GEOHYDROLOGY AND QUALITY OF SHALLOW GROUND WATER AT AND NEAR THE OLD LAUREL COUNTY AND G.C. SINGLETON LANDFILLS, LAUREL COUNTY, KENTUCKY

By James M. Parnell

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Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.06309	liter per second
microsiemens per centimeter at 25 degrees Celsius (μS/cm)	1.000	micromhos per centimeter at 25 degrees Celsius

Temperature in °F (degrees Fahrenheit) can be converted to °C (degrees Celsius) as follows:

$$°C = 5/9\ (°F-32)$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units used in this report: Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

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ABSTRACT

Between 1969 and 1983, municipal solid waste and various types of hazardous wastes were deposited at the Old Laurel County and G.C. Singleton Landfills in Laurel County, Kentucky. These uncontrolled landfills were developed on a bench created by strip mining for coal in the 1950's and 1960's when there were no regulations governing the operation of landfills. Because the disposal of hazardous wastes in uncontrolled landfills is a potential source of ground-water contamination, an investigation was performed to define the geohydrology and quality of the shallow ground-water system near the landfills.

Water-level data, from eight wells installed during the study, indicate that the general direction of ground-water flow in the shallow ground-water system is toward Slate Lick, which is at a lower altitude than the landfills.

Results of analyses of water samples from the wells indicate that the quality of the shallow ground water at and near the landfills is similar to that in coal strip-mined areas where landfills are not present. The pH of water from the wells ranged from 4.6 to 6.2 and indicates acidic conditions. Measured values of specific conductance were elevated from background values in ground water near the Old Laurel County Landfill and may indicate concentrations of dissolved constituents that may be associated with landfill leachate or acid-mine drainage. Several ground-water samples contained high concentrations of constituents commonly associated with acid-mine drainage, such as aluminum, iron, manganese, sulfate, and zinc. A relatively high concentration of fluoride, 4.5 mg/L (milligrams per liter), measured in water from one well may be related to leachate from the landfill.

Except for 3,4-dichloro-benzoic acid, a common bactericide that is widely used in certain herbicides, industrial chemicals, and medicines, organic constituents were not detected in the ground-water samples. Because of the widespread use of chemicals containing 3,4-dichloro-benzoic acid in the watershed where the landfills are located, the specific source of this constituent in the shallow aquifer system cannot be determined.

INTRODUCTION

Between 1969 and 1983, municipal solid waste was deposited at the Old Laurel County and G.C. Singleton Landfills in Laurel County, Kentucky. During this period, there were no regulations governing the operation of landfills; reportedly, various types of hazardous wastes were also deposited in the fill areas. The disposal of hazardous waste in uncontrolled landfills represents a potentially significant source of contamination to ground water. Knowledge of the occurrence and fate of hazardous constituents in ground water is needed by communities and natural resource protection agencies to develop effective management strategies. To help provide this knowledge, the U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (USEPA) and Kentucky Natural Resources and Environmental Protection Cabinet, Division of Waste Management (KDWM), made an investigation of the quality of shallow ground water at and near the Old Laurel County and G.C. Singleton Landfills.

Purpose and Scope

This report presents the results of a study of the quality of the shallow ground water at and near the Old Laurel County and G.C. Singleton Landfills. Data and interpretations concerning the shallow ground-water altitude and flow in the study area and the potential migration of contaminants associated with landfill wastes are presented. Hydrologic data and water samples from eight shallow wells and from an adjacent stream were analyzed for physical characteristics and selected inorganic and organic constituents.

Description of the Study Area

The study area is in the Eastern Coal Field physiographic region of Kentucky, which is part of the Cumberland Plateau section of the Appalachian Plateaus physiographic province (Fenneman, 1938). The Cumberland Plateau section is characterized by a broad upland of moderate relief (Fenneman, 1938). The Old Laurel County and G.C. Singleton Landfills are located in an abandoned strip mine on Pittsburg Slate Road approximately 3 mi north of the city of London, Laurel County, in southeastern Kentucky (fig. 1). The study area includes the landfills and the area encompassing the landfills that is within the watersheds of streams draining the two landfill sites (an unnamed tributary northeast of the Old Laurel County Landfill, and part of Slate Lick Creek south of the landfills).

The topography near the study area is hilly with relief in excess of 250 ft. Slopes vary from less than 1 percent in the valley bottoms to more than 30 percent on the hillsides. The ridges are cut by numerous streams forming a mature dendritic drainage system. Surface runoff from the study area is into Slate Lick Creek which flows in a northeasterly direction for about 2 mi and joins Raccoon Creek. Raccoon Creek joins the South Fork of Rockcastle River about 3.5 mi north of the study area.

History of Waste Disposal

Definition of the hydrology and quality of the shallow ground water at the landfill sites is complicated by past land-use practices. The landfills are on an abandoned strip-mine area on the bench created by the strip mining of the Lily Coal in the 1950's and 1960's. The earliest mining method removed overburden above the coal seam to expose the coal. The bench that was created after the coal was removed was the repository for solid waste, which was subsequently covered by mine spoil. In 1969, a sanitary landfill permit was issued by the KDWM for the Old Laurel County Landfill and the facility received waste until later that year when the landfill was closed. At that

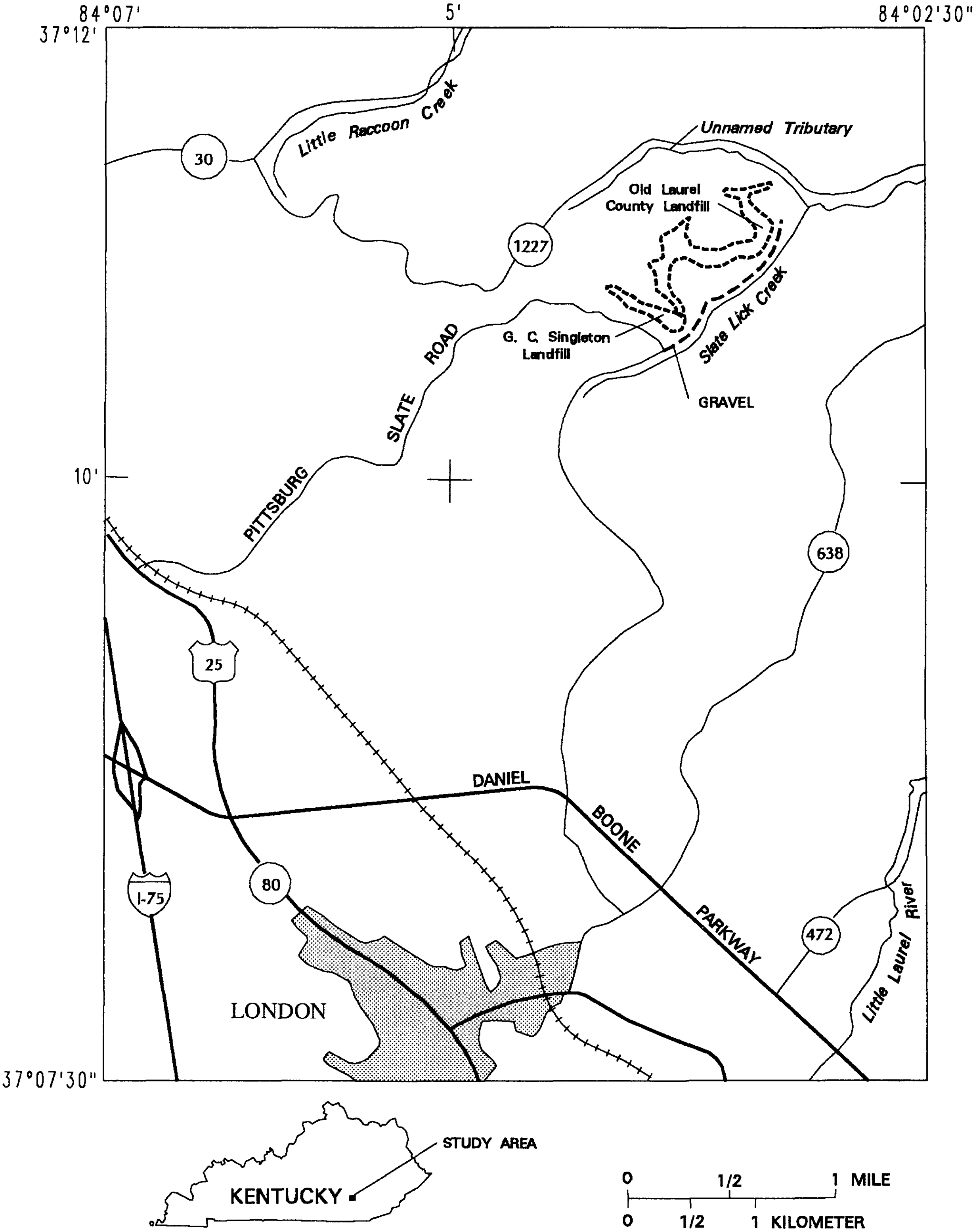


Figure 1.--Location of Old Laurel County and G.C. Singleton Landfills, Laurel County, Kentucky.

time, the KDWM issued a similar permit for the operation of a sanitary landfill, at an adjacent site, known as the G.C. Singleton Landfill. It remained in operation until February 1982, but continued to receive waste until 1983 when the landfill was closed by the KDWM. Investigations by the KDWM substantiated that uncontrolled dumping of potentially hazardous industrial wastes occurred at this site. During the period 1973 to 1975, it is estimated that 4,000 to 10,000 gal of assorted paint, coating, and ink waste were mixed and deposited with municipal solid waste at the G.C. Singleton Landfill.

Previous Investigations

Previously published reports do not describe the quality of shallow ground water at and near the landfills. The geology and ground-water resources of the London area (fig. 1) are described by Otton (1948). A description of the availability of ground water in an area, including Laurel County and several adjacent counties, is provided by Kilburn and others (1962). Ground-water quality in Laurel County is described in general terms by Faust and others (1980). Leist and others (1982) described the hydrogeology of part of the Eastern Coal Province, Kentucky and Tennessee, which includes part of Laurel County. The USGS has published a detailed geologic map for the London quadrangle (Hatch, 1963) that includes the study area.

The Commonwealth of Kentucky began an investigation of the landfills in April 1983, when inspectors from the KDWM discovered 55-gal drums of waste toluene at the G.C. Singleton Landfill. The KDWM determined that the illegal disposal of similar waste had occurred since mid-1981. A subsequent investigation by the KDWM during March 12-14, 1984 revealed open and partially buried drums of paint solvents and wood preservatives on the ground surface. Toluene was detected in water samples from Slate Lick Creek, which is at a lower altitude than the landfill, and in sediment and water samples collected at various locations at the site (Rodney Polly, Kentucky Division of Waste Management, written commun., 1989). Personnel of KDWM observed large amounts of uncovered solid waste over the entire G.C. Singleton Landfill site. Apparent leachate seepage was found in several areas of surface-water drains at the G.C. Singleton Landfill site; however, the Old Laurel County Landfill had no visible solid waste. The site appeared to be covered with soil from the regrading performed during the mining reclamation (Rodney Polly, Kentucky Division of Waste Management, written commun., 1989). Several orange leachate outbreaks, which may be attributed to acid-mine drainage, were reported below the Old Laurel County Landfill site.

Acknowledgments

Appreciation is expressed to Rodney Polly, Uncontrolled Sites Branch of the KDWM, and to Leonard Sparks, property owner, for their assistance during the study.

GEOHYDROLOGY

Geology

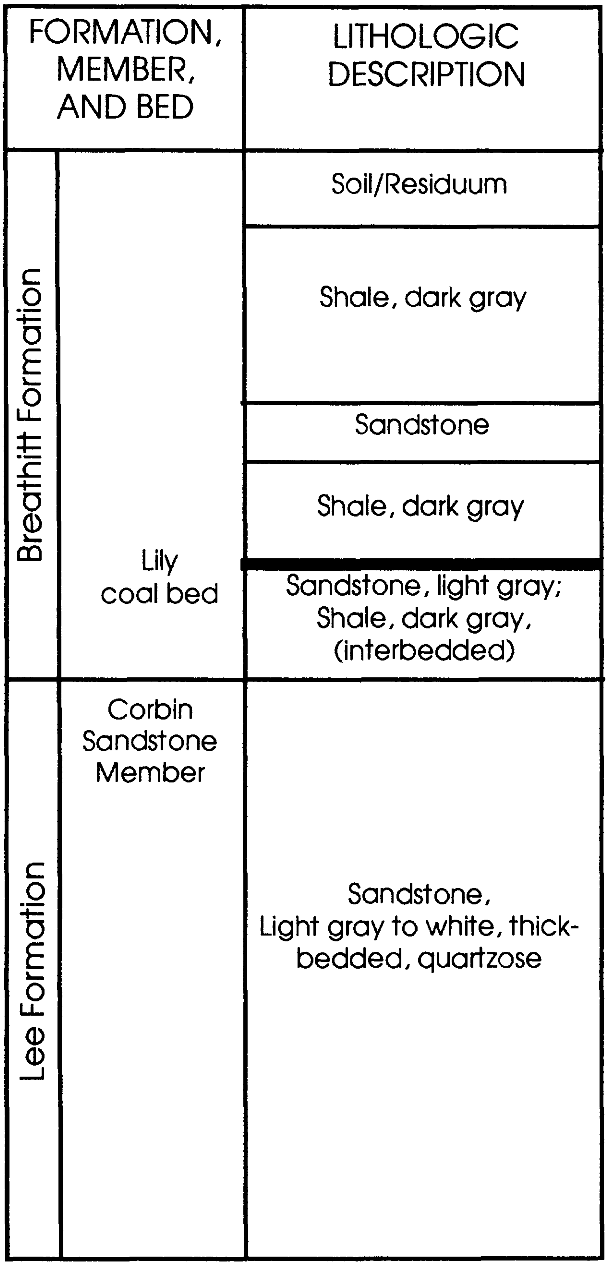
Only the near-surface geology is discussed in this report. The following discussion proceeds from younger or uppermost geologic units to successively older and deeper units. The landfills are underlain by shale, sandstone, siltstone, and coal of the Breathitt and Lee Formations of Pennsylvanian age (fig. 2). The base of the Breathitt Formation is considered to be at the top of the Corbin Sandstone Member of the underlying Lee Formation. Beds of light gray sandstone with black, carbonaceous shale containing ironstone nodules are typical of the lower Breathitt Formation. Shale, siltstone, and sandstone are frequently interbedded with the upper Lee Formation (Leist and others, 1982). The Corbin Sandstone Member is light gray to white, weathered to yellow-brown or pink, thick-bedded, cross-bedded, medium to coarse grained, and predominately quartzose. The shale in the upper part of the Lee Formation is light to medium gray, thin-bedded, and very silty to sandy. The Lily coal of the lower part of the Breathitt Formation was mined at the landfill sites and the spoil material, consisting of sandstone and shale, was subsequently used to cover the landfill waste deposited in the strip-mined areas. Bedding is essentially horizontal, but structure contours drawn on the base of the Lily coal bed indicate that the beds dip gently to the northeast (Hatch, 1963). Faults have not been mapped in the study area.

Ground-Water Hydrology

Shallow ground water in the study area occurs in the residual soil and mine spoil overlying bedrock. Ground water also occurs at depth, in fractured bedrock, primarily sandstone.

The direction of shallow ground-water flow is controlled primarily by the dip of the underlying bedrock surface, by the heterogeneous nature of the residual soil and mine spoil, and by the hydraulic gradient. Measured water levels in the wells indicate the slope of the hydraulic gradient in the residual soil and mine spoil (shallow aquifer). The shallow ground water seems to flow laterally from the landfill area toward the unnamed tributary of Slate Lick Creek (fig. 3). The altitude of water levels in wells and Slate Lick Creek are given in figure 3 and table 1. Shallow ground water is a component of baseflow to streams, but is not used for water-supply purposes in the study area.

In the study area, the expected ground-water flow path in the deep aquifer is from recharge areas on ridges to discharge areas in valleys or streams. Ground water is stored in and moves through intergranular pore spaces and in openings along vertical and horizontal fractures in the bedrock. Water moves primarily through interconnected fractures in the principle bedrock aquifer of the study area, the Corbin Sandstone Member of the Lee Formation (Otton, 1948). This aquifer is limited in extent across the valley but may extend for considerable distance along the length of the valley. The trend of the valley is generally from northeast to southwest. The ground-water flow paths are likely relatively short in the study area, thus ground



Drawing not to scale

Figure 2.--Generalized near-surface stratigraphic column for study area.

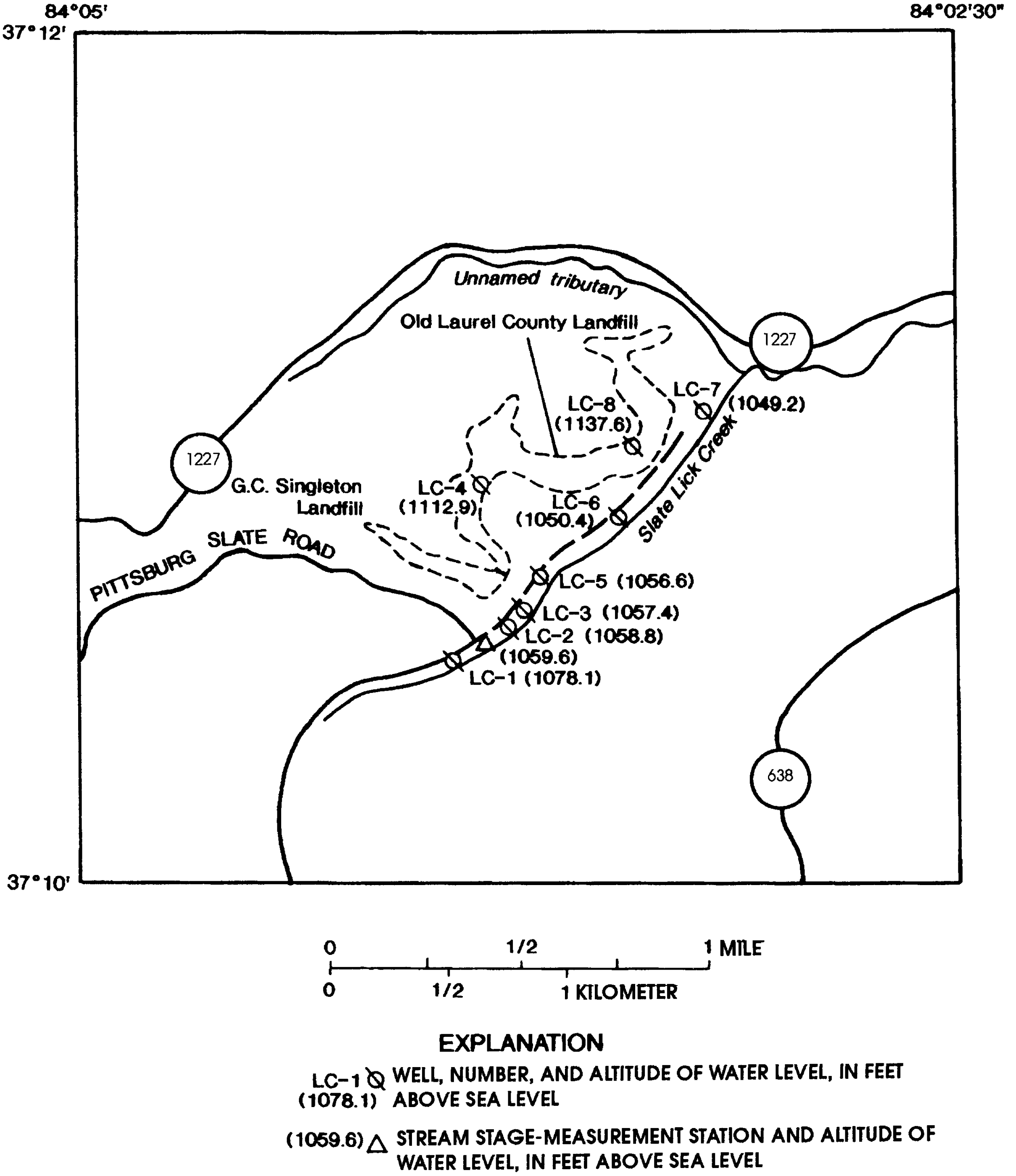


Figure 3.--Location of wells, stream stage-measurement station, and altitude of water levels.

Table 1. Water-level altitudes and physical properties measured in water samples from wells at the Old Laurel County and G.C. Singleton Landfills

[μS/cm, microsiemens per centimeter at 25 degrees Celsius]

Well	Water-level altitude[1] (feet)	Specific conductance (μS/cm)	pH (standard units)	Temperature (degrees Celsius)
LC-1	1,078.1	910	5.8	10.7
LC-2	1,058.8	810	5.7	10.4
LC-3	1,057.4	621	5.9	10.1
LC-4	1,112.9	859	5.0	13.1
LC-5	1,056.6	993	6.2	12.0
LC-6	1,050.4	743	6.2	11.4
LC-7	1,049.2	1,530	4.6	11.7
LC-8	1,137.6	3,220	5.0	14.2

[1] Datum is sea level.

water in this aquifer discharges downward and laterally to the outcrop of the aquifer. Lateral discharges can be seen as seeps or springs or as sustained flow in streams during periods of dry weather. The discharge from most springs is less than 5 gal/min (Kilburn and others, 1962).

METHODS OF STUDY

To define the geohydrology and water quality of the shallow ground-water system at the landfill sites, eight shallow wells were installed in early April 1991 (fig. 3). Well LC-1 was installed outside the landfills to obtain background water-quality information. The other wells were placed near the landfills in the most probable path of ground-water movement to intercept constituents which may be migrating from the landfills. Placement of the wells was based on information from previous site investigations, the requirement that the wells not penetrate a waste-fill area, and site evaluations performed by the KDWM and USGS during the study.

Well Construction

The wells were installed using a hollow-stem auger with a 3.75 in. interior diameter and 7.0 in. outside diameter. The boreholes were augered to refusal at bedrock. The nature of the mine-spoil material and residuum above the bedrock was noted while augering. A boring log for each well is provided in the supplemental information section of this report (figs. 4-11).

Threaded-joint riser and well screens made of polyvinyl chloride (PVC), 2 in. internal diameter, were installed inside the auger stem. The threaded joints enabled well construction without the use of glue. The screen length was about 5 ft and the slot size was 0.010 in. The screened interval extended upward from the contact of bedrock with the residual soil and mine spoil to include the anticipated vertical fluctuation of water levels in the shallow aquifer (residuum and mine spoil) at each well. This enabled the sampling of low-density constituents that may be floating on the ground-water surface.

As the augers were removed, a filter pack of clean silica sand was inserted (tremied) from the bottom of the borehole 1 to 2 ft above the top of the well screen. A bentonite seal, at least 1 ft thick, was placed at the top of the filter pack in the annular space between the riser pipe and borehole wall. The bentonite was allowed to hydrate for a minimum of 12 hours before a cement grout was placed from the bentonite seal to the ground surface. A concrete pad, approximately 6 in. thick and 4 ft in diameter, with a protective casing and lockable cap, completed each well installation. A generalized diagram of well construction is shown in figure 12, and construction details for each well are provided in the supplemental information section of this report (figs. 4-11).

The wells were developed by pumping and surging until the ground water was clear at the time of installation. After development, water levels in the wells were allowed to stabilize for at least 1 day before measuring and sampling.

Ground-Water Sampling

Prior to sampling, three well volumes of water were purged from each well. Water samples were collected using a Teflon bottom-loading bailer suspended from a Teflon cord. Before use, the bailer and cord were washed with a laboratory-grade detergent, rinsed first with a potable water, followed by a final rinse with deionized water. Ground-water samples were collected on April 11, 1991 from the wells installed near the landfills. Water samples were collected in the following order: (1) volatile organic compounds (VOC's), (2) semi-volatile organic compounds, (3) organochlorine pesticides and polychlorinated biphenyls (PCB's), (4) major ions and nutrients, and (5) trace elements. Care was taken not to aerate the water when lowering the bailer into the well. Water samples were transferred into the appropriate containers and preserved for shipment to the Enseco-Rocky Mountain Analytical Laboratory in Arvada, Colo. for analysis. All water samples were collected in accordance with standard techniques specified by Ward and Harr (1990).

Field Measurements and Laboratory Analyses

All ground-water samples were analyzed in the field for temperature, specific conductance, and pH. Temperature and specific conductance values were measured with a Yellow Springs Instrument 3000 meter; pH was measured with a Beckman 21 meter. Water levels were measured with a steel tape to the nearest 0.01 ft in each well prior to purging.

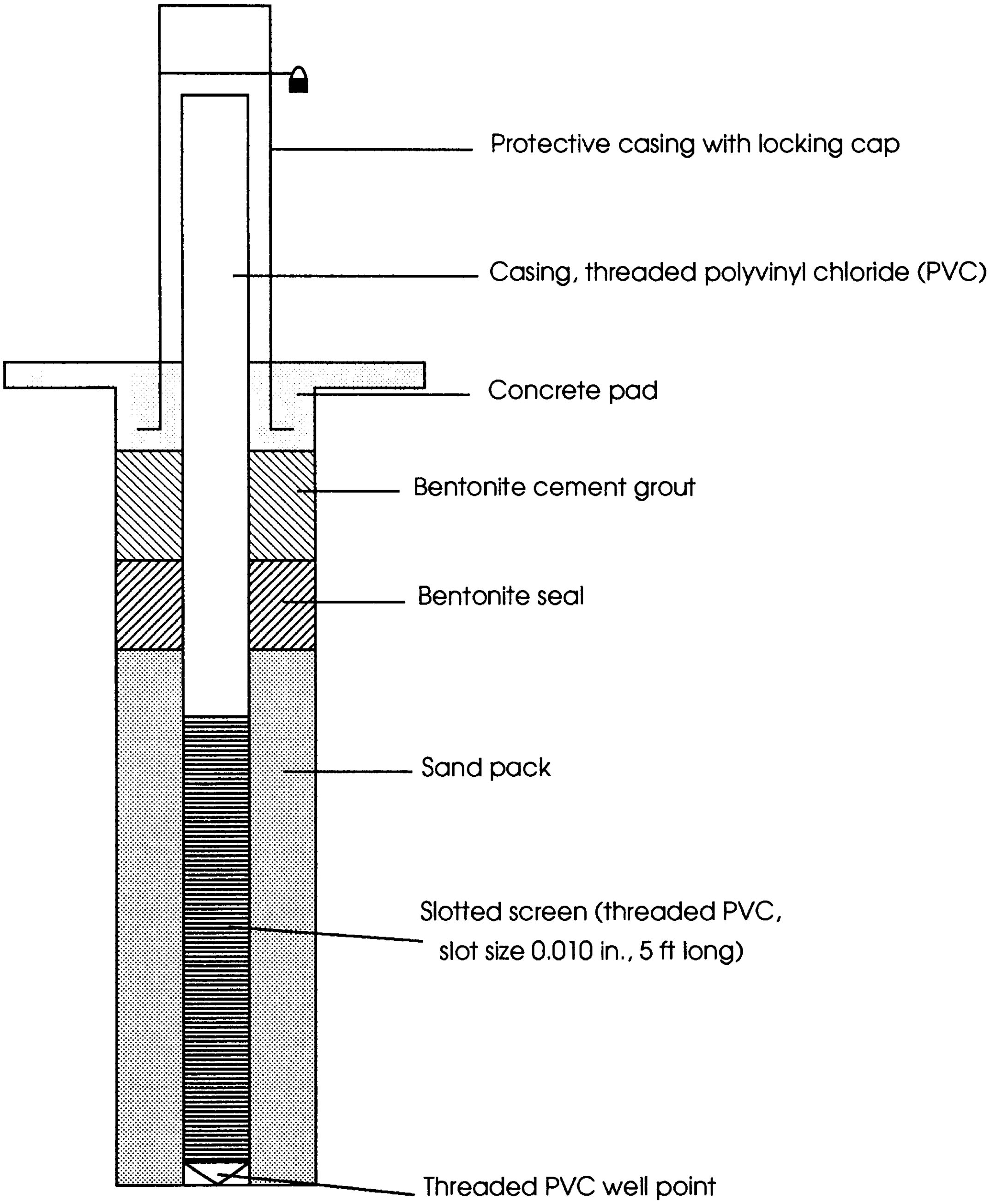


Figure 12.--Well-construction features.

Ground-water samples were analyzed in the laboratory for the following groups of organic compounds: VOC's; semi-volatile organic compounds, which included acid and base/neutral extractables; organochlorine pesticides; and PCB's. The ground-water samples were also analyzed for major ions, nutrients, and trace elements. The detection limits, maximum contaminant levels, and analytical methods for each constituent are provided by group of constituents in tables 2 through 6.

The sensitivity of an analytical method is related to the detection limit, which is the lowest concentration of an analyte that can be detected at a specific confidence level. Definitions and a description of procedures for determining detection limits used during this investigation are presented in the laboratory's quality assurance program plan (Enseco-Rocky Mountain Analytical Laboratory, 1989).

Quality Assurance

A quality assurance (QA) program was designed and implemented to ensure that the water-quality data collected during this study will

- Withstand scientific scrutiny,
- Be obtained by methods appropriate for its intended use, and
- Be of known precision, accuracy, and completeness.

To minimize the potential for cross-contamination during the installation of wells, all drilling equipment was decontaminated before the start of drilling, between drilling of boreholes, and before removal from the landfill sites. The decontamination of augers consisted of removal of soil using a wire brush followed by steam cleaning. After cleaning, all equipment was stored or maintained to prevent contamination before reuse.

All equipment used to collect water samples was decontaminated before and between sampling. The equipment was cleaned using steam, followed by a laboratory-grade detergent wash, followed by a methanol rinse, and a distilled-water rinse.

A duplicate water sample, from well LC-3, and a trip blank of deionized water used for rinsing sampling equipment was collected, prepared, and analyzed. The results were evaluated to determine the ability of the laboratory to replicate results and the integrity of water samples during processing and shipping of samples. Additional sample volumes were collected for use by the laboratory as matrix spike/matrix spike duplicate (MS/MSD) samples to evaluate matrix effects on analytical precision and accuracy.

Results of the analysis of the duplicate water samples from LC-3 were virtually identical. Purgeable volatile organics were not detected in the trip blank water sample. Analysis of water samples from all wells showed recoveries of the acid extractable surrogate compounds below established limits. The samples were reextracted and reanalyzed with similar results, therefore, indicating a matrix effect. The matrix spike and matrix duplicate analysis indicated low recovery of the spiked, acid extractable compounds, also indicating a matrix effect.

Table 2. Major ions and nutrients, detection limits, maximum contaminant levels, and analytical methods

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1990b and 1991a; SMCL, secondary maximum contaminant level, U.S. Environmental Protection Agency, 1990c; --, MCL/SMCL not established; SW6010, U.S. Environmental Protection Agency, 1986; A429, American Public Health Association and others, 1985]

Constituent	Detection limit	MCL	SMCL	Analytical method
	milligrams per liter			
Calcium	5	--	--	SW6010
Chloride	.5	--	250	A429
Fluoride	.5	4	2	A429
Magnesium	5	--	--	SW6010
Nitrate, as nitrogen	.5	10	--	A429
Potassium	5	--	--	SW6010
Ortho-phosphate	.5	--	--	A429
Sodium	5	--	--	SW6010
Sulfate	2.5	--	250	A429

Table 3. Trace elements, detection limits, maximum contaminant levels, and analytical methods

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1990a, 1991a, and 1991b; SMCL, secondary maximum contaminant level, U.S. Environmental Protection Agency, 1990c; --, MCL/SMCL not established; analytical methods, U.S. Environmental Protection Agency, 1986]

Constituent	Detection limit	MCL	SMCL	Analytical method
	milligrams per liter			
Aluminum	0.2	--	0.05	SW6010
Antimony	.2	--	--	SW6010
Arsenic	.005	0.05	--	SW7060
Barium	.1	2	--	SW6010
Beryllium	.002	--	--	SW6010
Cadmium	.005	.005	--	SW6010
Chromium	.03	.1	--	SW6010
Cobalt	.04	--	--	SW6010
Copper	.03	--	1	SW6010
Iron	.04	--	.3	SW6010
Lead	.005	.05	--	SW7421
Manganese	.01	--	.05	SW6010
Mercury	.0002	.002	--	SW7470
Molybdenum	.04	--	--	SW6010
Nickel	.04	--	--	SW6010
Selenium	.01	.05	--	SW7740
Silver	.03	.05	.1	SW6010
Thallium	2	--	--	SW6010
Vanadium	.04	--	--	SW6010
Zinc	.01	--	5	SW6010

Table 4. Volatile organic compounds, analytical method SW8240, detection limits, and maximum contaminant levels

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1990b and 1991a; --, MCL not established; analytical method, SW8240, U.S. Environmental Protection Agency, 1986]

Compound	Detection limit	MCL
	micrograms per liter	
Acetone	50	--
Acrolein	60	--
Acrylonitrile	25	--
Benzene	5	5
Bromodichloromethane	5	--
Bromoform	5	--
Bromomethane	10	--
2-Butanone	50	--
Carbon disulfide	5	--
Carbon tetrachloride	5	5
Chlorobenzene	5	--
Chloroethane	10	--
2-Chloroethyl vinyl ether	100	--
Chloroform	5	--
Chloromethane	14	--
Dibromochloromethane	5	--
Dibromomethane	10	--
trans-1,4-Dichloro-2-butene	50	--
Dichlorodifluoromethane	10	--
1,1-Dichloroethane	5	--
1,2-Dichloroethane	5	5
1,1-Dichloroethene	4	--
trans-1,2-Dichloroethene	5	--
1,2-Dichloropropane	5	5
cis-1,3-Dichloropropene	5	--
trans-1,3-Dichloropropene	5	--
Ethyl methacrylate	10	--
Ethyl benzene	5	700
2-Hexanone	50	--
Iodomethane	10	--
Methylene chloride	17	--
4-Methyl-2-pentanone	50	--
Styrene	5	100
1,1,2,2-Tetrachloroethane	7	--
Tetrachloroethene	5	--
Toluene	5	1,000
1,1,1-Trichloroethane	5	.2
1,1,2-Trichloroethane	5	--

Table 4. Volatile organic compounds, analytical method SW8240, detection limits, and maximum contaminant levels--Continued

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1990b and 1991a; --, MCL not established; analytical method, SW8240, U.S. Environmental Protection Agency, 1986]

Compound	Detection limit	MCL
	micrograms per liter	
Trichloroethene	5	--
Trichlorofluoromethane	10	--
1,2,3-Trichloropropane	10	--
Vinyl acetate	50	--
Vinyl chloride	11	2
Xylenes (total)	5	10

Table 5. Semi-volatile organic compounds, analytical method SW8270, detection limits, and maximum contaminant levels

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1991a and 1991b; --, MCL not established; analytical method SW8270, U.S. Environmental Protection Agency, 1986]

Compound	Detection limit micrograms per liter	MCL micrograms per liter
Acenaphthene	10	--
Acenaphthylene	10	--
Acetophenone	50	--
4-Aminobiphenyl	50	--
Aniline	50	--
Anthracene	10	--
Benzidine	170	--
Benzo(a)anthracene	10	--
Benzo(b)fluoranthene	10	--
Benzo(k)fluoranthene	10	--
Benzo(g,h,i)perylene	10	--
Benzo(a)pyrene	10	--
Benzoic acid	50	--
Benzyl alcohol	20	--
4-Bromophenyl phenyl ether	10	--
Butylbenzyl phthalate	10	--
4-Chloroaniline	20	--
bis(2-Chloroethoxy)methane	10	--
bis(2-Chloroethyl)ether	10	--
bis(2-Chloroisopropyl)ether	10	--
4-Chloro-3-methylphenol	10	--
1-Chloronaphthalene	50	--
2-Chloronaphthalene	10	--
2-Chlorophenol	10	--
4-Chlorophenyl phenyl ether	10	--
Chrysene	10	--
Dibenzo(a,h)anthracene	10	--
Dibenzofuran	10	--
1,2-Dichlorobenzene	5	--
1,3-Dichlorobenzene	5	--
1,4-Dichlorobenzene	5	--
3,3-Dichlorobenzidine	30	--
2,4-Dichlorophenol	10	--
2,6-Dichlorophenol	50	--
Diethyl phthalate	20	--
2,4-Dimethylphenol	10	--
7,12-Dimethylbenz(a)anthracene	50	--
Dimethyl phthalate	10	--

Table 5. Semi-volatile organic compounds, analytical method SW8270, detection limits, and maximum contaminant levels--Continued

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1991a and 1991b; --, MCL not established; analytical method SW8270, U.S. Environmental Protection Agency, 1986]

Compound	Detection limit	MCL
	micrograms per liter	
Di-n-butylphthalate	10	--
p-Dimethylaminoazobenzene	50	--
4,6-Dinitro-2-methylphenol	50	--
2,4-Dinitrophenol	50	--
2,4-Dinitrotoluene	10	--
2,6-Dinitrotoluene	10	--
Di-n-octyl phthalate	10	--
Diphenylamine	50	--
1,2-Diphenylhydrazine	50	--
bis(2-Ethylhexyl)phthalate	10	--
Ethyl methanesulfonate	50	--
Fluoranthene	10	--
Fluorene	10	--
Hexachlorobenzene	10	--
Hexachlorobutadiene	10	--
Hexachlorocyclopentadiene	10	--
Hexachloroethane	10	--
Indeno(1,2,3-c,d)pyrene	10	--
Isophorone	10	--
3-Methylchloroanthrene	50	--
Methyl methanesulfonate	50	--
2-Methylnaphthalene	10	--
2-Methylphenol	10	--
4-Methylphenol	10	--
Naphthalene	10	--
1-Naphthylamine	50	--
2-Naphthylamine	50	--
2-Nitroaniline	50	--
3-Nitroaniline	50	--
4-Nitroaniline	58	--
Nitrobenzene	10	--
2-Nitrophenol	10	--
4-Nitrophenol	50	--
N-Nitroso-di-n-butylamine	50	--
N-Nitroso-di-n-propylamine	10	--
N-Nitrosodimethylamine	50	--
N-Nitrosodiphenylamine	10	--
N-Nitrosopiperidine	50	--

Table 5. Semi-volatile organic compounds, analytical method SW8270, detection limits, and maximum contaminant levels--Continued

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1991a and 1991b; --, MCL not established; analytical method SW8270, U.S. Environmental Protection Agency, 1986]

Compound	Detection limit	MCL
	micrograms per liter	
Pentachlorobenzene	50	--
Pentachloronitrobenzene	50	--
Pentachlorophenol	30	1
Phenacetin	50	--
Phenanthrene	10	--
Phenol	10	--
2-Picoline	50	--
Pronamide	50	--
Pyrene	10	--
1,2,4,5-Tetrachlorobenzene	50	--
2,3,4,6-Tetrachlorophenol	50	--
1,2,4-Trichlorobenzene	10	--
2,4,5-Trichlorophenol	50	--
2,4,6-Trichlorophenol	10	--

Table 6. Organochlorine pesticides and polychlorinated biphenyls, analytical method SW8080, detection limits, and maximum contaminant levels

[MCL, maximum contaminant level, U.S. Environmental Protection Agency, 1990a and 1991a; --, MCL not established; analytical method SW8080, U.S. Environmental Protection Agency, 1986]

Compound	Detection limit micrograms per liter	MCL micrograms per liter
	Organochlorine pesticides	
Aldrin	0.02	--
alpha - BHC	.05	--
beta - BHC	.05	--
delta - BHC	.05	--
gamma - BHC (Lindane)	.05	0.2
Chlordane	.05	2
4,4' -DDD	.1	--
4,4' -DDE	.1	--
4,4' -DDT	.1	--
Dieldrin	.02	--
Endosulfan I	.05	--
Endosulfan II	.1	--
Endosulfan sulfate	.1	--
Endrin	.06	.2
Endrin aldehyde	.1	--
Heptachlor	.02	.4
Heptachlor epoxide	.05	.2
Methoxychlor	.5	40
Toxaphene	1	3
	Polychlorinated biphenyls	
Aroclor 1016	.5	--
Aroclor 1221	.5	--
Aroclor 1232	.5	--
Aroclor 1242	.5	--
Aroclor 1248	.5	--
Aroclor 1254	1	--
Aroclor 1260	1	--

GROUND-WATER QUALITY

The following discussion of ground-water quality is based on the results of analysis of ground-water samples collected from the eight wells on April 11, 1991.

Physical Properties

Values of pH in water from the wells ranged from 4.6 to 6.2 (table 1). The pH was 5.8 in one water sample, from well LC-1, located outside the landfill area. The values of pH suggest acidic conditions that may be a result of landfill leachate or weathered mine spoil. During this investigation, several outbreaks of orange leachate were observed along the strip bench near the edge of the landfill.

Measured values of specific conductance in the ground-water samples were variable (table 1). The highest values were measured in water from wells LC-7 (1,530 μS/cm) and LC-8 (3,220 μS/cm). Well LC-8 is adjacent to the Old Laurel County Landfill but is at a higher altitude than well LC-7. The specific conductance of the water from well LC-1 was 910 μS/cm. Leist and others (1982) reported that the specific conductance of ground water in the Eastern Coal Province of Kentucky and Tennessee, which includes part of Laurel County, ranged from 17 to 1,410 μS/cm. During this investigation, the highest values of specific conductance were measured in water from wells near the Old Laurel County Landfill and are indicative of an increase in dissolved mineral content which could be related to the weathering of mine spoil or leachate from the landfill.

Major Ions and Nutrients

Ground-water samples collected during this study were analyzed for major ions, nitrate, and ortho-phosphate (table 7). Water samples from wells LC-7 and LC-8 contained the highest concentrations of calcium, fluoride, magnesium, and sulfate. Nitrate-nitrogen was not detected in any of the ground-water samples. Concentrations of ortho-phosphate ranged from below the detection limit in the water from well LC-8 to 0.83 mg/L in the water from well LC-4.

The fluoride concentration was relatively high in water from wells LC-7 and LC-8, 1.7 and 4.5 mg/L, respectively. Hem (1985, p. 120) states that fluoride concentrations in most natural water are low, generally less than 1.0 mg/L. In the study area, fluoride does not usually occur in bedrock in concentrations sufficient to produce elevated values of fluoride in natural ground water. Therefore, the elevated values of fluoride may be related to leachate from the Old Laurel County Landfill.

The sulfate content exceeded the USEPA, Secondary Maximum Contaminant Level (SMCL) of 250 mg/L (U.S. Environmental Protection Agency, 1990c) in all but one of the ground-water samples. Concentrations of sulfate ranged from 229 mg/L in the water from well LC-3 to 1,420 and 3,350 mg/L in the water from wells LC-7 and LC-8, respectively. The high concentrations of sulfate may be related to past surface-coal-mining activities in the study area. The

Table 7. Concentrations of major ions and nutrients in water samples from wells at the Old Laurel County and G.C. Singleton Landfills

[<, less than; concentrations reported in milligrams per liter]

	Well							
Constituent	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8
Calcium	100	110	51	38	96	42	160	290
Chloride	2.4	3.4	3.1	27	31	2.1	2.9	.6
Fluoride	<.5	.6	<.5	.7	<.5	<.5	1.7	4.5
Magnesium	26	44	19	54	47	52	150	380
Nitrate, as Nitrogen	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
Ortho-phosphate	.71	.73	.7	.83	.76	.75	.76	<.5
Potassium	6	14	<5	9	<5	<5	7	13
Sodium	5.0	14	6.0	35	32	5.3	12	16
Sulfate	460	610	230	340	330	330	1,400	3,400

oxidation of pyritic (iron disulfide) materials yields sulfate ions that are readily soluble in water. The high concentrations of sulfate, derived from pyrite found in the shale and coal beds underlying the study area, indicate that acid-mine drainage affects ground-water quality.

Trace Elements

Trace elements are predominately metals of low solubility present in soils and rocks. During the weathering process, trace elements slowly leach into natural waters, usually in low concentrations. Certain trace elements, such as arsenic, cadmium, lead, mercury, and selenium, can be highly toxic to humans and other biota. However, low concentrations of some trace elements, such as copper, iron, and zinc, are beneficial to life (Hem, 1985). The trace-element data for water sampled from the wells are presented in table 8.

Several of the water samples, particularly those from wells LC-7 and LC-8, contained high concentrations of trace elements commonly associated with acid-mine drainage such as iron and manganese (Cunningham and Jones, 1990). The water from wells LC-7 and LC-8 contained the highest concentrations of aluminum, manganese, nickel, and zinc observed during the investigation. The concentration of aluminum in water from wells LC-1, LC-2, LC-4, LC-7, and LC-8 exceeded the SMCL of 0.2 mg/L (U.S. Environmental Protection Agency, 1990c). The concentrations of iron and manganese in water from all wells exceeded the SMCL of 0.3 and 0.05 mg/L, respectively.

The concentrations of beryllium and cobalt were highest in water from well LC-7. Of special interest during this investigation is that cadmium, a common constituent of paint pigments, was not detected in any water samples in concentrations greater than the detection limits.

Hem (1985) notes that iron and aluminum, the second and third most abundant elements in the earth's crust, respectively, are common in most rocks and soils. However, the solubility of these constituents in water is somewhat pH dependent. The chemistry of manganese is similar to that of iron, and the element is frequently associated with iron compounds. Ground water may contain more than 1.0 mg/L of manganese, often in association with high iron concentrations (Hem, 1985, p. 89).

During the surface mining of coal, the removal and exposure of soils and rocks often exposes pyritic materials. The oxidation of the pyritic materials results in ferrous iron and sulfuric acid. As a result, the pH of the ground water is lowered and the solubility of aluminum, iron, manganese, zinc, and other elements is increased. Because of coal mining at the landfill sites, it cannot be concluded if the relatively large concentrations of selected trace elements in ground water are a result of past coal-mining activities or leachate from waste material in the landfills.

Table 8. Concentrations of trace elements in water samples from wells at the Old Laurel County and G.C. Singleton Landfills

[<, less than; concentrations reported in milligrams per liter]

	Well							
Constituent	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8
Aluminum	1.6	0.92	<0.2	0.26	<0.2	<0.2	4.4	3.0
Antimony	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Arsenic	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Barium	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Beryllium	<.002	<.002	<.002	<.002	<.002	<.002	.003	<.002
Cadmium	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Chromium	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03
Cobalt	.073	.12	.07	.20	<.04	.051	.90	.067
Copper	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03
Iron	65.7	74.3	27.4	.68	7.8	12.4	26.8	313
Lead	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Manganese	9.8	14.8	24.4	17.2	13.1	19.9	111	116
Mercury	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002
Molybdenum	<.04	<.04	<.04	<.04	<.04	<.04	<.04	<.04
Nickel	.065	<.04	<.04	.17	<.04	<.04	.49	1.5
Selenium	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Silver	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03
Thallium	<2	<2	<2	<2	<2	<2	<2	<2
Vanadium	<.04	<.04	<.04	<.04	<.04	<.04	<.04	<.04
Zinc	.12	.069	.017	.19	.026	.015	.35	2.0

Organic Compounds

The ground-water samples were analyzed in the laboratory for the following groups of organic compounds: VOC's; semi-volatile organic compounds, which included acid and base/neutral extractables; organochlorine pesticides; and PCB's. VOC's were not detected in any of the ground-water samples (table 9). The semi-volatile organic compound, 3,4-dichloro-benzoic acid, was tentatively identified in all ground-water samples, including the sample from background-well LC-1 (table 10)[1].

Benzoic acid is used in substantial quantities for a wide variety of purposes. It is a component of medicines used for the treatment of arthritis and a common bactericide. Benzoic acid is also used in industrial applications as an alkyd-resin coating formation, a coolant additive in automobile systems, and in cutting and machine oils. In addition, benzoic acid is used in many herbicides as a plant-growth inhibitor (Williams, 1978). Thus, the source of the benzoic acid may not be limited to the landfills because land usage in the watershed of Slate Lick includes numerous small farms where herbicides may have been applied. PCB's and organochlorine pesticides were not detected in the ground-water samples (table 11).

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[1] Data for tentatively identified organic compounds (TIOC) in this report are based on comparison of sample spectra with library spectra followed by visual examination by gas chromatograph/mass spectrograph (GC/MS) analysts. TIOC data have not been confirmed by direct comparison with reference standards. Therefore, TIOC identification is tentative, and reported concentrations are semiquantitative.

Table 9. Concentrations of volatile organic compounds in water samples from wells at the Old Laurel County and G.C. Singleton Landfills

[ND, not detected]

	Well							
Compound	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8
Acetone	ND	ND	ND	ND	ND	ND	ND	ND
Acrolein	ND	ND	ND	ND	ND	ND	ND	ND
Acrylonitrile	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Bromoform	ND	ND	ND	ND	ND	ND	ND	ND
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND
Carbon disulfide	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloroethyl vinyl ether	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Dibromomethane	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND
cis-1,3-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl benzene	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl methacrylate	ND	ND	ND	ND	ND	ND	ND	ND
2-Hexanone	ND	ND	ND	ND	ND	ND	ND	ND
Iodomethane	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	ND
4-Methyl-2-pentanone	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,4-Dichloro-2-butene	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3-Trichloropropane	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl acetate	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes (total)	ND	ND	ND	ND	ND	ND	ND	ND

Table 10. Concentrations of semi-volatile organic compounds in water samples from wells at the Old Laurel County and G.C. Singleton Landfills

[ND, not detected; concentrations reported in micrograms per liter]

	Well							
Compound	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND
Acetophenone	ND	ND	ND	ND	ND	ND	ND	ND
4A-Aminobiphenyl	ND	ND	ND	ND	ND	ND	ND	ND
Aniline	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND
Benzidine	ND	ND	ND	ND	ND	ND	ND	ND
ABenzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND
Benzoic acid	ND	ND	ND	ND	ND	ND	ND	ND
Benzyl alcohol	ND	ND	ND	ND	ND	ND	ND	ND
4-Bromophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND	ND
Butylbenzylr phthalate	ND	ND	ND	ND	ND	ND	ND	ND
4-Chloroaniline	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroethoxy)methane	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroisopropyl)ether	ND	ND	ND	ND	ND	ND	ND	ND
4-Chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	ND	ND
1-Chloronaphthalene	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND	ND	ND	ND	ND	ND
2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND	ND
4-Chlorophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
3,3'-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND	ND
3,4-Dichloro-benzoic acid	18	36	100	130	110	67	150	120
2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND
2,6-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND
p-Dimethylaminoazobenzene	ND	ND	ND	ND	ND	ND	ND	ND
7,12-Dimethylbenz(a) anthracene	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND

Table 10. Concentrations of semi-volatile organic compounds in water samples from wells at the Old Laurel County and G.C. Singleton Landfills--Continued

[ND, not detected; concentrations reported in micrograms per liter]

	Well							
Compound	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8
Dimethyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butylphthalate	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND
Diphenylamine	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Diphenylhydrazine	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Ethylhexyl)phthalate	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl methanesulfonate	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	ND	ND	ND	ND	ND	ND	ND	ND
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND
3-Methylcholanthrene	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND
Methyl methanesulfonate	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylphenol	ND	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND
1-Naphthylamine	ND	ND	ND	ND	ND	ND	ND	ND
2-Naphthylamine	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitroaniline	ND	ND	ND	ND	ND	ND	ND	ND
3-Nitroaniline	ND	ND	ND	ND	ND	ND	ND	ND
4-Nitroaniline	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND
4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitroso-di-n-butylamine	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodimethylamine	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitroso-di-n-propylamine	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosopiperidine	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Pentachloronitrobenzene	ND	ND	ND	ND	ND	ND	ND	ND

Table 10. Concentrations of semi-volatile organic compounds in water samples from wells at the Old Laurel County and G.C. Singleton Landfills--Continued

[ND, not detected; concentrations reported in micrograms per liter]

	Well							
Compound	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND
Phenacetin	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	ND	ND	ND	ND	ND	ND	ND	ND
2-Picoline	ND	ND	ND	ND	ND	ND	ND	ND
Pronamide	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4,5-Tetrachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
2,3,4,6-Tetrachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
2,4,5-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND

[1] Tentatively identified organic compound: the reported concentration generally is accurate to one order of magnitude.

Table 11. Organochlorine pesticide and polychlorinated biphenyl concentrations in water samples from wells at the Old Laurel County and G.C. Singleton Landfills

[ND, not detected]

	Well							
Compound	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND
alpha - BHC	ND	ND	ND	ND	ND	ND	ND	ND
beta - BHC	ND	ND	ND	ND	ND	ND	ND	ND
delta - BHC	ND	ND	ND	ND	ND	ND	ND	ND
gamma - BHC (Lindane)	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDD	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDE	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDT	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan I	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan II	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan sulfate	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND	ND
Endrin aldehyde	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor epoxide	ND	ND	ND	ND	ND	ND	ND	ND
Methoxychlor	ND	ND	ND	ND	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND	ND	ND	ND	ND
			Polychlorinated biphenyls					
Aroclor 1016	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1221	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1232	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1242	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1248	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1254	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1260	ND	ND	ND	ND	ND	ND	ND	ND

CONCLUSIONS

The physical and chemical quality of the shallow ground water at the landfill sites, including the quality of water collected from the background-well, is similar to that expected in areas where coal has been strip mined and no landfills are present. The pH of the shallow ground water indicated acidic conditions that might be expected in coal strip-mine areas. The elevated values of specific conductance measured in water from wells near the Old Laurel County Landfill indicate contamination from either landfill leachate or acid-mine drainage. Several of the ground-water samples, particularly those from wells LC-7 and LC-8, contained relatively high concentrations of constituents commonly associated with acid-mine drainage, such as aluminum, iron, manganese, sulfate, and zinc. However, the relatively high concentration of fluoride, 4.5 mg/L, measured in water from well LC-8 could be related to leachate from the landfill.

Except for 3,4-dichloro-benzoic acid, organic constituents were not detected in the ground-water samples. Benzoic acid is a common bactericide that is also widely found in selected herbicides, medicines, and industrial chemicals. Thus, 3,4-dichloro-benzoic acid is not an indicator of drainage from leachate materials in the landfill in the study area.

Periodic water-level measurements from additional wells installed at a higher altitude than the streams are needed to better define seasonal fluctuations in the altitude of the water table and the direction of ground-water flow from the landfill areas. Periodic chemical analysis of water samples from the wells and also from the nearby streams would provide additional temporal and spatial information about the quality of water in the shallow aquifer system near the landfills.

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SUPPLEMENTAL INFORMATION

BORING LOG	BORING/WELL NO.: LC-1	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills		Site: Laurel County, Kentucky
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District		Driller: Doug Zettwoch
Drilling Started: 4/2/91	Drilling Ended: 4/2/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y / [✓ N]) From ____ to ____	Protection Level: D

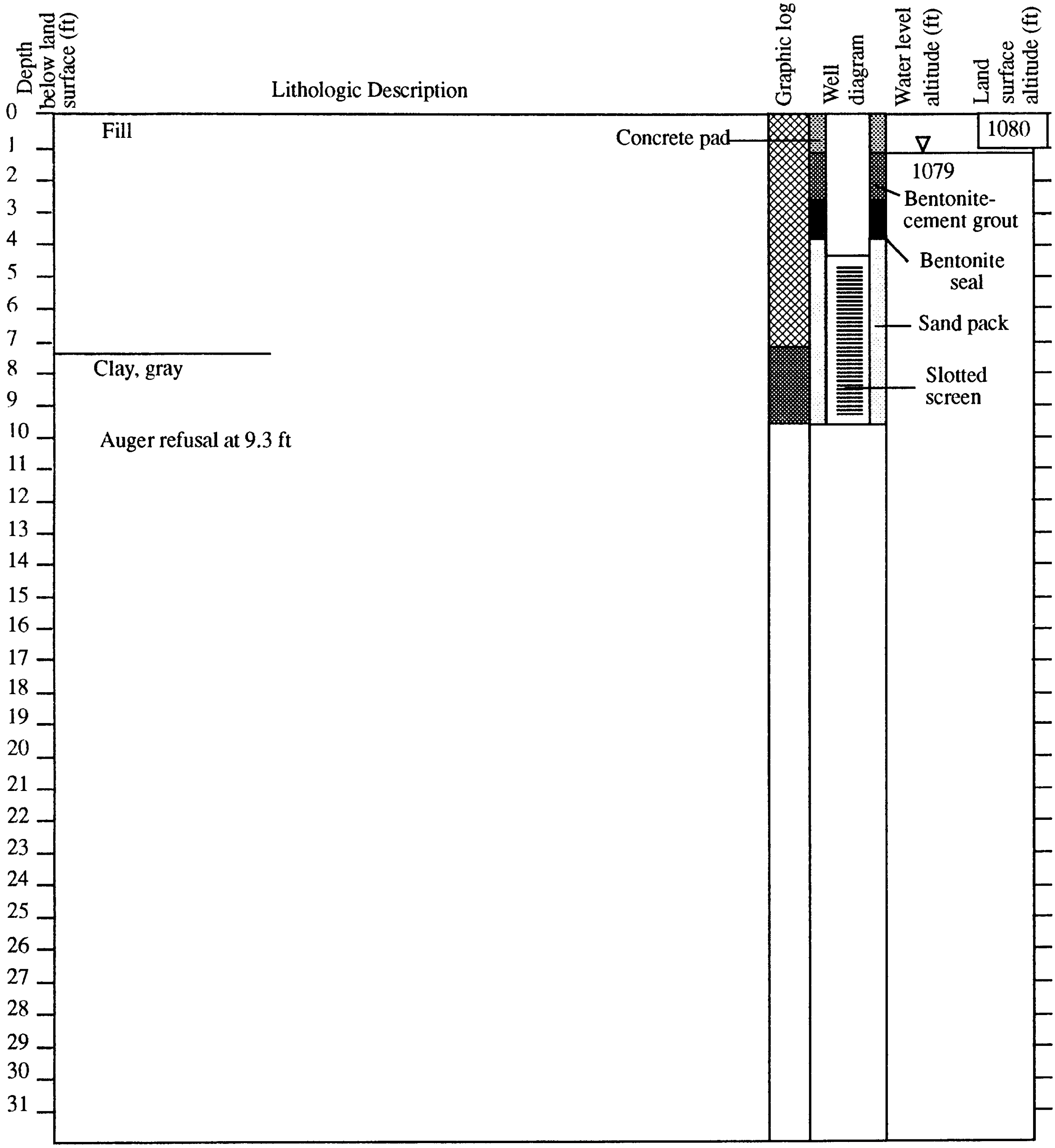

Figure 4.--Boring log and construction diagram for well LC-1.

BORING LOG	BORING/WELL NO.: LC-2	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills		Site: Laurel County, Kentucky
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District		Driller: Doug Zettwoch
Drilling Started: 4/2/91	Drilling Ended: 4/2/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y / [✓ N]) From ____ to ____	Protection Level: D

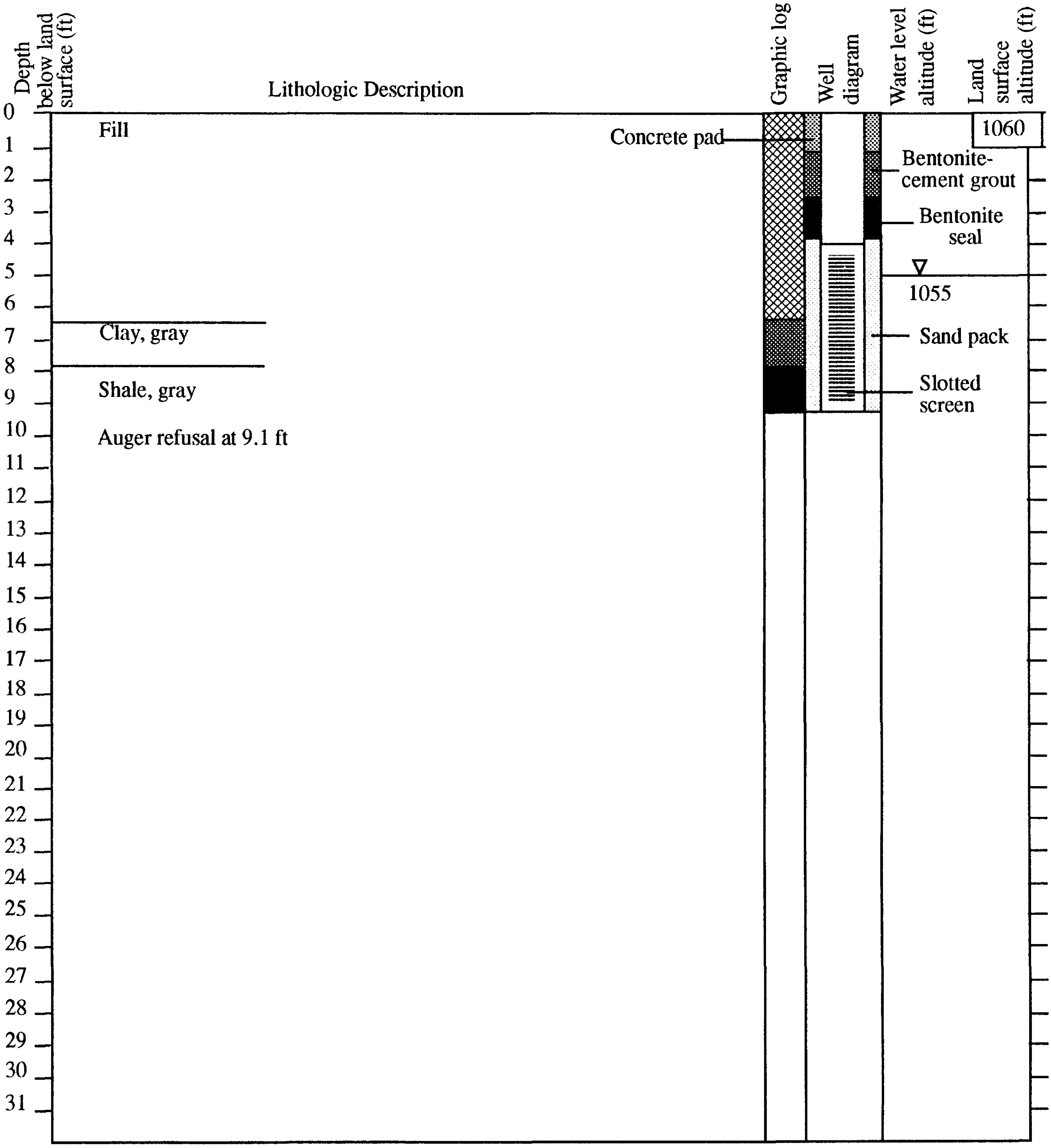

Figure 5.--Boring log and construction diagram for well LC-2.

BORING LOG	BORING/WELL NO.: LC-3	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills		Site: Laurel County, Kentucky
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District		Driller: Doug Zettwoch
Drilling Started: 4/3/91	Drilling Ended: 4/3/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y /[✓ N]) From ____ to ____	Protection Level: D

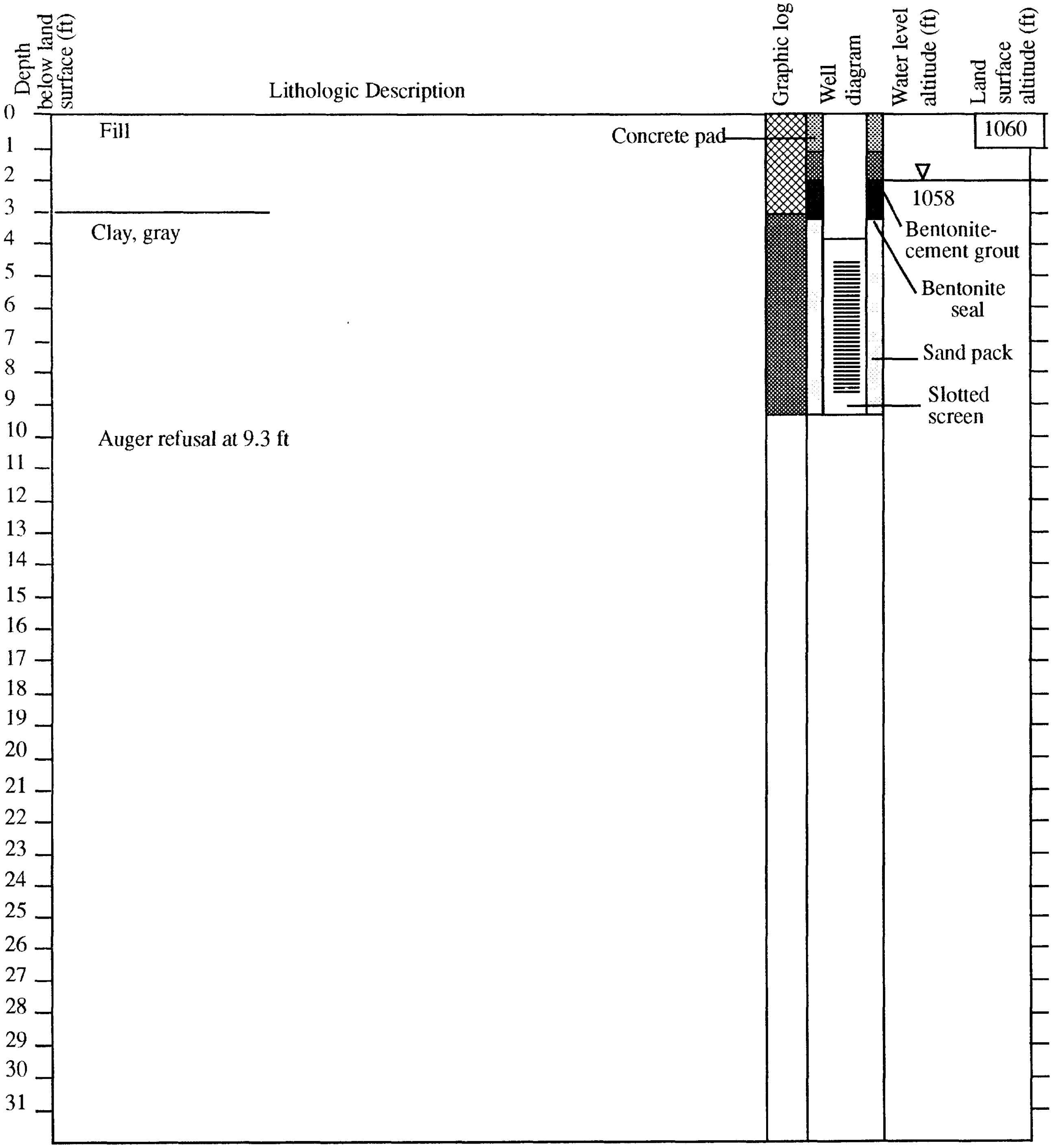

Figure 6.--Boring log and construction diagram for well LC-3.

BORING LOG	BORING/WELL NO.: LC-4	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills		Site: Laurel County, Kentucky
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District		Driller: Doug Zettwoch
Drilling Started: 4/4/91	Drilling Ended: 4/4/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y / [✓ N]) From ____ to ____	Protection Level: D

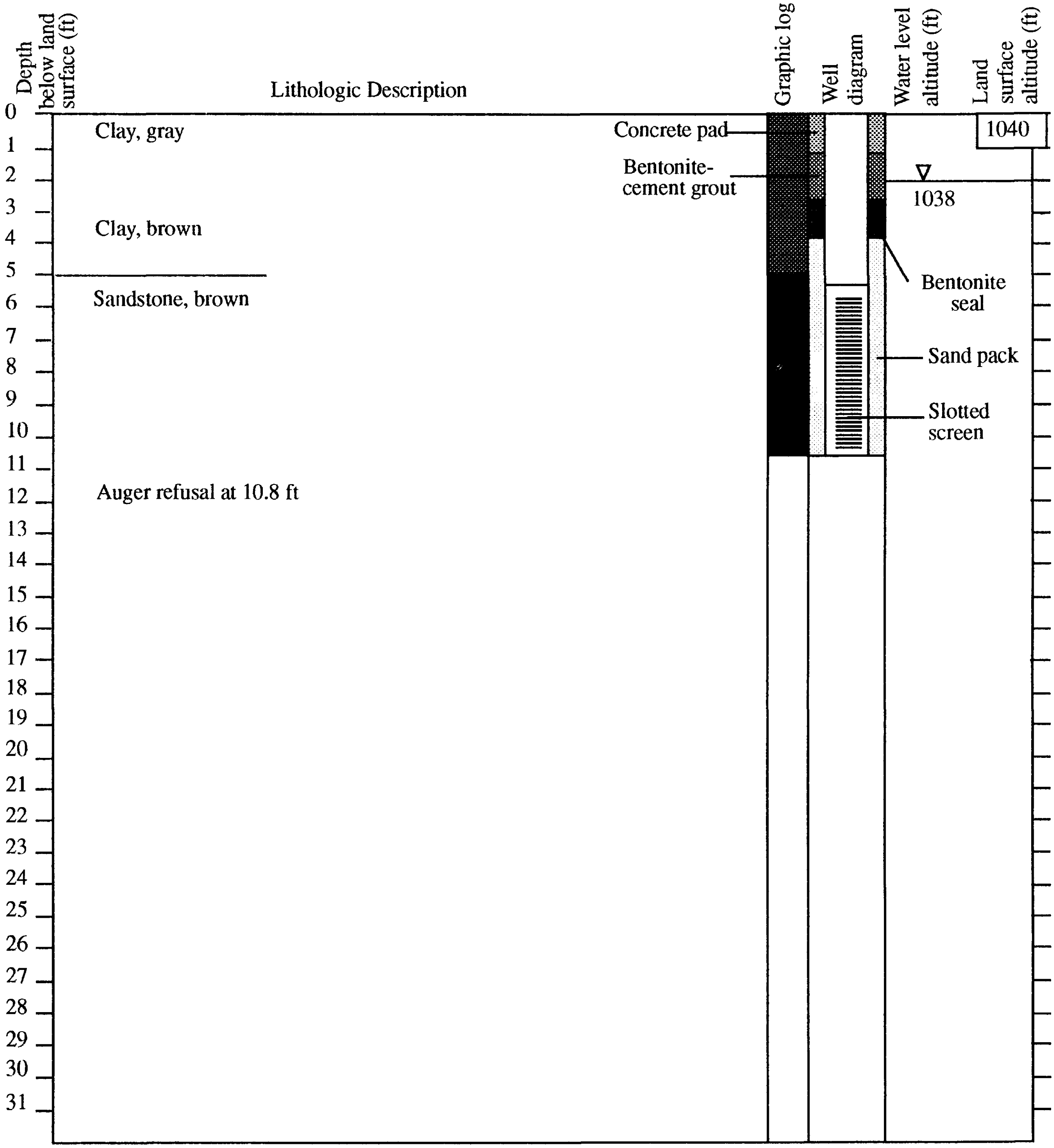

Figure 7.--Boring log and construction diagram for well LC-4.

BORING LOG	BORING/WELL NO.: LC-5	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills	Site: Laurel County, Kentucky	
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District	Driller: Doug Zettwoch	
Drilling Started: 4/3/91	Drilling Ended: 4/3/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y / [✓ N]) From ____ to ____	Protection Level: D

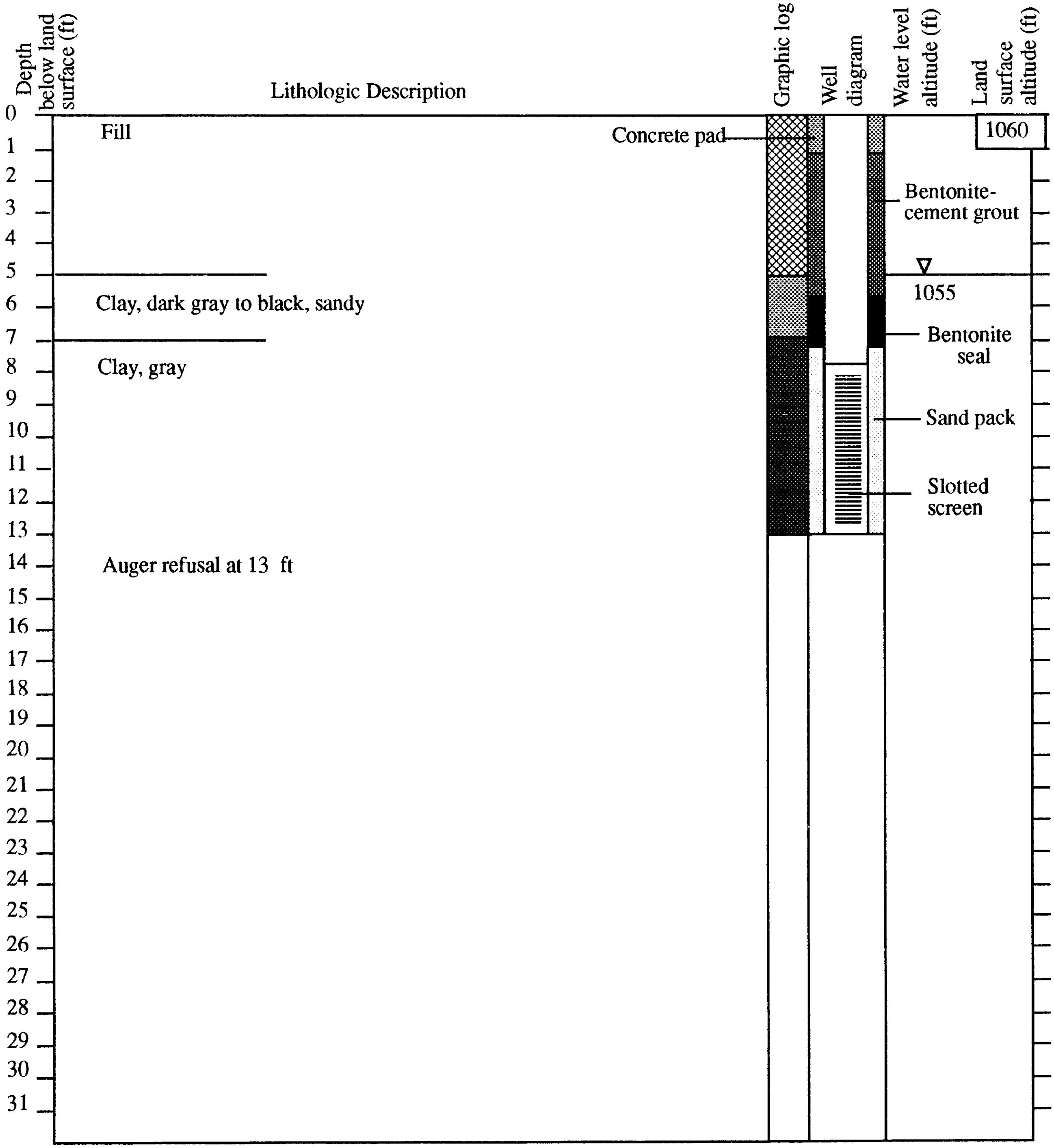

Figure 8.--Boring log and construction diagram for well LC-5.

BORING LOG	BORING/WELL NO.: LC-6	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills		Site: Laurel County, Kentucky
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District		Driller: Doug Zettwoch
Drilling Started: 4/3/91	Drilling Ended: 4/3/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y / [✓ N]) From ____ to ____	Protection Level: D

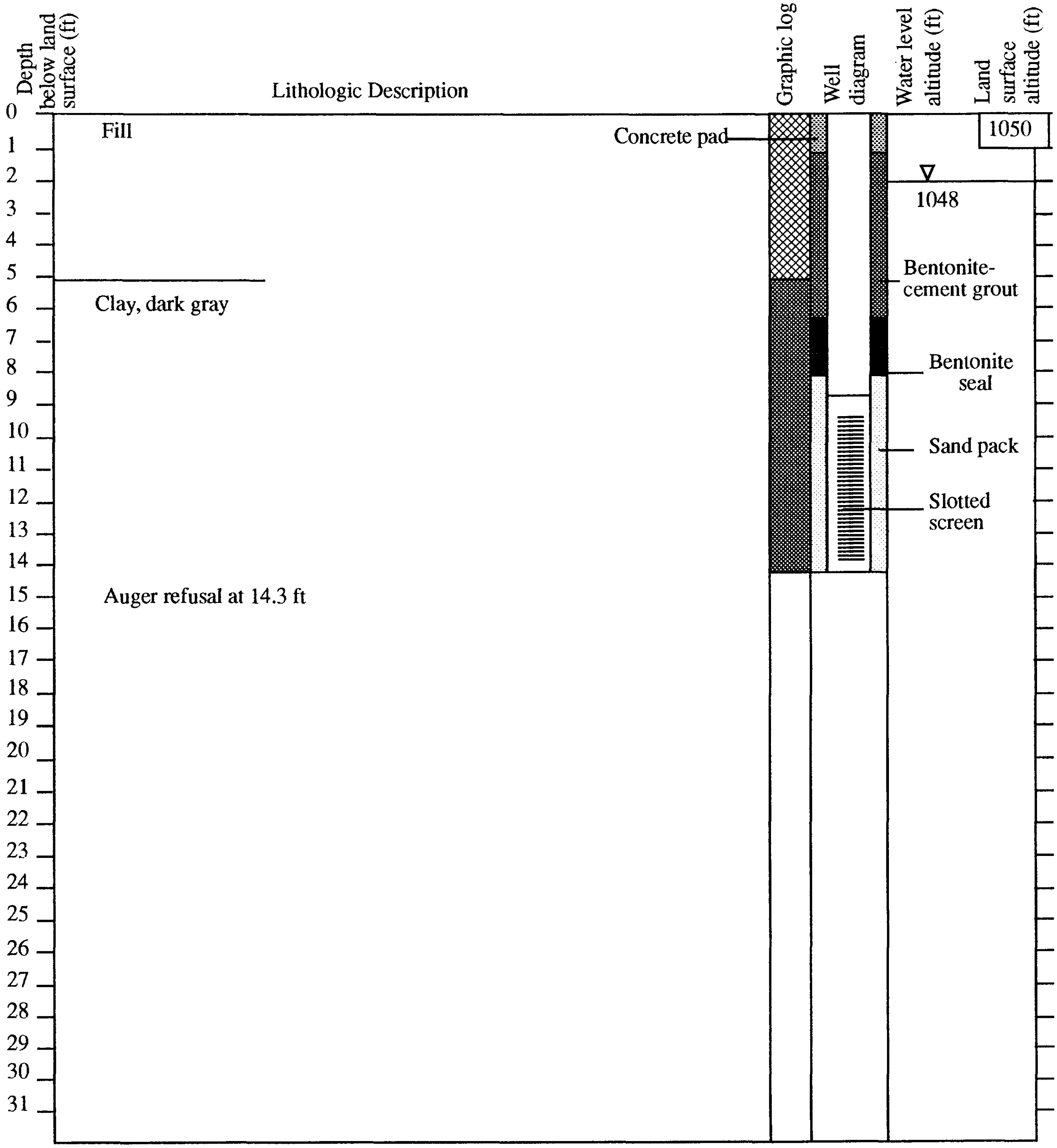

Figure 9.--Boring log and construction diagram for well LC-6.

BORING LOG	BORING/WELL NO.: LC-7	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills	Site: Laurel County, Kentucky	
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District	Driller: Doug Zettwoch	
Drilling Started: 4/3/91	Drilling Ended: 4/3/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y / [✓ N]) From ____ to ____	Protection Level: D

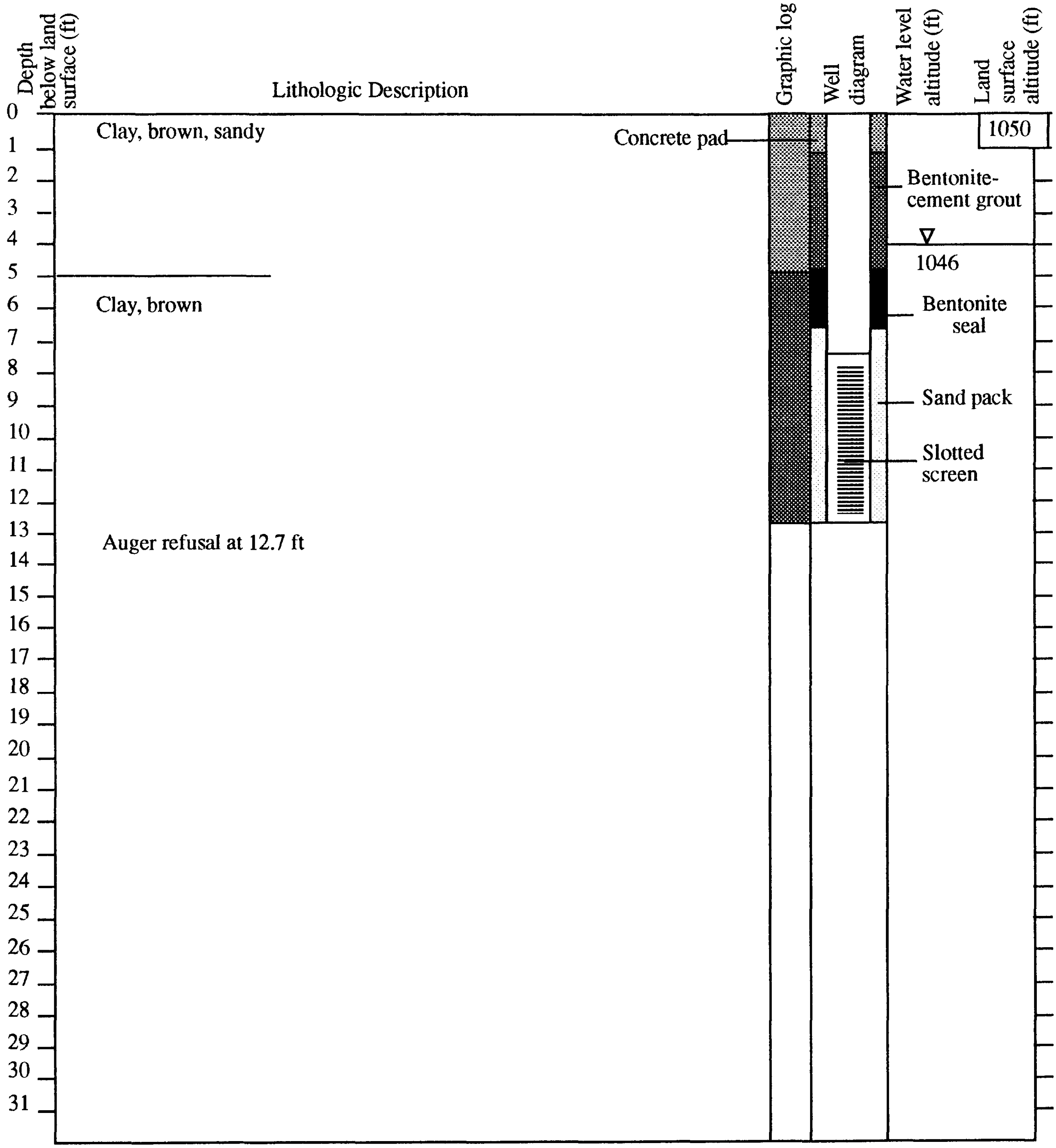

Figure 10.--Boring log and construction diagram for well LC-7.

BORING LOG	BORING/WELL NO.: LC-8	Page 1 of 1
Installation: Old Laurel County and G.C. Singleton Landfills		Site: Laurel County, Kentucky
Project No.: KY90-082	Client/Project: Site Investigation	
Drilled by the U. S. Geological Survey, Kentucky District		Driller: Doug Zettwoch
Drilling Started: 4/3/91	Drilling Ended: 4/3/91	Borehole dia(s): 7.0 in.
Drilling Method/Rig Type: Hollow-stem auger/ Mobile Drill Model B40		
Logged by: James Parnell	E-Log (Y / [✓ N]) From ____ to ____	Protection Level: D

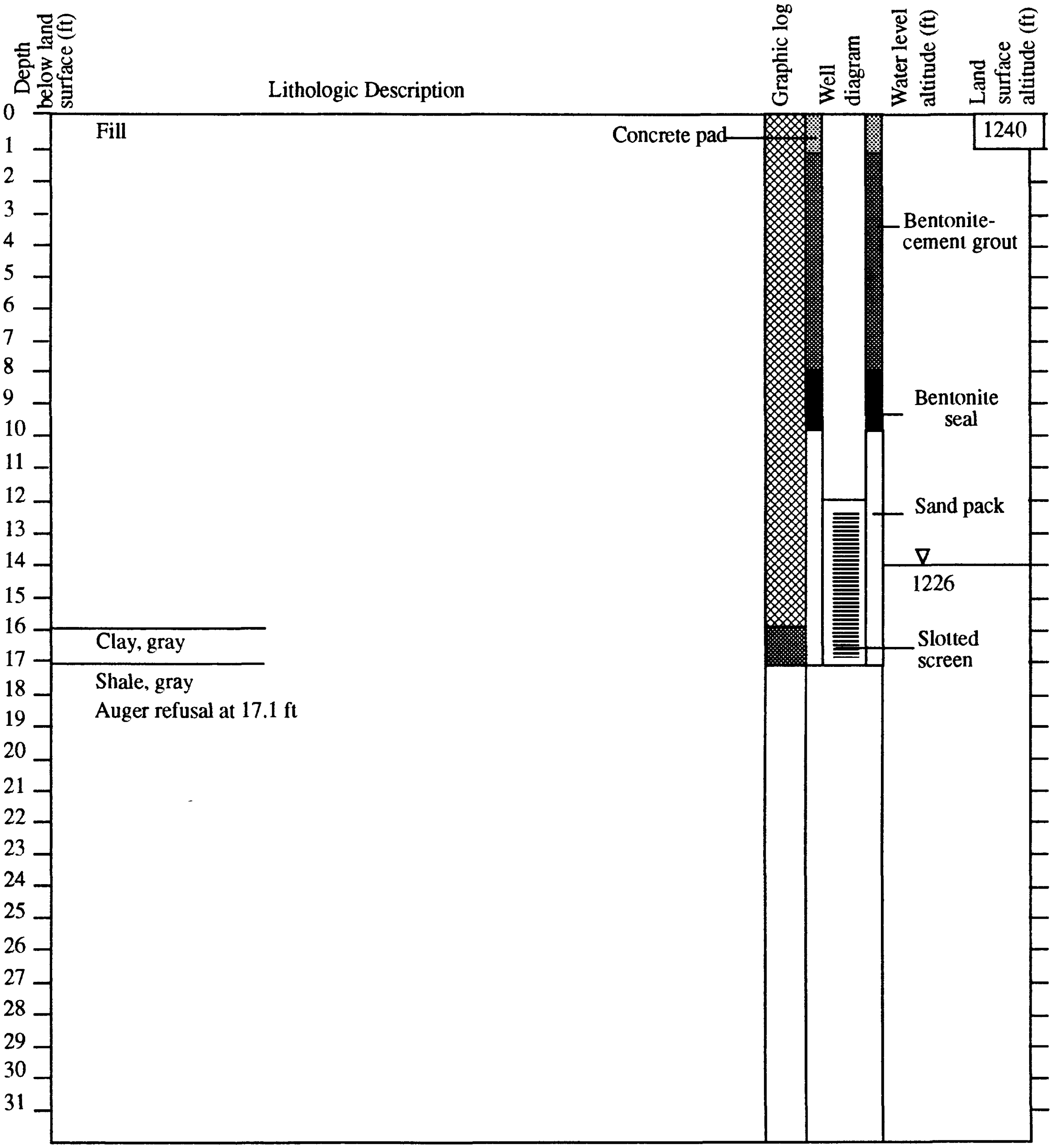

Figure 11.--Boring log and construction diagram for well LC-8.