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2 GEOLOGY

ANL is located on a glacial till plateau that forms a complex hills and depressions forming the Valparaiso Moraine, which has a north trend. The glacial till covering the area consists of a heterogeneous mixt

ANL/EAIS/TM-28

Hydrological Conditions at the 317/319 Area at Argonne National Laboratory

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

Environmental Assessment and Information Sciences Division,
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

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HYDROLOGICAL CONDITIONS AT THE 317/319 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 317/319 Area 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, based on 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 317/319 Area is located between Meridian Road and the southern border of ANL. The 317 Area was commissioned in the late 1940s for the temporary storage of radioactive waste. Low- and high-level solid radioactive waste is stored in partially buried concrete vaults. Low-level radioactive waste awaiting shipment for off-site disposal is stored in aboveground steel bins north of the vaults. The 319 Area is an inactive landfill, located east of the 317 Area that was used for the disposal of general refuse, demolition debris, and laboratory equipment. Fluorescent light bulbs, chemical containers, and suspect waste were also placed in the landfill. Liquid chemical wastes were disposed of at each site in gravel-filled trenches called "French drains."

The 317/319 Area is underlain by a silty clay glacial till. Dolomite bedrock underlies the till at an average depth of about 19.5 m (64 ft). 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. At the time of this report, no chemical quality analyses had 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 17 to 58 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 eight new well clusters and three background wells, thorough record-keeping, sample collection and analysis during borehole drilling, slug testing to measure hydraulic conductivity, 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 hydrogeology of the glacial till underlying the 317/319 Area at Argonne National Laboratory (ANL) near Lemont, Illinois. The study was conducted by the Environmental Assessment and Information Sciences 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 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 317/319 Area, 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 1986, App. C summarizes draft groundwater monitoring guidance from the Illinois Environmental Protection Agency (Illinois EPA), and App. D 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 317/319 Area (Section 16) is located just south of Meridian Road on the southern border of ANL (Fig. 2).

1.1.1 317 Area

The 317 Area is a fenced area about 151.6 m (497.5 ft) by 201.2 m (660 ft). The area was commissioned in the late 1940s for the temporary storage of radioactive waste. Radioactive waste is stored in partially buried concrete vaults that were constructed in the early 1950s in parallel east-west rows (Fig. 3). The tops of the vaults extend about 0.9 m (3 ft) above the land surface. The northern row consists of three separate vaults: the north vault to the west, the map tube facility in the center, and the deep vault to the east. The southern row also contains three vaults. The vault dimensions are given in Table 1. Most of the vaults are used to store containers of intermediate- and low-level solid radioactive waste. The map tube facility stores small containers of highly radioactive waste. North of the vaults is a gravelled area used for the aboveground storage of steel bins containing low-level radioactive waste awaiting shipment for off-site disposal (Moos 1990).

An interior drainage system was built into the vaults to collect and dispose of water entering the vaults through leaks in the concrete walls. Water is channeled into a series of sumps and, before 1987, was drained to off-site outfalls through an underground

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 317/319 Area

FIGURE 3 Locations of Burial Vaults, Manholes, French Drains, Monitoring Wells, and Subsurface Cross Sections at the 317/319 Area (the inset at the upper left corner identifies the vaults)

**TABLE 1 Approximate Dimensions of Burial Vaults
at the 317/319 Area**

Vault	Length		Width		Depth	
	m	ft	m	ft	m	ft
North vault	30	100	5	15	3	10
Map tube facility	9	30	5	15	6	20
Deep vault	12	40	5	15	6.4	21
Southern vaults	30	100	5	15	3	10

sewer system. Footing drains placed around the exteriors of the map tube facility and deep vault also drain water into the sewer system. The northern vaults drain into manhole 1E, and the southern vaults drain into manhole 2E (Fig. 3). Water from manhole 1E flows to manhole 2E. From these manholes, water then flowed through manhole 3E (Fig. 3) to an outfall that is now located on Waterfall Glen Forest Preserve property (ANL owned this property until 1973). Flow to this outfall was stopped in 1987 by the physical removal of manhole 3E and by the cutting and plugging of the sewer line about 150 ft south of manhole 2E (Moos 1990).

Currently, about 15,140 L (4,000 gal) of water is collected in manhole 2E each week. On an as-needed basis, about two or three times per week, ANL Waste Management Operations staff pump the water out of manhole 2E into a tanker truck. The water is then taken to Building 306 where it is tested for radioactivity before being discharged to the laboratory sewer system. Laboratory sewer effluent discharges into Sawmill Creek (Cheever 1988).

There are two RCRA-permitted facilities used to treat small amounts of hazardous nonradioactive waste within the 317 Area. The first, known as the "shoot and burn pile," is located southeast of the southwest vault. At this unit, containers of explosives or unstable wastes are placed on a 5-ft tall pile of sand and detonated, usually by rifle fire, and allowed to react. The residue is collected and disposed of off site. The second unit consists of a water reaction tank (built into the southwest vault) used to react alkali metals (Moos 1990).

During the early 1950s, a gravel-filled trench about 3-4 ft deep and 100-150 ft long was used to dispose of nonradioactive liquid chemical waste. Figure 3 shows the estimated location of the trench; its location is not apparent from current surface features in the area. The trench, known as a "French drain," was used for 4 or 5 years. Use of the trench was discontinued when a new French drain was constructed in the 319 Area (discussed in the following section). To date, no records describing the nature of the wastes poured into the French drain have been located. Waste Management personnel have said that a wide variety of wastes were probably disposed of in the drain,

including aromatic and aliphatic hydrocarbons, waste oils (possibly polychlorinated biphenyl [PCB] oils), halogenated hydrocarbons, and various solvents and heavy metals (Moos 1990).

1.1.2 319 Area

The 319 Area, about 122 m (400 ft) by 201 m (660 ft), is located east of the 317 Area (Fig. 3). It is an inactive landfill that was operated from the mid-1950s to 1968 and used for the disposal of general refuse, demolition debris, and laboratory equipment. Fluorescent light bulbs, chemical containers, and suspect waste* were also placed in the landfill. The landfill consists of as many as six trenches 10-15 ft deep. After the trenches were filled, waste was accumulated in piles above grade, creating the mound observed in the northern portion of the site. In the late 1950s or early 1960s, a French drain was constructed into the fill materials in the northern area of the mound. The drain consisted of a gravel bed, possibly 6-8 ft below grade. A corrugated steel pipe was placed vertically onto the gravel bed and backfilled. A pit surrounding the pipe was created by using railroad ties. Liquid chemical wastes were poured into the pit until the landfill at the 800 Area, also containing a French drain, was constructed in 1966. To date, no records describing the wastes poured into the French drain have been located. It is likely that the drain received solvents, degreasing solutions, cleaning solutions, and waste oils (Moos 1990).

1.2 TOPOGRAPHY

The major topographic feature of the region is the Des Plaines River valley. The Des Plaines River, located about 914 m (3,000 ft) south of ANL (Fig. 1), has an elevation of 183 m (600 ft) above mean sea level (MSL), about 23 m (77 ft) below that at the 317/319 Area.

Figure 4 shows the topography of the 317/319 Area. The 317 Area surface gently slopes from the northwest, where the elevation is 211.5 m (694 ft) above MSL, to the southeast, where the elevation is about 206.4 m (677 ft). In the 319 Area, the northern portion contains a mound with an elevation of 213.7 m (701 ft) above MSL. The elevation decreases to 203.6 m (668 ft) at the southernmost portion of this area.

*Suspect waste is from areas where radioactive material was used and for which radioactive contamination is suspected but not verified. For example, small pipes were considered suspect due to possible exposure of their interiors to radioactive material although, due to their configuration, it could not be verified.

FIGURE 4 Topography of the 317/319 Area (Source: Modified from Intech Consultants 1987)

2 GEOLOGY

ANL is located on a glacial till plateau that forms a complex arrangement of hills and depressions forming the Valparaiso Moraine, 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. 5 shows the sequence of lithologic units in DuPage County.

2.1.1 Bedrock Geology

Silurian-age dolomite bedrock beneath the 317/319 Area occurs at an average depth of 19.5 m (64 ft) below the land surface (Will County Water & 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 till underlying the 317/319 Area 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; it was identified by the Illinois State Geological Survey (ISGS) in a study conducted at the Advanced Photon Source (APS) site at ANL, located about 1.1 km (3,600 ft) northwest of the 317/319 Area (Fig. 2) (Killey and Trask 1989). The base of the Lemont drift consists of dolomite boulders, gravel, and rock fragments (shale and dolomite) that overlie 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 the 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).

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	PLEISTOCENE				Fissure Fillings	Shale, sandy, brown to black
SILURIAN	NIAGARAN	Racine Waukesha Joliet	Niagaran aquifer		0-170	Dolomite, very pure to highly argillaceous, silty, cherty; reefs in upper part
	ALEXANDRIAN	Kankakee Edgewood	Alexandrian aquifer		0-90	Dolomite, shaly, and shale, dolomitic; maroon, green, pink Dolomite, glauc.; thin grn. shale partings Dolomite, argillaceous, silty and/or sandy, cherty
	CINCINNATIAN	Neda Maquoketa	Confining beds of the Maquoketa Formation		0-20 85-230	Shale, red; oolites Shale, silty, dolomitic, greenish gray, weak (Upper unit) Dolomite and limestone, white, light gray interbedded shale (Middle unit) Shale, dolomitic, brown, gray (Lower unit)
ORDOVICIAN	MOHAWKIAN	Galena Decorah Platteville	Galena-Platteville		300-350	Dolomite, and/or limestone, cherty Dolomite, shale partings, speckled Dolomite and/or limestone, cherty, sandy at base
	CHAZYAN	Glenwood St. Peter	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
	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 Franconia Ironton Galesville	Trempealeau Franconia Ironton-Galesville		80-190 70-100 175-200	Dolomite, white, fine grained; geodic quartz; sandy at base Dolomite, sandstone and shale, glauconitic, green to red, micaceous Sandstone, fine to coarse grained, well sorted; upper part dolomitic
		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		2,000±	Sandstone, coarse grained, white, red in lower half; lenses of shale and siltstone, red, micaceous
Precambrian						

FIGURE 5 Stratigraphy and Geohydrology of DuPage County (Source: Zeisel et al. 1962)

In the drillers' logs for the 317/319 Area, no distinction was made between the Lemont drift and the clay till. Since the two tills are mainly distinguished by the 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.

2.1.3 Site Stratigraphy

Drillers' or geologists' logs describing the geologic materials encountered during drilling are available for 14 of the 16 monitoring wells and the 2 boreholes (8 and 9) drilled in the 317/319 Area (see Fig. 3 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 and 7 (see Fig. 3 for cross section locations). The log for well 7 did not contain enough detail to be useful in this endeavor. No boring data were recorded for wells 12 and 13. Therefore, only two cross sections were made across the site.

The cross sections show that the 317/319 Area is underlain by a silty clay till that is brown near the surface and grades with depth to a gray silty clay containing traces of gravel and sand. A sand lens is present at depths of 2.8 m (9.2 ft) and 5.3 m (17.4 ft) at wells 5 and 2, respectively. The sand lens does not appear to be continuous throughout the southern part of the site because it does not extend to western well 6 or eastern well 3. A gravel and sand layer was identified at depths of 6.1 m (20 ft) at both wells 10 and 11 and 9.8 m (32 ft) at well 4. Logs for borehole 9 record a thin sand lens at 6.7-7.3 m (22-24 ft). Soil boring logs for well 1 also show a sand lens, consisting of coarse- to medium-grained sand with some coarse gravel, at a depth of about 5.8 m (18.5 ft). This suggests that the sand and gravel lens at about 6 m is continuous across the site. Because logs were not recorded for wells 12 and 13, the northern portion of the site cannot be adequately characterized.

Two wells (DH-3 and DH-4 -- see Fig. 3) have been drilled into the Silurian dolomite bedrock. Depths to the bedrock at wells DH-3 and DH-4 were 21.0 m (69 ft) and 18.0 m (59 ft), respectively (Will County Well & Pump Co. 1983). At well DH-3, the drillers' log records two sand and gravel layers at depths of 1.5-6.1 m (5-20 ft) and 10.7-21.0 m (35-69 ft). At DH-4, two sand and gravel layers were encountered at 2.1-6.1 m (7-20 ft) and 9.8-18.0 m (32-59 ft).

2.2 HYDROLOGY

2.2.1 Surface Water

Surface drainage at the 317/319 Area is through a small ditch flowing southeast (see Figs. 3 and 4) toward the Des Plaines River, which is located about 1.2 km (0.7 mi) to the south.

FIGURE 6 Geologic Cross Section A-A'

FIGURE 7 Geologic Cross Section B-B'

2.2.2 Groundwater

Groundwater under ANL and the 317/319 Area 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. 5). The Niagaran dolomite occurs at depths of greater than 18.0 m (59 ft) in the 317/319 Area. Figure 8 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 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). Vertical leakage through the glacial till recharges the aquifer.

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 317/319 Area migrating downward in groundwater may be greatly retarded by the slow rate of percolation through the nearly impermeable clay in the glacial till; however, contaminants could migrate via fractures and the sand and gravel lenses present in the clay till and reach the dolomite aquifer. 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 below the site flows southeast, discharging into the Des Plaines River about 914 m (3,000 ft) from the site. Since no drinking water supplies are located between the 317/319 Area and the river (the area is a forest preserve), the potential for human consumption is considered to be low. Figure 9 shows a 1960 illustration of the piezometric surface of water in the Silurian (Niagaran) dolomite at ANL. More recent data are not available. The two depressions in the piezometric surface below the ANL site are the result of removal of water from the aquifer by three ANL domestic water supply wells.

FIGURE 8 Approximate Elevation of the Niagara Dolomite Bedrock Surface at ANL (Source: Modified from Knowles et al. 1963)

FIGURE 9 Piezometric Surface of Groundwater in the Niagaran Dolomite at ANL, June 1960 (Source: Modified from Knowles et al. 1963)

3 GROUNDWATER CONDITIONS AT THE 317/319 AREA

3.1 EXISTING WELL NETWORK

As part of the environmental monitoring program at ANL, ESH has installed 15 groundwater monitoring wells around the 317/319 Area since 1986. One well was installed by the U.S. Department of Energy (DOE) Environmental Survey Team in 1987. Initially drilled to measure local groundwater elevations and possible inorganic chemical or radioactive contaminants in the groundwater, in recent years the wells have been used to monitor organic chemicals as well. See Fig. 3 for the well locations and App. A for available construction diagrams and drillers' and geologists' logs.

Wells 1 through 4 were installed in September 1986. Because the general groundwater flow was assumed to be to the south, well 1 was installed north of the 317/319 Area as a control well. Wells 2 through 4 were placed on the southern perimeter to monitor water leaving the site. Well 4 has been dry since its emplacement. Depths of these wells range from 11.3 to 12.5 m (37 to 41 ft), and they are screened at the bottom with 1.5-m (5-ft) screens.

In July 1987, wells 5 and 6 were drilled along the southern perimeter of the site. Well 5 was drilled to a depth of 11 m (36 ft), but, due to collapse at the bottom of the hole, it was completed at a depth of 6.2 m (20.5 ft); it has been dry since its emplacement. Well 6 was drilled to a depth of 12.2 m (40 ft). Both wells were screened at the bottom with 1.5-m (5-ft) screens.

Well 7 was installed in the 319 landfill area by the DOE Environmental Survey Team in August 1987 and drilled to a depth of 19.2 m (63 ft). It was screened at the bottom with a 3.0-m (10-ft) stainless-steel screen 4 in. in diameter. Well 7 has been dry since its emplacement.

Boreholes were drilled to 9.1 m (30 ft) at locations 8 and 9 just south of the northern vaults in April 1988. After split-spoon samples were taken, the holes were filled with grout.

Wells 10 and 11, located about 6 m (20 ft) south of the southern vaults, were drilled in July 1988 to 9.3 m (30.5 ft). These wells were screened at the bottom with 3-m (10-ft) screens.

Wells 12 and 13, located on the northwest corner of the 317 Area fence, were drilled in September 1988 to depths of 11.7 m (38 ft). No further information is available regarding these wells. Also in September 1988, wells DH-3 and DH-4 were drilled into the dolomite at total depths of 24.1 m (79 ft) and 21.0 m (69 ft), respectively. The DH wells are cased with carbon steel and are not screened.

In August 1989, a new well was drilled near well 3 and two replacement wells were drilled near well 5. The new well near well 3 was drilled to a depth of 4.6 m (15 ft) and was designated well 3-15. Two replacement wells for well 5 were drilled to depths of 4.3 m (14 ft) and 7.6 m (25 ft) and designated as well 5-15 and well 5-25, respectively.

The old well 5 was sealed. A 4.6-m (15-ft) borehole was drilled near well 2 in an effort to locate and place a well in one of the sand/gravel lens found at that depth; because the soil was dry and the sand layer was not found, the well was not completed.

The depths of the monitoring wells drilled into the glacial till range from 4.6 to 19.2 m (15 to 63 ft). Except for wells 7, DH-3, and DH-4, polyvinyl chloride (PVC) casing and screens were used. The wells were screened at the bottom with 1.5-m (5-ft) screens (except for wells 7, 10, and 11, which have 10-ft screens) and packed with either pea gravel or silica sand over intervals ranging from 2.0 to 7.2 m (6.5 to 23.5 ft). Table 2 provides a summary of the design and construction of monitoring wells at the 317/319 Area. Figure 10 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 occurs at shallow depths. The fact that some wells yield water and others do not at the same depth (e.g., wells 2 and 3) indicates that the water table drops in places, possibly due to differences in hydraulic conductivity. Since 1986, ESH has measured static water levels in the till wells quarterly (see 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 3 gives shallow water table elevations for four recent quarters (5/89, 3/89, 11/88, and 9/88), and Fig. 11 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 southeast, toward the river, although groundwater may flow to the east and south in some locales. Estimates of the hydraulic gradient range from 0.022 to 0.085.

3.3 RATE OF GROUNDWATER FLOW

3.3.1 Horizontal Flow

If groundwater flow is assumed to be 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,

TABLE 2 Summary of the Design and Construction of Monitoring Wells at the 317/319 Area

Well	Elevation (m above MSL)			Monitoring Zone (m)	May 1989 Depth to Ground-water (m)	Casing Diameter/ Material ^a	Packing Material
	Top of Casing	Ground Surface	Well Point	Bottom of Seal			
1	210.27	209.81	197.38	202.80	5.18	2 in./PVC	Pea gravel
2	209.63	209.17	197.34	200.64	3.66	2 in./PVC	Pea gravel
3	204.43	204.28	192.11	198.18	6.40	2 in./PVC	Pea gravel
4	203.86	203.70	197.22	194.56	2.14	2 in./PVC	Pea gravel
5	208.78	208.32	197.35	204.05	6.70	2 in./PVC	Pea gravel
6	208.00	207.54	195.35	197.48	2.13	2 in./PVC	Pea gravel
7	208.03	207.57	188.73	192.03	3.66	2 in./PVC	Pea gravel
10	208.60	208.14	199.33	206.01	7.17	2 in./PVC	Pea gravel
11	208.96	208.14	199.97	206.37	7.17	4 in./SS	Pea gravel
12	211.50	211.04	199.28	b	b	4 in./SS	#4 Silica sand
13	213.48	213.02	201.22	b	b	4 in./SS	Silica sand
3-25 ^c	204.74 ^d	204.28	196.66	198.79	2.13	2 in./PVC	Silica sand
5-25 ^c	208.78 ^d	208.32	200.70	203.90	3.20	2 in./PVC	Silica sand
5-15 ^c	208.78 ^d	208.32	204.05 ^f	206.49 ^f	2.44 ^f	2 in./PVC	Silica sand
DH-3	207.88	207.57	183.49 ^f	186.54 ^f	3.05 ^f	6 in./CS	f
DH-4	203.86	203.56	182.53 ^f	185.58 ^f	3.05 ^f	6 in./CS	f

^aCS = carbon steel, PVC = polyvinyl chloride, and SS = stainless steel.^bUnknown.^cIn 1990, well 3-25 was redesignated as well 3-1, well 5-25 as well 5-1, and well 5-15 as well 5-2.^dThe ground surface elevation for well 3-25 is estimated to be the same as that for well 3.

Elevations for wells 5-25 and 5-15 are estimated to be the same as that for well 5.

^eNot measured.^fDolomite wells DH-3 and DH-4 are open rock wells and have no screen. The casing was placed 1 ft into the formation. The length of the monitoring zone is assumed to be the same as the length of exposed dolomite.

FIGURE 10 Schematic Diagram of Well Point Elevations and Monitoring Intervals for All Monitoring Wells Completed in the Till at the 317/319 Area

TABLE 3 Well Point and Water Elevations of Monitoring Wells Completed in the Till at the 317/319 Area, 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	209.81	12.43	197.38	198.58	197.77	197.59	198.19
2	209.17	11.83	197.34	202.42	197.92	199.32	201.21
3	204.28	12.17	192.11	dry	dry	dry	192.98
6	207.54	12.19	195.35	198.49	198.41	199.66	200.46
10	208.14	8.81	199.33	203.79	204.79	205.40	205.02
11	208.50	8.53	199.97	201.70	202.25	204.10	202.82
12	211.04	11.76	199.28	202.58	201.59	201.87	202.58
13	213.02	11.80	201.22	205.05	206.19	207.50	207.43

^aWater-equivalent precipitation for the 30-day periods prior to the measurements was 59.2 mm for 9/88, 125.0 mm for 11/88, 47.2 mm for 3/89, and 24.6 mm for 5/89. The 1988 values are from the meteorological station at O'Hare International Airport, and the 1989 values are from the station at ANL.

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) northwest of the 317/319 Area (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.

By using the APS site values for hydraulic conductivity, the horizontal groundwater velocity at the 317/319 Area was estimated to range from 1.7×10^{-2} to 5.8×10^{-2} m/yr (17 to 58 cm/yr). For the calculation, the hydraulic gradient was assumed to range from 0.022 to 0.085 and the volumetric porosity (for clay) was assumed to be 50% (U.S. EPA 1989).

FIGURE 11 Groundwater Elevations at the 317/319 Area, May 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 flow. Nested wells are needed to quantify this downward component.

3.4 GROUNDWATER LEVEL FLUCTUATIONS

Figure 12 is a hydrograph showing water level variations for all monitoring wells completed in till in the 317/319 Area. Water levels, which have remained fairly stable over time, are generally lowest during the third and fourth quarters due to seasonal changes in precipitation and evapotranspiration. Water levels did not decline significantly in response to the 1988 summer drought (relative to summer 1987).

3.5 GROUNDWATER QUALITY

3.5.1 Detected Contaminants

Groundwater quality data for 1988 analyses for wells completed in the till are summarized in Tables 4 and 5. When this report was prepared, no chemical data were

FIGURE 12 Groundwater Elevations for Monitoring Wells Completed in the Till, 1986-1989 (the absence of a point on a curve indicates a quarter during which no measurements were made)

TABLE 4 Concentrations of Inorganic Analytes in Samples from Monitoring Wells at the 317/319 Area, 1988^a

Analyte	Unit	Well 1	Well 2	Well 3	Well 6	Well 10	Well 11	Well 12	Well 13
Arsenic	µg/L	<5	<5	<5	<5	<5-571	<5-450	14-280	<5
Barium	µg/L	40-54	18-90	54-69	36-67	112-1,920	310-2,120	327-811	138
Beryllium	µg/L	0.01-0.05	0.01-0.05	b	0.01-0.05	0.02-2.34	0.02-2.45	0.01-2.34	<0.05
Cadmium	µg/L	0.40-0.90	<0.20-0.40	0.7 ^c	<0.20-0.40	0.5-173	1.6-140	3.8-75.0	1.00
Chloride	mg/L	25-29	12-16	24 ^c	50-57	6 ^c	12 ^c	86 ^c	107
Chromium	µg/L	<1-20	2-20	10 ^c	<1-20	24-446	87-479	101-194	2
Cobalt	µg/L	20-40	20-40	b	20-40	40-519	40-504	67-210	40
Copper	µg/L	10-30	11-51	14 ^c	13-20	75-1,530	110-2,010	184-669	12
Fluoride	µg/L	154-236	110-140	144-188	138-212	162-164	258 ^c	162 ^c	136
Iron	µg/L	100-4,510	28-19,500	1,770-2,130	108-1,080	74,300-	4,390-	141,000-	1,660
Lead	µg/L	5-32	2-58	15 ^c	3-46	1,130,000	1,240,000	586,000	7
Manganese	µg/L	53-267	13-716	335-384	28-120	25-862	168-1070	142-340	399
Mercury	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel	µg/L	20-40	22-69	40 ^c	20-40	74-1,160	40-947	153-458	40
Selenium	µg/L	<5	<5	<5	<5	<5	<5	<5-16	<5
Silver	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	b	<0.2 ^c	<0.2
Sulfate	mg/L	158-190	80-90	75-77	119-124	80 ^c	24 ^c	156 ^c	108
Zinc	µg/L	5-60	5-86	5-14	5-20	250-3,240	140-3,390	450-1,240	200
Dissolved solids	mg/L	486-739	308-469	334-542	452-626	b	b	b	b
pH	-	7.0	7.3-7.4	7.1	7.2-7.3	6.2 ^c	6.7 ^c	7.2 ^c	7.1
Temperature	°C	9.5-12.8	10.0-12.5	12.4-12.5	10.0-12.5	10.0 ^c	10.0 ^c	10.0 ^c	10.0
Tritium	pCi/L	<100-327	213-336	1,388-1,681	<100-192	735-3,206	322-995	153-371	191-227
Strontium-90	pCi/L	<0.25	<0.25	0.6-0.7	<0.25	7.7-28.8	<0.25-0.6	<0.25	<0.25
Cesium-137	pCi/L	<1	<1	<1	<1	<1	<1	<1	<1

^aRanges are the maximum and minimum concentrations determined for two to four samples except for well 13, for which results represent only one sample analyzed.

^bNot measured.

^cValue represents the result of analysis on one sample only.

TABLE 5 Concentrations of Organic Analytes in Samples from Monitoring Wells at the 317/319 Area, 1988 ($\mu\text{g/L}$)

Well ^a	Compound	5/19/88	6/17/88	9/15/88	11/16/88
2	1,1-Dichloroethane	18	25	60	50, 45 ^b
	1,2-Dichloroethane	ND ^c	ND	ND	64, 60 ^b
	1,1,1-Trichloroethane	28	26	39	46, 49 ^b
	Chloroform	2.3	5.0	5.0	ND
	Carbon tetrachloride	ND	ND	6	16
3	1,1-Dichloroethane	ND	0.4	d	d
10	1,2-Dichloroethene	-	-	11 ^e	48 ^f
	Trichloroethene	-	-	8	105
11	1,1-Dichloroethane	-	-	170	8
	1,2-Dichloroethene	-	-	10	93 ^f
	1,2-Dichloroethane	-	-	21	ND
	1,1,1-Trichloroethane	-	-	160	ND
	Trichloroethene	-	-	36	ND
12	Diethylphthalate	-	-	<10	g
13	4-Methyl fluorene	-	-	-	g

^aOrganics were not found in wells 1 and 6.

^bResults represent duplicate analyses.

^cNot detected.

^dWell was dry (no sample collected).

^eBoth cis and trans isomers.

^fCis isomer only.

^gTentatively identified.

Source: Golchert and Duffy 1989.

available for the dolomite wells. Concentrations of metals (cobalt, copper, iron, lead, manganese, nickel, and zinc) are much higher in groundwater from wells 10, 11, and 12 than in other wells. According to Golchert and Duffy (1989), this is most probably due to the fact that the wells were not completely developed by the September sampling date and therefore may have contained an abundance of suspended solids to which the metals adsorbed.

Samples were collected quarterly in 1988 and analyzed for volatile organic compounds (VOCs). In September 1988, samples collected from all wells except well 13 were also analyzed for semivolatile organics, PCBs, and pesticides (Golchert and Duffy 1989). Table 5 shows the results of the VOC analyses. Trichloroethane, 1,1,1-trichloroethane, and 1,2-dichloroethane, present in wells 2, 10, and 11, represent material known to be disposed of in the 317/319 Area. The compounds 1,1-dichloroethane and cis-1,2-dichloroethene, also present in wells 2, 10, and 11, are thought to result from biodegradation of tetrachloroethene, trichloroethene, and 1,1,1-trichloroethane by microorganisms (Golchert and Duffy 1989). Small amounts of carbon tetrachloride and chloroform were found in well 2. No semivolatile organic compounds, PCBs, or pesticides were detected.

3.5.2 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 317/319 Area should answer questions regarding the physical characteristics (bulk density, particle density, organic content, porosity, and hydraulic conductivity) of the glacial till and the 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.

No well design and construction data are available for wells 12 and 13. Wells 4 and 7 have been consistently dry. These wells should be decommissioned and sealed.

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 be kept during the drilling of well bores and the installation of wells (see Table 6).

4.2 RECOMMENDATIONS

4.2.1 Definition of Subsurface Geology

In order to identify potential pathways of contamination, it is necessary to understand more completely the subsurface geology beneath the 317/319 Area. Needs for additional data are discussed in the following sections.

4.2.1.1 Soil Borings

Soil borings should be drilled at discrete locations near the French drains. These will provide information on subsurface characteristics as well as data on the vertical extent of contamination near the drains.

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, especially in the 319 Area. During the drilling of new wells in

TABLE 6 Information That Should Be Logged in the Field during the Drilling of Well Bores

General

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

Information Columns

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

Narrative Description

Geologic observations

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

Drilling observations

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

Source: National Well Water Association 1986.

the 317/319 Area, continuous core samples should always be collected with a split-spoon sampler and recorded by a geologist in the field. Table 6 lists information that should be obtained during the drilling of well borings.

To reduce the number of potential migration 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 procedures.

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 measure in situ using well logging techniques. Cementation, moisture content, and hydraulic conductivity should also be determined for the dolomite.

4.2.1.3 Field Measurements

A total of eight monitoring well clusters should be installed within the 317 Area fence and around the 319 Area landfill to more accurately define the vertical hydraulic gradient in each of the areas and to obtain discrete water samples from at least two depths at each location. Because so little is known about the dolomite aquifer in this area, wells should also be drilled to 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. Figure 13 shows the proposed locations of the nested wells. Wells should not be drilled into the landfill area, but rather on its perimeter (Fig. 13). New wells may be coupled with existing wells 10 and 11 to form well nests. However, new wells packed with gravel over shorter intervals may be preferable. Because the subsurface geology has not been recorded for the northeast corner of the 317 Area and the monitoring intervals of wells 12 and 13 are unknown, it is recommended that one well nest be drilled in this area. Two nested wells should be located south of the 317/319 Area to monitor possible contaminant plumes (identified by soil gas analyses performed by ESH). One well nest should be located near the French drain at the 317 Area. Groundwater in this area analyzed by ESH shows high levels of a number of VOCs, including carbon tetrachloride and ketones. Since wells 4 and 7 have been consistently dry, they should be decommissioned and sealed. It is also recommended that wells 12 and 13 be sealed since no information is available on their construction and monitoring intervals.

FIGURE 13 Locations of Proposed Monitoring Wells at the 317/319 Area

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.

4.2.2 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 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 317/319 Area, the zone of contamination, if present, is likely to be shallow and no greater than a few feet thick. The U.S. EPA (1989) 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 C and D 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 specified intervals (depending on the well depth) and analyzed for suspected contaminants.

Most of the existing monitoring wells in the 317/319 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. C). Additionally, Illinois EPA 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. C and D, respectively, may be used during exploratory programs but not monitoring programs.

4.2.2.2 Background Monitoring

Figure 13 shows the locations of three proposed new control wells north and west of the 317 and 319 Areas. Since the groundwater flow is predominantly to the southeast,

these wells should provide data representative of upgradient (background) conditions. 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. To fully characterize the spatial variability of background water quality, it is recommended that more than one background well be installed (National Well Water Association 1986). It is also recommended that use of well 1 as a control well be discontinued, since it is not truly upgradient from the site.

4.2.2.3 Vadose Zone Monitoring

To characterize the areal extent of VOC contamination in the vadose (unsaturated) zone at the 317/319 Area, discrete soil and soil-gas samples should be taken at 5-ft intervals radiating away from each of the French drains (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. The need for a long-term monitoring program will depend on the results of the initial sampling.

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APPENDIX A:**AVAILABLE WELL INSTALLATION DIAGRAMS, DRILLERS' LOGS,
AND GEOLOGISTS' LOGS FOR BORINGS IN THE 317/319 AREA**

This appendix presents all available records for monitoring wells and boreholes drilled in the 317/319 Area from 1986 to 1989. These records provided the basis for the analysis of 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

Bore ^a	Geologist ^b	Item	Page
1	S. Heuer, PSI	Installation diagram	37
		Core (drillers') log	38
		Stratigraphic column	39
		(geologists' log)	
2	R. Pearl, ANL	Installation diagram	40
		Core log	41
		Stratigraphic column	42
3	R. Pearl, ANL	Installation diagram	43
		Core log	44
		Stratigraphic column	45
4	R. Pearl, ANL	Installation diagram	46
		Core log	47
		Stratigraphic column	48
5	R. Pearl, ANL	Installation diagram	49
		Core log	50-52
		Stratigraphic column	52
6	R. Pearl, ANL	Installation diagram	53
		Core log	54-56
		Stratigraphic column	57
7	M. Hampton, DOE	Installation diagram	58
		Subsurface exploration record	59-60
8	S. Miller, ANL	Subsurface exploration record	61
9	S. Miller, ANL	Subsurface exploration record	62
10	R. Pearl, ANL	Core log	63
11	R. Pearl, ANL	Core log	64
near 2	T. Patton, ANL	Completion record	65
3-25	T. Patton, ANL	Completion record	66
		Core log	66
5-15	T. Patton, ANL	Completion record	67
		Core log	67
5-25	T. Patton, ANL	Completion record	68
		Core log	68
DH-3	unknown	Completion record and core log	69
DH-4	unknown	Completion record and core log	69

^aIncludes both monitoring wells and boreholes.

^bS. Heuer is affiliated with Professional Service Industries, M. Hampton with the U.S. Department of Energy Environmental Survey Team, S. Miller with ANL's Energy Systems Division, T. Patton with ANL's Environmental Assessment and Information Sciences Division (EID), and R. Pearl, currently with Eder and Associates, formerly with EID.

Professional Service Industries

PROJECT NAME

Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

MW-1 DETAIL

PROJECT NO

152-65138

DATE

September 19, 1986

NEW WELL NO. 1 (300 Area)
SPLIT SPOON CORE LOG

Location: North of both the natural gas pipeline and rifle range, east of the radioactive waste storage area.

Date Drilled: Sept. 19, 1986

Total Depth: 40 ft.

Water level while drilling: 25 ft. approx.

10/8/86: 38.65 ft. below land surface.

Completion: Schedule 40 PVC blank casing and screen

0 - 35 ft. blank casing 0 - 21 ft. grout

35 - 40 ft. screen 21 - 23 ft. bentonite

23 - 40 ft. pea gravel

Geologist: S. Heuer, PSI

Depth (ft)	Description
0 - 1	Soil, dark brown silty clay, moist
1 - 2	Silt, clayey, tan and gray, very hard, moist. Contains medium to coarse sand and occasional iron stains.
2 - 4	As above.
4 - 6	As above
6 - 7	As above
7 - 8	Clay, silty, brown, moist with medium to coarse sand.
8 - 9	As above
9 - 10	Sand and gravel seam
10 - 11.5	Clay, silty, brown, moist with medium to coarse sand
11.5 - 12	Clay, silty, gray, moist, with medium to coarse sand
12 - 14	As above
14 - 16	As above
16 - 18	As above
18 - 18.5	As above
18.5 - 19.5	Sand, coarse to medium with some coarse gravel, Wet
19.5 - 20	Clay, silty, gray, moist
20 - 20.5	As above
20.5 - 21.5	Silt, brown moist, contains limestone fragments.
21.5 - 22	Clay, silty, gray, moist with brown medium to coarse sand seams and limestone gravel fragments.
22 - 24	As above
24 - 26	As above. Wet at 25 ft.
26 - 28	As above
28 - 30	As above
30 - 32	As above
32 - 34	As above
34 - 36	As above
36 - 38	As above
38 - 40	As above
40	Total Depth.

NEW WELL NO. 1 (300 Area)
STRATIGRAPHIC COLUMN

Location: North of both the natural gas pipeline and rifle range, east of the radioactive waste storage area.

Date Drilled: Sept. 19, 1986

Total Depth: 40 ft.

Water level while drilling: 25 ft. approx.

10/8/86: 38.65 ft. below land surface.

Completion: Schedule 40 PVC blank casing and screen

0 - 35 ft. blank casing	0 - 21 ft. grout
35 - 40 ft screen	21 - 23 ft. bentonite
	23 - 40 ft. pea gravel

Geologist: S. Heuer, PSI

Depth (ft)	Description
0.0	----- Soil, brown silty clay, moist
1.0	----- Silt, clayey, tan and gray. Very hard, moist. Contains medium to coarse sand and occasional iron stains.
7.0	----- Clay, silty, brown, moist, with medium to coarse sand Sand and gravel seam at 9 ft.
11.5	----- Clay, silty, gray, moist, with medium to coarse sand.
18.5	----- Sand, coarse to medium, with some coarse gravel. Wet
19.5	----- Clay, silty, gray, moist
20.5	----- Silt, brown, moist, with limestone fragments.
21.5	----- Clay, silty, gray, moist, with brown medium to coarse sand seams and limestone gravel fragments. Wet at 25 ft.
35.	----- Silt, gray, moist, with coarse limestone gravel fragments.
40.	Total Depth

Professional Service Industries

PROJECT NAME

Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

MW-2 DETAIL

PROJECT NO

152-65138

DATE

September 22, 1986

MONITORING WELL #2 (300 Area)
SPLIT SPOON CORE LOG

Location: SE corner of 317 area Total Depth: 40 ft.
Date Drilled: Sept. 19, 1986 Water Level while drilling: 17.5? ft.
10/8/46: 31.42 ft. below land surface

Completion: Schedule 40 PVC blank casing and screen
0 - 35 ft. blank casing 0 - 26 ft grout
35 - 40 ft. screen 26 - 28 ft Bentonite
28 - 40 ft Pea Gravel

Geologist: R. H. Pearl, ANL

Depth (ft)	Description
0 - 2	Soil, Clay, brown to dark brown, grass, weeds and roots.
2 - 4	Clay, silty and sandy, brown. contains some roots.
4 - 6	As above with some coarse gravel.
6 - 8	As above.
8 - 10	Clay, Dark brown, with some rock fragments. Moist
10 - 12	Clay, silty, brown, with rock fragments. Poor return drilled hard.
12 - 14	As above small rock fragments.
14 - 16	As above with large rock fragments.
16 - 17.5	As above.
17.5 - 18	Very sandy. Moist -wet
18 - 20	Clay, silty, brown, with sand and rock fragments. Damp.
20 - 22	As above
22 - 24	As above, poor returns.
24 - 26	As above. Not as many rock fragments. Bottom 6" very wet
26 - 28	As above. Poor returns, Rock blocked bit.
28 - 30	Silt, dark brown, Top foot very wet, bottom 6" rock
30 - 32	Top 2" weathered rock fragments. bottom 8" gray soft clay. Poor return
32 - 34	Clay, gray, soft.
34 - 35	Clay, silty, light brown, with rock fragments. wet.
35 - 36	Clay, black
36 - 38	Clay, black-brown, with rock fragments, wet
38 - 40	Clay, silty, light brown. Wet-very wet.
40	Total depth.

Depth (ft)	Description
0.0	----- Soil, Clay, brown silty. Grass, Weeds, roots
4	----- Clay, brown silty, Contains some sand, gravel and rock fragments. Moist
17.5	----- Very sandy, moist-wet
18	----- Clay, brown, silty, damp. Contains sand and rock fragments.
25.5	----- Clay, brown, silty, very wet
29.5	----- Rock fragments, weathered
31.3	----- Clay, gray, soft
35	----- Clay, silty, light brown. with rock fragments. WET.
38	----- Clay, silty, light brown, wet-very wet.
40	Total depth

Professional Service Industries

PROJECT NAME

Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

MW-3 DETAIL

PROJECT NO

152-65138

DATE

September 23, 1986

Total Depth: 41 ft.
Water Level while drilling: 19.5 ft
10/8/86: Dry

0 - 36 ft. blank casing	0 - 18 ft grout
36 - 41 ft. screen	18 - 20 ft Bentonite
	20 - 41 ft Pea Gravel

Depth (ft)	Description
0 - 2	Soil, Clay, brown to dark brown, grass, weeds and roots.
2 - 4	As above, big rock fragments, poor return.
4 - 6	Clay, silty, light brown, with some gravel and sand.
6 - 8	As above
8 - 10	As above
10 - 12	Clay, silty, dark brown, with sand and gravel
12 - 14	As above
14 - 16	As above becoming very black clay at bottom
16 - 18	As above very little sand and gravel
18 - 20	As above. Bottom .5 ft. damp
20 - 21.5	As above
21.5 - 22	Sand, silty, light brown. Wet
22 - 24	Silt, dark gray, wet
24 - 24.5	As above
24.5 - 26	Clay, dark gray, with some sand. DRY
26 - 28	As above dry
28 - 30	Big limestone rock fragment, poor return
30 - 32	Limestone fragments, with brown silt., Drilled hard.
32 - 33	Limestone. Drilled hard
33 - 34	Could not cut with split spoon sampler.
34 - 38	No samples.
38 - 39	Clay, silty, brown with rock fragments. Hard to drive sampler.
39 - 40	No samples.
40 - 41	As above. Could not drill it.
TD	41 feet.

MONITORING WELL #3 (300 Area)
STRATIGRAPHIC COLUMN

Location: South of 319 area. Total Depth: 41 ft.
Date Drilled: Sept. 23, 1986 Water Level while drilling: 19.5 ft.
10/8/86: Dry
Completion: Schedule 40 PVC blank casing and screen
 0 - 36 ft. blank casing 0 - 18 ft grout
 36 - 41 ft. screen 18 - 20 ft Bentonite
 20 - 41 ft Pea Gravel
Geologist: R. H. Pearl, ANL

Depth (ft)	Description
0.0	Surface
	Soil, Clay, brown to dark brown. grass, weeds and roots. some rock fragments
4.0	-----
	Clay, silty, light brown with some gravel and sand
10	-----
	Clay, silty, dark brown, with sand and gravel. Becoming black clay at bottom.
16	-----
	As above with very little sand and gravel Damp at 19.5 ft.
21.5	-----
	Sand, silty, light brown. WET
22	-----
	Silt, dark gray, WET
24.5	-----
	Clay, dark gray, with some sand. DRY
28	-----
	Limestone rock fragments, poor return some brown silt and fine sand.
38	-----
	Clay, silty, brown with rock fragments. Hard to drive sampler.
39	-----
	No samples
40	-----
	Clay, silty, brown with rock fragments. Hard to drive sampler
41	-----
	Total depth

Professional Service Industries

PROJECT NAME

Monitorwell Installation
Argonne National Laboratory
Argonne, Illinois

MW-4 DETAIL

PROJECT NO

152-65138

DATE

September 22, 1986

MONITORING WELL #4 (300 Area)
SPLIT SPOON CORE LOG

Location: East of 319 area.
Date Drilled: Sept. 22, 1986

Total Depth: 37 ft.
Water Level while drilling: Dry
10/8/86: dry

Completion: Schedule 40 PVC blank casing and screen

0 - 32 ft. blank casing
32 - 37 ft. screen

0-28 ft grout
28-30 Bentonite
30-37 Pea Gravel

Geologist: R. H. Pearl, ANL

Depth (ft)	Description
0 - 2	Soil, dark brown clay, roots
2 - 3	As above
3 - 4	Brown silty clay, hard
4 - 6	Brown silty clay, hard, with some small gravel, some yellow iron staining.
6 - 8	Sample missing
8 - 8.5	As above
8.5 - 10	Brown silty sand, wet
10 - 12	Brown and gray clay with some gravel, moist
12 - 14	As above
14 - 16	As above grading into black clay at bottom
16 - 18	Black clay with some gravel
18 - 20	As above, not as much gravel
20 - 22	As above
22 - 24	As above
24 - 26	As above, poor return
26 - 28	As above, good return
28 - 29.3	As above
29.3 - 30	Light brown sand with some gravel and silt
30 - 32	As above, big limestone fragments. Poor return, drilled hard
32 - 34	Broken limestone fragments, sandy
34 - 35.5	As above
35.5 - 36	Brown silty clay
36 - 37	Weathered limestone, clayey. Split spoon sampler would not go any further.
Total Depth 37 ft.	

MONITORING WELL #4 (300 Area)
STRATIGRAPHIC COLUMN

Location: East of 319 area. Total Depth: 37 ft.
Date Drilled: Sept. 22, 1986 Water Level while drilling: Dry
 10/8/86: Dry

Completion: Schedule 40 PVC blank casing and screen

0 - 32 ft. blank casing	0-28 ft grout
32 - 37 ft. screen	28-30 Bentonite
	30-37 Pea Gravel

Depth (ft)	Description
0.0	Surface
3.0	Grass, weeds, Dark brown clay
4.0	Brown, silty clay, hard
8.5	Brown silty clay, hard, with some small gravel, some yellow iron staining.
10	Brown silty sand, wet
16	Brown and gray clay with some gravel, moist becoming black clay at bottom
29.3	Black clay with some gravel, gravel content varies.
30	Light brown sand with some gravel and silt
32	Light brown sand with some gravel and silt. Also big limestone fragments. Drilled hard.
35.5	Broken limestone fragments, sandy
36	Brown silty clay
37	Weathered limestone, clayey. Split spoon sampler would not go any further.
	Total Depth

Professional Service Industries

MONITORING WELL NO. 5 (317 AREA)

Location: Approximately in middle of south fence line around 317 storage area.
Date Drilled: July 20, 1987
Total Depth: 36 feet
Water Level: while drilling; 9.3 ft (approx.), and others commencing at 20 ft.
 12.53 ft. (7/21/87)
 16.00 ft. (7/25/87)
 19.50 ft. (8/5/87)

Completion: Schedule 40 PVC blank casing and screen.
 +2.0 - 2 ft. blank steel protective casing
 +1.7 - 15.5 ft. blank casing 0 - 2 ft cement
 15.5 - 20.5 ft. screen 2 - 12 ft. grout
 12 - 14 ft. bentonite
 14 - 20.5 ft. sand

Geologist: R.H. Pearl, ANL

Drilling commenced at approximately 9:40 a.m. July 20, 1987 and ceased at approximately 2:30 p.m. The well was drilled to a total depth of 36 feet. Due to the nature of the subsurface geological materials (see below log) it was very difficult to accurately determine the water bearing zones. A 4 ft. thick zone was encountered at an approximate depth of 9.3 ft. Other questionable water bearing zones were encountered starting at about 20 ft and extending to the bottom of the hole. We attempted to complete this well using the same procedure used in 1986, i.e., the auger flights are pulled and the screen and casing placed into the hole. However, when the screen and casing were placed in the hole it was found that the hole had collapsed below a depth of 20.5 ft. As water was standing in the hole above the collapsed zone it was decided to complete the well at this depth rather than trying to redrill the hole. There is some question regarding this well. When PSI attempted to develop the well on August 5th the water level was found to be very near the bottom of the well. As noted earlier due to completion methods it was not possible to accurately determine the depth to the top of the sand pack or bentonite plug and the water bearing zones may have been sealed off accidentally.

SPLIT SPOON CORE LOG

<u>Depth (ft.)</u>	<u>Description</u>
00.0 - 1.5	Length of split spoon sample recovered: 1.0 ft. Brown silty clay with some gravel and organic material.
1.5 - 3.0	Length of split spoon sample recovered: N.M. Brown silty clay with rusty streaks
3.0 - 4.5	Length of split spoon sample recovered: 1.0 ft. Gray-brown silty and clay, drilled hard

4.5 - 6.0	Length of split spoon sample recovered: 1.2 ft. Gray-brown silt and clay, with some gravel. Drilled hard.
6.0 - 7.5	Length of split spoon sample recovered: 0.2 ft., poor recovery. Clay, dark brown.
7.5 - 9.0	Length of split spoon sample recovered: 1.2 ft. Clay, dark brown, with some gravel. Damp.
9.0 - 10.5	Length of split spoon sample recovered: 1.2 Brown silty clay with some sand. 9.3 - 9.6 ft. Medium-coarse sand lense All moist-wet.
10.5 - 12.0	Length of split spoon sample recovered: 0.7 ft. Sand and fine gravel, wet
12.0 - 13.5	Length of split spoon sample recovered: 0.0 ft. Wet core barrel. Auger cuttings at surface not very wet.
13.5 - 15.0	Length of split spoon sample recovered: 1.5 ft. Gray plastic silt and clay with some gravel.
15.0 - 16.5 bottom.	Length of split spoon sample recovered: 0.8 ft. Rock fragment at bottom. Gray plastic silt and clay with some gravel.
16.5 - 18.0	Length of split spoon sample recovered: 0.3 ft. poor recovery Gray plastic silt and clay with some gravel and large limestone rock fragments.
18.0 - 19.5	Length of split spoon sample recovered: 0.5 ft Gray plastic silt and clay, slightly damp.
19.5 - 21.0	Length of split spoon sample recovered: 0.9 ft. Top 2" wet gray plastic clay Gray clay grading to hard dry brown clay with some gravel pieces. Outside of split spoon wet.
21.0 - 22.5	Length of split spoon sample recovered: 0.4 ft. Gray plastic clay with sand and gravel. Rock fragment at base of sample. Wet auger cuttings to surface.
22.5 - 24.0	Length of split spoon sample recovered: 0.7 ft. Brown sandy silt, wet. Drilled very hard, Rock??
24.0 - 25.5	Length of split spoon sample recovered: 1.5 ft. Brown sandy silt with sand and gravel Top 6" wet.
25.5 - 27.0	Length of split spoon sample recovered: 0.5 ft. Brown silty clay with large rock fragments. Drilled like in rocks and gravel.

27.0 - 28.5	Length of split spoon sample recovered: 0.7 ft. Wet sample at top. Cored very hard. Broken limestone (8"), weathered, sandy. Not much trouble drilling out hole.
28.5 - 30.0	Length of split spoon sample recovered: 0.9' approx. Drilled very very hard. More weathered limestone and gravel 0.2 ft thick black silty clay at base.
30.0 - 31.5	Length of split spoon sample recovered: 0.0 ft. Outside of spoon very wet Drilled very hard.
31.5 - 33.0	Length of split spoon sample recovered: 0.0 Drilled hard
33.0 - 34.5	Length of split spoon sample recovered: 1.3 ft Sampler drove easily Gray silty clay with some sand and very small gravel, damp.
34.5 - 36.0	Length of split spoon sample recovered: N.M. Gray silty clay with some sand and very small gravel.
T.D. 36.0	

**MONITORING WELL NO. 5
STRATIGRAPHIC COLUMN**

<u>Depth (ft)</u>	<u>Description</u>
0.0	Surface Soil, brown silty clay, moist, roots and grass.
1.5	----- Clay, brown silty, with rusty streaks
3.0	----- Clay, gray-brown, silty, with some gravel, drilled hard
9.3	----- Sand, Medium-coarse, wet
9.6	----- Clay, gray-brown, silty; with some sand and gravel
10.5	----- Sand and fine gravel, wet
??	-----
13.5	Silt and Clay, gray, plastic with some gravel Some gravel and large limestone rock fragments
22.5	----- Silt, sandy, brown and gray, wet with some sand and gravel zones with some large rock fragments.
36	Total Depth

Professional Service Industries

PROJECT NAME

Monitor Well Installation
Argonne National Laboratory
Argonne, Illinois

MW-6

PROJECT NO.

152-75102

DATE

July 25, 1987

MONITORING WELL NO. 6 (317 AREA)

Location: SW corner of 317 area.
Date Drilled: Commenced 7/21/87, finished 7/25/87. Well developed 8/5/87.
Total Depth: 40 ft.
Water level: while drilling; 10.5 ft approximately
 12.5 ft. (7/25/87)
 27.57 ft (8/5/87)

Completion: Schedule 40 PVC blank casing and screen.
 +0.0 - 2 Blank protective steel casing
 +1.0 - 35 ft. blank casing 0 - 2 ft. (approx.) cement
 35 - 40 ft. screen 2 - 31 ft. (approx.) grout
 31 - 33 ft. (approx.) bentonite
 33 - 40 ft. (approx.) sand

Geologist: R.H. Pearl, ANL

Drilling commenced at approximately 10:00 p.m. and ceased at approximately 3:00 p.m. 7/21/87. Driller was unable to pull auger flights from hole. Attempted to pump water down hole but water pump was broken. Left auger flights in hole and returned to shop to have pump repaired. Returned on 7/25/87 and completed well. Well completed using following hollow auger stem method: Screen and blank casing installed inside the hollow auger stem to bottom of hole; approx. 2 ft. of fine silica sand then poured down the inside of the hollow auger stem and outside of the casing; the auger flights pulled up and the process repeated until the height of sand was approximately two feet above top of screen level. Bentonite slurry then emplaced in a similar manner. Upon completion of emplacing the bentonite slurry the remaining auger flights were removed from the hole and the hole filled with a cement grout. Due to the lack of space between the casing and the auger it was not possible to measure the depth to the top of the sand or bentonite seal. PSI personnel returned on 8/5/87 and developed the well by bailing it dry.

SPLIT SPOON CORE LOG

Drilling log

<u>Depth (ft)</u>	<u>Description</u>
0.0 - 1.5	Length of split spoon sample recovered: 1.0 ft. Brown and gray silty clay with roots.
1.5 - 3.0	Length of split spoon sample recovered: 1.2 ft. Brown and gray silty clay with some fine gravel.
3.0 - 4.5	Length of split spoon sample recovered: 1.5 ft.. Brown and gray silty clay with some fine gravel.
4.5 - 6.0	Length of split spoon sample recovered: 1.5 ft. Brown and gray silty clay with some fine gravel.
6.0 - 7.5	Length of split spoon sample recovered: 1.5 ft. Brown and gray silty clay with dark red rusty streak at bottom.
7.5 - 9.0	Length of split spoon sample recovered: 0.2 ft. Brown and gray silty clay.

**MONITORING WELL #6
SPLIT SPOON CORE LOG (CONT.)**

<u>Depth (ft)</u>	<u>Description</u>
9.0 - 10.5	Length of split spoon sample recovered: 1.5 ft. 9.0 - 10.3 ft. Brown and gray silty clay with dark red rusty streak. 10.3 - 10.5 ft. Fine gravel to fine sand, rusty.
10.5 - 12.0	Length of split spoon sample recovered: 1.5 ft. 10.5 - 11.0 ft. Brown clay with some gravel 11.0 - 12.0 ft. Black to gray plastic clay. Wet auger cuttings to surface.
12.0 - 13.5	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, moderately wet, with some gravel and sand.
13.5 - 15.0	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with some gravel and sand.
15.0 - 16.5	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet.
16.5 - 18.0	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet.
18.0 - 19.5	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet.
19.5 - 21.0	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet.
21.0 - 22.5	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet.
22.5 - 24.0	Length of split spoon sample recovered: 0.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet.
24.0 - 25.5	Length of split spoon sample recovered: 0.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet.
25.5 - 27.0	Length of split spoon sample recovered: 1.5 ft. Blow counts up from 26 to 33 b/12" Black to gray plastic clay, with some gravel and sand. Damp but not wet. Split spoon sampler very wet. Water level at 20 ft below surface after standing for approx. 2 hours.

**MONITORING WELL #6
SPLIT SPOON CORE LOG (CONT.)**

<u>Depth (ft)</u>	<u>Description</u>
27.0 - 28.5	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet. Spoon contained water when opened.
28.5 - 30.0	Length of split spoon sample recovered: 1.0 ft. Black to gray plastic clay, with some gravel and sand. Damp but not wet. Very hard to break sample.
30.0 - 31.5	Length of split spoon sample recovered: 1.5 ft. Black to gray plastic clay, with lots of gravel and sand. Gravel layer at base.
31.5 - 33.0	Length of split spoon sample recovered: 0.3 ft. Black to gray plastic clay with lots of gravel and sand. Limestone rock fragments.
33.0 - 34.5	Length of split spoon sample recovered: 0.7 ft. Sand and gravel with some clay. Some rock fragments. Split spoon barrel very wet on outside. Blow counts way up Very wet auger cuttings to surface -- soup. Driller said they came from up the hole. I have my doubts about this.
34.5 - 36.0	Length of split spoon sample recovered: N.D. Sand and gravel with some clay Split spoon barrel contained lots of water.
36.0 - 37.5	Length of split spoon sample recovered: 1.2 ft. 36.0 - 36.5 ft. gravel as above 36.5 - 37.5 gray to black clay with some gravel.
37.5 - 39.0	Length of split spoon sample recovered: 0.7 ft. Gray to black clay with some gravel.

Drilled to 40 ft. Sampled to 39 ft.

**MONITORING WELL #6 (317 AREA)
STRATIGRAPHIC COLUMN**

Location: SW corner 317 area **Total Depth:** 40 ft.
Date drilled: July 21, 1987 **Water level while drilling:**

Completion: Schedule 40 PVC blank casing and screen

Geologist: R.H. Pearl, ANL

<u>Depth(ft)</u>	<u>Description</u>
0.0	Surface Soil, Clay, brown to dark brown, grass, weeds, and roots. Some rock fragments.
1.5	----- Clay, silty, brown and gray with some fine gravel. Rusty streaks 7.5 - 10.3 ft.
10.3	----- Gravel and fine sand, rusty
10.5	----- Clay, brown with some gravel
11	----- Clay, black to gray, plastic, hard to break with some sand and gravel damp but not wet
31.5	----- Gravel layer, thin. Clay, black to gray, plastic, with lots of sand and gravel, limestone rock fragments.
33	----- Sand and gravel, with some clay and rock fragments
36.5	----- Clay, gray to black with some gravel
39	Total Sampled Depth
40	Total Drilled Depth

DOE ENVIRONMENTAL SURVEY

WELL COMPLETION RECORD

DOE SITE NAME: ARGOUCWELL ID NUMBER: 7WELL COORDINATES or WELL LOCATION:
319 APRNDRILLING COMPANY: Patterson (Bennis Avenue)
TYPE OF RIG: Cable ToolDATE INSTALLATION COMPLETED (dd/mm/yy):
28 DEC 1987TOTAL DEPTH: 63 ft.

DEVELOPMENT

METHOD: Preparation of well
submersible pumpSTART DATE: 29 DEC 1987
TIME: 1:00END DATE: 29 DEC 1987
TIME: 1:20TOTAL WATER REMOVED
DURING DEVELOPMENT: 0 gal.DESCRIPTION OF TURBIDITY AT END OF
DEVELOPMENT:
☐ Clear ☐ Slightly cloudy
☐ Mod. turbid ☒ Very cloudyADDITIONAL COMMENTS: Added Tap Water
To Bentonite To Ensure Seal
Development of water was 100%Plan previous 11/87 → After pump
2.5 feet of water was left in well
2.5 feet of water was left in wellRECORDED BY: Michael Hays (Signature) CHECKED BY: _____ (Signature)D.B. - 87

WELL CONSTRUCTION SUMMARY

WELL CAP ELEVATION: _____ ft.

GROUND SURFACE
ELEVATION: _____ ft.CONDUCTOR HOLE DIA.: 1 1/4 in.
_____ to _____ ft.SURFACE CONDUCTOR
TYPE: 1 1/4
ID: _____ in. OD: _____ in.
_____ to _____ ft.BOREHOLE DIA.: 7 in.
0 to 53 ft.FILLER
TYPE: 1/2 lb. Grout
46 to 0 ft.CASING (with screen)
TYPE: 3/16 SS
ID: 4.1 in. OD: 4.5 in.
53 to 0 ft.SEAL
TYPE: Bentonite Pellets
51 to 46 ft.SCREEN
TYPE: 3/16 SS 20 SGT
ID: 4.1 in. OD: 4.5 in.
63 to 53 ft.PACK
TYPE: #4 s. 1/2 S. 1/2
63 to 51 ft.

DOE ENVIRONMENTAL SURVEY

RECORD OF SUBSURFACE EXPLORATION

DOE SITE NAME: ALBUQUERQUEPAGE 1 of 2
DATE (dd/mm/yy): 21 DEC 19WELL ID NUMBER: 7WELL COORDINATES or DRILLING LOCATION: 319 AREAGROUND WATER FIRST ENCOUNTERED AT ft.

DEPTH (ft)	SAMPLE			BLANKS (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	10-12	16"		^{grey} Silty clay, 1200 staining noted, some pebbles
5-					
0-	2	20-24	0		No recovery
	3	25-29	0		No recovery
5-					
0-	4	30-34	12"		Silty sandy clay grey, easy to cut → 127. 1700 silty sandy clay ? grey silty
5-					

RECORDED BY: Mark Hamilton (Signature)67-06-67

CHECKED BY: _____ (Signature)

DATE (dd/mm/yy): 15/10/87

ALL COORDINATES or DRILLING LOCATION: 319 4200

POUND WATER FIRST ENCOUNTERED AT _____ ft.

HOLE NO.	SAMPLE			FLOWS (per 6 in)	DESCRIPTION OF MATERIALS (Indicate zones of lost circulation and water bearing zones)
	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERY (in)		
11-43	0'				<p>3.75 gal. / min. very little, some fines silty ? ? ? ? some fines</p> <p>no Recovery</p>

USED BY: Walter J. Martin (Signature)

CHECKED BY: _____ (Signature)

RECORD OF SUBSURFACE EXPLORATION

SITE NAME: ANL 317 AreaPAGE 1 of 1
DATE (dd/mm/yy)NUMBER: MW-8Start: 0 4 / A P R / 8 8
End: 0 4 / A P R / 8 8DRILLING LOCATION: MW-8 317 AreaGROUND WATER FIRST ENCOUNTERED AT ~25 ft.

DEPTH (ft)	SAMPLE			R.O.S. Feet & In	DESCRIPTION OF MATERIALS (Indicate zones of lost circulation and water bearing zones)
	NUMBER	INTERVAL AND TYPE	ADVANCE/ RECOVERY (in)		
	0-2	SS	24"/ 8"	4,6,8,14	Fill sandy gravel, some silt and clay, slightly moist, gray
	2-4	SS	24"/ 12"	5,3,4,5	Clay, fill, with silt, some sand, trace gravel, dark brown moist - very moist, mod. dense
	4-6	SS	24"/ 14"	3,4,6,7	
	6-8	SS	24"/ 20"	3,3,7,11	
	8-10	SS	24"/ 16"	2,4,10,10	
	10-12	SS	24"/ 18"	6,9,13,12	Clay, some silt, light gray, very moist, highly plastic, dense
	12-14	SS	24"/ 20"	6,11,15,18	
	14-16	SS	24"/ 18"	9,14,16,18	
	16-18	SS	24"/ 22"	4,13,24,16	
	18-20	SS	24"/ 22"	6,8,13,16	Groundwater encountered @ ~25 feet, more silt
	20-22	SS	24"/ 20"	4,6,8,8	
	22-24	SS	24"/ 20"	3,4,5,6	
	24-26	SS	24"/ 22"	2,5,7,13	
	26-28	SS	24"/ 20"	5,8,13,26	Stopped @ 30 feet Hole was filled with grout on 05APR88 by contractor
	28-30	SS	10"/ 8"	13,15	
					*SS - Split-Spoon Sampler

RECORDED BY: S. Miller (Signature)

RECORD OF SUBSURFACE EXPLORATION

SITE NAME: ANL 317 AreaPAGE 1 of 1NUMBER: MW-9

DATE (dd/mm/yy)

Start: 0 4 / A P R / 8 8End: 0 4 / A P R / 8 8DRILLING LOCATION: MW-9 317 AreaGROUND WATER FIRST ENCOUNTERED AT ~ 25 ft.

DEPTH (ft)	SAMPLE			S.O.S. (per 6 in)	DESCRIPTION OF MATERIALS (Indicate zones of lost circulation and water bearing zones)
	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED (in)		
	0-2	SS	24"/ 6"	5,7,12,20	Fill sandy gravel, some silt and clay, gray
	2-4	SS	24"/ 12"	10,5,3,5	
-5	4-6	SS	24"/ 14"	3,3,4,6	Clay fill, with silt, trace sand, dark brown, moist, mod. plastic, grayish, brown
	6-8	SS	24"/ 20"	3,4,5,6	
	8-10	SS	24"/ 20"	3,4,9,11	
-10	10-12	SS	24"/ 22"	3,4,9,12	
	12-14	SS	24"/ 12"	7,9,12,16	Clayey sand, trace gravel, with silt, dark brown, very moist
-15	14-16	SS	24"/ 12"	4,8,12,12	
	16-18	SS	24"/ 16"	4,8,11,13	
-20	18-20	SS	24"/ 18"	4,9,11,2	Clay, some silt, trace sand, gray, highly plastic, very moist
	20-22	SS	24"	4,4,9,12	
	22-24	SS	24"/ 14"	5,4,5,5	Thin sand lense (wet)
-25	24-26	SS	24"/ 14"	4,5,8,10	Wet
	26-28	SS	24"/ 12"	7,12,17,26	Groundwater encountered @ ~25 feet
-30	28-30	SS	24"/ 14"	4,8,12,17	
					Stopped @ 30'
					Hole was filled with grout on 05APR88 by contractor
					* SS - Split-Spoon Sampler

RECORDED BY: S. Miller (Signature)

Monitoring Well #10**Well Completion Record**

Location: About 20 ft south and 50 ft east of the sump between south vaults.

Date Drilled: July 12, 1988

Total Depth: 30.5 ft below land surface

Water Level While Drilling: about 13 ft below land surface

Completion:	0-20.5 ft - blank casing	0-5 ft - cement grout
	20.5-30.5 ft - No. 10 screen	5-7 ft - bentonite clay
	(2-in. OD casing and screen)	30.5-7 ft - pea gravel

Geologist: R.H. Pearl, ANL

Soil Description

<u>Depth (ft)</u>	<u>Description</u>
0 - 5	Brown clay, silt, with some sand and gravel, dry, drilled easy.
5 - 10	As above, becoming more damp with depth. Formed clay balls.
10 - 15	As above. Sand lens at 13-15 ft. Water. Samples very wet and roapy.
15 - 20	Black clay and silt with some sand and gravel. Samples very wet.
20 - 25	No samples, drilled moderately hard. Very rough drilling at about 24.5 ft may have been a gravel lens.
25 - 30.5	Light brown. Cuttings thin and muddy. Lots of water.

Monitoring Well #11**Well Completion Record**

Location: About 20 ft south and 50 ft west of the sump between south vaults.

Date Drilled: July 12, 1988

Total Depth: 30.5 ft below land surface

Water Level While Drilling: about 13 ft below land surface

Completion:	0-20.5 ft - blank casing	0-5 ft - cement grout
	20.5-30.5 ft - No. 10 screen	5-7 ft - bentonite clay
	(2-in. OD casing and screen)	30.5-7 ft - pea gravel

Geologist: R.H. Pearl, ANL

Soil Description

<u>Depth (ft)</u>	<u>Description</u>
0 - 5	Light brown clay, silt with some sand and gravel, dry.
5 - 8	As above. Samples getting damp with depth.
8 - 13	Sand and gravel. Rocks up to 3 inches in diameter.
13 - 15	Dark gray silt and clay, wet. Water.
15 - 20	As above.
20 - 25	As above. 21-22 drilled very rough, may have been a gravel layer.
25 - 30.5	Poor returns. Light brown silt and clay, very wet.

WELL COMPLETION RECORD

WELL NEAR MW-2 (317 Area)

Location: Approximately 10 ft west of MW-2, 317 area

Date Drilled: August 11, 1989

Total Depth: 14 ft

Water Level While Drilling: DRY

Completion: Bottom 5 ft of hole was filled with bentonite,
remainder was filled with bore hole material.

Geologist: T.L. Patton, ANL

NEW WELL MW-3-25 (317 Area)

Location: Approximately 6 ft west of MW-3, 317 area
 Date Drilled: August 10, 1989
 Total Depth: 25 ft
 Water Level While Drilling: 22 ft
 Completion: Schedule 40 PVC threaded blank casing and screen

0-20 ft blank casing	0-2 ft cement
20-25 ft screen	2-18 ft bentonite
	18-25 ft silica sand

Geologist: T.L. Patton, ANL

SOIL DESCRIPTION

Location: Approximately 6 ft west of well MW-3, 317 area
 Date Drilled: August 10, 1989
 Total Depth: 25 ft
 Water Level While Drilling: Approximately 22 ft
 8/17/89: 23.90 ft from top of casing
 Completion: Schedule 40 PVC blank casing and screen

0-20 ft blank casing	0-2 ft cement
20-25 ft screen	2-18 ft bentonite
	18-25 ft silica sand

Geologist: T.L. Patton, ANL

Depth (ft)	Description
0 - 2	Soil, clay, brown, some roots
2 - 6	Clay, brown
6 - 6.5	Clay, brown, with rock fragments
6.5 - 10	Clay, brown, damp, few rock fragments at 10 ft
10 - 14.5	Clay, brown, damp, few rock fragments at 12 ft
14.5 - 18	Clay, brown to gray, damp, no sand
18 - 20	Clay, gray, damp, no sand
20 - 22	Clay, gray, damp, containing some rock fragments
22 - 24	Clay, gray-brown, some rock fragments, more damp than previous layers
24 - 25	Clay, gray

REPLACEMENT WELL MW-5-15 (317 Area)

Location: Approximately 8.5 ft west of MW-5, 317 area
 Date Drilled: August 11, 1989
 Total Depth: 14 ft
 Water Level While Drilling: 12 ft
 Completion: Schedule 40 PVC threaded blank casing and screen

0-9 ft blank casing	0-2 ft cement
9-14 ft screen	2-6 ft bentonite
	6-14 ft silica sand

Geologist: T.L. Patton, ANL

SOIL DESCRIPTION

Location: Approximately 8.5 ft west of well MW-5, 317 area
 Date Drilled: August 11, 1989
 Total Depth: 14 ft
 Water Level While Drilling: approximately 12 ft
 8/17/89: 12.48 ft from top of casing
 Completion: Schedule 40 PVC blank casing and screen

0-9 ft blank casing	0-2 ft cement
9-14 ft screen	2-6 ft bentonite
	6-14 ft silica sand

Geologist: T.L. Patton, ANL

Depth (ft)	Description
0 - 2	Soil, clay, brown, roots
2 - 3	Clay, brown, gravel
3 - 4.5	Silty clay, reddish-brown, some gravel
4.5 - 7.5	Silty clay, reddish-brown, gravel at 6.5-7.5 ft
7.5 - 10	Silty clay, reddish-brown, gravel at 9-10 ft, dry
10 - 12.5	Silty clay, reddish-brown, sandy, wet
12.5 - 14	Sand, medium-coarse grained, mixed with brown clay, very wet

REPLACEMENT WELL MW-5-25 (317 Area)

Location: Approximately 3.5 ft west of MW-5, 317 area
 Date Drilled: August 10, 1989
 Total Depth: 25 ft
 Water Level While Drilling: 12.5 ft
 Completion: Schedule 40 PVC threaded blank casing and screen

0-17 ft blank casing	0-2 ft cement
17-22 ft screen	2-14.5 ft bentonite
	14.5-25 ft silica sand

Old Casing: Casing filled with bentonite.

Geologist: T.L. Patton, ANL

SOIL DESCRIPTION

Location: Approximately 3.5 ft west of well MW-5, 317 area
 Date Drilled: August 10, 1989
 Total Depth: 25 ft
 Water Level While Drilling: Approximately 12.5 ft
 8/17/89: DRY
 Completion: Schedule 40 PVC blank casing and screen

0-17 ft blank casing	0-2 ft cement
17-22 ft screen	2-14.5 ft bentonite
	14.5-25 ft silica sand

Geologist: T.L. Patton, ANL

Depth (ft)	Description
0 - 2	Soil, clay, brown, roots
2 - 3	Clay, brown, gravel
3 - 4.5	Silty clay, reddish-brown, some gravel 4 - 4.5 ft
4.5 - 10	Silty clay, reddish-brown, gravel at 8 ft, damp
10 - 12.5	Silty clay, sandy, reddish-brown
12.5 - 14	Sand, light brown, medium grained, wet
14 - 15	Clay, brown, with sand and pebbles, wet
15 - 19	Clay, gray, some sand, no pebbles, wet
19 - 23	Clay, gray, few rock fragments
23 - 24	Clay, gray-brown, wet, some sand, clay becoming reddish-brown with depth

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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 #3 (South of Radiation Waste Site) 317/319 Area

Total Depth of Well - 79'

Cased to - 70' with one foot of casing above ground.

Water Level - Dry Hole

Formations:

0' to 5' Clay

5' to 20' Sand & Gravel

20' to 35' Clay

35' to 69' Sand & Gravel

69' to 79' Limestone

Job #4 (S.E. of Radiation Waste Site by the Woods) 317/319 Area

Total Depth of Well - 69'

Cased to - 60' with one foot of casing above ground.

Water Level - Dry Hole

Formations:

0' to 7' Surface & Clay

7' to 20' Sand & Gravel

20' to 32' Clay

32' to 59' Sand & Gravel

59' to 69' Limestone

APPENDIX B:

**STATIC WATER LEVELS MEASURED IN
MONITORING WELLS SINCE 1986**

This appendix presents quarterly water level measurements for wells in the 317/319 Area. Tables B.1, B.2, and B.3 give quarterly and annual average water levels for 1988, 1987, and 1986, respectively. They are based on information provided by ESH.

**Table B.1 Well Point and Water Elevations of Monitoring Wells at the
317/319 Area, 1988 (m above MSL)**

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations ^a				1988 Avg.
			1st	2nd	3rd	4th	
1	209.81	197.38	201.78	200.76 ^b	198.58	197.77	199.72
2	209.17	197.34	202.05	201.53 ^b	202.42	197.92	200.98
3	204.28	192.11	193.32	194.06	dry	dry	193.69
4	203.70	197.22	dry	dry	dry	dry	-
5	208.32	197.35	c	c	c	c	-
6	207.54	195.35	200.56	199.91	198.49	198.41	199.34
7	207.57	188.73	dry	dry	d	d	-
10 ^e	208.14	199.33	-	-	203.79	204.79	204.29
11 ^e	208.14	199.97	-	-	201.70	202.25	201.98
12 ^e	211.04	199.28	-	-	202.58	202.59	202.09
13 ^e	213.02	201.22	-	-	205.05	206.19	205.62

^aWater-equivalent precipitation for the 30- or 60-day periods preceding the measurements was 93.0 mm for the 1st quarter, 21.2 mm for the 2nd, 59.2 mm for the 3rd, and 125.0 mm for the 4th. The 2nd- and 3rd-quarter measurements are averages of two 30-day periods.

^bValue is an average of two measurements made 5/17/88 and 6/16/88.

^cWell clogged at 6.4 m (21 ft).

^dNot measured.

^eWells 10 and 11 were installed 7/88; wells 12 and 13 were installed 9/88.

TABLE B.2 Well Point and Water Elevations of Monitoring Wells at the 317/319 Area, 1987 (m above MSL)

Well	Ground Surface Elevation	Well Point Elevation	Quarterly Elevations ^a				1987 Avg.
			1st	2nd	3rd	4th	
1	209.81	197.38	b	201.52	199.66	199.06	200.08
2	209.17	197.34	b	201.87	200.89	200.09	200.95
3	204.28	192.11	b	193.33	193.32	dry	193.33
4	203.70	197.22	b	dry	dry	dry	-
5 ^c	208.32	197.35	-	-	d	d	-
6 ^c	207.54	195.35	-	-	199.37	199.03	199.20
7 ^c	207.57	188.73	-	-	b	b	-

^aWater-equivalent precipitation for the 30-day periods preceding the measurements was 59.4 mm for the 2nd quarter, 106.7 mm for the 3rd, and 56.4 mm for the 4th.

^bNot measured.

^cWells 5 and 6 were installed 8/87; well 7 was installed 11/87.

^dWell clogged at 6.4 m (21 ft).

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**TABLE B.3 Well Point and Water Elevations
of Monitoring Wells at the 317/319 Area, 1986
(m above MSL)**

Well ^a	Ground Surface Elevation	Well Point Elevation	4th-Quarter Groundwater Elevation ^b
1	209.81	197.38	198.39 ^c
2	209.17	197.34	199.82 ^c
3	204.28	192.11	dry
4	203.70	197.22	dry

^aAll four wells were installed 9/86.

^bWater-equivalent precipitation for the 60-day period preceding the measurements was 21.0 mm. The value is an average of two 30-day periods.

^cValue is an average of two measurements made 11/11/86 and 12/22/86.

APPENDIX C:**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 C.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.

*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 C.1 Illinois EPA Procedures for Plugging Monitoring Wells

Well Construction	Plugging Procedure
<u>Unconsolidated sediment wells</u>	
Wells backfilled with cement grout above bentonite seal and/or sandpack and Wells of unknown construction	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> 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.
<u>Bedrock wells</u>	<ol style="list-style-type: none"> 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. C.1].

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

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

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. C.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 C.2].

Illinois Environmental Protection Agency		Well Completion Report																																				
Site #:	_____	County:	_____																																			
Site Name:	_____	Grid Coordinate: Northing:	_____																																			
	_____	Grid Coordinate: Easting:	_____																																			
Drilling Contractor:	_____	Date Drilled Start:	_____																																			
Driller:	_____	Geologist:	_____																																			
	_____	Date Completed:	_____																																			
Drilling Method:	_____	Drilling Fluids (type):	_____																																			
Annular Space Details		Elevations — .01 ft.																																				
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 _____																																						
Well Construction Materials																																						
	<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th></th> <th>Stainless Steel Specify Type</th> <th>Teflon Specify Type</th> <th>PVC Specify Type</th> <th>Other Specify Type</th> </tr> </thead> <tbody> <tr> <td>Riser coupling joint</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Riser pipe above w.t.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Riser pipe below w.t.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Screen</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Coupling joint screen to riser</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Protective casing</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>		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						
	Stainless Steel Specify Type	Teflon Specify Type	PVC Specify Type	Other Specify Type																																		
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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 C.2 Example of an Illinois Well Completion Report (Source: Illinois EPA 1987)

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

Parameter	Symbol	Unit
<u>Routine</u>		
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
<u>Background</u>		
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 C.2 (Cont'd)

Parameter	Symbol	Unit
<u>Background. (cont'd)</u>		
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

^aShould be reported annually.

Source: Illinois EPA 1987.

APPENDIX D:

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.

D.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.

D.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.

D.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.

D.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).

D.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. C.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.

D.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.

- END -

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