10	<5
Xylene	µg/L	<10	<5
Trichloroethylene	µg/L	<20	<10
Perchloroethylene	µg/L	<20	<10
Dichlorobenzene	µg/L	-	<5
Monochlorobenzene	µg/L	-	<5
1,2,4-Trichlorobenzene	µg/L	-	<

TABLE D.2 Concentrations of Chemical Species in Samples from Well 1-2, 1986-1988

Analyte	Unit	1986	1987	1988
Arsenic	µg/L	<5	<10	<5
Barium	µg/L	99-262	337	134-302
Beryllium	µg/L	-	-	0.1
Cadmium	µg/L	1.80-4.40	-	0.7-1.2
Chloride	mg/L	650-667	833	719-862
Chromium	µg/L	-	-	6-9
Cobalt	µg/L	-	-	<40
Copper	µg/L	20-22	-	10-13
Dissolved solids	mg/L	1,780-1,970	1,960	1,770-2,010
Fluoride	µg/L	172	168	172-248
Iron	µg/L	<100	<100	2,230-10,800
Lead	µg/L	1-3	-	9-12
Manganese	µg/L	250-424	368	504-554
Mercury	µg/L	<0.05	<0.10	<0.05
Nickel	µg/L	114-161	-	<40
pH	-	7.6-7.8	7.5	7.3-7.5
Selenium	µg/L	<5	<10	<5
Silver	µg/L	0.40-2.60	-	0.2-38.5
Sulfate	mg/L	126-148	151	132-143
Temperature	°C	11.4-13.2	12.0	5-46
Zinc	µg/L	20	-	5-46
Tritium	pCi/L	234-267	189	<100-171
Benzene	µg/L	<5		
Toluene	µg/L	<5		
Ethylbenzene	µg/L	<5		
Xylene	µg/L	<5		
Trichloroethylene	µg/L	<10		
Perchloroethylene	µg/L	<10		
Dichlorobenzene	µg/L	<5		
Monochlorobenzene	µg/L	<5		
1,2,4-Trichlorobenzene	µg/L	<5		

TABLE D.3 Concentrations of Chemical Species in Samples from Well 2, 1985-1986

Analyte	Unit	1985	1986
Arsenic	μg/L	<5	<5
Barium	μg/L	111-243	240-269
Beryllium	μg/L	-	-
Cadmium	μg/L	-	-
Chloride	mg/L	21-25	26-27
Chromium	μg/L	-	-
Cobalt	μg/L	-	-
Copper	μg/L	-	-
Dissolved solids	mg/L	252-353	360-366
Fluoride	μg/L	112-132	146-154
Iron	μg/L	<100	<100
Lead	μg/L	-	-
Manganese	μg/L	6-28	28-34
Mercury	μg/L	<0.05-0.10	<0.05
Nickel	μg/L	-	-
pH	-	7.6-8.8	7.8-7.9
Selenium	μg/L	<5	<5
Silver	μg/L	-	-
Sulfate	mg/L	71-86	75
Temperature	°C	9.9-13.2	11.6-12.3
Zinc	μg/L	-	-
Tritium	pCi/L	-	-
Benzene	μg/L	<10	<5
Toluene	μg/L	<10	<5
Ethylbenzene	μg/L	<10	<5
Xylene	μg/L	<10	<5
Trichloroethylene	μg/L	<20	<10
Perchloroethylene	μg/L	<20	<10
Dichlorobenzene	μg/L	-	<5
Monochlorobenzene	μg/L	-	<5
1,2,4-Trichlorobenzene	μg/L	-	<5

TABLE D.4 Concentrations of Chemical Species in Samples from Well 2-2, 1986-1988

Analyte	Unit	1986	1987	1988
Arsenic	µg/L	<5	<10	<5
Barium	µg/L	510-628	10	230-2,500
Beryllium	µg/L	-	-	<0.05
Cadmium	µg/L	<0.20-0.30	-	0.3-0.5
Chloride	mg/L	34-82	83	4-24
Chromium	µg/L	-	-	1-2
Cobalt	µg/L	-	-	<40
Copper	µg/L	3-10	-	<10
Dissolved solids	mg/L	642-739	415	421-520
Fluoride	µg/L	282	276	166-344
Iron	µg/L	100-196	<100	640-1,540
Lead	µg/L	1-2	-	3-6
Manganese	µg/L	3-3	1	372-521
Mercury	µg/L	<0.05	<0.10	<0.05
Nickel	µg/L	-	-	<40
pH	-	12.0	11	7.5
Selenium	µg/L	<5	<10	<5
Silver	µg/L	-	-	<0.2
Sulfate	mg/L	25-31	88	65-93
Temperature	°C	11.0-13.2	11.2	11.9-13.4
Zinc	µg/L	20	-	5-27
Tritium	pCi/L	201-323	268	<100
Benzene	µg/L	<5		
Toluene	µg/L	<5		
Ethylbenzene	µg/L	<5		
Xylene	µg/L	<5		
Trichloroethylene	µg/L	<10		
Perchloroethylene	µg/L	<10		
Dichlorobenzene	µg/L	<5		
Monochlorobenzene	µg/L	<5		
1,2,4-Trichlorobenzene	µg/L	<5		

TABLE D.5 Concentrations of Chemical Species in Samples from Well 3, 1985-1988

Analyte	Unit	1985	1986	1987	1988
Arsenic	μg/L	<5-10	<5-13.0	<10	<5
Barium	μg/L	229-353	94-367	207	153-315
Beryllium	μg/L	-	-	-	<0.05
Cadmium	μg/L	-	-	-	0.9-1.0
Chloride	mg/L	1-6	1-12	1-5	1-3
Chromium	μg/L	-	-	-	2-3
Cobalt	μg/L	-	-	-	<40
Copper	μg/L	-	-	-	10-49
Dissolved solids	mg/L	721-704	766-852	714-793	674-762
Fluoride	μg/L	106-144	136-150	110-128	68-172
Iron	μg/L	128-1,600	50-3,780	1,350-3,360	1,910-3,480
Lead	μg/L	-	-	-	10-13
Manganese	μg/L	168-196	174-224	72-178	74-94
Mercury	μg/L	<0.05	<0.05	<0.10	<0.05
Nickel	μg/L	-	-	-	<40
pH	-	6.7-6.9	6.7-6.9	6.8-6.9	6.8-7.0
Selenium	μg/L	<5	<5	<10	<5
Silver	μg/L	-	-	-	<0.02
Sulfate	mg/L	28-48	42-139	19-61	25-53
Temperature	°C	9.9-13.0	10.8-12.5	10.0-14.3	11.8-13.8
Zinc	μg/L	-	-	-	5-50
Tritium[d]	pCi/L	-	<100	<100	<100
Benzene	μg/L	<10	<5		
Toluene	μg/L	<10	<5		
Ethylbenzene	μg/L	<10	<5		
Xylene	μg/L	<10	<5		
Trichloroethylene	μg/L	<20	<10		
Perchloroethylene	μg/L	<20	<10		
Dichlorobenzene	μg/L	-	<5		
Monochlorobenzene	μg/L	-	<5		
1,2,4-Trichlorobenzene	μg/L	-	<5		

TABLE D.6 Concentrations of Chemical Species in Samples from Well 4, 1985-1986

Analyte	Unit	1985	1986
Arsenic	µg/L	<5	<5
Barium	µg/L	86-301	64-179
Beryllium	µg/L	-	-
Cadmium	µg/L	0.80	0.80
Chloride	mg/L	129-533	185-355
Chromium	µg/L	-	-
Cobalt	µg/L	-	-
Copper	µg/L	8	6
Dissolved solids	mg/L	910-2,190	1,090-1,320
Fluoride	µg/L	168-206	200-212
Iron	µg/L	100-493	479-538
Lead	µg/L	2	4
Manganese	µg/L	653-1,200	1,020-1,670
Mercury	µg/L	<0.05	<0.05
Nickel	µg/L	-	35
pH	-	6.7-6.9	6.8-6.9
Selenium	µg/L	<5	<5
Silver	µg/L	0.30	0.50
Sulfate	mg/L	219-722	149-274
Temperature	°C	8.7-15.2	8.0-12.7
Zinc	µg/L	20	20
Tritium	pCi/L	-	-
Benzene	µg/L	<10	<5
Toluene	µg/L	<10	<5
Ethylbenzene	µg/L	<10	<5
Xylene	µg/L	<10	<5
Trichloroethylene	µg/L	<20	<10
Perchloroethylene	µg/L	<20	<10
Dichlorobenzene	µg/L	-	<5
Monochlorobenzene	µg/L	-	<5
1,2,4-Trichlorobenzene	µg/L	-	<5

TABLE D.7 Concentrations of Chemical Species in Samples from Well 4-2, 1986-1988

Analyte	Unit	1986	1987	1988
Arsenic	µg/L	<5	<10	<5
Barium	µg/L	32-62	96	198-609
Beryllium	µg/L	-	-	0.05-0.25
Cadmium	µg/L	0.30-0.60	-	0.60-0.70
Chloride	mg/L	37-53	61	144-150
Chromium	µg/L	-	-	2-13
Cobalt	µg/L	-	-	<40
Copper	µg/L	8-18	-	10-41
Dissolved solids	mg/L	775-986	657	766-881
Fluoride	µg/L	304	212	76-164
Iron	µg/L	<100	<100	610-17,500
Lead	µg/L	1	-	7-18
Manganese	µg/L	6-13	12	160-764
Mercury	µg/L	<0.05	<0.10	<0.05
Nickel	µg/L	28-52	-	<40
pH	-	8.0-9.0	9.0	7.2-8.4
Selenium	µg/L	<5	<10	<5
Silver	µg/L	0.90-1.10	-	<0.2
Sulfate	mg/L	116-175	122	62-150
Temperature	°C	10.2-11.8	9.3	11.5-11.8
Zinc	µg/L	20	-	5-69
Tritium	pCi/L	<100-163	<100	<100-118
Benzene	µg/L	<5		
Toluene	µg/L	<5		
Ethylbenzene	µg/L	<5		
Xylene	µg/L	<5		
Trichloroethylene	µg/L	<10		
Perchloroethylene	µg/L	<10		
Dichlorobenzene	µg/L	<5		
Monochlorobenzene	µg/L	<5		
1,2,4-Trichlorobenzene	µg/L	<5		

TABLE D.8 Concentrations of Chemical Species in Samples from Well 5, 1986-1988

Analyte	Unit	1986	1987	1988
Arsenic	μg/L	<5	<10	<5
Barium	μg/L	61-86	95	124
Beryllium	μg/L	-	-	-
Cadmium	μg/L	-	-	-
Chloride	mg/L	8-10	7	6
Chromium	μg/L	-	-	-
Cobalt	μg/L	-	-	-
Copper	μg/L	-	-	-
Dissolved solids	mg/L	297-403	366	397
Fluoride	μg/L	158	144	218
Iron	μg/L	<100	<100	3,510
Lead	μg/L	-	-	-
Manganese	μg/L	26-285	13	553
Mercury	μg/L	<0.05	<0.05	<0.05
pH	-	7.6-7.9	7.8	7.5
Selenium	μg/L	<5	<10	<5
Sulfate	mg/L	91-147	103	38
Temperature	°C	9.7-10.9	9.2	11.3
Zinc	μg/L	-	-	14
Tritium	pCi/L	486-592	622	304
Benzene	μg/L	<5		
Toluene	μg/L	<5		
Ethylbenzene	μg/L	<5		
Xylene	μg/L	<5		
Trichloroethylene	μg/L	<10		
Perchloroethylene	μg/L	<10		
Dichlorobenzene	μg/L	<5		
Monochlorobenzene	μg/L	<5		
1,2,4-Trichlorobenzene	μg/L	<5		

TABLE D.9 Concentrations of Chemical Species in Samples from Well 6, 1985-1988

Analyte	Unit	1985	1986	1987	1988
Arsenic	µg/L	<5	<5	<10	<5-13
Barium	µg/L	149-324	61-256	151	91-160
Beryllium	µg/L	-	-	-	0.05-0.54
Cadmium	µg/L	-	-	-	1.2-3.9
Chloride	mg/L	134-204	215-294	272-292	198-272
Chromium	µg/L	-	-	-	<3-28
Cobalt	µg/L	-	-	-	40-41
Copper	µg/L	-	-	-	10-80
Dissolved solids	mg/L	1,080-1,320	1,280-1,350	970-1,330	1,170-1,200
Fluoride	µg/L	100-130	114-154	72-88	48-181
Iron	µg/L	4,150-17,900	50-15,100	6,090-8,210	4,700-45,900
Lead	µg/L	-	-	-	5-38
Manganese	µg/L	2,880-5,570	2,490-3,230	1,730-2,990	1,450-2,430
Mercury	µg/L	<0.05	<0.05	<0.10	<0.05
Nickel	µg/L	-	-	-	40-71
pH	-	6.5-6.6	6.4-6.6	6.6-6.7	6.6-6.8
Selenium	µg/L	<5	<5	<10	<5
Silver	µg/L	-	-	-	<0.2
Sulfate	mg/L	123-225	81-137	48-89	40-103
Temperature	°C	10.4-12.8	10.0-13.2	11.1-14.7	10.2-14.0
Zinc	µg/L	-	-	-	5-130
Tritium	pCi/L	-	517-557	393-490	380-542
Benzene	µg/L	<10	<5		
Toluene	µg/L	<10	<5		
Ethylbenzene	µg/L	<10	<5		
Xylene	µg/L	<10	<5		
Trichloroethylene	µg/L	<20	<10		
Perchloroethylene	µg/L	<20	<10		
Dichlorobenzene	µg/L	-	<5		
Monochlorobenzene	µg/L	-	<5		
1,2,4-Trichlorobenzene	µg/L	-	<5		

TABLE E.2 (Cont'd)

Parameter	Symbol	Unit
Background (cont'd)		
Boron, dissolved	B	µg/L

TABLE D.10 Concentrations of Chemical Species in Samples from Well 7a, 1985-1988

Analyte	Unit	1985	1986	1987	1988
Arsenic	µg/L	<5	<5	<10	<5
Barium	µg/L	115-203	72-225	182	60-123
Beryllium	µg/L	-	-	-	<0.05
Cadmium	µg/L	-	-	-	0.3-0.7
Chloride	mg/L	6-30	18-49	41-47	12-43
Chromium	µg/L	-	-	-	<1-2.4
Cobalt	µg/L	-	-	-	<40
Copper	µg/L	-	-	-	<10
Dissolved solids	mg/L	462-620	589-829	811-870	554-835
Fluoride	µg/L	120-138	108-138	80-124	64-162
Iron	µg/L	<100	100-598	100-1,700	930-2,450
Lead	µg/L	-	-	-	5-7
Manganese	µg/L	247-372	299-400	294-576	188-375
Mercury	µg/L	<0.05	<0.05	<0.10	<0.05
Nickel	µg/L	-	-	-	<40
pH	-	7.2-7.3	7.0-7.2	7.0-7.2	7.0-7.1
Selenium	µg/L	<5	<5	<10	<5
Silver	µg/L	-	-	-	<0.2
Sulfate	mg/L	93-150	114-165	189-199	105-227
Temperature	°C	8.8-12.6	10.0-14.1	9.2-15.8	10.8-13.3
Zinc	µg/L	-	-	-	5-41
Tritium	pCi/L	-	759-817	593-906	108-1,070
Benzene	µg/L	<10	<5		
Toluene	µg/L	<10	<5		
Ethylbenzene	µg/L	<10	<5		
Xylene	µg/L	<10	<5		
Trichloroethylene	µg/L	<20	<10		
Perchloroethylene	µg/L	<20	<10		
Dichlorobenzene	µg/L	-	<5		
Monochlorobenzene	µg/L	-	<5		
1,2,4-Trichlorobenzene	µg/L	-	<5		

TABLE D.11 Concentrations of Chemical Species in Samples from Well 8, 1986-1988

Analyte	Unit	1986	1987	1988
Arsenic	µg/L	<5	<10	<5
Barium	µg/L	86-128	98	45-71
Beryllium	µg/L	-	-	<0.05
Cadmium	µg/L	0.30-0.70	-	0.9-1.0
Chloride	mg/L	52-65	76-134	58-100
Chromium	µg/L	-	-	<3
Cobalt	µg/L	-	-	<40
Copper	µg/L	4-12	-	<10
Dissolved solids	mg/L	727-745	583-605	713-1,070
Fluoride	µg/L	210	100-112	90-221
Iron	µg/L	<100	100-397	123-1,170
Lead	µg/L	1	-	6-14
Manganese	µg/L	91-93	118-155	122-229
Mercury	µg/L	<0.05	0.10-0.13	<0.05
Nickel	µg/L	22-29	-	<40
pH	-	7.3	7.1	7.0-7.1
Selenium	µg/L	<5	<10	<5
Silver	µg/L	<0.20	-	<0.2
Sulfate	mg/L	121-136	176-202	177-202
Temperature	°C	10.8-12.3	10.2-13.8	11.7-11.9
Zinc	µg/L	10-20		5-26
Tritium	pCi/L	168-181	191-399	<100-233
Benzene	µg/L	<5		
Toluene	µg/L	<5		
Ethylbenzene	µg/L	<5		
Xylene	µg/L	<5		
Trichloroethylene	µg/L	<10		
Perchloroethylene	µg/L	<10		
Dichlorobenzene	µg/L	<5		
Monochlorobenzene	µg/L	<5		
1,2,4-Trichlorobenzene	µg/L	<5		

TABLE D.12 Concentrations of Chemical Species in Samples from Well 9, 1986-1988

Analyte	Unit	1986	1987	1988
Arsenic	µg/L	<5-14.0	<10	<5-86
Barium	µg/L	116-338	288	203-768
Beryllium	µg/L	-	-	0.14-2.26
Cadmium	µg/L	0.60-0.70	-	0.4-3.1
Chloride	mg/L	155-175	112-133	64-146
Chromium	µg/L	-	-	6-108
Cobalt	µg/L	-	-	40-63
Copper	µg/L	10-11	-	28-178
Dissolved solids	mg/L	1,070-1,120	961-1,040	772-1,020
Fluoride	µg/L	212	134-141	106-230
Iron	µg/L	730-2,060	3,390-37,300	18,000-151,000
Lead	µg/L	1	-	27-145
Manganese	µg/L	2,650-3,840	1,120-2,300	920-5,890
Mercury	µg/L	<0.05-0.15	0.10-0.20	<0.05
Nickel	µg/L	-	-	40-157
pH	-	6.6-6.7	6.7-6.8	6.7-7.0
Selenium	µg/L	<5	<10	<5
Silver	µg/L	<0.20-0.30	-	0.2-10.8
Sulfate	mg/L	28-53	22-382	2-30
Temperature	°C	11.2-13.5	10.5-14.9	11.8-13.1
Zinc	µg/L	10-20	-	27-502
Tritium	pCi/L	711-950	638-792	603-1,048
Benzene	µg/L	<5		
Toluene	µg/L	<5		
Ethylbenzene	µg/L	<5		
Xylene	µg/L	<5		
Trichloroethylene	µg/L	<10		
Perchloroethylene	µg/L	<10		
Dichlorobenzene	µg/L	<5		
Monochlorobenzene	µg/L	<5		
1,2,4-Trichlorobenzene	µg/L	<5		

TABLE D.13 Concentrations of Chemical Species in Samples from Well 10, 1986-1988

Analyte	Unit	1986	1987	1988
Arsenic	μg/L	<5	<10	<5
Barium	μg/L	83	146	72-115
Beryllium	μg/L	-	-	<0.05
Cadmium	μg/L	<0.20	-	0.6-1.4
Chloride	mg/L	18-22	1-9	4-7
Chromium	μg/L	-	-	<3
Cobalt	μg/L	-	-	<40
Copper	μg/L	1-7	-	<10
Dissolved solids	mg/L	494-656	580-630	622-714
Fluoride	μg/L	248	172-178	204-314
Iron	μg/L	<100	190-2,010	2,110-3,840
Lead	μg/L	1	-	8-12
Manganese	μg/L	540-595	230-543	174-240
Mercury	μg/L	<0.05	<0.10	<0.05
Nickel	μg/L	-	-	<40
pH	-	7.4	7.2	7.1-7.4
Selenium	μg/L	<5	<10	<5
Silver	μg/L	<0.20	-	<0.2
Sulfate	mg/L	138-147	75-193	187-205
Temperature	°C	10.1-13.5	9.3-16.6	11.9-14.8
Zinc	μg/L	10-20	-	5-34
Tritium	pCi/L	<100-823	<100-140	<100-152
Benzene	μg/L	<5		
Toluene	μg/L	<5		
Ethylbenzene	μg/L	<5		
Xylene	μg/L	<5		
Trichloroethylene	μg/L	<10		
Perchloroethylene	μg/L	<10		
Dichlorobenzene	μg/L	<5		
Monochlorobenzene	μg/L	<5		
1,2,4-Trichlorobenzene	μg/L	<5		

APPENDIX E:

DRAFT GROUNDWATER MONITORING NETWORK GUIDANCE FROM THE ILLINOIS ENVIRONMENTAL PROTECTION AGENCY, DIVISION OF LAND POLLUTION CONTROL*

The following outlines the general requirements for a groundwater monitoring network for an existing state-permitted facility. Facilities applying for horizontal expansions or for developmental permits are subject to Section 807.316 of Title 35: Subtitle G requirements and should refer to the Agency's Waste Management Facilities Design Criteria.

A. When proposing a groundwater monitoring network, the facility must be able to justify the proposed network by preparing a site-specific geological and hydrogeological report. The preparation of this report may necessitate a substantial amount of field work. This report must be prepared by a qualified geologist or geotechnical engineer and should include, at a minimum, the following:

1. A sufficient number of borings located in a manner that accurately represents the geological variations of the site. All test borings must be properly plugged and documented. Instructional information on test boring and monitoring well abandonment is included in the attachment [Table E.1]. Test borings should be continuously sampled and extend 30 ft below the bottom of the maximum depth of the landfill invert and include where water was first encountered during the test boring, the water levels after the test boring was completed and allowed to stabilize for 24 hours, geologic descriptions of the units encountered, the surveyed land surface elevation, and the test boring location. Sieve analysis should be performed on samples from the units proposed for monitoring. This will aid in approximating permeability and porosity values and in determining a proper screen and gravel/sand pack size before well installation. Textural classifications, particle size distribution curves, hydraulic conductivity, and ion-exchange capacities shall be determined for all unconsolidated material types present at the facility.

2. Cross sections depicting the stratigraphic relationships between the facility and the subsurface materials. The minimum number of cross sections at a site is two. The cross sections should intersect with the smallest angle of intersection of no less than 45° and extend up to the borders of the site.

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*This appendix presents draft guidance (dated Feb. 2, 1987) received from the Illinois EPA. Except for reformatting and changes in punctuation and spelling, it is presented essentially as received.

TABLE E.1 Illinois EPA Procedures for Plugging Monitoring Wells

Well Construction	Plugging Procedure
Unconsolidated sediment wells	
Wells backfilled with cement grout above bentonite seal and/or sandpack and Wells of unknown construction	1. Cut casing off at desired depth. 2. Mix near-cement slurry (5 gal water per 95-lb bag of cement). 3. Insert tremie pipe (1-in. i.d. PVC) into well and extend to bottom. 4. Slowly pump slurry under low pressure through tremie pipe. 5. Slowly withdraw tremie pipe while pumping, ensuring that the pipe bottom remains below pure slurry. 6. Continue slow pumping until all the formation water and watery slurry mix is displaced from top of casing.
Wells backfilled with soft sediment (cuttings) above bentonite seal and/or sandpack	1. Knock out and remove thin surface concrete plug, if present. 2. Re-auger entire length of well. 3. Remove well casing from re-augered borehole. 4. Mix near-cement slurry (5 gal water per 95-lb bag cement). 5. Insert tremie pipe (1-in. i.d. PVC) into augers and extend to bottom. 6. Slowly pump slurry under low pressure through tremie pipe. 7. Continue slow pumping until all the formation water and watery slurry mix is displaced from top of casing. 8. Slowly withdraw tremie pipe, ensuring that bottom of pipe remains below pure slurry. 9. Pull a flight of augers (5 ft if materials are unstable and hole collapse is likely or 10 ft if collapse is unlikely). 10. Top off cement slurry after each flight is removed.
Bedrock wells	1. Cut casing off at desired depth. 2. Mix near-cement slurry (5 gal water per 95-lb bag cement). 3. Insert tremie pipe (1-in. i.d. PVC) into well and extend to bottom. 4. Slowly pump slurry under low pressure through tremie pipe. 5. Slowly withdraw tremie pipe while pumping, ensuring that the pipe bottom remains below pure slurry. 6. Continue slow pumping until all the formation water and watery slurry mix is displaced from top of casing.

Source: Illinois EPA 1987.

3. A detailed description of all water-bearing units presently used or potentially usable as a source of water, including depth to and the areal extent of the aquifer(s), direction of flow, and the importance as a water supply.

4. A determination of groundwater fluctuations and aquifer characteristics, including flow directions, gradients, and hydraulic conductivities of water-bearing units beneath the site. In addition, seepage velocities of the groundwater through the aquifer(s) should be approximated based upon the preceding information.

5. Regional and local sources affecting groundwater flow at the site. Examples include recharge and depletion sources within one mile, such as lagoons, lakes, and wells.

6. Present groundwater surface map of the site in the form of a groundwater piezometric contour map. Datum should be referenced to mean sea level.

7. An assessment of the current groundwater quality at the site, including the facility's impact on groundwater quality, if applicable.

B. The groundwater system shall include:

1. Monitoring well(s) that yield groundwater samples that best represent the quality of ambient groundwater unaffected by the monitored facility.

2. Monitoring wells that yield groundwater samples that best represent the quality of groundwater passing beneath/through the facility.

3. An assessment of the proposed groundwater monitoring network based upon the geologic and hydrogeologic report required for paragraph A above. The assessment shall demonstrate that the proposed number, locations, and screening intervals of the monitoring wells are adequate to show background water quality and "immediately" (during the next scheduled sampling event) detect any point source release into the groundwaters of the state.

4. The above installed wells must be able to yield groundwater samples of a significant quantity for the completion of the required analyses within 24 hours after removing the appropriate volumes of water in the well casing from the wells (1 to 3 volumes, depending upon well recharge).

C. If a facility contains more than one regulated unit (individually permitted areas), separate groundwater monitoring systems are not required. The only additional requirement is that the monitoring program should be able to determine which area is responsible for the potential contaminant release and determine the characteristics of such a release at the waste boundary(ies).

D. Monitoring well construction:

1. The casing material(s) used must be such that it minimizes the well casing's effect on the analytical tests conducted on the water sample (any type of casing requiring solvent-cement type couplings may not be used). When organics are the contaminant of concern, the well casing material, as well as the well screen material, must be stainless steel (SS 316 or 304) or teflon. This casing must have an inside diameter of not less than 2 in. or more than 4 in.

2. The well must be screened at an appropriate interval to include relatively permeable zones encountered. The well screen must be of a manufactured type and not less than 2 ft or more than 10 ft in length.

3. The annular space (i.e., the space between the bore hole and the well casing) along the screened section must be packed with silica sand or gravel 2.5-3 times larger than the 50% grain size of the zone being monitored. The top of the sand- or gravel-packed zone shall not extend past 2 ft above or below the well screen.

Note: In settings where the native materials are sand and gravel and will readily cave around the well screen, an artificial gravel pack may not be necessary.

4. The annular space above the screened section must be sealed with hydrated bentonite to prevent the contamination of samples and the groundwater. This seal must be properly located and be at least 2 ft thick.

5. The annular space above the seal should be backfilled with expanding cement grout with 1% bentonite, by weight, added to the appropriate amount of water before being added to the cement or 5% bentonite, by volume, added to the cement before mixing with water.

6. All wells must be vented. The portion of the well casing extending above the ground surface must be protected to minimize damage or tampering. These precautions should include a protective casing with a locking cap and a concrete seal extending above the ground surface which is sloped away from the well casing so that surface water will be diverted away from the well casing and bore hole. The concrete cap shall extend down below the frostline (per diagram) [see Fig. E.1].

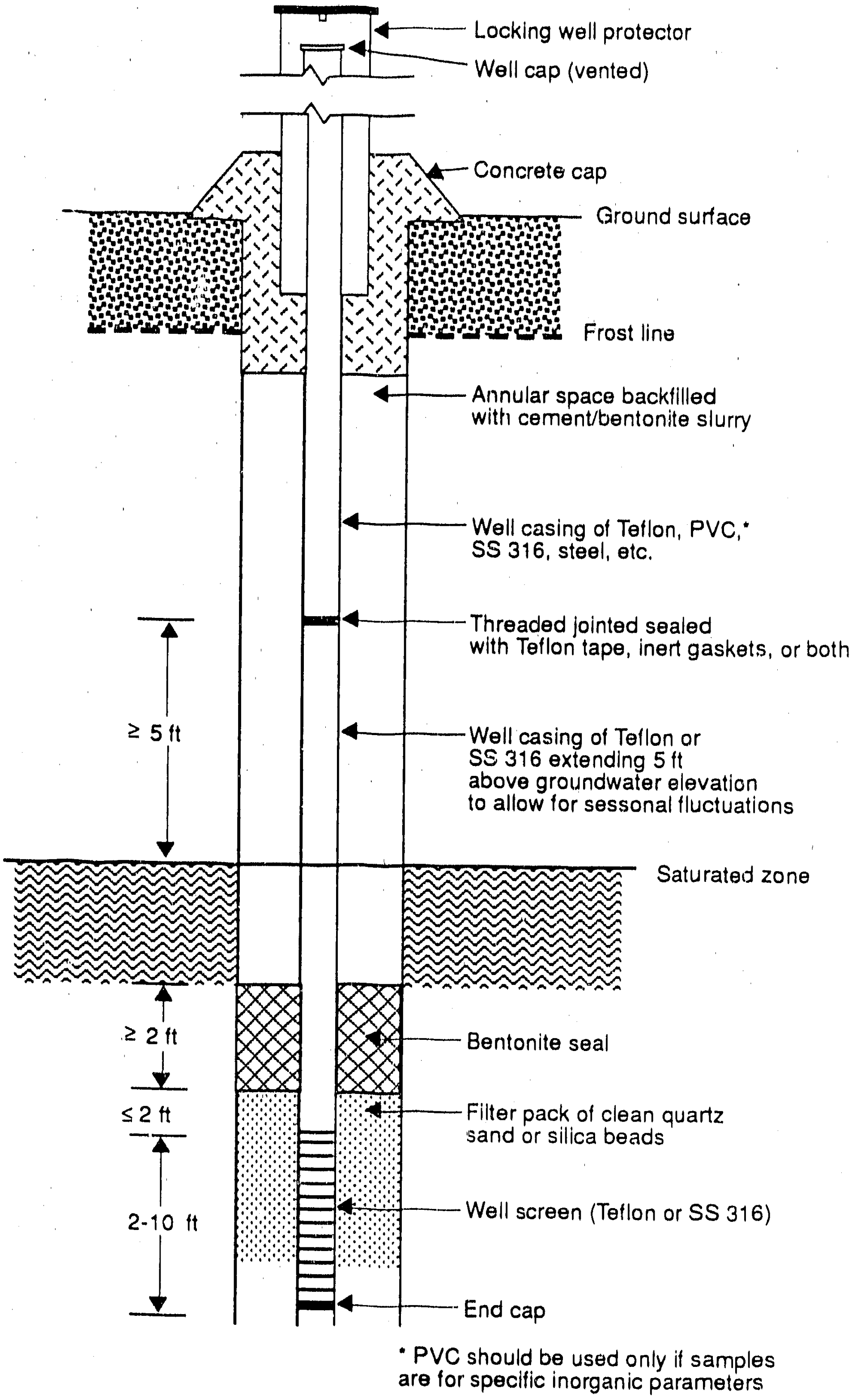


FIGURE E.1 Diagram of a Monitoring Well for a State-Permitted Facility (Source: Modified from Illinois EPA 1987)

7. After the monitoring well has been constructed and allowed to sit for 24 hours (this allows the cement grout to set properly before development), the well must be adequately developed to minimize turbidity within the well and increase flow into the well. To establish proper groundwater sampling protocol, a test must be conducted at each monitoring well to determine hydraulic conductivity near the well. The test method (i.e., slug tests, pumping tests) used and results must be submitted to the Agency. This test should be conducted after the well is developed.

8. All monitoring wells must have boring logs and well completion (as built) diagrams that have been surveyed by a registered surveyor and reported to the Agency in MSL. [See Fig. E.2.] Also, all test borings should have the elevations surveyed and reported in MSL (±0.01 ft).

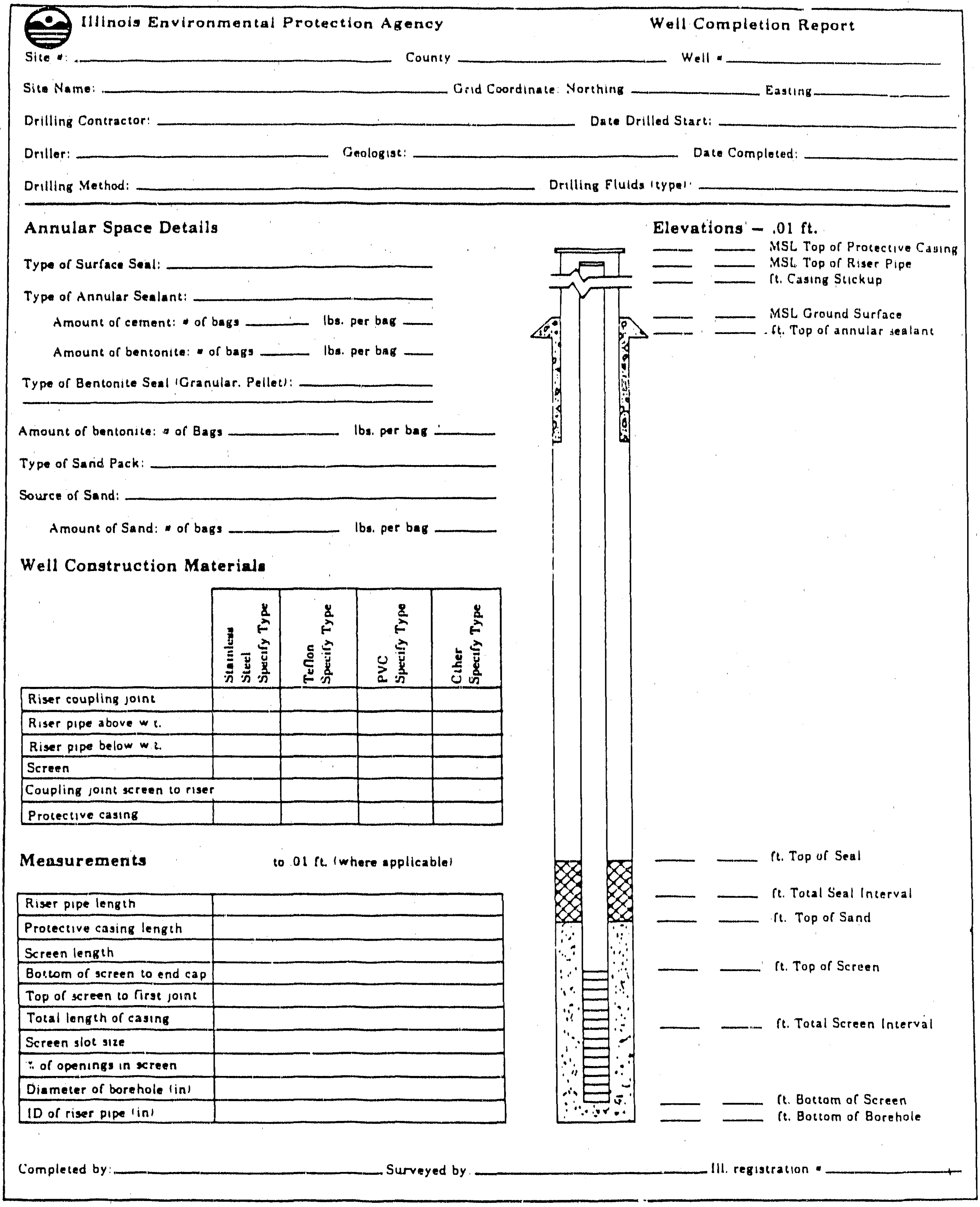
9. A scale drawing showing monitoring well and test boring locations. The drawing should also show buildings, roads, the site's property boundaries, areas permitted for waste disposal, and currently filled areas. In addition, a cartesian coordinate grid for the site should be established and shown on the map, and all test borings and monitoring wells should have coordinates surveyed and reported (i.e., establish a grid system).

E. Reports on the proposed groundwater monitoring program and site hydrogeology should be prepared and submitted:

1. The proposed groundwater monitoring program and hydrogeologic report should be submitted to the Agency with a supplemental permit application.

2. The monitoring program must include quarterly sampling (four times a year) of the monitor wells. Four quarters (one year) of *background* (initial water quality) parameters are required for new monitoring points. When a monitoring well is being replaced, the replacement well may not be required to sample background parameters if the construction details of the old well are known and the new well is screened in the same stratigraphic unit and is installed next to the old well's previous location. If the replacement well does not meet the requirements that may exempt it from background parameter sampling, one quarter of background parameters may be adequate to establish initial groundwater quality for the well.

After background parameters (initial groundwater quality) for the monitoring wells have been established, the monitoring program should call for quarterly sampling of *routine* parameters. The Agency reserves the right to add additional parameters for routine or background sampling. The lists of routine and background parameters for groundwater monitoring are included in the attachment [see Table E.2].



Illinois Environmental Protection Agency

Well Completion Report

Site #: County Well #

Site Name: Grid Coordinate: Northing Easting

Drilling Contractor: Date Drilled Start:

Driller: Geologist: Date Completed:

Drilling Method: Drilling Fluids (type):

Annular Space Details

Type of Surface Seal:

Type of Annular Sealant:

Amount of cement: # of bags lbs. per bag

Amount of bentonite: # of bags lbs. per bag

Type of Bentonite Seal (Granular, Pellet):

Amount of bentonite: # of Bags lbs. per bag

Type of Sand Pack:

Source of Sand:

Amount of Sand: # of bags lbs. per bag

Elevations – .01 ft.

MSL Top of Protective Casing

MSL Top of Riser Pipe

ft. Casing Stickup

MSL Ground Surface

ft. Top of annular sealant

ft. Top of Seal

ft. Total Seal Interval

ft. Top of Sand

ft. Top of Screen

ft. Total Screen Interval

ft. Bottom of Screen

ft. Bottom of Borehole

Well Construction Materials

	Stainless Steel Specify Type	Teflon Specify Type	PVC Specify Type	Other Specify Type
Riser coupling joint				
Riser pipe above w.t.				
Riser pipe below w.t.				
Screen				
Coupling joint screen to riser				
Protective casing				

Measurements to .01 ft. (where applicable)

Riser pipe length	
Protective casing length	
Screen length	
Bottom of screen to end cap	
Top of screen to first joint	
Total length of casing	
Screen slot size	
% of openings in screen	
Diameter of borehole (in)	
ID of riser pipe (in)	

Completed by: Surveyed by: Ill. registration #

FIGURE E.2 Example of an Illinois Well Completion Report (Source: Illinois EPA 1987)

TABLE E.2 Routine and Background Analytic Parameters for Groundwater Monitoring in Illinois

Parameter	Symbol	Unit
Routine		
Temperature of water sample, field-measured and unfiltered	-	°F
Specific conductance, field-measured and unfiltered	SC	μmho
pH, field-measured and unfiltered	-	standard unit
Elevation of groundwater surface	-	ft above or below MSL
Depth to water	-	ft below land surface
Well depth elevation[a]	-	ft above or below MSL
Depth to water	-	ft below measuring point
Alkalinity, total lab-measured	-	mg/L as $CaCO_3$
Total organic carbon	TOC	mg/L as carbon
Chloride, dissolved	Cl	mg/L
Sulfate, dissolved	SO_4	mg/L
Residue on evaporation at 180°C	ROE	mg/L
Background		
Temperature of water sample, field-measured and unfiltered	-	°F
Specific conductance, field-measured and unfiltered	SC	μmho
pH, field-measured and unfiltered	-	standard unit
Elevation of groundwater surface	-	ft above or below MSL
Depth to water	-	ft below land surface
Well depth elevation	-	ft above or below MSL
Depth to water	-	ft below measuring point
Alkalinity, total lab-measured	-	mg/L as $CaCO_3$
Ammonia, dissolved	NH_3+NH_4	mg/L as nitrogen
Nitrate-nitrite, dissolved	N	mg/L
Phosphorus, dissolved	P	mg/L
Total organic carbon	TOC	mg/L as carbon
Cyanide, total unfiltered	Cn	mg/L
Calcium, dissolved	Ca	mg/L
Magnesium, dissolved	Mg	mg/L
Sodium, dissolved	Na	mg/L
Potassium, dissolved	K	mg/L
Chloride, dissolved	Cl	mg/L
Sulfate, dissolved	SO_4	mg/L
Fluoride, dissolved	F	mg/L
Arsenic, dissolved	As	μg/L
Barium, dissolved	Ba	μg/L

TABLE E.2 (Cont'd)

Parameter	Symbol	Unit
Background (cont'd)		
Boron, dissolved	B	µg/L
Cadmium, dissolved	Cd	µg/L
Chromium, dissolved	Cr	µg/L
Iron, dissolved	Fe	µg/L
Lead, dissolved	Pb	µg/L
Manganese, dissolved	Mn	µg/L
Nickel, dissolved	Ni	µg/L
Silver, dissolved	Ag	µg/L
Zinc, dissolved	Zn	µg/L
Selenium, dissolved	Se	µg/L
Phenols, total unfiltered	-	µg/L
Residue on evaporation at 180°C	ROE	mg/L
Mercury, dissolved	Hg	µg/L

[a] Should be reported annually.

Source: Illinois EPA 1987.

APPENDIX F:

MONITORING WELL DESIGN AND CONSTRUCTION RECOMMENDATIONS OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY

In this time of environmental awareness, appropriate design and construction of environmental monitoring wells is critical. If the wells do not meet accepted regulatory standards, data obtained from them may be declared invalid by a regulatory agency. To avoid this possibility, all monitoring wells installed at ANL should meet minimum regulatory requirements. The following summary of monitoring well design and construction protocol is based on U.S. EPA (1989) recommendations and meets both federal and state of Illinois regulatory requirements.

F.1 DRILLING METHODS

A number of methods can be used to drill and install groundwater monitoring wells. The method employed should be selected to minimize the disturbance of subsurface materials and avoid inadvertent contamination of the subsurface and groundwater. The five most commonly used methods for drilling and installing groundwater monitoring wells are: (1) air rotary, (2) water rotary, (3) cable tool, (4) hollow-stem continuous auger, and (5) solid-stem continuous flight auger. Each of these drilling methods has its advantages and disadvantages. Hollow-stem augers are preferable for drilling shallow monitoring wells at ANL because they allow collection of geologic cores from known depths. Solid-stem augers are a distant second choice.

Hollow-stem augers are most commonly used for construction of monitoring wells in unconsolidated materials less than 150 ft thick. This method does not require the use of drilling fluids (muds), which can plug up silty formations and affect water sample analyses. Drilling fluids can also increase the disturbance of the geologic material penetrated during drilling. The maximum diameter of a well that can be constructed with a hollow-stem auger drill is 4 in.

Normal well drilling practices call for the well to be drilled to its designated depth, which usually is the first permeable water-bearing zone encountered. The drilling equipment is then removed from the well bore, and the well is completed by installing the screen, blank casing, gravel filter pack, and annular sealant. The well should be completed at a depth sufficient to allow for seasonal water-table fluctuations. In formations where the borehole will stand open, the well is completed after the auger flights are removed from the borehole. In formations where the borehole will not stand open, the well is completed inside the hollow-stem auger prior to its removal from the ground.

The well completion method often depends on the subsurface geologic conditions and the amount of groundwater encountered. In some cases, a well bore can stay open, especially when drilled in heavy clay soils where only a limited amount of groundwater is encountered. However, when the clay becomes wet, it may collapse into the well bore, causing the hole to close as soon as the augers are removed.

A monitoring well is only as good as its completion. Therefore the driller must be sure that the well is completed according to specifications. Precautions have to be taken so as not to adversely affect the integrity of the well when it is being constructed, especially when constructing the well inside the hollow-stem auger. If precautions are not taken, the screen may accidentally be pulled up from its designated depth when the auger flights are removed. If for this or any other reason the construction of the well is suspected of being inadequate, the screen and casing will have to be reinstalled. This may mean pulling and reinstalling the casing or redrilling the well and installing the casing.

F.2 WELL CASING AND SCREEN

A variety of construction materials are available for the casing and well screen, including polytetrafluorethylene (teflon), steel (stainless, black, or galvanized), polyvinyl chloride (PVC), polyethylene, epoxy biphenol, and polypropylene. Some of these materials may affect the quality of groundwater samples. In addition, some may not have the long-term structural characteristics required for monitoring wells. For example, steel casing deteriorates in corrosive environments; PVC deteriorates when in contact with ketones, esters, and aromatic hydrocarbons; and polyethylene deteriorates in contact with oxidizing acids, aliphatic hydrocarbons, and aromatic hydrocarbons. Studies have shown that deterioration of the screen and casing material may affect the quality of groundwater samples collected. Therefore, it is very important that the casing and screen are constructed of material compatible with suspected chemicals in the groundwater.

The U.S. EPA (1989) recommends that the monitoring well screen and those portions of the well casing in the saturated zone be constructed of materials that have proven chemically and physically stable, such as teflon and stainless steel 316. Other noninert material, such as steel, PVC, polyethylene, and polypropylene, may be used for casing the well above the saturated zone.

The plastic pipe sections must be flush threaded or have the ability to be connected by another method that will not introduce contaminants such as glue or solvents into the well.

Normally, either 2- or 4-in.-interior-diameter well casing is used in monitoring well construction. Larger casing diameters may be necessary where purging or sampling equipment is used or where the well is completed in a deep formation. Upon completion, the casing should extend from 1 to 3 ft above the surface of the ground.

The size of the well screen must be adequate to allow sufficient quantities of groundwater to flow into the well for sampling. It should be designed so as to minimize the passage of formation materials (turbidity) into the well, and it should have sufficient structural integrity to prevent the collapse of the screen.

For wells constructed in unconsolidated material, the intake of the monitoring well should consist of a screen or slotted casing with openings sized to ensure that the surrounding geological material does not enter the well during development.

Commercially manufactured screens and slotted casing should be used. Screens should not be slotted in the field. If the nature and particle size of the aquifer material is not known before the drilling takes place, several sizes of slotted well screens should be on site to ensure that the correct screen can be placed in the well.

At ANL, most of the shallow monitoring wells will be completed in silts and clays. Therefore, a No. 10 screen size should be used.

The U.S. EPA does not make any recommendations regarding well-screen length except that it should depend on the variability of the subsurface formations and the contaminant being monitored. Highly variable formations require a shorter well screen, which allows sampling of discrete portions of the formation. Certain hydrogeological settings -- for example, widely fluctuating water levels -- necessitate the use of longer well screens. Formations with low hydraulic conductivities may also necessitate the use of longer well screens to allow sufficient amounts of formation water to enter the well for sampling. Normally, well screens no longer than 5-10 ft are installed.

The chemical processes of dispersion and sorption greatly influence the potential contaminant migration pathways within an aquifer. To monitor for heavy metals, the screened interval should be just above the confining layer. For monitoring of light organics or hydrocarbons, the screened interval should be at the water-table/capillary-zone interface.

F.3 FILTER PACK AND ANNULAR SEALANT

To improve the performance of the monitoring well, the geological material immediately around the well screen is removed and replaced by a chemically inert, well-rounded, and dimensionally stable filter pack, such as clean quartz sand, silica, or glass beads. The filter pack must be sized to prevent most of the surrounding geological material from entering the well screen. The size of the screen opening is in turn selected to prevent about 90% of the filter pack from entering the well casing after development. Material used should be 2.5-3 times larger than 50% of the grain size of the zone being monitored. The U.S. EPA also recommends that the filter pack not extend more than 2 ft above the top or below the bottom of the base of the well screen.

Filter packing is especially advantageous when (1) the sediments are highly uniform and fine-grained or are highly laminated or (2) all the materials to be used in the well construction must be on site before drilling begins.

To prevent the migration of contaminants from the surface or intermediate zones to the sampling zone or prevent cross contamination between strata, the materials used to seal the well bore above the filter pack must be chemically resistant to ensure seal integrity during the life of the monitoring well. These materials should also be chemically inert so as not to affect the quality of the groundwater samples.

Proper construction of the annular sealant is very important. At a minimum, 2 ft of certified coarse-grit sodium bentonite should immediately overlie the filter pack. Where the saturated zone extends above the well screen, only certified coarse-grit sodium bentonite should be used. Above the bentonite seal, a cement and bentonite mixture, bentonite chips or pellets, or antishrink cement mixture should be used as the annular sealant extending into the unsaturated zone to a point just below the frost line. A cap of concrete should extend above the frost line and blend into a cement apron that slopes away from the outer edge of the borehole.

The untreated sodium bentonite seal should be placed around the casing either by dropping it directly down the borehole, or, if a hollow-stem auger is used, putting the bentonite between the casing and the inside of the auger stem. Both of these methods present a potential for bridging (the creation of air bubbles that prevent the formation of a tight seal). In shallow monitoring wells, a tamping device should be used to reduce this potential. In deeper wells it may be necessary to pour a small amount of formation water down the casing to wash the bentonite down the hole.

The cement-bentonite grout should be prepared using formation water and placed in the borehole using a tremie pipe. The cement-bentonite grout should extend to the base of the frost zone. The tremie method ensures a good seal for the borehole from the bottom. The cement-bentonite grout should be prepared using a mechanical mixing device.

The remainder of the well bore should be filled with a cement slurry. A cement collar, at least 2-ft in radius and sloping away from the casing, should be emplaced around the casing.

F.4 PROTECTIVE CASING

A steel protective casing should be installed around the well casing about 3 ft down into the grout and cement mixture and should extend about 3 ft above the ground surface. The aboveground portions of both the well casing and the protective casing should be vented. The aboveground portion of the protective casing should be painted a bright color, clearly marked, and equipped with a padlock.

Two steel posts or railroad ties should be placed in the ground around the well. These posts should extend a minimum of 4 ft above ground surface to protect the well from damage (e.g., if it were struck by a vehicle).

F.5 WELL DEVELOPMENT

After the well is constructed, it should be developed to remove fine particles to allow freer entry of water into the well. A variety of techniques are available to accomplish this. When flow is continuous in one direction, bridging of particles is common. To be effective, these techniques require reversals or surges in flow to avoid bridging by particles. Reversals and surges can be created by using surge blocks, bailers, or pumps. Formation water should be used for surging the well. It may be necessary to use an outside source of water when developing a low-yielding water-bearing formation. This water should be chemically analyzed to evaluate its potential impact on the in-situ water quality. The driller should not use air to develop the well.

A sufficient number of well volumes of water should be evacuated to ensure that the samples collected represent ambient conditions. If water is removed during the development process, it should be discharged at a point downgradient to all sampling points. Water levels should be measured after completion of well development and as many times as is necessary thereafter to determine the static water level in each well. All water level measurements should be documented. A well completion report (Fig. E.2) should be made to include such pertinent information as well construction materials, elevation of the protective casing and ground surface, annular sealant and filter pack material, position of the well screen, and any other measurements.

The elevation (above MSL) of the monitoring well casing should be surveyed by a licensed professional surveyor to an accuracy of ±0.01 ft. Spatial locations should be surveyed to an accuracy of ±1.0 ft. The designations of the well and the point on the casing from which its elevation was determined should be clearly marked on each casing.

F.6 QUALITY ASSURANCE/QUALITY CONTROL

To avoid introducing contamination into the subsurface or groundwater, it is important that the drilling equipment be steam-cleaned before each use and between borehole locations. The casing and screen should be steam-cleaned prior to emplacement to ensure that all oils, grease, and waxes have been removed.

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